U.S. DEPARTMENT OF AGRICULTURE

Department Bulletin

1350-1399

Only the numbers listed below have been retained:

1350	1371
1355	1372
1357	1374
1359	1393
1363	1395
1364	1397
1369	

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1350

Washington, D. C. ▼ October, 1925

BLUE-FOX FARMING IN ALASKA

By

FRANK G. ASHBROOK, In Charge of Division of Fur Resources, and
ERNEST P. WALKER, Administrative Officer for Alaska;
Bureau of Biological Survey

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1350

Washington, D. C. October, 1925

BLUE-FOX FARMING IN ALASKA

By Frank G. Ashbrook, *In Charge Division of Fur Resources;* and Ernest P. Walker, *Administrative Officer for Alaska; Bureau of Biological Survey*[1]

CONTENTS

INTRODUCTION

The production of blue foxes in Alaska is a comparatively new industry, at present confined chiefly to islands along the southern coast, including the Aleutian Chain (fig. 1). It is of particular importance to Alaska, since it utilizes outlying islands that are of little or no value for agriculture.

In island blue-fox raising the foxes are allowed to roam over an entire island, where they choose their mates and make their dens. In the early days the foxes had to forage for their food, but now practically all ranchers feed them. This system has proved profitable, and, together with the increased popularity of fur for apparel, has led many persons to lease certain islands from the United States

[1] The writers desire to acknowledge the help given in the preparation of this bulletin by the many fox farmers of Alaska in furnishing information of value, and the assistance in the section on diseases and parasites given by M. C. Hall, of the Bureau of Animal Industry.

Government and to claim others by squatters' rights for engaging in fur farming. So great has been the demand for islands that practically all the desirable ones under the control of the Department of Agriculture are leased for the purpose.

A number of individuals in Alaska have attempted to raise blue foxes in pens, and recent reports show that some of them have been successful (fig. 2). In addition, litters of blue foxes have been produced in captivity at the experimental fur farm of the Biological Survey, in New York State, as well as on ranches in other parts of the United States. A number of ranchers and raw-fur buyers maintain that blue-fox pelts produced in pens lack the quality and finish of those produced in the wild. This has been held to be the case with silver foxes also. Approximately 90 per cent of the silver-fox pelts sold on the raw-fur market in 1924, however, were from ranch-bred animals.

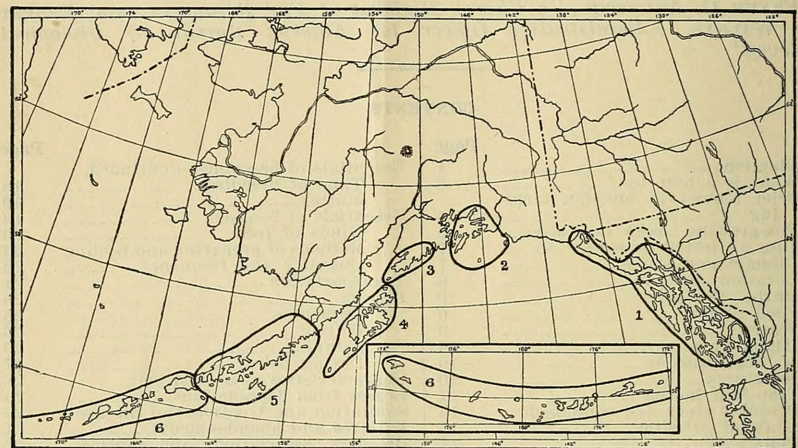


FIG. 1.—Sections of the Alaska coast where blue-fox production is becoming an important industry:

1. Southern Alaska.
2. Prince William Sound region.
3. Lower Cook Inlet region.
4. Kodiak-Afognak region.
5. Islands off the Alaska Peninsula.
6. Aleutian Islands.

Because the number of islands available for fox ranching is limited, those already engaged in the business should determine as quickly as possible whether blue foxes can be produced profitably in pens. If this is found possible, blue-fox ranching can spread to the mainland of Alaska, to Canada, and to the United States. With the resulting growth of the industry, there will be an increased demand for breeding stock as well as for pelts.

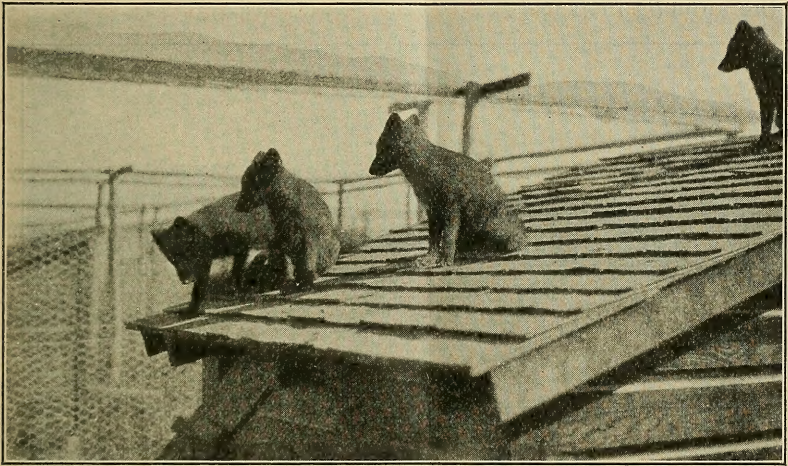
Blue-fox ranching is in a condition similar to silver-fox production in that it is an industry of too recent development to be supported by the results of extensive study and research. Sufficient is known, however, to assist beginners, as well as established ranchers, with information on some important phases of the business, such as organizing the ranch, breeding, feeding, pelting, and sanitation.

The information given in the following pages is based on a study of the methods and practices which have been found to give the greatest success on islands in Alaska.

WHAT IS A BLUE FOX?

A number of persons in Alaska and elsewhere mistakenly think that white foxes are found only in the Arctic, and that when they were brought to the Pribilof Islands and points farther south the climate changed the fur from white to blue.

The blue fox is a color phase of the Arctic or white fox (*Alopex*), which is circumpolar in range, being found particularly along the seacoasts of arctic and subarctic regions. Its normal winter coat is white, while the summer pelage is brown and tawny. The blue fox is dark bluish in winter and tends toward brownish in summer. There are intermediates in which the coat may be spotted blue and white, or the blue and white may be blended, producing a dingy or smoky-white appearance. Such mottled animals sometimes occur among blue foxes where there have been no white foxes. It is noted



B24761

FIG. 2. Blue-fox pups sunning themselves on the roof of their den

more frequently, however, where white and blue foxes are ranched together.

The white fox is more common in the wild than the blue, and smoky-white foxes are sometimes born from blue parents; but on islands where blue foxes have been introduced and raised a pure white fox is exceedingly rare.

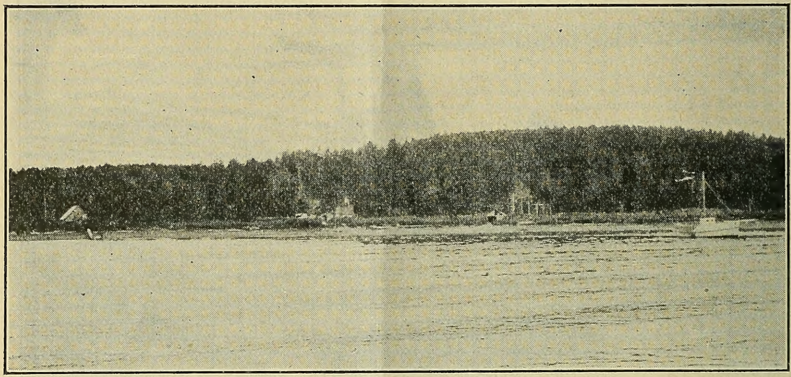
The prices usually paid for the different skins are governed largely by the relative scarcity of the animals and the market demand. On the raw-fur market, blue-fox skins generally bring from three to four times as much as white. At present both color phases are popular, the natural blue being preferred by the more exclusive trade; to supply the popular trade, white skins are dyed blue, steel, taupe, and rose.

In general, it may be said that prime blue-fox pelts produced in practically every section of Alaska shown on the map (fig. 1) are bringing good prices on the raw-fur markets.

BRIEF HISTORY OF BLUE-FOX FARMING

Veniaminof, a Russian writer, states that when the Pribilof Islands were discovered they were inhabited by blue and white foxes.[2] The larger islands of the Aleutian group also are said to have been inhabited by blue and white foxes when discovered by the Russians.[3] In 1835 the Russians introduced blue foxes on Kiska Island, possibly on Amlia, and perhaps on other islands in the Aleutian Chain.

In 1858 an official Russian proclamation permitted and ordered the killing of white foxes on the Pribilofs whenever and wherever found, but there were rigid restrictions on the killing of blue foxes. The Russians followed a wise and vigorous policy of stocking lands with fur-bearing animals, giving both native and introduced forms protection with the view of maintaining a constant supply of fur. There is nothing to indicate that fur farming was carried on in a manner similar to present-day fur farming, however; that is, caring for the animals in pens.



B24645

FIG. 3.—View of Long Island, near Kodiak; stocked with blue foxes. The dwelling is in the center; the buildings on the left and right are feed and storage houses, respectively

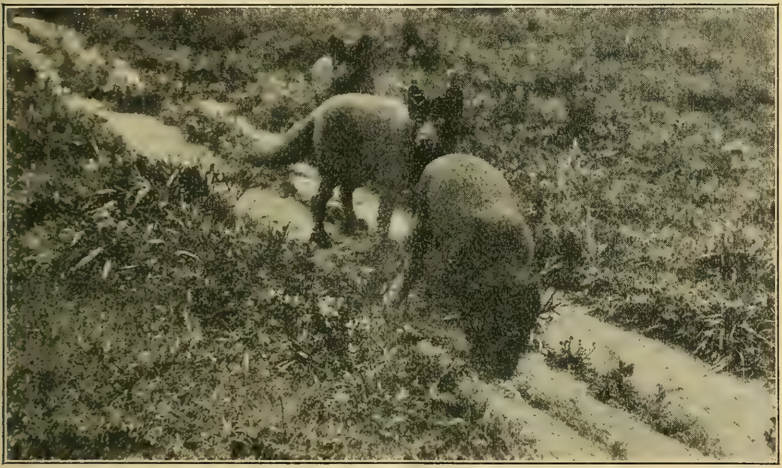
The first recorded efforts to raise blue foxes, after the purchase of Alaska by the United States, began in 1885. The Semidi Propagating Co., of Kodiak, obtained 8 or 10 pairs of blue foxes from the Pribilofs and placed them on Aghiyuk Island. This island is locally known as North Semidi, and is off the Alaska Peninsula near the present village of Chignik. About 1886 or 1887, 3 or 4 pairs were taken from the progeny on North Semidi and placed on Chowiet or South Semidi Island. A black male fox also was placed on this island, and this one killed off all the blue foxes. Chowiet was again stocked in 1891 by the Semidi Propagating Co. with 18 pairs of blue foxes from the Pribilof and Aghiyuk Islands. In 1891 this company also stocked Chirikof Island with 6 or 8 pairs from Aghiyuk and possibly some from the Pribilofs.

In 1895 the Semidi company obtained possession of Long Island, near Kodiak, from a person who had been raising cattle, sheep, and silver foxes there (fig. 3). After trapping and removing all the

[2] Veniaminof's Zapieska, 1840, translation by Henry W. Elliott, in "A Report upon the Condition of Affairs in Alaska" to the Secretary of the Treasury (p. 258), 1875.
[3] Dall, William H., "Alaska and its Resources," pp. 498–499, 1870.

silver foxes (1895–96), they placed on the island 30 pairs of blue foxes from Aghiyuk. Whale Island was stocked in 1899 with foxes produced on Long Island.

This stocking of islands was the real beginning of blue-fox farming in Alaska. The operations of the Semidi Propagating Co. were not a complete success, but were a start in the right direction. Through its efforts stock was brought to points accessible to breeders. It is neither necessary nor desirable to go into a detailed history of subsequent developments. In fact, this soon became so intricate as to make impracticable any attempt to trace it. For a time there was a boom; then there was a decline, during which many islands were abandoned and most or all of the stock of foxes removed. Interest revived about 1916, and since then the industry has developed so rapidly that in a very few years almost all the islands suitable for the enterprise have been occupied.



B26763

FIG. 4.—Blue foxes running wild on islands comb the beach for food. They will become very tame and even eat from the hand of their keeper

In 1898 a few pairs of blue foxes from Long Island were sent to Foxcroft, Me., and kept in pens. The animals were pups of that season and it is reported that several foxes were raised the next year.[4] A number of blue foxes were imported into the United States from Alaska between the years 1919 and 1924. Some, at least, of the operators in the States and on the Alaska mainland have been successful in raising blue foxes in pens.

FOX-GROWING AREAS IN ALASKA

The islands used for blue-fox farming in Alaska vary in size from about 40 to more than 6,000 acres, and fall into six geographic groups (see fig. 1): (1) Southeastern Alaska (in the Alexander Archipelago); (2) Prince William Sound region; (3) Lower Cook Inlet region; (4) Kodiak-Afognak region; (5) the Alaska Peninsula; (6) the Aleutian Islands. In the first two groups the islands

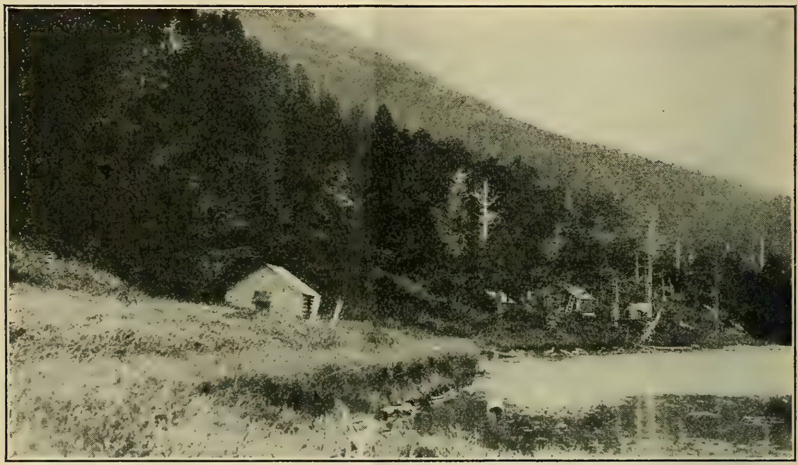
[4] Washburn, M. L., in Harriman Alaska Expedition, vol. 2, p. 360, 1901.

are almost all timbered and lie mainly within national forests. Some of the islands in the Kodiak region are timbered, but westward from Kodiak none have timber.

With respect to their availability for fur farming, these islands fall into four classes:

(1) Ten islands from Prince William Sound to the Shumagin group; namely, Little Koniuji, Simeonof, Chirikof, Long, Marmot, Pearl, Elizabeth (fig. 5), Middleton, Aghiyuk, and Chowiet. All of the islands in this group are leased and occupied for fur farming, the administration being by the Secretary of Agriculture through the Biological Survey.

(2) Islands in the Aleutian Islands Reservation are available for occupancy under permit and are administered by the Secretary of Agriculture through the Biological Survey. Applications for permits to occupy these islands should be sent to the office of the Biological Survey, Juneau.



B26708

FIG. 5.—Elizabeth Island, leased for fur farming by the Biological Survey. The timber is fairly dense in the valleys. This is also true of Pearl and Marmot Islands, similarly leased

(3) Islands on national forests are administered by the Secretary of Agriculture through the Forest Service, and practically all such islands suitable for fox farming are already under permit for that purpose. On the Tongass Forest, in southeastern Alaska, 150 such permits are in effect; and on the Chugach Forest in the Prince William Sound region, 36. Inquiries regarding the use of national-forest land for fox-farming purposes should be addressed to the Forest Supervisor, Cordova, Alaska, or Forest Supervisor, Ketchikan, Alaska, who are in charge of the Chugach and Tongass National Forests, respectively.

(4) Other islands, except a few small reserves, are of the public domain and under the jurisdiction of the General Land Office, Department of the Interior. No legal authority exists for leasing or granting title to these islands. A few are situated in southeastern Alaska, but the majority are west of Seward and Cook Inlet. Many

islands of this class are occupied for fur farming under the belief that those in possession will have their occupancy recognized should Congress pass the necessary law authorizing the issuance of leases or permits for them.

Shipments by mail of furs consigned to points outside of Alaska are required to be reported to the Alaska Game Commission, Juneau, Alaska, on appropriate blanks supplied for the purpose.[5]

SELECTING AN ISLAND OR RANCH SITE

CLIMATE AND SHADE

The production of a fine quality of fur is closely related to climate. A long, cold winter, with a fair amount of rainfall, particularly in spring, is conducive to the production of good pelts. Hot summers are not detrimental if short and if followed by a season of cold weather sufficiently severe to cause the renewal of heavy coats.

B24818

FIG. 6.—Paul Island. Scrubby underbrush is found here but no large timber

It has been stated that excessive sunshine makes the fur of live animals fade, but to what extent has not yet been definitely ascertained. The sun will make fur fade, however, after the pelt has been removed. When the fur of a blue fox is being shed the dead hairs turn to various shades of brown and chocolate. During the season when the blue-fox pelts are becoming prime, some will be found with a chocolate tinge, commonly known as rusty. This, however, is not conclusively proved to be the result of sun bleaching; in some cases it is due to inferior breeding stock, which has a tendency to produce rust color instead of a clear maltese.

A happy medium of shade and sunshine is necessary for the comfort and health of the foxes. Every animal likes to be in the shade during extremely hot weather. On the other hand, sunshine is the best natural means of keeping the ground clean and sanitary. Some of the treeless islands have scattering brush and shrubbery (figs. 6

[5] Full text of laws and regulations relating to fur farming and the trapping of fur-bearing animals can be had on application to the Alaska Game Commission, Juneau.

and 7), and many of them have luxuriant growths of grasses and herbaceous vegetation. Others have little or no plant life, but much outcropping of bedrock. An island of the type last described is of little value for fox raising, not only because of the lack of sufficient shade but also because the denning ground is too limited.

LOCATION AND SOIL

The northward extension of island fur farms is limited by the necessity for freedom from ice bridging to adjacent lands, either by the channel freezing over or by drifting ice. It is for this reason that island farms in Alaska are restricted mainly to the southern coast line and the Aleutian Chain. The southward limit is governed by the need for sufficient cold weather to produce good fur. Near the mainland, where the winter temperatures average lower than at

B24678

FIG. 7.—General view of the top of Aghiyuk Island. There are no trees on the island and, except in hollows, very little vegetation of any kind

the outer coast, the southern limit will be farther south than in the mild outer ocean belt. The mainland area has produced good blue-fox skins as far south as Petersburg, and fur farms are being started over 100 miles farther south. It is possible that the island blue-fox zone on the Pacific coast near the mainland may extend into northern British Columbia. Along the outer coast, blue-fox farms are being established as far south as Hydaburg, on the west coast of Prince of Wales Island, although the winter climate in the section is exceedingly mild. Fur farmers on the western islands of the Aleutian Chain, which also have a mild climate, receive satisfactory prices for blue-fox skins.

Blue foxes can be successfully raised on any type of soil that is well drained and affords suitable shade and denning grounds. It has not been definitely determined whether certain types of soil are more favorable than others to fox parasites; soils possessing an undue amount of moisture, however, and densely shaded situations are favorable to their development. The elements in the soil appear to have no bearing on the quality of the fur produced.

The latitude, climate, and soil having been determined, the next important consideration is the proper location for the ranch. Fox ranches are now established on islands in every conceivable location. Some are found many miles from civilization, where transportation by regular means can not be had at reasonable intervals, where it is difficult to obtain supplies, and where the rancher is practically shut off from many opportunities for the sale of breeding stock. Energetic, progressive men will not stay long under these conditions, however, and this makes it difficult to secure the necessary labor. On the other hand, an island used for fox farming should be at least half a mile away from adjacent islands or the mainland, as the animals may escape by swimming.

HARBOR FACILITIES

It is possible to operate an island fur farm which lacks a harbor, but the disadvantages are extremely great. The value of harbor fa-

B24726

Fig. 8.—A floating dock of the type illustrated can be built easily and cheaply and is a great convenience in landing supplies and tying up a boat in the harbor

cilities can scarcely be overestimated. A harbor permits keeping a boat for use in obtaining feed, in feeding, in the transportation of skins and breeding stock, and in communicating with towns and the mainland (fig. 8).

FOOD SUPPLY

Fish is the basic article in the diet of blue foxes; hence it is essential that it be readily obtainable throughout the year. Proximity to a cannery is a great advantage, as the waste material makes excellent feed. Seals and porpoises and members of the whale family might well be more utilized than is now the case. It is essential that the food be palatable, nutritious, and inexpensive.

WATER

The presence of fresh-water springs, streams, or ponds on an island is important. During the whelping season especially it is necessary that fresh water be supplied at or near the dens. It is almost impossible to avoid carrying water to some extent, but the problem is much simplified if the natural supply is well distributed about the island.

ISLAND AREA

The number of foxes that can be kept on a given area depends largely on the denning grounds, the number of feeding places, and the attention given. When fed at various locations on the island, foxes become accustomed to the feeding places and make their homes not far away. Even on the larger islands the dens are found in proximity to the feeding places. There is no immediate cause for concern about overcrowding. It has been estimated by the ranchers on the smaller islands—for example, those containing 40, 50, or 60 acres—that between 150 and 200 foxes can be maintained if properly fed.

B24714

FIG. 9.—Convenient arrangement of buildings for fox rancher. From left to right they are dwelling, woodshed, smokehouse, and feed-storage house

RANCH ORGANIZATION

STRUCTURES

The ranch site having been chosen, consideration should be given to the location of the dwelling house, feed-storage, cook house, smokehouse, and any other structure (figs. 9 and 10). For convenience the dwelling should be as near as possible to the harbor or landing place. In order to look after the foxes properly on large islands it may be necessary to construct one or more additional dwellings or cabins.

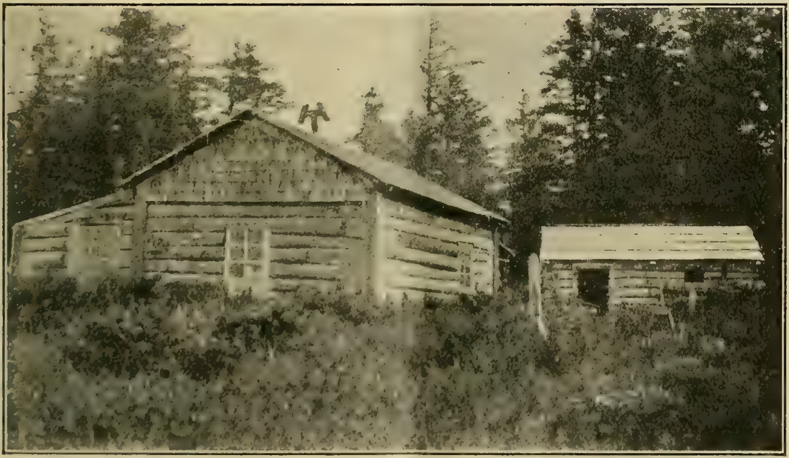
The feed-storage shed also should be built near the dock in order to make the haul from the boat as short as possible. This structure may be of roughly cut timbers, log-cabin style (fig. 11). For cleanliness and sanitation dressed lumber should be used when practicable. It is not essential to construct vats in which to brine-cure or salt-pack fish. Limited quantities of fish can be salted in barrels or tierces. A cutting table or chopping block is an aid when dressing the fish as well as when cutting them into suitable sizes to feed.

Most ranchers cook cereal with the fish at certain seasons of the

B26772A

FIG. 10.—Modern type of dwelling on fox island in southeastern Alaska

year, and for this purpose build a caldron or a specially designed steam cooker either in the feed house or just outside. The steam cooker, although somewhat slower than a direct-fire caldron, cooks the food more thoroughly and without burning or scorching it.



B24028

FIG. 11.—Living quarters and outbuildings constructed from native timber

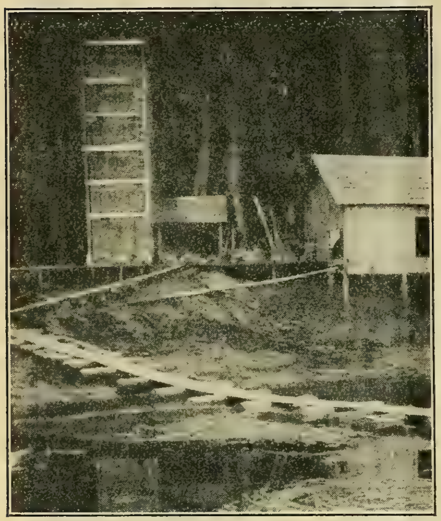
Steam-pressure cookers of various sizes on the market hasten cooking and simplify the process.

A smokehouse (fig. 12) for smoking fish or other feed for the foxes should be erected in the vicinity of the feed-storage house.

As dressed fish must be carried or otherwise conveyed to the smokehouse, distance is an item to be considered. The size of the house depends upon the quantity of feed required. The one shown in Figure 11 serves an island on which are 40 pairs of foxes.

Foxes should not be killed and pelted in the building where feed is stored or prepared; if necessary, a special shed should be built for the purpose. Such use of the feed house would not be sanitary and, in addition, it would favor the chances of transmission of disease.

Structures[6] for temporary occupancy, such as are required for injured, sick, or newly purchased foxes, may be comparatively small. The style and method of construction will depend upon the location and lay of the land. A temporary pen used for the purpose may be 10 feet long, 6 feet wide, and 6 feet high. A frame of 2 by 4 material is entirely covered by No. 15-gauge wire netting of 1½-inch mesh, with a small door in the front. As the pen rests directly on the ground, it is well to cover the floor wire with sand or fine gravel and earth. This material should be removed frequently and clean dirt substituted to prevent contamination. A small nest box should be placed inside the pen, or outside and connected with it by a chute.



B24724

FIG. 12.—The five-tiered smokehouse illustrated will smoke and store about 5,000 salmon

TRAP-FEED HOUSES

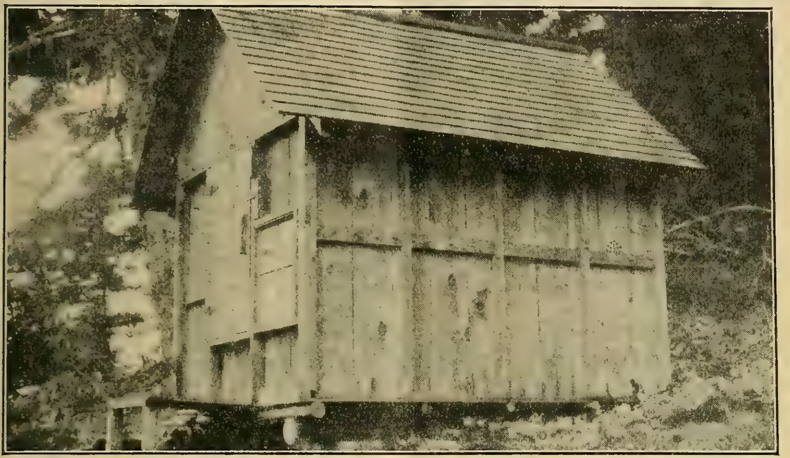
Trap-feed houses should be erected at various points, the number and the distance apart depending on the size and topography of the island as well as on the number of foxes ranched. They provide a place where foxes may eat unmolested by eagles, ravens, and crows; and where they may be captured uninjured for marking or examination, and when prime (fig. 13). They may be built of material at hand on the island; but dressed lumber makes a neater job, and houses so constructed are much more easily cleaned. These houses should have a floor measurement of at least 6 by 8 feet and be high enough to permit a man to stand upright.

There are two types of trap-feed houses. In one the foxes enter through a trap chute and eat on the floor of the house. In the other they eat on an upper floor and fall to the ground floor when they spring the trap (fig. 14).

Figure 15 shows the first-mentioned type of trap-feed house with the trap installed. This trap, however, can be made to fit a house of almost any size or shape (fig. 16). A detailed drawing of the

[6] Information which will be helpful to those constructing pens for raising blue foxes is contained in U. S. Dept. Agr. Bulletin No. 1151, "Silver-Fox Farming." Blue prints of plans for constructing pens and dens may also be obtained free on application to U. S. Department of Agriculture, Washington, D. C.

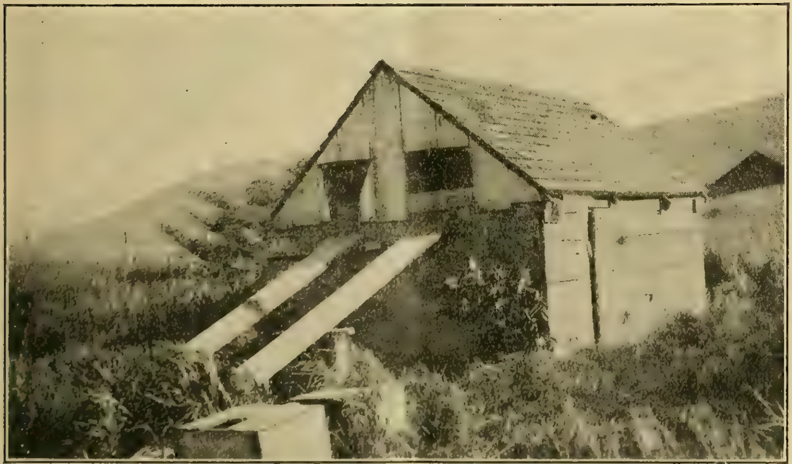
construction and operation of the trap itself is given in Figure 17. Foxes arrive at the entrance to the chute (1) by means of a sloped board (2). The trap floor pieces 3 and 3′ are pivoted at 4 and 4′, respectively. To make them reset automatically, counterweights (5



B26772

FIG. 13.—An excellent type of trap-feed house, trap for which is detailed in Figures 15 to 17

and 5′) are placed on the lower side at opposite ends of the floor pieces. Floor piece 3 is securely locked and supported by the square notch (6) portion of the trigger (7). Floor piece 3′ rests lightly on the beveled (8) portion of the trigger (7) so that the weight of the



B24650

FIG. 14.—Trap house in which the foxes eat on the second floor and when the trap is sprung fall to the floor below

fox's front feet on the ends of the floor piece 3′ depresses the board and forces outward the entire trigger, thus releasing the floor piece (3) from the support (6) portion of the trigger. Floor piece 3, with the weight of the hind part of the fox, and floor piece 3′, with the weight of the fore part of the animal, pivot at 4 and 4′, respectively, and drop the fox to the floor of the house.

The weight of the fox removed, the counterweights (5 and 5′) restore the floor pieces to position, ready for the next fox. The opening (9) of the inner end of the chute is ordinarily left open

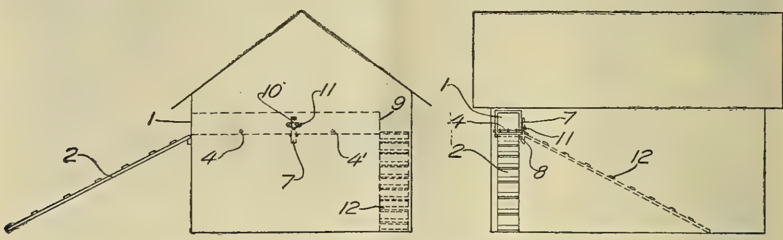


Fig. 15.—Front and side views of trap and feed house, with trap installed

in order that the animals may come and go at will, but it is closed with wire netting when the trap device is to be used. The drawings illustrate a runway board (12), similar to the board (2) previously mentioned, which is provided to permit free passage through the trap into the trap-house when desired.

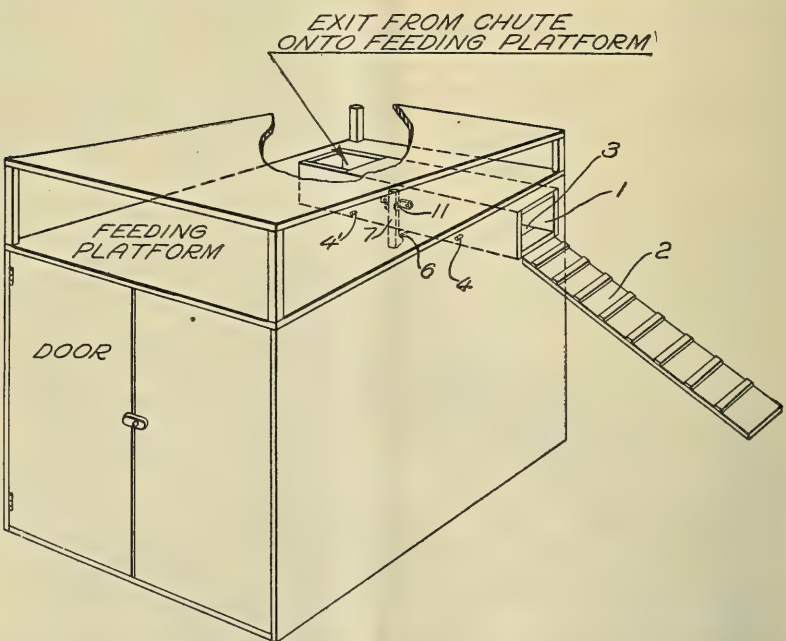


Fig. 16.—Trap and feed box that can be installed in a house of almost any description

A light spring (10), pushing outward above the pivot of the trigger, insures the trigger returning to place. When the trap is not in use the trigger should be removed and a cleat nailed across the free ends of the trap floor boards of the chute, thus making the floor solid. The trigger (7) should be made of hardwood, or the notch (6) and the bevel (8) faced with metal. All moving parts should fit accurately and work freely.

The entrance (2) and exit (12) may be interchanged to meet conditions of installation. Where this is done, however, the positions of the beveled notch (8) and the square notch (6) on the trigger (7) will have to be reversed.

Some ranchers make use of a box-trap similar to that shown in Figure 18. This type of trap is simple to construct, but is not very satisfactory for general use. It is sometimes used to capture foxes that have become too wary to be caught in trap-feed houses. In the front part is built a sliding door, temporarily held up by a nail in a slot. A wire fastened to this nail extends to the rear of the trap through a series of screw eyes, which serve to keep it straight. On the end of the wire the bait is fastened. When a fox enters the trap and gnaws at the bait the nail slips from the slot and drops the door. A treadle or pan is sometimes used instead of bait. To remove the foxes, the lid (which is the board propping up the trap in fig. 18) is taken off.

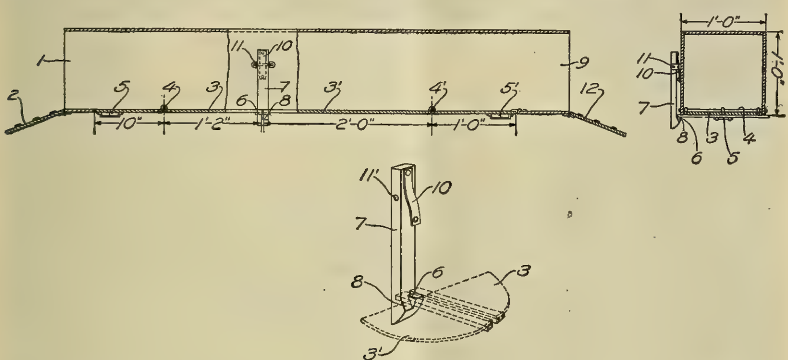


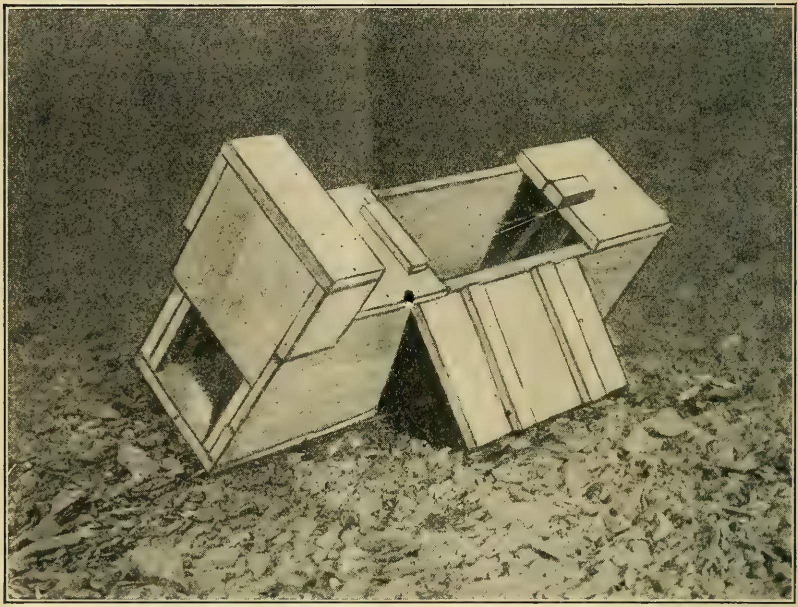
FIG. 17.—Details of construction of trap for feeding house. Operation described in text

BREEDING STOCK AND EQUIPMENT

The number of foxes to be purchased to stock an island depends very largely upon the financial ability of the person engaging in the industry and upon the size of the island. Some island ranches of 100 or more acres have been started with only 1 or 2 pairs of breeders; but this is impractical, for the reason that much time is involved in waiting for a sufficient increase to permit the taking of pelts or the selling of breeding stock. A 50 to 100 acre island may ordinarily be stocked with 10 to 20 pairs of foxes. Good breeding stock can usually be purchased for $300 to $400 a pair.

A moderate-sized dwelling of logs or frame construction for the caretaker and his family can be built for $500 to $2,000, depending largely on the cost of labor. Large islands sometimes require more than one dwelling to provide proper distribution of caretakers. A combined feed, storage, and cook house, frame construction, will cost $300 to $500. Smokehouses cost $500 to $700, depending upon the plan. Trap-feed houses, which should be erected at numerous points about the island, cost $15 to $25 each, depending upon the quality of lumber used and the labor. Feed cookers can be constructed or purchased at a cost of $15 to $50. Detention pens are necessary to confine foxes during short periods for various purposes, and can be built for $25 to $50.

A good, substantial boat is needed to procure fish for feed, to feed the foxes, and to transport supplies to and from the mainland or other points. The location of the island, harbor facilities, and the quantity of supplies to be transported will help determine the kind of boat to be purchased. A motor boat used for short, light hauls



B24651

FIG. 18.—A box trap used on some island fox ranches. The fox, feeding on the bait at the rear, pulls a wire which drops the entrance door. (Top removed and used to prop trap on side for showing interior wire)

can be purchased for $600 to $1,000. A boat used for traversing long distances will cost $2,000 to $4,000.

ESSENTIALS OF BREEDING

Success in fox raising is directly dependent upon a careful and intelligent selection of the right type of breeding stock. Those engaged in the industry should have a clear conception of the important factors involved in breeding. When the animals are confined in pens and the ancestry is known, selective breeding is a comparatively simple matter. When the foxes run wild and breed promiscuously, however, as is the case on the islands of Alaska, it is impracticable to follow any definite system. In other words, the rancher is never quite sure that certain young foxes are the offspring of any particular pair of adults. Some ranchers, of course, may feel reasonably certain of the ancestry of one, two, or even three litters on an island, but this is generally a very small part of the breeding operations.

The real basis for selecting breeding foxes is the quality of fur produced. Indications from conformation occupy a secondary place.

PELTS

At the time the foxes are trapped to pelt, the rancher should carefully select and retain desirable animals for breeding stock. The pelt should be perfectly and evenly furred all over, both on the back and on the belly. A fur that is reasonably long, lustrous, and silky indicates that the animal is in good physical condition. The underfur should be abundant, soft, and dark in color, the darker the better. Matted or woolly underfur is not desirable. (See fig. 19.)

When prime, a blue fox should be a dark maltese color throughout the entire pelt. Clearness of color is one of the most important

B2433M

FIG. 19.—Blue-fox pelts ready for inspection by raw-fur buyers

factors in determining quality. Deficiency in luster and a rust or tinge, which gives a brownish or chocolate cast to the fur, reduce the value. A breeding fox possessing a rusty pelt, no matter to what degree, should be eliminated. A perfectly furred pelt, slightly tinged, is less valuable on the fur market than one fairly well furred but clear in color. Rust or tinge has been attributed to many causes, including breeding, feeding, and sunlight. It is possible that heredity is a determining factor and that the undesirable characteristic can be eliminated by careful selection.

The term "samson" is applied to foxes devoid of guard hairs and having a very inferior woolly fur. This condition has been variously attributed to feeding, breeding, and parasites. The real cause is not definitely known, and for this reason it is highly inadvisable to use such foxes for breeding. The pelts have small value on the market.

47437°—25——3

The brush should be reasonably long, in order to balance properly with the length of the body. The general principles determining the quality of fur on other parts of the body are equally applicable to the brush.

CONFORMATION

Conformation involves the individual structure of each part as a unit. A defect in any part offsets to some extent an otherwise perfect structure. Some parts, as the chest, back, loin, or leg, are relatively of greater importance than the others; a deficiency in such parts would have more effect on the serviceability of the whole than a similar inferiority elsewhere.

Constitutional vigor is evidenced by a well-developed heart girth, chest, front flank, and loin, and both vixen and dog should be deep, wide, and well coupled in these regions. There should be no indication of a pinched appearance behind the shoulders or in the loin. If breeding foxes are strong in these regions it is safe to assume that, other things being equal, they have strong lungs and heart, and consequently are stronger, healthier, and more able to resist disease.

BREEDING

It is to be constantly borne in mind that blue foxes are not domesticated animals in any sense of the term. The purpose of breeding blue foxes is to produce good fur and to improve the stock. The business of blue-fox ranching is comparatively new, and he who would succeed in it must give it careful thought, study the moods of the animals, and prepare himself to meet intelligently emergencies as they arise. Many companies formed for the sole purpose of raising foxes have failed because of the great difficulty in hiring a keeper having the necessary personal interest in the welfare of the animals. The more thoroughly a man studies breeding practices and his foxes, the more closely he may approach a uniform degree of success in his breeding operations.

The only method of breed improvement that the blue-fox rancher can use, unless he is raising the animals in pens, is grading and close culling of inferior stock. On islands where steel traps are used instead of trap-feed houses, all animals trapped are killed. In this way the best may be killed and the poorest left for breeding stock. By use of trap-feed houses, however, the poorest animals can be killed and the best liberated for breeders. On islands formerly producing pelts having a high percentage of white hairs, this condition has now largely been eliminated by following this system, and the stock is darker and clearer colored.

Grading is the mating of a common or relatively unimproved animal with one that is more highly improved. In the case of domestic animals the male is selected as the improved one of the pair for reasons of economy. In the blue-fox business, however, it is well for the improvement to be made both ways. Improvement by grading is, of course, limited to the foxes on a particular island. This method distributes breed excellence rapidly and with certainty; that is, the unimproved blood soon becomes insignificant and finally disappears. Only those individuals meeting standard requirements should be retained for breeding.

Of the effective means at the command of the breeder to improve the stock, next in importance to selection is the judicious mating of related animals. This process is known as inbreeding. Inbreeding can be carried on successfully only where animals are kept in confinement and their identity known. Following the method of grading just described, however, and not introducing new and better males from other sources, would eventually result in inbreeding.

TIME OF BREEDING

Most blue-fox pups mate at the age of 10 months and produce young when they are about a year old. Apparently the breeding season varies slightly in different regions and at times is influenced by variation in the climate. The mating season, or, as it is commonly known among ranchers, the "barking" period, starts about the first of February and continues for approximately 40 days. Most of the matings occur during February and March.

So far as known, the oestrum, or heat period, occurs once a year and lasts 3 or 4 days. While the vixen will accept service only at this time, it seems to make little difference whether it is early or late in the period.

The gestation period is 51 or 52 days and the young are usually whelped in April or May, although sometimes as late as the middle of June. Litters vary in number from 1 to 14, but the average number raised is about 5.

MATING

Improving the stock by selective breeding will undoubtedly result in increased profits in fox raising. If the more remote as well as the immediate ancestors have been bred with the aim of producing extra fine pelts, then the chances are that this will be transmitted to most of the offspring from such matings.

In selecting blue foxes for breeders, it is to be borne in mind that pelts have a tendency to become lighter with age. No foxes showing white markings in the fur should be kept for breeding. Occasionally, however, a blue fox may show a white star on its breast, but this is not objectionable.

The possibilities of modification or improvement by selective breeding are fully as great with foxes as with domesticated animals, and selective breeding will therefore in time produce a much finer strain of foxes.

Ordinarily blue foxes have only one mate, but occasionally a male will have two, and there are a few reports of a male having three.

ESSENTIALS OF FEEDING

The real object to be kept in mind in feeding foxes is to supply nutritive material for building and repairing the body and for producing good fur. The ration must be wholesome and acceptable, and at the same time reasonably cheap. Cleanliness in preparation and regularity in feeding are important.

While it is recognized that it is almost impossible to follow out ideal systems of feeding under present conditions on islands, yet it would be well to adopt as nearly as possible the methods here outlined.

For the best results, a palatable feed must be provided. The same combinations should be used steadily, and sudden changes either in the diet or in the manner of feeding should be avoided. It is not meant that the same kinds of feed should be given during every season of the year; but the danger is pointed out that foxes may be "thrown off their feed" by such radical changes as occur when a rancher suddenly adopts a new ration on learning of another's success with it.

KINDS OF FEED

As fish is readily obtainable in this region and forms part of the natural diet of blue foxes, it constitutes in one form or another the

B2462M

FIG. 20.—Dall porpoises are used to some extent as a fox feed. (Photograph by J. L. Hill)

major part of the feed. Salmon, cod, halibut, rockfish, skates, and herring are all used. The kind most commonly fed, however, is salmon, because of its comparative abundance during the summer and of the fact that many ranchers are able to obtain heads and discarded fish from local canneries. In localities where hair seals, porpoises, and white whales can be procured, these also are used. (Fig. 20.) Occasionally larger whales drift or are towed ashore, and foxes have been fed on them.

Mushes also form part of the diet, and are made of a variety of ingredients. Cereals, such as rice, oatmeal, bran, shorts, middlings, bread, and cracker waste, are used, and in some cases seal, whale, and porpoise oil. Ranchers who can raise root crops have added potatoes and turnips. These vegetables are never fed raw. Where obtainable, cracklings resulting from the rendering of lard in packing houses are used extensively.

A ration composed of a variety of feeds gives better results than a very simple fare, even though the latter supplies the proper proportion of proteins, carbohydrates, fats, and minerals.

METHODS OF PREPARING AND FEEDING

The preparation of the feed and the method of feeding have a great influence on the breeding of foxes and the production of fine pelts. Only clean and wholesome food should be supplied—never putrid or diseased material. A few extra dollars spent to obtain the right kind may save many hundreds later, for a proper diet and satisfactory methods of feeding are important factors in lessening the chances of outbreaks of disease.

Fish are generally obtained by the rancher fresh from the water; or, if the ranch is near a cannery, cull fish and refuse may be procured. (Fig. 21.) Fish may be fed fresh, salted, smoked, or dried.

B24650

FIG. 21.—Cull fish and fish refuse from canneries are used for fox feed

Formerly most ranchers prepared their fish for winter by salting, but more recently many have adopted the method of smoking and drying a large portion. The process of smoking is practically the same as that followed with fish intended for human consumption; that is, each one is split, cleaned, and hung in a smokehouse until lightly smoked. If the smokehouse is of sufficient capacity, the fish may remain there until needed. This enables the rancher to supply a little heat occasionally to prevent mildewing. Where climatic conditions permit, fish are dried in the sun without smoking and then stored in a dry place until needed for winter feeding. (Fig. 22.)

In salting, the fish are split and cleaned and each piece rubbed lightly with salt and packed tightly in barrels or tanks, or the cleaned pieces may be placed in layers and the salt sprinkled over them. The same method is followed with fish heads.

Some ranchers report satisfactory results in packing both fish and whale meat in fish, whale, or seal oil. Their experiments were made for the purpose of determining the value of the oil as a preservative and whether or not it is palatable to the foxes.

Dried and smoked fish has the advantage over other feeds that it can be fed without any further preparation and does not freeze in winter. Some ranchers, however, cook it in mushes. It is essential that all salt fish be soaked in running water for a period of five days to a week before being used. (Fig. 23.) It can then be given to the foxes without further preparation, or be cooked in mushes.

All mushes fed to foxes are prepared along one general line. The chief ingredient is generally fish in one form or another. This is boiled for a time, and then there is added rice, finely ground wheat, or rolled oats. All of these cereals may be used, but one is sufficient. Chopped vegetables, such as potatoes, turnips, or mangels, may be added and the whole boiled until the cereals and vegetables are

B24658

FIG. 22.—Fish being dried in the sun for storing for winter use

thoroughly cooked. Whale, seal, or fish oil is sometimes added and thoroughly mixed in. This forms a reasonably thick mush. The relative proportions of the various ingredients are roughly as follows:

	Per cent
Fish	40
Cereals	25
Vegetables	25
Oil	10

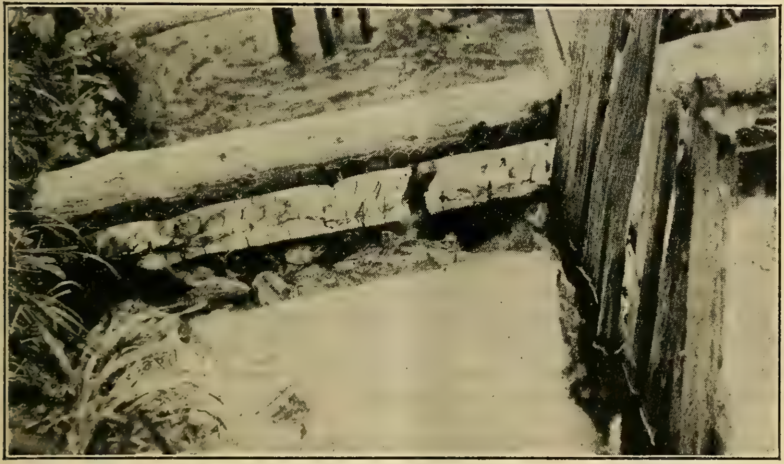
Feed can be cooked in large kettles over an open fireplace or in the double-boiler manner. Although it cooks more quickly in kettles, there is danger of burning it. The use of a double boiler, though slower, prevents this. To simplify the process some silver-fox ranchers use a steam-pressure cooker. Where this is practicable, it would be entirely satisfactory for the blue-fox rancher also.

A number of kinds of fox biscuits can be purchased, but analyses have shown that the majority are deficient in the needed mineral material. Biscuits prepared according to the following recipe have been used successfully and are relished by young as well as old foxes:

Biscuits.—To a mixture of ground whole wheat, middlings, and cracker waste weighing 70 pounds, add 1 pound of baking powder and 30 pounds of cracklings or fish meal. Mix with enough water to form a stiff dough. Place in pans approximately 10 by 12 inches in size and 1½ inches deep, and bake in a slow oven 1½ to 2 hours.

When thoroughly baked these biscuits are not dry and hard, but are more like cake. They are not fed fresh, but are allowed to stand for a day or two.

All feed should be given in dishes, preferably of aluminum or earthenware. Under no circumstances should it be thrown on the ground, as such practice makes it impossible to keep the surroundings clean and sanitary and the feed itself from becoming contaminated.



B24640

Fig. 23.—A basket arrangement like that illustrated is built in a stream to freshen salt fish

Fresh clean water should be accessible to the foxes at all times, whether supplied by streams on the island or placed in dishes.

QUANTITY AND FREQUENCY OF FEEDING

The quantity of feed supplied depends entirely on the season of the year and the age, appetite, and condition of the stock. Foxes should be fed fairly heavily just before the breeding season, so they will be in good, vigorous condition. Some ranchers believe that heavy feeding at this time will bring on the oestrum quicker and increase the chances of conception. Forced feeding has a tendency to make the fur prime sooner than it would be naturally, but the advisability of practicing this is questionable, because in many cases the fur thus becomes prime before the skin.

Appetite is a good index to feeding, and the quantity of feed supplied should be regulated so that the foxes will remain active and show an eagerness to eat.

In the early days of island fox farming few, if any, of the ranchers fed their animals, and the foxes were compelled to forage for their food, living on rodents, birds, and such material as they could find on the beach. While such practices resulted in small litters and high mortality, a number of ranchers still follow them, but the more successful are giving considerable attention to methods and time of feeding. There is still room for improvement, however, for although some ranchers feed every day, others feed only every other day or only twice a week. Those who feed at long intervals place the feed at widely separated points on the island, while those who feed more frequently usually have more evenly distributed feeding places. Feeding in quantity at widely separated points results in the animals' colonizing in the vicinity of these places.

Wherever possible the foxes should be fed once a day. The feed, no matter of what kind, should never be thrown on the ground or on the floor of the trap house, but should always be placed in dishes.

During the whelping season, fish—either fresh, dried, salted, or smoked—should be cut into convenient sizes so that the adult foxes can carry it to the dens for the young. It is very important that plenty of feed be supplied at this time to insure that the pups shall receive sufficient nourishment. In every case where it is at all practicable to do so, it will well repay the rancher to carry feed and water to dens where young are known to be. Five-gallon oil cans with the tops cut out and wooden handles fitted in, or galvanized buckets are used for carrying feed to the foxes.

Difficulty is often experienced at the pelting season in inducing the foxes to go into the trap house. This can be avoided if a practice is made of feeding the animals in these houses regularly at all seasons. It has the further advantage of furnishing old as well as young foxes a sheltered place in which to eat, thus protecting both the feed and the animals from eagles.

TRANSPORTATION

Foxes in good condition can be shipped almost any distance; but if the journey is long, as is generally the case in Alaska, or the shipment large, it is well to have an attendant go along to feed and care for the animals. Foxes can go without feed for two or three days with no apparent ill effects. In transit they have a tendency to lose their appetites, and should be fed carefully, although fresh water should always be supplied. Small pieces of meat, preferably liver or beef, and fox biscuit may be given.

It is not advisable to place more than one fox in a compartment of a shipping crate. A crate 2 feet high containing two compartments and having a total floor space of approximately 2 by 3½ feet is large enough to carry a pair of foxes. It should be made of wood, and wire of 1-inch mesh should be nailed inside to prevent the foxes from chewing the wood. In the front of each compartment dishes for feed and water should be fastened where they can be filled from the outside. A good substantial crate, such as is detailed in Figure 24, receives better treatment in transit than a poor one.

PELTING

The business of fox raising is based on pelt value, and the most successful fox ranchers market some pelts every year. This, of course, can not be done on islands where the business has just started. In such cases it will be necessary to wait two or three years for the stock to increase.

It is not good practice to pelt pups, as their skins lack finish both in the fur and in the leather. Occasionally a pup skin of exceptional development sells for a good price, but this is not the rule. It is better for the rancher to carry the young over until they are at least a year and a half old and the pelt has developed into a more marketable skin. Foxes not desirable for breeders, however, should be pelted at the first opportunity.

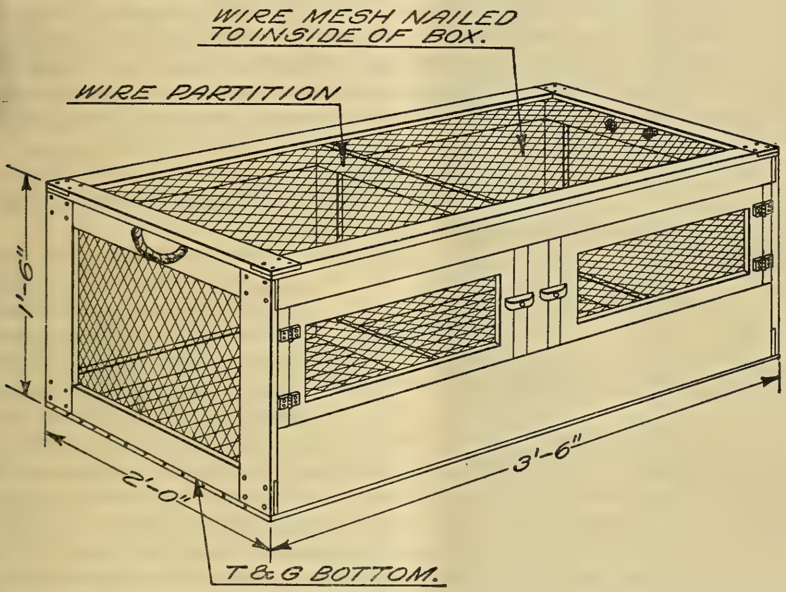


FIG. 24.—Shipping crate for two foxes, made of ⅞-inch material, tongue-and-groove bottom, and 1-inch mesh, 14-gauge wire netting

When animals are caught for examination and pelting, those not killed should be marked in order to show that they have been trapped and then released for breeding. Males can be marked by clipping a ring of fur around the tail near the body. Females can be marked in the same manner, the ring clipped being near the tip of the tail. Records should be kept of animals pelted and of those released for breeding. Wherever practicable more females should be left than males.

PRIMENESS

Pelts of foxes usually become prime in November or December, depending upon the weather, climate, and feeding. Primeness is the highest perfection of quality in a pelt. When the pelt shows high quality and finish, determined by its texture and sheen, it is said to be prime.

Ability to judge primeness comes only through experience. When the fur is coming prime it does so rapidly, and after it reaches the peak of perfection it soon becomes overprime, losing its sheen and finish. When foxes are running wild this point can not be watched so closely as when they are raised in pens.

KILLING

In killing, the method generally pursued is for the caretaker to catch the fox with the tongs (fig. 25), lay it on its side, and then press his foot on its chest. Striking the fox on the back of the head with a club leaves a blood clot on the pelt and sometimes cuts it. A more humane and satisfactory method of killing is by the injection of a solution of strychnine sulfate. Objection has been made to this on the supposition that strychnine may injure the pelt by causing the hair to fall out. This, however, is not the case. The effect, if any, of strychnine on the hair follicles is contracting rather than relaxing.

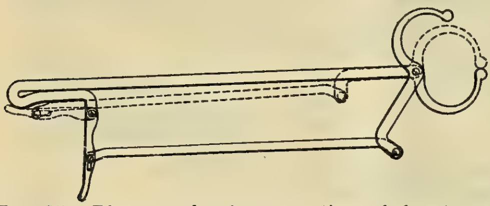


FIG. 25.—Diagram showing operation of fox tongs. Tongs are useful in handling animals after they are captured in the trap house

The operation of injecting strychnine is very simple. The instrument used is a small hypodermic barrel syringe with a reasonably long needle, and a quantity of a 3 per cent solution of strychnine sulfate. The syringe is filled with the solution and the gauge set for 1 cubic centimeter. The fox is placed on its right side and held by an attendant. The operator places his hand on the chest to locate the heart, at the same time feeling for a space between the ribs to avoid running the needle into the bone. The needle is inserted in the direction of the heart and the dose discharged. In less than a minute the fox dies without a struggle. Great care should be exercised in using strychnine as it is a deadly poison.

SKINNING

After the animal heat leaves the body the flesh shrinks from the skin, thus permitting the pelt to be removed more easily and keeping the skin side free from blood. Cooling will take place in about half an hour, but during this interval care should be taken to prevent the carcass from freezing.

The only tool needed in skinning a fox is a jackknife, and this should be kept sharp during the operation. A slit is made up the back of each hind leg, starting at the inside of the paw and running to the hock, then from the hock to a point just below the root of the tail. The back of each front leg is slit in the same manner from the paw to the first joint. The skin of the hind legs is then worked free from the flesh from the first joint to the claws, and the bones of the claws are cut free from the pelt, but the nails are allowed to remain with the skin. A slit on the under side is made from the root of the tail about half its length and all of the tail bone is pulled out of the brush.

The carcass is then hung on a hook or nail by the tendons of the hock joints and the pelt is pulled down, the knife being used whenever necessary to free it, until it is removed as far as the neck. Careful work is necessary to cut around the base of the ears, including them in the pelt, then around the eyes, and around the mouth and lips in such way as not to injure their margins. Carcasses should be disposed of immediately by burying or burning.

DRYING PELTS

As soon as it is taken from the carcass the pelt is placed flesh side out on a wooden frame for drying. This may be made of softwood one-half to five-eighths of an inch thick. Soft material will facilitate drying and the drawing of tacks. A board 45 inches long and approximately 7 inches wide should be used, tapering at the end so as to enter the nose. At a distance of 12 inches from the nose the board should be 6 inches wide, and at the base 7 inches. Cut the board in halves, lengthwise, and on the sides of one of the pieces fasten two cleats extending at right angles at the base, so that when the frame is inserted into a pelt and a wedge is forced in to stretch it tight there will be no overlapping of the boards (fig. 26). By varying the size of the wedge any frame may be used for both large and small pelts. No more stretching should be done than is required to bring the skin into natural shape, for undue stretching detracts from the value of the pelt. To allow the skin to dry, the hind legs and tail are fastened to the frame by means of tacks and small strips of wood, and the front legs are tacked to small pieces of wood, as illustrated in Figure 27.

B21648

FIG. 26.—Frame for drying pelts. Instead of having a middle wedge, some frames are made in one piece and serve the purpose equally well

A tablespoon is used as a scraper to flesh the skin and remove any excess fat. Scraping should not be so close as to remove all the fat and part of the membrane, for this will make the skin shrink from the roots of the guard hairs, permitting them to be pulled out, thus limiting the life of the pelt. Fur buyers look for this defect, and skins having it are severely cut in price.

After the skin has been fleshed and dried on the frame for a day or so, depending on conditions, it should be taken off, turned fur side out, and immediately replaced. After another day or two it should be again removed and hung on a rope to finish drying. The drying usually takes about four or five days, and should not be hurried by use of artificial heat as this has a tendency to injure it.

After the skin is thoroughly dry it is shaken vigorously and worked with the hand to make it pliable. It is then brushed with a stiff brush and rubbed with burlap to remove all foreign material. A comb may be used, if necessary, to remove dead hairs. All cleaning is done by hand, and no chemicals should be applied. Frequent handling and brushing at this time does not injure the pelt, but rather puts it in better condition for the raw-fur market.


B2010M

FIG. 27.—Pelts on drying frames, illustrating method of thoroughly drying legs and brush

CHARACTERISTICS OF A GOOD PELT

Primeness.—In general, in judging a blue-fox pelt the main thing to be kept in mind is quality, and this is affected by many factors. First, the pelt must be prime. This is determined by examining the skin side, which, if the pelt is fresh, should be fairly white or cream-colored and show some "life" when handled. This side turns yellow with age and loses its firmness. The skin should be perfectly and evenly furred, both on the back and on the belly, with the fur reasonably long, lustrous, and silky. Guard hairs should be evenly and thickly distributed, as the silky texture and luster are largely dependent upon them. The brush should be sufficiently long to maintain a balance with the rest of the pelt. There should be no rubbed spots or defects.

Clearness of color is an important factor in determining the quality of a pelt. There should be no tinge or rust to give the characteristic chocolate or brownish cast. Careful fur buyers make a greater cut in the price of a pelt having a rust or tinge than for any other defect. As a rule, more is paid for a clear, bright-colored pelt not so well furred than for a well-furred skin with a brownish or faded appearance.

Size is the last consideration in valuing a pelt. A difference of 3, 4, or 5 inches does not reduce the value of a skin, provided it passes other requirements. An extra large pelt is not desirable, for the principal reason that it is not becoming to the average wearer.

LOSSES FROM DEPREDATIONS

Some losses among foxes are caused by predatory birds and mammals. Eagles are widely charged with catching young foxes, and there are authentic records of their doing so. The fur farmer is well warranted in making war upon them in the vicinity of the fox ranch. Wolves have been reported as killing foxes, but it is believed that instances are rare.

The extent of losses from poaching is not known. Marking animals and skins with registered brands, as required by Territorial law, reduces the likelihood of handling stolen skins. The drastic laws and substantial penalties now imposed are reducing losses from poaching.

SANITATION AND TREATMENT OF DISEASE [7]

The diseases of the blue fox in Alaska are few, and the distances between islands lessen the danger of transmission of diseases and parasites. In maintaining the health of foxes, preventive measures against disease must be chiefly relied upon. With the blue fox the prevention of disease is far easier than its treatment.

Sanitation.—Places frequented by foxes should be kept reasonably clean, particularly in the vicinity of the dens and feeding grounds. This is very difficult, especially where foxes are at liberty to roam an entire island; but in spite of this, some attempts to clean up should be made.

Close attention should be given to the methods of feeding. Nothing but clean, wholesome feed should be given. Animals that have died should not be fed to foxes unless the meat can be made safe by thorough cooking. No moldy feed should ever be used, as it causes diarrhea and sometimes death. Foxes can not be prevented from carrying food into their dens, but this habit can be lessened by feeding them at regular intervals and by giving only as much as will be consumed with relish. Food left at the dens or the feed houses for any length of time will mold or otherwise spoil. All dishes used should be clean and the water supplied should be pure and fresh.

When blue foxes are first purchased they should be carefully examined for any abnormal conditions. Even though apparently in good health, they should be placed in pens and kept under quarantine and close observation two to four weeks before being turned loose. Sick animals should be captured and isolated at once to prevent the spread of disease; and if disease breaks out on an island or on a ranch, a strict quarantine should be maintained.

Dead foxes should never be permitted to lie around, but should be burned or buried. If it is desirable to examine a dead body, cut open the chest and abdomen the entire length. Examine the stomach and intestines for worms. If pneumonia was the cause of death, the lungs will be a dull red and will sink when placed in water.

---

[7] This section was prepared by D. E. Buckingham, a veterinarian sent to Alaska by the Biological Survey during the summer of 1924 to investigate blue-fox farms, particularly on islands, with special attention to the matter of sanitation and disease.

Treatment of disease.—Taking measures looking toward sanitation and the prevention of disease are functions of the fox farmer. Treating disease, however, calls for a veterinarian, and the diagnosis of disease and the administration of drugs are the province of experts. A fox farmer's general knowledge of diseases and the application of remedies is naturally limited. Blue foxes are difficult to treat, and in administering remedies it is necessary to employ strategy. Mature foxes usually can not be treated successfully except by catching and then restraining them with either wooden or metal tongs, such as are advertised extensively in fur-farming magazines (see fig. 25). Sometimes the fox can be induced to eat tasteless medicine placed in food.

When fox pups start to look for food they sometimes eat to excess, and the resulting indigestion is indicated by cramps or colic. A fox showing such symptoms should be captured and given 1 or 2 teaspoonfuls of castor oil. If the animal is cold or has been wet it should be kept warm and confined in a box; if it is bloated or swollen, Epsom salt should be administered, one-half teaspoonful in 2 tablespoonfuls of hot water. No food should be given but hot milk or hot beef tea. Rough handling should be avoided, and time enough should be allowed for the frightened puppy properly to swallow liquids. A fatal pneumonia is apt to be caused by pouring more liquid into the mouth than can be swallowed.

Foot disease is a pus infection. It is first localized in the sweat glands between the toes and then spreads into the lymph channels and the blood-stream, causing a lymphangitis with extreme swelling of the foot. A number of cases have developed into gangrene of the foot bones as well as multiple abscesses along the back and tail. One case revealed on post mortem an acute abscess of the dorsal gland of the tail, with other clinical symptoms of pyemia. The so-called foot disease may be communicable, but the general indications are that it is not. The causes of foot disease are not definitely known, but extreme moisture, insanitary dens and surroundings, or faulty feeding may be causative factors. Affected parts of blue foxes having foot disease are being examined by specialists of the Bureau of Animal Industry, and the findings will be made known as soon as definite information is obtained.

Wounds.—The lameness sometimes noted in young foxes found on the shore is generally due to wounds from stepping on sea urchins, one of their favorite foods. The spines of sea urchins are very sharp and sometimes will penetrate the sole of a shoe.

Slight wounds of the skin from bites and lacerations from other foxes readily heal because of the dust-free air and licking by the animals, but large wounds should be treated. If the wound has hanging flaps, cut them off. Remove all hair, grit, and pus from the sore, and then flush it with peroxide of hydrogen. After the wound has been properly cleansed, apply boric acid 4 parts and alum 1 part.

Cannibalism.—Cannibalism among foxes is not normal. Some authorities believe that it is purely a mental disorder, though it may be further increased by the taste of blood. There seems also to be an instinct among wild animals to kill sick mates. The vixen's desire to destroy her young may result from any of a number of causes. If constipated, she becomes feverish and develops an abnormal appetite, and in this condition may eat her pups. To prevent this, laxative feeds, as cod-liver oil, eggs, liver, linseed-oil meal, and biscuits, should be fed during pregnancy. Undue excitement or injury during this period may also influence the destruction of young. Some ranchers have advocated the feeding of salt pork and salt fish to eliminate this tendency, but this remedy is not always successful. Extraction of canine teeth is a mechanical way of stopping widespread injuries and losses from cannibalism.

First-aid remedies.—The following remedies should be kept on all fox farms in about the quantities mentioned:

Alum (dried), 4 ounces.

For light bleeding. Added to boracic acid, 1 part in 4, it makes a nonpoisonous dusting or wound powder.

Boracic (boric) acid, 1 pound.

Nonpoisonous and used freely as a dusting powder on open wounds. Dissolved in hot water it is valuable for bathing inflamed parts.

Epsom salt, 1 pound.

For use as a laxative, 1 teaspoonful in half a glass of warm water.

Flaxseed, 1 pound.

For warm, antiseptic poultices for boils, abscesses, and swollen feet. Boil in water until it assumes the consistency of a thick mush and apply while warm and moist.

Iodine (tincture), 4 ounces.

Used in full strength just as for human cuts and wounds.

Lysol (1 to 2 per cent), 8 ounces.

Disinfectant and antiseptic. Follow directions on bottle.

Peroxide of hydrogen, 1 pound.

Follow instructions on bottle and the directions in this bulletin.

Sulfur (powdered), 1 pound.

Use in ointment made with 1 part sulfur and 4 parts lard, or other pure fatty base, for skin diseases and bald spots.

FAILURES AND ABANDONMENTS

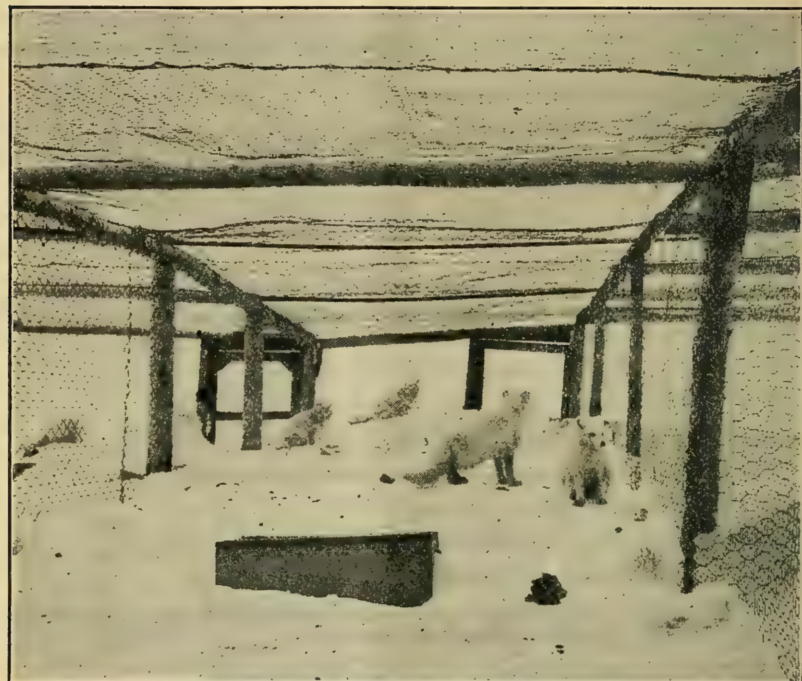
In the course of the development of the blue-fox industry, there have been a number of failures and abandonments of undertakings. Almost every one of these can be attributed to neglect of important factors of one kind or another. Some ranchers have attempted to raise foxes by placing a few animals on an island and then going away for long periods and leaving them to take care of themselves; others have left negligent or incompetent caretakers in charge; and still others, starting without sufficient capital to carry them to a producing state, have been compelled to neglect or even to abandon the industry. Failures under such conditions are not surprising, for successful fur farming requires the same attention and energy that is necessary to success in any other business.

BREEDERS' ASSOCIATIONS AND RANCHES

Blue-fox raising in Alaska has increased rapidly in the past few years. At present (1925) there are four breeders' associations representing the industry in the Territory, as follows:

The Southeastern Alaska Blue Fox Farmers Association, at Juneau.
The Blue Fox Farmers Association of South Central Alaska, at Cordova.
Cook Inlet Silver and Blue Fox Breeders Association, at Seldovia.
Southwestern Alaska Blue Fox and Fur Farmers Association, at Kodiak.

According to the most recent reports to the Biological Survey, there are 232 ranches in the Territory, distributed as follows: In



B2753M

FIG. 28.—White foxes in pens at Shishmaref, on the Seward Peninsula. Overhead wire is necessary to prevent the foxes from escaping over snowdrifts

southeastern Alaska, 129; in the Prince William Sound region, 36; in the Lower Cook Inlet region, 14; in the Kodiak-Afognak region, 14; in the islands off the Alaska Peninsula, 13; and in the Aleutian Islands region, 26.

WHITE-FOX FARMING IN NORTHERN ALASKA

Several experiments have been undertaken by individuals in northern Alaska in raising white foxes for their fur. The white fox is the normal phase of the Arctic fox *Alopex*, as noted on page 3 of this bulletin, and the description of the white and blue phases and their relationships are there mentioned. The experiments already undertaken have indicated the possibility that white-fox farming will become an important part of the fox-farming industry, not only of Alaska, but wherever the animals are found in the pure white, or normal, phase.

The increasing demand for fox furs is evidenced by the growth of the fox-farming industry, and that white foxes will play an important part in its future is indicated by the fact that of 92 permits issued in 1925 by the department for the capture of Alaskan fur bearers for propagating purposes, 33 were for taking white foxes. Persons engaged in the production of white foxes in the northern parts of Alaska are optimistic regarding the future of the industry and predict that it will some day equal or even surpass other industries which to-day are of much greater importance in the Territory.

The habitat of the Arctic or white fox is limited chiefly to the north polar regions, but extends south as far as Labrador. In the wild the white fox is more common than its relative in the blue phase.

Although the white fox is one of the smaller foxes existing, its pelt is one of the most popular. The estimated annual production of white-fox pelts in 1925 was as follows: North America, 30,000; Asia, 25,000; and Europe, 10,000. The prices paid for pelts are controlled largely by the relative scarcity of the animals and the market demand. Blue-fox pelts generally sell for much more than those of white foxes. Owing to the difference in the price of the skins many white pelts are dyed to imitate the natural blue. White-fox pelts are dyed various other shades also to harmonize with present-day colors in dress.

Like silver foxes, white foxes are confined in pens (fig. 28) and a number of ranches for them have been established on the Seward Peninsula. This section of Alaska is well adapted to fox ranching because of the abundance of cheap food, as herring, humpbacked salmon, seal meat, and reindeer offal, which white foxes take readily. The production of these animals in captivity has not been carried on long enough, however, to give definite advice regarding their feeding, breeding, and handling. The information found in this bulletin and in Department Bulletin 1151, "Silver-fox Farming," will be found helpful to pioneers in white-fox raising.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO FUR ANIMALS

FOR FREE DISTRIBUTION BY THE DEPARTMENT

Economic Value of North American Skunks. (Farmers' Bulletin 587.)
The Muskrat as a Fur Bearer. (Farmers' Bulletin 869.)
Rabbit Raising. (Farmers' Bulletin 1090.)
American Moles as Agricultural Pests and as Fur Producers. (Farmers' Bulletin 1247.)
Game Laws for the Season 1925–26. (Farmers' Bulletin 1466.)
Laws Relating to Fur Animals for the Season 1925–26. (Farmers' Bulletin 1469.)
Beaver Habits, Beaver Control, and Possibilities in Beaver Farming. (Department Bulletin 1078.)
Reindeer in Alaska. (Department Bulletin 1089.)
Silver-fox Farming. (Department Bulletin 1151.)
Blue-fox Farming in Alaska. (Department Bulletin 1350.)
Trapping on the Farm. (Yearbook Separate 823.)
Directory of Officials and Organizations Concerned with the Protection of Birds and Game, 1925. (Department Circular 360.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Deer Farming in the United States. (Farmers' Bulletin 330.) Price, 5 cents.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September 24, 1925

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	————
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	THOMAS P. COOPER, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This bulletin is a contribution from

Bureau of Biological Survey	E. W. NELSON, *Chief.*
Division of Fur Resources	F. G. ASHBROOK, *in Charge.*
Division of Alaska Investigations	E. W. NELSON and W. F. BANCROFT, *in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
7

U. S. DEPARTMENT OF AGRICULTURE
OFFICE OF INFORMATION
DIVISION OF PUBLICATIONS

DEPARTMENT BULLETINS
Nos. 1351-1375

WITH CONTENTS

PREPARED IN THE INDEXING SECTION

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1928

CONTENTS

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1355

Washington, D. C. November, 1925

FOOD HABITS OF THE VIREOS

A Family of Insectivorous Birds

By

EDWARD A. CHAPIN, formerly Assistant Biologist
Division of Food Habits Research
Bureau of Biological Survey

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1355

Washington, D. C. ▲ November, 1925

FOOD HABITS OF THE VIREOS:

A Family of Insectivorous Birds

By Edward A. Chapin, formerly *Assistant Biologist, Division of Food Habits Research, Bureau of Biological Survey* [1]

CONTENTS

ECONOMIC RELATIONS

During the summer almost anywhere in the United States at least one species of vireo, and usually more than one, is to be found flitting about in the trees or shrubbery. In the eastern and central parts of the country the common species is the red-eyed vireo, which is considered the most abundant of all species of woodland birds. Others more or less common in the East are the white-eyed, warbling, and yellow-throated vireos, and in the far West there is another form of the warbling vireo that is abundant. The Philadelphia, the blue-headed, the Hutton, and the Bell vireos are found more or less locally. The black-whiskered vireo in the United States is found only in Florida, and the gray vireo is confined to the southwestern portion of the country where it is not at all common. One other species, the black-capped vireo (*Vireo atricapillus*), is very rare in the United States, and as no stomachs have reached the collection of the Biological Survey nothing can be said concerning its food habits.

Though in general the food items of all the vireos are very similar, their proportions vary in the diet of different species. For instance, the food of the red-eyed vireo is made up of about seven-eighths animal matter and one-eighth vegetable, whereas that of the yellow-throat contains vegetable matter only to the extent of one-fiftieth of the total, and that of the Bell vireos apparently to an even less extent. Caterpillars make up an eighth of the food of the Hutton and more than a third of the warbling vireos. Bugs are seldom eaten by the Philadelphia vireo and amount to but a tenth of the food, whereas

[1] Doctor Chapin has been transferred from the Biological Survey to the Zoological Division of the Bureau of Animal Industry since preparing this report.

50209—25†——1

the Hutton vireos obtain nearly half their food from this source. Stink-bugs form about a fifth of the food of both the blue-headed and the Hutton vireos. The red-eyed and Philadelphia vireos each make nearly a seventh part of their food of wasps and other hymenopterous insects, whereas the other vireos take barely half as much of this kind of food. Beetles form about an eighth of the total food of vireos, but in the case of the Philadelphia vireo they are a favored article of diet and amount to nearly a fourth. The useful ladybird beetles are notable in the diet of these birds and are especially important with the warbling and Hutton vireos, in each species amounting to about a twelfth of the food.

Most of the insects in the food of the vireos are either neutral or definitely injurious in their economic relations and may be placed on the credit side of the account of these birds. All vireos are especially fond of caterpillars, creatures which are almost exclusively injurious. Scale insects, which are uniformly destructive and numbered among the worst pests of horticulture, are a notable item of vireo food; and other tree pests, as round-headed and flat-headed borers, leaf beetles, click beetles, leaf hoppers, and tree hoppers are freely eaten. Weevils, a group of beetles whose very name has become almost a synonym for pest, also are preyed upon. Among the species taken are such well-known destructive forms as the clover-root, clover-leaf, cotton-boll, and nut weevils, the plum curculio, and bark beetles. Vireos must be given credit also for destroying ants and grasshoppers.

Useful insects taken by the vireos include some of the hymenopterans, predacious bugs, and beetles, among which are ladybird beetles (Coccinellidae). Vireos either find more ladybirds in the ordinary course of their feeding habits than do most other birds, or specialize upon them, an unfortunate habit economically, as these beetles are almost uniformly beneficial. Since vireos themselves devour many of the pests attacked by ladybirds, however, and since their capacity is so much greater, their depredations on ladybirds must be excused on the principle that the greater pest destroyer is more valuable than the lesser.

TABLE 1.—*Percentages of various items in the food of vireos*

Species	Number of stomachs	Animal food	Vegetable food	Scarabaeidae	Coccinellidae	Chrysomelidae	Elateridae, Buprestidae, Cerambycidae	Other Coleoptera	Rhynchophora
Black-whiskered vireo (*Vireosylva calidris*)	4	87.50	12.50	--------	--------	--------	--------	15.75	2.50
Red-eyed vireo (*Vireosylva olivacea*)	569	85.28	14.72	3.31	1.29	1.63	2.70	.78	1.13
Philadelphia vireo (*Vireosylva philadelphica*)	75	92.78	7.22	6.94	5.03	7.99	.96	.47	3.43
Warbling vireos (*Vireosylva gilva*, subspp.)	340	94.24	5.76	1.28	8.74	2.48	1.03	.55	1.45
Yellow-throated vireo (*Lanivireo flavifrons*)	160	98.26	1.74	1.84	.62	.82	3.57	1.82	4.23
Blue-headed vireos (*Lanivireo solitarius*, subspp.)	306	96.32	3.68	1.67	4.88	.96	3.39	.81	1.80
White-eyed vireos (*Vireo griseus*, subspp.)	221	88.24	11.76	.66	1.36	3.78	2.31	1.46	3.21
Hutton vireos (*Vireo huttoni*, subspp.)	70	98.23	1.77	.27	8.12	.25	.85	1.01	2.75
Bell vireos (*Vireo belli*, subspp.)	52	99.30	.70	--------	2.19	3.98	1.69	1.31	6.09

TABLE 1.—*Percentages of various items in the food of vireos*—Continued

Species	Caterpillars	Other Lepidoptera	Pentatomidae	Other Hemiptera	Hymenoptera	Diptera	Other insects	Arachnida	Other animal matter
Black-whiskered vireo (*Vireosylva calidris*)	11.75	2.50		2.75	3.00		10.00	39.25	
Red-eyed vireo (*Vireosylva olivacea*)	32.43	2.76	7.03	8.33	10.79	4.46	4.59	4.05	Trace.
Philadelphia vireo (*Vireosylva philadelphica*)	24.13	2.17	1.67	8.79	13.96	11.76	1.14	4.34	
Warbling vireos (*Vireosylva gilva*, subspp.)	35.40	4.99	5.47	11.24	5.97	9.46	4.44	1.74	
Yellow-throated vireo (*Lanivireo flavifrons*)	23.10	19.35	15.50	7.62	5.07	7.36	4.92	2.38	0.06
Blue-headed vireos (*Lanivireo solitarius*, subspp.)	22.49	9.31	20.13	10.29	6.86	4.29	6.56	2.63	.25
White-eyed vireos (*Vireo griseus*, subspp.)	20.66	9.83	8.56	11.71	7.23	4.41	9.10	3.59	.37
Hutton vireos (*Vireo huttoni*, subspp.)	12.22	12.33	20.15	25.73	6.30	2.99	3.21	2.05	
Bell vireos (*Vireo belli*, subspp.)	15.89	4.74	9.34	25.09	6.44	.78	18.77	2.71	.28

In the fall, winter, and spring months, when insects are in hibernation, the vireos which remain in this country turn to plants for part of their food. The vegetable food varies according to the species, as shown in Table 1, from 0.7 per cent to 14.72 per cent of the total.[2] In no case did stomachs of any of the vireos contain a large proportion of cultivated fruit, and very few stomachs had any; so that, as fruit eaters the vireos are practically harmless. In all species almost the entire bulk of the animal food was made up of insects.

A list of all the items identified in the food of the vireos, showing the number of stomachs in which each item was found, is given in Tables 2 and 3, beginning on page 28.

BLACK-WHISKERED VIREO

Vireosylva calidris barbatula

The black-whiskered vireo is found in the United States only in the southern portions of Florida, where it is fairly common in the vicinity of Key West, and may be found as far north as Anclote Keys. Unfortunately, only four stomachs were available for examination, collected on Anclote Key, May 21 and 22, and at Seven Oaks, June 7.

Of the entire food, 87.5 per cent was of animal origin. By far the largest single item was spiders, 39.25 per cent of the whole; in one stomach were the remains of 10 individuals of one kind (*Tetragnatha*). Caterpillars and eggs of some moth or butterfly made up 14.25 per cent of the food. In one stomach were 10 small earwigs (Forficulidae), which represented about 10 per cent of the animal food. Miscellaneous beetles, including weevils from one stomach, made up 18.25 per cent, and the remaining 5.75 per cent was composed of wasps or bees and assassin bugs (Reduviidae).

The vegetable food, 12.5 per cent of the total, was composed of fruit of barberry (*Berberis*) and of ragweed (*Ambrosia*), found in three of the four stomachs.

[2] The figures available show no vegetable food for the gray vireo; but this is probably not trustworthy, because of the very small number of stomachs representing the fall months.

Although the number of stomachs examined was small, it is possible to check the results by comparison with those obtained by Wetmore, who analyzed the contents of 84 stomachs of the typical subspecies from Porto Rico. His findings [3] show that the bird is decidedly frugivorous, inasmuch as wild fruits or berries were detected in 80 of the 84 stomachs examined and amounted to 57.82 per cent. The remaining 42.18 per cent represented animal matter, of which all but 0.61 per cent was composed of insects or spiders, this small item being made up of two little tree toads (*Eleutherodactylus*). As in the case of the Florida birds, spiders made up one of the larger items, occurring in 30 stomachs and comprising 7.74 per cent of the bulk. Orthopteroid insects, consisting of grasshoppers (Locustidae) in three stomachs, walking sticks (Phasmidae) in two, praying mantids (Mantidae) in three, and miscellaneous orthopterans in nine, formed together 6.34 per cent. Cicadas, a lantern fly, and some small homopterans amounted to 8.29 per cent. Caterpillars were eaten by 21 birds and made a total of 9.7 per cent, the largest item of animal food. Weevils and leaf beetles, including the sugar-cane root borer and coffee-leaf weevil, occurred in more than a third of the stomachs, forming a total of 5.37 per cent. The remainder of the animal food was composed of ladybeetles (0.42 per cent), miscellaneous beetles (0.64 per cent), hymenopterans, including a wasp and an ant (2.03 per cent), flies (0.21 per cent), and earwigs, which were detected six times (0.83 per cent).

SUMMARY

It is evident from both the Florida and the Porto Rico accounts that there is little actual harm done by the black-whiskered vireo, and that it is entitled to encouragement. The spiders and some of the beetles eaten may be considered beneficial, but the caterpillars, weevils, and earwigs are certainly injurious. The bugs are about equally divided between injurious and beneficial forms, and the remaining items are either too small to be of importance or are neutral in their economic aspects.

RED-EYED VIREO

Vireosylva olivacea

The red-eyed vireo (fig. 1) is probably the most abundant of the members of its family. In the United States its range is restricted in general to the territory east of the Rocky Mountains; in Canada, it is practically transcontinental, with Great Slave Lake in the Mackenzie region approximately its northern limit. In migration the red-eye is reported as far south as Brazil.

During the summer months in almost any bit of woodland one may find this olive-colored bird going about its business of catching insects, or later selecting the berries of many of our native shrubs, and singing as if it were second nature to be cheerful. Even at noon, when most of the feathered tribe seek the cool shade, this little fellow continues its song and its search for food.

[3] Wetmore, Alexander, Birds of Porto Rico. U. S. Dept. Agr. Bul. No. 326, pp. 97–98, 1916.

B2554M

FIG. 1.—Red-eyed vireos, male and female

When the mating season arrives, from the middle of May to the last of June, the nest is started in a convenient fork of a branch, often near the ground; and, when finished, this is suspended by the rim rather than supported from below. The nest is a trim affair, about the size of a small teacup, woven of fibrous matter, among which may be instanced such substances as bits of birch bark, grapevine bark, or flax. Diligent search is required to disclose a nest when the leaves are green, but the number visible in fall is surprising. The first egg may be laid even before the nest is finished, and when this is the case the female remains at the nest while her mate searches for additional building materials. During the season of rearing the young, the patience of the red-eye is taxed to the utmost by the cowbird. Brewer has reported a case of this form of parasitism where the vireos reared three young cowbirds without laying eggs of their own, and other records show that one or two cowbirds' eggs are not uncommonly found in a vireo nest.

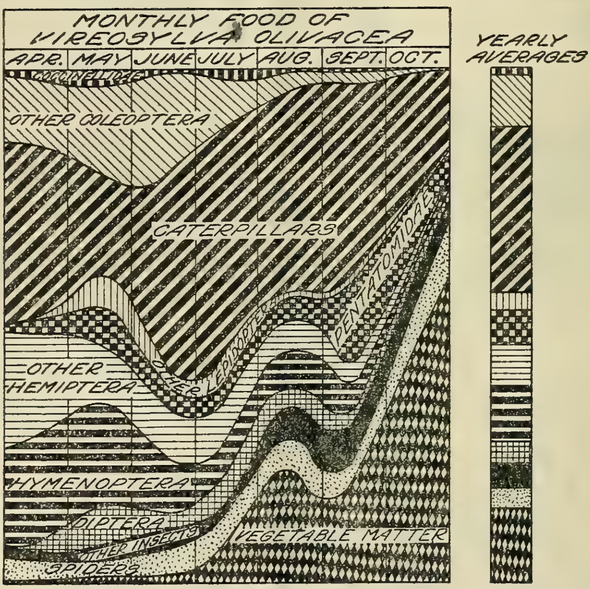


FIG. 2.—Monthly proportions of the various items in the food of the red-eyed vireo (*Vireosylva olivacea*), based on the analysis of the contents of 569 stomachs, with the average of each item for the year

The annual food of the red-eyed vireo is composed of 85.28 per cent animal matter and 14.72 per cent vegetable. (See fig. 2.) The vegetable matter is taken more often late in summer and in fall and consists of the berries and fruits of such plants as wild cherry, sassafras, cornel (or dogwood), wild grapes, and woodbine. Of a total of 653 stomachs available, 569 contained sufficient food for the correct estimation of percentages, and it is on the examination of the latter that the present report is based. This material was collected during the months April to October, inclusive, over the greater part of the range of the species in North America.

ANIMAL FOOD

Practically six-sevenths of the food consumed by the red-eye is of animal origin, and very nearly all of it is insects. The remainder is composed of the small snails that are found more or less frequently on leaves and grass.

Lepidoptera.—Caterpillars form by far the largest single item in the yearly sustenance, and amount to 32.43 per cent of the total, or more than one-third of the animal matter eaten. They were found in 371 of the stomachs, over half of the number examined. In general it is difficult or even impossible to identify the species of caterpillars found in stomachs, but the larvae of sphinx moths, swallowtail butterflies, tent caterpillars, and codling moths were detected. Most caterpillars are injurious to man's interests or have characteristics which at any time may cause them to become so. Hence, so great a destruction of these larvae as the figures show is a strong argument in favor of this vireo.

Lepidopterous forms other than caterpillars make up a small percentage (2.76) of the annual food. Adult moths and butterflies were found in 26 stomachs, pupae (cocoons and chrysalids) in 14, and eggs in 3. These may all be placed with caterpillars as injurious forms.

Coleoptera.—Beetles make up 10.84 per cent of the total food for the year, 1.29 per cent of which is composed of lady beetles. Lady beetles, or "ladybirds," as the members of the family Coccinellidae are often called, are, with a very few exceptions, decidedly beneficial to man's interests. Eighty-five of the stomachs examined contained coccinellids, some from three to eight individuals each. It can only be said that, considered in connection with all the food taken, the destruction of lady beetles is more than repaid by beneficial activities in other directions.

Scarabaeid beetles, otherwise known as "leaf chafers" and "dung beetles," form a small item in the yearly food of this bird. During June, when the larger leaf-infesting species are in greatest abundance, the percentage of this item rose to 11.88. Among the forms recognized are many species of the medium-sized and robust brown leaf chafers, which are capable of considerable damage. Scarabaeids were found in 75 of the 569 stomachs examined and made a total of 3.31 per cent of the food.

Leaf beetles (Chrysomelidae) are injurious in their feeding habits; hence the quantity taken by the vireo is to be considered a gain to man. Though a species of leaf beetle may be known to attack only wild plants, there is always the possibility that it may adapt itself at any time to life among the cultivated plants, shrubs, or trees, and with that adaptation become detrimental to man's interests. Examination of the stomachs shows that the percentage of leaf beetles rises to 4.4 in May, after which it becomes less, disappearing entirely in October. In fact, the percentages vary directly with the abundance of the item, as is to be expected. Considered as part of the annual diet, chrysomelids make up 1.63 per cent and were found in 136 of the stomachs examined.

Representatives of the three families Cerambycidae, Buprestidae, and Elateridae have been grouped for convenience. The larvae, or grubs, of all these beetles pass their lives either within wood or among the roots of plants and are very destructive to lumber and grain each year. As with the leaf beetles, any check on these forms is to be welcomed, and a percentage as high as 2.7 is to be considered favorable to the bird. Nearly a third of the individual birds had taken this kind of food.

Under the heading of weevils are grouped all members of the suborder Rhynchophora, commonly known as curculios, billbugs, bark beetles, and the like. Weevils or their remains were detected in 141 of the stomachs and formed 1.13 per cent of the yearly sustenance. This percentage is small, but the average size of individuals among the Rhynchophora also is small, much smaller than in the preceding groups, and it is probable that the number of individuals represented is very large. Little good can be said of weevils. While many species have not yet come into direct conflict with man, their pernicious habits have been demonstrated by those which have; and although the percentage of these beetles eaten by the red-eye is relatively small, their consumption must be considered a favorable economic tendency.

Other miscellaneous beetle material formed less than 1 per cent (0.78) of the red-eye's food. It would be difficult to determine the economic status of these beetles as a whole. Certain families, as the ground beetles (Carabidae) and rove beetles (Stapyhlinidae), are usually considered beneficial. The checkered beetles (Cleridae) are beneficial and are now believed to be one of the most efficient checks on boring beetles. On the other hand, the forms which may be called injurious are few; for instance, the deathwatch or drug-store beetles (Ptinidae) and meal worms (larvae of Tenebrionidae).

Hemiptera.—Each year approximately 7.03 per cent of the food eaten by a red-eyed vireo is composed of stink-bugs (Pentatomidae). This family of insects includes the well-known harlequin cabbage bug, and several other species injurious to man. In fall, when other bugs and wasps become scarce, the red-eye eats a considerable number of stink-bugs, the quantity taken in September forming 16.15 per cent of the total food, and during September and October they are third in the list. The number of birds selecting this form of diet also is large, a total of 158, or over a fourth of those examined.

The rest of the true bugs make up 8.33 per cent of the annual food, but the frequency of their appearance in the stomachs is exactly the reverse of that of the stink-bugs. In April the percentage is very high, 20.26, and from then on it diminishes steadily, until in October it is 0.29 per cent. Among the species identified from stomachs are squash bugs, cicadas, scale insects, leaf hoppers, and assassin bugs. Hemipterans appear attractive to this bird, and it was found that of the stomachs examined 250 contained the remains of at least one bug. The small bulk percentage of this item is due mainly to the fact that most of the plant-infesting bugs are of small size.

Hymenoptera.—Over half (321) of the stomachs contained the remains of some species of the order which includes the wasps, bees, ants, and most of the insect parasites. Of these forms, ants are the most injurious and were taken by 93 of the birds. The remainder of the group is for the most part beneficial, as in it are found innumerable minute parasitic forms which do much to prevent the earth from being overrun with insects. Fortunately, the majority are so small as to avoid the notice of birds. The wild bees, wasps, and arger ichneumon flies, which are of service in the pollination of flowers, suffer most from the red-eye; but their number is so great that it is probable that no one species is much affected by the vireo. As only two instances were found of the eating of a honeybee by this bird, it is evident that this vireo is not destructive to these useful insects. As with most of the hemipterans, the greatest destruction of the hymenopterans by the bird is in spring, the percentage for April being 20.39. This figure is increased to 20.97 in May, and from then on to the close of the season it diminishes steadily to 3.18 in October. Hymenopterans, with 10.79 per cent, stand third in quantity in the annual food of this species.

Diptera.—Flies, although eaten more or less regularly, do not at any time form a large portion of the diet of the red-eye. Remains of these were found in 119 stomachs and amounted to 4.46 per cent of the total food. Crane flies and midges appear to be the kinds usually taken; this is undoubtedly because such forms are more abundant in the natural feeding haunts of the bird.

Other insects.—Grasshoppers, katydids, stone flies, tree crickets, and similar insects together make up 4.59 per cent of the food. Of 569 stomachs examined, 88 contained at least traces of these forms, the percentage steadily increasing toward fall. This increase may be attributed to the greater abundance of the grasshoppers and katydids at that season and also to the growing scarcity of the foods which formed substantial percentages in spring. There are both beneficial and injurious forms included in the miscellaneous category; but it is evident from the stomach analyses that the injurious forms, as grasshoppers, outnumber the beneficial forms—dragonflies, and other predacious amphibious insects—by more than two to one. One can hardly begrudge the vireo this small toll (about 2 per cent) collected while performing a good service.

Spiders.—Most spiders make their homes on bushes and in the branches of trees and there spread their filmy nets to catch whatever unwary insect may stumble into them. Thus both the red-eye and the spider are helping to check the increase of insects. But as the predatory activity of 10 or even 100 spiders is not comparable to that of one vireo, the bird is economically the more useful. That the remains of spiders were detected in 188 of the stomachs examined indicates that they are a favorite article of diet with this vireo. In August, when they are most abundant, spiders amount to nearly 6.5 per cent of the total food, but this figure is not maintained either in spring or fall, and the annual percentage is only 4.05.

Other animal food.—Apparently it is only curiosity which leads a red-eyed vireo to take animal food other than insects or spiders. Remains of snails, probably of a kind usually found on leaves and grass, were found in two stomachs collected in June, and as they form only 0.02 per cent of the food of that month they are entirely lost in the yearly averages.

VEGETABLE FOOD

During the first part of the year, when insect food is plentiful, the red-eyed vireo takes very little vegetable matter. From August on, however, the vegetable food increases rapidly, until in October the percentage of 49.41 is reached. Berries of all kinds find favor with this bird, from the sweet mulberry to the bitter barberry. Of the berries most used by man and eaten also by the red-eyed vireo may be mentioned white mulberries, found in 3 stomachs; wild cherries, in 1; currants (probably wild), 1; blackberries, 9; elderberries, 10; blueberries, 1; and grapes (the wild chicken grape), in 2. Berries without even so much economic importance, that appear most often in the stomachs are those of spice bush, found 7 times; cornel of various species, 22 times; bay, 5; Virginia creeper, 11; and sassafras, 6 times. Thus the predominance in the food of the nonuseful fruits over the useful is great. The total vegetable matter, which also includes a few grass seeds and flower and leaf buds, amounts to approximately one-seventh (14.72 per cent) of the yearly food, and is second of the items in quantity.

SUMMARY

During the months April to October, inclusive, the food of the red-eyed vireo is made up of six-sevenths animal matter, practically all insects, and one-seventh vegetable, mostly fleshy fruits and berries. Not more than 5 per cent of the entire food can be considered of great economic value, while most of the remaining 95 per cent is of kinds decidedly injurious to man's best interests. It is, therefore, obvious that in usefulness the red-eyed vireo ranks high.

PHILADELPHIA VIREO

Vireosylva philadelphica

The Philadelphia vireo is rather uncommon in the United States over the greater part of its range, but may be found in considerable abundance at times in Canada. Somewhat smaller and more gray than the red-eyed vireo, it may be recognized by its small size and the yellow of the throat and breast. The breeding range is in general north of the United States, although there are records of breeding birds as far south as Indiana.

The collection of the Biological Survey contains 84 stomachs of this bird; only 75, however, taken in the months of May, June, and September, contained sufficient food for the proper estimation of percentages. (See fig. 3.) The food is largely animal in nature, there being but 7.22 per cent not of this character.

ANIMAL FOOD

Insects make up all but 4.34 per cent of the animal food consumed by the Philadelphia vireo in the summer months—this small percentage representing the spiders so frequently present in the food of insectivorous birds.

Lepidoptera.—The largest single item is the group consisting of caterpillars and adult moths and butterflies, which together make an average yearly percentage of 26.3, or more than a fourth of all the food consumed. Of this, only 2.17 per cent refers to adults, leaving a total of 24.13 per cent for the caterpillars. It appears that as the season advances caterpillars become more and more important in the food, for in May the percentage is only 15, while by September it has risen as high as 39.94, which, taken with 5.59 per cent of adults, makes a total of 45.53 per cent, or nearly half the entire food of the month.

Coleoptera.—A total for the year almost as great as that of caterpillars and their adult forms is found to be made up of beetles and weevils, which form almost a fourth (24.82 per cent) of the total. The beneficial beetles eaten are almost all of the family Coccinellidae, or ladybirds, well-known as enemies of plant lice and scale insects. Thirteen species of ladybirds have been identified from stomachs of the Philadelphia vireo, and these make up a little more than a fifth of all the beetles consumed, or about 5 per cent of the total food. This large percentage, however, is more than offset by the remaining beetles most of which are species of distinctly injurious tendencies.

The leaf-eating beetles (Chrysomelidae) lead the list of families of injurious beetles, with a total of 7.99 per cent. During May the leaf eaters seem to be more abundant, as then they make up a total of nearly 11 per cent. This high percentage is not maintained throughout the year, however, and by September only 4.59 per cent of the food is of this description. Next in order of importance from the viewpoint of quantity consumed come the leaf chafers and dung beetles (Scarabaeidae). The true dung beetles should be considered

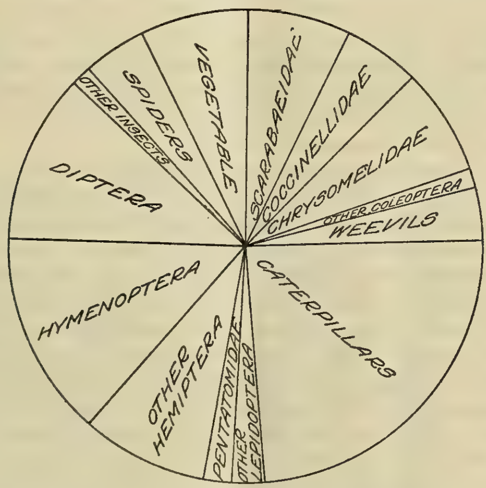


FIG. 3.—Yearly summary of the various items in the food of the Philadelphia vireo (*Vireosylva philadelphica*), based on the analysis of the contents of 75 stomachs

mildly beneficial, inasmuch as they carry beneath the surface quantities of fertilizing elements. As the very nature and mode of life of the vireo, however, prevents it from catching many of these, they have been included with their injurious cousins, the leaf chafers. Taken together, they represent a total of 6.94 per cent, all eaten before September. In June the percentage is very high (14.08), and it is almost all leaf chafers.

A third group of injurious beetles found with some frequency in the stomachs is the suborder Rhynchophora, or weevils, which make up 3.43 per cent of the food of the Philadelphia vireo. Although this proportion is not very great, it appears to be evenly distributed throughout the year. The wood-boring beetles, Buprestidae and Cerambycidae, and the plant-feeding Elateridae together make up a little less than 1 per cent of the total. Except in June, when these forms exceed 2 per cent, the item is insignificant. The rest of the beetles eaten, including beneficial, injurious, and neutral forms in varying proportions, amount to only 0.47 per cent and may be disregarded for practical purposes.

Hymenoptera.—Approximately 14 per cent of the annual subsistence of the Philadelphia vireo is composed of wasps, bees, and related insects. Here are to be found some of the most beneficial of all insects, the parasitic ichneumon flies and the minute chalcids. On the other hand, the kinds of ants eaten are usually injurious, especially the large, black, carpenter ants (*Camponotus herculeanus*), and even if some of them do no direct damage they are indirectly injurious in fostering plant lice. At times the birds fill their stomachs with many individuals of the same species; for instance, one bird had eaten 20 individuals of a certain ant (*Aphaenogaster*); another, 10 sawflies (Tenthredinidae); and a third, 15 sawfly larvae. In its economic status the Philadelphia vireo, so far as hymenopterans are concerned, must be considered beneficial in that the injurious insects captured outnumber by far the beneficial forms.

Diptera.—In the 84 stomachs examined the remains of flies were detected in 36, or more than a third. In 19 of these the flies were of the midge family (Chironomidae), and in some, midges made up nearly the entire contents. Flies form 11.76 per cent of the food. This item includes both beneficial and injurious forms and may be listed as economically neutral.

Hemiptera.—True bugs make up 10.46 per cent of the annual food of this vireo, 1.67 per cent being composed of stink-bugs (Pentatomidae). These are large, flat insects, and the majority are injurious. One group, including the species of the genus *Podisus*, are, because of their predacious habits, reckoned among the beneficial forms. Fortunately, members of this genus are rarely found in the stomachs of the Philadelphia vireo, hence the stink-bugs in general may be placed on the credit side. Assassin bugs (Reduviidae), another group of beneficial bugs, are entirely lacking in these stomachs, so that on the whole the true bugs eaten are to the credit of the bird.

Other insects.—The remainder of the insect food of this bird, amounting to but 1.14 per cent, has little or no economic significance. It is made up of a few neuropteroid insects, together with fragments so comminuted that further determination was impossible.

Spiders.—It is not surprising that spiders, so common on the leaves and twigs of bushes and trees, should have been taken by 34 of these birds to the extent of 4.34 per cent of their food. Once the kind eaten proved to be a daddy longlegs or harvestman (Phalangidae), and 10 times the fragments were readily determined as of the family of jumping spiders (Attidae). In the other cases, however, it was impossible to decide the kind of spiders represented. Spiders are probably all beneficial in a small degree, but the eating of a few should not count heavily against an insectivorous bird.

VEGETABLE FOOD

Lack of stomach material of the Philadelphia vireo, representing early spring or late fall, makes it impossible to show exactly how the relation between animal and vegetable food varies with the season. As the new crop of wild fruits develops, however, the birds are attracted to it, and in September this item forms 18.71 per cent of the diet. Among fruits identified were dogwood berries, taken four times, while bayberries (*Myrica carolinensis*), wild rose hips (*Rosa*), and wild grapes (Vitaceae) were identified in only one or two stomachs each. No cultivated fruits or seeds were found, and there is nothing in the list of vegetable items to discredit the bird in any way. Although 18.71 per cent of the September food was of vegetable origin, the seasonal average from the stomachs available amounts to but 7.22 per cent.

SUMMARY

Outstanding features of the food habits of the Philadelphia vireo are its moderate consumption of vegetable food and the comparatively high percentage of ladybirds. This last item appears to be the one blot on the escutcheon of all members of the family of vireos. The rarity of the Philadelphia vireo, however, insures that it will do little harm in reducing the numbers of ladybird beetles.

THE WARBLING VIREOS

Vireosylva gilva, subspp.

The warbling vireo in its two subspecies is one of the more common of the vireos over the entire United States. A total of 356 stomachs were available for examination from 29 States and the District of

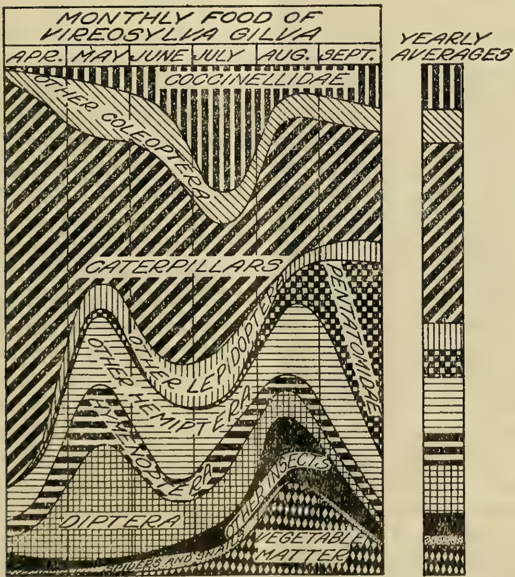


FIG. 4.—Monthly proportions of the various items in the food of the warbling vireos (*Vireosylva gilva*, subspp.), based on the analysis of the contents of 340 stomachs, with the average of each item for the year

Columbia and a few from southern Canada. Of these, 340 contained sufficient food to permit the estimation of percentages of the various items.

Between 5 and 6 per cent of the food consumed by the warbling vireos during the year is of vegetable origin. This is considerably less than half the proportion taken by the red-eyed vireo. The food of animal origin is discussed under its several classes. (See fig. 4.)

ANIMAL FOOD

Coleoptera.—Beetles make an annual total of 15.53 per cent, or nearly a sixth, of the food. Of these the ladybird beetles (Coccinellidae) are the most common. More than half of the coleopterans eaten are of this family, and more than one-twelfth of the food by bulk is composed of these valuable insects. During July about 26 per cent of all the animal food is ladybirds, a remarkable percentage, for coccinellids are far from being a fourth as plentiful as all other insects together. The remaining 6.79 per cent of beetles is composed almost entirely of injurious forms, as leaf eaters, wood-boring forms, and weevils.

Lepidoptera.—Caterpillars, usually injurious, make up the commendable percentage of 35.4—more than a third of the yearly food. This is undoubtedly the most important item in the dietary of the warbling vireo, especially in spring, when it amounts to 69.74 per cent. The percentage of this item fluctuates more or less during the season, reaching its lowest ebb, 22.75 per cent, in September. The other forms of butterflies and moths, amounting to 4.99 per cent, are included with the caterpillars and make a grand total for this type of food of 40.39 per cent.

Hemiptera.—The third class of animal food of the warbling vireo of sufficient importance to be considered separately is composed of the true bugs. These annually form 16.71 per cent of all the food, a little greater in quantity than the beetles. About a third of the bugs taken belong to the family of stink-bugs (Pentatomidae). These are mostly large, ill-smelling insects and are considered by some as protected from birds by their odor. In the present case, however, the odor is either pleasing to the birds or at least not repelling.

Other animal food.—The remainder of the food of animal origin amounts to a little more than a fifth of the total yearly food. The largest single item is made up of the different forms of flies (Diptera). During May, this item represents 22.63 per cent, or nearly a quarter of the food. From June on, however, there is a rapid decrease in the number eaten, so that by September, flies in the food constitute only 2.64 per cent. Considered for the whole year, a percentage of 9.46 is reached, a fair index to the value of these insects in the food of the warbling vireo. To this is to be added 5.97 per cent, representing the wasps, bees, and other hymenopterous insects consumed during the year. The incidence of hymenopterans is paralleled by that of dipterans, May being the month of greatest consumption, here equaling 12.02 per cent.

All other insects eaten together form the comparatively small percentage of 4.44. Only during August, when grasshoppers are abundant and a convenient form of food, does this item assume importance, at which time it forms 12.29 per cent of the monthly sustenance.

With the exception of a few snails, a mere trace, the rest of the animal food is composed of spiders, an almost insignificant item for the year, but amounting in June to 3.03 per cent.

VEGETABLE FOOD

The vegetable food of the warbling vireo is made up in great part of the smaller wild fruits, as cherry, sassafras, bayberries, and blackberries. During the early part of the year vegetable matter appears to figure in the food only incidentally, but after the height of the insect season has passed the birds turn to the ripe fruits as a source of supply. Thus in April the vegetable matter formed but 0.12 per cent, but in August and September it ran as high as 18.69 and 9.33 per cent, respectively. Of the total food, this item makes up 5.76 per cent.

SUMMARY

The economic status of the warbling vireo is in some ways more distinctly unfavorable than that of the other species of this family of birds, especially in its consumption of ladybirds. In more than a third of the stomachs examined the remains of these beneficial beetles were found. Destruction of ladybirds is most evident in stomachs collected in California, where the members of this group of beetles are known to be unusually common. The species known as the California ladybird leads the list in number, appearing in 41 stomachs, as high as eight to a single stomach in a few instances. A second category of insects, which from predacious habits are to be considered beneficial to man, is made up of the species of stink-bugs of the genus *Podisus*, detected in 18 stomachs. Owing to their size, a few will completely fill the stomach of the bird, and thus the likelihood of extensive meals so far as numbers of the insects are concerned is not great.

On the other hand, the injurious insects taken by the warbling vireo make up the greater part of the food. Lepidopterous remains, including adult moths and butterflies, caterpillars, pupae, and eggs, were taken from about 77 per cent of those examined. This alone should atone for the bird's injurious proclivities along other lines. In addition to lepidopterans, the consumption of scale insects, which were found in 18 stomachs, and of bugs, omitting the forms of *Podisus* and a few others, swells the total of injurious kinds consumed. Little if any of the vegetable food taken was obviously cultivated, in most cases being from plants not used for their fruits. It seems reasonable, then, to class the bird as neither beneficial nor injurious.

It is probable that a warbling vireo in a citrus grove would be economically a liability, but in the woods and other places where the conservation of coccinellids is not of so great importance there is little to be considered objectionable in its habits.

YELLOW-THROATED VIREO

Lanivireo flavifrons

The yellow-throated vireo is the handsomest of the family and spends much of its time high up in the trees. This species is not uncommon in the eastern part of the United States, where it remains during the summer months to breed. It arrives in Florida and Texas about the last of March and by the first week in May many individuals have reached their breeding grounds. The return migration in fall commences early in September, and by October there are few birds of this species left in the United States.

One hundred and sixty stomachs of the yellow-throated vireo, collected during the months April to September, inclusive, were available for analysis, the most noticeable fact established by the examination of which is the very small percentage of vegetable matter—only 1.74 per cent of the total. (See fig. 5.)

ANIMAL FOOD

The animal food of the yellow-throated vireo makes up 98.26 per cent of the total, and may be divided as follows: 95.82 per cent insects, 2.38 per cent spiders, and 0.06 per cent other animal matter.

Lepidoptera.—More than 42 per cent of the yearly food of the yellow-throat is made up of butterflies and moths in their different stages. As in the food of other species of this family of birds, caterpillars are the most important item (23.1 per cent). Almost all adult insects of this order found in the stomachs were moths, and together made up a total of 19.35 per cent. There appears to be no definite time of year when the birds prefer lepidopterous food, although in September a maximum of 36 per cent was reached for

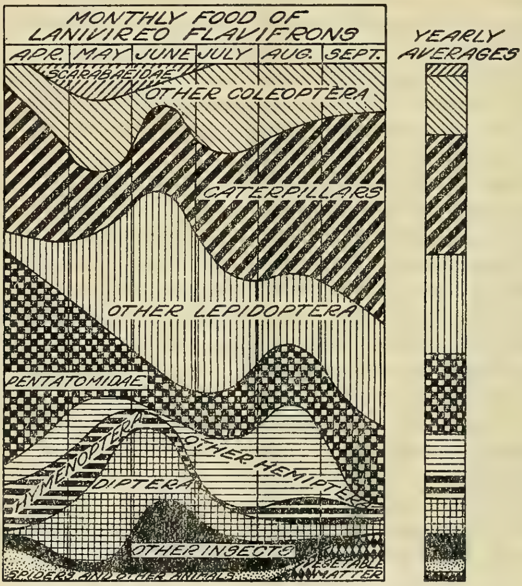


FIG. 5.—Monthly proportions of the various items in the food of the yellow-throated vireo (*Lanivireo flavifrons*), based on the analysis of the contents of 160 stomachs, with the average of each item for the year

caterpillars, and the same month showed an advance of 7 per cent over the previous month's total of 43.73 for all lepidopterans. Adults were consumed in greatest quantity in June, more than one-third (35.15 per cent) of all the food taken that month being of this character.

Hemiptera.—In quantity consumed, the bugs occupy second place in the list of food items of the yellow-throat. Two-thirds of those identified are referable to the family of stink-bugs (Pentatomidae), 15.5 per cent for the year. The remaining, 7.62 per cent, is composed of such forms as assassin bugs (Reduviidae), scale insects (Coccidae), and leaf hoppers (Membracidae). Owing to the great discrepancy in size between the pentatomids and the smaller leaf-feeding bugs, the actual number of leaf hoppers and other small bugs is probably as great as that of the stink-bugs or even greater.

Coleoptera.—Beetles of all kinds, making up 12.9 per cent of the yearly food, stand third in the diet. Ladybird beetles, usually plentifully found in the stomachs of vireos, in this species amount to less than 1 per cent of the total. The rest of the insects may be classed as injurious, or potentially so. The weevils, or snoutbeetles, make 4.23 per cent, or about one-third of all the coleopterans eaten. The wood-boring forms belonging to the families Buprestidae and Cerambycidae and the plant-feeding Elateridae, together form more than one-fourth of the beetle food, or 3.57 per cent. Dung beetles and leaf chafers (Scarabaeidae) amount to 1.84 per cent, whereas leaf beetles (Chrysomelidae) and ladybird beetles (Coccinellidae) make, respectively, 0.82 and 0.62 per cent of the yearly food. Fragments of beetles that could not be associated with any of the above-mentioned families together make up 1.82 per cent of the whole.

Diptera.—Two-winged, or true, flies, make up 7.36 per cent of the yearly subsistence, of which the major part is consumed in May and June. More than one-fourth of the stomachs of the yellow-throat examined contained remains of flies, although in most cases the insects were not in condition to permit more specific identification. Midges (Chironomidae) and horseflies (*Tabanus*) were among the dipterans eaten.

Hymenoptera.—No honeybees were identified in the 160 stomachs of the yellow-throated viero examined, but other bees, as *Andrena* or *Halictus*, were found. Sawflies and ichneumon flies also were determined. Other hymenopterans were detected in lesser quantity, and together the insects of this order made up 5.07 per cent of the annual food.

Other insects.—The rest of the insect food amounts to 4.92 per cent, about equivalent to the bulk hymenopterans taken. Under this head are gathered all records of grasshoppers, crickets, locusts, and dragon flies and other water-inhabiting forms. In the food of the yellow-throated vireo this group is not of very great importance economically.

Other animal food.—Spiders, with the few snails the bird happened on, made up 2.38 per cent of the food. Snails were taken during April only and then only to the extent of 0.36 per cent, which, translated into a yearly percentage, makes the insignificant total of 0.06. Among the spiders eaten, the Attidae, or jumping spiders, were the most common. Species of *Phidippus* were determined four times, and fragments referable to family only were found in six other stomachs. The tetragnathids, which infest marshy localities, were identified twice, and once a minute pseudoscorpion of the genus *Chthonius* was detected. In general, the spiders eaten are only slightly beneficial.

VEGETABLE FOOD

The yellow-throated vireo eats comparatively little vegetable food, practically none during April and May, none during June and July, less than 2 per cent in August, and less than 9 per cent in September. The average for the year is only 1.74 per cent. Among the items specifically determined were sassafras berries and seeds of wild grapes. No cultivated fruit of any kind was found.

50209—25†——3

SUMMARY

There can be no reasonable doubt that with an annual consumption of 42.25 per cent of caterpillars and moths, the yellow-throated vireo is to be classed as a beneficial bird. Adding to this the 7.62 per cent representing bugs, most of which are injurious, and the 10.46 per cent of distinctly injurious beetles, the total of 60.53 per cent is a fair estimate of injurious insects in the bird's food. To offset this, only 0.62 per cent is made up of the benficial ladybird beetles. The rest of the food is neutral economically and may be passed with this mention. This is a record to commend the yellow-throated vireo, and one that is not closely approached by other birds of this family.

THE BLUE-HEADED VIREOS

Lanivireo solitarius, subspp.

The blue-headed vireos, or, as they are sometimes called, the solitary vireos, are of fair abundance over a wide range, including all of the United States, most of Canada, and parts of Mexico and Lower California. The material used in this study includes 306 well-filled stomachs, collected in all months except December. January and November are represented by but 8 and 9 stomachs, respectively, whereas the greatest number for any one month, 79, is for May. Twenty-three other stomachs, only partially filled, gave some additional data regarding food items.

The blue-heads eat about twice as much vegetable food as the yellow-throat (3.68 per cent), but otherwise the diet is similar in its constituent items. (See fig. 6.)

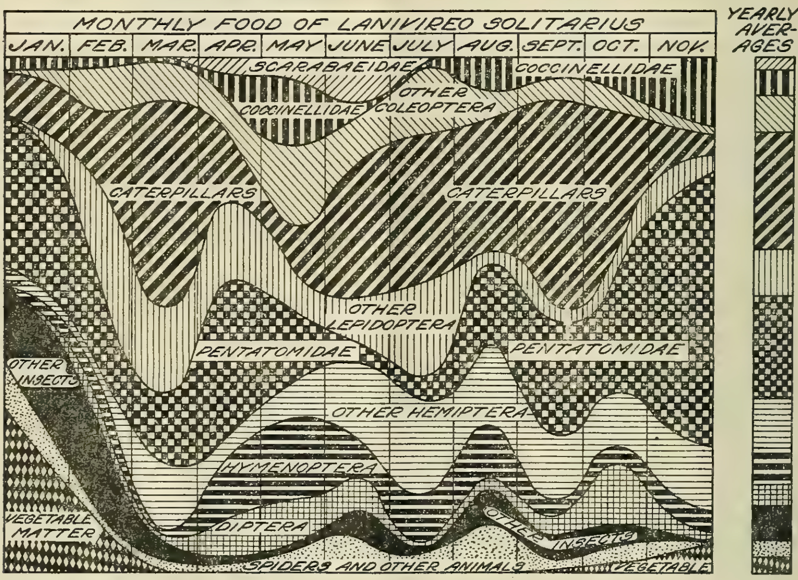


FIG. 6.—Monthly proportions of the various items in the food of the blue-headed vireos (*Lanivireo solitarius*, subspp.), based on the analysis of the contents of 306 stomachs, with the average of each item for the year

ANIMAL FOOD

Animal matter (96.32 per cent) in the food of birds of this species is, as usual in this family, composed almost entirely of insects, the few spiders eaten forming but 2.63 per cent and the snails 0.25 per cent, respectively, of the whole. This represents a slightly greater preference for each of these items than that displayed by the yellow-throat; but, even so, the quantity consumed is of academic rather than economic interest.

Lepidoptera.—The blue-headed vireos eat almost as many caterpillars during the year as does the yellow-throat, but their record for chrysalids and adults is not so favorable. The consumption of caterpillars increases rapidly during January, February, and March, when they constitute 41.56 per cent of the food of that season, and then drops to 10.47 per cent in May, and rises again to 40.39 per cent in September, after which it decreases rapidly with the approach of winter. This fluctuation is marked and, as it does not coincide with the known life cycle of the insects, may be attributed to fluctuating abundance of other more palatable or attractive foods. The average of the monthly percentages is found to be slightly below that for the yellow-throated vireo, being 22.49 per cent. On the other hand, the consumption of adult moths commenced in February with the relatively high percentage of 20.32 and steadily dwindled to 7.26 per cent in May. A rise, culminating in July with a percentage of 18.38, was immediately followed by a drop to 2.22 per cent in August. From August until the end of the season, the adult lepidopterans were taken in steadily increasing quantity, closing in November at 5.1. The yearly average of this item is 9.31 per cent, less than half that of the yellow-throat. Lepidopterans in all stages contribute 31.8 per cent of the entire annual subsistence.

Hemiptera.—True bugs form the second largest item of food of the blue-headed vireos. Owing to the predominance of stink-bugs (Pentatomidae) over all other kinds, this family has been tabulated separately. During the winter months hibernating pentatomids constitute one of the most important sources of food for the blue-headed vireos, as shown by the November and January percentages of 48.7 and 29.02, respectively. During February, March, April, and May there is considerable fluctuation in the quantities eaten, but all these months have relatively high percentages, the highest being 29.6 in April. June and July apparently offer more attractive food along other lines, as the consumption of stink-bugs then drops to 3.45 and 4.38 per cent, respectively. August shows a sudden increase to 16.4 per cent, and from then on the item assumes considerable importance. The yearly average (20.13 per cent) is considerably more than that of the yellow-throat.

The other bugs make up only about half as much of the total bulk of the food as do the pentatomids, but it is interesting to note that the ratio between these forms and the rest of the bugs is almost identical in both species of *Lanivireo*. There appears to be no rule followed by the blue-heads in their selection of bugs other than pentatomids for food, but in general they eat few before June and a great many in the later months of the year. March is an exceptional month, in that 12.91 per cent represents the miscellaneous bugs taken.

Coleoptera.—Considering the enormous numbers of beetles available, it is somewhat surprising that not more are eaten. The blueheads manage to seek out enough, however, to make up 13.51 per cent of their entire diet. Of this, the ladybird beetles make up 4.88 per cent, or more than a third. It is certain that there are not a third as many ladybird beetles as all other beetles combined; and thus it must be considered that the blue-headed vireos, like the warbling, either find these brilliantly colored forms in abundance in their environment or else make special search for them, a most undesirable habit economically. Roughly, a second third of the total bulk is composed of the metallic wood borers, the longicorns, and the click beetles. The remaining portion includes, among others, the weevils, which comprise 1.8 per cent of the food.

Hymenoptera.—With the exception of the month of March, miscellaneous hymenopterans were eaten in quantities varying from 1.75 per cent (in January) to 16.78 per cent (in May). Remains of no very important insect pests were found among the fragments from the stomachs, though several sawflies and ants were detected. The average for hymenopterans eaten during the year was 6.86 per cent.

Diptera.—Two-winged flies make up the comparatively small percentage of 4.29, or less than that of the single family of coccinellids (ladybird beetles), although flies are almost universally present. The flies of the woods are in general of little importance, excepting the bloodsucking forms; and as these are not often found in the stomachs, the economic importance of the dipterans in the food is slight.

Other insects.—Among the insects eaten which do not belong in the above classes are the stone flies, dragon flies, grasshoppers, crickets, and locusts (6.56 per cent for the year). In January this group is one of the most important, making 21.76 per cent of the food. February shows a slight decrease (18.38 per cent), and from then on the percentage varies from 1.24 in May to 7.5 in August. In general, this group is of no more importance economically than the dipterans.

Other animal food.—Spiders run very evenly in the food of birds of this species and are probably picked up whenever occasion offers. With the exception of February, when they amount to but 0.18 per cent, spiders are present in percentages varying from 1.51 to 5.55, the last figure representing August. The average of 2.63 per cent may be taken as a fair estimate of the quantity of this type of food eaten by the blue-headed vireos.

Snails are sometimes eaten, but so rarely that they are not to be considered an essential part of the diet (yearly average, 0.25 per cent).

VEGETABLE FOOD

During the winter months vegetable food is of considerable importance in the diet of this bird. In January nearly a quarter of the total was of vegetable origin (24.37 per cent) and in February less than a tenth (9.81 per cent). From March to and including August no trace of vegetable matter appeared in the food, but by November it formed 4.44 per cent. For the most part it was in the form of fleshy fruits, such as wild grape, dogwood, viburnum, and wax myrtle. No cultivated fruit was identified, and it is practically certain that none is eaten.

SUMMARY

The economic value of the blue-headed vireos rests largely upon their work in the consumption of caterpillars, moths, and hemipterans. Their destruction of ladybird beetles is to be regretted. The balance of favor, however, swings to the birds because of the overwhelming predominance of injurious forms in the food.

THE WHITE-EYED VIREOS

Vireo griseus, subspp.

The white-eyed vireos, in their subspecies, are locally common over the greater part of the eastern United States and Mexico. They are preeminently dwellers in damp, dense underbrush, one of their favored types of retreat being impenetrable growths of catbrier. In such places, during the proper season, one may hear the birds giving, in addition to their own song, impromptu imitations of other birds. The nest is similar to that constructed by the red-eyed vireo, but is placed lower, usually from 2 to 5 feet from the ground.

In the Biological Survey's collection of stomachs are 221 of this species suitable for tabulation. Eight others, nearly empty, afforded additional information concerning food items. These were collected over the entire range of the bird during the first 10 months of the year. Vegetable matter plays a much more important part in the economy of the species than in the case of either the yellow-throated or blue-headed vireos, but slightly less than in that of the red-eye, amounting to 11.76 per cent of the entire food. (See fig. 7.)

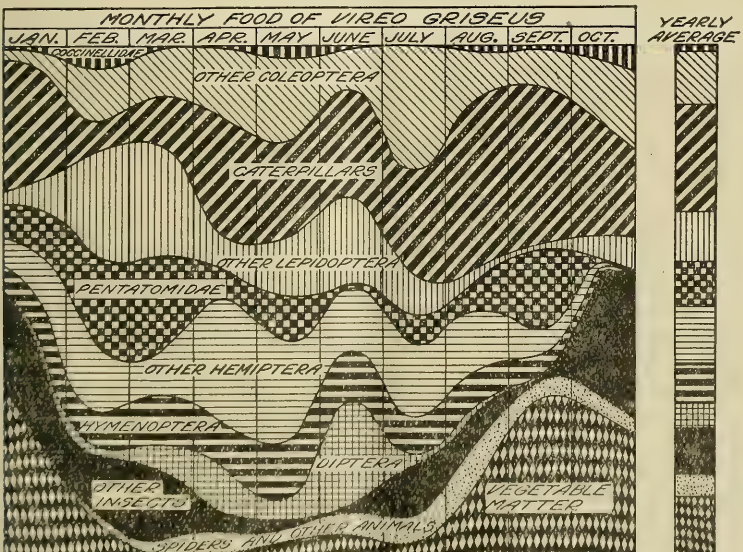


FIG. 7.—Monthly proportions of the various items in the food of the white-eyed vireos (*Vireo griseus*, subspp.), based on the analysis of the contents of 221 stomachs, with the average of each item for the year

ANIMAL FOOD

Nearly nine-tenths of all the food eaten by the white-eyed vireos is composed of insects, spiders, and other animal matter; of this all but 3.96 per cent is of insects.

Lepidoptera.—Moths and butterflies and their larvae (caterpillars) make up slightly less than one-third of the food of this species and form the most important item of the diet. Of this portion, 20.66 per cent is represented by caterpillars, and except for February and March a minimum of 18.7 per cent of the monthly food is of this item. The maximum is reached in August with a percentage of 33.12. The adult insects, on the other hand, are not nearly so plentiful in the stomachs, except during February and March, at the time when the caterpillars have become scarce. Taking adults and larvae together, the total does not fall below 26.33 per cent, and rises to 37.93 in June. The yearly average for the adult forms is 9.83 per cent, which with the caterpillars makes a total percentage of 30.49.

Hemiptera.—As with other species of this family of birds, the white-eyed vireos prey heavily upon stink-bugs (Pentatomidae) at nearly all times, although the toll taken in February and March is much greater than in summer. A second high point comes in September with 15.74 per cent. The yearly average is 8.56 per cent. The rest of the bugs make up 11.71 per cent of the yearly food. April is the time of maximum consumption, with a total of 24.18 per cent, and May follows with 19.25 per cent. Scale insects (Coccidae), which have not figured in quantity in the economy of the vireos previously discussed, are eaten by the white-eyes to the extent of 2.85 per cent. This is not a high percentage, yet, considering the small size of scales in general, it represents a great many individuals. In April, 12.78 per cent of the total food, or more than half of all the hemipterans eaten, was of the family Coccidae.

Coleoptera.—Beetles of all kinds make up 12.78 per cent of the total food. The leaf-eating forms (Chrysomelidae) and weevils (Rhynchophora) represent more than half of these, or 6.99 per cent. Except for the Philadelphia and Bell vireos, no other of the vireo family eats so many leaf beetles as this, while in percentage of weevils consumed the white-eyed vireos are exceeded by three others. Ladybird beetles (Coccinellidae), with a percentage of only 1.36, seem not to be greatly in favor with the white-eyes. The wood-boring beetles make up 2.31 per cent, the scarabs 0.66 per cent, and all other beetles 1.46 per cent.

Hymenoptera and Diptera.—Of the annual subsistence of the white-eyed vireos 11.64 per cent is composed of wasps, bees, ichneumons, and flies. The hymenopterans appear in the food in moderate quantity each month, their greatest frequency being in May, at which time they have a relative value of 11.16 per cent. On the other hand, flies, though not found in stomachs collected after August, are taken freely earlier in the year. In June 20.43 per cent of the total food is made up of these insects, few of which are species of economic importance.

Orthoptera.—In discussing the food of the white-eyed vireos it seems best to separate the grasshoppers from the miscellaneous insects. The average percentage for the year is 5.36. In January they make up 13.25 per cent and in February 11.88 per cent of the food. In March the percentage drops to 4.79, in April to 0.52, and in May and June none are eaten. A few are taken in July and August, and by October as much as 20 per cent of the food may be from this source.

Other insects.—Miscellaneous insects other than grasshoppers make up 3.74 per cent of the diet. The quantities eaten from month to month show no coordination, and the item appears to be greatly affected by chance. For instance, in January 5.68 per cent is to be referred here, in February none, in March 8.68 per cent.

Other animal food.—Spiders are at no time very abundant in the food, although in August they form as much as 7.76 per cent of it. The yearly average is 3.59 per cent. Other animal food is composed mainly of snails, and in one stomach were bones of a small chameleon, the two together making up only 0.37 per cent of the whole food.

VEGETABLE MATTER

In the spring and fall months foraging for suitable food compels the birds to turn to the berries and small fruits, which are usually to be had in almost any locality. In January 22.93 per cent of the entire food is vegetable, in February only 5.62, still less from March to July, in August 16.2, and in the next two months the percentage rises to 32.37. The vegetable food is composed of such berries as those of sumac, dogwood, wild grape, and wax myrtle, and has no economic importance.

SUMMARY

There is remarkably little in the food habits of the white-eyed vireos to condemn. The record of this species for the destruction of ladybird beetles is not bad and is more than offset by the destruction of many caterpillars, moths, plant bugs, and grasshoppers. These birds take very few beneficial hymenopterans and no valuable fruit.

THE HUTTON VIREOS

Vireo huttoni, subspp.

The Hutton vireos, in their subspecies, range over the greater part of the Pacific coast and eastward into southern Arizona and western Texas. Throughout their range birds of this species are locally somewhat common in thickets along streams. There are in the collection of the Biological Survey 77 stomachs available for study, 70 of which contained sufficient food for use in the tabulations. Unfortunately, these stomachs were not collected in consecutive months, none in March, April, May, or November, and only a few in each of the other months. The data available show a preponderance of animal food (98.23 per cent), with but 1.77 per cent of vegetable origin. It is probable that an investigation of more stomachs will materially alter the conclusions reached at this time. (See fig. 8.)

ANIMAL FOOD

The animal food is made up of insects and a few spiders, no trace of the few mollusks usual with other vireos being found. Caterpillars and other lepidopterous forms are not the dominating element of the food, as in most of the other species, but are subordinate to the true bugs.

Hemiptera.—Nearly 46 per cent of all the food eaten by the Hutton vireos is composed of true bugs. A little less than half of this, or 20.15 per cent of the total, consists of stink-bugs (Pentatomidae). So far as the available data show, no stink-bugs are eaten in June or July. As the percentage for August is 33.6, however, it is probable that more stomachs would give a more even distribution for this item. The rest of the bugs do not figure very high until June, from which time on they are, in general, the largest element in the diet.

Lepidoptera.—Caterpillars, and moths and butterflies are about evenly balanced in the total subsistence of the Hutton vireos, the caterpillars amounting to 12.22 per cent and the adult forms to 12.33 per cent. July is apparently the month when this kind of food is most in demand.

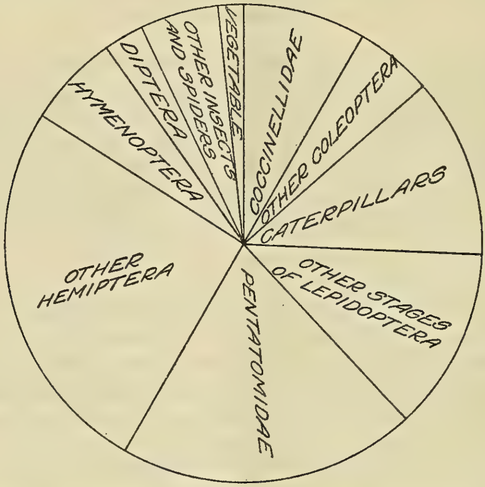


FIG. 8.—Yearly summary of the various items in the food of the Hutton vireos (*Vireo huttoni*, subspp.), based on the analysis of the contents of 70 stomachs

Coleoptera.—Of the 13.25 per cent representing beetles in the food of the Hutton vireos, about five-eighths are ladybird beetles (8.12 per cent). Ladybirds were found in nearly half the stomachs examined and appear to be a common food. Weevils (2.75 per cent) were fairly evenly distributed, but the rest of the beetles were found only infrequently.

Hymenoptera.—Hymenopterans were found regularly in the stomachs, and rather remarkably, the two months with the high averages are December and January. This unusual condition will in all probability be modified when additional material is examined. Otherwise, the monthly percentages appear to be normal, and the average for the year is 6.3 per cent.

Other insects.—Insects other than those belonging to the orders noted above occur so irregularly in the few stomachs examined that it is difficult to make any definite statement on their relative abundance in the food. During July, when miscellaneous insects should be taken in some quantity, none appear to be eaten, whereas in February, when according to our point of view few should be found, they amount to 14.1 per cent. The yearly average, from the data available, is 6.2 per cent.

Spiders.—Except for February, spiders were eaten in all months of the year that are represented by stomachs. The percentage is never high, December with 6.83 being the maximum and June next with 4.16 per cent. The average for the eight months is 2.05 per cent.

VEGETABLE FOOD

The record of vegetable food for the Hutton vireos is fragmentary, though coinciding so far as it goes with the known habits of other species of this family of birds. Except for months when no vegetable matter was found in the stomachs, the known data show a steady rise in the quantity eaten as the year approaches its end. The December percentage is 7.67 as compared with 0.7 in August. The yearly average is only 1.77 per cent.

SUMMARY

The evidence before us, though of questionable value because of the limited quantity of material, points to the fact that the Hutton vireos have a propensity for consuming undue numbers of ladybird beetles and rather fewer caterpillars than other vireos. Final judgment should be deferred, however, until additional material is available for analysis.

THE BELL VIREOS

Vireo belli, subspp.

The forms of the Bell vireos, like those of the Hutton, are birds primarily of the western United States, though their range extends much farther east than that of the Hutton vireos. In the willow thickets along water courses birds of this species may be found locally distributed in the greater part of the territory west of the Mississippi River. Although the available material in the collection of the Biological Survey suitable for examination consists of only 52 stomachs, these were collected in the months from May to August, inclusive, and serve as a fair index of the summer food. (See fig. 9.) Eleven additional, partially filled stomachs yielded other data concerning food items. Nothing can be said of the winter food at this time.

ANIMAL FOOD

Nearly all (99.3 per cent) of the food taken is of animal origin, such forms as bugs, beetles, caterpillars, and grasshoppers predominating.

Hemiptera.—Bugs make up 34.43 per cent of the summer food of the Bell vireos. Of these about a quarter (9.34 per cent of the total food) are referable to the family of stink-bugs (Pentatomidae). More stink-bugs are eaten early and late in summer than in July and August. On the other hand, the rest of the hemipterans show a steady decrease as the season advances. In May more than half the hemipterous food was made up of bugs other than stink-bugs; June shows a decrease to 28.07 per cent, July to 11.61 per cent, and in August only 4 per cent belongs in this category.

Orthoptera.—No other species of vireo of which the food habits are known takes so large a quantity of such bulky insects as grasshoppers, locusts, and the like. Though the present species is one of the smallest in size, it includes in its diet for July enough of the orthopteroids to make 34.88 per cent of that month's food. This form of food is essentially a summer type, none being taken in May, a considerable quantity in June, and 21.87 per cent in August. The average percentage for the summer months is 18.52.

Lepidoptera.—About one-fifth (20.63 per cent) of the subsistence of the Bell vireos during the summer is made up of caterpillars, and of adult moths and butterflies, and their eggs. As the last-named items are rarely found in a stomach, the figures given refer mainly to the first two. Caterpillars do not become an important factor in the economy of the birds before June, although a few (1.67 per cent) are eaten in May; in each of the months July and August the consumption amounts to about 25 per cent, and the average for the

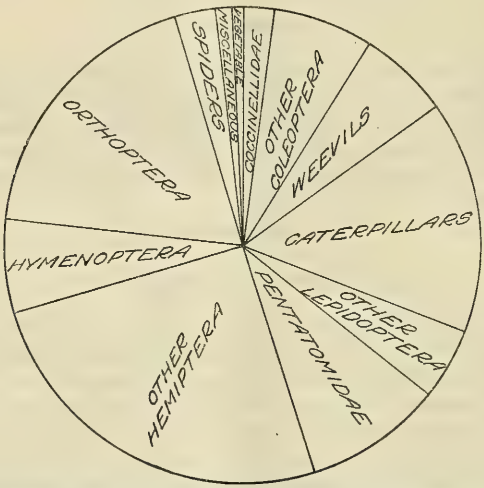


FIG. 9.—Yearly summary of the various items in the food of the Bell vireos (*Vireo belli*, subspp.), based on the analysis of the contents of 52 stomachs

four months is 15.89 per cent. Lepidopterans in other stages make up 4.74 per cent of the food, the consumption being heaviest in July (11.07 per cent).

Coleoptera.—Beetles of all kinds make up 15.26 per cent of the summer food of the Bell vireos. Ladybird beetles are taken in moderate numbers and form 2.19 per cent of the total food. Weevils (6.09 per cent) and leafbeetles (3.98 per cent) account for the most of remainder of the coleopterous food.

Hymenoptera.—Hymenopterans of all sorts (bees, wasps, etc.) amount to 6.44 per cent of the total diet during the summer months. The increase in consumption is at first slight, May and June being represented by 2.33 and 3.2 per cent, respectively. In July a sharp rise is noted to the maximum of 12.83 per cent; in August it is only 7.38. The evidence at hand probably gives a fairly correct view of the facts.

Other insects and spiders.—The rest of the animal food of the Bell vireos is composed of a few miscellaneous insects and spiders and a very few snails, spiders (2.71 per cent) being the most important. The first appearance of this group of food items was in the stomachs of birds taken in June, at which time it composed 6.93 per cent of the food. An immediate drop to 2.52 per cent took place the next month, and the percentage in August was nearly the same.

VEGETABLE FOOD

It is not until July that the Bell vireos feed on wild fruits. At that time 1.57 per cent of the subsistence is of vegetable matter. In August the percentage decreased slightly to 1.25. The average percentage for the year is only 0.7.

SUMMARY

During the summer months the Bell vireos consume a great many injurious insects and very few beneficial ones. Grasshoppers, locusts, caterpillars, and moths are frequently injurious to man's best interests, as also are many of the hemipterans. The percentage of these insects in the food of birds of this species is 73.58, nearly three-fourths of the total. Of the remainder about half the beetles and hymenopterans are injurious. This will add about 11 per cent, leaving about 16 per cent of the food of debatable import. As the small quantity of vegetable matter eaten is of no economic significance it may be disregarded. Ladybird beetles are about the only beneficial forms that the birds take, and these are not consumed in very great numbers.

GRAY VIREO

Vireo vicinior

The gray vireo is a rare bird in a restricted range, and for this reason is of very little economic importance. It may be seen in southern California, southern Nevada, Arizona, New Mexico, as far east as western Texas, and south to northern Mexico and on the peninsula of Lower California.

There are only two stomachs in the collection of the Biological Survey, and, while from such limited material it is impossible to draw more than an inference, it may be said that the habits indicated are similar to those of the Hutton and Bell vireos. Caterpillars and a small moth were found in one stomach, together with a stink-bug (*Prionosoma podopioides*), a tree hopper (*Platycentrus acuticornis*), and a tree cricket (*Oecanthus*). In the other stomach two dobson flies (*Chauliodes*), a small cicada (*Tibicinoides hesperius*), and a long-horned grasshopper made up the greater part of the contents; two beetles (*Acmaeodera neglecta* and *Pachybrachys*) complete the list.

Because of the relative infrequency of its occurrence and the chiefly beneficial nature of its food habits as here indicated, it is probable that the gray vireo will never prove destructive.

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found* [1]

Kind of food	Red-eyed	Philadelphia	Warbling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS **Gastropoda** (snails)								
Unidentified	2		1	2	5	6		2
Zonitidae:								
Zonitoides arboreus					1	1		
Helicidae:								
Pyramidula alternata					1			
Helicodiscus lineatus			1					
Polygyra jejuna					1			
Vallonia sp			1					
Pupidae:								
Pupa armifera						1		2
Pupa sp			1					
CLASS **Arachnida** (spiders, etc.)								
Order PSEUDOSCORPIONIDA (pseudoscorpions)								
Cheliferidae:								
Chelifer sp			1					
Obisiidae:								
Chthonius sp				1				
Order PHALANGIDA (harvestmen)								
Unidentified	10	1			8	6		
Order ARANEIDA (spiders)								
Unidentified	129	23	66	29	50	45	20	15
Argiopidae (orb weavers):								
Unidentified	6							1
Tetragnatha elongata	2		1			3		
Tetragnatha straminea	1							
Tetragnatha sp	2			2	1	2		
Araneinae, unidentified	11			1	1	5		
Scoloderus tuberculiferus						1		
Aranea sp	1		2		1		1	
Micrathena gracilis						1		
Thomisidae (crab spiders):								
Unidentified			1		1			
Misumena sp							1	1
Xysticus sp						1		
Clubionidae:								
Clubiona sp	1		1					
Lycosidae (wolf spiders):								
Unidentified	2		1		1			
Sosippus sp	1							
Lycosa sp						1		
Attidae (jumping spiders):								
Unidentified	32	7	17	6	14	20	3	3
Synemosyna formica			1			2		
Phidippus sp	1		2	4		2		
Thiodina puerpera						1		
Dendryphantes capitatus		1						
Dendryphantes sp		2	1					
Wala palmarum	2							
Pellenes sp			1					
Lyssomanes viridis	1							
Order ACARINA (mites)								
Parasitidae (unidentified)	1							
CLASS **Insecta** (insects)								
Unidentified adults	2		2	1	2			
Unidentified eggs	4	1				2		1

[1] The number of stomachs recorded here often exceeds the number used in tabulating food percentages as recorded in the text, because a portion of the stomachs examined did not contain sufficient food for the estimation of percentages but did yield data concerning food items. The food items of the black-whiskered vireo (4 stomachs) (see pp. 3-4) and of the gray vireo (2 stomachs) (see p. 27) have not been included in the tabulation.

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Order ODONATA								
Unidentified	11		1	1	7	1	1	1
Zygoptera (damsel flies) unidentified	1				2	6		
Argia bipunctata	1							
Argia sp					1			
Anisoptera (dragon flies) unidentified				4		3		
Order EPHEMERIDA (May-flies)								
Unidentified	2			1			1	
Unidentified eggs				1				
Order PLECOPTERA (stone flies)								
Unidentified					1			
Order ISOPTERA (white ants)								
Unidentified				1				
Order ORTHOPTERA (grass-hoppers, etc.)								
Phasmidae (walking sticks):								
Unidentified adults	1							1
Unidentified eggs	1							1
Diapheromera femorata	2					1		
Diapheromera femorata (eggs)				1				
Acridiidae (short-horned grass-hoppers)								1
Unidentified	26		9	2	14	9		16
Tryxalinae, unidentified					2	10	1	4
Acridiinae, unidentified							1	
Melanoplus sp	2		1	2				
Tettigidae (unidentified grouse locusts)			1			1		
Locustidae (long-horned grasshoppers):								
Unidentified adults	14		9			5		7
Unidentified eggs	6		4		1	1		
Neoconocephalus sp					1			
Gryllidae (crickets):								
Unidentified	1		1			1		
Oecanthus sp	1		6	1		4		8
Nemobius sp					1			
Order PALAEOPTERA (roaches)								
Blattidae (unidentified eggs)	1							
Order DICTYOPTERA (mantids)								
Mantidae					1			
Order CORRODENTIA (book lice)								
Psocidae					2			
Order NEUROPTERA (stone flies)								
Perlidae	2	1	1	2		2		
Order HEMIPTERA (true bugs)								
Unidentified adults	129	11	74	18	16	39	22	22
Unidentified eggs						2		
Scutelleridae (shield bugs):								
Diolcus chrysorrhoeus						1		
Eurygaster alternatus					2			
Cydnidae (negro bugs):								
Corimelaena sp			1					

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Pentatomidae (stink-bugs):								
Unidentified	63	2	17	26	45	36	7	12
Unidentified eggs				2				1
Brochymena affinis							2	
Brochymena arborea					1	1		
Brochymena cariosa					1			
Brochymena quadripustulata	1			1	2			
Brochymena sp	7			18	34	4	2	
Peribalus sp								1
Mormidea lugens			1					
Euschistus tristigmus			1	1	3			
Euschistus sp	5	4	4	11	13	16	2	3
Cosmopepla sp	1						1	
Thyanta custator	1		3			1	9	
Thyanta sp			2			10	3	
Nezara hilaris	24		1		1	2	2	
Nezara sp	1				2			
Banasa sp	1			4	7			
Dendrocoris contaminatus			1					
Meadorus lateralis	1		2		1			
Perillus bioculatus	2							
Podisus maculiventris	4			2	1	1		
Podisus placidus		1			1			
Podisus sp	58	1	18	9	44	12	9	3
Coreidae (squash bugs):								
Unidentified			1	1		1	4	
Leptoglossus sp	1							
Anasa armigera	2							
Alydus pilosulus	1							
Alydus sp					5		1	
Corizus sp						1		
Leptocoris trivittatus			2					
Lygaeidae (chinch bugs, etc.):								
Unidentified			5	2	1	2		
Lygaeus bicrucis					2			
Belonochilus numenius					2			1
Ischnorrhynchus sp	1	5	7		4	4	1	
Oedancala dorsalis				1				
Ligyrocoris sp	1					1		
Phymatidae:								
Phymata fasciata	1							
Phymata sp			2	3	2			
Reduviidae (assassin bugs):								
Unidentified	6			3	2	7	1	5
Unidentified eggs					7			
Zelus exsanguis	1							
Zelus sp	2		1					
Acholla sp			1					
Sinea diadema	4							1
Sinea sp	17		5	4	3	6	2	2
Nabidae (damsel bugs):								
Nabis sp	1							
Capsidae (plant bugs):								
Unidentified			3			1	1	
Lygus pratensis			1					
Cicadidae (cicadas):								
Unidentified						1		
Tibicen sp	1			1				
Cicada sp	3				1			
Platypedia putnami					2			
Cercopidae (spittle insects):								
Unidentified	1	1	2					
Aphrophora parallela			1					
Aphrophora quadrinotata	1							
Aphrophora sp					1			
Membracidae (tree hoppers):								
Unidentified	27	4	44	14	41	40	12	12
Ceresa sp	3			2				1
Stictocephala sp			1					
Acutalis calva			2					
Telamona sp							1	
Telamonanthe rileyi							1	
Cyrtolobus sp	2	1	9	1	9	1		
Vanduzea arcuata		1						
Entylia sinuata	1							
Platycotis minax					1			
Platycotis sp	1			3				
Tylocentrus reticulatus								2

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS **Insecta** (insects)—Contd.								
Cicadellidae (leaf hoppers):								
Unidentified					4			
Idiocerus sp		1	1					
Aulacizes irrorata				3	3	10		
Aulacizes sp					1			
Graphocephala coccinea					1	1		
Gypona sp		1	1		2	1	1	
Xerophloea sp								1
Jassinae	6	2	31		2	12	8	5
Athysanus sp						1		
Phlepsius sp					1			
Thamnotettix sp			1					
Delphacidae (unidentified)					1			
Psyllidae (unidentified jumping plant lice)			1				5	
Aphididae (unidentified plant lice)						1		
Coccidae (scale insects):								
Unidentified	51	6	18	9	10	44		2
Lecanium caryae				1	1			
Lecanium pruinosum					1			
Lecanium corni				1				
Eulecanium sp	5							1
Neolecanium sp						2		
Kermes kingii				1				
Pulvinaria vitis				1				
Toumeyella liriodendri				1				
Saissetia oleae							9	
Order LEPIDOPTERA (butterflies, moths, etc.)								
Unidentified adults	35	4	28	53	57	39	19	5
Unidentified pupae	16	2	19	4	3	4		
Unidentified caterpillars	371	42	222	78	145	128	31	28
Unidentified eggs	4	1	7	3	16	24	3	7
Papilionidae (swallow-tailed butterflies):								
Papilio troilus (caterpillar)	1							
Nymphalidae (brush-footed butterflies):								
Chorippe celtis (caterpillar)	1							
Hesperiidae (skippers):								
Unidentified adults	1							
Unidentified caterpillars						1		
Sphingidae (hawk moths):								
Unidentified caterpillars	1							
Ceratocampidae:								
Anisota sp. (caterpillars)				1				
Arctiidae (tiger moths):								
Unidentified caterpillars		1						
Noctuidae (cut worms):								
Unidentified caterpillars	3							
Apatela sp. (caterpillars)	1							
Acronycta afflicta (caterpillars)	1							
Neuronia sp. (caterpillars)	1							
Notodontidae:								
Unidentified caterpillars	1	1						
Notodonta unicornis (caterpillars)	1							
Heterocampa sp. (caterpillars)	4					1		
Fentonia marthesia (caterpillars)	1							
Lasiocampidae (tent caterpillars):								
Malacosoma sp. (eggs)	5							
Geometridae (loopers):								
Unidentified caterpillars	1							
Tineidae:								
Unidentified moth								1
Unidentified pupa						1		
Unidentified case bearers			1					

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Order COLEOPTERA (Beetles)								
Suborder COLEOPTERA Genuina								
Unidentified	49	1	12	7	6	9	14	4
Carabidae (ground beetles):								
Unidentified	3		1				1	
Pterostichus sp.	1							
Platynus sp.	1							
Lebia ornata			1					
Lebia viridis	3							
Lebia sp.			1		1			
Callida viridipennis	1							
Harpalus sp.					1			
Hydrophilidae (water beetles):								
Hydrochus sp.						1		
Philhydrus sp.		1						
Staphylinidae (rove beetles):								
Unidentified	1						1	
Philonthus sp.							1	
Paederini			1					
Cryptobium sp.		1						
Tachinus sp.								1
Phalacridae:								
Unidentified					1			
Phalacrus politus	1							
Coccinellidae (ladybirds):								
Unidentified	7	2	19	2	4	3	4	3
Anisosticta strigata	1							
Megilla fuscilabris	3	2	3			1		
Hippodamia ambigua			1				2	
Hippodamia convergens			7		2		3	1
Hippodamia parenthesis	1		1	1				
Hippodamia tredecimpunctata	2	1	4					
Hippodamia sp.			1		3			
Cycloneda munda	2		4	1	3	6		
Coccinella abdominalis			2					1
Coccinella californica			41		24		26	1
Coccinella franciscana	1							
Coccinella novemnotata	3	1	3			1		
Coccinella transversoguttata	1		2					
Coccinella trifasciata	6	4	2	1	1			
Coccinella trifasciata juliana			8		1		2	
Coccinella sp.		1						
Adalia annectans	1							
Adalia bipunctata	25	5	4		6	7	1	
Adalia frigida	2	2	6		1			1
Adalia sp.				1				
Anisocalvia quattuordecimguttata		4						
Harmonia duodecimmaculata					3			
Harmonia picta	2		4				1	
Neomysia pullata	3		1		2			
Anatis quindecimpunctata	21	1	6	7	39	1		
Anatis quindecimpunctata mali	1		1		1			
Psyllobora vigintimaculata		2	4		1	1		
Chilocorus bivulnerus	1					4		
Axion tripustulatum	3		1		2	3		
Brachyacantha ursina	1	1						
Brachyacantha sp.						1		2
Hyperaspis signata			4		1			
Hyperaspis signata binotata	1					1		
Hyperaspis sp.		1						
Scymnus collaris	1	2						
Scymnus haemorrhous			1			1		
Scymnus sp.							1	
Colydiidae:								
Lasconotus complex							1	
Histeridae (shining carrion beetles):								
Unidentified	1						1	
Unidentified (larva)			1					
Hister perplexus	1							
Temnochilidae:								
Tenebrioides sp. (larva)					1			

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS **Insecta** (insects)—Contd.								
Elateridae (click beetles):								
Unidentified	68	6	19	11	32	16		6
Deltometopus amoenicornis						1		
Elater linteus						1		
Elater nigricollis	2				2			
Elater sp	1				1			
Drasterius sp	1				1			
Agriotes ferrugineipennis	2							
Agriotes oblongicollis	6	1						
Agriotes stabilis				1				
Agriotes sp				1				
Melanotus americanus	1							
Melanotus communis	2							
Melanotus sp	1					1		
Limonius basilaris	2			1		3		
Limonius crotchii	1							
Limonius griseus					1			
Limonius quercinus	1							
Limonius sp	3	3	1	5	2	6		
Athous brightwelli	1							
Corymbites aethiops	1							
Corymbites hamatus					1			
Corymbites hieroglyphicus	5			1	2			
Corymbites propola					1			
Corymbites resplendens					4			
Corymbites spinosus	1							
Corymbites tarsalis	2			1				
Corymbites triundulatus					1			
Corymbites sp	1							
Hemicrepidius decoloratus						1		
Buprestidae (metallic wood borers):								
Unidentified			1	4	4		1	1
Dicerca sp	2							
Trachykele lecontei						1		
Cinyra gracilipes	1							
Melanophila drummondi	1							
Melanophila sp					1			
Anthaxia quercata	2							
Anthaxia sp		1						2
Chrysobothris chryseola					3			
Chrysobothris femorata	2		1	1				
Chrysobothris sp			1	4	2	1		
Acmaeodera tubulus	1							
Agrilus egenus						1		
Agrilus politus	1							
Agrilus ruficollis						1		
Agrilus sp	21		15	1	5	4	1	7
Brachys aerosa	1							
Brachys sp	1							
Telephoridae (fireflies):								
Chauliognathus marginatus						1		
Chauliognathus sp	1							
Telephorus scitulus		1						
Telephorus sp						1		
Malachiidae:								
Malachius spinipennis			1					
Attalus sp			2					
Cleridae (checkered beetles):								
Cymatodera ovipennis							2	
Derestenus furcatus						1		
Enoclerus ichneumoneus (larva)				1				
Enoclerus lunatus						1		
Placopterus thoracicus	2							
Hydnocera discoidea								1
Hydnocera pallipennis	3							
Hydnocera unifasciata	1							
Hydnocera verticalis	1					1		
Phyllobaenus dislocatus	1							
Orthopleura texana			1					
Ptinidae:								
Eupactus nitidus				1				
Eupactus punctualatus						1		
Eupactus viticola						3		
Catorama sp								1
Caenocara sp						1		
Ptilinus ruficornis					1			

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Bostrychidae:								
Polycaon plicatus						1		
Amphicerus bicaudatus				1	1			
Lucanidae (stag beetles):								
Platycerus quercus	1		2	4		1		
Scarabaeidae (dung beetles and leaf chafers):								
Unidentified	21	3	7	7	15	3	1	
Ataenius cognatus	1							
Aphodius femoralis		2		1		1		
Aphodius fimetarius	1	1	2	1	5			
Aphodius granarius	1		1	1	1	1		
Aphodius inquinatus		2			4	2		
Aphodius lividus		1						
Aphodius wolcotti		1						
Aphodius sp		1		1	1			
Hoplia trifasciata	4		2	2				
Hoplia sp	1	1		8	2	3		
Dichelonyx bachii			1		6			
Dichelonyx crotchii			3					
Dichelonyx elongata	10	1		1				
Dichelonyx fuscula	1							
Dichelonyx subvittata		2						
Dichelonyx sp	25	1	6		3			
Serica sericea		1						
Serica sp	1							
Phyllophaga sp							1	
Anomala binotata	2		1					
Anomala lucicola	2					1		
Anomala oblivia					1			
Anomala sp	8					1		
Gnorimus maculosus	1							
Trichius sp					1			
Valgus squamiger					1			
Cerambycidae (long-horned wood borers):								
Unidentified	22	3	8	19	28	6	6	2
Phymatodes amoenus	1							
Physocnemum brevilineum	1			1		1		
Elaphidion villosum	1			2				
Elaphidion sp								1
Molorchus bimaculatus					1	1		
Molorchus sp			1		1			
Xylotrechus colonus						1		
Xylotrechus sp	1			1				
Neoclytus erythrocephalus						1		
Neoclytus sp	1							
Clytanthus ruricola	1							
Clytus marginicollis						1		
Clytus sp			2		2			
Cyrtophorus verrucosus	1							
Euderces pini	1					2		
Euderces sp					2			
Centrodera picta	1				1			
Acmaeops directa					2			
Gaurotes cyanipennis	1							
Anthophilax viridis					1			
Anthophilax sp					1			
Typocerus sp					1			
Leptura militaris			1				1	
Leptura nitens	2							
Leptura scripta	1							
Leptura sphaericollis	1							
Leptura vagans	1							
Leptura vittata	1		1					
Leptura sp			1		1			
Ipochus fasciatus							1	
Psenocerus supernotatus			1		1	3		
Leptostylus aculiferus	1				1	1		
Leptostylus sp			1	1	1			
Liopus adspersus	1							
Liopus alpha						1		
Liopus fascicularis						1		
Liopus sp	1		1	3	1	2		
Lepturges querci					1			
Lepturges signatus					1			

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Cerambycidae—Continued.								
Hyperplatys maculata	4		1	3		1		1
Hyperplatys sp		1	1	1	1	1		
Pogonocherus crinitus							1	
Ecyrus dasycerus	1							
Spalacopsis filum			1					
Saperda lateralis	1							
Saperda tridentata	2							
Saperda sp	2							
Mecas inornata	1							
Chrysomelidae (leaf beetles):								
Unidentified adults	30	5	25	4	8	24	5	5
Unidentified larvae								1
Donacia aequalis						1		
Donacia sp	1				1			
Orsodacna atra	3	3	6			1	1	
Zeugophora scutellaris			1					
Syneta carinata			1					
Syneta ferruginea	22	10	2	2	7	1		
Syneta sp			1		2			
Saxinis omogera	2							
Chlamys plicata					1	1		
Bassareus sellatus						1		
Cryptocephalus castaneus								1
Cryptocephalus guttulus	1			1		1		
Cryptocephalus mutabilis	1					3		
Cryptocephalus quadriguttatus			1					
Cryptocephalus quadrinotatus	1							
Cryptocephalus sp	1			1		3		
Pachybrachys abdominalis	1		1					1
Pachybrachys atomarius		1	2					
Pachybrachys viduatus			1					
Pachybrachys sp	3		3	1	4	5		2
Myochrous denticollis	1					1		
Glyptoscelis barbata				1				
Glyptoscelis pubescens	2			2	2	3		
Glyptoscelis sp	3				1	2		
Typophorus canellus	10	6	2	2		11		1
Tymnes picipes	2					1		
Tymnes tricolor						1		
Tymnes sp	1		1			3		
Xanthonia decemnotata	8	8	5	6	4	1		
Fidia sp		1						
Colaspis brunnea	1				1	3		
Colaspis favosa						1		
Colaspis sp	1							
Nodonota puncticollis	4							
Nodonota tristis	4	1				3		
Nodonota sp			1					
Chrysodina globosa	1		1			3		
Gastroidea dissimilis			1					
Gastroidea sp			6		3			
Lina interrupta		1						
Lina lapponica	1		2					
Lina scripta	1		5	1				
Lina sp			1		1			
Ceratoma trifurcata	1							
Galerucella sp			2					
Monoxia consputa							3	
Diabrotica duodecimpunctata	8	1	1			3	1	1
Diabrotica vittata	6	1						
Diabrotica sp	1							
Halticini		1	1			2		
Oedionychis limbalis			1					
Oedionychis sexmaculatus						5		
Oedionychis suturalis						3		
Oedionychis sp						1		
Disonycha pennsylvanica			1					
Disonycha triangularis	1							
Disonycha sp								1
Phyllotreta picta	1							
Haltica chalybea	2	1				11		
Haltica ignita	1		1			4		1
Haltica sp	6	2				4		
Chaetocnema sp		1						

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS **Insecta** (insects)—Contd.								
Chrysomelidae—Continued.								
Crepidodera helxines	6	7	10		2	9		1
Epitrix parvula								1
Systena bitaeniata		1						
Systena marginata			2					
Systena sp.						1		1
Dibolia borealis	1							
Chalepus dorsalis	3							
Chalepus nervosa			1					
Chalepus rubra	3					1		
Stenispa metallica	1							
Coptocycla bicolor			1					
Coptocycla sp.								1
Bruchidae (bean weevils):								
Spermophagus robiniae	1							
Bruchus cruentatus					1			
Bruchus prosopis	1							2
Tenebrionidae (darkling beetles):								
Unidentified					1	2	1	
Haplandrus ater					1			
Blapstinus metallicus					1			
Blapstinus sp.			2					
Hypophloeus sp.	1							
Helops aereus				2				
Helops micans	2			1	2	1		
Helops sp.					1		1	
Strongylium crenatum				2				
Cistelidae:								
Hymenorus sp.						1		
Cistela brevis	1							
Isomira sericea	3					2		
Isomira texana						8		
Isomira sp.	2					4		
Melandryidae:								
Unidentified	2			5	2	3		1
Synchroa punctata	1			2				
Marolia fulminans							1	
Eustrophus sp.	1							
Mycterus scaber	1		1					
Oedemeridae (unidentified)			2			1		
Cephaloidae:								
Cephaloon lepturides	1							
Mordellidae:								
Unidentified								1
Mordella octopunctata	1							
Mordella sp.	2							
Anthicidae (flower beetles):								
Unidentified			2					
Eurygenius sp.				1				
Stereopalpus sp.	1		1					
Macratria confusa						1		
Notoxus monodon						1		
Notoxus sp.							1	
Pyrochroidae:								
Dendroides sp.						1		
Meloidae (blister beetles):								
Pomphopoea aenea				5				
Pomphopoea sp.						2		
Rhipiphoridae:								
Rhipiphorus pectinatus			1					
Suborder RHYNCHOPHORA (weevils)								
Unidentified	75	10	27	25	23	35	12	11
Anthribidae (fungus weevils):								
Ischnocerus sp.	1							
Anthribus cornutus						1		
Brachytarsus sp.				1				
Araeocerus fascicularis						3		
Curculionidae (curculios):								
Unidentified	17							1
Rhinomacer sp.	1				1			
Auletes sp.						1		
Eugnamptus collaris	2		11			1		
Eugnamptus sp.	1		2					
Rhynchites bicolor						1		

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Curculionidae—Continued.								
Attelabus analis			1			2		
Attelabus bisustulatus						1		
Attelabus nigripes						2		
Apion cribricolle			1					
Apion sp						1	1	1
Ithycerus noveboracensis	1							
Phyxelis rigidus	1							
Otiorhynchini	1	2	4	2	8	2	4	2
Coleocerus sp						1		
Geoderces sp	1							
Pachnaeus distans						1		
Tanymecus confertus	2		2					
Pandeleteius hilaris	2	1		2				
Brachystylus acutus				1				
Pantomorus sp			1					
Aphrastus taeniatus	2					3		
Polydrusus sp	1							
Scythropus elegans			1		7		1	
Eudiagogus pulcher						1		
Sitona hispidula	1	2	1	5		2		
Sitona sp				1	3	6	1	
Hypera punctata	1							
Phytonomus nigrirostris	1	5		1				
Phytonomus sp			2	2			1	
Hyperodes solutus						1		
Erirhinini								1
Dorytomus sp	1	1	2	2				
Desmoris constrictus								1
Otidocephalus myrmex						1		
Magdalis armicollis	2							
Magdalis sp					1			
Balaninus caryatrypes	1							
Balaninus occidentis							1	
Balaninus sp	21		3	10	6		4	
Elleschus sp			1					
Anthonomus grandis						2		
Anthonomus signatus						1		
Anthonomus sp		1	2			1		2
Prionomerus calceatus	2					2		
Barini			1					
Madarellus undulatus						2		
Centrinus picumnus						1		
Gelus oculatus	1							
Cylindrocopturus koebeli							1	
Cylindrocopturus quercus	1							
Ceutorhynchini						2		
Coelogaster zimmermanni						1		
Cryptorhynchini						1		
Conotrachelus albicinctus	2							
Conotrachelus anaglypticus				3	2	4		
Conotrachelus coronatus						1		
Conotrachelus elegans	1							
Conotrachelus nenuphar	4			3	8			
Conotrachelus sp				2	3	2		
Cryptorhynchus sp						1		
Cossonini				1				
Rhyncholus oregonensis	1							
Scolytidae (bark beetles):								
Unidentified			3			1	3	2
Platypus flavicornis						1		
Scolytus quadrispinosus	2							
Hypothenemus sp		1						
Pityophthorus sp		1						
Ips pini	1				2	1		
Ips plastographus							1	
Ips sp						1		
Dendroctonus valens				1	2			
Order MEGALOPTERA (Dobson flies)								
Sialidae:								
Unidentified		1	3	3	3	1		
Chauliodes pectinicornis	2			3	2			
Chauliodes sp						1		
Sialis sp		1						

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Philadelphia	Warbling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Order RHAPHIDIOIDEA								
Rhaphidiidae:								
Rhaphidia arizonica			2					
Rhaphidia sp	6		8				2	
Order NEUROPTERA (net-winged insects)								
Unidentified adults	2		1			1		
Unidentified eggs	1							
Chrysopidae:								
Chrysopa sp	4		1			1	1	
Myrmeleonidae (ant lions):								
Myrmeleon sp					3			
Order DIPTERA (flies)								
Unidentified adults	79	9	103	39	42	33	11	5
Unidentified pupae	2		1		1	1		
Unidentified eggs			1					
Tipulidae (crane flies):								
Unidentified adults	29	1	6		8	1		2
Unidentified eggs	3		3					
Tipula sp						1		
Psychoididae unidentified moth flies)					1			
Chironomidae (unidentified midges)	6	19	2	2	1	6		
Bibionidae (March flies):								
Unidentified			1			1		
Bibio sp	1				1	2		
Simuliidae (black flies):								
Simulium sp		1						
Leptidae (snipe flies):								
Leptis sp			1					
Stratiomyiidae (soldier flies):								
Odontomyia sp	1							
Tabanidae (horse-flies):								
Tabanus sp				2				
Asilidae (robber flies):								
Unidentified	3					1		
Asilus sp					1			
Dolichopodidae (unidentified)								1
Syrphidae (flower flies):								
Unidentified	5	2	2		5	2		
Myiolepta nigra		1						
Syrphus sp							1	
Temnostoma excentricum					1			
Ortalidae:								
Pyrgota valida				1				
Chloropidae (unidentified)			3		1	1		
Scatophagidae (dung flies):								
Scatophaga sp		1						
Muscidae (house flies)	11	2	3		2	2		
Pollenia rudis					1			
Tachinidae (unidentified parasitic flies)	3							
Order HYMENOPTERA (wasps, bees, etc.)								
Unidentified adults	181	28	74	30	52	65	22	17
Unidentified pupae					1	2		
Xyelidae:								
Macroxyela sp					3			
Pamphiliidae:								
Unidentified			1					
Pamphilus sp					1			
Tenthredinidae (sawflies):								
Unidentified adults	3	1	8	1	3	1		
Unidentified larvae		2	3					
Dolerinae	1		1	1				
Dolerus unicolor			1	1	2	1		
Dolerus sp		2	6	3	2			
Macrophya sp		1						
Nematinae		2						
Nematus erichsoni		1						
Pteronidea sp		1						
Pteronidea ventralis		1						
Arge clavicornis	1							

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	365	160	329	229	77	63
CLASS Insecta (insects)—Contd.								
Xiphydriidae:								
Xiphidria sp	2				1			
Siricidae:								
Sirex sp					1			
Tremex columba	1				1			
Oryssidae (unidentified)					2			
Vipionidae:								
Apanteles sp		1						
Braconidae:								
Unidentified						1		
Earinus limitaris			2	1	2	1		
Urosigalphus sp			1				1	
Heterospilus sp						1		
Trigonalidae:								
Trigonalys sulcata	1							
Ichneumonidae (ichneumon flies):								
Unidentified	4			3	5	5	2	
Aphidius sp		1						
Campoplex sp		1						
Mesochorus sp						1		
Paniscus geminatus	2							
Paranomalon sp	1	1						
Enicospilus purgatus	2							
Ophion bilineatus	3	1			1			
Ophion sp	4	1			1	1		
Catoglyptinae		1						
Tryphoninae					1	1		
Diplazon sp						1		
Exochinae					1			
Chorineus sp					1			
Lissonotinae				1				
Glypta rufiscutellaris					1			
Glypta tuberculifrons				1				
Glypta sp					3			
Conoblasta sp	1							
Ichneumoninae					1			
Scambus sp	1							
Pimplidea pedalis				1				
Itoplectis conquisitor			1	1	1			
Ichneumon irritator	1			1	9			
Calliephialtes sp						1		
Mesosteninae						1		
Phygadeuon sp	1							
Plesignathus sp	1							
Hemiteles aleator tenellus						1		
Hemiteles sp	1							
Amblyteles sp					1			
Pterocormus sp	1					1		
Melanichneumon sp	1							
Cratichneumon coerulens	1							
Cratichneumon sp	2							
Cynipidae (gall wasps):								
Unidentified adults				1	2	2		
Unidentified cocoons			1			2		
Callirhytis maxima					1			
Callirhytis sp					1			
Andricus sp					2			
Figitidae:								
Figitodes sp								1
Callimomidae:								
Callimome sp			1					
Chalcididae:								
Unidentified	3		2	1				
Chalcis ovata			1					
Chalcis robusta						1		
Formicidae (ants):								
Unidentified	70	4	34	21	40	25	6	7
Aphaenogaster fulva	1							
Aphaenogaster sp		2						
Myrmica punctiventris	1							
Myrmica rubra	1							
Myrmica sp		1						
Camponotus pennsylvanicus	11	4	1	1	6	1		1
Camponotus whymperi					1			
Camponotus sp	9	1	2	1	1	1	1	1
Colobopsis sp						2		

TABLE 2.—*List of items of animal food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Phila-delphia	War-bling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
CLASS **Insecta** (insects)—Contd.								
Formicidae—Continued.								
Lasius americanus	1							
Lasius sp	1							
Formica pallidefulva		1						
Formica sanguinea						1		
Formica subsericea	1	2					1	
Formica sp	4	1			1			
Chrysididae (gold wasps):								
Unidentified						1	1	
Omalus sinuosus			1					
Bethylidae:								
Isobrachium sp	1							
Scoliidae (digger wasps):								
Tiphia inornata	2							
Tiphia sp	4	1	1			1		
Eumenidae (potter wasps):								
Odynerus sp	1							
Ancistrocerus tigris					1			
Vespidae (hornets and yellow jackets):								
Unidentified			1					
Vespula vulgaris				1				
Vespula sp							1	
Dolichovespula diabolica	1							
Sphecidae (solitary wasps):								
Hoplisus sp					1			
Solenius sexmaculatus	1							
Solenius sp	1							
Crabro sp	1							
Aphilanthops frigidus	1							
Larropsis distincta			1					
Xylocelia sp	2							
Halictidae (green bees):								
Halictus lerouxi	2							
Halictus sp	1		1	1		3		
Augochlora sp							1	
Oxystoglossa pura	2							
Oxystoglossa sp	1							
Evylaeus arcuatus						1		
Evylaeus pectoralis	1							
Chloralictus coeruleus	1		1					
Chloralictus pilosus	1		1					
Chloralictus zephyrus			1		1	1		
Chloralictus sp				1		4		1
Andrenidae (burrowing bees):								
Andrena bisalicis	1					1		
Andrena claytoniae						1		
Andrena cressoni			1			1		
Andrena flavoclypeata	1		1			1		
Andrena mariae concolor					1			
Andrena nasoni						2		
Andrena robertsoni					1			
Andrena salictaria			2			2		
Andrena vicina				1	1			
Andrena sp	2		2	4	2	2		
Parandrena wellesleyana					1			
Trachandrena crataegi					2			
Trachandrena forbesi				1				
Trachandrena rugosa					2			
Trachandrena sp					2			
Nomadidae (parasitic-bees):								
Nomada sp					2	3		
Colletidae:								
Colletes sp					1			
Apidae (honeybees):								
Apis mellifera	2							1
CLASS **Reptilia** (reptiles)								
Iguanidae (iguanas):								
Anolis carolinensis						1		

TABLE 3.—*List of items of vegetable food identified in stomachs of vireos and the number of stomachs in which found* [1]

Kind of food	Red-eyed	Philadelphia	Warbling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
Unidentified vegetable matter			5					
Anthers of unidentified flower	1							
Unidentified bud scales		2	4	2		2		
Unidentified woody galls	6		7		2		2	
Unidentified fruit skins	36	2	3	1	2	6		1
Unidentified seeds and seed pods	4					5	2	1
Pinaceae:								
Juniperus sp.					1			
Gramineae:								
Digitaria ischaemum (small crab grass)	1							
Digitaria sanguinale (large crab grass)								2
Setaria glauca (yellow foxtail)	1							
Zea mays (maize)	1							
Liliaceae:								
Smilax sp. (greenbrier)					1			
Myricaceae:								
Myrica carolinensis (bayberry)	5	1	1		6	24		
Urticaceae:								
Morus alba (white mulberry)	3							
Morus rubra (red mulberry)						1		
Polygonaceae:								
Polygonum convolvulus (black bindweed)								1
Polygonum sp. (smartweed)						1		
Chenopodiaceae:								
Chenopodium sp. (lamb's quarters)				1				
Amaranthaceae:								
Amaranthus sp. (pigweed)	1							1
Phytolaccaceae:								
Phytolacca decandra (pokeweed)	1		3	1		1		
Magnoliaceae:								
Magnolia foetida (evergreen magnolia)	2							
Lauraceae:								
Sassafras variifolium (sassafras)	6			1				
Benzoin aestivale (spicebush)	7							
Saxifragaceae:								
Ribes sp. (currant)	1					1		
Rosaceae:								
Pyrus arbutifolia (chokeberry)	1							
Amelanchier sp. (shadbush)	1							
Rubus sp. (blackberry)	11					7		
Rosa sp. (rose)	1	2						
Prunus pennsylvanica (fire cherry)	1							
Prunus serotina (black cherry)	1							
Prunus virginiana (choke-cherry)	1							
Prunus sp. (cherry)			1					
Rutaceae:								
Xanthoxylum americanum (prickly ash)	1							
Anacardiaceae:								
Rhus diversiloba (western sumac)			1					
Rhus glabra (smooth sumac)						1		
Rhus toxicodendron (poison ivy)						9		1
Rhus typhina (staghorn sumac)	2							
Rhus sp. (sumac)			1		4	8	6	
Aquifoliaceae:								
Ilex vomitoria (youpon)						1		
Celastraceae:								
Celastrus scandens (bittersweet)	1							
Rhamnaceae:								
Berchemia scandens (supplejack)					1			

[1] See footnote to Table 2, p. 28.

TABLE 3.—*List of items of vegetable food identified in stomachs of vireos and the number of stomachs in which found*—Continued

Kind of food	Red-eyed	Philadelphia	Warbling	Yellow-throated	Blue-headed	White-eyed	Hutton	Bell
Total number of stomachs examined	653	84	356	160	329	229	77	63
Vitaceae:								
Unidentified		1						
Vitis cordifolia (frost grape)	1							
Vitis sp. (grape)	2		3	2	1			
Psedera quinquefolia (Virginia creeper)	12					2		
Eleagnaceae:								
Shepherdia sp. (buffalo berry)	1							
Cornaceae:								
Cornus alternifolia (alternate-leaved dogwood)	9							
Cornus amomum (kinnikinnik)	1							
Cornus asperifolia (rough-leaved dogwood)	1							
Cornus canadensis (bunch-berry)	1							
Cornus florida (flowering dogwood)	1		1		1	1		
Cornus paniculata (panicled dogwood)	15	3	3					
Cornus sp. (dogwood)	5	1	12		1			
Ericaceae:								
Vaccinium sp. (blueberry)	1							
Verbenaceae:								
Callicarpa sp. (Mexican mulberry)	1							
Solanaceae:								
Solanum dulcamara (deadly nightshade)	1							
Solanum sp. (nightshade)						1		
Caprifoliaceae:								
Lonicera hirsuta (hairy honey-suckle)	1							
Viburnum dentatum (black haw)						1		
Viburnum sp. (black haw)	3				1			
Sambucus canadensis (elder)	11		1			3		1
Sambucus sp. (elder)			8		1	1	1	

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO THE FOOD HABITS OF BIRDS

FOR FREE DISTRIBUTION BY THE DEPARTMENT

The English Sparrow as a Pest. (Farmers' Bulletin 493.)
Some Common Game, Aquatic, and Rapacious Birds in Relation to Man. (Farmers' Bulletin 497.)
Food of Some Well-known Birds of Forest, Farm, and Garden. (Farmers' Bulletin 506.)
Some Common Birds Useful to the Farmer. (Farmers' Bulletin 630.)
Common Birds of Southeastern United States in Relation to Agriculture. (Farmers' Bulletin 755.)
The Crow in Its Relation to Agriculture. (Farmers' Bulletin 1102.)
Canaries: Their Care and Management. (Farmers' Bulletin 1327.)
Homes for Birds. (Farmers' Bulletin 1456.)
Eleven Important Wild-duck Foods. (Department Bulletin 205.)
Propagation of Wild-duck Foods. (Department Bulletin 465.)
Waterfowl and Their Food Plants in the Sandhill Region of Nebraska. (Department Bulletin 794.)
Food Habits of Seven Species of American Shoal-water Ducks. (Department Bulletin 862.)
Wild Ducks and Duck Foods of the Bear River Marshes, Utah. (Department Bulletin 936.)
Food and Economic Relations of North American Grebes. (Department Bulletin 1196.)
Food Habits of Some Winter Bird Visitants. (Department Bulletin 1249.)
Food Habits of the Vireos. (Department Bulletin 1355.)
Food of American Phalaropes, Avocets, and Stilts. (Department Bulletin 1359.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE' WASHINGTON, D. C.

Fifty Common Birds of Farm and Orchard. (Farmers' Bulletin 513, with 50 colored plates). *Price 15 cents.*
Food Habits of the Swallows. (Department Bulletin 619.) *Price 5 cents.*
Food Habits of the Mallard Ducks of the United States. (Department Bulletin 720.) *Price 5 cents.*

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September 1, 1925

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	————
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	THOMAS P. COOPER, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAIN, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This bulletin is a contribution from

Bureau of Biological Survey	E. W. NELSON, *Chief.*
Division of Food Habits Research	W. L. MCATEE, *in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the Bureau of Plant Industry
Pennsylvania Department of Agriculture

DEPARTMENT BULLETIN No. 1357

Washington, D. C. ▼ January, 1926

THE STRAWBERRY ROOTWORM
A NEW PEST ON GREENHOUSE ROSES

By

C. A. WEIGEL, Associate Entomologist
Fruit Insect Investigations
Bureau of Entomology

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the Bureau of Plant Industry
Pennsylvania Department of Agriculture

DEPARTMENT BULLETIN No. 1357

Washington, D. C. ▼ January, 1926

THE STRAWBERRY ROOTWORM, A NEW PEST ON GREENHOUSE ROSES [1]

By C. A. WEIGEL, *Associate Entomologist, Fruit Insect Investigations, Bureau of Entomology*

CONTENTS

During the last 40 years the native insect known as the strawberry rootworm, or strawberry leaf beetle, *Paria canella* (Fab.), varieties *quadrinotata* (Say) and *gilvipes* (Crotch), was considered a serious enemy of strawberry, raspberry, and a few other plants only. Suddenly this little beetle appeared in greenhouses, attacking roses in Virginia, Indiana, New Jersey, Pennsylvania, and Maryland. Prior to 1916 a suggestion that this insect would abandon its usual hosts (*29, p. 67*)[2] for the succulent rose might have been subject to considerable doubt; but when simultaneous reports were received by the Bureau of Entomology concerning two widely separated infestations of an insect injuring roses in greenhouses at Alexandria, Va., and Richmond, Ind., such doubts would have been dispelled, because an examination of the specimens which accompanied

---

[1] The account of the strawberry rootworm and its control contained in this bulletin is the result of an investigation started in July, 1919, when the first reports were received by the Bureau of Entomology concerning injury by this insect to greenhouse roses. E. L. Chambers assisted in the work until August, 1920, and C. F. Doucette from January, 1921, until it was completed. Through the courtesy of J. G. Sanders, then director of the bureau of plant industry, Pennsylvania Department of Agriculture, a large portion of the work was done in cooperation with that bureau with headquarters at Doylestown, Pa. Credit is due J. K. Primm and A. W. Buckman, of the Pennsylvania Bureau of Plant Industry, and also Miss B. M. Broadbent and A. T. Grimes, of the Bureau of Entomology, for the assistance which they rendered at intervals in the work. Figures 3, 4, 7, 8, and 9 were prepared by Miss Almé Motter. Special thanks are accorded to John A. Andre, of Doylestown, for providing laboratory space, plants, and facilities for carrying on the work, as well as to other florists who offered assistance. The writer is also indebted to Prof. Herbert Osborn, of Ohio State University, for his interest, advice, and encouragement throughout the progress of the work. Acknowledgment is given to Dr. A. L. Quaintance and E. R. Sasscer, of the Bureau of Entomology, for their many valuable suggestions.

[2] Figures in italics in parentheses refer to "Literature cited," p. 47.

these reports proved them to be the chrysomelid beetle referred to above. Unfortunately the name "strawberry rootworm" does not imply that the greenhouse rose is a host or food plant, but in view of its long standing this name must be retained.

An investigation of these reports revealed the seriousness of the situation and indicated that the rose-growing industry was confronted with another important problem. Moreover, according to their statements, the florists were unable to check the ravages of these beetles by the use of measures ordinarily employed for controlling leaf-feeding insects. A review of the available literature on this species indicated that little was known of its life history and habits under greenhouse conditions. Naturally, owing to the change from the normal temperate climate out of doors to the subtropical conditions prevailing under glass, and to the intensive and specialized culture of the rose, important differences in biology and control would result.

The data collected during the last three years of research on the biology and control of this insect under conditions which exist in commercial greenhouses are presented in this publication.

SYSTEMATIC HISTORY

The two forms of the strawberry rootworm beetle encountered in the greenhouse and covered by these investigations appear to be *Paria canella quadrinotata* (Say) and *P. canella gilvipes* (Crotch), but so much conflict of opinion is apparent among various authorities who have published upon this group of beetles that the status of these varieties or species is still a matter of conjecture. The following discussion relates to the changes in nomenclature of these two varieties only.

The first name applied to this group of forms was *Cryptocephalus canellus*, given by Fabricius (*9, p. 52*) in 1801. Seven years later this was changed to *Eumolpus canellus* by Olivier (*22, p. 914*). In 1824 Thomas Say (*26, p. 446*) first described as *Colaspis quadrinotata* the four-spotted form here treated. In 1858 LeConte (*20, p. 86*) erected the genus Paria for five species, including *canella* and *quadrinotata*. In 1873 Crotch (*7, pp. 33, 39*), in revising the North American eumolpids, distinguished the genera Typophorus and Paria and placed *quadrinotata* (misprinted "*6-notata*") and *gilvipes* as varieties of *Paria sexnotata* Say. In 1882 Jacoby (*18, p. 182*) mentioned Paria as very closely related to Typophorus, but kept the two genera separate. In 1884 Forbes (*13, p. 159*) in his economic treatise associated *quadrinotata* and *gilvipes* as synonymous with *Paria sexnotata* Say.

In 1892 Paria and Typophorus were united by Horn (*16, p. 208*), in his monograph on the Eumolpini of Boreal America, under the older name Typophorus. He listed *canellus* as one of the two included species and reduced all of the other specific names used under Paria to the rank of varieties or synonyms under *canellus*, in which he placed *quadrinotatus* as a variety, and *gilvipes* as a subvariety of the variety *aterrimus* Oliv. In 1910 Blatchley (*2, p. 1139*), in his Coleoptera of Indiana, followed Horn's nomenclature for the forms above mentioned. In 1914 Clavareau (*4, pp. 153–157*) catalogued

Paria and Typophorus as separate genera, with *canella*, *quadrinotata*, and *gilvipes* as distinct species of Paria, and in 1920 Leng (*21, p. 294*) also separated the two genera, but listed only the one species *canella* under Paria with *gilvipes* and *quadrinotata* as two of the nine varieties of the species. The writer has followed Leng's use of the names.

The synonymy of *Paria canella quadrinotata* (Say) appears, therefore, to be as follows:

1824. *Colaspis quadrinotata* Say (*26, p. 446*).
1858. *Paria quadrinotata* (Say) LeConte (*20, p. 86*).
1873. *Paria sexnotata quadrinotata* (Say) Crotch (*7, p. 39*).
1892. *Typophorus canellus quadrinotatus* (Say) Horn (*16, p. 208*).
1914. *Paria quadrinotata* (Say) Clavareau (*4, p. 156*).
1920. *Paria canella quadrinotata* (Say) Leng (*21, p. 294*).

The synonymy of *P. canella gilvipes* (Crotch) appears to be as follows:

1833. *Metachroma gilvipes* Dejean (nomen nudum) (*8, p. 412*.)
1873. *Paria sexnotata gilvipes* (Dejean) Crotch (*7, p. 39*).
1892. *Typophorus canellus aterrimus gilvipes* (Crotch) Horn (*16, p. 208*).
1914. *Paria gilvipes* (Crotch) Clavareau (*4, p. 156*).
1920. *Paria canella gilvipes* (Crotch) Leng (*21, p. 294*).

ECONOMIC HISTORY AND FOOD PLANTS[3]

Cook (*5*), in a paper read in 1880 and published in 1881, seems to have been the first to mention the four-spotted Paria as injurious to strawberry. Since then a number of accounts have referred to the insect as a strawberry pest. Strawberry, raspberry, juniper, wild crab apple, and cinquefoil are mentioned as hosts of the adults by Forbes (*13, p. 169*) in 1884. In 1893 Webster (*28, p. 202*) "observed them in Ohio eating holes in the leaves of blackberry and raspberry." Injury to raspberry is recorded in Canada by Fletcher (*11, p. 81; 12, p. 216*) in 1894 and 1895, and in Maine by Harvey (*15, pp. 106–110*) in 1896.

In correspondence received by the Bureau of Entomology on May 10, 1905, from Rutland, Md., it was stated that the foliage of Prairie and Harrison rose plants was being perforated by beetles. The specimens were probably *Typophorus canellus* but because of their crushed condition the determination was not positive.

Felt (*10, p. 537*) records butternut, mountain ash, and heath aster (*Aster ericoides*) as hosts. According to Swenk (*27, p. 83, pl. 3, b*) thousands of the beetles were found feeding voraciously in an apple orchard in Nebraska. Neither of these references associates any particular variety of *Paria canella* with these hosts. The variety *sexnotata* is recorded on juniper by Say (*26, p. 446*) in 1824.

Black walnut buds were reported as being injured by specimens received by the Bureau of Entomology in April, 1921, from Ithaca, N. Y., and determined[4] as *Paria canella* Fab. In the same month Britton (*3, p. 195*) reported injury on the tender terminal leaves of Japanese walnut by adults of the varieties *gilvipes* and *quadrinotata* at Wilton, Conn. In July, 1921, J. K. Primm found adults of the variety *gilvipes* feeding on leaves of butternut in a nursery at West

[3] Because of the confusion in the varietal nomenclature, it has been difficult in many cases to decide whether references to the species *Paria canella* refer to *quadrinotata* or to *gilvipes*. Where a description was given which corresponded with the characters of either of these varieties, the reference has been cited.

[4] Determined by E. A. Schwarz, Bureau of Entomology.

Chester, Pa. Grapes, oats, rye, millet heads, peach, and apple are reported as hosts in correspondence from State entomologists.

The earliest published record of its occurrence under glass is by Cory (*6*, *p. 206*), who reported that "it was found injuring a rose planting in the establishment of a Baltimore florist," during 1916. Specimens received by the Bureau of Entomology which bear the date of October 28, 1916, were taken from rose by R. E. Snodgrass, at Indianapolis, Ind. Specimens now in the Indiana State collection were obtained in greenhouses at Cumberland on November 8, 1916, and H. F. Dietz collected beetles in the same greenhouses on December 5, 1917. Peterson (*23*, *p. 468*) reports severe injury in a greenhouse in New Jersey in 1917.

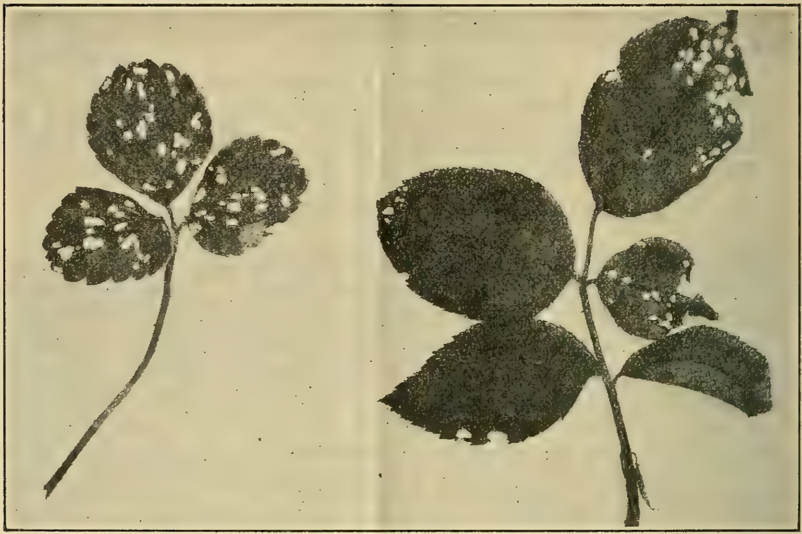


FIG. 1.—The "shot-hole" punctures characteristic of the feeding of adults of the strawberry rootworm on strawberry and rose foliage

A number of other reports which relate to its occurrence in greenhouses have been published within the last three years, but no earlier records have been found.

To sum up the foregoing reports and records, the following may be listed as food plants:

Amygdalus persica	Peach.
Aster ericoides	Heath aster.
Avena sativa	Oats.
Chaetochloa italica	Millet.
Fragaria spp	Strawberry.
Juglans cinerea	Butternut.
Juglans nigra	Black walnut.
Juglans sieboldiana	Japanese walnut.
Juniperus spp	Juniper.
Malus spp	Wild crab.
Malus sylvestris	Apple.
Potentilla spp	Cinquefoil.
Rosa spp	Rose.
Rubus spp	Raspberry, blackberry.
Secale cereale	Rye.
Sorbus spp	Mountain ash.
Vitis spp	Grape.

RECENT INJURY IN GREENHOUSES

In 1919, shortly after receipt of the reports concerning the infestations in Virginia and Indiana, a visit to the one in Alexandria, Va., on July 25 revealed the seriousness of the injury and the reason for the appeal for assistance. The stock in eight large houses suffered infestation, five, of the open-range type, being extremely heavily infested. The damage was caused mainly by the adults, which were present in unusually large numbers. As a result of their voracious feeding practically all of the foliage was badly perforated and ragged (fig. 1). In addition, a large proportion of the young shoots had the wood badly scarred and girdled, giving it a very unsightly appearance. It was found that the adults had a marked preference for this new wood, of which there was an abundance at this particular season, owing to the fact that the roses were being forced vigorously. Further examination showed that the larvæ had also been feeding on the roots (fig. 2) earlier in the season. As a result of these injuries a gradual killing of the affected parts ensued, producing a stunted growth of the plants. In attempting to establish the possible origin of the infestation in Alexandria, records by A. D. Borden showed that this insect had been attacking roses in the same houses three years previously. Recent evidence disclosed that the soil in which the roses were growing had been in the benches since then; hence it seems that their occurence dated back to that time.

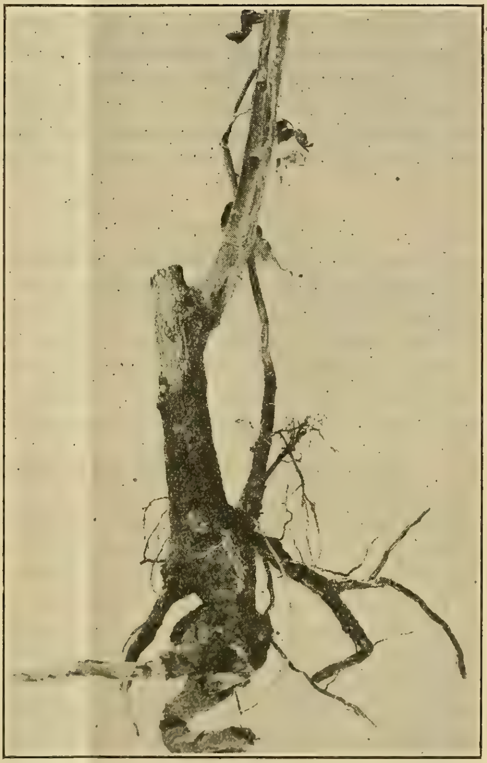


FIG. 2.—Roots of rose plant devoid of rootlets and severely injured by larvæ of the strawberry rootworm

Judging from the report made by H. F. Deitz, the Indiana infestation obviously was not so severe as the one at Alexandria. It was learned from the florist, however, that serious injury had occurred during May, the injuries being confined to Killarney rose plants growing in a solid bed in one of the five open-range houses infested. The condition there was similar to that existing at Alexandria, since the plants had been forced for about three weeks and had put forth an abundance of young, tender shoots. In the same locality Dietz noted this insect feeding on the foliage of out-of-door roses "growing next to a large strawberry bed, the leaves of which were badly riddled by the beetles."

Early in November, 1919, specimens of the strawberry rootworm were collected in the rose houses of the United States Botanical Garden at Washington, D. C., where they were doing serious injury.

During the winter of 1919–20 Primm and Trimble, of the Pennsylvania Bureau of Plant Industry, found infestations in 15 different establishments in the vicinity of Philadelphia. According to two florists in this locality, the beetles, known to them as "chocolate bugs," had been encountered in their houses for 12 and 18 years, respectively.

A careful survey by means of a circular letter sent to all the State entomologists and the subsequent publicity accorded this insect and its injury in florists' trade journals (*1*, *17*, *19*, and *24*) have brought to attention infestations in the States of Michigan, Missouri, Louisiana, Rhode Island, and Massachusetts. These reports emphasize the fact that the insect is now of prime importance in practically all of the commercial rose districts of the United States east of the Rocky Mountains. The severity of injury found in houses or beds where the plants were 3 or more years old indicated that they were the sources of infestation, and that the insect had been brought in either with the soil or the plants in those sections.

DISTRIBUTION

The strawberry leaf beetle, or adult of the rootworm, which is a native insect, has been frequently recorded as occurring out of doors generally throughout the United States and Canada (*14*, *p. 25*). The records available at the present time show that it is injurious to roses under glass in the District of Columbia, Illinois, Indiana, Louisiana, Maryland, Massachusetts, Michigan, Missouri, New Jersey, Pennsylvania, Rhode Island, and Virginia.

NATURE OF INJURY AND ECONOMIC IMPORTANCE

Two stages of the strawberry rootworm are involved in the injury to the plants, (1) the adult and (2) the larva. The casual observer immediately notices the ravages of the beetles on almost every part of the plant above ground. The leaves become perforated so extensively that one easily imagines charges of small shot being fired at the plants. This shot-hole appearance (fig. 1) is very characteristic and completely destroys the ornamental value of the foliage. The beetles also eat the green succulent bark of the forced plants, particularly in crotches, scarring and often girdling the stems.

The most serious injury to the plants occurs when the tops are "cut back," because little foliage remains for the beetle to feed upon. At this time the beetles severely scar the stems and eat into the "eyes," as the developing buds are termed by the florists. The importance of this particular type of injury is very evident when it is considered that the future crop of flowers depends on these buds, which require from six to eight weeks to develop, and that any setback naturally results in a decreased production and financial return. The succulent nature of this growth, as compared with the woody stems, causes the beetles to center their attention upon it, and in a single night they may eat the heart out of almost every eye. In one infestation observed in March, after the buds of Ophelia plants had been destroyed during September and October of the previous year, the first growth produced from these nodes was only from 3 to 5 inches long. During this period no marketable blooms were obtained from these plants.

The beetles seldom attack the flowers, but when present in large numbers sometimes feed on the sepals, probably because they contain chlorophyll. In severe infestations the blooms of Columbia and Ophelia roses occasionally suffer injury, but the double white Killarney is rarely attacked.

Although the damage to the foliage occasioned by the beetles is more conspicuous, the roots are severely injured by the feeding of the larvæ, which not only devour the young feeder roots but also interfere with the normal functioning of the root system by girdling and gnawing into the older roots. (Fig. 2.) After two or three successive seasons of this feeding the plants become considerably weakened and the foliage assumes a "sickly" appearance, due to the cumulative effect of this injury. In some infested greenhouses the resulting mortality of plants in some beds ranged as high as 75 per cent, as indicated in Table 1, in which are recorded observations taken in 1920 by Primm and Chambers.

TABLE 1.—*Mortality due to larval injury by the strawberry rootworm in 17 ground beds, each containing 800 rose plants*

Bed No.	Number of dead plants	Mortality	Bed No.	Number of dead plants	Mortality
		Per cent			*Per cent*
1	333	41.6	11	25	3.1
2	279	34.9	12	5	0.6
3	333	41.6	13	22	2.8
4	145	18.1	14	67	8.4
5	425	53.1	15	27	3.4
6	276	34.5	16	312	39.0
7	209	26.1	17	600	75.0
8	280	35.0			
9 [1]	42	5.3	Total and average	3,398	25.0
10 [1]	18	2.3			

[1] Plants not cut back the previous season.

In one badly infested bed containing 800 plants 6 larvæ, on an average, were found among the roots of each plant, and in one case a maximum of 23 larvæ and pupæ were collected. When it is considered that these plants had been in the bed for five years and there subjected to larval attack for at least three years, it is not surprising that the foliage was yellow and that no flowers of any value were being produced.

Wounds in the roots are favorable points for the entrance of pathological organisms, and the resulting weakened condition of the plants renders them more susceptible to plant diseases.

The enormous number of beetles actually present in a heavily infested greenhouse may be readily appreciated from the following data: Since other control measures appeared inadequate, one establishment hired schoolboys for several weeks to hand-pick the adults, paying them at the rate of 25 cents per 100 beetles. The pay roll for these boys showed that as many as 60,000 were collected in one week at a cost of $150 (*32, p. 285*). Although several hundred thousand beetles were removed in this way, no diminution in their numbers was apparent. At another place many beetles were shaken from the plants onto paddles covered with sticky fly paper, and where they were very numerous enough were collected along a 150-foot walk to cover a sheet of the paper; nevertheless, the plants continued to suffer from the ravages of those which escaped collection.

According to estimates of florists in Bucks and Montgomery Counties, Pa., damage to the extent of $70,000 was done to their greenhouse rose plants in 1920. The records of one grower show his gross income from one rose house to have been 74 cents per plant from July 1, 1919, to February 1, 1920, as compared with an income of $1.17 for the same period the preceding year. The decrease of 43 cents per plant was attributed almost entirely to the ravages of the beetles.

Another florist, whose gross annual return from 40,000 rose plants was from $70,000 to $80,000, estimated that his loss during 1921 was $9,000. He was unable to cut any salable flowers from June 25 until late in September, and his production suffered to some extent during the rest of the year. His loss may be analyzed as follows:

Cut flowers:		
Expected return during period when shipping was stopped	$4,320	
Actual return		$0
Loss		4,320
Estimated loss because of reduction of production		2,000
Insecticides:		
Tobacco dust, 50 tons at $35 per ton	1,750	
Fertilizer value at $10 per ton	500	
Insecticidal expense		1,250
Wood ashes, 25 tons at $30 per ton	750	
Fertilizer value at $10	250	
Insecticidal expense		500
Arsenicals and miscellaneous proprietary compounds and equipment	400	
Labor in application of insecticides, etc., 2,000 (estimated) man hours at 30 cents	600	
		1,000
Total		9,070

Losses and expenses such as are illustrated above will quickly absorb all the profits of a grower, because of the competition with other florists whose establishments are not suffering from the ravages of this insect.

LIFE HISTORY AND HABITS

ADULT STAGE

The original description of the variety *quadrinotata* as given by Say (*26, p. 446*) is as follows:

> Colaspis 4-notata: Black; head rufous; elytra testaceous, with two black spots. Inhabits the United States. Body black, punctured; head obscure rufous; antennae paler at base; thorax black; immaculate; punctures sparse, not profound; scutel pale reddish-brown; elytra pale testaceous, with striae of punctures which become obsolete before the tip; a black, oblique spot near the base of each and a larger obliquely quadrate one on the middle, exterior edge black; feet pale; thighs with a minute angle beneath. Length about three-twentieths of an inch.

It is evident that the name was given because of the four black spots on the elytra. The principal distinguishing color features are the black thorax, the brown elytra bearing the four black spots, and the absence of black markings along the suture.

Although Dejean (*8, p. 412*) used the name *gilvipes* for a species of Metachroma in his catalogue of Coleoptera, its use is held invalid because of the absence of description or reference to any type; and since Crotch (*7, p. 39*) was the first to use distinguishing characteristics for this variety, the authorship of the name is credited to him. Crotch lists *gilvipes* as a variety of *Paria sexnotata* with the very brief description: "Entirely black, legs pale." The name is evidently derived from gilvus (yellow) and pes (foot) and refers to the pale yellowish legs.

Horn (*16, p. 208*) indicates that the head of *gilvipes* is black, but Blatchley (*2, p. 1139*) shows that it may be reddish, and also that the antennæ as well as the legs are pale. The writer has found that the head is reddish in all specimens of *gilvipes* observed, and also that the black of the elytra grades into a pale Van Dyke brown color near the tips.

All individuals of both varieties of the beetles found in the greenhouses have been of a uniform size, and no differences have been noted among specimens from the several widely separated infestations. The length ranges from 2.8 to 3.6 millimeters and the width from 1.6 to 2 millimeters. It is interesting to note, however, that specimens of the same varieties which had been collected out of doors were much larger, being 4.5 millimeters long and 2.3 millimeters wide.

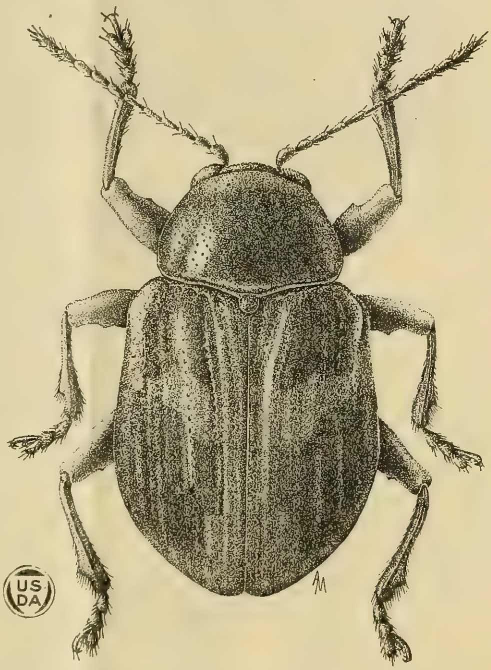


FIG. 3.—The strawberry rootworm. Adult of the variety *quadrinotata*

When the beetles are first transformed from the pupæ they are very light in shade, but upon exposure to the air soon acquire the normal coloration and markings. The ventral surface of the body becomes black in both varieties.

The four-spotted variety, *quadrinotata* (fig. 3), has been more prevalent in greenhouses, and was encountered in every infestation observed; but the closely related *gilvipes*, with its black body and pale legs, has also been found simultaneously in several establishments in considerable numbers. Practically all of the observations on the adult were made on individuals of the variety *quadrinotata.*

CAGE FOR OBSERVATIONS ON ADULT STAGE

The type of cage used for most of the observations on the adult stage was a glass vial or test tube 1 inch in diameter and from 3 to 5 inches long closed with a cork. A piece of cloth placed under the cork before the latter was pushed down into the vial was found advantageous in preventing the beetles from laying eggs in the crevices of the cork and also in absorbing any moisture of condensation which might otherwise drip down the sides of the vial.

LONGEVITY

It was not possible to reduce to an arithmetical basis the longevity of the adults in the greenhouses, because the time from emergence to date of collection could not be determined. Beetles under observation lived as long as 234 days after date of collection.

It seems probable that under favorable greenhouse conditions the adults which emerge during the spring and summer months may live from 75 to 100 days, whereas those which emerge later in the season and pass the winter in the semidormant condition may remain alive for a longer period. Table 2 indicates an average longevity of 52 days for reared specimens in confinement, although one individual lived 364 days.

TABLE 2.—*Longevity of 45 strawberry rootworm beetles reared from pupæ in 1921 and 1922*

Number of beetles	Date of— Emergence	Date of— Death	Length of life	Remarks
OBSERVATIONS AT WASHINGTON, D. C.				
	1921	1921	*Days*	
3	June 27	June 29	2	No feeding.
6	27	July 1	4	Do.
2	27	2	5	Do.
3	27	9	12	
1	27	21	24	
1	27	27	30	
1	27	Aug. 17	51	
6	27	Oct. 19	114	4 eggs from 1 beetle.
1	27	Dec. 4	160	58 eggs.
		1922		
1	27	June 26	364	51 eggs.
OBSERVATIONS AT DOYLESTOWN, PA.				
	1921	1921		
1	June 1	June 16	15	
1	1	Sept. 6	97	40 eggs.
1	4	July 7	33	No data on egg deposition.
1	July 2	Oct. 3	93	Do.
1	Aug. 3	Sept. 22	50	Do.
1	3	Aug. 30	27	Do.
1	4	Oct. 17	74	Do.
	1922	1922		
1	June 27	June 28	1	
2	27	July 25	28	
1	30	Aug. 14	45	
1	July 7	14	38	
1	17	Nov. 1	107	
1	27	Aug. 21	25	
1	27	Sept. 21	56	
1	29	Aug. 3	5	
1	29	Oct. 26	89	
1	Aug. 1	Aug. 22	21	
1	7	Nov. 1	86	
1	16	Sept. 21	36	
Total, 45			2,343	

	Days
Average length of life	52
Maximum length of life	364
Minimum length of life	1

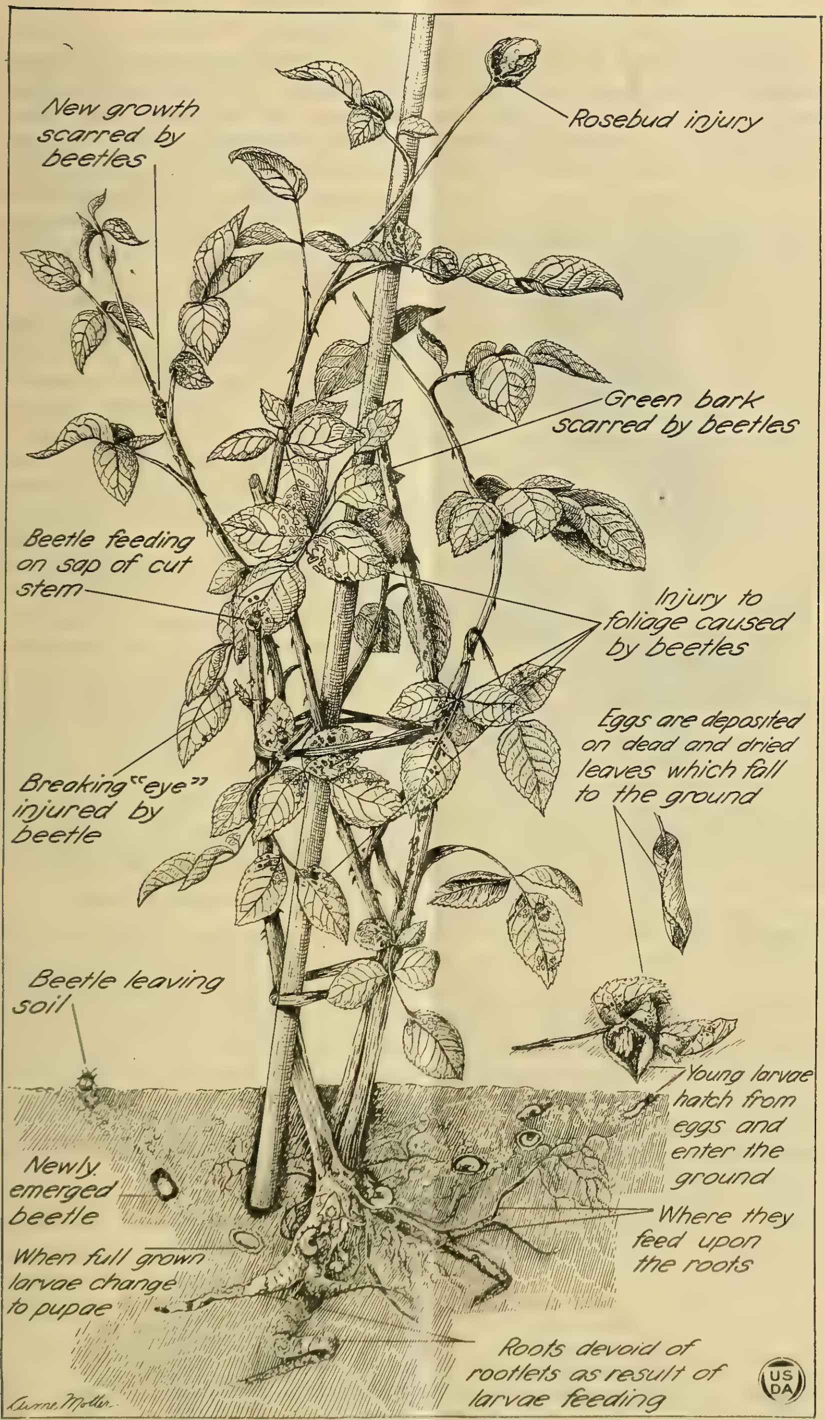


FIG. 4.—The stages in the life history of the strawberry rootworm and the injury caused by the larvæ and adults

HABITAT

On bright days the beetles hide in the dried leaves on the bushes, between adjacent green leaves, in the crotches, or in any place where they are away from the light, and come out to feed in the late afternoon (Fig. 4). Usually wherever fresh feeding is evident on the foliage an examination of the nearest dry leaf will reveal their presence. They may often be found in depressions one-half inch deep in the ends of cut stems where the pith has dried out.

FIG. 5.—The strawberry rootworm: Characteristic feeding of the adults on terminal growth and flower bud

Syringing causes many of the beetles on the plants to drop to the ground, where they may remain for some time. Watering as well as syringing wets the soil to such an extent that the adults dislike it and run up the stems, stakes, and plants, or rest on the wires, apparently to dry themselves. While the beetles were thus exposed, more than a thousand were collected within an hour by the workmen in a house containing 30,000 plants. Two or three hours after syringing the beetles again hide among the foliage of the plants or elsewhere.

FEEDING HABITS

The leaves (fig. 1) furnish most of the adults' food, although the bark of the stems, the buds (fig. 5), and the flowers do not escape attack. The beetles are attracted particularly by the sap on the ends of new-cut stems, and in the evening as many as 10 have been found feeding there. Under these conditions hand picking may be successfully practiced. In the absence of foliage the beetles cause very serious injury by feeding on the breaking buds. The extent of this feeding is shown in Table 3, which records data gathered in three separate greenhouses.

TABLE 3.—*Injury to "wood buds" of rose plants by strawberry rootworm beetles in three different establishments*

Establishment	Total number of—			Percentage of injured buds
	Plants examined	Breaking buds	Injured buds	
A	50	2,313	878	38
B	30	1,013	637	62
C	53	590	349	59

Sixty adults given fresh leaves twice daily ate 372 of the characteristic "shot-hole" punctures (fig. 1) the first day, 386 the second day, and 325 the third day, averaging 6.2, 6.4, and 5.4 feeding punctures per adult on the respective days, or an average over the whole period of 6 such areas for each beetle per day. It was observed to require about six minutes for a beetle to eat one hole in a leaf.

Further experiments, as indicated in Table 4, gave an average of between 4 and 5 feeding punctures per day for each individual.

TABLE 4.—*Amount of feeding by strawberry rootworm beetles during September, 1921*

Period (first and last dates, inclusive)	Number of—		Feeding punctures—			Remarks
	Days	Adults	Total number	Average: Per day	Average: Per adult per day	
Aug. 31 to Sept. 2	3	47	645	215	4.57	
Sept. 3 to Sept. 6	4	46	1,103	276	6.00	1 dead.
Sept. 7 to Sept. 10	4	45	947	237	5.27	Do.
Sept. 11 to Sept. 14	4	43	704	176	4.09	2 dead.
Sept. 15 to Sept. 17	3	43	528	176	4.09	
Sept. 18 to Sept. 22	5	43	463	93	2.16	
Sept. 23 to Sept. 27	5	43	446	89	2.07	

PROTECTIVE HABITS

As is characteristic of certain other insects, this beetle at the least disturbance folds its legs and antennæ under its body, rolls from the leaf, and remains motionless on the ground for several minutes. This so-called "possum" or death-feigning habit is also protective and is more common than the "squirrel" habit, by which they escape being seen. If approached during the day, any beetles visible on the plants immediately conceal themselves behind leaves, stems, stakes, or elsewhere. When one walks through a heavily infested house at night he can hear the beetles dropping from the bushes about 10 feet ahead, and when the beetles are present in large numbers the sound is similar to the patter of a gentle rain. The coloration of the beetles blends with that of the earth or mulch, and it is difficult to locate them on the soil unless they move.

The beetles do not necessarily reach the ground when they drop from the plants, for they are apt to fly at any time during their fall. In fact, when within a foot of the soil they have been observed to spread their wings and fly to near-by leaves. The range of continuous flight appears to be limited, as 30 feet was the maximum distance observed. In one house, where the plant tops had been cut back and removed during the day, many beetles were seen on the walls and roof, where they were apparently trying to escape from the house by making short flights of from 5 to 10 feet at a maximum altitude of 10 feet.

FERTILITY AND PARTHENOGENESIS

Mating was not observed and males have never been seen among the numbers of individuals collected under glass. Peterson (*23*, *p.*

473) says: "No male adults have been seen at any time in our three years of observation with this species." Males are known to occur out of doors, and these observations indicate possible thelyotoky in the greenhouse forms. Whether or not they are fertilized, it is an outstanding fact that practically all the eggs in the masses observed in greenhouses have hatched.

Although 25 adults which emerged on the same day were removed from the rearing cage and confined singly, so that the only possible access to males was before they were isolated, three of them deposited eggs. In another case eggs were obtained from two reared adults which were segregated immediately after emergence. In this connection Peterson (*23, p. 473*) observes that the ovaries of newly emerged adults are in an immature condition and do not develop to any extent until the adult has consumed some food. At first the

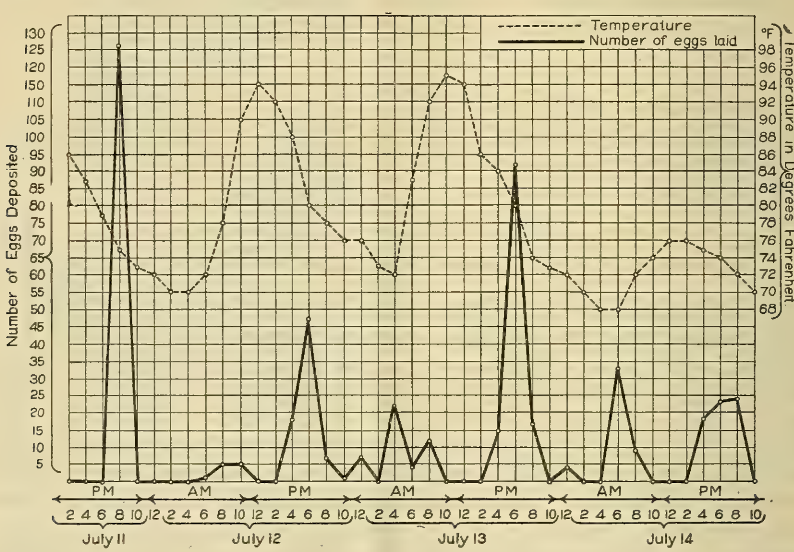


FIG. 6.—Egg deposition by strawberry rootworm adults. Records every two hours from July 11 to 14, inclusive, Doylestown, Pa., 1922

abdomen is very soft and does not become full and hardened until seven days after emergence, so that, although possible, it is doubtful whether mating takes place while the female is in this undeveloped state. Furthermore, as is shown in Table 7, no eggs were laid by reared individuals until 19 days after emergence, or 18 days after they were isolated. From the foregoing circumstantial evidence it would appear that parthenogenesis is a possible feature of the biology of this insect under greenhouse conditions.

OVIPOSITION

Oviposition may take place, at least to a limited extent, throughout the year, since the eggs have been obtained from caged beetles in each month. In the greenhouse, however, most of the eggs were laid in the spring and early summer months. The earliest records of the finding of eggs in the rose houses are March 9, 1920, March 1, 1921, and March 14, 1922, and after these dates eggs could be found almost continuously until August, at which time they were less numerous, and none have been collected in greenhouses after August 31 in any year. These records are very similar to observations on caged beetles, as indicated in Table 5.

TABLE 5.—*Total number of eggs laid by caged strawberry rootworm beetles, 1922*

Date of deposition	Number of— Eggs	Adults	Eggs per adult	Date of deposition	Number of— Eggs	Adults	Eggs per adult
Mar. 27	12	59	0.20	June 21	20	124	0.16
29	17	90	.19	22	57	123	.46
Apr. 3	67	107	.63	23	105	121	.87
6	28	115	.24	26	221	117	1.89
8	34	115	.30	28	27	116	.23
10	149	115	1.30	29	101	109	.93
13	168	111	1.51	30	13	109	.12
15	68	111	.61	July 1	434	102	4.25
17	33	76	.43	3	251	98	2.56
19	21	52	.40	5	243	95	2.56
21	22	52	.42	8	352	147	2.39
24	92	50	1.84	10	206	131	1.57
26	39	50	.78	12	53	127	.42
28	35	50	.70	14	532	127	4.19
May 3	147	50	2.94	15	56	118	.47
6	76	48	1.58	18	322	117	2.75
8	142	47	3.02	22	621	114	5.45
11	153	46	3.33	25	636	114	5.58
15	112	44	2.55	28	561	134	4.19
17	62	44	1.41	31	622	131	4.75
20	76	43	1.77	Aug. 1	378	131	2.89
22	160	42	3.81	2	176	129	1.36
24	148	64	2.31	3	101	128	.79
26	122	66	1.85	5	296	128	2.31
29	221	65	3.40	7	583	128	4.55
31	181	59	3.07	9	182	127	1.43
June 3	176	54	3.26	11	265	123	2.15
5	246	56	4.39	14	159	120	1.33
7	303	55	5.51	17	125	118	1.06
9	178	65	2.74	21	124	114	1.09
13	468	64	7.31	29	116	93	1.25
14	12	64	.19	Sept. 21	34	46	.74
17	157	62	2.53				
19	105	66	1.59	Total	12,002	6,016	2.00

Figure 6 shows the results of observations on 60 caged adults made every 2 hours over a period of 80 hours, during which 490 eggs were laid, and is based on data contained in Table 6. According to these records, the time of day most favored by the female for egg deposition is the late afternoon, and next to that the early morning hours.

TABLE 6.—*Egg deposition by adults of the strawberry rootworm; observations upon which graph of Figure 6 is based*

Date of oviposition	Number of eggs laid— p. m.	a. m.					m.	p. m.					Total number of eggs
	12	2	4	6	8	10	12	2	4	6	8	10	
July 11	(1)	----	----	----	----	----	----	(2)	(1)	----	126	0	126
12	0	0	0	1	5	5	0	0	18	47	7	1	84
13	7	0	22	4	12	0	0	0	15	92	17	0	169
14	4	0	0	33	9	0	0	0	18	23	24	0	111

[1] No data. [2] Observation started.

Observations on the process of egg deposition by two beetles confined in one vial at 2 p. m. were as follows: While seeking a place to deposit eggs the beetles, moving their heads with a rocking motion, touched or "measured" the surfaces of crevices or depressions in the cork alternately with the tip of each antenna, and then tried them out with the tip of the ovipositor slightly extended, moving rapidly from one to another. These two individuals were then placed in separate vials with a small piece of dry and crumpled leaflet. One adult ran nervously about for a time, while the other on finding the leaf settled immediately and began to oviposit.

Considerable time was spent in preparing a resting place for the eggs. After the long, flexible ovipositor had been inserted, a thin

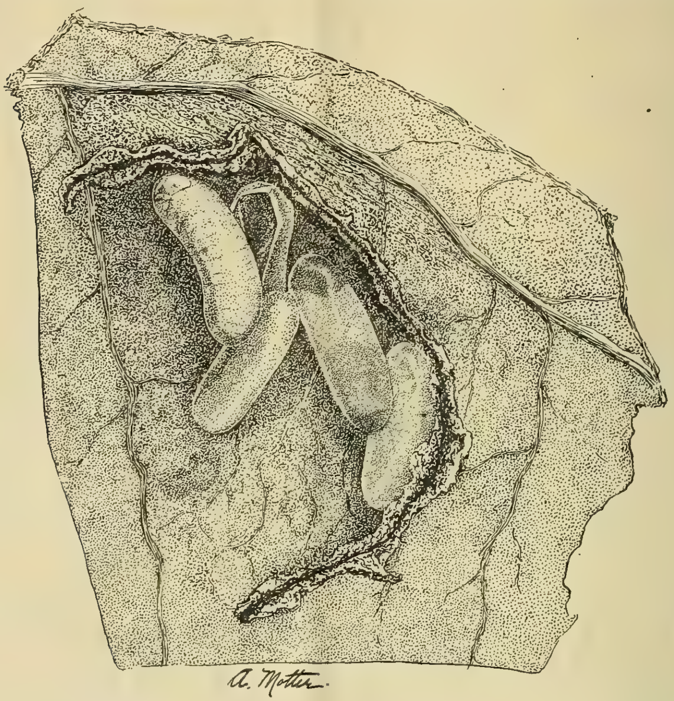


FIG. 7.—Egg mass of the strawberry rootworm on portion of dead leaf, showing development and characteristic wall which surrounds each egg mass. Enlarged

transparent fluid was secreted at its tip in tiny droplets, and then spread or brushed over both surfaces of the depression with two hairy palpuslike projections of the ovipositor. Twelve minutes were spent preparing the surface and four minutes in forming that portion of the wall against which the eggs were to be placed. A tiny droplet of the thin fluid preceded and another followed each egg as it was ejected from the ovipositor, and an interval of about two minutes elapsed between the ejection of each egg. The egg was placed with the help of the palpuslike brush, which at the same time spread some of the fluid over the egg and in the spaces around it. When all the eggs had been placed the beetle constructed a wall (fig. 7) to surround the egg mass by secreting a second fluid, which was thicker and contained small lumps, and which evidently served as a means of keeping the two surfaces between which the eggs were laid from pressing together and crushing them.

The material forming this wall was translucent when secreted, but turned dark and finally black about three hours later. While the fluid was being spread the beetle rubbed its hind and middle tarsi together, apparently for the purpose of removing the sticky fluid which adhered to them. Although the legs were usually kept well braced, the beetle occasionally supported the turgid ovipositor with one of its hind legs. At times the ovipositor would be retracted, only to be immediately extended again. The beetle turned slightly several times to allow the ovipositor to reach a different spot, but all reaching was done by the ovipositor alone and there was no motion of the body which assisted in placing it between the leaf surfaces. In another instance an adult was observed to begin oviposition at 7.15 p. m. and finish at 8.05 p. m., a period of 50 minutes, during which four eggs were deposited.

A few records of duration of the preoviposition and postoviposition periods of strawberry rootworm beetles and of the number of eggs deposited are contained in Table 7.

TABLE 7.—*Duration of preoviposition and postoviposition periods of the strawberry rootworm beetle, 1921*

Date of—		Preoviposition period	Number of eggs deposited	Date of—		Postoviposition period
Emergence	First egg			Last egg	Death	
		Days				*Days*
June 1	June 20	19	40	July 31	Sept. 6	37
27	July 27	30	58	Aug. 12	Dec. 4	114
27	27	30	51	12	June 26[1]	318
27	Aug. 8	42	4	8	Oct. 19	72

[1] 1922.

The maximum number of eggs laid was 216, and these eggs were deposited by a beetle in 22 different egg masses in a period of three months after it was collected in the greenhouse. Several instances have been noted in which collected individuals have laid more than 100 eggs. Observations on caged beetles under greenhouse conditions indicate an average of 135 eggs as the probable normal capacity of a female.

EGG STAGE

The egg (fig. 7.) of the strawberry rootworm beetle is pale lemon yellow when deposited and becomes slightly orange as it develops. It is elongate oval and very slightly arched. The cephalic end is somewhat blunter than the caudal end. The length is from 0.93 to 0.98 millimeters and the width from 0.25 to 0.27 millimeters.

In greenhouses the eggs are usually deposited on old dead leaves (fig. 4) more or less folded or curled. Although eggs have been found in such leaves on the soil, it is more than probable that they are laid before the leaf falls to the ground, since, where an infestation is heavy, eggs may be found in 50 per cent of the dead leaves still clinging to the plants. In one instance two egg masses were noticed between the petals of half-opened buds, and in two other cases egg masses were discovered inside of flattened straw in the manure mulch. Captive beetles, in glass vials closed with cork, have deposited eggs on green leaves, in crevices of the cork, and in practically any place where there were two contiguous surfaces; eggs have even been laid between the cork and the glass or on the glass when a leaf rests against it. These beetles, however, have shown a preference for dry leaves when such have been kept in the vials.

Observations on egg deposition in cages and in the greenhouse during three successive years gave a maximum of 23 eggs per mass. The data presented in Table 8 indicate that this number is exceptional, and that more of the egg masses contain 2 to 5 than 6 to 10 eggs. Although these figures are based on deposition by caged beetles, egg masses collected in the greenhouse did not vary from these results.

TABLE 8.—*Number of eggs per mass in egg masses of the strawberry rootworm beetle*

Number of—		Number of—		Number of—	
Eggs per mass	Egg masses	Eggs per mass	Egg masses	Eggs per mass	Egg masses
1	81	8	50	15	3
2	167	9	24	16	2
3	258	10	24	17	3
4	212	11	11	18	5
5	141	12	11	19	1
6	123	13	4	20	1
7	76	14	8	23	1

DEVELOPMENT

The first signs of development are noted as the ends of the egg become translucent 36 to 60 hours after deposition. Segmentation becomes indistinctly visible about the seventh day or later. The tips of the mandibles begin to show as they become chitinized about the eighth day. At this time the embryonic larva is nearly developed and within 24 hours the larva breaks the shell.

The period of incubation was usually from 7 to 18 days in length, although a few individuals hatched in 4 days and a few others not until 27 days, the length of time depending on seasonal conditions. The reasons why the records for 1921 varied from those of 1920 are unknown, and in order to check these results the incubation periods of large numbers of eggs were observed during 1922. These data are given in Tables 9 and 10.

TABLE 9.—*Variation in length of the period of incubation of eggs of the strawberry rootworm beetle during 1920 and 1922, by months*

1920

Period of incubation	Number of eggs hatched during— March and April	May	June	July	August	Total number of eggs hatched
Days						
7	0	0	0	2	0	2
8	0	0	2	6	0	8
9	0	0	4	1	0	5
10	0	1	1	0	0	2
11	0	3	0	0	0	3
12	2	5	1	0	0	8
13	6	12	0	0	0	18
14	1	2	0	0	0	3
15	0	2	0	0	0	2
Average in days	12.89	12.68	9.25	7.89	0	11.32

1922

Period of incubation	March and April	May	June	July	August	Total number of eggs hatched
4	0	0	0	6	0	6
5	0	0	0	1	0	1
6	1	0	0	7	0	8
7	1	0	158	707	99	965
8	0	0	174	58	245	477
9	0	14	389	577	166	1,146
10	2	119	393	244	137	895
11	1	52	160	327	56	596
12	6	208	115	45	17	391
13	10	34	4	49	6	103
14	8	68	64	27	0	167
15	9	74	0	0	0	83
16	40	62	0	0	0	102
17	25	54	0	0	0	79
18	35	12	0	0	0	47
19	0	13	0	0	0	13
20	2	2	0	0	0	4
21	0	1	0	0	0	1
22	0	0	0	0	0	0
23	1	0	0	0	0	1
Average in days	15.96	13.07	9.62	8.92	8.84	9.89

TABLE 10.—*Time of deposition and hatching and period of incubation of eggs of the strawberry rootworm beetle in 1921*

Date of deposition	Number of eggs— Deposited	Hatched	Date of hatching	Incubation period	Date of deposition	Number of eggs— Deposited	Hatched	Date of hatching	Incubation period
				Days					*Days*
Mar. 22	52	15	Apr. 8	17	Apr. 6	33	1	Apr. 26	20
		2	12	21	6	19	1	26	20
30	64	4	26	27	19	33	2	May 9	20
31	35	8	18	18	21	26	2	9	18
		2	21	21	21	36	4	9	18
Apr. 2	11	3	19	17					
4	65	7	26	22					
		2	27	23					

HATCHING

Observations on the hatching of two larvæ, A and B, were as follows: When first observed A was yellowish in color with a transparent head and dark brown mandibles. It had already broken or chewed one end of the shell and had freed its entire abdomen by moving backward through the opening, after which it crawled inside and began to chew and swallow small portions of the broken shell, consuming about one-fourth of it. About an hour later it turned around and chewed at the other end. After 70 minutes the head was still rather transparent but had become brownish.

When observed at 10.15 a. m., specimen B was curled up in the shell, flexed dorsally at about the division of the thorax and abdomen, and seemed to be pushing upward on the shell. No ruptures in the shell were visible at this time. The larva then straightened out and twisted itself around so that its mouth reached the place where the back had been pressing against the shell, where it had chewed an opening by 10.55 a. m. At 11.45 a. m. it again returned to its first position and was pressing with its back against the break in the shell, enlarging the opening. A wavelike motion, extending from the tip of the abdomen forward toward the head, accompanied the pushing and helped break open the shell. Following this the little larva straightened its head and thorax, keeping the abdomen in the same position as when pushing. The opening was apparently not

FIG. 8.—Strawberry rootworm. Lateral view of larva, enlarged

large enough for the head to get out. At noon the larva, by curling the end of its abdomen slightly forward, shoved itself backward until its head could be thrust out through the opening made. At this time there was no differentiation in the color of the head and the body.

LARVA STAGE[5]

The full-grown larvæ or grubs (fig. 8) are from 4 to 5 millimeters long and 1.1 to 1.4 millimeters wide. They are entirely white except for the head and the dorsal surface of the prothorax, which are pale yellowish brown. The prothoracic segment, which is firmer in structure and bears only one fold, is leathery and smooth above and a little longer than the other segments. The remaining segments are each marked with three transverse dorsal folds, which terminate on the sides in large, low elevations, pointed ovate in form (the pointed ends being upward), one to each segment of the body excepting the head, prothorax, and anal segment.

There are nine spiracles on each side of the body, the first larger than the others and located between the prothoracic and mesothoracic segments, whereas the others are placed on the abdominal segments, except the last. They are at the lower ends of the ovate elevations mentioned above. Below the row of spiracles there is a row of prominent tubercles, one to each segment, forming a longitudinal groove between this row and the elevations above the spiracles. On each ovate elevation there is just above the spiracle a small mound from the center of which arises a seta. A similar seta arises from each tubercle of the first row. Below this row of tubercles is a longitudinal fold on each segment,

[5] The description of the larva is based on that given by Forbes (*13, pp. 151–152*), with some additions and modifications.

which forms the upper side of a longitudinal groove, the lower edge of which is made up of the coxæ of the legs on the thoracic segments and a row of only slightly prominent tubercles on the abdominal segments, one on each. Each tubercle in this second row bears a bunch of from two to four setæ. A transverse ventral ridge is present on each abdominal segment and bears two groups of short spines on each side of the ventrimeson. These form two longitudinal rows along the abdomen. The medial groups are each composed of from 8 to 10 spines, except those on the last segment, which only have 4 or 5 spines, while the outer groups have from 4 to 6 spines. All the spines on the abdominal ventral ridges arise at a sharp, acute angle from the body and point backward.

The head is smooth, somewhat flattened in front, and bears a few setæ. The clypeus is transverse, trapezoidal, narrowing forward, and the labrum is rounded in front. The minute antennæ are four-jointed, the outer angle of the third joint being continued in a cylindrical process which reaches to the end of the triangular fourth joint. The maxillæ are moderately developed. The cardinal and basal pieces are not well distinguished, the maxillary lobe is armed with stout spines within, and the palpi are prominent and four-jointed The labium is thick and semicircular, with little appearance of a palpigerous tubercle. The labial palpi are slender, cylindrical, and unarticulated. The bifid mandibles are dark brown with black tips, and therefore stand out in marked contrast to the light-colored head and body.

The legs are about as long as their corresponding segments and are white, with the exception of the simple claws, which are dark brown at the tips. There are a few setæ on the legs, becoming short and spinelike toward the claws.

EARLY ACTIVITIES AND LOCATION IN THE SOIL

That the newly emerged grubs are very active and have considerable vitality was demonstrated when five larvæ were kept in a small gelatine capsule with only the dried leaf bearing the empty eggshells from which they hatched. They remained alive from three to five days.

The leaf (fig. 4) carrying the egg mass may drop or be washed to the ground by the force of the syringing water before the larvæ hatch, so that they may crawl off directly on the soil; but if the leaf is still stuck to the twigs or stakes the larvæ do not hesitate to drop off. Newly hatched larvæ have been placed on a piece of paper and their course of travel traced. Their tortuous trail was in every case made up of a series of loops, always to the right if the little larva started that way, or to the left if the first turn was to the left. One larva traveled a distance of approximately 36 inches in 63 minutes, at the end of which it was 4¼ inches in a straight line from the starting point, having crossed its path 15 times, always turning to the right. These actions probably explain why the larvæ always bore their way into the soil with a spiral motion.

Presumably the larvæ enter the ground (fig. 4) as soon as they abandon the leaf on which they hatched. Larvæ placed on the soil of beds immediately after hatching entered the ground not more than 2 inches from where they were first placed. Others put on the soil of potted plants would bore into the first crevices or openings which they encountered. Only in a very few instances were these newly hatched larvæ observed to remain on the soil surface longer than 15 minutes. Some larvæ which were dropped on soil from a height of 18 inches immediately worked their way into the ground, and 75 per cent of them were found alive three days later.

The entire larval stage is spent in the soil (fig. 4), usually close to the ball of roots of the rose plants. Oftentimes larvæ have been collected 8 to 10 inches from the main stem of a plant, and at a depth of 6 to 7 inches from the surface. Usually they are found at a depth of 2 to 3 inches, and as many as 19 specimens have been found among the roots of a single plant.

FEEDING HABITS

Although their first attention seems to be given to the smaller feeding rootlets, the larvæ also gnaw and penetrate the main roots. (Fig. 2.) They have been observed to girdle the crowns just below the soil surface, resulting in the loss at one establishment of over 100 "own-root" plants which had been set about three months previously. Older bushes can withstand more severe feeding before showing the effects. Plants in a decidedly poor condition had been growing in a bed for five years and showed many furrows in the main roots which had evidently been the source of larval nourishment. Only a few new growths were produced after "pinching" the shoots, and these were short and weak because the vitality of the plants was very low, and the foliage lacked its normal green color. These plants were used for experimental work on the soil stages and accurate counts were made of the number of larvæ and pupæ found in each. During the examination of 481 of these plants 2,991 larvæ and pupæ were found, or an average of 6.22 to a plant, the maximum being 23 specimens.

Examination made in August, 1921, of the roots and soil around 58 plants dug up at random in different sections of a greenhouse where 3,000 plants were being removed, showed that 130 larvæ and 150 pupæ were present, or an average of 4.8 specimens of the soil stages to each plant. If this condition prevailed throughout the house it would mean that there were 14,400 individuals in the soil at that time. Since egg laying is continuous throughout the spring and early summer months, the roots of these plants had probably been subjected for several months to attacks by successive large broods of larvæ.

A comparative lack of the fresh white feeding rootlets was conspicuously evident in the case of the infested plants mentioned above. Even though very few of the older plants die as a direct result of the larval attack, they become so weakened that many of them fail to withstand the rigorous treatment accorded the bushes when subjected to artificial dormant conditions. It is a cultural practice among the growers during the drying-off period to withhold water from the plants for a period of from two to four weeks or longer, after which the greater part of the growth is pruned off until only from 12 to 18 inches of the main stems are left. Moisture is again made available to the roots, and normal plants will immediately put forth new growth from the buds. Extensive injury to the root systems (fig. 2) prevents them from functioning normally and results in the loss of the more severely injured plants.

In less than three days 23 newly hatched larvæ confined in a vial with soil containing roseroots chopped in half-inch lengths have eaten the equivalent of 10 inches of roots which were approximately one-sixteenth to three thirty-seconds of an inch in diameter. In several instances where pupæ were kept in the same cage they were chewed by the larvæ. That the larvæ are able to burrow through the bed from plant to plant is indicated by the fact that when confined in pill boxes or cages with soil they pulverized the earth very thoroughly.

MOLTING

Very little is known regarding the number of molts and the time of molting. One larva which was 4 days old was seen freeing itself from the old skin. This was probably the first molt, but nothing further was noted.

DURATION OF THE LARVAL STAGE

From an examination of Table 11 it will be seen that the duration of the larval period is from 33 to 74 days. Seasonal conditions, as well as moisture and temperature, undoubtedly affect the length of this stage. In cases where the date of pupation was not noted, the duration of the larval period was calculated by deducting 8 to 11 days, the time usually required for the pupal stage, from the number of days between hatching and the emergence of the adult.

TABLE 11.—*Duration of larval and pupal stages of the strawberry rootworm, 1920, 1921, and 1922*

[Observations taken at Doylestown, Pa., except those on June 11, 12, and 14, 1922, which were taken at Washington, D. C.]

Number of individuals	Date of— Hatching	Pupation	Emergence	Duration of stages Larva	Pupa	Larva and pupa	Remarks
	1920	1920	1920	*Days*	*Days*	*Days*	
1	Mar. 24	June 4	June 16	72	12	84	
2	24	6	18	74	12	86	
2	June 3 and 4	Aug. 1	Aug. 14	58 to 59	13	71 to 72	
4	3 and 4	1 to 5	16	58 to 63	11 to 15	73 to 74	
4	3 and 4	1 to 5	18	58 to 63	13 to 17	75 to 76	
	1921	1921	1921				
1	May 2		June 29			58	Pupation not observed.
4		July 1	July 12		11		Hatching not observed.
2		2	12		10		Do.
5		7	15		8		Do.
2		Aug. 4	Aug. 15		11		Do.
2		5	14		9		Do.
	1922	1922	1922				
1		June 5	June 15		10		Do.
3	Apr. 30 to May 6		27			52 to 58	Pupation not observed.
1	30 to May 6		30			55 to 61	Do.
2	May 11	July 5		55			Died before emergence.
2	26	19	July 27	54	8	62	
1	27	15		49			Do.
1	29	15		47			Do.
1	31		July 27			57	Pupation not observed.
3	June 3		29			56	Do.
1	7	July 27	Aug. 1	50	5	55	
1	7	27	7	50	11	61	
2	23	Aug. 16		54			Died before emergence.
1	11		July 25			44	Pupal stage estimated as 8 to 11 days.
2	12		25			43	Do.
5	14		25			41	Do.

	Days
Average length of larval stage (based on 23 specimens)	58
Maximum length of larval stage	74
Minimum length of larval stage	47
Minimum length of larval stage (estimated)	33
Average length of pupal stage (based on 33 specimens)	10.9
Maximum length of pupal stage	17
Minimum length of pupal stage	5

PUPA STAGE [6]

The pupæ (fig. 9) at first are whitish throughout. The eyes are dark and the mandibles become brown about the middle of the pupation period. When the pupa is about three-fourths mature the tips of the metathoracic wings become dark gray, following which the mesothoracic wings, which develop into the elytra of the adult, become somewhat brownish owing to the development of the chitin. When first formed, with the wings still folded close to the body, the pupa is from 3.8 to 4.3 millimeters long and 1.9 to 2.1 millimeters wide. As it develops the pupa becomes somewhat shorter and a little stouter, approaching the shape of the adult. The head of the pupa is bent down slightly and the legs folded against the under side of the body, the metathoracic pair being applied against the sides of the abdomen, while the femora of the prothoracic and mesothoracic pairs project at right angles, with the tibiæ folded up close to the femora. The wing pads are wrapped around the metathoracic legs. The antennæ are held close to the body and curve under the distal part of the femora of the two anterior pairs of legs. The front of the head bears a few long setæ with bulblike bases; three transverse rows of similar hairs are present on the dorsal side of the prothorax, and the scutellum bears one on each anterior corner with a pair on either side and slightly in front. There are six on the upper side of the metathorax and a row of eight on each abdominal segment. The last segment of the abdomen terminates in two simple spines which curve dorsally. The spines are dark in color and become quite dark when the pupa is almost mature. In front of these hooklike projections are two pairs of lateral setæ, one on the last and the other on the next to the last segment, which project backward. A strong, curved hook, similar to the anal hooks, arises from the posterior inferior angle of the tibiofemoral articulation of the metathoracic legs. These curve down and in toward the body and each bears a long bristle near the point. The anterior angles of this joint bear two long setæ with inflated bases, and similar setæ arise from the anterior angles and the middle of the inferior margin of the corresponding joints of the other two pairs of legs, which do not bear spines, however. The ventral surface of the pupa bears no setæ or spines. The abdomen is slightly curved ventrally.

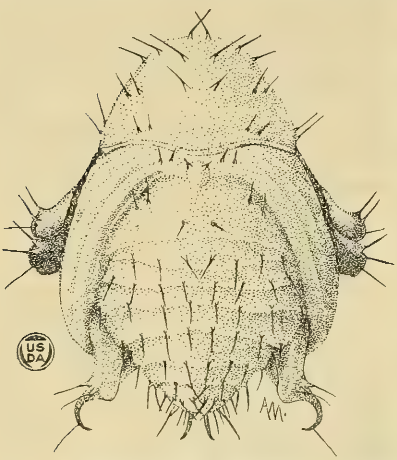


FIG. 9.—Strawberry rootworm. Dorsal view of pupa. Enlarged

PUPATION, LOCATION OF PUPA, AND LENGTH OF PUPAL PERIOD

The full-grown larvæ hollow out small earthern cells and there change to pupæ. (Fig. 4.) Most of the pupæ collected have been found within 2 inches of the soil surface, and when the cells were broken into the disturbed pupæ would move their abdomens back and forth very vigorously with a motion which apparently served the purpose of keeping the cavity hollowed out. When sifted soil is dropped on a pupa resting in one-half of its cell, the particles are swept out of this cavity by three or four movements.

The duration of the pupal stage was from 5 to 17 days, as indicated in Table 11, but from 8 to 11 days appeared to be the usual time required for this stage.

[6] The description of the pupa is based on that given by Forbes (*13, pp. 152–153*), with some additions and modifications.

SEASONAL HISTORY

There are two generations a year of the strawberry rootworm when it spends its life in greenhouses. The curious feature of its habits under greenhouse conditions is the pseudohibernation which it undergoes. The beetles which emerge in late summer and early fall—August, September, and October—pass the greater part of the winter in hiding, either in the surface mulch or in the dried leaves on the plants. During this time they are not in a true dormant state, since they occasionally come from their hiding places, particularly on warm, clear days, and feed. It is possible that this habit can be accounted for as a vestige of the natural life of the insect out of doors, where it hibernates as an adult in a true dormant condition.

Since a minimum temperature of 60° F. at night and about 80° F. during the day is maintained in rose houses during the winter, temperature conditions apparently do not account for the semidormant state of the beetles. From November until February only a few beetles are seen on the plants, but they may be located by searching in the mulch or dried leaves. In February many of the beetles come out of their hiding places and start feeding.

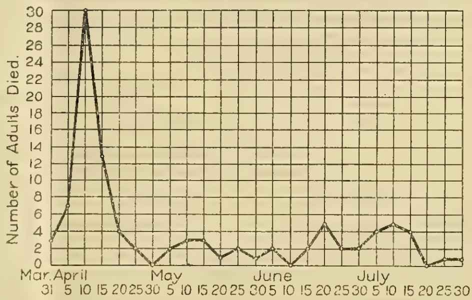


FIG. 10.—Time of death of 99 adults of the strawberry rootworm collected in greenhouses in March, 1922. Records every five days from March 26 to July 31

Very few beetles collected during March have lived until May, although a few have thrived until June and July. (Fig. 10.) Most adults collected in May and June have lived through the summer and fall months, and a few individuals have survived until December. Reference to Table 5 will show a general decrease in the number of collected adults during two general periods, April and May, and August and September.

Egg laying commences early in March, continuing through April and to a limited extent in May. From these eggs develops a new brood of adults which emerge from early May until late in July. The maximum number of beetles are found from late in June until August, which is also the period of severest injury to the plants. Many individuals of the second brood, which develops from eggs deposited by these beetles, and which emerges during September and October, live through the winter and lay eggs the following spring.

The generations are usually indistinctly separated, owing to the long period of egg deposition and the fact that a female may continue laying eggs after adults have developed from her earlier eggs. Frequently, even in severely infested greenhouses, there are periods when a comparative absence of adults may lead a grower to believe that some cultural or other method has successfully controlled the insect, but the emergence of a new brood of adults a few days later proves any decrease to have been merely seasonal. For example, on June

10 one grower believed he had rid his plants of the insects because he found only a few beetles and very little evidence of fresh feeding. Ten days later, however, large numbers of soft, light-colored adults, indicating recent emergence, were on the plants feeding voraciously. Such periods of comparative scarcity are of indefinite duration, and are more likely to occur in the intervals between broods, especially in May and June, and again in August and early September.

Eggs have not been found in greenhouses between September 1 and March 1. Soil examinations in September and October have shown only well-developed larvæ and pupæ; never any young larvæ. That the adults which emerge in the fall do not lay eggs until after the hibernating period is indicated in Table 12. It will also be seen that most of the eggs were deposited after February, even though a few were laid during December and January, owing possibly to cage conditions.

TABLE 12.—*Period of egg deposition of strawberry rootworm beetles collected from September, 1921, to January, 1922*

[Eggs were deposited by caged beetles from December, 1921, to March, 1922, although none were found in greenhouses in the same period]

Date	A 10 beetles		B 17 beetles		C 13 beetles		D 15 beetles		E 2 beetles		F 9 beetles	
	Alive	Eggs	Alive	Eggs	Alive	Eggs	Alive	Eggs	Alive	Eggs	Alive	Eggs
1921												
Aug. 31	[1] 10	0										
Sept. 12	10	0					[1] 15	0				
15	10	0	[1] 17	0			15	0				
Oct. 12	10	0	17	0	[1] 13	0	15	0				
27	9	0	9	0	11	0	14	0	[1] 2	0		
Nov. 10	6	0	7	0	9	0	14	0	1	0		
17	6	0	7	0	9	0	8	0	1	0		
23	5	0	7	0	9	0	5	0	1	0		
Dec. 5	5	0	4	1	9	0	5	0	1	0		
6	5	0	4	2	9	0	5	0	1	0		
13	5	0	4	0	9	0	3	0	1	0		
22	4	0	4	1	9	0	3	0	1	0		
24	4	0	4	27	9	0	3	0	1	0		
27	4	0	4	10	9	0	3	6	1	0		
29	4	0	3	10	9	4	3	0	1	0		
30	4	0	3	0	9	2	3	4	1	0		
31	4	0	3	0	8	0	3	0	1	0		
1922												
Jan. 3	3	0	3	0	7	3	3	10	1	0	[1] 9	0
5	2	0	3	2	6	0	3	0	1	0	9	0
Feb. 7	2	0	3	0	4	2	3	0	1	0	7	0
13	2	0	3	7	4	0	3	0	1	0	7	0
21	2	0	3	0	4	0	3	4	1	6	6	6
28	2	0	3	11	2	0	3	0	1	8	6	17
Mar 6	2	0	3	11	2	1	2	0	1	7	6	5
13	1	0	2	4	2	0	2	0	1	0	5	15
18	1	3	2	9	2	0	2	0	1	14	5	0
25	[2] 0	0	2	18	2	0	2	0	1	2	5	50
Apr. 1			1	0	2	0	[2] 0	0	1	0	3	4
8			1	0	2	0			1	0	2	26
15			1	0	2	0			1	0	2	19
24			1	0	2	4			1	0	2	15
29			[2] 0	0	2	0			1	0	2	0
May 6					2	0			1	0	2	0
13					2	5			1	0	2	0
20					1	11			1	25	[2] 0	0
27					1	0			1	0		
June 3					[2] 0	0			1	3		
10									[2] 0	0		
Total		3		113		32		24		65		157

[1] Date collected. [2] Cage closed.

NATURAL ENEMIES

Natural enemies of the strawberry leaf beetle are apparently very few in the greenhouse, since no parasites have been observed attacking any of the several stages. Among the predators, carabid beetles and their immature stages are occasionally found in the soil and will devour any adults, larvæ, or pupæ which they may encounter by chance; these insects show no preference for *Paria canella*, however, and are not plentiful enough to render any practical assistance in control. Adults of Paria are often found bearing numbers of small mites, *Uropoda* sp., on their elytra. These mites are very prevalent in manure and soil, and it is probable that they use the beetles as transporting agents, since they have also been found attached to sowbugs and millipeds. Spiders and toads will eat adult beetles coming within their reach. In one packing room a large spider which had a web close to the sorting bench immediately attacked and killed all beetles carried in on cut flowers which were placed on a knife point within its reach. In the same room a large toad was observed to devour any of the beetles which dropped to the floor. None of these creatures, however, can be considered as an important factor in controlling this insect.

EXPERIMENTS IN CONTROL

Early in the progress of these investigations the futility of attempting to control the strawberry rootworm in greenhouses by methods normally employed against leaf-feeding insects was illustrated in Dietz's report on an infestation in Indiana, as published in a paper by Weigel and Chambers (*30*, *p. 227*). The roses had been sprayed several times with a mixture consisting of 2 pounds of powdered arsenate of lead and 12 teaspoonfuls of Paris green in 50 gallons of water. This solution did not adhere well and proved ineffective against the beetles. A commercial brand of kerosene emulsion, diluted 1 part to 16 parts of water, killed the adults by contact, but burned the leaves so severely that the injury was still visible five weeks later. Volatile nicotine at the rate of 36 teaspoonfuls to 4 gallons of water stupefied but failed to kill the beetles.

In 1920 the writer investigated an infestation in Cumberland, Ind., where he found that, as a result of the failure of all poison applications, the growers had resorted to hand picking the adults, using the specially constructed pan described on page 37.

Peterson (*23*, *pp. 479–493*), of New Jersey, and Primm and Trimble, of Pennsylvania, encountered similar difficulties, and as a last resort the florists concerned turned to the laborious but certain control by hand picking, in some cases using the special-pan method. When the first control experiments were undertaken at Alexandria, Va., a serious infestation existed, and the ravages of the insects were progressing at such an alarming rate that the entire crop was threatened. Since the roses at that season of the year were being forced because of favorable weather conditions, the control program necessarily had to be in accordance with the cultural methods in order not to prove deleterious to the future growth of the plants.

SPRAYING WITH ARSENICALS

Ordinarily arsenicals used as stomach poisons are the standard remedies applied in combating such ravenous leaf feeders. For this reason preliminary tests were made with varying strengths of calcium arsenate, arsenate of lead, and Paris green. In spraying the plants at Alexandria, Va., with a pressure sprayer, special care was taken to cover all of the foliage so that it presented a whitewashed appearance which lasted many days. The arsenates of lead and calcium did not injure the rose foliage when used at the rate of from 2 to 2½ pounds to 50 gallons of water, to which one-half ounce of soap was added for each gallon of spray material, provided they were applied only on bright days; otherwise severe burning resulted. This was demonstrated in experiments conducted later at Oak Lane, Pa., where one block of 40 rose bushes sprayed at the foregoing dilution on a dark, cloudy day showed severe burning and the plants shed 50 per cent of the foliage, whereas a similar group sprayed on the following day, which was clear, suffered no injury.

Fig. 11.—Rose plant cut back at end of resting period. Many adults were found hiding in the débris on the soil. (See fig. 14)

In marked contrast with the reported control of this insect on strawberry plants by means of spraying with calcium arsenate or lead arsenate, it was found that under the conditions existing in rose houses this treatment was not only impracticable and objectionable but was actually ineffective. It was impracticable because the beetles fed at night on the young and tender growth, which was being forced so rapidly during the hot, sultry nights that it could not be sprayed frequently enough to keep the new foliage covered with the poison. Moreover, the whitish deposit which remained on the leaves after spraying was objectionable to the florists, because it reduced the market value of the cut flowers. It was ineffective in controlling the beetles because they avoided feeding on the arsenate-coated foliage but continued to devour the new leaves.

There is, however, one period in the culture of roses when the use of an arsenical as a spray has proved effective against the beetles. When the rose plants are cut back (fig. 11) practically all the foliage is removed and the fresh growth develops from new buds. The absence of foliage forces the beetles to feed on the green bark as well as on the swelling and breaking eyes or buds, which causes serious retardation of the growth. For about six weeks after the cut back, during which period no blooms are produced, the plants may be sprayed rather than dusted with arsenates to keep the foliage protected. When a solution of from 4 to 5 pounds of powdered arsenate of lead or calcium arsenate to 50 gallons of water, with soap added as a "sticker," was used to spray the stems and swelling buds the same day, so that the beetles found them covered with an arsenical, the plants in several infested rose houses passed this critical stage with almost no injury.

For several seasons one florist sprayed his plants with a Bordeaux-arsenate of lead mixture which served as a repellent in protecting them from the insects' voracious feeding at the time the plants were making their new growth after being cut back.

In the earlier experiments at Alexandria, Va., Paris green was soon rejected as a spray because no diminution in the numbers of adults was noticeable, even though the florist had been using it over the entire range of infested houses prior to tests by the Bureau of Entomology. No injury to the plants followed its application. But in Indiana its use at a greater strength failed to afford any relief from the work of the beetles. Peterson's (*23, p. 481*) observations made eight days after application indicated that Paris green at the rate of from 4 to 8 ounces to 50 gallons of water did not kill the adults in sufficient numbers to warrant its use, and that 8 ounces of Paris green to 50 gallons of water may burn rose foliage. Furthermore, it has been noticed during the last three seasons that although florists have occasionally felt certain that they had succeeded in controlling the strawberry leaf beetle by using Paris green, they have found it later continuing its ravages. From all this it is apparent that this treatment is ineffective.

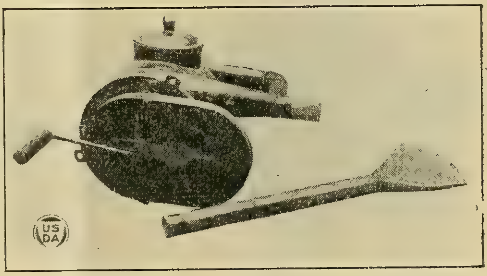


FIG. 12.—Fan type of hand duster, useful for applying insecticidal dusts in greenhouses

DUSTING WITH ARSENICALS

The deposit which remains on the leaves of rose plants after spraying with arsenicals is objectionable, because it impairs the ornamental value of the foliage. Attention was therefore directed to other means of application. A dust mixture containing 10 per cent, or preferably 15 per cent, of either lead arsenate or calcium arsenate and superfine sulphur or other carriers, applied with an improved hand duster of the fan (fig. 12) or the bellows (fig. 13) type, overcame this difficulty. The following formulas are recommended and may be purchased or mixed:

	Pounds
10 per cent formula:	
Superfine sulphur (200 mesh)	90
Lead arsenate or calcium arsenate (powdered)	10
15 per cent formula:	
Superfine sulphur (200 mesh)	85
Lead arsenate or calcium arsenate (powdered)	15

The use of this dust mixture is practical in greenhouses, because the foliage can be easily and quickly covered with the arsenical without being injured or disfigured by it, and the sulphur in it also operates against mildew and black spot. Eight pounds of the dust can be applied to 3,000 plants 2 to 3 feet tall in less than eight minutes. Because of its relatively nonsticking quality, the dust covering is washed from the foliage and must be renewed after each syringing, or about two or three times a week. By this means the new growth produced in the periods between dusting is also kept covered. From the middle of February, when the beetles begin feeding, until November, when they become inactive, the leaves must be constantly covered with an arsenical to protect them from injury.

It was not possible to determine with accuracy the effect of these dusts when applied on a commercial scale in the greenhouses, unless diminution of numbers be used as an index. The results presented in Table 13, however, indicate the effect of various mixtures on caged beetles.

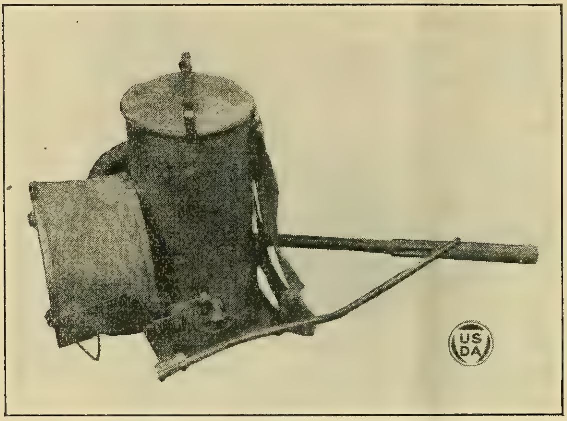


Fig. 13.—Bellows type of hand duster, useful for applying insecticidal dusts in greenhouses

The outstanding fact in the cages where arsenicals were used is the very greatly reduced amount of feeding as compared with the foliage consumed in the check cages, and this indicates a repellent action in addition to the poisonous effect when eaten in larger quantities. In some cages the arsenicals seem to affect the beetles almost immediately, whereas in others the action appeared to be prolonged over several days. The amount of feeding on leaves dusted with superfine sulphur was somewhat reduced, but did not result fatally. There was no evidence that the effectiveness of dusts would be increased by the addition of cornstarch as a possible bait. Hellebore proved valueless. Beetles which were caged with untreated rose leaves ate voraciously, while others confined without food remained alive from 7 to 15 days.

In three establishments which had suffered severe injury dusts were applied during three seasons. In two of these places the plants were treated persistently and thoroughly with a mixture of lead arsenate and sulphur (10 per cent formula) during the periods when the beetles were present in large numbers. Although many of these insects were actually removed by tearing out infested beds, by replacing the soil, by setting new plants, and by hand picking, the dusting was undoubtedly a very important factor in reducing the infestation in these establishments.

TABLE 13.—*Experiments with arsenical dusts on caged strawberry rootworm beetles*

[Five beetles were used in each experiment]

Material and strength	First day		Second day		Third day		Fourth day		Fifth day	
	Dead	Feeding punctures	Dead	Feeding punctures	Dead	Feeding punctures	Dead	Feeding punctures	Dead	Feeding punctures
Sulphur ....90 parts Arsenate of lead ....10 parts	1	10	3	8	0	3	1	0	------	------
Sulphur ....90 parts Arsenate of lead ....10 parts	0	4	0	1	1	5	0	3	1	0
Sulphur ....90 parts Arsenate of lead ....10 parts	0	9	0	9	0	0	0	0	1	0
Sulphur ....80 parts Arsenate of lead ....20 parts	0	9	1	12	2	1	0	2	2	0
Sulphur ....80 parts Arsenate of lead ....20 parts	5	1	------	------	------	------	------	------	------	------
Sulphur ....80 parts Arsenate of lead ....20 parts	0	0	1	1	0	3	0	0	3	1
Sulphur ....80 parts Arsenate of lead ....10 parts Bordeaux, dry ....10 parts	0	11	3	0	------	------	------	------	------	------
Sulphur ....50 parts Arsenate of lead ....10 parts Kaolin ....40 parts	0	0	0	6	2	3	0	0	3	1
Sulphur ....80 parts Arsenate of lead ....15 parts Powdered sugar ....5 parts	0	1	0	3	0	0	0	0	0	0
Arsenate of lead, pure	3	4	2	2	------	------	------	------	------	------
Sulphur ....90 parts Calcium arsenate ....10 parts	1	3	3	0	1	0	------	------	------	------
Sulphur ....90 parts Calcium arsenate ....10 parts	0	1	0	6	0	5	0	0	4	3
Sulphur ....80 parts Calcium arsenate ....20 parts	0	2	1	1	2	0	1	0	1	0
Sulphur ....80 parts Calcium arsenate ....20 parts	0	1	0	0	3	2	0	0	2	1
Calcium arsenate ....2 pounds Water ....50 gallons	1	3	3	3	0	0	1	0	------	------
Sulphur ....50 parts Calcium arsenate ....10 parts Kaolin ....40 parts	0	1	0	2	1	1	0	0	2	1
Sulphur ....72 parts Arsenate of lead ....18 parts Cornstarch ....10 parts	0	3	0	3	0	5	0	0	0	0
Sulphur ....81 parts Arsenate of lead ....9 parts Cornstarch ....10 parts	0	3	0	3	0	2	0	0	------	------
Hellebore, dry	0	24	0	20	0	6	0	7	0	0
Sulphur, pure	0	18	0	13	0	8	1	4	(1)	(1)
Check (untreated leaf)	0	52	0	36	0	26	0	15	(1)	(1)
Do	0	0	0	65	0	50	0	0	0	91
Do	0	0	0	0	0	25	1	19	0	0
Check (no food, 14 beetles)	0	------	0	------	0	------	0	------	0	------

[1] No data.

TABLE 13.—*Experiments with arsenical dusts on caged strawberry rootworm beetles*—Continued

Material and strength	Sixth day		Seventh day		Total		Control	Remarks
	Dead	Feeding punctures	Dead	Feeding punctures	Dead	Feeding punctures		
							Per cent	
Sulphur 90 parts; Arsenate of lead 10 parts	-----	-------	------	-------	5	21	100	
Sulphur 90 parts; Arsenate of lead 10 parts	0	0	2	0	4	13	80	1 alive.
Sulphur 90 parts; Arsenate of lead 10 parts	0	0	2	0	3	18	60	1 dead on eighth day, 1 dead on ninth day.
Sulphur 80 parts; Arsenate of lead 20 parts	-----	-------	------	-------	5	24	100	
Sulphur 80 parts; Arsenate of lead 20 parts	-----	-------	------	-------	5	1	100	
Sulphur 80 parts; Arsenate of lead 20 parts	1	0	------	-------	5	5	100	
Sulphur 80 parts; Arsenate of lead 10 parts; Bordeaux, dry 10 parts	-----	-------	------	-------	3	11	60	2 escaped.
Sulphur 50 parts; Arsenate of lead 10 parts; Kaolin 40 parts	-----	-------	------	-------	5	10	100	
Sulphur 80 parts; Arsenate of lead 15 parts; Powdered sugar 5 parts	0	6	0	1	0	11	0	1 died on eleventh day.
Arsenate of lead, pure	-----	-------	------	-------	5	6	100	
Sulphur 90 parts; Calcium arsenate 10 parts	-----	-------	------	-------	5	3	100	
Sulphur 90 parts; Calcium arsenate 10 parts	1	0	------	-------	5	15	100	
Sulphur 80 parts; Calcium arsenate 20 parts	-----	-------	------	-------	5	3	100	
Sulphur 80 parts; Calcium arsenate 20 parts	-----	-------	------	-------	5	4	100	
Calcium arsenate 2 pounds; Water 50 gallons	-----	-------	------	-------	5	6	100	Solution sprayed.
Sulphur 50 parts; Calcium arsenate 10 parts; Kaolin 40 parts	2	0	------	-------	5	5	100	
Sulphur 72 parts; Arsenate of lead 18 parts; Cornstarch 10 parts	0	5	------	-------	0	16	0	3 died on eleventh day.
Sulphur 81 parts; Arsenate of lead 9 parts; Cornstarch 10 parts	-----	-------	------	-------	0	8	0	1 died on eleventh day.
Hellebore, dry	0	0	------	-------	0	57	0	Fresh untreated leaf given on sixth day.
Sulphur, pure	(1)	(1)	(1)	(1)	1	43	20	
Check (untreated leaf)	(1)	(1)	(1)	(1)	0	129	0	
Do	0	36	0	27	0	269	0	New leaf given on fifth day.
Do	(1)	(1)	(1)	(1)	1	44	20	
Check (no food, 14 beetles)	0	-------	2	-------	2	0	40	All dead on fifteenth day.

[1] No data.

In the third establishment dusting was practiced to only a limited extent during 1920. In 1921 a heavy infestation existed and dusting was employed as one of several methods of controlling the beetles. After the plants had started new growth following the cut-back period (fig. 14), they were kept continually dusted until the middle of November, at which time very few beetles were to be found, and it was supposed that they were in their usual inactive state for the winter. For the first month the sulphur-arsenate of lead (10 per cent) mixture previously mentioned was applied, and after that the following dust mixture was used:

	Pounds
Superfine sulphur (200 mesh)	80
Calcium arsenate	15
Powdered sugar	5

The powdered sugar was added in the hope that it might prove attractive as a bait, and the arsenical content was increased on the theory that it would be more effective than the 10 per cent mixture. The dust was applied in accordance with the florists' program, i. e., after each syringing, or about two or three times weekly, so that from midsummer until November about 1,500 pounds of this material were used in keeping the foliage covered. During 1922 the insects failed to appear in appreciable numbers, and this infestation was found to be so very materially diminished that it became practically negligible. As a precautionary measure, however, a dust coating was maintained on the foliage from February 15 until the plants were cut back or torn out in the summer. As was the case in the first two establishments, other control measures were employed also, and reliance was not placed on dusting alone in combating the beetles.

Fig. 14.—Growth made by plant four weeks after being cut back. (See fig. 11)

It was unfortunate that the effectiveness of dusts alone, uncomplicated by other simultaneous methods of control, could not have been tested in a commercial range; but the fact that dusting with arsenicals was the principal control measure common to all three establishments, with the possible exception of a limited amount of hand picking, indicated that this treatment was an important factor in reducing these infestations. The florists who used this dust felt well satisfied with the results obtained from an insecticidal view-point, and because of the fungicidal value of the sulphur in the mixture.

FUMIGATION

The use of one of the standard fumigants, such as hydrocyanic-acid gas and volatile nicotine, which are frequently employed in greenhouse fumigation (fig. 15), was given consideration early in this investigation. According to several florists the use of volatile nicotine painted on pipes was entirely ineffective against the beetles (*25, p. 70*), and subsequent experiments verified this conclusion. In the case of hydrocyanic-acid gas it was necessary to determine the killing strength for the beetles and then to test the advisability of using such measures on young and tender growth. For this purpose preliminary experiments were carried out, in which from one-fourth ounce to 2 ounces of sodium cyanide per 1,000 cubic feet of space was used. The results demonstrated that the adults could be killed by fumigation at night with a 1½ to 2-ounce dosage of the sodium cyanide[7] and an exposure lasting two hours.

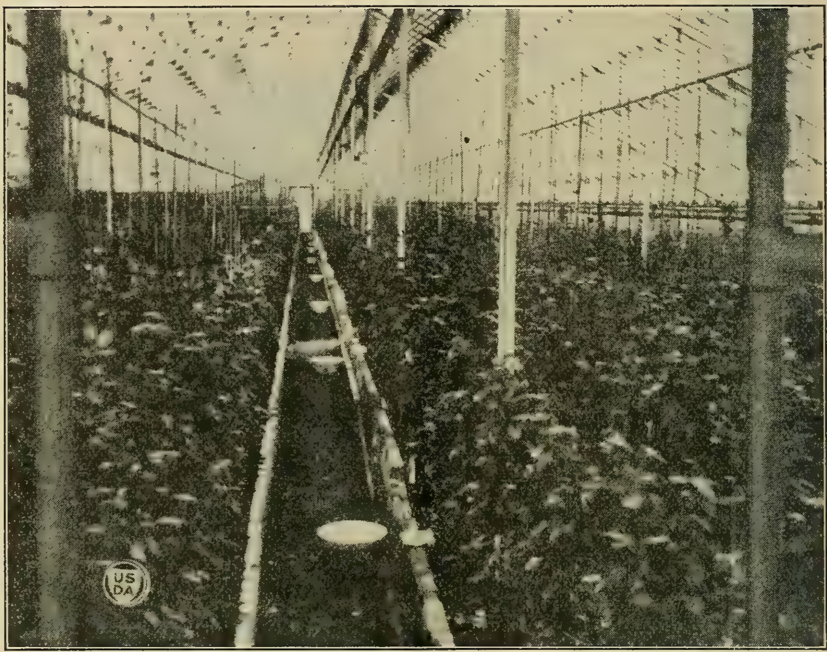


FIG. 15.—Greenhouse prepared for fumigation with hydrocyanic-acid gas

After the first commercial test in which a killing dosage was used, an examination of the fumigated houses at 8.30 o'clock the next morning showed the following results: Large numbers of the beetles were found exposed on the surface of the foliage, lying on their backs and sides. Many were killed in the act of feeding, while others could be found lying on the surface of the soil and under-

[7] A 1–1½–3 formula was used, which required 1½ fluid ounces of sulphuric acid (about 1.84 sp. gr.), 3 fluid ounces of water, and 1 ounce of sodium cyanide (containing approximately 51 per cent cyanogen) for each 1,000 cubic feet of space in the house. This was a slight divergence from the 1–1½–2 formula, and it was adopted in order to insure a more complete generation and equal distribution of the gas by providing a sufficient amount of dilute acid to submerge the cyanide, particularly in cases where only small quantities of the chemicals were being used in each generator. The quantities of materials used at the respective rates of 1½ and 2 ounces of sodium cyanide per 1,000 cubic feet were as follows:

Sodium cyanide	1½ ounces.
Sulphuric acid	2¼ fluid ounces.
Water	4½ fluid ounces.
Sodium cyanide	2 ounces.
Sulphuric acid	3 fluid ounces.
Water	6 fluid ounces.

Further directions for the use of this gas are contained in Farmers' Bulletin 880, entitled "Fumigation of Ornamental Greenhouse Plants with Hydrocyanic-Acid Gas," which may be obtained by applying to the Office of Publications, U. S. Department of Agriculture.

neath the plants. Because of the fact that the adults showed a marked tendency to feign death, 317 were collected and held in cages several days for further observations. Less than 3 per cent of these revived, and a total mortality of 97 per cent was therefore obtained from this fumigation. It is advisable to emphasize the fact that although fumigation at this strength and duration is contrary to the general recommendations for fumigating greenhouses, it is an effective though very drastic means of checking the ravages of the beetles in severe infestations. Moreover, by destroying the females at this time further egg laying is precluded and subsequent infestation thereby reduced.

As had been anticipated, some of the young and tender growth was burned, thus depriving the few remaining adults of their favorite feeding places. This injury, however, was only temporary, for three weeks later the plants had produced an abundance of newly forced growth, attributed to the stimulating effect which usually follows fumigation with hydrocyanic-acid gas, and were in excellent condition. During the subsequent months these plants produced a bountiful crop of cut flowers in comparison with the very inferior production prior to the fumigation.

In one establishment during the summer of 1921 approximately 32,000 plants, including 1,000 newly set young plants in the resting or drying-off period, were fumigated at a dosage of 2 ounces of sodium cyanide per 1,000 cubic feet of space, with an exposure lasting one and one-half to two hours, at temperatures ranging from 66 to 88° F., and not one plant was lost or even retarded in general growth (*31*, *p. 230*). The anticipated burning on the tender growth proved to be a negligible factor, since it was removed by the severe pruning when the plants were cut back. The results of the experiments, together with similar ones carried on at Alexandria, Va., and Baltimore, Md., are given in detail in Table 14. As will be observed, several houses received three or four successive fumigations. Moreover, these tests demonstrated on a practical scale that muslin curtains (fig. 16) could be used successfully to confine the gas in any section of an open-range house.

During the last three seasons 21 commercial houses, involving many thousands of plants, have been fumigated with consistent results, demonstrating the successful use of this gas on a practical and commercial scale for controlling the adult beetles.

Since a series of three or more successive fumigations with hydrocyanic-acid gas at night, at the rate of 1½ or 2 ounces of sodium cyanide per 1,000 cubic feet of space, with an exposure lasting two hours, at intervals of three or four days during the drying-off period, and with the final fumigation the night before the plants are cut back, kills all adults above the ground without permanent injury to the plants, fits in with the cultural practice in the summer when the beetles are most numerous, and may be applied in individual sections of open-range houses by separating them with muslin curtains, canvas, or oiled paper to confine the gas, it is without doubt one of the most effective and satisfactory means of destroying the beetles.

TABLE 14.—*Effects on strawberry rootworm beetles and rose plants of fumigating infested rose houses with hydrocyanic-acid gas*

Date	Contents of house	Number of plants	Sodium cyanide per 1,000 cubic feet	Exposure	Temperatures Inside	Temperatures Outside	Relative humidity	Control [1]	Effect on plants	Remarks
1919	*Cubic feet*		*Ounces*	*Hours*	*° F.*	*° F.*	*Per cent*	*Per cent*		
July 30	146,000		½	2	78		85	0	No burning	Ineffective.
31	146,315		2	2				97	Young growth burned	
Aug. 1	78,412		2	2	77		91	97	do	
1	114,061		1½	2	75		92	97	do	
1920										
June 2	146,000		2	14				100	All foliage burned	Roots washed, plants cut back and used in other houses. Very healthy and thriving.
1921										
July 8	34,612	2,500	2	1¾	85	80		97	Young growth burned	2 successive fumigations.
15	[2] 34,612	2,500	1½	1¾	78	76		97	do	
11	47,449	3,600	2	2	76	75		97	do	3 successive fumigations.
12	47,449	3,600	2	2	75	72		97	do	
15	[2] 47,449	3,600	1½	1¾	78	76		97	do	
11	30,408	3,000	2	1¾	75	75		97	do	4 successive fumigations.
18	[2] 30,408	3,000	2	1½	76	75		97	do	
20	[2] 30,408	3,000	2	1¾	72	72		97	do	
29	[2] 30,408	3,000	2	2	73	71		97	do	
18	108,536	7,300	2	1½	76	75		97	Young plants slightly injured	Injury offset by stimulation in new growth.
20	108,536	7,300	2	1¾	72	72		97	do	Do.
21	[2] 33,299	2,800	1¾	1¾	71	70		97	Young growth burned	
27	[2] 79,488	6,400	2	2	84	83		97	do	
Aug. 2	[2] 59,823	4,100	2	2	66	62		97	do	
8	[2] 19,844	1,500	2	10	69	68		97	do	
1922										
July 28	188,100		1½	1	81		91	97	do	

[1] The figures on which the percentages of control are based are omitted in this table, the main purpose of the table being to demonstrate that the injury to the plants by the gas was only temporary and that they soon recovered.
[2] Muslin curtains used to separate house to be fumigated from others.

HAND PICKING

Many florists, failing to control the beetles with sprays, fumigants, or traditional "cures," had recourse to hand picking as a last resort, thus assuring themselves of the positive removal from consideration of all beetles collected and killed. In some establishments the workers merely collected the beetles visible on the plants, sometimes using ordinary pans. Others devised more thorough methods, such as beating the plants with a stick in order to jar the beetles into a pan held between the crossrows. For this purpose they used a special pan about 3 feet deep, wide enough to span the bench, and which had the lower ends rounded to reach underneath the plants. Oil was kept in the bottom of the pans to kill the beetles coming in

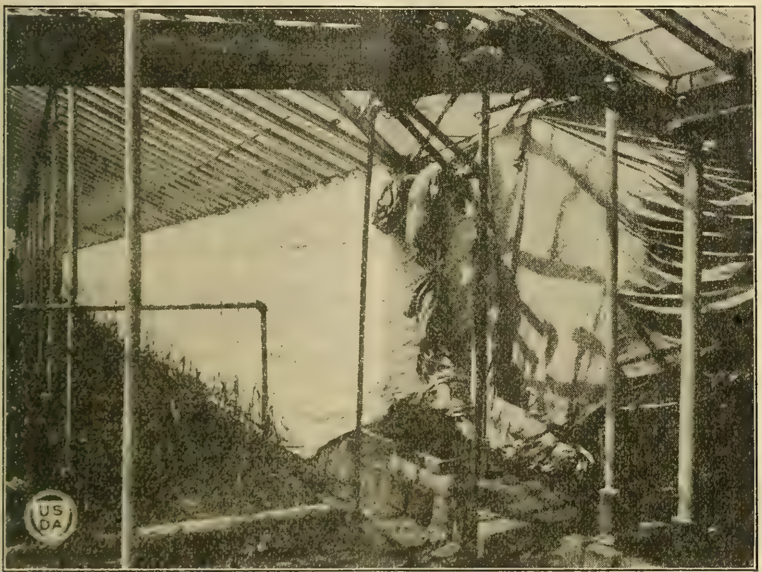


FIG. 16.—Muslin curtains used to separate sections of an open range of greenhouses during fumigation with hydrocyanic-acid gas

contact with it. Paddles covered with sticky fly paper served a similar purpose.

These methods were very effective, particularly when the beetles were gathered on the "bleeding" ends of the cut-back plants (fig. 11), where they were plainly visible. In one greenhouse where the plants had been cut back in April over 1,000 beetles were collected on 3,000 plants, even though they were not very numerous because the new brood had not yet begun to appear.

In another place, where no other control measures were practiced, the workmen took advantage of the adults' habit of climbing the wire supports after the plants had been syringed, by spending an hour after this operation each day in collecting and killing the beetles. Large numbers were thus disposed of. This method was followed diligently day after day throughout September and October of 1921, when many adults were present. Cleanliness was also practiced by keeping the beds free from dried leaves and applying no mulch. In the spring of 1922, despite a continued and careful search, only a few scattered beetles were found and the greenhouse was practically free from infestation. Undoubtedly the constant hand picking had resulted in a great decrease in the numbers of beetles of the overwintering brood.

In one instance a modification of the hand-picking method was advised, which resulted in a greater efficiency because of the greatly reduced labor required. It is customary among rose growers to water the plants so heavily every three or four days that the water collects in puddles or pools on the surface of the bed, from which it gradually drains off. Where heavy infestations exist the beetles are dislodged and thrown to the ground during the syringing and watering, and on landing in the water they make vigorous efforts to reach the nearest plant or other object on which to make their escape. Various growers took advantage of this habit by haying the gardeners follow the man who watered the plants to collect all floating or swimming beetles possible. In a very short time as many as 1,000 beetles were gathered from three beds of roses.

Although this method of warfare is crude and only partially effective, it appealed to the florists, and for this reason efforts were directed toward improving the practice by "filming" the surface of the flood water with a contact insecticide, such as kerosene nicotine oleate.[8]

Spraying the insects on the plants with the same solution proved ineffective, because of their hard wing covers and body. The success of this treatment therefore depended on the beetles swimming through the poison so that it came in direct contact with the softer body parts under the wing covers. Preliminary tests were made with one-half pint of kerosene nicotine oleate stock solution diluted with 4 gallons of water. This solution was applied over about 6 square feet of surface by means of a sprinkling can, and the results were promising. Applied in this manner the insecticide was greatly diluted by filming and spreading over the water surface; nevertheless its effect on the beetles was apparent almost immediately after they came in contact with it.

Fourteen beetles were collected and held for observation. Seven of them had been subjected to this treatment, whereas the others had merely been washed from the plants by the force of the water. Two days later the treated specimens were dead and the "checks" were still alive. Three days after the preliminary test 7,000 plants in one large range were treated. Specimens of the treated beetles kept

[8] Kerosene nicotine oleate stock solution is prepared as follows and is a slight modification of William Moore's original formula.

Stock solution:

Solution 1—	
Kerosene	8 parts or 1 gallon.
Oleic acid	1 part or 1 pint.
Solution 2—	
Volatile nicotine	2 parts or 2 pints.
Water	8 parts or 1 gallon.

Solution 1 is prepared by slowly pouring the oleic acid into the kerosene, stirring constantly. In another vessel solution 2 is made up by adding the volatile nicotine to the water. The stock solution is then prepared by stirring solution 1 into solution 2 and bringing the mixture to a creamy consistency by churning it rapidly for several minutes, pouring from one vessel to the other, or pumping the liquid back upon itself through a bucket pump.

under observation succumbed shortly thereafter, thus corroborating the earlier results. Other extensive tests were tried on a total of about 20,000 bushes with the same degree of effectiveness.

This treatment therefore finds convenient application, especially when the new growth has started after the resting period, and in the fall when it would be inadvisable to employ other remedies, such as fumigation or spraying. Furthermore, every adult killed then would mean so many less the following spring.

SCRAPING THE SOIL OF BEDS

It is a cultural practice among rose growers to scrape off 1 or 2 inches of the loose, dry surface soil from the beds during the drying-off period immediately after the plants have been cut back. The soil is then thoroughly soaked with water, bone meal is applied as a fertilizer, and a mixture of well-rotted manure and composted soil is used to replace the removed layer. Certain modifications of this method, such as making deep furrows between crossrows of plants and filling them with manure, are also used.

Examination of the material removed from infested beds disclosed 30 adults in the soil surrounding 6 plants, and in another place 14 were found near 3 plants. Their prevalence at this time suggests a practical means of destroying many beetles by shaking the plants and by removing the soil from the house and treating it as soon as the plants have been cut back. Unless this is done at once, however, the beetles will severely injure the plants by devouring the buds and girdling the stems.

CLEAN CULTURE

In a certain establishment already discussed under hand picking it was customary to keep the beds immaculately clean and to apply liquid manure instead of a mulch to the soil. At all times the beds were kept free from dead leaves and débris by the workmen, who removed them at frequent intervals and burned them. These beds had the appearance of having been swept with a broom. Undoubtedly this practice contributed much toward reducing the infestation, not only by removing many beetles and preventing the remainder from hiding in the dead leaves over winter but also by decreasing proportionately the amount of egg deposition in the spring. Moreover, it prevented many newly hatched larvæ from reaching the soil. From February until September the leaves should be removed every 10 days in order to destroy the eggs in them. In heavy infestations it is desirable to fertilize the beds with liquid manure instead of mulching.

SOIL TREATMENT

Since the larva and pupa stages, requiring about six to eight weeks for their development, are spent in the soil, they appeared to furnish a period when the insects would be susceptible to control by means of soil treatments. During the first season efforts were therefore directed primarily toward finding some soil application, either an insecticide or a fertilizer, which would operate against these stages and hence prevent the emergence of the adults. With this object in mind the following materials were tested during the season of 1920 by E. L. Chambers:

(1) Carbon disulphide: 5 to 25 cubic centimeters injected between bushes approximately 14 inches apart.

(2) Carbon disulphide in solution: One-fourth to one-half ounce dissolved in 4 gallons of water applied to 24 square feet.

(3) Sodium cyanide in solution: One-eighth to one-half ounce per gallon of water applied to 6 square feet.

(4) Cyanamide: One-half pound to 2 pounds to 40 square feet.

(5) Acid phosphate: 200 pounds to 1,200 square feet.

(6) Wood ashes: 200 pounds to 1,200 square feet.

(7) Tobacco dust: 200 pounds to 1,200 square feet.

(8) Hydrated lime: 200 pounds to 1,200 square feet.

These materials were applied over large areas, but no counts were made which would indicate accurately the mortality of the larvæ and pupæ resulting from their use. Although in some instances apparent diminution in number was noted, it could not be definitely associated with any particular treatments.

During 1921 in wholesale rose houses at Doylestown, Pa., a solid bed containing approximately 800 plants, which had been growing there for eight years, afforded an excellent opportunity for further experimental work. These plants were very heavily infested, and in some cases had as many as 23 larvæ and pupæ around the roots of a single plant.

Preliminary tests with various chemicals were made with potted rose plants, in the soil of which a definite number of larvæ and pupæ had been buried at their normal depth of 2 inches. The results are presented in Table 15.

Thirty-nine experiments, based on the results obtained from these preliminary tests, were then conducted in the infested beds on plots containing from 5 to 25 plants each. At approximately five-day intervals examinations of the treated and the check plants were made by digging them up and examining the roots and surrounding soil for the larvæ and pupæ. Thus observations were made on the effectiveness of the materials used as well as on the minimum time required for them to exert their insecticidal action.

The results of these experiments indicated that orthodichlorobenzene and kerosene nicotine oleate emulsion might prove satisfactory in practical tests. These materials were therefore applied in plots in the ground bed. Orthodichlorobenzene used in three plots at the respective rates of 1, 2, and 3 cubic centimeters per plant produced mortalities of 36 per cent, 26 per cent, and 52 per cent, respectively. Injury to the plants, however, was so pronounced, even before they were removed for examination, that the use of this chemical is precluded. Five plots containing 45 plants were treated with kerosene nicotine oleate emulsion in varying dilutions. This material proved unsatisfactory and was removed from further consideration, because it left the soil in a greasy and objectionable condition. Mercuric chloride used at the rate of one-half ounce dissolved in 3 gallons of water was tried in a pot experiment and on a plot of 15 plants, where it proved entirely ineffective. The use of wood ashes and tobacco dust was tested further in plot experiments and is discussed on page 43.

TABLE 15.—*Effect against the strawberry rootworm of miscellaneous treatments on larvæ and pupæ in soil of potted rose plants*

Material and amount per plant	Number of—		Period after treatment	Condition when examined							
				Larvæ				Pupæ			
	Larvæ	Pupæ		Dead	Alive	Missing	Control	Dead	Alive	Missing	Control
			Days				*P. ct.*				*P. ct.*
Borax, 1 gram in ½ pint water [1]	20	0	5	1	7	11	5	0	1	0	0
Borax, 2 grams in ½ pint water [2]	20	0	5	0	3	17	0	0	0	0	0
Orthodichlorobenzene, 3 c. c.[3]	20	10	5	20	0	0	100	10	0	0	100
Mercuric chloride (1–800), ½ pint [3]	40	5	3	0	17	23	0	0	0	5	0
Wood ashes, soil covered ½ inch deep [4]	10	0	9	0	3	5	0	0	2	0	0
Do.[5]	10	10	6	0	8	2	0	2	7	1	20
Tobacco dust, soil covered ½ inch deep [2]	10	10	6	0	3	7	0	0	1	9	0
Lye (sodium hydroxide), 1 teaspoonful in ½ pint water [5]	10	0	5	3	6	1	30	0	0	0	0
Lye (sodium hydroxide), 1 teaspoonful dry and then watered [6]	10	0	5	5	5	0	50	0	0	0	0
Nicotine sulphate, 2 drops in 225 c. c. water [2]	10	0	5	0	1	9	0	0	0	0	0
Kerosene nicotine oleate, 8 c. c. in 250 c. c. water [6]	20	10	5	12	0	8	60	5	0	5	50
Kerosene nicotine oleate, 16 c. c. in 250 c. c. water [3]	20	10	5	18	0	2	90	9	0	1	90
Checks (no treatment)	20	10	5	0	9	11	0	1	0	9	10
Do	20	7	5	0	1	19	0	0	0	7	0
Do	43	5	5	0	4	39	0	0	0	5	0
Do	9	4	5	0	6	3	0	0	2	2	0

[1] One larva pupated.
[2] Ineffective.
[3] Effective.
[4] Two larvæ pupated.
[5] Slightly effective.
[6] Fairly effective.

TABLE 16.—*Effects of paradichlorobenzene soil treatments on larvæ and pupæ of the strawberry rootworm buried in pots*

Amount of material	Number of—		Period after treatment	Condition when examined							
				Larvæ				Pupæ			
	Larvæ	Pupæ		Dead	Alive	Missing	Control	Dead	Alive	Missing	Control
Grams			*Days*				*Per cent*				*Per cent*
2	25	10	6	24	0	1	96	10	0	0	100
3	25	10	6	25	0	0	100	10	0	0	100
4	10	0	5	5	0	5	50	0	0	0	0
4	20	0	6	17	0	3	85	0	0	0	0
8	10	4	5	6	0	4	60	4	0	0	100

The results obtained with paradichlorobenzene in preliminary tests were so satisfactory (see Table 16) that this material was used in 15 plots in an infested bed. In 10 of these the larvæ and pupæ were counted and their condition was noted in order to determine the insecticidal effect of this chemical. These data are presented in Table 17.

TABLE 17.—*Results of plot experiments with paradichlorobenzene against larvæ and pupæ of the strawberry rootworm*

Dosage	Period after treatment	Number of plants	Number of larvæ and pupæ: Examined	Number of larvæ and pupæ: Dead	Control	Average control	Dosage	Period after treatment	Number of plants	Number of larvæ and pupæ: Examined	Number of larvæ and pupæ: Dead	Control	Average control
Ounce	*Days*				*Per cent*	*Per cent*	*Ounce*	*Days*				*Per cent*	*Per cent*
0.2	6	2	10	6	60.0	45.9	0.4	6	2	15	9	60.0	
0.2	10	3	27	11	40.7		0.4	7	7	35	32	91.4	88.8
0.25	5	5	69	53	76.8		0.4	9	7	20	20	100.0	
0.25	10	5	27	24	88.9	80.5	0.4	10	3	19	18	94.7	
0.25	14	5	22	18	81.8		0.5	5	3	19	16	84.2	
0.3	6	2	20	5	25.0		0.5	6	2	15	8	53.3	79.2
0.3	7	7	24	22	91.7	76.3	0.5	10	6	31	25	80.6	
0.3	9	7	25	23	92.0		0.5	13	4	12	12	100.0	
0.3	10	3	28	24	85.7		0.6	6	2	10	8	80.0	92.9
0.375	5	5	32	25	78.1		0.6	10	3	18	18	100.0	
0.375	10	5	39	35	89.7	85.2							
0.375	13	5	10	9	90.0								

To determine plant tolerance of paradichlorobenzene it was also applied to plants in five plots which were receiving the regular cultural treatment accorded roses. The crystals were placed around the base of the plant and covered with soil. At the end of 10 days to two weeks they were removed from some plants but were left around the others until vaporized. The results were not satisfactory in either case. Even in the cases where the crystals had been removed and the lowest strength—one-fourth ounce per plant—was used, the bushes gradually declined in vigor and eventually died.

SODIUM CYANIDE

Sodium cyanide in solution was tried during the season of 1920, but sufficient data on the mortality of the larvæ and pupæ were not obtained at that time. Pronounced stimulation of root growth, with a corresponding increase in terminal growth, had been observed repeatedly to result from light dosages of this material. This treatment would therefore be desirable because of its stimulating effect on the plants, provided it was also effective in killing the soil stages of this insect.

TABLE 18.—*Effects of sodium cyanide in solution on larvæ and pupæ of the strawberry rootworm in pot experiments*

Amount of sodium cyanide in one-half pint water	Number of—		Condition 5 days after treatment							
			Larvæ				Pupæ			
	Larvæ	Pupæ	Dead	Alive	Missing	Control	Dead	Alive	Missing	Control
Grams						*Per cent*				*Per cent*
0.45	20	10	17	0	3	85	8	0	2	80
0.89	20	10	17	0	3	85	6	0	4	60
1.33	20	10	18	0	2	90	10	0	0	100
1.77	20	10	20	0	0	100	9	1	0	90

As shown in Table 18, the mortality in the preliminary pot experiments was promising, hence nine plots of five or six plants each were treated with sodium cyanide in solution. Sodium cyanide was also pulverized and then spread around the base of every plant in three plots of five plants each. The mortalities resulting from these plot treatments are listed in Table 19.

TABLE 19.—*Results obtained in plot experiments with sodium cyanide, in solution and pulverized, against larvæ and pupæ of the strawberry rootworm*

Dosage	Period after treatment	Number of plants	Number of larvæ and pupæ		Control	Dosage	Period after treatment	Number of plants	Number of larvæ and pupæ		Control
			Examined	Dead					Examined	Dead	
Grams	*Days*				*Per cent*	*Grams*	*Days*				*Per cent*
0.5	4	7	57	4	7.0	2	6	3	18	9	50.0
0.5	7	4	11	1	9.1	3	2	2	24	21	87.5
0.75	4	4	28	4	14.3	3	6	3	20	13	65.0
0.75	7	4	15	3	20.0	5	2	2	25	24	96.0
0.75	8	3	17	1	5.9	5	6	3	21	11	52.4
1	4	4	35	4	11.4	2 [1]	8	5	16	4	25.0
1	8	7	57	7	12.3	3 [1]	8	5	37	26	70.3
2	2	2	19	3	15.8	5 [1]	8	5	21	20	95.2

[1] Applied in pulverized form.

In these experiments the mortality of larvæ and pupæ in soil which had been drenched with sodium cyanide was insufficient to justify its use as a means of destroying the soil stages. Moreover, the practical use of the pulverized crystals would be precluded because the collars of the plants were severely injured by this treatment.

WOOD ASHES AND TOBACCO DUST

Because of their fertilizing value, wood ashes and tobacco dust, but especially the wood ashes, are used extensively by florists. It was thought that the free lye present in wood ashes, and the nicotine, which is an ingredient of the tobacco dust, might leach into the soil and be effective in killing the larvæ and pupæ. To determine its effectiveness in three plots containing 10 plants each, a handful of this mixture was applied around the base of each plant and then watered. Examinations of the larvæ and pupæ in soil around the plants were made seven or eight days later, and the results are given in Table 20.

TABLE 20.—*Effects on strawberry rootworm larvæ and pupæ in soil treated with tobacco dust and wood ashes*

Material	Period after treatment	Number of larvæ		Control	Number of pupæ		Control	Larvæ and pupæ control
		Examined	Dead		Examined	Dead		
	Days			*Per cent*			*Per cent*	*Per cent*
Tobacco dust	7	44	4	9.1	41	9	22.0	15.3
Wood ashes	8	36	2	5.5	33	7	21.2	13.0
Tobacco dust and wood ashes mixed	7	17	2	11.8	18	2	11.1	11.4

The foregoing figures were based on only one treatment, whereas the maximum insecticidal effect could be obtained only by continuous leaching of these materials over an extended period, which would necessitate several successive applications.

In an establishment containing 40,000 rose plants two carloads of each of these materials were used during the spring of 1922. The mixture was applied on the soil several times at intervals of about two weeks. Occasional soil examinations during the season disclosed very few larvæ and pupæ. The balls of soil around the roots of 293 plants were examined and the larval and pupal stages infesting 19 of them were counted. Nine larvæ, ten pupæ, and one newly emerged adult were found, and all were alive. Several other control measures were also being practiced, however, and it is therefore a matter of conjecture whether the lightness of this infestation can be credited entirely to the use of the wood ashes and tobacco dust treatment.

Other experiments were performed to determine the effect on newly hatched larvæ of tobacco dust containing not less than one-half of 1 per cent of nicotine. A layer of this dust one-fourth inch deep was spread over the entire surface of the soil in flowerpots every two weeks. In some cases this treatment was followed by watering. All larvæ which were removed from egg cages immediately after hatching and placed on the treated surfaces died in a short time, whereas larvæ placed in a vial on untreated soil immediately showed greater activity by boring down below the surface in a lively manner.

These experiments indicate that a layer of tobacco dust on the soil from March to September, and the subsequent leaching of this material when larvæ are hatching and dropping to the ground, aids in the control of an infestation.

Since the rose plant can not tolerate heavy applications of wood ashes, it was found sufficient to use a handful per plant every two or three weeks.

PREVENTIVE MEASURES

Several preventive measures may be practiced to keep rose houses free from infestation with the strawberry rootworm. The fact has been established that some houses have become infested with the larvæ and pupæ of this insect by filling the beds with soil in which strawberry plants have been growing. In order to destroy these stages the soil should either be composted for several months or be sterilized before it is used. It is desirable to avoid using soil in which strawberry plants have recently been grown. Propagate young plants in separate houses free from the insects, and under no conditions expose them to contamination by proximity to infested beds or houses. In purchasing plants be certain that they are free from all stages of this pest, and that all precautions have been taken by the propagator to protect them. Keep the greenhouse free from rubbish and burn all dead leaves and débris removed from the beds, as well as the tops of the bushes which are removed when cut back. The importance of such precautionary measures is too frequently underestimated, and due consideration must be accorded them for preventing insects from gaining a foothold in greenhouses.

Observations have shown that plants retained in beds for three years or longer are usually the more heavily infested. By removing the plants and soil at the end of three years at the latest, the chances of severe infestation are very much reduced. A rotation should be planned and followed whereby the plants in no section will remain in the beds longer than three years. For example: If a range of several houses is divided into three separate sections—A, B, and C—all of the plants in section A should be completely torn out and replanted the first season, all those in section B the next season, and those in section C the third season. In this way the 3-year-old plants in section A would be replaced the fourth season, and so on. Several florists are now of the opinion that forcing their plants as much as possible for three years, instead of retaining them for a longer period, increases their production and more than compensates for any extra expense due to the more frequent replanting.

SUMMARY

Within the last seven years two varieties of the strawberry rootworm, *Paria canella*—*quadrinotata* and *gilvipes*—have appeared in greenhouses in the commercial rose-growing districts east of the Rocky Mountains and have done great injury to the rose plants. Although normally an outdoor pest on strawberry, raspberry, and a number of miscellaneous plants, this insect has become one of the serious enemies of roses grown under glass.

The plants are injured by the larvæ and adults. The larvæ feed on the roots and the adults eat foliage, stems, buds, and flowers.

The overwintering adults appear in February and lay eggs during a period of two or three months. The larvæ from these eggs feed on the roots for a period of from 33 to 74 days, after which they transform to pupæ. The adult beetles emerge from 8 to 17 days later. Because of the long period of egg-laying, the emergence of the adults during June and July is almost continuous. From the eggs which are laid by these beetles a second brood of adults develops and emerges during September and October. The two generations overlap to such an extent that oftentimes no distinctions can be noted.

Natural enemies of the strawberry leaf beetle are apparently few in the greenhouse, as no parasites have been observed attacking any of the stages. Among the predators may be mentioned carabid beetles, spiders, and toads. Uropod mites frequently attach themselves to adults.

Early experiments established the fact that the usual measures recommended for leaf-eating insects were practially useless in controlling the strawberry rootworm. Spraying with the arsenicals did not prove practical under ordinary conditions, but was found to be successful in protecting the swelling and breaking buds at the time the plants were cut back. Under similar conditions a Bordeaux-arsenate of lead mixture served as a repellent. In extensive trials the use of a 10 or 15 per cent dry mixture of arsenate of lead or calcium arsenate and superfine sulphur showed that dusting with these materials was a satisfactory and effective method of keeping the foliage coated with an arsenical to repel the beetles. Experiments with Paris green gave unsatisfactory results. In 21 commercial houses fumigation with hydrocyanic-acid gas during the resting

period of the plants consistently produced an average mortality of at least 95 per cent of all beetles above ground. Fumigation with vaporized nicotine did not kill the adults.

The effectiveness of hand picking the beetles, as practiced by many florists, may be counteracted by the overlapping of generations of this insect. It is therefore evident that to be successful hand picking must be done very thoroughly and persistently.

A modification of hand picking, wherein kerosene nicotine oleate was used to film the surface of the pools and puddles in heavily watered beds, killed any beetles which came in contact with the insecticide while struggling in the water.

Cleanliness was practiced persistently in one greenhouse and was of material assistance in reducing a heavy infestation. Immediately after cutting back the plants many adults in the soil and débris were destroyed by scraping and removing a layer of surface soil to a depth of about 2 inches, and then treating it to kill them.

Treatments of the soil with the following insecticides either failed to kill the larvæ and pupæ or were detrimental to the plants:

Acid phosphate.
Borax.
Carbon disulphide.
Hydrated lime.
Kerosene nicotine oleate.
Lye (sodium hydroxide).
Nicotine sulphate solution.
Orthodichlorobenzene.
Paradichlorobenzene.
Sodium cyanide solution.

Contact with tobacco dust, which was placed on the soil surface, killed newly hatched larvæ, and the leaching of tobacco dust and wood ashes also killed some larvæ and pupæ in the soil.

RECOMMENDATIONS FOR CONTROL

A successful control program entails a combination of several measures, since no single practice will suffice. In order to be effective such measures must be persistently followed and applied in such a manner that they will not conflict with the normal cultural program and conditions under which roses are grown.

During the summer months the protection of the plants from immediate as well as future injury is the paramount consideration. This may be accomplished by fumigating with hydrocyanic-acid gas during the drying-off period to kill as many adults as possible, and by scraping the surface soil from the beds when the plants are cut back, and then spraying them with lead arsenate or calcium arsenate, using 4 pounds to 50 gallons of water, to protect the swelling buds from the further depredations of the beetles.

From September to December *eradication* of the beetles should be the florists' aim, because they are still emerging and continue to feed voraciously for some time. Every effort should therefore be directed toward ridding the houses of as many of the overwintering beetles as possible in order to prevent a recurrence of an infestation the following spring. During this period dusting must be very thorough and continuous, in order that the foliage may be kept coated with the poison. Hydrocyanic-acid gas, however, can not be used at this time at a killing strength without causing severe injury to the plants. Two or more treatments by filming the surface water of the bed with kerosene nicotine oleate may then be most effectively used to kill many adults. Beginning about the middle of

February the plants must be kept coated with an arsenical dust to poison any beetles which may come out of hiding and resume feeding. The soil in the beds should be kept covered with a layer of tobacco dust until drying-off time, with additional applications of wood ashes at monthly intervals. The tobacco dust will kill any newly hatched larvæ which come in contact with it while crawling on or entering the soil, and the mixture of wood ashes and tobacco dust will operate to some extent against the larvæ and pupæ in the soil. To prevent the larvæ from entering the soil at an unprotected spot, it is important that the tobacco dust be spread over the entire surface of the soil in the bed.

Plants and soil should not be retained in the greenhouses longer than three years if the establishment of an infestation is to be prevented. In addition cleanliness, involving the removal of dead leaves and trash, must be practiced incessantly. Soil which is used in the beds should either be composted for several months or sterilized before being brought into the houses.

LITERATURE CITED

(1) Anonymous.
1920. Seek relief from new rose scourge. *In* Florists' Review, vol. 46, no. 1171, pp. 15–16, illus., May 6.

(2) Blatchley, W. S.
1910. An illustrative descriptive catalogue of the Coleoptera or beetles (exclusive of the Rhynchophora) known to occur in Indiana. (Ind. Dept. Geol. and Nat. Resources Bul. 1.) 1385 pp., illus. Indianapolis.

(3) Britton, W. E.
1922. Twenty-first report of the State entomologist for 1921, Conn. Agr. Exp. Sta. Bul. 234, pp. 111–204, illus.

(4) Clavareau, Henri.
1914. Junk's Coleopterorum catalogus, pars. 59. 215 pp. Berlin.

(5) Cook, A. J.
1881. A new insect enemy. *In* 10th Ann. Rpt. Sec. State Hort. Soc. Mich., 1880, pp. 293–295. Lansing.

(6) Cory, E. N.
1917. Insects of 1916. *In* Rpt. Md. Agr. Soc., vol. 1, for the year 1916, pp. 200–208, illus.

(7) Crotch, G. R.
1873. Materials for the study of the Phytophaga of the United States. *In* Proc. Acad. Nat. Sci. Phila., vol. 25, pp. 19–83.

(8) Dejean, P. F. M. A.
1833. Catalog des coléoptères de la collection de M. le Comte Dejean, ed. 3, 443 pp. Paris. (Same reference on p. 436 of ed. 4, 1837.)

(9) Fabricius, J. C.
1801. Systema Eleutheratorum, vol. 2. 687 pp. Kiliae.

(10) Felt, E. P.
1906. Insects affecting park and woodland trees. N. Y. State Museum Mem. 8, vol. 2, pp. 333–877, illus.

(11) Fletcher, James.
1894. Injurious fruit insects of the year 1894. *In* 25th Ann. Rpt. Ent. Soc. Ontario, 1894, pp. 76–81, illus.

(12) ———
1895. Report of the entomologist and botanist. *In* Rpt. Exp. Farms [Canada] f. 1894, pp. 183–226, illus. Ottawa.

(13) Forbes, S. A.
1884. Insects injurious to the strawberry. *In* 13th Rpt. State Ent. . . . Illinois (or 2d Ann. Rpt. of S. A. Forbes for the year 1883), pp. 60–180, illus. Springfield, Ill.

(14) Gibson, Arthur, and Ross, W. A.
1922. Insects affecting greenhouse plants. Dominion of Canada Dept. Agr. Bul. 7, n. s., 63 pp., illus.

(15) Harvey, F. L.
1896. Report of botanist and entomologist. *In* Ann. Rpt. Maine State Coll. Agr. Exp. Sta. for the year 1895, pp. 89–126, illus. Augusta.

(16) Horn, Geo. H.
1892. The Eumolpini of Boreal America. *In* Trans. Amer. Ent. Soc., vol. 19, pp. 195–234.

(17) Irish, H. C.
1921. Report of the entomologist [of the Society of American Florists]. *In* American Florist, vol. 57, p. 318.

(18) Jacoby, Martin.
1882. Biologia Centrali-Americana Insecta Coleoptera, vol. 6, pt. 1. 625 pp. London.

(19) Junge, Herman.
1921. Battling rose beetle. *In* Florists' Review, vol. 48, no. 1229, pp. 17–18, June 16.

(20) Le Conte, J. L.
1858. Description of new species of Coleoptera, chiefly collected by the United States and Mexican Boundary Commission under Maj. W. H. Emory, U. S. A. *In* Proc. Acad. Nat. Sci. Phila., vol. 10, 1858, pp. 59–89.

(21) Leng, C. W.
1920. Catalogue of the Coleoptera of America, north of Mexico. 470 pp. Mount Vernon, N. Y.

(22) Olivier, A. G.
1808. Entomologie ou Histoire Naturelle des Insectes, vol. 6, pp. 613–1104, illus. Paris.

(23) Peterson, Alvah.
1921. The strawberry rootworm, a serious pest of roses in the greenhouse. *In* 41st Ann. Rpt. N. J. State Agr. Exp. Sta., and 33d Ann. Rpt. N. J. Agr. Coll. Exp. Sta. for the year ending June 30, 1920, pp. 468–493.

(24) "Phil."
1921. Progress of the battle. *In* Florists' Review, vol. 48, no. 1235, p. 21, July 28.

(25) Sanders, J. G.
1920. Strawberry root-worm injuring greenhouse roses. *In* American Rose Annual, pp. 69–70. Harrisburg.

(26) Say, Thomas.
1823–4. Descriptions of coleopterous insects collected in the late expedition to the Rocky Mountains performed by order of Mr. Calhoun, Secretary of War, under the command of Major Long. *In* Jour. Acad. Nat. Sci. Phila., vol. 3, pp. 139–216, 238–282, 298–331, 403–462; vol. 4, pp. 83–99. *Also in his* Complete Writings on the Entomology of North America, Le Conte ed., vol. 2, pp. 89–236. New York, London, etc., 1859.

(27) Swenk, M. H.
1909. The principal insects injurious to horticulture during 1908–09. *In* 40th Ann. Rpt. Nebr. State Hort. Soc., pp. 75–128, illus.

(28) Webster, F. M.
1893. Insects affecting the blackberry and raspberry. Ohio Agr. Exp. Sta. Bul. 45, pp. 151–217, illus.

(29) Weigel, C. A.
1920. A serious menace to greenhouse roses. *In* American Rose Annual, pp. 66–69, illus. Harrisburg.

(30) Weigel, C. A., and Chambers, E. L.
1920. The strawberry root-worm injuring roses in greenhouses. *In* Jour. Econ. Ent., vol. 13, pp. 226–231.

(31) Weigel, C. A., and Doucette, C. F.
1922. Further observations on the strawberry root worm on roses. *In* Jour. Econ. Ent., vol. 15, pp. 204–209.

(32) ——— ———
1923. Control of the strawberry rootworm in commercial rosehouses. *In* Jour. Econ. Ent., vol. 16, pp. 283–288.

O

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1359

Washington, D. C. ▼ October, 1925

FOOD OF AMERICAN PHALAROPES, AVOCETS, AND STILTS [1]

By Alexander Wetmore, *Assistant Secretary, Smithsonian Institution,* formerly *Assistant Biologist, Division of Food Habits Research, Bureau of Biological Survey* [2]

CONTENTS

GENERAL DESCRIPTION

The five species of shorebirds of which the economic status is discussed in the following pages are forms that have become specialized for life under certain conditions, and on the whole are not of common occurrence, save in the particular marshes or on the large bodies of fresh or salt water which form their haunts. They are thus unknown to many persons familiar with bird life in more thickly populated districts. All are at present fully protected by law and because of their commendable food habits there can be no question of the inadvisability of any attempt to establish an open season for any of them. The phalaropes—small, close-feathered, snipelike birds that swim on the water like tiny ducks—are too slight in body to be killed for their flesh; avocets and stilts, though larger, do not produce meat of a quality suitable for table use. All these birds are tame and fearless, so that there is little sport in hunting them. In addition to possessing habits of the greatest interest, it is found that the phalaropes, avocets, and stilts have a certain economic importance.

The family of phalaropes includes three species, all of which occur within the United States. The northern and red phalaropes are practically world-wide in their distribution, but the Wilson phalarope is restricted to the Western Hemisphere. The two cosmopolitan species are boreal in occurrence during the breeding season and do not often come in close contact with man, except in migration. The northern phalarope, a species that in point of size ranks among our

[1] This bulletin presents a detailed study of the food and feeding habits of the phalaropes, avocets, and stilts that occur in the United States, showing the economic status of the five species, for the information of conservationists, sportsmen, and others interested in our shorebirds.

[2] This report was prepared while the author was on the staff of the Biological Survey from which he resigned on November 19, 1924.

32519—25†——1

smallest shorebirds, is of importance economically in that it destroys many of the larval forms of mosquitoes, thus aiding in keeping these pests in check. The red phalarope within our limits is most abundant on the oceans off our shores and so does not often come in direct contact with injurious insects. The Wilson phalarope is the one most frequently found near cultivated districts and is perhaps better known than the other two. It does considerable good in destroying mosquitoes and also consumes many of the larvæ of horseflies. Adult horseflies are often the greatest of pests in districts adjoining marshes. No injurious traits are recorded against any of the three phalaropes; their food, save as indicated, consists of insects, crustaceans, or other animals which are of neutral economic significance.

The stilt may be commended for its evident taste for billbugs and other weevils, as well as crawfish and giant water bugs, all of which are destructive. Though it may eat a few small fishes, the forms taken are not of value for human food. The avocet shares with the stilt a taste for weevils, including forms that are injurious. It takes much more vegetable food than any of the other birds treated in this bulletin. Like the phalaropes, the stilt and the avocet have no marked injurious traits.

Because of their specialized habits, the Wilson phalarope, the avocet, and the stilt have suffered a considerable reduction in numbers from man's encroachment upon their haunts. The draining of swamps and marshes has decreased the areas available to them as breeding and feeding grounds, and many have been destroyed by gunners. With the well-merited protection accorded them at present, these birds may be expected to hold their own or even to increase wherever they meet especially favorable conditions; it is even possible that they may repopulate some of the areas from which they have been absent for many years.

RED PHALAROPE

Phalaropus fulicarius

The red phalarope, circumpolar in distribution during the summer season, in the Western Hemisphere breeds from northern Alaska and northern Ellesmere Land south to the mouth of the Yukon and southern Greenland. The winter range can not be traced with any degree of certainty, but at this season the birds are known to pass south well over the southern half of the globe. Except during the breeding season, the red phalarope is maritime in range, though stragglers are taken casually in the interior. The writer has examined in the flesh one collected in eastern Kansas, and others are recorded from Colorado, Illinois, and Maryland.

During migration, flocks of red phalaropes occasionally come to brackish lagoons or fresh-water ponds near the seashore, or run along sand beaches in company with other shorebirds. More usual haunts are broad salt-water bays or the open ocean, so that the present species is less commonly observed than the other phalaropes. Ocean expanses have no terrors for the red phalarope, and at times flocks are found several hundred miles from shore. In the breeding plumage the red phalarope is handsomely marked with dull cinnamon-brown beneath, whereas in winter the plumage of the lower parts is pure white. In the latter condition care must be taken not to confuse it with the northern phalarope.

FOOD

The material at hand representing the food of the red phalarope, 36 stomachs in all, is in the main from the Pribilof Islands, Alaska, though some comes from New York and Maine. The stomachs available were collected from May to November, with August best represented. The red phalarope is active in feeding, seizing living prey on the surface of the water, or searching for food along the beaches. The food may be considered to be entirely animal, as a seed or two encountered in two stomachs make a mere trace of vegetable matter.

Crustacea.—Crustaceans, the group best represented among the animals eaten, constitute 33.5 per cent of the total food. Among these, amphipods (8.9 per cent) were identified in 14 stomachs. In one case the remains were those of *Carinogammarus mucronatus* and in another *Hyallela knickerbockeri.* The peculiar seedlike winter eggs of certain water-fleas (Daphniidæ) were encountered three times. Miscellaneous unidentified crustaceans composed the remainder of this part of the food. It is probable that the bulk of these fragmentary individuals consisted of amphipods also.

Coleoptera.—Beetles amount to 27.3 per cent and are well represented in birds taken in Alaska. Ground beetles belonging to a genus that is very common in the Pribilof Islands (*Pterostichus*), were taken six times. A representative of another genus (*Amara*) was encountered once. Rove beetles (in one instance *Olophrum fuscum* and in another *Hadrotes*) were found four times in all. A peculiar beetle (*Eurystethus californicus*) of small size, and for many years known in museums from only one or two specimens, was found in two instances. Weevils were encountered twice, crawling water-beetles (Haliplidæ) once, and the larval stage of another beetle once.

Diptera.—Following beetles, the flies (22.7 per cent), are the order of insects eaten most frequently. A group of dung flies (including *Scatophaga crinita*, *S. dasythrix*, and allied species) abundant in the North was best represented, as it was encountered in 14 stomachs. Gnats (Chironomidæ) were identified twice and their larvæ once. A larval soldier fly (stratiomyid) was eaten by one bird and a crane fly (tipulid) by another. Larvæ and pupæ of dipterans that were not identified were found in eight instances.

Pisces.—Tiny fishes had been eaten by 15 of the birds examined. In one case the fragments remaining were indeterminate, but in the others all fish remains were sculpins (Cottidæ), species of no economic value. These totaled 6.8 per cent, and were eaten in August and September.

Miscellaneous.—The remaining part of the food (9.7 per cent) was composed of miscellaneous animals picked up apparently at random. Ants, water-boatmen (Corixidæ), and spiders, were each taken by one bird. One phalarope had eaten a very small mussel (*Mytilus edulis*) and a second mollusk was found in another. The former, although used as human food, is so small an item in the diet of this bird as to have no importance. A tiny ball of hair completed the miscellaneous animal matter.

SUMMARY

The red phalarope exhibits no marked economic tendencies, as its food is composed of forms that are more or less neutral. The ground beetles taken are in all probability scavengers and are not active in the control of injurious insects. The flies are not known to be of economic importance. and the crustaceans have value merely as food for other animals. From this review it may be seen that the red phalarope is entirely harmless and should be protected when it chances to occur within our boundaries.

NORTHERN PHALAROPE

Lobipes lobatus

Like the preceding species, the northern phalarope (Pl. I) nests in the Northern Hemisphere in both Old and New Worlds. In North America the breeding range extends from the Near Islands in the Aleutian Chain across to eastern Greenland, and from Melville Island south to the delta of the Yukon and to Rupert House, Ontario. The place and extent of the winter home of the northern phalarope at present is uncertain, though it is supposed that at this season the birds remain at sea in the Southern Hemisphere. They have been noted casually on the coasts of Patagonia and Peru, but on the whole are unknown after they leave our shores. In migration they occur casually throughout our country save in the States bordering the Gulf of Mexico, but are more abundant near the eastern and western coasts, and great numbers pass through the interior by way of Great Salt Lake, Utah.

In migration these phalaropes often gather in great flocks where food is abundant. On reaching their breeding grounds in the north, they pair off to nest in marshy spots or near small fresh-water lakes in the tundras. On Kiska Island in the Aleutians in June, the writer found them breeding about innumerable shallow lakes in the small valleys that lead back from the beaches of the deeper bays. The eggs, four in number, were placed in shallow nests concealed in grass 8 or 10 inches high. Adults were greatly excited by intruders and flew swiftly about calling sharply. Many fed in the surf, often riding the waves until these were about to break, when to avoid being dashed on the sand they rose lightly in the air and flew out a few feet to a point of safety. Both sexes go through curious gyrations on the water surface, whirling rapidly about and nodding the head.

Domestic cares after the eggs have been deposited devolve entirely upon the willing males, and many of the females depart southward at once, to be followed by males and young when the latter are able to fly. The northward migration in Utah does not end until the middle of June, and by the first week in July females begin to return from the north. The southward movement continues from July through the month of October.

Northern phalaropes swim as readily as ducks and secure much of their food from the water. Little flocks alight on the surface, and the individuals, separating 12 or 15 feet from one another, begin to quarter back and forth in search of food. They swim rapidly with quickly nodding heads, jabbing constantly at any morsels that appear within reach. When thus occupied the course pursued by individual birds is most erratic, as they turn constantly from side to side or whirl quickly about as food appears within reach behind them or at one side. Occasionally they run about on mud bars or beaches like other sandpipers, or when filled to repletion gather in the shallows, where they bathe or stand about resting, caring for their feathers, or sleeping.

B2630M

NORTHERN PHALAROPE
Lobipes lobatus

One hundred and fifty-five stomachs examined in determining the economic status of the northern phalarope are representative of the food of this bird, save when it is absent from the United States in winter. The material available is distributed rather evenly throughout the months from May to October, inclusive. That representing the food during the breeding season comes from Alaska, but the remainder was taken through the Northern States and California. Animal food forms 97.2 per cent, and seeds and some miscellaneous vegetable matter make up the remainder (2.8 per cent).

ANIMAL FOOD

Crustacea.—In the series of stomachs examined crustaceans come to 9.3 per cent, and are represented in every month. Eighteen birds taken in September had eaten these animals to the extent of one-fourth of their food, but at other seasons the number taken is less. When phalaropes are feeding at sea, no doubt crustaceans are eaten in much greater quantity than here indicated. Amphipods, fragments of which were found in 10 stomachs, form an easily obtained food, especially in northern waters. The curious winter eggs of another group of crustaceans (Daphniidæ) were found in two individuals. These eggs resemble a small seed pod with two black spots on either side. They must be present in abundance in some Alaskan localities, as they are eaten frequently by small shorebirds.

Brine shrimps (*Artemia fertilis*) were identified in eight birds taken on Great Salt Lake, Utah. These curious animals, less than an inch in length, abound in the concentrated brine of lakes in the Great Basin, being one of the few creatures that have become adapted to water so strongly saline. In Great Salt Lake these shrimps swarm in the shallow bays. The bodies of brine shrimps are soft and friable with no hard parts to resist digestion. Their detection in stomach examination is difficult, as the diffuse eye-spots or eggs in the case of breeding females, are the only characters that may be recognized. In the field it was observed that northern phalaropes were feeding extensively upon brine shrimps, and stomachs of those killed bear out this observation. It is certain that these crustaceans are an attractive food and that large numbers are eaten. Other crustaceans than those previously mentioned, in two instances isopods (Cymothoidea), were found in four other stomachs.

Hemiptera.—True bugs are an important source of food, amounting to 31.8 per cent of the whole. The bulk of them are the widely distributed water-boatmen (Corixidæ), eaten by 42 birds. Back-swimmers (Notonectidæ) were eaten by 5 birds, and miscellaneous forms, mainly unidentified, by 12. The favored species in this order of insects are those of aquatic habit.

Coleoptera.—Beetles were found abundantly in the examination of these stomachs and totaled 16.5 per cent of the food. Species that live in the water or are found on muddy shores are well represented. Ground beetles (Carabidæ) were found 12 times. Crawling water-beetles (Haliplidæ), small species occurring in submerged vegetation, were taken 10 times. Four species were definitely identified. The predacious diving beetles (Dytiscidæ) seem to be especially favored, adult forms being found in 20 stomachs and larval in 14. Water-scavenger beetles (Hydrophilidæ) were found in 19 stomachs and their larvæ in 6. Unidentified aquatic beetles occurred 14 times.

Weevils also were well represented, occurring in 24 stomachs. Miscellaneous beetles of other groups were represented by casual individuals in a number of stomachs. The identified material is listed in Table 1.

Diptera.—Flies made up the greatest part of the food of the northern phalarope—32.8 per cent of the whole. The most important element in this division is the larvæ of mosquitoes, which alone amount to 6.3 per cent of the entire food. Remains of these larvæ, identified usually by their breathing tubes, were found in 29 stomachs, all but one collected in May and June. The strange, long-legged crane flies were taken twice, while their larvæ, aquatic in habit, were found 13 times. Gnats (Chironomidæ) were abundantly represented. Larvæ were identified in 22 stomachs, pupæ in 17, and adults in 16. The immature stages are found in water, in which they swarm in many localities.

In the salt lakes of the Great Basin region larvæ, pupæ, and adults of the alkali flies (Ephydridæ) furnish an abundant food. On Great Salt Lake northern phalaropes divide their attention between brine shrimps and the young stages of the alkali flies. Larvæ and pupæ of the latter abound in the shallows and form a rich supply of food. Adult individuals of *Ephydra,* found 14 times, are secured as they rest on the surface film of the water or congregate on muddy shores. Larvæ and pupæ were identified 24 times. So abundant are these alkali flies that cast skins of the pupæ drift ashore to form brown windrows, which often extend for miles along the beaches. Formerly the Indians utilized this food supply by gathering the pupæ and preserving them for winter use.

Mollusca.—Small mollusks amounted to 2.7 per cent of the food of the northern phalarope for the period under consideration. All of those identified were snails (*Physa gyrina* one and *Planorbis trivolvis* eight) or other gastropods.

Miscellaneous.—Dragonfly nymphs (amounting to 0.2 per cent of the total) were eaten by three birds. Arachnida, another minor item in the food, came to 0.1 per cent. Spiders were identified four times, water-mites (Hydrachnidæ) twice, and another mite once. Other miscellaneous animal food, a grouping including a variety of forms not found abundantly enough to merit separate tabulation, amounted to 3.8 per cent. In these the larvæ of Mayflies were encountered four times and a grasshopper once. A marine worm of an abundant genus (*Nereis*) and neuropterans were found in the stomachs of two birds each. Fragments of moths in two cases, and skins of caterpillars in two, represented the Lepidoptera; and several small species, the Hymenoptera. These latter include ants and a few parasitic forms, which, from the fact that they must have been picked up by chance, have no particular economic significance. The class of vertebrates was represented by bones of a tiny fish.

VEGETABLE FOOD

The vegetable diet of the northern phalarope was made up of seeds, and, though amounting to only 2.8 per cent of the entire food, was taken regularly. In all, vegetable matter was identified in 38 stomachs. Among the more important plants represented may be mentioned widgeon grass (*Ruppia*), eaten 10 times; sago pondweed (*Potamogeton pectinatus*), 3; bulrush (*Scirpus*), 11; and salt grass

(*Distichlis spicata*), 3 times. These seeds are in the main fairly firm and hard, and this, with the small number taken, suggests that they were swallowed in part in lieu of gravel. Gravel is a fairly common element in these stomachs but may at times be difficult to obtain.

SUMMARY

The northern phalarope is among the smallest of our shorebirds. Although better known than the preceding species its ways do not bring it directly in contact with man. The bulk of its food is composed of animal matter. A large part is of slight economic importance, as the forms taken are of no significance in relation to crops or other products save as they may perchance furnish food for other organisms. Attention must be called however to the large number of mosquito larvæ consumed by the birds in May and June. In helping to check these pests, the northern phalarope demonstrates its value, and for this reason is worthy of every consideration.

TABLE 1.—*Material identified in the food of the northern phalarope as determined from the examination of 155 stomachs, and the number of stomachs in which each item was found*

Animal Matter	
ANNULATA	
Nereis sp. (marine worms)	2
CRUSTACEA	
Unidentified	2
PHYLLOPODA	
Artemia fertilis (brine shrimps)	8
Daphniidæ (waterfleas) (winter eggs)	2
AMPHIPODA (shrimplets)	
Pontoporeia sp	1
Gammarus confervicolus	5
Gammarus sp	1
Other amphipods	3
ISOPODA (sowbugs)	
Cymothoidea	2
ODONATA (dragonflies)	
Dragonfly nymphs	3
EPHEMERIDA (Mayflies)	
Ephemeridæ (larvæ)	4
ORTHOPTERA (grasshoppers, etc.)	
Unidentified grasshopper	1
HEMIPTERA (true bugs)	
Corizus sp	1
Notonecta sp. (back-swimmers)	5
Corixidæ (water-boatmen)	42
Other heteropterans	6
Agallia sanguinolenta (leaf hopper)	1
Other homopterans	4
TRICHOPTERA (caddisflies)	
Chilostigma praeteritum	1
LEPIDOPTERA (butterflies and moths)	
Unidentified moths	2
Unidentified caterpillars	2

Animal Matter—Continued	
COLEOPTERA (beetles)	
Dyschirius sp	1
Bembidion sp	7
Pterostichus sp	1
Amara sp	1
Other Carabidæ (ground beetles)	2
Haliplus borealis	1
Haliplus ruficollis	1
Haliplus longulus	1
Haliplus sp	4
Peltodytes callosus	2
Other Haliplidæ (crawling water-beetles)	1
Laccophilus sp	1
Coelambus sp	5
Deronectes sp	3
Hydroporus sp	3
Dytiscidæ (larvæ)	14
Other Dytiscidæ (predacious diving beetles)	8
Berosus sp	18
Berosus sp. (larvæ)	2
Other Hydrophilidæ (larvæ)	4
Other Hydrophilidæ (water-scavenger beetles)	1
Sphaeridium scarabaeoides	1
Unidentified aquatic beetles	14
Cafius bistriatus	1
Other Staphylinidæ (rove beetles)	1
Heterocerus sp	3
Dolopius lateralis	2
Unidentified Elateridæ (click beetles)	1
Monoxia sp	2
Systena bitaeniata	1
Systena sp	1
Crepidodera sp	1
Other Chrysomelidæ (leaf beetles)	1
Blapstinus sp	1
Otiorhynchidæ (weevils)	1
Hyperodes sp	1
Bagous restrictus	1
Rhinoncus pyrrhopus	1
Other Curculionidæ	7
Scolytidæ (bark beetles)	3
Unidentified Rhynchophora	10
DIPTERA (flies)	
Tipulidæ (crane flies)	2
Tipulidæ (larvæ)	13
Chironomus sp	3
Orthocladius sp	2

TABLE 1.—*Material identified in the food of the northern phalarope as determined from the examination of 155 stomachs, and the number of stomachs in which each item was found*—Continued

Animal Matter—Continued	
DIPTERA (flies)—Continued	
Chironomidæ (larvæ)	22
Chironomidæ (pupæ)	17
Other Chironomidæ (gnats)	11
Aëdes (Heteronycha) spencerii (larvæ)	26
Other Culicidæ (mosquitoes) (larvæ)	3
Stratiomyiidæ (soldier flies) (larvæ)	4
Dolichopodidæ (long-footed flies)	1
Syrphidæ (flower flies) (larvæ)	8
Leria leucostoma	2
Ephydra gracilis (adults and pupæ)	5
Ephydra hians (larvæ)	1
Ephydra sp. (adults)	14
Ephydra sp. (larvæ and pupæ)	18
Other Ephydridæ (alkali flies)	1
Unidentified dipterous larvæ and pupæ	6
Other dipterans	12
HYMENOPTERA (ants, bees, and wasps)	
Syrphoctonus sp	1
Alloxysta sp	1
Zelotypa sp	1
Camponotinæ	1
Unidentified ants	5
Bethylidæ	1
Crabronidæ	1
Other hymenopterans	1
ARANEIDA (spiders)	
Spiders	4
Animal Matter—Continued	
ACARINA (mites)	
Hydrachnidæ (water-mites)	2
Unidentified mite	1
MOLLUSCA (snails)	
Physa gyrina	1
Planorbis trivolvis	8
Littorina sitchana	2
Other gastropods	7
PISCES (fishes)	
Unidentified fish	1
Vegetable Matter—Seeds	
Ruppia occidentalis (widgeon grass)	10
Potamogeton pectinatus (sago pondweed)	3
Panicum sp. (switch-grass)	1
Distichlis spicata (salt grass)	3
Cyperus sp. (nut-grass)	1
Scirpus paludosus (bayonet-grass)	9
Scirpus sp. (bulrush)	2
Carex sp. (sedge)	1
Unidentified Cyperaceæ (sedges)	4
Rumex crispus (curled dock)	1
Rumex sp. (dock)	1
Castalia sp. (waterlily)	1
Unidentified legume (beans and peas)	1
Euphorbiaceæ (spurges)	1
Malvaceæ (mallows)	1
Menyanthes trifoliata (bog bean)	1
Unidentified seeds	8
Vegetable rubbish	1

WILSON PHALAROPE

Steganopus tricolor

The Wilson phalarope (Pl. II), unlike the other two phalaropes, is limited in its range to the Western Hemisphere. The species breeds in the northern part of the United States and southern Canada, from Indiana, Colorado, and eastern California north to central Alberta and Lake Winnipeg. It is more inland in distribution than other species o' this family. In the winter season it is found in southern South America in Chile and Argentina, and ranges south to the Falkland Islands. In spring it reaches this country late in April and is on its breeding grounds early in May. The return southward takes place in August, and by September the birds have departed.

For a summer home the Wilson phalarope chooses open grassy marshes surrounding shallow pools and lakelets. The birds may arrive in flocks but soon separate into pairs that form little colonies in the marshes. For a few days all is animation about their chosen homes, as ardent, brilliantly plumaged females pursue coy, plainly colored males on the wing or across the water. Later, when the eggs have been deposited, the birds are more retiring, so that it is possible to traverse the channels leading through the breeding colonies without suspecting that phalaropes are concealed close at hand. On walking out through the shallow water one or two males may be seen to appear and rest on the water near by, or circle restlessly about uttering soft honking calls. For a week or so the females accompany them and share their anxiety, but later these emancipated wives desert their husbands, band together, and drift away to join others

B2531M

WILSON PHALAROPE
Steganopus tricolor

of their sex, many of which perhaps have been unmated and have given no attention that season to the reproduction of their kind. Nests are placed in little clumps of grass and are of the simplest construction. Four large eggs, handsomely spotted and colored, are deposited on a slight cushion of broken grass stems. The care and incubation of these falls entirely to the male. Once the eggs are hatched the birds are more retiring than ever. The grasses in the marshes have grown steadily since nesting began, increasing the cover, and the young slip about through this as readily as do rails. It is rare indeed to capture them. Young and adults in winter plumage are nondescript, plain-colored birds, entirely different from the old birds in spring.

Though the Wilson phalaropes often feed while swimming on the surface of the water, they are much more frequently seen walking about on mud bars than other phalaropes. Since the birds appear to range entirely on inland waters, their food shows certain differences from that of the related species. In all, 106 stomachs of this bird were examined, representing the months from May to September. The majority were taken in May, June, and July, and the material for August and September is comparatively slight. The stomachs at hand were collected throughout the range of the bird in the United States, with a small number of specimens from Canada. The animal food represented amounts to 93.3 per cent of the total, and the vegetable, 6.7 per cent. Gravel was present in many stomachs in fair quantity.

ANIMAL FOOD

Crustacea.—In the food of the Wilson phalarope, crustaceans amount to 3.6 per cent, a much smaller quantity than in the two related species. The winter eggs of water fleas (Daphniidæ) were found 7 times, and the brine shrimp (*Artemia fertilis*) 4. Large flocks of phalaropes frequented the lake front on Great Salt Lake, where these tiny shrimps are available in large numbers. Amphipods not identified were found in 7 instances. The majority of the crustaceans were taken in May.

Heteroptera.—Aquatic bugs were favored food, forming 24.4 per cent of the total. Water-boatmen (Corixidæ) were especially sought, being found in 36 stomachs, some of which were crammed with them. Back-swimmers (Notonectidæ) were found 5 times, and shore bugs (*Salda*) 5 times, picked up as they ran about on the mud. Other bug remains not further identified were found in 4 instances. Although heteropterans made nearly one-fourth of the food, the groups represented were very few in number. The number of water-boatmen secured, insects which frequently are found in great abundance in the shallow waters of ponds and marshes, is worthy of attention.

Coleoptera.—Beetles are found in much greater variety than the true bugs, and in number of species replace the crustaceans taken by other phalaropes. They amount to 20.1 per cent. Ground beetles (Carabidæ) were found 13 times; among these a group of small shore-haunting species (*Bembidion*) was represented in 7 instances. Crawling water-beetles (Haliplidæ) were noted 15 times, and predacious diving beetles (Dytiscidæ) 34, in 8 cases being larval individuals. Water-scavenger beetles were also commonly represented, having been taken by 33 birds, in 6 cases in the larval state. The proportion of weevils present among the beetles was very large, as members of this group were identified 27 times. Many were small forms found on aquatic vegetation. Other groups of beetles are represented by scattering individuals picked up at random from the mud or the scanty growths of grass in marshy lowlands. Many of these miscellaneous beetles probably represent individuals which had drifted in on the shore after having been drowned. A few are forms found about decaying bodies, objects encountered frequently on borders of pools where the Wilson phalarope makes its home. Rove beetles (Staphylinidæ) and shining carrion-beetles (Histeridæ) belong especially in this class.

Diptera.—Flies are one of the main sources of food supply for the Wilson phalarope, constituting 43.1 per cent of the total. Mosquito larvæ which alone amounted to 5 per cent of the whole, constituted one-tenth of the food in 27 stomachs collected in May; in 45 taken in June they composed 2.5 per cent. These larvæ were taken also in numbers in birds killed in August. That large numbers of larvæ were often consumed at a single meal was shown by the presence of many of the breathing tubes through which the wrigglers obtain air when at the surface of the water. Crane flies (Tipulidæ) were found 10 times, their larvæ, which are aquatic, 8 times, and adults twice. Gnats (Chironomidæ) were more abundant in the food, being identified in 20 stomachs, the larvæ and pupæ in 10, and adult flies in a like number. In the immature stages insects of this group live in water, but the adults frequently swarm over marshes. To birds secured in the Great Basin region alkali flies (Ephydridæ) were favorite food. In all, members of this family were found 23 times, mostly in the larval or pupal stages, when they are easily accessible. The abundance of these insects in many localities is almost beyond expression in words, and they form a prime source of food in saline situations where few other creatures can exist. Other aquatic fly larvæ that occur in fresh water were taken, among them a large horsefly (*Tabanus*).

Miscellaneous.—Snails were found in two stomachs taken in March, but amounted to only 0.3 per cent of the diet for the whole period. Other miscellaneous animal food came to 1.8 per cent, including a few larvæ of Mayflies and in one case the immature form of a dragonfly. Caddisflies were found once and caterpillar remains once. Ants were found twice, and remains of a few other hymenopterans, but amounted to very little in bulk. Fragments of spiders were found three times. The comparatively small number of miscellaneous forms is surprising considering the manner in which the birds feed.

VEGETABLE FOOD

The vegetable food of the Wilson phalarope composed 6.7 per cent of the total and was made up almost entirely of seeds of aquatic plants or of plants that grow in marshy situations. Material that may be called vegetable rubbish was encountered 5 times and consisted of small particles that probably were obtained incidentally and swallowed by the birds when in eager pursuit of active prey. Seeds of pondweeds were found 6 times and of widgeon grass 5. Species of rushes (*Scirpus*) were identified 19 times, other sedges 6, and seeds of smartweed (*Polygonum*) 5 times. It will be noted at once that most of these seeds have hard outer coverings, and it seems probable that in addition to furnishing some nutriment they also serve as substitutes for bits of gravel, often difficult to get in the silt of lowland marshes but useful in grinding up food.

SUMMARY

In its apparent predilection for mosquito larvæ the Wilson phalarope is perhaps more useful than either of the other two species, as it ranges throughout the summer season on the fresh-water marshes, where mosquitoes often abound. Its destruction of larvæ of horseflies should also be placed to its credit. A large part of the food is composed of other marsh-haunting insects, which, so far as known at present, are of neutral economic significance. From no item can it be charged that this phalarope is injurious, and there could be no excuse for removing it from the protected list. The inroads of agriculture will restrict its breeding grounds, but with the adequate protection now accorded it the bird should maintain its numbers. Fortunately its body is so small that there is no incentive for poachers to kill it as game.

TABLE 2.—*Material identified in the food of the Wilson phalarope as determined from the examination of 106 stomachs, and the number of stomachs in which each item was found*

Animal Matter	
PHYLLOPODA	
Artemia fertilis (brine shrimps)	4
Daphniidæ (water fleas) (winter eggs)	7
AMPHIPODA (shrimplets)	
Unidentified amphipods	7
ODONATA (dragonflies)	
Dragonfly larva	1
EPHEMERIDA (Mayflies)	
Ephemeridæ (larvæ)	2
HETEROPTERA (true bugs)	
Salda sp	5
Notonectidæ (back-swimmers)	5
Corixidæ (water-boatmen)	36
Other heteropterans	4
TRICHOPTERA (caddisflies)	
Unidentified caddisfly larva	1
LEPIDOPTERA (butterflies and moths)	
Caterpillars	1
COLEOPTERA (beetles)	
Bembidion sp	7
Stenolophus limbalis	1
Other Carabidæ (ground beetles)	5
Haliplus ruficollis	1
Haliplus sp	5
Other Haliplidæ (crawling water-beetles)	4
Canthydrus bicolor	1
Coelambus punctatus	1
Coelambus sp	8
Hydroporus morio	2
Dytiscidæ (larvæ)	8
Other Dytiscidæ (predacious diving beetles)	14
Helophorus inquinatus	1
Helophorus sp	8
Berosus striatus	1
Berosus sp	15
Philhydrus sp	1

Animal Matter—Continued	
COLEOPTERA (beetles)—Continued	
Hydrophilidæ (larvæ)	6
Other Hydrophilidæ (water-scavenger beetles)	1
Staphylinidæ (larva)	1
Other Staphylinidæ (rove beetles)	2
Hister sp	1
Cytilus sericeus	1
Heterocerus sp	7
Aphodius sp	1
Monoxia sp	1
Other Chrysomelidæ (leaf beetles)	1
Tenebrionidæ	1
Phytonomus posticus (alfalfa weevil)	1
Onychilis nigrirostris	2
Anchodemus angustus	1
Bagous restrictus	9
Bagous sp	1
Mecopeltus aeneosquamosus	1
Other Curculionidæ (weevils)	5
Sphenophorus sp	2
Unidentified weevils	5
Other coleopterans	11
DIPTERA (flies)	
Tipulidæ (larvæ)	8
Adult Tipulidæ (crane flies)	2
Chironomidæ (larvæ and pupæ)	10
Adult Chironomidæ (midges)	10
Aëdes (Heteronycha) dorsalis (larva)	1
Aëdes (Heteronycha) spencerii (larva)	1
Other Culicidæ (mosquitoes) (larvæ)	6
Stratiomyiidæ (soldier flies) (larvæ)	11
Tabanus sp. (horseflies) (larvæ)	1
Dolichopodidæ (long-footed flies)	3
Syrphidæ (flower flies) (larvæ)	3
Ephydra gracilis (larvæ and pupæ)	3
Ephydra hians (larvæ)	4
Ephydra sp	7
Ephydra sp. (larvæ and pupæ)	8
Other Ephydridæ (alkali flies)	1
Other dipterous larvæ and pupæ	14
Other dipterans	27
HYMENOPTERA (ants, bees, and wasps)	
Unidentified ants	2
Pteromalini	1
Chelonus sp	1
Other hymenopterans	4

TABLE 2.—*Material identified in the food of the Wilson phalarope as determined from the examination of 106 stomachs, and the number of stomachs in which each item was found*—Continued

Animal Matter—Continued	
ARANEIDA (spiders)	
Unidentified spiders	3
MOLLUSCA (snails)	
Physa gyrina	1
Planorbis sp.	1
Vegetable Matter—Seeds	
Potamogeton pectinatus (sago pondweed)	3
Potamogeton sp. (pondweed)	3

Vegetable Matter—Seeds—Continued	
Ruppia sp. (widgeon grass)	5
Panicum sp. (switch-grass)	8
Distichlis spicata (salt grass)	2
Scirpus paludosus (bayonet-grass)	12
Scirpus robustus (bulrush)	1
Scirpus sp. (bulrush)	6
Cyperaceæ (sedges)	6
Polygonum sp. (smartweed)	5
Amaranthus sp. (pigweed)	1
Galium sp. (cleavers)	4
Unidentified seeds	4
Vegetable rubbish	5

AVOCET

Recurvirostra americana

The large, strikingly marked avocet is found in greatest abundance west of the Mississippi River, where it ranges from southern Canada south to the Mexican border. In winter avocets pass south through Mexico as far as Guatemala, some remaining in southern California and on the Gulf coast of Texas. Formerly they were found regularly along the Atlantic coast, but now are known only as stragglers in that region. Avocets are most common at present perhaps in the northern part of the Plains region and the Great Basin. Wherever found they attract attention, even from those ordinarily unobservant of birds. Though the long, slender legs and long neck may seem ungainly, avocets are graceful whether in movement or at rest. The bill, which is broad at the base, is flattened and thin, and at the tip is curved upward. The toes are webbed. The long pointed wings are black in contrast to the white of the remainder of the plumage, which in the breeding season is varied by a cinnamon wash on the head and neck.

Though found at times alone, avocets are habitually gregarious, like many other shorebirds. During the breeding season they gather in colonies and nest on low ground adjacent to ponds, bays, or slow-running channels. Four strongly marked eggs are deposited in a slight hollow scantily lined with a few bits of grass or weed stems. The sites chosen often are subject to inundation by sudden floods, when the birds scurry about, seemingly in confusion, but in reality working actively to build up the nest in order to support the eggs above the level of the encroaching water. In some cases it may be necessary to erect a structure 12 or 15 inches in height. Weeds, small sticks, bones, or dried bodies of ducks or other birds, feathers, or any other materials available are utilized as building materials.

Young avocets are able to run about at birth and accompany their parents across the open flats in search of food. A visit to a nesting colony is of the greatest interest to one who enjoys observing birds. Male avocets come flying out with loud calls to meet the intruder, and when he is actually near the nests or young the uproar becomes almost deafening. The adults dart at the head of the supposed enemy, or limp or flutter about, posturing grotesquely. Young birds are hustled away by parents, with the aid of solicitous neighbors, to be concealed in the scanty herbage, or piloted far out on the open flats, where they may be safe from capture.

After the breeding season avocets are more quiet and sedate and pay little attention to those who may visit their haunts, except to walk up and inspect them with mild curiosity. Flocks of the birds search for food scattered about in shallow water, and do not hesitate to swim when necessary in crossing the deeper channels. Frequently a dozen or more feed in company, walking slowly along, shoulder to shoulder, as though in drill formation, at each forward step thrusting the head under water and sweeping the recurved bill along the bottom with a scythe-like swing that must arouse consternation among water-boatmen and other aquatic denizens of the bays and ponds. At times the writer has observed as many as 300 of these handsome birds feeding thus in a single company, a scene at once spirited and striking. The hunter who through idle curiosity chances to kill one of these beautiful birds near his blind may well repent his wantonness, as other avocets with low calls gather about and examine the body of their former comrade with the greatest solicitude.

The avocet stomachs studied in the present work come in the main from California, Utah, Saskatchewan, and North Dakota. In all 67 stomachs were examined, taken during a continuous period of eight months from March to October. Animal food in these amounted to 65.1 per cent and vegetable to 34.9 per cent.

When feeding, avocets prefer shallow bays or ponds with muddy bottoms where the water varies from half an inch to 4 inches or more in depth. Some have supposed that the extreme thinness of the bill was caused by abrasion on sandy bottoms, a theory without basis, as the form of the bill conforms to the shape of the bones of the mandibles and no wear is apparent. As the birds feed much of the time by immersing the head, anything that may touch the bill is gathered indiscriminately, as in feeding they depend upon the sense of touch. From their manner of feeding, avocets are often scavengers, taking living or recently dead prey without much choice. The large tapeworms found almost without fail in the duodenum of the avocet are transmitted from one bird to another in this manner. The cast-off terminal segments of the worms (bearing the eggs) are picked up and swallowed by other avocets, a proceeding which the writer has personally observed. Avocets also pick up matter floating in the water, on or near the surface, or take insects and seeds from mud bars. The insects may be those living in such localities or may be individuals that have been washed up in drift.

ANIMAL FOOD

Crustacea.—Though represented only by remains of a flattened phyllopod known as *Apus*, crustaceans amount to 8.6 per cent of the total food. These strange animals inhabit shallow ponds but are so local in distribution that they may be found only occasionally in long distances, so that they are hardly a common article of bird food. Large numbers had been eaten by the three avocets in which such remains were found.

Odonata.—Dragonfly nymphs were found in three avocets killed in May and June, but amounted only to 0.1 per cent of the total food.

Hemiptera.—True bugs were more staple diet, and were common in occurrence, though forming only 5.9 per cent of the bulk of the food. They were identified in 26 of the birds examined. Back-swimmers

(*Notonecta*) were found 3 times and a form of water bug (Belostomatidæ) once. Water-boatmen, identified in 23 instances, seem to be standard article of diet.

Coleoptera.—Beetles as a group constitute 11.4 per cent of the food. Among them small shore-haunting ground beetles were common, none known to be of economic importance. A few crawling water-beetles (Haliplidæ) were found and a number of predacious diving beetles. Larvæ of this latter group were identified 9 times. Water-scavenger beetles in both adult and larval stages also were well represented. Weevils were as abundant as other groups of beetles and included billbugs (*Sphenophorus*) in 5 instances.

Diptera.—Flies, amounting to 23.8 per cent of the total subsistence, compose the largest single item in the animal food. Although abundantly represented, the species taken belong to comparatively few groups. Larvæ of crane flies (Tipulidæ) were taken 4 times and larvæ and pupæ of flies that could not be certainly identified 5 times. The immature stages of gnats (Chironomidæ) were especially sought. Individuals identified as belonging to the typical genus *Chironomus* were found 6 times, and those of related forms, 11. Often many were found in one stomach, though ordinarily so broken that they could not be counted with accuracy. In a number of instances, however, it was ascertained that several hundred had been swallowed by one bird.

In the Great Basin region alkali flies (Ephydridæ) were favored as food, as they were not only palatable but abundant about brackish or saline waters and in most cases easily secured. In spring and early summer thousands of these flies are found gathered in close array on expanses of soft, alkaline mud. Avocets run up hastily to such congregations and strike at them with lateral sweeping motions that fill their bills with them and with soft mud before the insects can escape. At such attacks the flies in limited areas rise in sudden swarms, but others at a short distance remain quiet, so that by taking a few steps the birds are able to make another attack on gatherings whose numbers have been augmented by the arrival of individuals frightened up at the first onslaught. The larvæ of these flies abound in many places, especially in the strongly saline waters of the lakes characteristic of the Great Basin. At Great Salt Lake many avocets after the nesting season frequent shallow bays near the lake front, where these larvæ swarm, in order to feed upon them.

Miscellaneous.—Snails are eaten occasionally by avocets and were found in 6 stomachs, although they amount only to 0.8 per cent of the total. The species are those common in shallow ponds and marshes. Other miscellaneous items of animal food, 14.5 per cent, include a varied assemblage of forms, none of which were present in sufficient number to merit separate tabulation. Nymphs of Mayflies were found twice, and cases and other remains of caddisfly larvæ 3 times. Caterpillars were identified 3 times, and fragments of small grasshoppers (Acridiidæ), 4. The Hymenoptera were represented by single findings of ants, a larrid, a braconid, and one other form not identified. Spiders were found in 2 instances. A small chub (*Leuciscus lineatus*) had been eaten by one bird and an unidentified fish by another. Bones of a tiny salamander were encountered in the stomach of one bird.

VEGETABLE FOOD

Vegetable matter was a regular constituent in the diet of the avocet, being found in 56 of the 67 stomachs examined, and totaling 34.9 per cent for the entire period. A considerable part of this is composed of seeds of marsh or aquatic plants. Thus seeds of the sago pondweed (*Potamogeton pectinatus*) were found 17 times and those of some related form once. Salt grass (*Distichlis spicata*) was taken 3 times, bayonet-grass (*Scirpus paludosus*) 7, and related bulrushes of the same genus as the latter, also were found 7 times. The names of a few scattered seeds from other groups are given in Table 3.

Vegetable matter other than seeds also was eaten. Thus leaves and stems of the sago pondweed were abundantly represented and were identified in 17 stomachs. Miscellaneous bits of vegetation classed as vegetable rubbish were found 19 times. This matter in part was evidently picked up at random in feeding in shallow water. Some of this must be classed as waste, but as it is possible to extract nutriment from a portion it must be considered of some value. It is ground up in digestion by means of the gravel and hard seeds swallowed for the purpose.

SUMMARY

Analysis of the food of the avocet shows that this species has no injurious tendencies whatever. Much of the animal food belongs to forms that are economically neutral. The weevils eaten are to be placed on the credit side of the account, as they are nearly always harmful or may become so if given opportunity.

In some regions the "snipe," as the avocet is sometimes known, is considered a game bird or is hunted for food. Shooting avocets has no element of sport, however, as it is easy to walk up within gun range of them, and they are fearless and frequently come around to examine the hunter. Though the birds are of fair size, the flesh is not savory and offers no excuse for killing them. They rightfully have been removed from the category of game birds and are now accorded full protection under the regulations of the Federal migratory-bird treaty act. This is fortunate indeed for their continuance, as they are large and conspicuous and easily killed. They rear but one brood of four young each season and are subject normally to many dangers, so that with shooting the species would soon be exterminated. With increase in cultivation of lands throughout their range their haunts have been much restricted. The birds remaining have in many instances been brought into closer relation with man, so that the good they do is more apparent.

TABLE 3.—*Material identified in the food of the avocet as determined from the examination of 67 stomachs, and the number of stomachs in which each item was found*

Animal Matter	
PHYLLOPODA	
Apus sp	3
ODONATA (dragonflies)	
Dragonfly nymphs	3
EPHEMERIDA (Mayflies)	
Ephemeridæ (nymphs)	2

Animal Matter—Continued	
ORTHOPTERA (grasshoppers, etc.)	
Acridiidæ	4
HETEROPTERA (true bugs)	
Notonecta sp. (back-swimmers)	3
Belostomatidæ (giant water bugs)	1
Arctocorixa dispersa (water-boatman)	1
Other Corixidæ (water-boatmen)	22
Other heteropterans	1

TABLE 3.—*Material identified in the food of the avocet as determined from the examination of 67 stomachs, and the number of stomachs in which each item was found*—Continued

Animal Matter—Continued	
TRICHOPTERA (caddisflies)	
Caddisfly larvæ	3
LEPIDOPTERA (butterflies and moths)	
Caterpillars	3
COLEOPTERA (beetles)	
Bembidion insulatum	1
Bembidion scudderi	1
Bembidion sp	1
Pterostichus sp	2
Selenophorus sp	1
Peltodytes callosus	1
Other Haliplidæ (crawling water-beetles)	2
Coelambus sp	2
Hydroporus sp	2
Dytiscidæ (larvæ)	9
Other Dytiscidæ (predacious diving beetles)	1
Helophorus sp	4
Tropisternus sp	2
Berosus sp	5
Berosus sp. (larvæ)	1
Hydrophilidæ (water-scavenger beetles) (larvæ)	5
Heterocerus sp	2
Tenebrionidæ	1
Phytonomous sp	1
Hyperodes sp	1
Other Curculionidæ (weevils)	2
Sphenophorus ochreus (billbug)	1
Sphenophorus mormon (billbug)	1
Sphenophorus sp. (billbug)	3
Other coleopterans (including larvæ)	10
DIPTERA (flies)	
Tipulidæ (crane flies) (larvæ)	4
Chironomus sp. (larvæ)	6
Other Chironomidæ (gnats) (larvæ)	11
Ephydra gracilis (alkali flies) (adults and larvæ)	2
Ephydra hians (larvæ)	2
Ephydra sp	8
Other dipteran larvæ and pupæ	5
Animal Matter—Continued	
HYMENOPTERA (ants, bees, and wasps)	
Larridæ	1
Ant	1
Braconidæ	1
Other hymenopterans	1
ARANEIDA (spiders)	
Spiders	2
MOLLUSCA (snails and mussels)	
Physa gyrina	2
Planorbis trivolvis	3
Planorbis sp	1
Other mollusks (eggs)	1
PISCES (fishes)	
Leuciscus lineatus	1
Other fishes	1
AMPHIBIA (frogs, toads, and salamanders)	
Salamander	1
Vegetable Matter—Seeds	
Marsilea vestita (pepperwort)	1
Marsilea sp. (pepperwort)	3
Juniperus utahensis (juniper)	1
Potamogeton pectinatus (sago pondweed) (seeds)	17
Potamogeton pectinatus (leaves and stems)	17
Potamogeton sp. (pondweed)	1
Ruppia occidentalis (widgeon grass)	1
Distichilis spicata (salt grass)	3
Scirpus paludosus (bayonet-grass)	7
Scirpus sp. (bulrush)	7
Other Cyperaceæ (sedges)	1
Polygonum sp. (smartweed)	4
Atriplex sp. (saltbush)	1
Other Chenopodiaceæ	1
Legume	1
Composite	1
Other seeds	1
Vegetable rubbish	19

BLACK-NECKED STILT

Himantopus mexicanus

The black-necked stilt (Pl. III) is one of the comparatively few species of shorebirds that have a center of distribution within the Tropics and extend from there northward to within our limits. In the western United States the stilt ranges north to southern Oregon, northern Utah, and Colorado; in the East it is found at present in Florida, Louisiana, and Texas, though formerly it nested as far north as Delaware Bay or possibly even more northern latitudes.

In the West during the breeding season stilts are found in company with avocets about shallow pools and lakes or on the muddy banks of channels running through lowland marshes. Though usually less common than their larger neighbors, they add to the uproar and excitement when the breeding colonies are invaded. Stilts are not so demonstrative as avocets and remain more in the background, where the steady repetition of their sharp notes furnishes a yelping accompaniment to the more vociferous outbursts of the others. When greatly excited, stilts spring in the air and circle about or, with steadily beating wings, remain stationary a few feet from the

B2529M

BLACK-NECKED STILT

Himantopus mexicanus

ground, their long, red legs hanging straight down. The dead black of the upperparts with its greenish sheen and the pure white of the breast form a pleasing contrast of color, which, with the greatly elongated legs, serves to distinguish the stilt from any other of our shorebirds.

The nests and eggs of stilts are very similar to those of the avocet, and the young when first hatched closely resemble young avocets, but may be distinguished by the lack of a hind toe. The young grow rapidly, and the increase in the length of their legs is amazing. Until the bones are well formed the young, when not feeding, prefer to rest with the full length of the tarsus extended on the ground, but even then appear as tall as other shorebirds of similar body size.

Stilts show considerable attachment for their young, and, unless dispersed by some untoward accident, frequently remain in family groups long after the young are able to care for themselves. As the latter become strong on the wing the family parties range over the country in search of suitable feeding grounds. As the nights grow cold in the North the birds band together in larger flocks and finally, on some moonlit night in September, young and old may be heard calling as they pass overhead on their southward migration.

Stilts feed by picking up insects on muddy shores or in shallow water, and though not averse to frequenting alkaline areas, on the whole prefer fresher water than do avocets. For detailed analysis, 80 stomachs of the black-necked stilt were available, distributed from March to August, and collected in California, Utah, Florida, and Porto Rico. Vegetable food in these amounted to only 1.1 per cent, whereas the animal matter formed 98.9 per cent. The birds are adept in seizing rapidly-moving prey and in general are very methodical in their manner of obtaining food. Gravel is picked up to some extent to aid digestion, and part of the seeds taken may have been swallowed for the same purpose.

ANIMAL FOOD

The animal food of the black-necked stilt shows more diversity than in the case of preceding species, though some of the items taken are present in comparatively small quantity.

Crustacea.—Crustaceans constitute 0.5 per cent of the total food and were identified in stomachs collected in March and April. In eight remains of crawfishes were found, an important item, as these animals are highly destructive to crops in some localities.

Odonata.—Nymphs of dragonflies make up 2.9 per cent and were eaten by nine birds, mainly in April and July.

Trichoptera.—Cases of caddisflies with their occupants were found abundantly in stomachs taken in March and April and amount to 3.3 per cent of the entire food. In many instances the cases had been attached to submerged vegetation, part of which had come away when the container was torn loose and had been swallowed with the larvæ.

Agnatha.—Mayfly nymphs, a number of which were taken during April, were identified in five stomachs (1.3 per cent).

Heteroptera.—Aquatic bugs with a few others were eaten in large quantities and amount to 35 per cent, the largest single item in the food of the stilt. They were found regularly in all months for which material was available. Water-boatmen (Corixidæ), encountered

27 times, were most abundantly represented. Remains of many were found in several of the stomachs opened, and small fragments were often present in stomachs filled with other insects. Water striders (*Gerris*) were found three times, true water bugs of small size (*Belostoma*) six times, and back-swimmers (Notonectidæ) twice. A shore bug (*Salda*) was identified once. Shore bugs are often abundant on mud bars where stilts delight to feed, but apparently are usually overlooked or disregarded.

Coleoptera.—Beetles, practically as important in the food as the bugs, composed 32.4 per cent, but were present in much greater variety. A tiger beetle (*Cicindela*), found in one instance, is the only species taken that may be considered beneficial. Small flat beetles of the genus *Bembidion*, of which a variety of species inhabit muddy shores, were found twice and other ground beetles (Carabidæ) seven times. Crawling water-beetles (Haliplidæ) were identified in 18 instances, among them representatives of various species. Predacious diving beetles were identified 26 times and their larvæ 9 times. The species of this group taken by the stilt were those of small size, as the bird is unable to swallow the larger forms. The same fact was observed in the water-scavenger beetles identified in 58 stomachs. The genus *Berosus*, the species of which are frequently abundant in shallow water, was found 21 times and the genus *Tropisternus*, 28. Larvæ of water-scavenger beetles were identified in 22 instances, so that on the whole this group of beetles was abundantly represented.

An abundance of weevils is noted as one of the prominent items among the beetles. Curculionidæ alone were represented in 44 stomachs and billbugs (*Sphenophorus*) in 6. The curculios eaten were mainly individuals of the genera *Bagous* and *Onychilis*, which occur on aquatic vegetation. Weevils are mostly injurious, and attention may be drawn to the evident predilection for these beetles shown by the stilt.

Diptera.—Flies amount to 9.7 per cent of the total food. The majority were still in the immature stages, though occasionally adult flies were eaten. These remains were most abundant in material from the Great Basin region, where certain groups of dipterans abound. The young of small crane flies (Limnobiinæ) were found 3 times and of gnats (Chironomidæ) 4 times. The larval forms of mosquitoes were identified twice, evidence of good that may be accomplished in the destruction of these pests. Alkali flies (Ephydridæ), and soldier flies (Stratiomyiidae), represented by several forms, were encountered 9 times each. The species of flies taken, so far as it was possible to identify them, are without exception those having larval forms of aquatic habit.

Mollusca.—Represented by several common species of marsh or pond inhabiting snails, mollusks make up 7.9 per cent of the food, and were identified 35 times in all, most abundantly in material collected in Florida. In 37 birds taken in April (all but 2 from Florida) snails amounted to 15.4 per cent of the food.

Pisces.—Small fishes were identified in 7 instances, but amount to only 3.2 per cent of the total food. A carp was found once and tiny sunfishes twice, but remains of others were not identified. The fishes eaten were of the smallest size and have little economic significance.

Miscellaneous.—Other animal food, amounting to 2.7 per cent, included remains of grasshoppers in 3 instances, and crickets, caterpillars, and a tiny frog in 1 each. The grasshoppers and crickets may be mentioned as of distinct economic importance and as a further indication of the value of the stilt as an insect destroyer.

VEGETABLE FOOD

The vegetable food of the black-necked stilt, composing 1.1 per cent of the total, has little significance in determining the economic status of the bird. It consisted in the main of a few seeds of aquatic or marsh plants, with fragments of vegetable débris in a few instances, taken as rubbish adhering to other food. The flattened sporocarps of *Marsilea* were found in 1 stomach and seeds of the sago pondweed (*Potamogeton pectinatus*) in 4. Seeds of several species of bulrush were encountered in 7 instances and leaves and stems of the sago pondweed in 2. The latter is an item in favor with many water birds and may be considered nutritious and readily digestible. As most of the seeds eaten were hard and firmly surfaced, it is probable that like gravel they perform an important function in preparing softer food for digestion, in addition to serving as nutriment themselves.

SUMMARY

From the foregoing details it seems that the black-necked stilt is of somewhat greater importance from an economic viewpoint than the avocet. The fact that it eats crawfishes, though in small quantity, is one point in its favor. Among the insects taken, a great majority are of no particular importance, but attention must be called to an evident predilection of stilts for billbugs (*Sphenophorus*). The only valuable beetle eaten was a single tiger beetle, of which fragments were found in one stomach, an item of small weight compared with the destructive beetles consumed. Mosquito larvæ were found in two instances, an indication of a valuable feeding habit which in suitable localities may render these birds of importance. The true bugs eaten are of neutral significance, save in the case of the waterbugs (*Belostoma*), which, being predatory on small fry of fishes, must be considered injurious, and they form a part of the food to the credit of the bird. Flies and mollusks are taken in abundance, but except for the mosquito larvæ mentioned, are of neutral significance. The small fishes eaten are tiny individuals of species having no particular value.

Economically the stilt has a decided balance in its favor. It apparently has never been considered a game bird, as it is small in body and poor in flesh. The tameness and lack of sophistication of the birds have often led to their destruction by careless gunners, so that they have greatly decreased in numbers or have even disappeared from more thickly settled regions. As they are conspicuous in form, and fearless and noisy during the breeding season, they attract attention which often is disastrous. They should be protected and encouraged generally and under such conditions should maintain or even increase their present numbers. Those who chance to come intimately in contact with stilts will find that they are not only beneficial in their food habits but that they merit observation for their many interesting ways.

TABLE 4.—*Material identified in the food of the black-necked stilt as determined from the examination of 80 stomachs, and the number of stomachs in which each item was found*

Animal Matter	
CRUSTACEA (crabs, shrimps, etc.)	
Cambarus sp. (crawfishes)	8
Other crustaceans	1
ODONATA (dragonflies)	
Dragonfly nymphs	9
EPHEMERIDA (Mayflies)	
Ephemeridæ (nymphs)	5
ORTHOPTERA (grasshoppers, etc.)	
Acridiidæ (short-horned grasshoppers)	3
Gryllidæ (crickets)	1
HETEROPTERA (true bugs)	
Pentatomidæ (stink-bugs)	1
Miridæ (plant bugs)	1
Gerris sp. (water-striders)	3
Salda sp. (shorebugs)	1
Notonecta undulata (back-swimmers)	1
Other Notonectidæ (back-swimmers)	1
Belostoma flumineum (giant water-bug)	1
Belostoma sp. (giant water-bug)	5
Arctocorixa interrupta (water-boatman)	1
Other Corixidæ (water-boatmen)	26
Other heteropterans	1
TRICHOPTERA (caddisflies)	
Caddisfly larvæ	19
LEPIDOPTERA (butterflies and moths)	
Caterpillars	1
COLEOPTERA (beetles)	
Cicindela sp. (tiger beetle)	1
Bembidion insulatum	1
Bembidion sp	1
Other Carabidæ (ground beetles)	7
Haliplus concolor	2
Haliplus sp	8
Peltodytes callosus	4
Peltodytes muticus	3
Other Haliplidæ (crawling water-beetles)	1
Coelambus pedalis	1
Coelambus sp	11
Deronectes striatellus	1
Coptotomus obscurus	1
Thermonectes ornaticollis	1
Dytiscidæ (larvæ)	9
Other Dytiscidæ (predacious diving beetles)	1
Helophorus sp	3
Berosus pugnax	2
Berosus infuscatus	2
Berosus sp	17
Tropisternus limbalis	6
Tropisternus nimbatus	6
Tropisternus californicus	1
Tropisternus sp	15
Cercyon sp	1
Hydrophilidæ (larvæ)	22
Other Hydrophilidæ (water-scavenger beetles)	5
Animal Matter—Continued	
COLEOPTERA (beetles)—Continued	
Heterocerus sp	1
Heterocerus sp. (larvæ)	1
Hyperodes sp	1
Onychilis nigrirostris	2
Bagous mammillatus	1
Bagous obliquus	14
Bagous restrictus	13
Other Curculionidæ (weevils)	11
Sphenophorus ochreus (billbugs)	1
Sphenophorus pertinax (billbugs)	2
Sphenophorus sp. (billbugs)	3
DIPTERA (flies)	
Limnobiinæ (crane flies) (larvæ)	3
Chironomidæ	1
Chironomidæ (midges) (larvæ)	4
Culicidæ (mosquitoes) (larvæ and pupæ)	2
Stratiomyia sp. (larvæ)	1
Odontomyia sp. (larvæ)	7
Other Stratiomyiidæ (soldier flies, larvæ)	1
Syrphidæ (flower flies) (larvæ)	1
Ephydra gracilis (alkali flies)	5
Ephydra subopaca (alkali flies) (larvæ)	1
Ephydra sp. (alkali flies) (larvæ)	3
Other dipterous larvæ	5
Other dipterans	1
ARANEIDA spiders)	
Spiders	3
PELECYPODA (mussels)	
Small bivalves	2
GASTROPODA (snails)	
Bittium varium	1
Amnicola sp	9
Vivipara georgiana	3
Physa gyrina	2
Physa sp	1
Planorbis trivolvis	3
Planorbis sp	1
Other snails	12
PISCES (fishes)	
Cyprinus carpio (carp)	1
Centrarchidæ (sunfishes)	2
Other fishes	4
AMPHIBIA (frogs, toads, etc.)	
Frog	1
Vegetable Matter	
Marsilea sp (pepperwort)	1
Potamogeton pectinatus (sago pondweed) (seeds)	4
Potamogeton pectinatus (leaves)	2
Potamogeton sp. (pondweed)	1
Scirpus americanus (three-square)	2
Scirpus paludosus (bayonet-grass)	4
Scirpus sp. (bulrush)	1
Cephalanthus occidentalis (buttonbush)	1
Vegetable rubbish	6

TABLE 5.—*Percentages of principal groups of items in the food of the five shorebirds discussed*

Bird	Number of stomachs	Crustacea	Odonata, Trichoptera, Ephemerida	Hemiptera	Coleoptera	Diptera	Mollusca	Pisces	Miscellaneous	Total animal food	Vegetable food
Red phalarope	36	33.5			27.3	22.7		6.8	9.7	100.0	Tr.
Northern phalarope	155	9.3	.2	31.8	16.5	32.8	2.7		3.9	97.2	2.8
Wilson phalarope	106	3.6		24.4	20.1	43.1	.3		1.8	93.3	6.7
Avocet	67	8.6	.1	5.9	11.4	23.8	.8		14.5	65.1	34.9
Black-necked stilt	80	.5	7.5	35	32.4	9.7	7.9	3.2	2.7	98.9	1.1

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1925

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1363

Washington, D. C. ▼ February, 1926

HOST RELATIONS OF COMPSILURA CONCINNATA MEIGEN, AN IMPORTANT TACHINID PARASITE OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH

By R. T. Webber, *Assistant Entomologist*, and J. V. Schaffner, Jr., *Principal Scientific Aid, Gipsy Moth and Brown-Tail Moth Investigations, Bureau of Entomology* [1]

CONTENTS

The depredations wrought by the gipsy moth (*Porthetria dispar* L.) and the brown-tail moth (*Euproctis chrysorrhoea* L.) in eastern Massachusetts have been responsible for the introduction of many European parasites into the United States. Among the imported parasites which were successfully established is *Compsilura concinnata* Meigen, a tachinid fly common to the European countries where the brown-tail moth is found and credited with a long and varied host list. This parasite was first introduced into Massachusetts in 1906 and found to be generally distributed over considerable territory in 1909. A brief account of the life history, colonization, etc., of this tachinid appeared in a bulletin by Howard and Fiske issued by the Bureau of Entomology in 1911 (*7*),[2] and a much more elaborate summary, detailing the life history, was published by Culver in 1919 (*2*). Tothill (*9*), in 1922, also published on the life history of Compsilura.

Since the establishment of a foreign insect in a new environment may bring about some change either beneficial or detrimental to its hosts and host affiliations, plans were made to study the effect of this introduced parasite on native larvæ. Accordingly, during the spring

---

[1] The writers are indebted to the personnel of the Gipsy Moth Laboratory for their assistance; to H. G. Dyar, of the U. S. National Museum, and the late F. H. Mosher, of the Gipsy Moth Laboratory, for identification of the Lepidoptera; and to C. F. W. Muesebeck for determination of the Hymenoptera.

[2] Reference is made by number (italic) to "Literature cited," p. 31.

56991—26——1

of 1915, arrangements were made by A. F. Burgess, in charge of the gipsy-moth investigations at Melrose Highlands, Mass., for the collection of larvæ and the study of their parasites.

SOURCES OF COLLECTIONS AND DATA

The laboratory is so situated that the opportunities for obtaining large collections of insect material are numerous. In addition to the laboratory force, quarantine inspectors in infested areas, scouts, local moth superintendents in Massachusetts, and people interested in the moth work in all of the New England States gather material and send it to the laboratory for study. The larval collections received from 1915 to 1922 include the following: For 1915, 68 species, 18,457 larvæ; 1916, 151 species, 20,712 larvæ; 1917, 140 species, 23,086 larvæ; 1918, 117 species, 20,427 larvæ; 1919, 141 species, 54,628 larvæ; 1920, 144 species, 58,313 larvæ; 1921, 136 species, 57,512 larvæ; 1922, 138 species, 49,421 larvæ.

During the eight years in which larvæ have been collected there have been received at the laboratory about 300 identified species, together with many specimens which failed to produce adults and the identity of which can never be established. A list of the host insects of Compsilura received during this period is given in Table 1.

TABLE 1.—*List of host insects of Compsilura concinnata Meig. received at the gipsy moth laboratory, Melrose Highlands, Mass., from 1915 to 1922, inclusive* [1]

	1915	1916	1917	1918	1919	1920	1921	1922	Total
Aglais milberti Godart	0	0	*355*	*2,337*	0	0	0	0	2,692
Alypia octomaculata Fabricius	80	3	*31*	12	*37*	*166*	*375*	*179*	883
Ampelophaga myron Cramer	0	0	0	0	0	*16*	0	2	18
Anisota rubicunda Fabricius	2	2	10	144	889	42	*516*	0	1,605
Anisota senatoria Smith and Abbot	20	0	0	48	*530*	200	798	516	2,112
Anosia plexippus Linné	0	61	*70*	*192*	0	0	0	*33*	356
Apatela americana Harris	1	2	52	4	2	*6*	0	1	68
Apatela furcifera Guenée	0	*10*	*19*	*10*	4	*31*	*5*	*4*	83
Apatela brumosa Guenée	0	*4*	8	*27*	4	20	0	0	63
Apatela sp	0	0	2	*2*	*2*	2	1	3	12
Arctiid	0	0	4	*10*	*16*	4	0	0	34
Arsilonche albovenosa Goeze	0	*47*	4	*120*	95	*21*	6	0	293
Autographa brassicae Riley	42	48	391	*167*	37	*103*	*269*	129	1,186
Automeris io Fabricius	0	91	18	1	0	2	1	*29*	142
Basilarchia archippus Cramer	20	*16*	*53*	*119*	*245*	*134*	*172*	*52*	811
Basilarchia astyanax Fabricius	0	3	0	0	0	0	*3*	3	9
Callosamia promethea Drury	*755*	284	537	*661*	53	20	12	9	2,331
Calpe canadensis Bethune	10	1	1	0	*31*	18	1	19	81
Catocala sp	0	5	1	2	7	12	15	*8*	50
Cerura occidentalis Lintner	0	3	4	2	1	16	6	*5*	37
Charidryas nycteis Doubleday and Hewitson	0	0	0	0	*36*	54	101	18	209
Cimbex americana Leach	*19*	3	24	*16*	41	27	38	1,590	1,758
Cingilia catenaria Drury	0	0	0	0	*501*	436	398	*974*	2,309
Cirphis unipuncta Haworth	15	0	0	0	*6*	2	17	10	50
Cnidocampa flavescens Walker	0	12	392	0	0	0	0	*1,195*	1,599
Croesus latitarsus Norton	20	494	609	*567*	*2,868*	*1,405*	*2,130*	*1,187*	9,280
Datana angusii Grote and Robinson	0	0	*35*	0	69	0	40	37	181
Datana integerrima Grote and Robinson	0	65	7	*327*	0	*478*	0	0	877
Datana major Grote and Robinson	0	*42*	*1*	0	3	0	17	*60*	123
Datana ministra Drury	0	224	*2,449*	*432*	199	*259*	*955*	*299*	4,817
Datana perspicua Grote and Robinson	0	0	0	0	0	*120*	*152*	308	580
Deidamia inscriptum Harris	*9*	0	1	2	1	0	0	0	13
Deilephila gallii Rottemburg	*12*	0	0	0	1	1	0	0	14
Deilephila lineata Fabricius	0	2	1	0	0	0	2	*8*	13
Diacrisia virginica Fabricius	*161*	*118*	*184*	*328*	8	*20*	*18*	*19*	856
Ennomos subsignarius Hübner	*1,200*	*865*	403	*353*	257	2	0	0	3,080
Epargyreus tityrus Fabricius	0	21	0	0	0	*65*	*62*	*226*	374

[1] Numbers in italic indicate that Compsilura was reared.

TABLE 1.—*List of host insects of Compsilura concinnata Meig. received at the gipsy moth laboratory, Melrose Highlands, Mass., from 1915 to 1922, inclusive*—Continued

	1915	1916	1917	1918	1919	1920	1921	1922	Total
Epicnaptera americana Harris	0	4	6	9	4	3	3	4	33
Estigmene acraea Drury	25	208	696	185	619	105	106	114	2,058
Euchaetias egle Drury	0	152	675	345	497	72	155	779	2,675
Eugonia j-album Boisduval and Leconte	16	43	2	13	0	0	0	0	74
Euproctis chrysorrhoea Linné [2]	------	------	------	------	------	------	------	------	------
Euthisanotia grata Fabricius	0	0	8	0	0	3	0	0	11
Euvanessa antiopa Linné	250	551	418	2,243	667	430	1,124	1,075	6,758
Evergestis straminalis Hübner	20	14	11	2	0	48	0	5	100
Halisidota caryae Harris	0	367	1,647	47	250	4	4	22	2,341
Halisidota tessellaris Smith and Abbot	0	229	1,572	255	26	34	12	161	2,289
Hemaris thysbe Fabricius	0	0	0	0	0	77	22	6	105
Hemerocampa leucostigma Smith and Abbot	0	99	222	480	60	781	543	1,937	4,122
Hemileuca maia Drury	685	195	934	3,059	2,730	780	2,004	955	11,342
Heterocampa guttivitta Walker	0	3	3	276	1,749	842	3	0	2,876
Heterocampa umbrata Walker	0	0	0	0	10	0	0	0	10
Hydria undulata Linné	0	0	71	87	1,161	817	419	560	3,115
Hyphantria cunea Drury [3]	0	836	1,373	1,671	7,577	8,623	2,940	2,478	25,498
Lycia cognataria Guenée	0	0	0	28	3	35	6	9	81
Malacosoma americana Fabricius [4]	8,650	2,099	1,156	810	13,574	10,832	4,850	966	42,937
Malacosoma disstria Hübner	2,520	278	57	207	302	348	679	688	5,079
Mamestra adjuncta Boisduval	0	11	6	5	1	4	0	4	31
Mamestra legitima Grote	0	2	6	5	3	3	2	2	23
Mamestra picta Grote	206	534	340	9	291	166	118	18	1,682
Melalopha inclusa Hübner	0	0	0	50	261	456	257	45	1,069
Nadata gibbosa Smith and Abbot	0	2	3	0	8	7	0	12	32
Notolophus antiqua Linné	8	5	99	21	3	0	7	106	249
Olene basiflava Packard [5]	10	2,543	399	12	153	0	90	3	3,210
Olene sp.	0	0	0	1	0	0	0	0	1
Paonias myops Smith and Abbot	0	2	0	20	0	59	5	19	105
Papilio polyxenes Fabricius	35	49	179	8	71	20	62	42	466
Papilio troilus Linné	0	0	2	0	0	78	72	53	205
Papilio turnus Linné	2	2	7	3	3	58	13	8	96
Pheosia rimosa Packard	0	0	0	1	0	16	5	1	23
Phigalia titea Cramer	396	527	54	8	3	6	1	15	1,010
Phlegethontius quinquemaculata Haworth	3	89	79	1	202	109	6	37	526
Pholus achemon Drury	0	0	0	0	0	1	0	0	1
Plathypena scabra Fabricius	0	0	0	0	237	1	1	0	239
Plusiodonta compressipalpis Guenée	------	------	------	------	------	------	------	------	------
Polygonia comma Harris	1	0	0	0	0	0	0	0	1
Polygonia interrogationis Fabricius	0	6	0	79	266	10	7	0	368
Pontia rapae Linné [6]	0	174	1,139	256	1,234	1,368	1,030	222	5,423
Porthetria dispar Linné [2]	------	------	------	------	------	------	------	------	------
Pteronidea ribesi Scopoli	300	500	524	162	1,980	552	521	1,584	6,123
Pyrophila pyramidoides Guenée	0	24	3	5	8	9	0	10	59
Rhodophora florida Guenée	------	------	------	------	------	------	------	------	------
Samia cecropia Linné	4	7	31	2	7	8	3	12	74
Schizura concinna Smith and Abbot	85	449	3,473	2,074	3,608	1,995	498	187	12,364
Schizura unicornis Smith and Abbot	0	3	1	4	1	4	4	9	26
Scoliopteryx libatrix Linné	0	0	0	0	2	3	0	7	12
Sphecodina abbotii Swainson	0	13	13	9	13	14	10	12	84
Sphingid larva	0	0	0	0	0	1	0	0	1
Sphinx gordius Stoll	0	1	1	0	4	19	3	6	34
Stilpnotia salicis Linné [7]	0	0	0	0	0	627	0	0	627
Thanaos sp.	0	0	0	0	0	83	55	3	141
Telea polyphemus Cramer	12	3	18	3	2	2	3	2	45
Tenthredinid larvæ [8]	0	150	215	25	153	805	47	181	1,576
Tenthredinid larvæ [9]	0	0	0	0	0	0	86	0	86
Vanessa atalanta Linné	25	0	9	266	683	143	5	88	1,219
Vanessa huntera Fabricius	0	1	0	1	18	25	3	7	55
	15,619	12,601	21,118	18,630	44,382	34,168	21,894	19,377	187,789

[2] Collections of E. chrysorrhoea and P. dispar are not included in this table. These collections, numbering several thousand larvæ, are made each year for various purposes and are handled by the laboratory force.

[3] Nearly 6,000 larvæ of H. cunea were received in 1921 and 9,000 in 1922, but the writers were unable to handle more than the number listed.

[4] Nearly 25,000 larvæ of this species were received in 1921 and 20,000 in 1922, but the writers were unable to handle more than those listed.

[5] Collections of O. basiflava include the hibernating larvæ of which 90 per cent died from unknown causes.

[6] Large collections of P. rapae were received at the laboratory during 1914 and 1915 but were used by Culver (?) in his life-history experiments.

[7] Collections received during 1922 and 1923 were handled by the laboratory force.

[8] Neurotoma fasciata Norton.

[9] Pteronidea coryla Cresson.

The territory from which the collections were received is representative of the gipsy-moth area of New England, the bulk of the material, however, being from those sections about Melrose Highlands, Mass.; Bangor, Me.; Claremont, N. H.; Westerly, R. I., and Putnam, Conn.

There are also collections (not included in the above summary) from the gipsy-moth territory in New Jersey. In this area there had been prior to 1921 no systematic introduction of parasites and the material obtained answers well for check purposes. These collections are represented by over 125 species aggregating at least 10,000 larvæ.

CARE OF COLLECTIONS AND METHODS OF REARING

Ordinary mailing tubes, 2 inches in diameter and 7 inches long, with screw tops, are used with great success for the shipment of material from the field. On receipt of the collections at the laboratory the contents are sorted, identified if possible, and placed in receptacles for rearing.

Various methods are used in handling the collections. In the case of known insects the task is easy since many species can be successfully reared in pasteboard boxes or in covered trays. The framework of these trays is of wood, measuring 12 by 12 by 5 inches; the bottom is covered with cloth and can readily be replaced when necessary. All trays are furnished with tightly fitting glass covers which slip into a grooved top. Where there is any doubt as to how the species may best be reared, glass jars, supplied with earth, are used.

Hibernating larvæ and species which pass the winter as pupæ or prepupæ are difficult to handle successfully. In caring for the hibernating larvæ the best results were obtained from the use of Riley cages. For pupal hibernation, glass jars, galvanized-iron cylinders with bottoms of fine mesh wire screening, and wooden boxes of various sizes are used. These are partially filled with earth and the larvæ allowed to transform at will. The glass jars are either retained in the outside rearing cage or brought into the cellar of the laboratory, where they are not subject to extreme temperatures. The cylinders and boxes which have been successfully used are set in the earth as soon as the larvæ pupate, and covered with straw. Practically the same methods are used in caring for the tachinid and hymenopterous parasites.

LIFE HISTORY AND HIBERNATING HOSTS

Briefly, the life history of *Compsilura concinnata* is as follows: During the spring the last-stage larvæ issue from their hibernating hosts and pupate close by. Ten days or so later the adults appear. In New England there are two or more generations upon alternate hosts, the progeny of the last generation hibernating as larvæ within certain lepidopterous pupæ. Spring emergence of the overwintering generation is variable, depending upon climatic conditions (Table 2). During 1921 a few flies issued in April, whereas the material collected in 1916 gave no results in 1917 until June 11 and later. Most of the rearing records, however, which have been conducted under natural conditions show a much earlier date of emergence. In the field, collections of adults range from May 1 to November 1.

TABLE 2.—*Showing the emergence of hibernating flies from their host pupæ (natural environment)*[1]

Date of individual emergence	Host	Period of emergence
1916		
June 8, 10, 12	Deilephila gallii Rottemburg	June 3–12.
June 3	Diacrisia virginica Fabricius	
June 6, 12	Callosamia promethea Drury	
1917		
June 11	Arsilonche albovenosa Goeze	June 11–15.
June 13	Apatela brumosa Guenée	
June 14	Apatela furcifera Guenée	
June 15	Papilio polyxenes Fabricius	
1918		
May 24, 27	Diacrisia virginica Fabricius	May 24–June 6.
June 6	Schizura concinna Smith and Abbot	
1919		
May 27	Apatela furcifera Guenée	May 27–June 10.
May 27, 29, 31	Hyphantria cunea Drury	
May 27, 28, 31	Apatela brumosa Guenée	
May 28–31, June 10	Euchaetias egle Drury	
May 28	Arsilonche albovenosa Goeze	
May 29	Pontia rapae Linné	
May 31	Pheosia rimosa Packard	
1921		
Apr. 12–25	Papilio polyxenes Fabricius	Apr. 12–May 28.
Apr. 14	Hyphantria cunea Drury	
May 4	Paonias myops Smith and Abbot	
May 14, 16, 24	Pontia rapae Linné	
May 21	Arsilonche albovenosa Goeze	
May 21, 23, 28	Apatela furcifera Guenée	
May 23	Apatela americana Harris	
May 23–24	Estigmene acraea Drury	
1922		
May 1	Estigmene acraea Drury	May 1–June 10.
May 21–June 10	Euchaetias egle Drury	
May 15	Thanaos sp.	

[1] No hibernating records for 1920 were obtained.

There are other records of Compsilura being reared from overwintering pupæ of *Diacrisia virginica*, *Callosamia promethea*, *Mamestra picta*, *Mamestra legitima*, *Ampelophaga myron*, *Papilio troilus*, *Sphinx gordius*, *Paonias myops*, *Apatela americana*, and *Deidamia inscriptum*, but since these are all laboratory records, the rearings having taken place under artificial conditions, no mention is made of them in the table. *Schizura unicornis*, which overwinters as a prepupa, has also given Compsilura under laboratory conditions. Among the hosts recorded by Culver (*2*, *p. 5*) are two species, *Plusiodonta compressipalpis* and a geometrid; the record of the former was dated April 7, 1913. Smith (*8*) records a rearing of *Callosamia promethea*, the parasite issuing May 2, 1914. At West Springfield, Mass., in 1915, the same writer succeeded in recovering Compsilura from the overwintering pupa of *Diacrisia virginica*, two flies issuing May 12 to 15, 1916. The conditions under which the rearing took place are not known.

STATUS OF HIBERNATING HOSTS OF COMPSILURA

The abundance of Compsilura in the spring and consequently the degree of parasitism upon the brown-tail and gipsy moths are to a great extent due to the abundance of its hibernating hosts.[3] With two exceptions (*Schizura concinna* and *S. unicornis*), these host insects pass the winter in the pupal stage either above or below the surface of the earth. The majority of the species are solitary, although a few are gregarious, such as *Hyphantria cunea*, *Euchaetias egle*, and *S. concinna*, colonies of which are usually found each year in some locality or other.

Arsilonche albovenosa, *Diacrisia virginica*, *Mamestra picta*, and *Pontia rapae*, although not strictly gregarious, are often found in large numbers. This is particularly true of *P. rapae.* Probably no native species has been received in such numbers and from so many localities as this insect. As a hibernating host its status is doubtful. Occasionally a fly or two is reared, but considering the hundreds of overwintering chrysalids, the percentage of parasitism is negligible.

Ampelophaga myron feeds on Virginia creeper and grape; it is solitary and is usually found in small numbers. This species is considered common, although none had ever been received by the writers until 1920. It is single-brooded and hibernates as a pupa, and although the collections of this year were heavily parasitized by *Apanteles congregatus* Say, only a single specimen of Compsilura was recovered from overwintering material.

Paonias myops, solitary usually but sometimes found in considerable numbers on wild black cherry, appears to be of little consequence as a winter host. In the collections *Trogus* spp. (*brullei* Prov. and *canadensis* Prov.) and *Apanteles smerinthi* Riley assume prime importance as natural checks.

Sphinx gordius, of the same general habits as *Paonias myops* but with a more varied list of food plants, occupies about the same host status.

Diacrisia virginica is without doubt the most favored overwintering host yet recorded. It is common; a specimen is frequently found here and there and sometimes in the most unexpected places; still it has never been received in abundance.

So much difficulty has been experienced in the rearing of *Mamestra picta* that the records are far from complete. The larvæ are gregarious in the first three stages at least, after which they disperse. The species seems particularly subject to disease and the hibernating pupæ nearly always succumb. If disease is as prevalent in the field as it is in the trays, the chances are slight of its being of much importance as an overwintering host.

Callosamia promethea has been abundantly received from Rhode Island and Connecticut as cocoons and only upon a few occasions

---

[3] That a higher percentage of parasitism upon the gipsy moth could be reached in an area where there is a mixed infestation of gipsy and brown-tail moths is not borne out by the parasite records. A careful study of these records over a series of years when one or both of the species were present indicates that a very small percentage of the flies issuing from the brown-tail moth are able to attack the gipsy moth. The few that do must necessarily prey upon larvæ of the last stage and here success would not be at all certain. It is doubtful, even though a considerable number of this first generation attacked the gipsy moth, whether their presence could offset the lost efficiency of the parent fly caused by the drain on its reproductive capacity in its attack upon the brown-tail moth. According to Culver (*2, p. 9*), all that can be expected of Compsilura is an average progeny of about 100. Naturally, in a mixed infestation, the parasite would attack the first host that made its appearance. This would be the brown-tail moth. Finding the larvæ abundant and favorable, it would prey upon this host until the appearance of the gipsy-moth larvæ two weeks or so later. By this time its reproductive capacity would have been reduced by the extent of its attack upon the brown-tail moth, and consequently it would be less effective against the gipsy-moth larvæ.

has it given forth Compsilura. Whatever may be its status as a summer host, it is certainly of minor importance as a hibernating one.

There is only one record of an abundance of *Papilio polyxenes.* Usually the larvæ are solitary. A great many adults have been reared and Compsilura often secured. The collections indicate a partial second generation, the insects passing the winter as chrysalids. *P. troilus* is seldom of economic importance and is similar in its life history to *P. polyxenes.* Undoubtedly it is common, although collections have been received only during the last three years. It is one of the most acceptable hosts; and, were it not restricted to certain food plants (sassafras and Lindera), it would rank high in importance as a hibernating host. Collections totaling 65 larvæ made during September, 1920, gave 24 adult Compsilura the following spring—a record for hibernation far ahead of any other met in the writers' studies. As many as five individuals have been known to winter successfully in one host chrysalid.

Apatela furcifera and *A. brumosa* are strictly solitary and, although never plentiful, seem constant in their appearance each year.

There is great difficulty in satisfactorily determining the species of the genus Thanaos, and so the larvæ have been separated according to their food plant. It is only those species which feed upon the oaks that are of immediate concern. Adults, identified as *T. juvenalis* Fab. and *T. horatius* Scud. and Burg., were reared from these collections. Some of the species have at least a partial second generation and the larvæ are found in the field from July to October. Though solitary, they are sometimes found in abundance. Compsilura has been reared from larvæ collected in August, the parasite issuing a few weeks later and also on two occasions from larvæ collected in the fall, the parasite issuing the following spring. The host value of the entire group is uncertain.

GENERATIONS OF COMPSILURA

As will be seen by reference to Table 2, the time of emergence of Compsilura varies from year to year. Doubtless this factor is greatly influenced by climatic and environmental conditions as would also be the number of generations. However, in order to estimate the field appearance of the various generations, there must first be chosen what seems to be an average year. For this purpose, let us say that the period of emergence for the first generation extends from May 24 to June 15. Allowing an 18-day longevity period for the adults,[4] this would extend the range of the first generation to July 3. Granting 30 days for a second generation and a longevity of 18 days for the adult, we would then have flies of the second generation from June 24 to August 22. At the time of the first emergence of the individuals of the second generation, there are still many adults of the first generation in the field. Thirty days later (July 24) adults of the third generation would begin to appear, and it is perfectly possible that stragglers of this generation would be found as late as October. During an extremely mild season a partial fourth generation, the adults of which would issue August 24 and later, is not at all unlikely.

[4] Culver (*2, p. 16*) found that the fertilized females would live for an average of 18 days in confinement and that mated males would live a few days longer. Unmated flies lived but a short time.

The range of Compsilura and the overlapping of generations may be given as follows: First generation, May 24 to July 3 (40 days); second generation, June 24 to August 22 (59 days); third generation, July 24 to October 1 (69 days); fourth generation, August 24 to November.

For the most part it is the progeny of the second to fourth generations that hibernate, for it is rarely that a collection made before September 1 gives Compsilura in the spring. There are exceptions, however, one collection being dated August 22.

STATUS OF SUMMER HOSTS

During the latter part of May and the early part of June, Compsilura finds at hand a good many insects favorable for its development. The flies that issue first attack the hosts then accessible, and the flies that issue later attack not only those but many more. In Table 3 are listed the known hosts of Compsilura, the horizontal black line indicating the presence of host larvæ in the field at the time when they are subject to the attack of the parasite. The records indicate that, although Compsilura may successfully attack early-stage larvæ, the intermediate stages are more acceptable.

TABLE 3.—*Host list of Compsilura concinnata, showing the field appearance of the insects based upon the larval collections received at the gipsy-moth laboratory* [a]

Hosts	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	Apr.
Aglais milberti Godart		———	———	———	—							
Alypia octomaculata Fabricius		———	———	———	—							
Ampelophaga myron Cramer				—	—	------	------	------	------	------	------	------
Anisota rubicunda Fabricius		—	———	———	—							
Anisota senatoria Smith and Abbot			—	———	—							
Anosia plexippus Linné			—	———	—							
Apatela americana Harris				———	———	------	------	------	------	------	------	------
Apatela furcifera Gueneé		—	———	———	———	------	------	------	------	------	------	------
Apatela brumosa Gueneé		—	———	———	———	------	------	------	------	------	------	------
Apatela sp				—								
Arctiid larvæ			—	———	—							
Arsilonche albovenosa Goeze		—	———	———	———	—						
Autographa brassicae Riley			—	———	———	—						
Automeris io Fabricius				—	———	—						
Basilarchia archippus Cramer	———	———	———	———	—							
Basilarchia astyanax Fabricius	—	———	———	—								
Callosamia promethea Drury			—	———	———	------	------	------	------	------	------	------
Calpe canadensis Bethune	—	—										
Catocola sp	—	———	—									
Cerura occidentalis Lintner			—	———	—							
Charidryas nycteis Doubleday and Hewitson	———	———	—									
Cimbex americana Leach		—	———	———	—							
Cingilia catenaria Drury		—	———	—								
Cirphis unipuncta Haworth	———	———	———	———	———	———	———					
Cnidocampa flavescens Walker			—	———	—							
Croesus latitarsus Norton		—	———	———	—							

[a] ——— Period in which hosts are subject to attack; ------- period of hibernation (indicating hibernating hosts from which Compsilura has been reared). Adults of Compsilura concinnata issue from hibernating hosts April to June.

TABLE 3.—*Host list of Compsilura concinnata, etc.*—Continued

Hosts	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Datana angusii Grote and Robinson				—	—	—						
Datana integerrima Grote and Robinson				—	—	—						
Datana major Grote and Robinson				—	—	—						
Datana ministra Drury		—	—	—	—							
Datana perspicua Grote and Robinson				—	—	—						
Deidamia inscriptum Harris			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Deilephila gallii Rottemburg			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Deilephila lineata Fabricius			—	—	—	—						
Diacrisia virginica Fabricius			—	—	—	—	—	- - -	- - -	- - -	- - -	- - -
Ennomos subsignarius Hübner	—	—	—									
Epargyreus tityrus Fabricius			—	—	—	—						
Epicnaptera americana Harris		—	—	—								
Estigmene acraea Drury			—	—	—	—	—	- - -	- - -	- - -	- - -	- - -
Euchaetias egle Drury		—	—	—	— - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Eugonia j-album Boisduval and Leconte	—	—	—									
Euproctis chrysorrhoea Linné	—	—	—									
Euthisanotia grata Fabricius				—	—							
Euvanessa antiopa Linné		—	—	—	—							
Evergestis straminalis Hübner			—	—	—	—						
Halisidota caryae Harris			—	—	—	—						
Halisidota tessellaris Smith and Abbot			—	—	—	—						
Hemaris thysbe Fabricius			—	—	—	—						
Hemerocampa leucostigma Smith and Abbot		—	—	—	—	—						
Hemileuca maia Drury		—	—	—								
Heterocampa guttivitta Walker			—	—								
Heterocampa umbrata Walker			—	—								
Hydria undulata Linné			—	—	—							
Hyphantria cunea Drury		—	—	—	— - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Lycia cognataria Gueneé			—	—	—							
Malacosoma americana Fabricius	—	—	—									
Malacosoma disstria Hübner	—	—	—									
Mamestra adjuncta Boisduval			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Mamestra legitima Grote				—	—	—	- - -	- - -	- - -	- - -	- - -	- - -
Mamestra picta Grote			—	—	—	—	— - -	- - -	- - -	- - -	- - -	- - -
Melalopha inclusa Hübner		—	—	—	—	—						
Nadata gibbosa Smith and Abbot			—	—								
Notolophus antiqua Linné		—	—	—	—	—						
Olene basiflava Packard	—	—	—									
Olene sp		—	—									
Paonias myops Smith and Abbot			—	—	—	— - -	- - -	- - -	- - -	- - -	- - -	- - -
Papilio polyxenes Fabricius		—	—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Papilio troilus Linné		—	—	—	— - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Papilio turnus Linné			—	—	—	—						
Pheosia rimosa Packard			—	—	—	— - -	- - -	- - -	- - -	- - -	- - -	- - -
Phigalia titea Cramer		—	—	—								
Phlegethontius quinquemaculata Haworth			—	—	—	—						
Pholus achemon Drury			—	—	—							
Plathypena scabra Fabricius			—	—								
Plusiodonta compressipalpis Gueneé				—	—							
Polygonia comma Harris		—	—	—	—							
Polygonia interrogationis Fabricius	—	—	—	—	—							
Pontia rapae Linné		—	—	—	—	—	— - -	- - -	- - -	- - -	- - -	- - -
Portheria dispar Linné		—	—	—								
Pteronidea ribesi Scopoli	—	—	—	—								

TABLE 3.—*Host list of Compsilura concinnata, etc.*—Continued

Hosts	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Pyrophila pyramidoides Guené	—	—	—									
Rhodophora florida Guené				—	—							
Samia cecropia Linné			—	—	—	—						
Schizura concinna Smith and Abbot			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Schizura unicornis Smith and Abbot			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Scoliopteryx libatrix Linné			—	—	—							
Sphecodina abbotii Swainson		—	—	—								
Sphingid larvæ			—									
Sphinx gordius Stoll			—	—	—	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Stilpnotia salicis Linné	—	—	—									
Telea polyphemus Cramer			—	—	—							
Pteronidea coryla Cresson			—	—								
Neurotoma fasciata Norton		—	—	—	—							
Vanessa atalanta Linné		—	—	—	—							
Vanessa huntera Fabricius		—	—	—	—							

There is a great variety of insects among the summer hosts of Compsilura. Three orders are represented and in the Lepidoptera 18 families are included. The species attacked are widely divergent in habit as well as in external appearance. Apparently there are no distinguishing characters peculiar to the host insect. Just what means Compsilura uses to select its host is not known. It is possible that it has no sense of discrimination. Experiments positively show that year after year it will attack hibernating brown-tail moth caterpillars without the least chance of survival. The same behavior has been observed in its relation to *Olene basiflava.* During the winter of 1922 C. F. W. Muesebeck of the gipsy-moth laboratory, while dissecting some of the overwintering larvæ of *O. basiflava*, found a single hibernating larva of Compsilura. It seems certain that the parasite would here meet the same fate as it does in its attack upon the brown-tail moth, but since the writers have been unable successfully to rear many of the overwintering larvæ of the host there are insufficient data to settle this point. It is probable that in most cases the death of the parasite is due to the lack of correlation between the host and the parasite; that is, in the spring, the development of the parasite exceeds that of its host, thereby resulting in the death of both (*7, p. 220*). Culver (gipsy-moth laboratory records) found in his laboratory experiments that, although Compsilura would in many instances larviposit upon the last-stage caterpillars, the results were seldom successful. He found that the silkworm (*Bombyx mori* L.), when attacked in the advanced stages, would often complete its cocoon and the parasites reaching the adult stage would be unable to escape therefrom. He also noted larviposition on a chrysalid of *Pontia rapae* which achieved no results. There are other records of attempted larviposition upon lepidopterous pupæ, all of which resulted in failure. In the laboratory experiments, larvæ of several species have been attacked, but no progeny obtained. It is these facts which lead one to believe that Compsilura uses but little discrimination in its choice of hosts and that it will waste much effort in futile attack upon an unsuitable one.

LIPARIDAE

Among the host insects readily accessible to Compsilura in the spring are species belonging to the family Liparidae. Two of these in particular, the brown-tail moth (*Euproctis chrysorrhoea* L.) and the satin moth (*Stilpnotia salicis* L.), are species hibernating as larvæ and periodic in their abundance. Both of these insects seem to be firmly established in Massachusetts. Although *chrysorrhoea* has several introduced tachinid parasites of importance, it would appear that *salicis* has none of consequence except Compsilura. Without doubt these species are primary hosts.

The remaining species, the gipsy moth (*Porthetria dispar* L.), the white-marked tussock moth (*Hemerocampa leucostigma* S. and A.), and the rusty tussock moth (*Notolophus antiqua* L.), hibernate in the egg stage. As Compsilura does not habitually attack larvæ that have not reached the third stage, its attack upon these species is somewhat later than upon those liparids which hibernate as larvæ. In abundance, *P. dispar* exceeds all of the others by far, and for this reason would naturally be the most advantageous host for Compsilura. Because of the great number of this host, Compsilura need waste no time hunting for a more suitable one, but attacks this species with a vengeance. With such an abundance of favored host material, it follows that Compsilura could reproduce at best and increase in such proportions that there would be at the close of the gipsy-moth season the maximum number of individuals in the field. This is most fortunate, for from now on there is no general infestation of insects to replace the gipsy moth and Compsilura must seek out its host.[5] At times, naturally, there might be in certain localities an ample supply of favored ones, but more often it would be a case of finding a solitary or at least a less abundant species. On the other hand, it may be that because of the fact that there are so many Compsilura in the field the hibernating hosts in and adjacent to a heavily infested area are eventually reduced to a minimum, thereby causing a shortage of winter hosts. Since the amount of parasitism of the gipsy moth by Compsilura is governed largely by the abundance of the first generation, less parasitism should be expected in a heavily infested area. An apparent corroboration of this reasoning appears in the parasite records of the gipsy moth laboratory, which show that the high percentages of parasitism are invariably from the lightly infested areas. In the opinion of the writers, this conclusion is not justified by the facts, the records merely representing a percentage method of reckoning. It seems certain that there is an equal distribution of Compsilura over the entire infested area (fluctuations from year to year in certain localities, due to various causes, excepted) and that if the number of parasites were based upon the

---

[5] A factor of considerable importance pertaining directly to this subject is that of the dispersion of Compsilura. For several reasons the collections of native larvæ examined by the writers shed but little light on this point. Culver (*2, p. 7*) places the spread of Compsilura at approximately 25 miles per year, basing his claim upon scouting and larval collections, rather an unsatisfactory way to obtain notes on the dispersion, but nevertheless about the only data there are to go by. Tothill (*9, p. 39*) found Compsilura 3 miles away from the colony site two weeks after liberation. This definite record, together with Culver's deductions, would indicate that the tachinid was a strong flier and that under certain conditions a yearly spread of 25 miles might be expected.

proportionate number of larvæ per locality the ratio would be approximately the same.

Hemerocampa leucostigma and *Notolophus antiqua* are apparently double-brooded. Larvæ of these species can be found in the field from June until October. The periodic abundance of the former, usually during the latter part of July, makes it a very desirable host. *N. antiqua* is not at all common but what collections have been obtained usually gave forth a few specimens of Compsilura. Studies made by the writers indicate that it also is a desirable host. There are but few insects among those studied where the competition between the tachinid parasites is so keen as in *Hemerocampa leucostigma*. From data secured by Wooldridge [6] in 1910 we find in *H. leucostigma*, besides a great number of hymenopterous parasites, seven species of Tachinidae:[7] Compsilura, *Phorocera claripennis* Macq., *Tachina mella* Walk., *Frontina aletiae* Riley, *Frontina frenchii* Will., (*Exorista*) *Zenillia amplexa* Coq., and *Winthemia quadripustulata* Fab. Of these tachinids the first four species were the more numerous. The following year collections were again made from this locality with similar results.

No collections were received at the laboratory from 1912 to 1915. In 1916 several small ones were sent from Westerly and Newport, R. I. Only one species of Tachinidae was recovered, *Compsilura concinnata*. In 1917 five collections were received from points in Rhode Island and Connecticut and from these were reared 14 Compsilura and 2 *Zenillia amplexa*.

The infestation of *Hemerocampa leucostigma* at Westerly, R. I., reached its height in 1918, and from seven collections of material sent from this locality there were reared, besides Compsilura, a few *Tachina mella*, *Frontina aletiae*, *Phorocera claripennis*, and several unknown larviform puparia. The parasites obtained in 1918 were somewhat similar to those secured in 1910 and 1911. The native tachinids were far less abundant, however.

Owing to the great decrease in the infestation at Westerly, R. I., in 1919, only two small collections were received from there that year. These collections gave forth 10 Compsilura and 1 specimen of *Frontina frenchii*. It was not until 1920 that there was really an abundance of the species around Boston. The results of the rearings of this year were not sufficient to check the findings of 1910, but they show clearly that Compsilura was the most efficient tachinid parasite present. In fact only one specimen of native Tachinidae was obtained—*Phorocera claripennis*.

In 1921 there was a small outbreak of *Hemerocampa leucostigma* at Everett, Mass., near Boston. A collection of over 500 larvæ of various stages was received at the laboratory, and from these were reared 4 specimens of *Apanteles melanoscelus* Ratz. and 68 tachinid puparia. These puparia were all Compsilura.

The following year collections were again made in the same locality. Over 1,000 larvæ of various stages were collected, and from these were reared two species of Hymenoptera and 67 Compsilura.

---

[6] Gipsy moth laboratory notes. A large outbreak of *Hemerocampa leucostigma* occurred around Boston, Mass., in 1910 and 1911. Many collections of material were received at the laboratory and considerable data concerning the parasites were obtained.

[7] With a single exception (Compsilura), these tachinids were the same species as those reared by L. O. Howard at Washington, D. C., in 1897 (*6*).

Later a collection of 171 larvæ was obtained, but no tachinid parasite other than Compsilura was reared. It was not until a small collection of five last-stage larvæ was received on September 20 that any of the native tachinids were recovered, two specimens of *Phorocera claripennis* being bred.

The results obtained from the collections secured at Brooklyn, N. Y., and Philadelphia, Pa. (1921–22), are interesting. The tachinids recovered from this material were the same species as those bred at the laboratory in 1910 and 1911. Furthermore, with hardly an exception, the relative importance of each species was similar. The similarity of records is probably due to the conditions existing; that is, a heavy infestation and the absence of Compsilura.

It is obvious from the records that in a territory where Compsilura is established a light infestation of *Hemerocampa leucostigma* is comparatively free from native tachinid parasites. Such a condition would hardly exist, however, were there not some interference from the exotic parasite. To what extent this interference reaches is problematical, but two things seem assured: (1) There is no excessive parasitism by the native species in localities where the introduced parasite is absent, and (2) the host species must be materially affected by the presence of this additional enemy.

LASIOCAMPIDAE

The lasiocampids *Malacosoma americana* Fab. (the tent caterpillar) and *Malacosoma disstria* Hübn. (the forest tent caterpillar), although close relatives of the liparids and having some points in common, are among the most unfavorable of hosts. Their appearance in the field during May and early June, when there is not an overabundance of insect larvæ of sufficient growth for the early issuing Compsilura, would lead one to believe them most desirable. Such is not the case, however, for hundreds of larvæ of both species have given forth but few parasites.

It is difficult to explain why Compsilura so steadfastly ignores these species. In the case of *Malacosoma americana*, where the species is of the tent-making kind, some interference might be expected on account of this habit; but when the same species is isolated and used in laboratory experiments the results are likewise negative. Reproductive experiments, using the tent-making arctiid *Hyphantria cunea* Dru. (the fall webworm) as a host, have proved that far better results can be obtained under laboratory conditions, where the larvæ are not allowed to web up, than can be obtained from field collections. The field collections nearly always result in failure as far as Compsilura is concerned. It seems clear, in the latter case at least, that the web must offer considerable protection to the larvæ within it. *M. disstria*, which does not make a tent, has a much better host value than *M. americana*.

Another species of this family, *Epicnaptera americana* Harr., appears in the field at a later period and the larvæ are frequently found during the last of August. Unlike the species of Malacosoma, this insect is solitary and is never found in abundance. Its value as a host species is doubtful.

NYMPHALIDAE

The family Nymphalidae offers the greatest number of host insects. Species of the genera Polygonia, Eugonia, Charidryas, Euvanessa, Vanessa, Aglais, and Basilarchia have all given forth Compsilura. With the exception of Basilarchia and Charidryas, which hibernate as larvæ, the life history of these hosts is similar. All except *Charidryas nycteis* are double-brooded, or at least have a partial second generation, and are to be found in the field from early spring until late fall. The larvæ are, for the most part, gregarious, in the early stages, at least.

In this group are to be found the most constant alternate hosts and in some respects the most favored. In percentage of parasitism the rate here is as high as in any other group. In the future other species of this family will no doubt be found to harbor Compsilura. It is useless to speculate, however, on the host possibilities of any species of a given group, for no matter how closely the hosts are allied, they may be unsuitable. For instance, among the arctiids we find favored hosts, such as *Diacrisia virginica* and *Estigmene acraea*, and on the other hand we find species of little or no host value, such as *Hyphantria cunea*, *Phragmatobia fuliginosa*, and *Isia isabella.*

In behavior there is some variance. *Euvanessa antiopa* L. always remains in a colony until the time of pupation and is usually found high above the ground feeding on willow, elm, poplar, and birch. *Eugonia j-album* and *Polygonia interrogationis* do not remain gregarious for so long a period; otherwise their habits are much the same.

One of the most conspicuous examples of competitive parasitism occurs in the spiny elm caterpillar (*Euvanessa antiopa* L.). Collections of this species have been constant and, for one year in particular, abundant (Table 1). Nearly all of the larvæ received were in the last stage. It is doubtful whether we have any other species where there are more data available for studying the relationship which Compsilura bears to a single competing tachinid than in this species. Material has been reared in bulk collections and as individuals. The results have been studied from every angle, and yet it is exceedingly difficult to draw any definite conclusions. Facts ascertained from one year's data and corroborated by a second, or in some cases by a third, are contradicted by the results of the fourth. Conditions are so entirely different each year that it is useless to attempt to arrive at average results. The two tachinids playing such an important part in the control of this species are the native tachinid, *Pelatachina pellucida* Coq., and Compsilura. The former has but a single generation and appears to be peculiar to this host alone.

Not the least of our difficulties in estimating value of these parasites is the great amount of superparasitism which occurs among them.[8] This is still further complicated by a good deal of multiple parasitism.[9] Nearly one-half of the collections received during the eight years of study is subject to the latter phase of parasitism. It

---

[8] The term "superparasitism" is used to indicate that more than one parasite of a single species attacks the individual host.

[9] The term "multiple parasitism" indicates that two or more different species of primary parasites attack the same individual.

varies in degree from year to year and is shown by the following examples: 1 larva gave 1 Compsilura and 1 Pelatachina; 1 larva gave 3 Compsilura and 1 Pelatachina; 1 larva gave 5 Compsilura and 1 Pelatachina; 1 larva gave 2 Compsilura and 2 Pelatachina; 1 larva gave 1 Compsilura and 2 Pelatachina.

From material reared in bulk, 61 larvæ gave 67 Compsilura and 75 Pelatachina; 100 larvæ gave 69 Compsilura and 15 Pelatachina; 52 larvæ gave 70 Compsilura and 29 Pelatachina; 80 larvæ gave 7 Compsilura and 107 Pelatachina.

The aggregate of superparsitism far exceeds that of multiple parasitism. Individual rearings have shown as many as 4 Pelatachina to a single host and with Compsilura as many as 6 per host. Other collections from which Pelatachina alone was reared furnish striking examples of this sort of parasitism; 5 larvæ gave 15 Pelatachina; 89 larvæ gave 90 Pelatachina.

There are similar records for Compsilura, some of which are as follows: 8 larvæ gave 23 Compsilura; 10 larvæ gave 50 Compsilura; 41 larvæ gave 108 Compsilura.

The presence of a hymenopterous parasite (*Hyposoter* n. sp.) makes the problem still more intricate. Frequent rearings of this species were obtained during 1915 and again in 1919. In 1921, five cocoons were obtained and from these adults were secured in the spring of 1922. This species hibernating in its cocoon is one of the most difficult to rear to the adult stage.

The conclusions drawn from the records of the writers indicate that the presence of Compsilura is not detrimental to any great extent to the native tachinid. It is realized, of course, that there is a considerable amount of duplicate parasitism and that the native tachinid may suffer somewhat through the aggressiveness of Compsilura. On the other hand, the records show that Pelatachina emerges at least two weeks and, in most instances, three weeks before Compsilura; it is no doubt owing to this fact primarily that it is able to compete successfully with the introduced parasite. It is probable that during this period, while its attack is unhampered, its effectiveness is most pronounced and that by the time Compsilura appears the development of its progeny has progressed to such a degree that it is in no way affected by that species. Furthermore, the fact that Pelatachina is single-brooded and has never been recovered from the collections of *Euvanessa antiopa* made in summer months adds much to the credit of Compsilura. The records show that the most that can be expected from this species (Pelatachina) is its check upon the first generation; and, as the host species may be found in the field up to October, it would therefore be allowed to increase without restraint as far as that species is concerned were it not for Compsilura.[10]

Polygonia interrogationis Fab. is an excellent host. It is of little economic importance, and is usually found in small numbers on the elm. In New York, it is somewhat injurious to hop vines but is believed to be held in check by the chalcis fly *Pteromalus vanessae*

[10] Collections received from places outside the Compsilura territory, made during a period of two years, aggregate over 1,000 larvæ. From these collections Pelatachina has frequently been reared, but on two occasions only has any other tachinid been obtained. This species, *Phorocera claripennis* Macq. (two individuals reared), is of apparently little importance in its relation to *E. antiopa*.

Harris (*5, p. 213*). The writers have never succeeded in rearing this parasite, but they have obtained records of two Hymenoptera, *Amblyteles caliginosus* Cress. and *Hoplismenus morulus* Say.

The species *Aglais milberti*, *Vanessa atalanta*, *Vanessa huntera*, and *Polygonia comma* are nearly always found just a few feet above the ground, feeding on nettle and everlasting. The two former usually feed in colonies, the two latter are apparently not so gregarious. All are favorable hosts.

In its struggle with the native tachinids, there is little fear that Compsilura may not be fully capable of taking care of itself; but it is less certain that it can successfully compete with certain Hymenoptera. In the collections of *Aglais milberti* (1917, 1918) there are but two parasites of importance, the hymenopteron *Apanteles atalantae* Pack. and Compsilura. *A. atalantae* is gregarious and is reared more frequently than the tachinid. The latter, however, breeds freely upon this host, and it is a frequent occurrence to rear five or six from a single individual. A few rearing records showing the best examples of superparasitism are as follows:

From a collection of 143 larvæ, 34 were killed by *Apanteles atalantae*, and from the remaining larvæ (109) there were reared 310 Compsilura. No adults of *Aglais milberti* were secured. From a collection of 101 larvæ, 74 were killed by *Apanteles atalantae* and from the remaining larvæ (27) there were reared 41 Compsilura. A single adult *Aglais milberti* issued. From 19 larvæ, there were reared 53 Compsilura. No host adults issued. From 26 larvæ there were reared 40 Compsilura. No host adults issued.

Of the two parasites, Compsilura and *Apanteles atalantae*, the latter has much the advantage, because of its ability to attack the host in an earlier stage. It is probable that, if any parasite which is capable of attacking the early-stage caterpillars should compete with Compsilura, the latter species would be the loser. This is the case as regards *A. atalantae*, for here there is a considerable number of progeny already well advanced in development before the host is subject to the attack of Compsilura. It is assumed that if the host already parasitized by *A. atalantae* was in turn attacked by Compsilura there would be but little chance for its development, since the parasites would crowd it out. This opinion is strengthened by the absence of multiple parasitism in this species. *A. atalantae* attacks the larva in the first and second stages only. This habit, as previously noted, has its advantages; and yet, because of it, those individuals which have reached the third stage and have escaped the attack of that parasite are free to develop without apparent check.[11] It is from the third stage on that Compsilura proves its worth; and, although it probably wastes many of its progeny in futile attempts at parasitism on some already parasitized host, it nevertheless accomplishes its purpose and must be credited with a considerable amount of parasitism.

Vanessa atalanta L., a species closely allied to *Aglais milberti* and similar in habits and behavior, is at times heavily parasitized by Compsilura. For example, a collection of 25 last-stage larvæ

---

[11] This fact, and also taking into consideration the rearing of a few specimens of (*Exorista*) *Zenillia futilis* O. S. and *Winthemia quadripustulata* Fab., would perhaps indicate some interference from Compsilura.

was received from Deering, N. H., July 30, 1915, and from them 20 Compsilura were obtained. No other parasites were reared; and, since this was the only collection obtained during 1915, there are very few data concerning the species for that year. No material was collected in 1916, and only 9 specimens received during 1917. The species was plentiful during 1918, 1919, and 1920, being especially abundant in 1919. The position occupied by Compsilura in its relation to this species is about the same as in *A. milberti*, except that it is still more complicated by the presence of two native tachinids (*Frontina archippivora* Will. and [*Exorista*] *Zenillia futilis* O. S.). The hymenopteron *Apanteles atalantae* Pack. is present in considerable numbers, but the true struggle lies between the tachinids themselves. There is little to guide us in determining the status of *F. archippivora*. From 25 collections, this species was bred from but 4, and, except in the case of 1 collection, only 5 specimens were recovered. The exception, however, proves somewhat confusing, as in this instance 17 flies were reared from 16 larvæ. Biologically, the species is distinct from the other two, its method of reproduction being that of oviposition on host. The writers' records indicate *Anosia plexippus* as its primary host, although Coquillett (*1 p. 15*) lists it from seven others, among which are two species of the genus Vanessa. Eliminating Frontina, the contest narrows to (*Exorista*) *Zenillia futilis* and Compsilura; and, although there were many more Zenillia reared in 1919 [12], the results of the year previous were much in favor of Compsilura. Parasite summaries of 1918 show five times as many Compsilura as *Z. futilis*. The 1920 results resembled those of 1919, showing but one record of Compsilura. Apparently Compsilura has the worst of the argument and the explanation may lie in its biology. *Z. futilis* belongs to the masiceratine series (species whose reproductive habit is leaf oviposition of microtype eggs), whereas the method of Compsilura is larviposition. The latter species is double-brooded and has a number of hosts. In the species belonging to the first series the capacity for reproduction is enormous, the uterus usually containing hundreds of eggs, whereas Compsilura is far less fecund. Considering the method of reproduction of the former parasite, it is not surprising that it is able to work advantageously, particularly in this instance, where the host is gregarious, the larvæ clustered together on a limited patch of nettle. Superparasitism is obvious in a few of the collections but multiple parasitism is rare, only one instance being recorded (*Z. futilis* and *A. atalantae*).

Charidryas nycteis D. and H. passes the winter as a larva and attains its full growth by the middle of June. Adults issue shortly thereafter and their offspring may be found from late July until the ensuing spring. The food plants are chiefly aster and goldenrod. All of the collections have been small and infrequently received. The species is probably of little host value, since most of the larvæ attain their full development so early in the spring, at about the time when Compsilura emerges.

---

[12] From 22 collections of this species, Zenillia was reared from 17 and a total of 249 puparia was obtained; Compsilura was present in 6 collections only and only 20 puparia were recovered.

Species of Basilarchia are distinct from any of the above both in larval appearance and in behavior. The species *archippus* Cramer is most commonly received, there being only a few collections of *astyanax* Fab. The food plants of the former are numerous, with poplar and willow most in favor. Like *Charidryas nycteis*, it passes the winter in the second or third larval stage, but not gregariously. The collections of the early-stage larvæ are exceedingly limited, but there are enough data to indicate considerable parasitism by *Apanteles limenitidis* Riley. There is at least a partial second generation, and it is not uncommon to find full-grown larvae up to frost. Although of a solitary nature, *B. archippus* is constant in its appearance and is often found in large numbers. Since the larvæ in the last stages seem to be peculiarly free from insect enemies (there are no rearing records other than Compsilura), few species are better hosts; and, from the records, it is apparent that Compsilura has made the most of its opportunity. From a total of 81 collections, this parasite has been obtained from 35. Free from competition as it is in this case, it its not at all surprising to find a high degree of parasitism. Some rearing results suggestive of this are as follows: 19 larvæ gave 48 Compsilura and 5 *B. archippus;* 17 larvæ gave 34 Compsilura and no *B. archippus;* 10 larvæ gave 17 Compsilura and no *B. archippus;* 3 larvæ gave 9 Compsilura and no *B. archippus;* 12 larvæ gave 21 Compsilura and 2 *B. archippus;* 16 larvæ gave 26 Compsilura and no *B. archippus.*

Obviously there is much superparasitism, and individual rearings have often registered from three to seven parasites per host.

NOTODONTIDAE

Insects of still another group, the Notodontidae, are to be classed with the favored hosts. These insects commonly appear in the field in late summer and specimens can be found until cold weather puts a stop to all insect activity.

Species of the genus Datana (*integerrima* G. and R., *ministra* Dru., *major* G. and R., *perspicua* G. and R., and *angusii* G. and R.) are gregarious and have a variety of food plants. One species or another is usually abundant in restricted localities; and, although Compsilura is commonly reared during the fall, it has never been reared from overwintering pupæ.[13] For some reason, there is great difficulty in rearing some of the Datanas and successfully overwintering the pupæ. This is particularly true of the walnut caterpillar (*D. integerrima*), a species common on black walnut. Because of its great abundance it is of especial interest as a host possibility, but owing to the heavy mortality of the larva when reared under artificial conditions, there are few data for judging its status. About all that can be said is that it has given one or more Compsilura for three years in five. It was from this host, too, that several Compsilura were reared in 1921, establishing a new dispersion record for that parasite.[14]

[13] Since the above was written, Compsilura has been reared on two occasions from overwintering pupæ.

[14] A collection of 200 fourth-stage larvæ collected at the gipsy-moth infestation at Greenport, L. I., August 16, 1921, gave five Compsilura in September, 1921.

Heterocampa guttivitta Walk. and *Heterocampa umbrata* Walk. pass the winter as pupæ. The former is periodic in abundance, the latter never so. It is, in fact, rather rare, only a few specimens reaching the laboratory during the entire period in which collections were made. The food plants of both are chiefly maple and beech. Neither of the species is nearly so favorable as the Datanas.

Melalopha inclusa Hübn. is a tent-making species and hibernates as a pupa. The species feeds on willow and poplar and has been received in abundance during the last three years. *Frontina frenchii*, *Eulimnerium validum* Cress., and *Apanteles sarrothripae* Weed seem to be its chief parasites. The species has given Compsilura several times but it can not be considered highly as a host.

Pheosia rimosa Pack. is solitary; its food plants are willow and poplar. It is uncommon and only during the last year have there been received any good-sized collections. It has about the same status as the species of Heterocampa.

Larvæ of the red-humped caterpillar (*Schizura concinna* S. and A.) are found in the field from July to October. This species hibernates in the prepupal stage under leaves and rubbish. Its food plants are varied, apple, birch, willow, and bayberry being much favored. It is common in many localities and is one of the insects most constantly received. It is at times much favored by Compsilura as a summer host, but is of little consequence as a winter one. It has on one occasion, however, given Compsilura in the spring.

In *Schizura concinna*, Compsilura meets with considerable competition from *Winthemia quadripustulata*, *Phorocera claripennis*, *Phorocera erecta*, and *Gymnophthalma americana* Town. The last named, however, attacks the larvæ in an earlier stage than the rest, and its growth is so far advanced by the time the host larva is attacked by the others that it probably has no trouble in maturing. At any rate, a very good percentage of parasitism is maintained each year by *G. americana.* A summary of the tachinid parasites shows that the combined efforts of the native species (*G. americana* excepted) are less effective than that of the exotic. Such may not always be the case, however, for in its relationship to this host Compsilura is most variable. Certain years have given but a negligible amount of parasitism, whereas others have given a parasitism as high as the most favorable host. The principal hymenopterous parasites seem to be *Hyposoter fugitivus* Say and *Eulimnerium validum* Cress. These species attack the host in the second and third stages, the former usually issuing from the fourth and fifth stages and the latter from the cocoons.

Schizura unicornis S. and A. is apparently a solitary species and has always been received in small numbers, usually during September. The larvæ feed upon a great variety of food plants. There is but one record of rearing Compsilura from it and that was from a full-grown larva collected in the fall, the parasite issuing the following spring.

Cerura occidentalis Lint. also appears to be solitary and the collections of it are always small. The larvæ are found chiefly on willow and poplar. Compsilura has been reared only once, the adult issuing during August from a larva collected in July.

ARCTIIDAE

Differing but slightly from the liparids in behavior and in external appearance are the arctiids. Compsilura shows marked partiality for the species noted below.

The yellow-bear caterpillar (*Diacrisia virginica* Fab.) and the salt-marsh caterpillar (*Estigmene acraea* Dru.) are both common species and, although solitary, are often found in abundance. They have a long period in the field, from June until November, and a great variety of food plants. Both are favorable to Compsilura, particularly the former, it being without doubt one of the most acceptable winter hosts.

The tussock caterpillars *Halisidota caryae* Harr. and *Halisidota tessellaris* S. and A.[15] are gregarious. They are general feeders and are occasionally reported as injurious. There is but one generation, the insects pupating in the fall and passing the winter in that stage. Several of the collections have given hymenopterous parasites, especially those of *tessellaris*, but there are few records of Compsilura. Of the two species, *caryae* is the most favorable.

Euchaetias egle Dru. is also gregarious but, unlike the species of Halisidota referred to above, its food plants are limited and it has never been found by the writers on anything but milkweed. In New England it is apparently single brooded; the larvæ are usually found in August and September, pupating during the latter month and hibernating in that stage. There are a number of parasites both hymenopterous and tachinid, the latter perhaps being the more common. Not only does this species serve as an admirable alternate, but it is also an excellent hibernating host. Four of the five tachinids often bred from *E. egle* are the same species as those secured from *Hemerocampa leucostigma;* that is, Compsilura, *Tachina mella*, *Phorocera claripennis*, and *Frontina frenchii.*

Several other species of this family, solitary in nature, and as yet undetermined, have yielded the parasite. On the other hand, certain species previously cited are for some reason or other seemingly unsuitable.

NOCTUIDAE, AGARISTIDAE, AND PYRALIDAE

In the family Noctuidae are found the most divergent forms both in behavior and in external appearance. Species belonging to the genera Apatela, Arsilonche, Mamestra, Catocala, Nadata, Euthisanotia, Calpe, Pyrophila, Plathypena, Scoliopteryx, Autographa, Cirphis, Plusiodonta, and Rhodophora have all yielded Compsilura.

Only one of these, however, *Autographa brassicae*, has been at all constant in its abundance; and, although Compsilura has been occasionally reared from it, there is little to be said in its favor. In the collections, it is always closely associated with *Pontia rapae* and, like that species, has but few parasites.

Apatela americana Harris is rather a common species, but it is never received in large numbers. It is usually found late in the fall feeding upon maple, oak, and other growth. It is solitary and passes the winter as a pupa. Compsilura and *Tachina mella* have been

---

[15] *Halisidota tessellaris* is perhaps found more often, in the last stages, as a solitary larva.

reared from overwintering material. *Rogas stigmator* Say has also been bred, five adults issuing in September from a larva collected during that month.

Collections of *Apatela furcifera* Guen. extend over a period of seven years. The larvæ are found in the field from the middle of June until the latter part of September. The food plants of this species seem restricted to the various varieties of cherry. It is not considered uncommon, although it has never been received in abundance. From these collections (83 individuals) there has never been reared any other tachinid than Compsilura. On three occasions only have any hymenopterous parasites appeared, species belonging to the genera Apanteles, Meteorus, and Rogas being bred. *A. furcifera* is of first importance as a summer and winter host of Compsilura.

Apatela brumosa Guen. and another species of Apatela as yet undetermined are never found in abundance but are received in small numbers each year. The insects are usually found in the woodlands, principally on willow, birch, cherry, and oak. Larvæ of these species may be found in the field from the middle of June until September and, although never abundant, are among the most sought of the host insects.

Calpe canadensis Beth. appears early in June; it is common and sometimes plentiful. There seems to be but a single generation, the adults issuing during July. The larvæ feed principally upon meadowrue (Thalictrum) and are somewhat difficult to find because of their protective coloration. Perhaps because of this, only a limited number of Compsilura has been bred.

Scoliopteryx libatrix L. is either double-brooded or else has a very remarkable larval stage. It is a rather rare species in the writer's collections, only 12 specimens having been received in eight years. It is said to hibernate as an adult, the food plants being listed as willow, poplar, and cherry. Unlike many of the noctuids it does not enter the soil to pupate but transforms within its cocoon attached to the twigs of the host plant. Like *Calpe canadensis*, the species is well protected by its coloration and has given a few Compsilura.

The zebra caterpillar (*Mamestra picta* Grote), *Mamestra legitima* Grote, *M. adjuncta* Boisd., and *Pyrophila pyramidoides* Guen. are all acceptable as hosts to Compsilura. They are, as a rule, garden-crop insects, and the two former are at times very abundant. All of them hibernate as pupæ beneath the soil.

Arsilonche albovenosa is ordinarily found on marshland. Cattail (*Typha latifolia* L.) and the various marsh grasses are its chief food plants. It ranges in the field from June until October, hibernates as a pupa, and is considered a favorable host. Besides Compsilura, another tachinid, *Masicera* sp., overwinters in this host. There have also been two hymenopterous parasites bred, *Rogas stigmator* Say and *Microplitis quadridentatus* Prov.

Euthisanotia grata Fab. is rather uncommon. It appears in the field during the latter part of July and feeds principally on grape and Virginia creeper. It is an acceptable host, but the collections have been small and the data give little idea of its true status.

Nadata gibbosa S. and A. is a species not uncommon, appearing in the field during July and August and overwintering as a pupa.

Food plants are given as maple, beech, and birch. It is a favorable host for Compsilura.

The green clover worm (*Plathypena scabra* Fab.) was abundant for one year only. Several good-sized collections were obtained and from them were reared Compsilura, *Winthemia quadripustulata*, and *Archytas aterrima* Desv. The species feeds chiefly on clover but at times causes considerable injury to the pea and bean crops. Hibernation takes place in the adult and pupal stages.

Plusiodonta compressipalpis Guen. and *Rhodophora florida* Guen. are present in the locality, but they have never appeared in the laboratory collections. Both of the records are from Reiff[16] rearings. The species probably hibernate as pupæ.

The army worm (*Cirphis unipuncta* Haw.) is a favorable host for Compsilura. It is found throughout the entire season from May until frost. Hibernation is in the caterpillar stage usually, although the insect is said to overwinter sometimes as an adult. It is of national importance, and serious outbreaks, either locally or over a wide area, are not uncommon. Tachinid flies play an important part in the natural control of this species and their success has probably increased since the advent of Compsilura. During the last eight years only a few collections of *C. unipuncta* were received at the laboratory, but in 1914 several good-sized collections were secured. From these collections there was obtained a very good percentage of parasitism by Compsilura. In the various host and parasite lists where this species appears there are many tachinids recorded but only five of them have been reared at the laboratory. Of these native parasites, *Winthemia quadripustulata* Fab. is the only one of consequence and the recoveries of this species, although many times greater than all of the rest combined, are not comparable to Compsilura. For example: Six collections, totaling nearly 1,000 larvæ (from six localities) gave nearly twice as many Compsilura as Winthemia.

The eight-spotted forester (*Alypia octomaculata* Fab.) is received commonly in small numbers and was once obtained in abundance. The species feeds on grape and woodbine. It hibernates as a pupa and is of little host value. The records show three native tachinid parasites, (*Exorista*) *Zenillia eudryae* Town., *Chaetophlepsis tarsalis* Town., and *Winthemia quadripustulata* Fab., and a few Compsilura. A summary of the parasite records would indicate the superiority of the native species.

Evergestis straminalis Hübn. is of little or no host value at the present time. It is constant in its appearance, however, and might, should there be an absence of favorable hosts, prove more worthy. The insect is found in gardens feeding mostly on radish and turnip. It hibernates as a pupa beneath the soil.

Catocala sp.: The great difficulty experienced in separating the larvæ of this genus necessitated their treatment as a single group. There are at least five species represented in the collections. In most cases the larvæ have been received in small numbers during May and June, sometimes in July. Compsilura was recovered from two larvæ collected in June, 1922. Catocala is of doubtful host value.

---

[16] William Reiff, Forest Hills, Mass., 1913.

GEOMETRIDAE

Phigalia titea Cram. was very abundant for several years but is now scarcely to be found. It has a variety of food plants, chiefly oak, elm, and chestnut. It appears in the field early in June and hibernates as a pupa. It is not a satisfactory host for Compsilura.

Hydria undulata L. is a somewhat common, gregarious species, the larvæ of which web together the leaves of wild black cherry. Although a great number of collections have been received at the laboratory, it was not until 1922 that Compsilura was recovered. The recovery of 2 adults from 6 larvæ in one case and 11 adults from 200 in another would ordinarily be considered a fair host record, were it not for the fact that all the past collections have resulted in failure. In all probability this host was abundant at a time when there was a shortage of favored ones.

Ennomos subsignarius Hübn. is a gregarious species and was found in great abundance for three or four years, less abundantly the fifth, difficult to find the sixth, and entirely absent the seventh and eighth years. Larvæ appear in the field early in May, complete their larval stages in June, and issue as adults in July. The species feeds on red maple principally and hibernates in the egg stage. It has never been a much favored host.

Cingilia catenaria Dru. has been received in abundance only during the last four years. It appears in the field during late June and has a great variety of food plants, including false indigo, birch, huckleberry, and cherry. The species hibernates in the egg stage. It has given a considerable number of Compsilura and has a better host value than any other of the geometrids.

Lycia cognataria Guen. and an unidentified geometrid are solitary and are never found in abundance; the former feeds on willow and hibernates as a pupa. As host insects their value is small.

LYMNADIDAE

Anosia plexippus L. was received in abundance in 1918 and in smaller numbers the two preceding years. During 1919 to 1921, inclusive, there were no collections received. In 1922, the insect was found in small numbers and the 14 collections received represent only a few individuals. The species is still scarce. Without exception, its food plant is given as milkweed. The species is migratory and winters as an adult in the Southwest. Three native parasites are recorded from it and one of these, *Frontina archippivora* Will., is of prime importance. The two remaining species (*Winthemia obscura* Coq. and [*Exorista*] *Zenillia vulgaris* Fall.) are apparently of little consequence. Frontina appears to meet but little opposition from Compsilura and the sum total of its parasitism is much greater. Over 50 per cent of the collections have given Frontina, whereas Compsilura was recovered from only 11 collections. Superparasitism is common with both species but particularly with Frontina, where the average from one collection of 22 larvæ was 4.86 per individual. The best records found for Compsilura are three adults per individual. Multiple parasitism is uncommon, there being no instance noted by the writers. In a general way, Anosia can be considered a favorable host for Compsilura.

PAPILIONIDAE

The species *Papilio polyxenes* Fab. and *Papilio troilus* L. have been discussed elsewhere in this bulletin. *Papilio turnus* L., a species similar in habit to the others of its genus, has given Compsilura frequently. It is very probable that the future will show this species to be of the same host value as its relatives.

PIERIDAE

The cabbage worm (*Pontia rapae* L.) is nearly always to be found in abundance in some locality or other. It hibernates in the chrysalid stage. It is an acceptable host and, because of its abundance and wide distribution, possesses a certain attractiveness. In 1910, Tothill (*7, p. 223*) succeeded in rearing a great many flies and, in some instances, a total of 40 per cent parasitism was obtained. Some years later, Culver,[17] who had received large collections of this material for life-history work, recorded a fair amount of parasitism, but in no case did he equal the record of the former investigator. In contrast to these records, however, the data obtained by the writers show but little parasitism.

SATURNIIDAE

Callosamia promethea Dru., *Telea polyphemus* Cramer, *Samia cecropia* L., *Automeris io* Fab., and *Hemileuca maia* Dru. are five species of doubtful host value. From the last-named Compsilura has been reared occasionally, but considering the hundreds of larvæ of all stages used in the experiments, the host value of this insect is insignificant.

As has been previously stated, the value of *Callosamia promethea* Dru. as a winter host for Compsilura appears to be negligible. Its status as a summer host is apparently much more important. Since Culver [18] found, while experimenting with this species and Compsilura, that he could readily obtain larviposition and successfully rear adults when using early-stage caterpillars, there seems little doubt that were large collections of early-stage larvæ received, a fair amount of parasitism would be recorded.

The collections of *Telea polyphemus* Cram. have nearly always been made in the pupal stage and no Compsilura were recovered from them. It is sufficient to say that, in three separate collections of one larva each, there were obtained two Compsilura from one of them.

Samia cecropia L. seems to have about the same host status as *T. polyphemus.* The material when collected as cocoons has never given Compsilura. Larval collections, however, show better results. A single instance of the rearing of four flies from nine third-stage and fourth-stage larvæ is recorded.

Automeris io Fab. has a greater host value than any of the saturniids mentioned. Although none of the collections received prior to 1922 has given Compsilura, the recoveries made that year were gratifying. Furthermore, all of the material was from New York, at points well outside the gipsy-moth area. From these records there

---

[17] Gipsy Moth Laboratory Records, 1917–18.

was established a new dispersion line for Compsilura. (*Phorocera claripennis* Macq. was the only other tachinid reared.)

SPHINGIDAE

Deilephila gallii Rott. and *Deidamia inscriptum* Harr. have both been taken abundantly near lights, but they appear only occasionally in collections received by the writers. The larvæ of both species appear in the field from July until October. The former feed on Galium and primrose, the latter on grape and Virginia creeper. Both species hibernate as pupæ. Their host status is favorable.

Deilephila lineata Fab. was received intermittently over a period of eight years. The larvæ are usually found feeding on Portulaca. There are probably two generations, the later one hibernating as pupæ. Most of the collections were received during September and October. An exception to this was the receipt of one last-stage larva collected July 21, from which two Compsilura emerged August 14, 1922. The host status is favorable.

The northern tobacco hornworm or tomato worm (*Phlegethontius quinquemaculata* Haw.) is constant in its appearance and is in the field from July until October. It feeds on tomato and hibernates in the earth as a pupa. As a summer host it has occasionally given Compsilura, and in all probability would be one of the most favored were it not for *Apanteles congregatus* Say. In this hymenopteron *P. quinquemaculata* finds its worst enemy, and it is with difficulty that specimens of mature larvæ are obtained free of this parasite. Possibly on account of its great size a number of the larvæ harbor both Apanteles and Compsilura. As many as three adult Compsilura per larva have been obtained from material previously parasitized by Apanteles. The species should be a good host for overwintering Compsilura, but since it is difficult to handle in confinement during hibernation there are few data on its fitness.

Hemaris thysbe Fab. has been received but three times in eight years. It has about the same life history as *Phlegethontius quinquemaculata* and feeds chiefly on Viburnum. It is a very acceptable host.

HESPERIIDAE AND CERATOCAMPIDAE

Epargyreus tityrus Fab. has been received in good-sized collections only once in eight years. The species feeds on a variety of food plants, principally locust (*Robinia pseudoacacia* L.) and groundnut (*Apios tuberosa* Moench). It appears in the field during July, and specimens are to be found until late October. It hibernates as a pupa and is of fair value as a host. The parasitism by the Hymenoptera is negligible, as is also the case with the tachinids other than Compsilura. This fly alone has been reared in considerable numbers, especially during 1921.

The orange-striped oak worm (*Anisota senatoria* S. and A.) is abundant at times and has been received in particularly large numbers during the last two years. The species feeds principally on oak and hibernates as a pupa. A few of the collections have given Compsilura, but the native parasites predominate. Among the tachinids, *Frontina frenchii* Will., *Winthemia quadripustulata* Fab., (*Exorista*) *Zenillia ceratomiae* Coq., and *Sturmia* sp. were reared.

The principal Hymenoptera were *Hyposoter fugitivus* Say and *Apanteles anisotae* Mues.

A number of collections of the green-striped maple worm (*Anisota rubicunda* Fab.) were received during 1919 and 1921, most of them coming from Western Massachusetts and New Hampshire. Usually *A. rubicunda* is to be found in company with *Heterocampa guttivitta.* The species feeds principally upon maple and hibernates as a pupa. Several specimens of *Frontina frenchii* Will. and a species of Sturmia have been bred. There is but one rearing record credited to Compsilura.

COCHLIDIIDAE

Native species of the family Cochlidiidae are rarely sent to the laboratory and none have ever given Compsilura. Collections of the exotic oriental moth *Cnidocampa flavescens* Walk. were received in large numbers during 1917 and 1922. The species has but a single generation, the winter being passed in the prepupal stage. During 1922 weekly collections of the larvæ were received, aggregating nearly 1,200 individuals. From this material a single Compsilura was reared, the adult issuing in September. The host value of the species is apparently slight.

TENTHREDINOIDEA

The large elm and willow sawfly (*Cimbex americana* Leach) is constant in its appearance and is in the field from July until September. Only once during a period of eight years has it been abundant and then the infestation was confined to a small area. Willow and elm seem the most favored food plants. There is but one generation, the last-stage larva burrowing in the ground and forming its cocoon, where it passes the winter as a larva, pupating in the spring. It offers little attraction to Compsilura.

Croesus latitarsus Nort. is a very common species found abundantly each year on gray birch. It has at least a partial second generation and larvæ of this species are in the field from the middle of June until October. The larva passes the winter within its cocoon and pupates in the spring. It is possible that Compsilura attacks this species more than is recognized, for the examination of cocoons has revealed a certain amount of unlooked-for parasitism that may be of considerable importance. Dissections have shown that in some instances the cocoons contained adult Compsilura which were unable to work their way out. Culver (gipsy-moth laboratory records) made a similar finding in his experiments with the last-stage larvæ of *Bombyx mori*, the larvæ being freely attacked, the parasite maturing within the host pupa and being unable to emerge because of the tough cocoon.

Neurotoma fasciata Nort. is a gregarious species commonly received each year in fair abundance. The larvæ feed upon cherry, webbing the leaves together and leaving their nest only when they seek the earth for hibernation. The period of hibernation in New England usually extends over two seasons. (Larvæ collected in September, 1920, gave adults in May and June, 1922.) Owing to the extreme difficulty in overwintering the prepupæ, very few adults have been obtained. At most, the parasitism of this species by Compsilura is negligible.

Pteronidea coryla Cress., a rather uncommon species, has been received at the laboratory but twice, in June and September, 1921. Evidently there are two generations, individuals of the later one passing the winter in their cocoons, the adults issuing the following spring. The larvæ are gregarious and feed in colonies on hazel nut (*Corylus americana* Walt.). The collections, aggregating about 100 larvæ, gave mostly adults, there being but one parasite, Compsilura, a female fly issuing in July, 1921.

The imported currant worm (*Pteronidea ribesi* Scop.) has been abundantly received over a period of eight years. There are two or at least a partial second generation, cocoons [18] of either generation overwintering in soil. It is of very little, if any, importance as a host, for Compsilura has been reared from it on only one occasion.

COLEOPTERA

So accustomed have we grown to the ever-increasing host list of Compsilura that a new record obtained from some lepidopteron causes but little comment. There have been but few collections of coleopterous larvæ, however, and none has ever given the parasite. A rearing attended by peculiar circumstances was reported to the writers by C. W. Johnson, of the Boston Society of Natural History, who in 1914 recovered the parasite from the white-pine weevil (*Pissodes strobi* Peck). In September of that year he was looking over some of the mounted specimens of various insects in the Libby Museum at Wolfboro, N. H. One mount containing a terminal shoot of white pine, illustrating the work of the weevil, contained a fly which seemed out of place. Upon inquiry it was found that the mount had been made up as usual and that the fly must obviously have issued after the mount was completed. At Johnson's request the fly was given him, and he identified it as *Compsilura concinnata*. Since there was no puparium in sight, the maggot evidently pupated within the burrow of the host.

RECORDS OF COMPSILURA REARINGS OTHER THAN THOSE RECORDED AT THE GIPSY MOTH LABORATORY

The writers are indebted to D. W. Jones, of the European Corn Borer Laboratory, Arlington, Mass., for the following notes on Compsilura:

> *Compsilura concinnata* Meig. has been bred from the European corn borer (*Pyrausta nubilalis* Hübn.) several times during the last few years. We consider it of little importance as a parasite of that species.

To C. W. Johnson, the writers are indebted for the following:

Thanaos brizo B. and L. April 19, 1920.
Symmerista albifrons S. and A.
(Rearings by E. T. Learned, Fall River, Mass.)
Diprion simile Hartig. April 15, 1921.
(Rearing record of M. P. Zappe, New Haven, Conn.)

EFFECT UPON NATIVE PARASITES

What the final outcome of the introduction of Compsilura will be is for the future to decide. What has been accomplished by the

[18] The species probably hibernates as a larva within its cocoon.

establishment of Compsilura, by its subsequent parasitism upon native species, and by its present relation to the native parasites, is more obvious.

As regards the majority of native parasites there is little to indicate anything detrimental to their welfare in the introduction of Compsilura, except an occasional scarcity of host material brought about by the successful attack of this insect. That this absence of host material is in itself of importance, inasmuch as it might materially change or upset the natural balance already existing, does not seem to be borne out by the records of the writers. It is true that there were no systematic collections of native larvæ prior to 1915 against which to check the larval collections of the last few years; there is, however, first-hand knowledge concerning serious outbreaks of native insects in this locality since 1907. The abundance of any insects for which the introduction of Compsilura might be held responsible, because of its interference with the native parasites of the species in question, has not been recorded. On the other hand, infestations of insects which are due for their periodic outbreaks are, so far as known, not on the increase. That there is a considerable amount of duplicate parasitism, there can be no doubt; and that this would be detrimental to one species or another, must also be true. Such an occurrence would take place in any case, however; and, although the presence of Compsilura probably adds to it, the results are not necessarily serious. It is possible that, because of the rapid larval development of Compsilura, it would crowd out forms which develop more slowly. This probably happens where Compsilura and a native tachinid attack the host simultaneously. If, however, the native tachinid were in a stage of development more advanced than that of Compsilura, the latter would in all probability be the loser. There are few positive data on the rapidity of development of many of the competing species, but it is believed that in some of them the development is much slower than in Compsilura.

What appears best to illustrate an occasion where there is a likelihood of Compsilura usurping the position of a native tachinid is found in its relation to *Tachina mella* Walk. Here is a species far less specialized than Compsilura, its reproductive habit being host-oviposition of a flat macrotype egg. Not only have the two species apparently similar hosts, but in nearly every instance where there is competition the native tachinid is the one that suffers most. That there has been a marked decrease in the number of *T. mella* in the gipsy-moth area since the establishment of Compsilura is probable. The parasite records of the writers show this, and there is corroborative evidence as well. Forbush and Fernald, in 1896 (*4, p. 388*), cited several instances of rearing *mella* from the gipsy moth. It is rare that any *mella* are reared to-day, however, and in their aggregate the larval collections of the gipsy moth are far greater than in the past. Forbush and Fernald (*4, p. 385*) call attention to the great number of tachinid eggs deposited upon gipsy-moth larvæ. It is possible, of course, that these eggs were not all laid by one species; but it is probable that a large percentage of them belonged to *T. mella*, as the records of rearing will show. During the past few years thousands of gipsy-moth larvæ have been sent to the laboratory and less than 1 per cent have tachinid eggs on them. Evidently one of two things has happened; either *mella* has found a host more favorable than the gipsy moth or it has suffered a marked decrease in numbers. The latter view is the more logical. Compsilura is not entirely responsible for this condition, however, for there must be considered the prodigious waste of eggs by *mella* upon the gipsy moth. In the studies of Forbush and Fernald (*4, p. 386*) made during July, 1895, it was found that, whereas about 29 per cent of the gipsy-moth larvæ had tachinid eggs on them, these were in nearly every case moulted off before hatching. It is obvious that, if this futile attack by *mella* continued at the same rate for several years, there would necessarily be a great scarcity of the species.

There are other instances besides that of *Tachina mella* in which the native tachinids meet with great competition, and a certain amount of duplicate parasitism results, in which the native species appear to be at a disadvantage.

The tachinids *Phorocera claripennis*, *Frontina frenchii*, and *Winthemia quadripustulata* have a great variety of hosts, nearly all of which are also acceptable to Compsilura. Like *Tachina mella* they deposit eggs on the host larva and so are handicapped by the subcutaneous larviposition of Compsilura. Probably *P. claripennis* fares the worst of these species, for with a single exception—*Lophyrus lecontei* Fitch—the host species are mutual. There is evidence to indicate that not only does this species overwinter as a larva within its host pupa, but that it often successfully hibernates in the puparium. This habit is of the greatest importance, for it should be borne in mind that Compsilura depends upon certain lepidopterous pupæ for hibernation and that the number of overwintering individuals is to that extent limited. The hibernating quarters of *claripennis*, on the other hand, are unlimited, and it can depend upon its abundance in the spring for successful competition.

Frontina frenchii and *Winthemia quadripustulata* seem to be the least affected by the presence of Compsilura. As has been previously mentioned, *frenchii* finds an excellent overwintering host in the saturniids and meets there with little competition from Compsilura. There are many examples of the value of *Samia cecropia* as a winter host for *frenchii*. Fiske and Thompson (*3*) reared it in large numbers and mention an instance in which 90 adults were reared from a single cocoon by C. H. T. Townsend. No other species met in the writer's studies proves itself so generous a host.

Of these native tachinids which possess the same general hosts as Compsilura, *Winthemia quadripustulata* seems best fitted for the contest. Not only does it more nearly approach Compsilura in the number of its hosts, but it also has a variety of others from which Compsilura has never been reared. It has, too, a decided advantage over Compsilura, inasmuch as it, like *Frontina frenchii*, has several hosts which are capable of supporting a large number of individuals. Finally, it also has the advantage of hibernation as a full-grown larva or in the pupal state.

Taken as a whole, the native larval collections reveal but few cases of tachinids peculiar to a single host. Among the species attacked by Compsilura, there were found but 10 where there is a single competing tachinid with apparently no other host. Of these, the majority are of no particular host value to Compsilura. In one case only, that of *Euvanessa antiopa* L., is there any serious competition, and here the native tachinid—*Pelatachina pellucida* Coq.—is well able to hold its own against Compsilura. A spring emergence at least two weeks in advance of Compsilura and an ability to hibernate in a puparium sufficiently guarantee its survival.

EFFECT UPON HOST SPECIES

Data concerning the relation of the native tachinids to their hosts prior to the introduction of Compsilura have been obtained through miscellaneous host records and published accounts of the insect. Data have also been obtained from two years of systematic collecting of native larvæ outside the Compsilura area, together with a few collections of larvæ made in a territory where Compsilura was hardly established.

From comparative data thus obtained and from what can be surmised, it seems very clear that the addition of Compsilura to our fauna has been of great benefit. Not only has it accomplished the purpose for which it was introduced, namely, to act as a primary parasite on the larvæ of the gipsy and brown-tail moths, but the rapidity of its dispersion has exceeded all expectations and it is now found established in an area independent of its primary hosts. It is in this area and especially along the outskirts of the moth infestation that the presence of Compsilura means so much. The reasons are twofold: (1) Its attack upon a light infestation of gipsy-moth larvæ, such as would be found along the border of the infested area, would be, or at least has always been, attended with maximum results, and the check exerted here is of the greatest importance; (2) possible dispersion of the gipsy-moth larvæ by the wind or otherwise in an unscouted area, and subsequent infestation, would result perhaps in complete annihilation by Compsilura. The establishment of Compsilura in this area is, of course, due to the alternate hosts upon which its existence is dependent.

Of the many native hosts from which Compsilura has been reared, at least one-half are decidedly favorable for its development. The fact that Compsilura has, since its introduction into New England in 1906, made its presence felt in no less than 92 species of native insects is in itself a manifestation of its efficiency. So thoroughly has this tachinid established itself in this region that it is now able to act as automatically as any native species whose mission is that of a controlling agent. Surely no better example of its ability to cope with the unexpected can be asked than its encounter with the satin moth (*Stilpnotia salicis*). Here an injurious insect, recently imported from Europe, in a single year appeared in astonishing numbers without the least semblance of control by native tachinids. It is extremely doubtful if any of the native parasites would have proved effective had they had the field to themselves. Fortunately, however, Compsilura had become acclimated, and the control exercised by it was remarkable. From certain last-stage larval collections, there have been obtained as high as 78 per cent parasitism. In their aggregate (last-stage larval collections) they will average at least 50 per cent parasitism. On the other hand, the sum total of the native tachinids obtained from 20 collections is but 19 individuals, less than 2 per cent parasitism. Although this is perhaps one of the most spectacular instances of Compsilura's potency, it is by no means exceptional. The accidental introduction of other dangerous insect pests into the United States is probable, and it is possible that Compsilura may again serve as efficiently as in the case just cited.

LITERATURE CITED

(1) Coquillett, D. W.
1897. Revision of the Tachinidæ of America north of Mexico. U. S. Dept. Agr., Div. Ent. Tech. Bul. 7, 156 pp.

(2) Culver, J. J.
1919. A study of *Compsilura concinnata,* an imported tachinid parasite of the gipsy moth and the brown-tail moth. U. S. Dept. Agr. Bul. 766, 27 pp., illus.

(3) Fiske, W. F., and W. R. Thompson.
1909. Notes on the parasites of the Saturniidae. *In* Jour. Econ. Ent., vol. 2, pp. 450–460.

(4) Forbush, E. H., and C. H. Fernald.
1896. The gypsy moth. *Porthetria dispar* (Linn.). 495 pp., illus. Boston. (Mass. Bd. Agr.)

(5) Hawley, I. M.
1918. Insects injurious to the hop in New York with special reference to the hop grub and the hop redbug. N. Y. Cornell Agr. Exp. Sta. Mem. 15, pp. 143–224, illus.

(6) Howard, L. O.
1897. A study in insect parasitism. U. S. Dept. Agr., Div. Ent. Tech. Bul. 5, 57 pp., illus.

(7) ——— and W. F. Fiske.
1911. The importation into the United States of the parasites of the gipsy moth and the brown-tail moth. U. S. Dept. Agr., Bur. Ent. Bul. 91, 344 pp., illus.

(8) Smith, H. E.
1917. Notes on New England Tachinidæ, with the description of one new genus and two new species. *In* Psyche, vol. 24, pp. 54–58.

(9) Tothill, J. D.
1922. The natural control of the fall webworm (*Hyphantria cunea* Drury) in Canada. Canada Dept. Agr. Bul. 3, n. s. (Ent. Bul. 19), 107 pp., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

January 16, 1926

Secretary of Agriculture	W. M. Jardine.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	———
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Information	Nelson Antrim Crawford.
Director of Personnel and Business Administration	W. W. Stockberger.
Solicitor	R. W. Williams.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Agricultural Economics	Thomas P. Cooper, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	W. B. Greeley, *Chief.*
Bureau of Chemistry	C. A. Browne, *Chief.*
Bureau of Soils	Milton Whitney, *Chief.*
Bureau of Entomology	L. O. Howard, *Chief.*
Bureau of Biological Survey	E. W. Nelson, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Bureau of Dairying	C. W. Larson, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. Cottrell, *Director.*
Office of Experiment Stations	E. W. Allen, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*
Insecticide and Fungicide Board	J. K. Haywood, *Chairman.*
Packers and Stockyards Administration	John T. Caine, *in Charge.*
Grain Futures Administration	J. W. T. Duvel, *in Charge.*

This bulletin is a contribution from

Bureau of Entomology	L. O. Howard, *Chief.*
Gipsy Moth and Brown-Tail Moth Investigations	A. F. Burgess, *in Charge.*

32

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1364

Washington, D. C. ▼ May, 1926

EFFECTS ON HONEYBEES OF SPRAYING FRUIT TREES WITH ARSENICALS

By N. E. McIndoo, *Entomologist, Fruit Insect Investigations*, and G. S. Demuth,[1] *Apicultural Assistant, Bee Culture Investigations, Bureau of Entomology.*

CONTENTS

INTRODUCTION

Ever since fruit trees have been sprayed with arsenicals beekeepers have been interested in the effect of this practice on the honeybee. Years ago, when sprayed materials were often applied while the trees were in full bloom, beekeepers became greatly excited and widely distributed literature entitled "Don't Spray While in Bloom." As a result of this agitation, according to Gates (*7*)[2] one Province in Canada and four States in the United States enacted laws prohibiting the spraying of fruit trees in full bloom. As late as December, 1920, there were laws to this effect in four States.

The subject of poisoning bees is very large and of vital interest, not only to beekeepers but to everyone who is interested directly

---

[1] Resigned June 30, 1923. The following men, who have also resigned from the Bureau of Entomology, had charge of the spraying in these experiments at their respective field stations: E. B. Blakeslee at Winchester, Va., 1914, 1915, and 1916; F. L. Simanton at Winthrop, Me., and at Benton Harbor, Mich., 1914 and 1915, respectively; and E. W. Geyer at Roswell, N. Mex., 1915. The junior writer did part of the work at Winchester, Va., 1915 and 1916, and at Fennville, Mich., 1916, and the senior writer did the remaining portion of the work here reported. Credit is due the Insecticide and Fungicide Laboratory, Bureau of Chemistry, for the chemical work reported in this bulletin.

[2] Reference is made by number (italic) to "Literature cited" p. 32.

56797°—26——1

or indirectly in the growing of crops, including particularly fruit growers, entomologists, and plant pathologists. Of course the beekeeper does not want his bees poisoned, chiefly because as a result his honey crop is reduced; but this loss is only secondary in comparison with the loss from lack of cross-pollination of flowers. In pollination the beekeeper, the fruit grower, and in fact everyone is benefited by honeybees. For several years evidence has been accumulating to prove beyond doubt that bees are extremely important as agents of pollination, and in fact should be protected and raised if only for this purpose. The honey they produce may be left for separate consideration.

The investigation here reported was begun in the spring of 1914 at the suggestion of Dr. A. L. Quaintance, in charge of fruit insect investigations, and was originally planned to determine the effect on honeybees of spraying fruit trees in full bloom. After one season's work in two States, it was ascertained that spraying at this stage under favorable conditions was detrimental to bees, and these results suggested that spraying even at the customary time, when at least 90 per cent of the petals have fallen, might be slightly injurious to them. This idea is in accord with the one which beekeepers often express by claiming theoretically that spraying fruit trees at any time is injurious to bees, the degrees of damage done depending on the time and on other conditions. Entomologists, however, do not recommend spraying orchards in full bloom (1) because the codling moth can be as well controlled by spraying when 90 per cent of the petals have fallen and (2) because spraying when the trees are in full bloom is injurious to insect pollinators.

After three seasons' work on this problem, in four States and five localities, it was determined that spraying at the customary time under nearly ideal conditions was not injurious to bees; but it will be noted that these nearly ideal conditions seldom occur.

Other projects were discussed and partially planned, but only one of these was finally investigated. The subject of the poisoning of bees by sprayed or dusted cover crops, often grown in orchards, is vitally important to beekeepers, but it seems that fruit growers pay little attention to this phase of the general subject of poisoning bees. This subject was only incidentally touched upon, as reported under the experiments performed at Roswell, N. Mex.

During the past few years it has become common to dust calcium arsenate or lead arsenate upon a large variety of plants, including fruit trees, flowering shrubs, fields of cotton, and even forest trees. This general practice of spreading poisons keeps the beekeepers constantly excited, although probably without warrant, and they have a feeling that their business may be doomed any day. Furthermore, it is now common in certain localities of the South to mix calcium arsenate with molasses and then to spray or to daub this poisonous mixture on cotton plants for the purpose of attracting and poisoning the boll weevil. As a part of this general project, the senior writer in July and August, 1922, carried on experiments at Tallulah, La., to determine the effects on honeybees of dusting cotton plants with calcium arsenate, and also of treating these plants with poisoned sweet mixtures. A summary of their results (*10*) has already been published, and, since there is no immediate prospect of doing more work along this general line, it is considered expedient to publish the result of the other, earlier work.

It is now generally admitted that in using arsenicals as a control for the codling moth the best results are in nearly all cases obtained by applying the first spray after most of the petals have fallen, although in commercial orchards where hundreds of acres of trees must be sprayed within a limited time it is necessary to begin spraying early in order to finish the work before the calyx cups close. Furthermore, in regions where the trees bloom irregularly, causing a long blooming period for an entire orchard, the trees sprayed vary from those in full bloom to those from which all the petals have fallen.

Many reports from beekeepers concerning the effect on the honeybee of spraying trees in full bloom have been published, but only a few systematic investigations have actually been carried on to determine whether or not the practice is injurious to bees. Some beekeepers believe that the honeybee is damaged slightly, even when the trees are sprayed at the customary time, after at least 90 per cent of the petals have dropped. No careful observations have been reported on this phase of the subject.

In the hope of reaching definite answers to some of these questions, so long debated, the writers planned and conducted the research here reported. Investigations, extending from 1914 to 1917, were made along three lines: (1) The effect on honeybees of spraying fruit trees in full bloom; (2) the effect on honeybees of spraying the trees at the customary time, after most of the petals have fallen; and (3) a determination of the minimum amount of arsenic required to kill bees in confinement.

EFFECT ON HONEYBEES OF SPRAYING FRUIT TREES IN FULL BLOOM

PRELIMINARY EXPERIMENTS, WINCHESTER, VA., 1914

Three small, more or less isolated orchards in full bloom, lying southeast of Winchester, Va., were selected in 1914 for the preliminary experiments. Three strong colonies of bees were installed in each orchard. Twenty-five trees in the first orchard were sprayed with a mixture of 5 ounces of Paris green, 1 gallon of limewater, and 49 gallons of water; 25 trees in the second orchard were sprayed with a mixture of 3 pounds of paste lead arsenate, 1 gallon of limewater and 49 gallons of water; and 25 trees in the third were sprayed with a mixture of 3 pounds of paste lead arsenate, 1.5 gallons of lime-sulphur and enough water to make 50 gallons in all.

As a result of these preliminary experiments the following points were ascertained: (1) Bees work equally as well on trees sprayed in full bloom as on unsprayed ones; (2) they do not fly away from the sprayed orchard very much if the orchard is well isolated; (3) they are slightly affected when a small orchard is sprayed in full bloom; this conclusion is supported by observations and by the analyses of the samples collected; and (4) of the three mixtures named, the lime-sulphur spray mixture is most satisfactory for experimental purposes, because the lime-sulphur in it serves well as a stain, so that the mixture can be easily seen on the foliage and blossoms. Its presence assures the observer that he is dealing with sprayed material when collecting blossoms for analyses and when watching bees at work on the supposedly sprayed flowers.

MORE EXTENDED EXPERIMENTS, WINTHROP, ME., 1914

It seemed desirable to continue on a larger scale the experimental work with the spray of lime-sulphur and lead arsenate. A large isolated commercial orchard in full bloom, almost ideally located three-fourths of a mile east of Winthrop, Me., was selected for that purpose. The orchard, consisting of 700 apple trees, was rectangular in form, bounded on the north by a 4-year-old orchard and a pasture, on the west by a pasture, on the south by cleared land and a 2-year-old orchard, on the east by a thicket, a lake, and a forest, and on the northeast by forest. There was a small orchard one-half mile north of this one and several commercial orchards one-half mile west of Winthrop. No other orchards were within sight of the one described.

Since only two small 7-frame hives of bees could be had at Winthrop, eight strong colonies belonging to the Bureau of Entomology were sent there by express from Philadelphia, Pa. All 10 colonies were free from brood disease.

APPLICATION OF SPRAY MIXTURE

Owing to a delay in the departure of the bees from Philadelphia, the spraying was begun before the bees were installed in the orchard. On May 25 and 26 Mr. Hinds, the owner of these trees, wishing to kill certain caterpillars, sprayed his entire orchard with a mixture of 4 pounds of paste lead arsenate and 1 quart of lime-sulphur to each 50 gallons of water, applying it with a 200-gallon power sprayer. On May 28 and 29, 310 of the trees, then in full bloom, were again sprayed, this time with a mixture composed of 3 pounds of paste lead arsenate and 1 pint of lime-sulphur to each 50 gallons of water

To kill the larvæ of the codling moth, *Carpocapsa pomonella* L., Mr. Hinds again sprayed the entire orchard on June 3, 5, and 6, using 3 pounds of paste lead arsenate and 1 gallon of lime-sulphur to each 50 gallons of water.

INSTALLATION OF BEES AND APPARATUS

The two colonies of bees procured at Winthrop were moved on May 29 from Mr. Wentworth's apiary, three-fourths of a mile northwest of that town, to the sprayed orchard. So far as could be determined none of the bees returned to their original location. The eight colonies from Philadelphia left there in the afternoon of May 27 and arrived at Winthrop late in the afternoon of May 29. They were installed in the orchard the following morning; but, owing to unfavorable weather, the bees did not have a good flight until 2 o'clock that day, after having been confined to the hives about 91 hours.

The 10 hives were placed between rows of sprayed trees at the south side, near the center of the orchard. Two sheets, each 7 yards square, were placed beneath two large sprayed trees, to catch the dead bees that fell from them.

To catch most of the dead bees removed from the hives a bee trap was devised, constructed as follows: A rectangular framework, 30 by 16 inches, was made of wooden strips 1½ inches wide by seven-eighths inch thick. The lower side (bottom of the trap) of the framework was covered with cheesecloth, and parallel pieces of twine one-fourth inch apart were stretched lengthwise over the upper side, seven-eighths inch above the cheesecloth. One side of the framework was nailed to the lower side of the alighting board, so that the framework projected 7 inches on either side of the hive. The sides of the trap were made of glass, 8 inches high, firmly fastened to the framework, and so snugly joined at the corners and where they united with the sides of the hive that a bee could escape only by going over the glass. A worker removing a dead bee from inside the hive usually flew from the alighting board with its load, but seldom flew sufficiently high to pass above the sides of the trap. Workers carrying dead bees therefore flew against the sides of the trap and fell to the bottom, where the hairs of the dead bees became fastened either to the cheesecloth or to the twine. The live bees then pulled themselves loose from the dead ones. One of these traps was placed in front of each hive entrance.

DAILY OBSERVATIONS OF BEES AND WEATHER

Notes pertaining to the bees and weather were carefully made, but only a brief report of the daily observations will be given here.

During the early morning of May 29 the two Wentworth colonies were installed; it was a clear, cool day, and the bees worked well on the sprayed blossoms. In the morning of May 30 the eight bureau colonies were installed, but as the weather was cool and rainy the bees did not leave their hives till 2 o'clock that afternoon. By this time the sun was shining brightly, the weather became warmer, and the bees, particularly the young ones, came in great numbers out of the hives. They flew to the nearest trees and began immediately to drink the water standing on the sprayed leaves and petals. Later the field bees were abundant in the trees and eagerly collected nectar and pollen. May 31 and June 1 were warm and cloudy, with occasional showers, although the bees worked well in the trees. June 2 was a cloudy, cool, and windy day, and the bees flew very little. Most of the petals had fallen, and many sick bees were seen in the bee traps and in the grass near the hives. June 3 was cool and clear, and the bees flew only fairly well during the middle of the day. June 4 was cool and rainy. One bee trap contained a half hatful of dead and dying bees. June 5 was a cool, clear and windy day, and practically all of the petals had fallen. Each trap contained many dead and dying bees. June 6 was a clear warm day; the bees flew well, and collected pollen from the wild flowers. Hundreds of dead and dying bees were seen in the traps and in the grass around the hives. June 7 was warm and cloudy, and the bees flew well. The bees were still dying rapidly; many were removed from the traps as usual and hundreds of sick ones lay in the grass, particularly to the leeward of the hives. On June 8 the bees were still dying to an abnormal extent; nevertheless, the colonies were prepared for shipment. The two Wentworth colonies were returned to their own apiary and the eight bureau colonies were expressed direct to Washington, D. C., where they were released June 11, 87 hours after having been closed. Nine pints of dead bees were removed from the eight hives, whereas only 3.75 pints had been taken from them at Winthrop upon their arrival from Philadelphia. It is safe to say that 5 of the 9 pints died on account of the poison, not taking into account the cooler weather and less crowded condition in favor of the bees in the hives during their journey to Washington.

In regard to the dead bees caught in the bee traps, it was found in the preliminary experiments that the average daily number per trap, counted before the trees had been sprayed, was 18, which represents about 3 per cent of all those that died, the 97 per cent dying in the field. The average daily number of dead bees per trap, counted in the traps at Winthrop after the trees had been sprayed, was 136. Evidently the bees in the sprayed orchard died more than seven times as rapidly as those in a normal environment. This ratio does not include the hundreds of sick bees that crawled out of the traps and died in the grass near the hives. If it had been possible to count all the bees that died from the effects of the poison and all those that died normally, the proportion of deaths from poisoning would certainly have been many times higher.

The unusual mortality of the bees was first noticeable the second day after they had had access to the sprayed flowers; on the third day after they had been poisoned the damage was unmistakable. This heavy mortality continued as long as the sprayed flowers lasted, and in some of the colonies did not cease until all the bees had died. Most of the sick and dead bees appeared to be young, and many of them bore wax scales. The field bees seemed to have died in the fields as usual, although only a few of them were found dead daily on the sheets under the sprayed trees. Under normal conditions the few field bees that die in the hives represent only a small percentage of the total number of the dead. Most of the dead and sick bees had swollen abdomens and often when an abdomen was gently squeezed a thick yellowish liquid was discharged from the anus. Most of the sick bees clustered for a short time in the traps, and later many of them climbed to the tops of the traps, where, after perching a few moments, they attempted to fly, but every bee observed fell into the grass only a few feet from the hive. During the later stages of arsenic poisoning a sick bee was usually drowsy and stupid, but often acted "crazily" by continuously turning around; then one or more legs became paralyzed, and the bee could walk only in a staggering manner, and could not fly; a little later it became paralyzed to such a degree that it could not get upon its feet, but could yet crawl about by dragging its swollen abdomen; it finally died in a state of coma.

When installed in the orchard 1 hive of bees was weak, 8 were strong, and 1 very strong. When transferred from the orchard 1 colony was slightly weaker than when it was brought there, 1 was weak, 1 strong, and 7 slightly less strong than when placed in the orchard. On June 15 the 2 Wentworth colonies experimented with were dying rapidly; on June 25 they were nearly depopulated, and on July 27 entirely so; and 1 of Mr. Wentworth's other 2 colonies (not experimented with) was nearly depopulated. The bees from the latter colony probably visted the sprayed orchards, for it was only 1½ miles distant. In regard to the 8 bureau colonies, on June

23 2 colonies were about as strong as when they left Maine, 4 were weak, 1 was nearly depopulated, and 1 entirely so. On July 3 one other colony was entirely depopulated; on August 1, one more; on September 14, three were fairly strong and 2 were weak. Not 1 of the 10 colonies used was killed outright, but 5 of them in a comparatively short time were entirely depopulated, while the other 5 were rendered more or less weak.

In the preliminary experiments the bees were installed in the orchards before the spraying had been done and were therefore working actively in the trees when the mixtures were applied. In most cases the bees were wetted by the sprays, by which they were driven from the trees, but returned in a few moments and continued to collect nectar and pollen. The lime-sulphur was the only substance used really repellent to the bees, but it did not keep them from the sprayed trees. In all cases they returned to the sprayed flowers before the lime-sulphur-arsenate mixtures on the foliage and blossoms had become entirely dry.

Immediately after the application of the spray mixtures, in the preliminary experiments, many sprayed flowers were closely examined. Most of them were thoroughly wetted with the sprays. Sometimes the cavities containing the stamens and pistils were completely filled with the mixtures, but never was any of the spray seen in the nectaries. These observations were repeated at Winthrop after applying the already-mentioned mixture of 3 pounds of paste lead arsenate to each 50 gallons of water in a 200-gallon power sprayer. In one tank of mixture 4 gallons of lime-sulphur was used; in another tankful one-fourth ounce of methylviolet was dissolved and a third tankful contained 3 ounces of an aqueous solution of eosin. The object of the dyes was to determine whether or not they would color the flowers better than the lime-sulphur, so that the presence of the spraying materials might be traced in the blossoms. They proved no better than the lime-sulphur for this purpose, but all three substances were fairly satisfactory for these tests. It was common to see the spray mixtures in the interior of the flowers, but they were never traced into the nectaries; the analyses of the nectaries from fresh flowers (Table 1), however, indicated that the mixtures did pass into the nectaries. Fine spray was generally seen on the anthers and stigmas; and, after it had evaporated, the petals were usually covered with small brown, violet, or pink dots, but the inner surfaces of the stamen bars at or near their bases never appeared to be stained.

On several occasions bees were closely observed when collecting pollen and nectar. Several bees with more or less pollen on their hind legs were seen collecting only nectar, but most of those with pollen on their hind legs were taking only pollen, while those without pollen on their hind legs were collecting only nectar. A bee collecting nectar usually alighted on the bunch of anthers and stigmas and instantly thrust its mouth parts between the stamen bars in order to reach the nectar. The anthers carrying the pollen came in contact with the upper portions of the front legs and with the throat of the bee, and some of the pollen adhered to the many branched hairs on the parts touched.

A bee collecting pollen also usually alighted on the bunch of anthers and stigmas. It removed the pollen from the anthers with its mouth parts, and, in transferring the pollen to the pollen baskets by means of the legs, much of the pollen adhered to the hairs on all the legs. A few bees were seen completely covered with pollen dust. When a bee returns to the hive with its load of nectar or pollen, it is usually cleaned before it leaves the hive again, most of the pollen dust adhering to the hairs being removed. The cleaners certainly eat some of the pollen dust removed, for bees in an observation hive are often seen to steal pollen from the pollen baskets before the bee carrying the pollen has placed its burden in a cell. Bees collecting the pollen probably swallow a small portion of the grains while biting them loose from the anthers.

RESULTS OF CHEMICAL ANALYSES

To ascertain whether chemical analyses would corroborate the results obtained by observation, many samples were collected on various dates, consisting of parts of sprayed flowers, fresh pollen from legs of bees and from combs, honey, entire bees, foreign substances removed from bees, parts of bees, dead pupæ, and dead larvæ. The results of analyses of these samples are briefly summarized in Table 1, which, with the exception of the last column, is self-explanatory. In that column the weight of arsenic found is expressed as parts per million in terms of metallic arsenic (As). For illustration, let us consider a sample containing flowers without the anthers and stigmas. The entire sample weighed 6.031 grams (about 0.21 ounce) and the metallic arsenic found in it weighed 0.1 milligram (about 0.0000035 ounce). One tenth of a milligram is found by a simple computation to be 16.6 millionths of 6.031 grams. The weight of arsenic found in the sample is therefore 16.6 millionths, or parts per million, of the weight of the sample itself.

Of all the parts of the flowers analyzed the pollen bore the most arsenic. Expressed as parts per million (using only whole numbers), pollen from the legs of bees bore 117 (Table 1); fresh pollen stored in the hives, 96; anthers and stigmas of sprayed flowers, 55; and sprayed flowers, not including the anthers and stigmas, which had been cut off, 32.

Of the 12 samples of honey analyzed only 1 contained arsenic, and that only a trace. Most of this honey was probably collected before the bees had been installed in the sprayed orchard. Entirely unripened honey was scarce, perhaps owing to the fact that the bees ate the honey almost as rapidly as it was collected. In the preliminary experiments 18 samples of more or less unripened honey were collected, but when analyzed not 1 of them was found to contain arsenic.

Nectaries carefully dissected from flowers sprayed in full bloom bore 0.0003 milligram each of arsenic, on an average (Table 1); nectaries from other flowers, sprayed after the petals had fallen, bore each 0.0007 milligram of arsenic. In computing these averages and others in Table 1 only the samples containing arsenic (As) were considered.

TABLE 1.—*Results obtained from chemical analyses of samples collected at Winthrop, Me., 1914, after trees in full bloom had been sprayed*

Material analyzed	Number of samples analyzed— Showing arsenic	Number of samples analyzed— Showing no arsenic	Average weight or number [1]	Average amount of arsenic (As) per individual in samples showing arsenic	Parts of arsenic (As) per million
			Grams	*Milligrams*	
Sprayed flowers, after removal of anthers and stigmas	5	0	4.24		32
Anthers and stigmas of the flowers	6	0	.40		55
Pollen from legs of bees	4	0	.43		117
Fresh pollen stored in hives	12	0	1.18		96
Honey, partially ripe	1	11	7.40		2
			Individuals		
Nectaries from flowers sprayed in full bloom	6	1	25	0.0003	
Nectaries from flowers sprayed after petals had fallen	8	2	25	.0007	
Dead bees from traps	15	4	37	.0004	
First wash, containing foreign matter from other bees from traps (no arsenic in subsequent washes)	1	3	95	.0002	
Nectar and pollen carriers	8	0	30	.0005	
Nectar and pollen carriers, after being washed five times	14	0	30	.0003	
Washings from 81 pollen carriers:					
First wash, containing foreign matter	1	0	81	.0003	
Second wash	1	0	81	.0001	
Third wash	1	0	81	.0002	
Fourth wash	1	0	81	.0001	
Fifth wash	1	0	81	.0001	
Nectar carriers, after removal of honey stomachs and intestines	4	0	25	.0002	
Honey stomachs of the nectar carriers	4	0	25	.0004	
Intestines of the nectar carriers	4	0	25	.0005	
Pollen carriers, after removal of honey stomachs and intestines	1	0	35	.0011	
Pollen carriers, washed five times, then honey stomachs and intestines removed	1	0	100	.0001	
Dead bees from traps, after removal of contents of abdomens	21	0	34	.0003	
Contents of abdomens of the bees	16	25	31	.0002	
Dead bees from traps, washed five times, then contents of abdomens removed	3	0	50	.0002	
Dead pupæ from traps	0	2	15		
Dead larvæ from traps	0	2	50		
Total number of samples analyzed	139	50			

[1] Average weight per individual of sample, or average number of individuals per sample, taken for analysis.

A large number of dead bees from the traps bore on an average 0.0004 milligram of arsenic each, including arsenic both within and without the body. To determine how much of this was carried outside the bodies, 95 other dead bees from the traps were washed four times in a 20 per cent solution of arsenic-free concentrated nitric acid and the fifth time in 95 per cent alcohol. These five liquids (here called washes), containing the foreign matter from the bees, were then analyzed; the first one contained 0.0002 milligram of arsenic per bee, the other four none.

Eight samples of live nectar and pollen carriers, averaging 30 bees each, caught on the alighting boards and killed in a cyanide bottle, carried, externally and internally, 0.0005 milligram of arsenic per bee, or 25 per cent more than was carried by the average of the dead bees from the traps. Fourteen other samples of live nectar and pollen carriers, averaging 30 bees each, caught and killed in the same manner, were washed five times, after which analysis showed that the bees still carried an average of 0.0003 milligram of arsenic per bee. The difference between these two averages, 0.0002 milligram per bee, agrees with the average (0.0002 milligram) removed from the 95 dead bees from the traps by five successive washes. Eighty-one pollen carriers, caught and killed in the same manner, were washed five times, and the successive washes analyzed; these contained per bee, in their consecutive order, 0.0003, 0.0001, 0.0002, 0.0001, and 0.0001 milligram of arsenic, respectively.

To trace the arsenic inside the bees, samples were analyzed as follows: Four samples of nectar carriers and one of pollen carriers, not washed, after removal of their honey stomachs and intestines, contained 0.0002 milligram and 0.0011 milligram, respectively, of arsenic per bee. The honey stomachs and intestines of the nectar carriers bore 0.0004 and 0.0005 milligram, respectively, of arsenic per bee. Pollen carriers, washed five times and deprived of their honey stomachs and intestines, averaged 0.0001 milligram of arsenic. Dead bees from the traps, after most of the abdominal contents had been squeezed out, averaged 0.0003 milligram of arsenic, while these contents carried 0.0002 milligram of arsenic per bee. Other dead bees, washed five times and similarly treated, averaged 0.0002 milligram of arsenic.

Two samples each of dead pupæ and dead larvæ were analyzed, but none of them were found to contain arsenic.

EFFECT ON HONEYBEES OF SPRAYING FRUIT TREES AT THE CUSTOMARY TIME

The experiments just described, performed at Winthrop, Me., in 1914, when the fruit trees were sprayed in full bloom, proved conclusively that the bees tested had been seriously injured; but since fruit trees are now seldom sprayed in full bloom, this knowledge does not have the economic significance that it would have had when spraying in full bloom was commonly practiced; nevertheless, there are other times, approaching the period of full bloom, when spray materials are commonly applied. In certain regions the time for the so-called pink application is often very short; accordingly some orchardists are still spraying when the blossoms burst open. In other regions the fruit trees of the same variety may bloom irregularly, and in still other localities an orchard often contains trees of different varieties, some blooming early and some late. Under such conditions an orchardist when spraying does not usually select the trees to be sprayed at the proper time, but sprays all as he approaches them, regardless of the age of their blossoms. That bees may be seriously damaged when the trees are sprayed in full bloom strongly indicates that they may also be injured under the conditions just mentioned, and it is furthermore suggested that bees might be slightly injured by spraying at the customary time, when 90 per cent of the petals have fallen.

To ascertain the effect on bees of spraying fruit trees at the customary time, the senior writer undertook a research at Roswell, N. Mex., in the spring of 1915, and later in the season repeated the experiments at Benton Harbor, Mich., using the dead-bee traps and analyzing samples of the dead bees collected. In the same season, at Winchester, Va., the junior writer undertook to determine the death rate of bees by daily weighing the colonies. Owing to unfavorable weather in all three localities, the results obtained were not conclusive, and the experiments were repeated in 1916 at Winchester and at Fennville, Mich., a town in the fruit belt of the Great Lakes, lying 6 miles from the eastern shore of Lake Michigan, by both writers working together, using both methods.

EXPERIMENTS AT ROSWELL, N. MEX., 1915

In regions where the irregular blooming of apple trees causes a long blooming period for an entire orchard, the trees to be sprayed range in condition from those in full bloom to those from which all the petals have fallen. Since it was desired to determine the damage done to honeybees by spraying trees in such regions, three commercial orchards, consisting of hundreds of acres of trees in an arid region about Roswell, N. Mex., were selected for experimental purposes.

On April 8, 1915, two apiaries totaling 105 colonies lying near these orchards were examined, and 10 dead-bee traps were installed. Daily observations of the bees were made as usual. From this date till April 23, when the first spray mixture was applied, bees in all the colonies, except the two numbered 3 and 8, were dying apparently at a normal rate. These two colonies suffered abnormal losses and exhibited symptoms of arsenic poisoning; and when 10 samples from them, each of 75 dead bees, were examined, all were found to contain arsenic, averaging 0.0003 milligram per bee. Eight samples of old pollen, stored in these two hives and probably collected from cover crops the preceding year, were also analyzed. Each one contained arsenic, averaging 9 parts per million.

On April 23, when on an average about 90 per cent of the petals had fallen, the spraying was begun. During the afternoon of April 24 a hailstorm stripped the trees of practically all the remaining petals, so that by April 26 every orchardist in the vicinity was beginning to spray. The spray mixture consisted of 2 pounds of paste lead arsenate to each 50 gallons of water, and was applied through three leads of hose under pressure varying from 200 to 240 pounds. Two 200-gallon power sprayers were used in all the orchards.

At regular intervals after the spraying was begun samples of dead bees were taken from each of the 10 traps. Of 8 samples taken from hives Nos. 3 and 8, which contained pollen stored in 1914, 7 contained arsenic, and of 16 samples from the other hives 15 contained arsenic in very small quantities. On April 28, when these experiments were discontinued, the 10 hives with traps were apparently as strong as when the work was begun, and no symptoms of arsenic poisoning were noticed except in the case of hives Nos. 3 and 8.

EXPERIMENTS AT BENTON HARBOR, MICH., 1915

Heavy rains and frequent hailstorms in the region about Roswell, N. Mex., made conditions there abnormal for experimenting with bees. As the blooming period in the fruit belt of the Great Lakes is comparatively long, it was decided to repeat at Benton Harbor, Mich., the experiments just described. On May 6, 1915, three small orchards and two apiaries of 35 colonies were selected there for this purpose. Ten dead-bee traps were installed and observations were made daily as usual. Owing to rainy weather and irregularity in the blooming of the different varieties of apple trees, spray mixtures of lead arsenate and lime-sulphur were applied whenever the weather permitted. As a result, a few trees were sprayed in nearly full bloom, several when 80 per cent and many when 90 per cent of their petals had dropped, and many after all of the petals had fallen.

Observations showed that a small percentage of the mortality of the bees was caused by arsenic poisoning, but none of the colonies was apparently reduced in number of bees. Thirty-three samples of dead bees were analyzed, of which 30 were found to contain arsenic in very small quantities.

EXPERIMENTS AT WINCHESTER, VA., 1915 AND 1916

The experiments conducted at Winchester in 1915, inconclusive in result because of unfavorable weather, were continued there in the spring of 1916 by both writers, using the dead-bee traps and analyzing samples of the dead bees collected, and also weighing certain colonies day by day. The latter method of investigation was first tried at Winchester in 1915. In both years the experiments were conducted in three apiaries, each free from foulbrood and surrounded by large commercial orchards: The Cooper apiary, of 70 colonies, lying 3 miles south of Winchester; the Miller apiary, of 40 colonies, 3 miles southwest; and the Lupton apiary, of 5 colonies, 2 miles west. For the weighing experiments in 1915 only the Cooper apiary was used, but in 1916 they were carried on in both the Cooper and Lupton apiaries. Six colonies, selected from the former apiary, were weighed daily, and the three following factors were considered in selecting them: (1) As a precaution against an abnormal death rate they were not transferred from their own apiary, nor were they unnecessarily disturbed; (2) they showed the best evidence of having had uninterrupted brood-rearing during the spring, and so of having a well-balanced ratio of old and young bees; and (3) they occupied well-marked positions in the apiary, thus preventing, so far as possible, errors due to the bees entering the wrong hive.

APPARATUS AND METHODS

Platform scales, sensitive to a variation of one-fourth ounce, were used to weigh the colonies. At Winchester these scales were located in a small building at one side of the apiary, and at Fennville, Mich., a temporary shelter was constructed for them. The primary purpose of the shelter, in each case, was to protect the scales from the wind and so prevent or reduce errors in the readings.

Chemical balances were used to determine the weight of the samples of a known number of bees and to ascertain the variation in the weight of the bees from day to day. In each case these balances were located in a building adjacent to the apiary.

In order to weigh the colonies when the bees were in the hive, the weighing was done in the morning, as soon as there was sufficient daylight for the work (about 4.30 o'clock). Each of the six hives containing the colonies under observation was in turn carried to the scales, weighed, the weight recorded, and the hive returned to its place in the apiary. After the gross weights of all hives, each with its contents, had been determined, the bees in each hive were quickly transferred to another, and the hive from which they were taken, together with its combs of brood and honey, was again weighed. The difference in the two weights was the weight of the bees, plus that of any honey they were able to take from the combs during the process of transferring. To prevent any addition to the population of the colonies by the emergence of young bees during the experiment, all combs containing nearly mature brood were removed from the hives as the brood approached maturity.

Since in this experiment the daily loss of individual bees was to be determined by the daily loss in weight of the colony, the variation in the quantity of honey that the bees might take from the combs and carry with them while being transferred would be a disturbing factor, but the method used in transferring them from one hive to another was such that they had no opportunity to take any honey from the combs, because they were kept moving from the time the hive was opened until they were in the other hive.

To shorten the necessary manipulation, only 5 combs instead of 10 were used in each hive. After the gross weights of all the hives had been determined hive No. 1 was removed from its stand and an extra hive with five empty combs but no cover was put in its place. Hive No. 1 was then lifted from its bottom board and set on top of the prepared hive. Its cover was removed, the five combs spread apart, and by means of a brush the bees were dislodged from the combs, while smoke was applied to prevent their return. Each comb was then removed, swept clean of bees, and placed in an empty hive body. Hive No. 1, now emptied and free from bees, was then reassembled and again weighed, with all parts, including the combs of brood and honey. This hive, with its five combs of brood and honey, then received colony No. 2, similarly transferred. This process was repeated until the weight of each of the hives and contents, minus the bees, was determined. The five combs of brood from colony No. 6 were then given to colony No. 1, and the empty combs which had been given temporarily to colony No. 1 when it was transferred were removed. This routine was repeated daily during the experiment, care being taken to finish the work before any bees could return from the fields with nectar, and so introduce error from that source.

To determine how much variation, if any, there was in the weight of individual bees from day to day, caused chiefly by their greater activity during the honey flow, a sample averaging 22.5 bees was weighed each day on the chemical balances. These bees were taken each morning from the same colony (No. 6) to avoid differences that might result from a difference of temperament. The bees were taken after having been dislodged from the combs to the hive from which they were transferred, and before they could reach the combs of the hive to which they were being transferred.

To obtain data on the collection of nectar from the fruit blossoms at various intervals during the day, the following methods were employed: To determine the load, largely of nectar, which the bees carried during the most favorable time for foraging, 10 outgoing and 10 returning field bees caught at the hive entrances were weighed on the chemical balances hourly during each day. To ascertain the increase, also consisting largely of nectar, of an undisturbed colony, a hive of bees was kept on the scales at Winchester in 1916, and hourly readings were made of the weight of the entire hive and contents. In 1916, at both Winchester and Fennville, the hives and combs of the colonies weighed daily were kept together in sets in order to obtain the daily gain or loss in weight. Furthermore, observations were made hourly during the day on the amount of visible nectar in the blossoms and the number of bees visiting them.

To determine the gain or loss of both old and emerging bees, two colonies (Nos. 17 and 18) in the Lupton orchard were weighed on the evenings of April 29, May 4, and May 11, after the bees had all returned to the hives. The weight of the bees, separate from the hive and combs, was found by a method similar to that used in the daily weight determinations previously described, but in this case the maturing brood was not removed.

Four dead-bee traps (Nos. 7 to 10) were installed in the Cooper apiary, four (Nos. 11 to 14) in the Miller apiary, and two (Nos. 15 and 16) in the Lupton apiary.

Data on the local temperature and humidity prevailing during the experiments were obtained by means of a thermograph, hygrograph, maximum and minimum thermometers, and a sling psychrometer. Observations were also made on the direction and velocity of the wind and character of day.

DAILY OBSERVATIONS

In 1915, at Winchester, abnormal weather conditions greatly hastened the development of the fruit blossoms. No weight records were obtained previous to the application of the spray mixture. On the morning of April 30 the first weight record (on the platform scales) was obtained, and spraying was begun in a large orchard 100 yards distant from the bees weighed. On April 29, when about 60 per cent of the petals had fallen, the bees worked freely on the blossoms; on April 30, after a strong wind and when 95 per cent or more of the petals had dropped, the bees worked less freely; and from this date till the end of the experiments on May 8 very little nectar was gathered from the sprayed blossoms.

On April 30 the total weight of the bees in the six hives weighed was 215 ounces (Table 2); but on May 8, eight days after the spraying was begun, the bees weighed 84 ounces less. The average daily loss was therefore 10.5 ounces, or 4.88 per cent of the initial weight. The loss in ounces for each of the several days from April 30 to May 8, inclusive, beginning with May 1, was 40, 15, 7, 5.5, 7, 1.5, 0.5, and 7.5 ounces. The first daily loss was exceedingly large; the others relatively small.

TABLE 2.—*Results obtained by weighing honeybees at Winchester, Va., 1915, to determine the effect on them of spraying fruit trees at the customary time*

Colony number	Weight of adult bees (after spraying) on the dates specified								
	April 30 [1]	May 1	May 2	May 3	May 4	May 5	May 6	May 7	May 8
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1	43.25	34.00	32.25	31.75	30.25	29.50	29.50	28.50	26.00
2	22.00	17.75	14.00	13.25	11.50	10.75	11.25	10.50	9.25
3	40.50	34.00	33.50	31.00	30.25	29.00	27.50	29.50	27.50
4	37.75	31.50	27.25	27.00	26.50	26.75	24.50	23.75	22.75
5	30.75	24.75	23.75	21.25	21.75	19.00	19.00	17.75	18.25
6	40.75	33.00	29.25	28.75	27.25	25.50	27.25	28.50	27.25
Total weight	215.00	175.00	160.00	153.00	147.50	140.50	139.00	138.50	131.00
Daily loss		40.00	15.00	7.00	5.50	7.00	1.50	0.50	7.50

[1] Date on which spraying was begun.

In 1916, at Winchester, from the time the trees were almost in full bloom till all the petals had dropped, the weather was almost ideal and the bees worked normally. Spraying was begun May 5, in the Lupton orchard; occasionally on that day a tree still having 50 per cent of its petals was sprayed, although most of the trees had lost more than 50 per cent but less than 90 per cent of their petals. On the same day a few bees were seen visiting these trees. On May 6 about 98 per cent of the petals had fallen from most of the trees, but a few trees still bore 10 per cent of their petals. A bee was occasionally seen visiting the large sprayed trees, but more were observed on a few young trees of a later variety which had also been sprayed. On May 7 a few bees were still observed visiting the sprayed trees; on May 8, when practically all the petals had fallen, only now and then was a bee seen in the trees.

On May 5 spraying was also begun 1¼ miles south of the Cooper apiary, but no spray was applied nearer this apiary until May 8. On the latter date, when more than 90 per cent of the petals had fallen, spraying was begun in the orchards near the Cooper apiary. On this date and during the three following days very few bees were seen in the trees in these orchards, but they were common on the sprayed dandelion and grape hyacinth under and between the fruit trees.

On May 8 spraying was begun 1 mile southwest of the Miller apiary and on May 10 it was general in the Miller neighborhood, but the Miller orchard was not sprayed till May 11. On that date no petals were left on the trees and no bees could be seen in the trees.

In regard to the dead bees counted in the bee traps before spraying, those caught in traps Nos. 7 to 10 averaged 35 a day; those in traps Nos. 11 to 14 also 35; and those in traps Nos. 15 and 16 only 17, making a general daily average of 31 dead bees per trap. After spraying was begun, the dead bees caught in traps Nos. 7 to 10 averaged 23 a day; those in traps Nos. 11 to 14, 19 a day; and those in traps Nos. 15 and 16, only 12 a day, making a general daily average of 19 dead bees per trap. It will be shown later that these figures represent only a small percentage of the mortality of the bees, but it is believed that they nevertheless represent a true mortality index of the colonies before and after the spraying was begun.

TABLE 3.—*Results obtained by weighing honeybees at Winchester, Va., 1916, to determine the effects on them of spraying fruit trees at the customary time*

Colony number	Weight of adult bees (before spraying) on the dates specified										Weight of adult bees (after spraying) on the dates specified				
	April 28	April 29	April 30	May 1	May 2	May 3	May 4	May 5	May 6	May 7	May 8[1]	May 9	May 10	May 11	May 12
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1	50.25	50.00	50.00	50.50	49.25	50.50	44.50	44.50	41.50	37.50	38.00	32.00	33.00	31.00	29.00
2	55.25	56.00	53.75	54.50	55.00	54.75	50.25	49.25	47.25	40.00	40.00	38.75	38.50	32.50	33.00
3	49.75	47.50	48.25	48.75	46.00	48.25	45.75	44.25	40.50	35.50	34.00	33.75	31.25	31.00	28.25
4	45.25	47.50	44.75	44.74	44.50	45.25	42.50	39.50	38.00	33.75	34.00	30.00	28.50	25.75	24.25
5	50.00	47.75	46.00	48.50	45.50	44.75	44.00	41.50	40.00	34.50	33.75	32.00	32.50	28.75	28.25
6	48.00	45.25	44.00	46.25	44.25	46.50	42.00	39.50	36.25	33.75	32.00	32.00	32.25	28.00	27.75
Total weight	298.50	294.00	286.75	293.25	284.50	290.00	269.00	258.25	243.50	215.00	211.75	198.50	196.00	177.00	170.50
Daily loss or gain	----------	−4.50	−7.25	+6.50	−8.75	+5.50	−21.00	−10.75	−14.75	−28.50	−3.25	−13.25	−2.50	−19.00	−6.50
	Gram	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*
Average daily load per returning field bee	----------	----------	----------	----------	----------	0.0510	0.0260	0.0170	0.0070	0.0070	0.0080	0.0020	----------	----------	----------
Average daily weight per individual bee in colony No. 6	0.0968	0.0999	0.1094	0.1121	0.1195	0.1088	0.1120	0 1095	0.1079	0.1057	0.1185	0.1041	0.1110	0.1004	0.1098
Maximum temperature	61	72	78	86	86	81	74	82	84	80	87	78	78	79	----------
Minimum temperature	45	43	43	50	56	59	58	55	59	56	56	58	46	56	56
Character of day	Part cloudy.	Clear.	Clear.	Clear.	Part cloudy.	Part cloudy.	Part cloudy.	Clear.	Clear.	Showers	Part cloudy.	Clear.	Part cloudy.	Clear.	Clear.
Character and direction of wind	Light W.	Calm S.	Calm S.	Light S.	Light S.W.	Calm S.	Light N.	Light W.	Light W.	Calm S.W.	Light S.W.	Strong W.	Strong S.	Strong W.	Strong S.W.

[1] Spraying begun on this date near the bees under observation.

On April 28, 1916, the total weight of the bees in the six hives weighed in the Cooper apiary at Winchester was 298.5 ounces (Table 3). The daily loss (or gain) in ounces from April 28 to May 12, inclusive, beginning with April 29, was 4.5, 7.25, 6.5 (gain), 8.75, 5.5 (gain), 21, 10.75, 14.75, 28.5, 3.25, 13.25, 2.5, 19, and 6.5 ounces. Reference to Table 3 shows slight daily losses, and on two days (May 1 and 3), slight gains, from April 28 to May 3, and heavier losses thereafter. Since none of the samples of dead bees collected before May 8 in this apiary contained arsenic when analyzed, it is reasonable to suppose that these bees had not visited the sprayed trees 1¼ miles south of their apiary. Before the weighed bees had visited the sprayed trees they lost 9.28 ounces as a daily average, being 3.11 per cent of their initial weight; after having visited the sprayed trees near by, they lost 8.9 ounces as a daily average, being 3 per cent of their initial weight. The theoretical daily mortality, based on six weeks as the normal life of bees, is 2.38 per cent.

RESULTS OF CHEMICAL ANALYSES

At Winchester, in 1915, 6 samples of dead bees, 9 samples of pollen, and 6 samples of honey were collected and analyzed. Not one was found to contain arsenic. In 1916, at Winchester, samples of dead bees and pollen were, as usual, collected and analyzed. Five of 18 samples, each of 100 dead bees, contained no arsenic; analysis of the others indicated the presence of arsenic, although not enough to have killed the bees analyzed (see pp. 24 to 26). Six of 10 samples of pollen analyzed contained no arsenic; the others had only a trace of it.

EXPERIMENTS AT FENNVILLE, MICH., 1916

The experiments just described were repeated in 1916 at Fennville, Mich. Three apiaries, surrounded by commercial orchards, were selected. The Langley apiary of 12 colonies lay 4½ miles west of Fennville, the Pratt apiary of 14 colonies 6 miles west and 100 yards from the lake shore, and the Pshea apiary of 30 colonies 5 miles northwest. For the weighing experiments 6 colonies in the Langley apiary were used.

APPARATUS AND OBSERVATIONS

The platform scales and chemical balances were installed in a temporary shelter by the side of the Langley apiary, and three dead-bee traps (Nos. 7 to 9) were also installed in front of hives Nos. 7 to 9 in this apiary. Four bee traps (Nos. 10 to 13) were installed in the Pratt apiary and four (Nos. 14 to 17) in the Pshea apiary.

From May 22 to June 2 (the period of the experiments) the weather was almost ideal (Table 4), the blossoms secreted nectar more abundantly than they did at Winchester, and the bees worked well in the trees. The number of bees visiting the trees during full bloom and later agreed closely with the number observed during the same period at Winchester.

On May 22, 24, and 25, two orchardists sprayed their fruit trees, nearly in full bloom, located 1 mile west and southwest of the Langley apiary, with lime-sulphur and lead arsenate. Daily observations showed that the trees were not visited by bees. On May 29 spraying was begun near the Langley apiary. Practically all the petals had fallen and the bees had almost ceased visiting the trees. On May 30 the orchards nearest the Langley and Pshea apiaries were sprayed, but no bees were observed in the trees. On May 31 spraying was general in the neighborhood of all the bees under observation, and spray mixture was applied thereafter for several days.

TABLE 4.—*Results obtained by weighing honeybees at Fennville, Mich., 1916, to determine effect on them of spraying fruit trees at the customary time*

Colony No.	Weight of adult bees (before spraying) on the dates specified					Weight of adult bees (after spraying) on the dates specified				
	May 24	May 25	May 26	May 27	May 28	May 29 [1]	May 30	May 31	June 1	June 2
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1	71.50	65.50	63.25	60.00	55.25	50.00	50.50	48.50	44.75	45.00
2	53.75	49.25	50.00	43.50	46.00	38.00	37.00	35.50	31.50	31.00
3	92.25	89.00	88.00	81.50	77.25	68.75	68.50	64.75	59.25	58.25
4	82.25	74.50	78.00	73.00	69.00	64.00	61.75	61.00	52.00	50.75
5	34.75	33.00	34.75	28.75	30.00	26.25	26.00	24.50	22.50	19.00
6	65.75	59.00	56.00	51.25	50.25	44.00	44.75	42.00	36.00	34.75
Total weight	400.25	370.25	370.00	338.00	327.75	291.00	288.50	276.25	246.00	238.75
Daily loss	--------	30.00	.25	32.00	10.25	36.75	2.50	12.25	30.25	7.25
	Gram	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*	*Gram*
Average daily load per returning field bee	0.0412	0.0485	0.0529	0.0369	0.0316	0.0250	0.0149	0.0249	0.0209	--------
Average daily weight per individual bee in colony No. 6	.1210	.1232	.1255	.1288	.1225	.1089	.1271	.1197	.1147	.1074
Maximum temperature	75	79	85	73	73	74	64	69	74	--------
Minimum temperature	55	62	62	62	51	59	53	45	52	62
Character of day	Part cloudy.	Clear.	Clear.	Part cloudy.	Clear.	Rainy.	Clear.	Clear.	Part cloudy.	Clear.
Character and direction of wind	Light W.	Strong SW.	Calm SW.	Strong N.	Light NW.	Light SW.	Strong N.	Calm NW.	Strong S.	Light SW.

[1] Spraying begun near the Langley apiary and continued for several days.

On the basis of the number of dead bees counted in the bee traps before spraying was begun, they died in hives Nos. 10 to 13 at the rate of 13, and in hives Nos. 14 to 17 at the rate of 12 per day, making an average of about 13; after spraying was begun they died in hives Nos. 10 to 13 at the rate of 8 and in hives Nos. 14 to 17 at the rate of 10 per day, an average of 9. Colonies Nos. 7 to 9 in the Langley apiary have not been considered in computing these figures, because both before and after the spraying was begun they did not behave normally, being weak and badly diseased, and one was queenless.

On May 24, 1916, the total weight of the bees in the six hives weighed in the Langley apiary at Fennville was 400.25 ounces (Table 4). The daily loss in ounces from May 24 to June 2, inclusive, beginning with May 25, was 30, 0.25, 32, 10.25, 36.75, 2.5, 12.25, 30.25, and 7.25 ounces. The apparent heavy losses on May 25 and 27 and June 1 occurred coincidentally with an interference in balancing the scales when a strong wind was blowing. The weight of the bees in the sample taken on May 29, when the weather was rainy, suggests that the apparent heavy loss on this date may have been due to the lighter loads carried by the bees at the time they were weighed.

Since none of the samples of dead bees collected before May 29 in this apiary contained when analyzed more than a trace of arsenic (the amount usually found in control samples) it is reasonable to suppose that they had not visited the trees sprayed almost in full bloom 1 mile from their apiary. Before the weighed bees had visited the sprayed trees they lost 18.12 ounces as a daily average, or 4.53 per cent of their initial weight; after having visited the sprayed trees they lost an average of 17.8 ounces per day, or 4.45 per cent of the same initial weight. The theoretical daily mortality is 2.38 per cent.

RESULTS OF CHEMICAL ANALYSES

Samples of dead bees and pollen were collected and analyzed as usual. Of 19 samples of dead bees analyzed, 10 yielded traces of arsenic, although not enough to have killed the bees (see p. 24 to 26). Of 9 samples of pollen analyzed, 2 contained no arsenic, 2 a trace of arsenic, and 5 arsenic in larger amounts although not enough to have killed the bees.

EXPERIMENTS AT DRUMMOND, MD., 1917

The experiments just described were repeated on a small scale in 1917 at Drummond, Md., where the bee culture laboratory of this bureau was then located. Observations extended from April 27 to June 9. On April 30 the 11 apple trees there available were in full bloom and the bees worked abundantly in them. On May 7, when about 90 per cent of the petals had fallen and several bees were still visiting the blossoms, these trees were sprayed. From this date till May 14, when practically all the petals had fallen, very few bees were seen visiting the sprayed blossoms, and during much of this interval the weather was unfavorable for flying. On May 9 and 10 bees were observed collecting brown pollen from sprayed apple blossoms from which the petals had fallen. On May 26 they began storing nectar; from June 2 to 9 there was a heavy honey flow, although not from apple blossoms.

On April 27 the total weight of the bees in the 6 hives weighed at Drummond was 519 ounces. The daily losses (or gains) in ounces from April 27 to May 12 inclusive, and on May 19, May 26, June 2, and June 9, beginning with April 28 as the first day and ending with June 9 as the 43d day (Table 5) were 34.75, 16, 9, 21.75, 0.75 (gain), 11.75, 3.5, 18.75, 19.75, 30.5 (gain), 40.5, 0.25, 5.75, 12.75, 18.5, 35, 27.5, 35.5, and 33 ounces. Before the weighed bees had visited the sprayed trees they were losing daily 14.94 ounces, on an average, or 2.88 per cent of their initial weight; after having visited the sprayed trees, they lost during the first 6 days 7.88 ounces as a daily average, which was 1.52 per cent of their initial weight, or they lost 1.01 per cent as a daily average for the full period of 34 days after the trees had been sprayed. The theoretical daily mortality, based on six weeks as the normal life of bees, is 2.38 per cent.

Samples of pollen and bees were collected and analyzed as before, but this time the dead-bee traps were not used. Twenty samples of pollen were analyzed, none of which was found to contain arsenic; 10 of these were taken from the hives before and 10 after the trees had been sprayed. None of the 10 samples of pollen carriers, collected on May 10 and 11 was, when analyzed, found to contain arsenic. Of 10 samples of dead bees collected on May 14 and 22 in front of the hives, arsenic was found in only 3, and these came from three colonies which apparently had been suffering for some time from bee paralysis. However, no arsenic was found in samples of pollen taken from two of the three hives.

TABLE 5.—*Results obtained by weighing honeybees at Drummond, Md., 1917, to determine the effect on them of spraying fruit trees at the customary time*

Colony No.	Weight of adult bees (before spraying) on the dates specified									
	Apr. 27	Apr. 28	Apr. 29	Apr. 30	May 1	May 2	May 3	May 4	May 5	May 6
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1	89. 00	84. 00	83. 75	81. 50	76. 00	75. 00	73. 00	73. 00	69. 50	66. 25
2	100. 50	89. 50	85. 75	87. 50	85. 50	89. 25	81. 50	82. 50	81. 25	78. 00
3	63. 50	55. 25	57. 00	54. 00	54. 00	53. 00	54. 00	51. 50	49. 50	47. 00
4	98. 00	97. 50	90. 00	91. 00	83. 00	84. 50	84. 25	83. 00	77. 00	73. 25
5	111. 00	108. 00	99. 75	96. 50	91. 50	90. 00	88. 25	87. 50	83. 25	77. 50
6	57. 00	50. 00	52. 00	48. 75	47. 50	46. 50	45. 50	45. 50	43. 75	42. 50
Total weight	519. 00	484. 25	468. 25	459. 25	437. 50	438. 25	426. 50	423. 00	404. 25	384. 50
Daily loss or gain		−34. 75	−16. 00	−9. 00	−21. 75	+0. 75	−11. 75	−3. 50	−18. 75	−19. 75
Average daily weight per individual bee in colony No. 6	*Gram*	*Gram* 0. 1060	*Gram* 0. 0965	*Gram* 0. 0974	*Gram* 0. 1087	*Gram* 0. 0990	*Gram* 0. 0973	*Gram* 0. 0958	*Gram* 0. 0852	*Gram* 0. 0923

Colony No.	Weight of adult bees (after spraying) on the dates specified									
	May 7[1]	May 8	May 9	May 10	May 11	May 12	May 19	May 26	June 2[2]	June 9
	Ounces	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*	*Ounces*
1	69. 00	61. 00	64. 00	63. 25	59. 50	55. 00	48. 00	49. 00	46. 00	45. 50
2	78. 50	74. 50	72. 00	73. 50	70. 25	65. 50	62. 75	56. 75	53. 00	44. 25
3	52. 25	47. 25	49. 00	45. 25	44. 50	43. 75	40. 50	36. 00	32. 25	25. 00
4	83. 00	71. 25	69. 00	71. 50	67. 00	65. 00	61. 50	53. 75	51. 50	40. 50
5	85. 00	77. 75	75. 00	72. 50	74. 00	69. 25	57. 50	49. 25	26. 00	31. 00
6	47. 25	42. 75	45. 25	42. 50	40. 50	38. 75	32. 00	30. 00	30. 50	20. 00
Total weight	415. 00	374. 50	374. 25	368. 50	355. 75	337. 25	302. 25	274. 75	239. 25	206. 25
Daily loss or gain	+30. 50	−40. 50	−0. 25	−5. 75	−12. 75	−18. 50	−35. 00	−27. 50	−35. 50	−33. 00
Average daily weight per individual bee in colony No. 6	*Gram* 0. 0953	*Gram* 0. 1131	*Gram* 0. 0910	*Gram* 0. 0893	*Gram* 0. 0992	*Gram* 0. 0922	*Gram* 0. 1092	*Gram* 0. 1030	*Gram* 0. 1390	*Gram* 0. 1242

[1] Eleven neighboring trees sprayed. [2] Heavy honey flow from June 2 to June 9.

Table 6 is a summary of the results obtained by weighing bees at Winchester, Fennville, and Drummond. The daily losses in ounces, recorded in Tables 2 to 5, have been changed to percentages. For comparative purposes these percentages and the theoretical normal daily mortalities are represented in Table 6 as accumulated daily losses. The daily losses of the bees at either Fennville, Winchester (1916), or Drummond may be compared singly with the theoretical daily losses, or the average daily losses recorded for these three localities may be compared with the theoretical figures. Since no weight records were taken at Winchester in 1915 before the spraying was begun, the percentages for this locality after the spraying was begun are not averaged with those of the other three localities, but are merely given for general purposes of comparison.

Table 6 clearly shows that the spraying did not affect the daily mortalities of the bees experimented with.

Table 6.—*Summary of results obtained by weighing honeybees at Winchester, Va., 1915 and 1916; Fennville, Mich., 1916; and Drummond, Md., 1917*

		Number of days before spraying								
		9	8	7	6	5	4	3	2	1
Accumulated daily loss	Loss, as indicated by actual weights at—	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
	Fennville, 1916	----	----	----	----	----	7.50	7.56	15.55	18.11
	Winchester, 1916	1.51	3.94	1.76	4.69	2.85	9.88	13.48	18.43	27.97
	Drummond, 1917	6.70	9.78	11.51	15.70	15.56	17.82	18.50	22.11	25.92
	Average	4.10	6.86	6.63	10.19	9.20	11.73	13.18	18.70	24.00
	Theoretical loss, based on 6 weeks as normal life of bees	2.38	4.76	7.14	9.52	11.90	14.29	16.67	19.05	21.43

		Number of days after spraying									
		1[1]	2	3	4	5	6	13	20	27	34
Accumulated daily loss	Loss, as indicated by actual weights at—	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
	Fennville, 1916	27.30	27.92	30.98	38.54	40.35	----	----	----	----	----
	Winchester, 1916	29.06	33.50	34.34	40.70	42.88	----	----	----	----	----
	Drummond, 1917	20.04	27.84	27.89	29.00	31.45	35.02	41.76	47.06	53.90	60.26
	Average	25.47	29.75	31.07	36.08	38.23	----	----	----	----	----
	Theoretical loss, based on 6 weeks as normal life of bees	23.80	26.19	28.57	30.95	33.33	35.71	52.38	69.05	85.71	100.00
	Loss, as indicated by actual weights at Winchester, 1915	18.60	25.58	28.84	31.40	34.65	35.35	----	----	----	----

[1] Day on which spraying was done or begun.

INTERPRETATION OF RESULTS

It is to be expected that the bees carried increasing quantities in their honey sacs from day to day as the honey flow increased, owing to the beginning of such activities as wax secretion and the evaporation of nectar, and that they carried decreasing quantities from day to day as the honey flow declined toward its close. This is verified in a general way by the weights of samples of a known number of bees taken in colony No. 6 previous to, during, and after the honey flows (Tables 3 to 5). For this reason it is to be supposed that the apparent loss in number of bees, as indicated by the weights, is less than the actual loss during the beginning of the honey flow and greater than the actual loss at the close of the honey flow. This is verified by the weight records (Table 3) obtained at Winchester in 1916, previous to (April 27 to 29) and during the honey flow (April 30 to May 5), and after its close (May 6 to 12). Using the average weight (0.0968 gram) per individual bee in the hives on April 28, just before the honey flow started, the average weight (0.1195 gram) on May 2, at the height of the honey flow, and the average weight (0.1098 gram) on May 12, after the close of the honey flow, it follows that, since there are 28.350 grams per avoirdupois ounce, an ounce of bees on the first date contained 292.9 bees; on the second, 237.2 bees; and on the third, 258.2 bees. The general average per bee of the 1,170 individual bees weighed in 52 samples at Winchester in 1915 and 1916 and at Fennville and Drummond is 0.1099 gram. Using this value, an ounce of bees is found to contain on an average 258 individual bees, or a pound would contain 4,128 bees.

At Winchester in 1915 (Table 2) and Fennville in 1916 (Table 4), the weights of the colonies were ascertained only during and after the honey flow from apple trees; it is therefore to be expected that the loss in number of bees as indicated by the weights at the close of the honey flow is, because of the decreasing quantities carried in their honey sacs, greater than the actual loss. This expected decrease is verified in the average weight of honey per bee in the samples taken at Fennville (Table 4); but, judging from the average weight per bee in the samples taken at Winchester in 1915, this decrease had already taken place before any samples were weighed, since none was weighed on the chemical balances in 1915 until May 2. These weighings are not published, as the season's work was brief and inconclusive.

During a 5-day period before the spraying, colony No. 17 in the Lupton apiary gained 12 ounces, or an average of 2.4 ounces per day; colony No. 18 gained 20 ounces, or 4 ounces per day. During a 7-day period after the spraying, colony No. 17 gained 18 ounces, or an average of $2\frac{4}{7}$ ounces per day; colony No. 18 gained 14 ounces, or 2 ounces per day. The total gain of 32 ounces for the two colonies both before and after the spraying was begun was certainly due to the addition of young bees to the colony, as the maturing brood had not been removed. It seems evident that the spraying had no effect on the combined weight of all the old and emerging bees; if the old bees were affected their decrease was balanced by an increase of the young ones.

The figures representing the nectar stored in the combs of the six hives weighed in the hive kept on the scales, and as a daily load per returning field bee, are all in harmony and their curves take the same general direction.

The weighing experiments showed that the death rate in a normal colony averaged about 600 bees per day, whereas the dead bees caught in the bee traps averaged only about 18 per day, thus indicating that about 97 per cent of the bees that died succumbed in the fields.

In summing up the results of the experiments conducted at Winchester and Fennville in 1916, and at Drummond in 1917, when the fruit trees were sprayed at the regular time, it appears for several reasons that the spraying did not injure the bees: (1) The daily weight records and the counts of dead bees in the traps show that the bees died more rapidly before than after the trees were sprayed. (2) The gain in weight of all the old and emerging bees before the spraying was begun was equal to the gain after, in the case of the two colonies tested. (3) After the spraying was begun the results obtained from the chemical analyses of the samples of dead bees did not indicate that the bees had died of arsenical poisoning. (4) No symptoms of arsenical poisoning were noticed at any time among the bees.

MINIMUM AMOUNT OF ARSENIC FATAL TO BEES IN CONFINEMENT

Chemical analyses of the samples of dead bees collected in 1914 at Winchester and Winthrop, after fruit trees had been sprayed in full bloom, showed that some samples taken at Winchester contained 0.0002 milligram of arsenic (As) per bee, and that some taken at Winthrop contained as much as 0.0004 milligram per bee. It was yet to be shown whether these quantities were fatal to bees. A series of experiments intended to decide this question was conducted at the bee culture laboratory at Drummond in July, August, and September of that year.

METHODS

To determine the behavior and to time accurately the longevity of bees fed definite quantities of arsenicals in confinement, 11 triangular observation cages were used, each made of 3 narrow wooden strips 1 inch wide, 2 of which were 10 and the third 6 inches long. Wire screen was used for the bottoms and tops of the cages, which lay on a table by a window. Fifty workers from alighting-boards were placed in each cage and fed definite quantities of poisoned candy or honey in small feeders, one to each cage, so covered with wire that the bees could not waste the food.

As an illustration of the method of procedure, 20 grams of finely pulverized confectioner's sugar and 1 milligram of finely pulverized Paris green were thoroughly mixed together; 20 grams of honey were added and the mixture again stirred thoroughly. The cages and feeders were carefully washed and dried to be sure that they were free of arsenic. One-tenth of this poisoned paste candy was put in each of 10 feeders, and nonpoisoned candy in the eleventh, for the control bees; in each cage were placed the 50 workers, and lastly the feeder containing the food, poisoned or otherwise. In a similar manner definite quantities of other arsenicals were thoroughly mixed with definite quantities of honey. After the bees had eaten all the poisoned food, great care was taken to see that they had plenty of nonpoisoned food. Bees soon die in such cages when deprived of food. The dead bees were counted and removed daily, and samples, each of 25 bees, were prepared for analysis. The results obtained are only comparative and are based on the average time required to kill all the bees tested, rather than on the absolute single lethal doses required to kill them. It was assumed that the bees ate equal quantities of the poisons, although this may never have been true; but even if bees do not eat equal quantities of the food given to them they have the habit of feeding one another, and consequently may on this account digest approximately equal quantities of food. In order to reduce the probable errors to a minimum, a large number of bees were used for each individual experiment.

EXPERIMENTS AND RESULTS

After the manner described in the preceding paragraph, 1 milligram of Paris green was fed to 500 bees; assuming that they shared it equally, each bee ate 0.0008 milligram of arsenic. These bees lived 1.5 days, on an average, with a minimum of 0.7 and a maximum of 2.7. Three samples of the dead bees yielded on analysis an average of 0.0006 milligram of arsenic per bee. A second lot of 500 bees was fed 0.5 milligram of Paris green in the poisoned candy, or 0.0004 milligram of arsenic per bee, and lived an average of 3.3 days, with a minimum of 0.6 and a maximum of 7 days. A third lot of 500 bees was fed 0.25 milligram of Paris green, or 0.0002 milligram of arsenic per bee, and lived an average of 8.3 days, with a minimum of 0.6 and a maximum of 18 days. On analysis, 3 samples of these bees were found to contain an average of slightly more than 0.0002 milligram of arsenic per bee. A fourth lot of 500 bees was in the same manner fed 0.15 milligram of Paris green, or a little more than 0.0001 milligram per bee, and lived from 1 to 13 days, with an average of 7. Two samples of these bees were found on analysis to contain an average of 0.0002 milligrams of arsenic per bee. As a control, 1,000 bees were fed nonpoisonous candy in confinement, and lived from 1.6 to 17.6 days, with an average of 9.8. Two samples of these were analyzed and found to contain 0.0001 milligram of metallic arsenic per bee. These experiments, with others of the same kind yet to be mentioned, are summarized in Table 7, with the results of analyses of dead bees and other data.

During this investigation many samples of bees, supposedly not poisoned, were analyzed. Some were found to contain as much as 0.0001 milligram of arsenic per bee, others a trace, and still others none at all. Since all animal tissue is said to carry at least a trace of arsenic, 0.0001 milligram each of metallic arsenic may here be considered the maximum quantity carried by control bees.

TABLE 7.—*Summary of results obtained by feeding arsenicals to bees in observation cages, 1914 and 1920*

Substances fed bees in each experiment	Number of bees fed	Average life of bees after eating the arsenical	Average quantity of arsenic (As)—		Number of bees analyzed
			Fed to each bee	Found per bee by analysis	
		Days	*Milligram*	*Milligram*	
Nonpoisoned candy (control)	1,000	9.8	Trace.	0.0001	50
Paris green in candy	500	.15	0.0008	.0006	75
Do	500	3.3	.0004	.0004	50
Do	500	8.3	.0002	.0002	75
Do	500	7.0	.0001	.0002	50
Acid lead arsenate in honey	500	6.0	.0010	.0009	125
Do	500	5.4	.0007	.0004	100
Do	500	5.0	.0005	.0004	100
Do	500	5.0	.0003	.0004	50
Arsenic acid in honey	100	5.46	.00049		
Acid lead arsenate in honey	100	5.71	.00049		
Sodium arsenate in honey	100	5.59	.00049		
Paris green in honey	100	5.59	.00057		
Do	100	5.76	.00057		
Do	100	5.77	.00057		
Zinc arsenite in honey	100	6.23	.00057		
Calcium arsenate in honey	100	6.91	.00049		
Poisoned pollen	500	6.9	.00004	.0003	100
Nonpoisoned pollen (control)	1,000	10.4	Trace.	Trace.	100

A fifth set of 500 bees was fed 5 milligrams of paste lead arsenate in honey, and lived from 0.3 to 21.3 days, with 6 days as an average. Providing they ate equal quantities of the poison, each one took 0.0010 milligram of metallic arsenic. When analyzed, 5 samples of them were found to contain an average per bee of 0.0009 milligram of metallic arsenic (Table 7). A sixth set of 500 bees was fed 3.5 milligrams of lead arsenate, or 0.0007 milligram each of arsenic, and lived from 2 to 10.7 days, with an average of 5.4. When analyzed, 4 samples of them contained only 0.0004 milligram of arsenic as an average per bee. A seventh set of 500 bees was fed 2.5 milligrams of lead arsenate, or 0.0005 milligram of arsenic each. They lived from 0.8 to 12 days, with 5 days as an average; when analyzed, 4 samples of them contained an average of about 0.0004 milligram of arsenic per bee. An eighth set of 500 bees was fed 1.5 milligrams of lead arsenate; if they ate equal quantities of the poison, each one took 0.0003 milligram of arsenic. When analyzed, each of 2 samples of these dead bees contained 0.0004 milligram of arsenic per bee.

For several days after the trees in the orchard at Winthrop, Me., had been sprayed in May and early June, 1914, poisoned pollen was stored in the hives. One of the bureau hives returned to Washington in June became depopulated August 1. To ascertain if the combs in this hive still contained poisoned pollen, 10 grams of the pollen were removed and were thoroughly mixed with 40 grams of honey. This mixture was then fed to 500 bees, as usual. They lived from 0.6 to 14.6 days, with 6.9 days as an average, whereas 1,000 control bees fed nonpoisoned pollen lived an average of 10.4 days (Table 7). When analyzed, 2 samples of pollen from the same combs were found to contain 2.57 parts and 1.19 parts of arsenic per million, the average being only one-fifty-first as much arsenic as was found in fresh pollen stored in the combs only a short time after it was collected from the sprayed trees. If the 500 bees ate equal quantities of the arsenic fed to them, each one took 0.00004 milligram of it, and this small quantity would not have noticeably affected them. When analyzed, 1 sample of the dead bees was found to contain 0.0001 milligram of arsenic per bee, each of 2 samples 0.0002 and 1 sample 0.0006 milligram, making an average of 0.0003 milligram of arsenic per bee (Table 7). It is thus seen that the small amount of arsenic still contained in this pollen was not equally eaten by the bees, and therefore the combs containing it should not be used again.

In June, 1920, eight arsenical spray mixtures were so prepared that they contained equal contents of arsenic acid or arsenious acid. A small portion of each of these was diluted 20 times, and 1 cubic centimeter of this dilution was thoroughly mixed with 4 cubic centimeters of honey in one of the small feeders. Providing the poisons were homogeneously mixed, each feeder contained 0.038 milligram of arsenic acid or arsenious acid; and, if the 50 bees in each feeder ate an equal share, each bee took nearly 0.0005 milligram of metallic arsenic when the arsenic acid or the arsenates were eaten, or 0.00057 milligram when the 3 mixtures of Paris green and the zinc arsenite were eaten. This series of tests was made a second time. Of these 8 arsenicals, the arsenic acid was most toxic (Table 7), but the sodium arsenate and 1 preparation of Paris green were close seconds, and the powdered acid lead arsenate third; the average life of bees after eating the 3 mixtures of Paris green is exactly the same as that of those eating the lead arsenate. The zinc arsenite and calcium arsenate seemed considerably less toxic, probably because the bees did not eat the mixtures containing them as readily as they did the others.

According to these figures, it appears that 0.0005 milligram of metallic arsenic is a conservative quantity to represent the minimum lethal dose per bee. Some of these results have already been published (*4, pp. 28, 48*).

In these experiments the behavior of the poisoned bees was carefully observed to determine whether it was similar to that of bees poisoned by arsenic in the fields. On the second day after having been poisoned many of these bees became more or less inactive and a few died; after that most of them were seldom seen eating; by the third day they were dying rapidly, their abdomens were much swollen, they could not fly, but could yet walk in a staggering manner, dragging their abdomens on the table. The visible effects of arsenic poisoning on them were similar to those of nicotine poisoning on bees already described by McIndoo (*9, pp. 91–92*), except that nicotine acts the more quickly, and its symptoms are the more pronounced, also that in cases of arsenic poisoning the abdomens are always more or less swollen, while this effect is rarely observed in cases of nicotine poisoning. Judging from the symptoms observed, bees fed arsenic seem to die of motor paralysis, although the paralysis may be only a secondary cause.

DISCUSSION OF LITERATURE

Only one of the many reports of the experiences of beekeepers will be cited here. This one, presented by Felt (*6*), states that several men sprayed their fruit trees with arsenicals while in full bloom, May 18 and 19, 1900. The first dead bees were observed on May 20. One beekeeper says:

> In front of each hive lay the full working force of the bees, some in clusters apparently dormant and others wriggling about as if in great agony. With the appearance of the sun there was a general movement among the bees in an effort to get as far away from the hive as possible. Those that had the strength would try to fly, but could only succeed in making 3 or 4 feet before they would drop to the ground.

The next day, May 21, a few hives were opened. Practically all of the field bees were gone, but a large quantity of brood and a few young bees were left. This beekeeper claims to have lost his entire apiary of 100 colonies, valued at $500.

According to the same report, another beekeeper claims to have lost between 80 and 95 per cent of the workers in his apiary of 95 colonies. Orchards were sprayed while in full bloom, 1½ miles north and the same distance northwest of a third beekeeper's apiary of 200 colonies, May 21 and 22. May 23, handfuls of dead and dying bees lay near the hives.

The following scientists have carried on experiments to determine the effects of arsenic on bees.

Brose (*1*) mixed London purple and Paris green in sirups in the same proportions in which these two insecticides are mixed with water for spray materials. When these poisoned sirups were fed to bees, they were not eagerly eaten. Some of the bees tested died 30 minutes after taking the poison, while others lived 4 hours. The chemical analyses of the sirups stored in the combs did not show arsenic, but traces of it were found in the bees killed by eating the sirups.

Cook (*2, p. 261*) claimed that bees are very susceptible to arsenicals sprayed on trees, but he did not ascertain this experimentally. The same author (*3*) experimented later with honeybees and several other insects. He confined them in cages and fed them mixtures composed of 1 pound or less of London purple to 200 gallons of water or sirup. Mixtures of 1 pound to 200 gallons were quickly fatal to honeybees.

Webster (*13*) sprayed a plum tree in full bloom with a mixture of Paris green and water; he then covered the tree with sheeting and mosquito netting and the ground with a canvas; a few hours later a hive of bees was placed inside the inclosure. The bees, instead of working normally, flew wildly about inside the inclosure, probably striking the foliage, flowers, sheeting, and netting; dead bees soon began to accumulate on the canvas. When a few of them were analyzed, arsenic was found; but its presence means nothing under the circumstances. The same author (*14*) performed experiments on a larger scale by spraying two apple trees in full bloom and a small orchard in which nearly all the petals had fallen. Several bees caught visiting the trees sprayed in full bloom were killed in a cyanide bottle, and parts of them were analyzed for arsenic; none was found in the hind legs with pollen and contents of the thoraces, but analyses of the contents of the abdomens, including the honey stomachs, revealed arsenic. Other bees, taken from the same trees, were killed, washed in dilute ammonia water, and analyzed, giving distinct traces of the poison. A few days after spraying the small orchard one of three colonies of bees near by suddenly became extinct and a second one greatly reduced in number of bees. From the totally depopulated colony Webster took dead bees, uncapped honey, and dead larvæ. When analyzed, the honey gave no evidence of arsenic, but the dead larvæ and the contents of the dead bees were found to contain it.

Woodworth (*15, pp. 111, 112*), reporting the work done by Volck at Watsonville, in the Pajaro Valley, Calif., states that a hive of bees was placed in the center of a 40-acre apple orchard, and then the trees were sprayed when just coming into full bloom. Analyses showed no arsenic in the new honey, but some in the pollen and dead bees, that in the latter approaching a toxic dose.

Holland (*8*) examined periodically in the laboratory many samples of dead bees and comb. A large percentage of the bees under observation died within two or three days. No cause for their deaths was known, except perhaps the spraying in the neighborhood. A small quantity of arsenic was found in 12 of 23 samples submitted for analysis. The detection of arsenic in the stored pollen was of special interest. Holland, using the approximate toxic dose for the horse, ox, sheep, and fowl as a basis, would call the toxic dose of arsenic for a honeybee about 0.005 milligram of arsenious oxide (As_2O_3) or 0.006 milligram of arsenic oxide (As_2O_5), which is 10 or 12 times the actual lethal dose arrived at as shown in the preceding pages.

Price (*12*) carried on experiments for two years in the field and laboratory. In the first year two apple trees were caged with cheesecloth. One was sprayed with lime-sulphur and the other dusted with flowers of sulfur and arsenate of lead, and a colony of bees was put within each inclosure and liberated. In the second year (1919) three trees were caged with wire screen, of which one was sprayed and one dusted, as in the first year, the third used as a control, and a normal colony of bees, with ample stores, placed in each of the three inclosures. Dead bees, collected from the cages, were counted and analyzed for arsenic in the laboratory. Three trees in full bloom in the open were also sprayed, while more than 200 were left unsprayed; live bees were counted on the sprayed blossoms and dead bees analyzed. In spite of the criticism that might be made in regard to the methods employed of confining bees with trees in large cages and of confining them singly in glass funnels when testing for fatal doses of arsenic, Price's conclusions are not far different from those reached in the present investigation. Less than 0.0005 milligram of arsenious oxide (As_2O_3) was found a fatal dose for a bee. The longevity of bees poisoned with arsenic was found to depend upon the size of the dose; some died within 1½ hours, others lived 5 or 6 hours, and most of those poisoned in the field died within 3 hours. Bees worked freely on sprayed trees in the open, even when there were unsprayed ones near by. The mortality of the bees in the control cage was 19 per cent, as compared with 69 per cent in the cages containing the trees sprayed with lime-sulphur and lead arsenate, and 48 per cent in the cage containing the tree dusted with sulphur and lead arsenate.

Doane (*5*) sprayed an apple tree, almost in full bloom, and then covered it with a cage. Two days later he placed a colony of bees inside this cage, and the following morning, while the bees were confined in their hive, the tree was again sprayed. He claims that these bees worked in an apparently normal way and were not injured by the arsenical spray material. This experiment was repeated, using another tree and another hive of bees, and similar results were obtained. His chemist reported for the small number of bees collected and analyzed that the dead bees collected in the cage at the end of the first experiment contained 0.0025 milligram, those collected alive during the first experiment 0.002 milligram, and those found dead during the second experiment 0.0006 milligram, respectively, of arsenic per bee. According to the results obtained by the present writers, less than these amounts of arsenic would, if eaten, have killed the bees. The next spring Doane repeated his experiments on a slightly larger scale, and finally concluded that spraying in full bloom under California conditions is not injurious to honeybees.

Merrill (*11*), while not repeating Doane's experiments, severely criticizes his methods, and compares his results with those obtained by Price, concluding that the latter were more likely to be correct.

SUMMARY

In the preliminary experiments conducted at Winchester, Va., 1914, three small, more or less isolated orchards were selected, and three strong colonies of bees were installed in each orchard. Twenty-five trees were sprayed in each orchard, the first 25 with a mixture of Paris green, the second 25 with a mixture of paste lead arsenate, and the third 25 with a mixture of paste lead arsenate and lime-sulphur. The following results were obtained: (1) Bees work equally as well on trees sprayed in full bloom as on unsprayed ones; (2) they do not fly away from the sprayed orchard very much if the orchard is well

isolated; (3) they are slightly affected when a small orchard is sprayed in full bloom, a conclusion supported by observations and by the analyses of the samples of bees collected; and (4) of the three mixtures named, the arsenate-lime-sulphur mixture was found the most satisfactory for experimental purposes.

In the more extended experiments conducted at Winthrop, Me., 1914, a large isolated commercial orchard, consisting of 700 apple trees and almost ideally located, was selected, and 10 colonies of bees were installed in it on May 29 and 30. On May 25 and 26 all of these trees, nearly in full bloom, were sprayed with a mixture of paste lead arsenate and lime-sulphur; on May 28 and 29, 310 of them, now in full bloom, were again sprayed with the same mixture; and on June 3, 5, and 6 the entire orchard was again sprayed.

The unusual mortality of the bees at Winthrop was first noticeable the second day after they had had access to the sprayed flowers, and on the third day after they had been poisoned the damage was unmistakable. This heavy mortality continued as long as the sprayed flowers lasted, and in some of the colonies until all the bees had died. The symptoms of arsenic poisoning were very pronounced. In the early stage the adult bees became sluggish and soon neglected their duties, so that the brood apparently died of starvation; later their abdomens became greatly swollen, being filled with a yellowish watery liquid; still later the legs and wings became paralyzed; and finally the bees died in a state of coma. Not one of the 10 colonies used was killed outright, but in a comparatively short time 5 of them were entirely depopulated, while the other 5 were rendered more or less weak. It was thus ascertained that spraying fruit trees in full bloom under certain conditions is very injurious to bees.

The results obtained from the chemical analyses of the samples collected at Winchester and Winthrop agree with the field observations. Arsenic was found on all parts of the sprayed flowers, particularly on the pollen, and in most of the samples of the adult bees analyzed, but none was found in the samples of dead pupæ and larvæ. Of 12 samples of partially ripened honey analyzed only 1 contained arsenic, and that merely a trace. Dr. E. E. Tyzzer, of the Harvard Medical School, reports by correspondence that during the spring of 1920 and that of 1921 he experimented along similar lines. He says:

> I have had analyzed two samples of unripe honey, gathered during the spraying of fruit trees in full bloom, and found that both showed a very slight trace of arsenic. A sample of "honeydew" saved from a previous year showed 0.00045 per cent of arsenic, and another of ripe honey of good quality showed no trace of arsenic.

It thus seems that the bees obtained most of the arsenic from the pollen, although most of the nectaries analyzed contained arsenic. We should expect the honey to be poisoned, but so far only traces of arsenic have been found in it (see Table 1 for details).

The preceding results were obtained by daily observations, the use of several dead-bee traps, and analyses of the samples collected. One of these traps was installed in front of each hive selected for this purpose; it caught most of the bees that died in the hive, but their number was only about 2.5 per cent of the total mortality, the other 97.5 per cent dying in the field. When the mortality was heavy these traps were fairly satisfactory, for it is believed that the number of dead bees caught by them, before and after the spraying, represented a true mortality index of the bees tested. Because of the difficulties encountered in this kind of investigation, particularly when bees are poisoned but little or not at all, a more reliable method was introduced, in which all the interfering factors were either controlled or eliminated. Briefly stated, this method consisted of the following points: (1) The maturing brood was removed from six strong colonies, and by closely following a special procedure while weighing the hives with their contents on the platform scales the daily loss or gain in ounces of the adult bees were obtained independently of the weight of the stores, which were an interfering and variable factor; (2) an undisturbed colony was kept on these scales and was weighed hourly each day; (3) all the adult bees and the maturing brood in two other colonies were weighed three times on these scales, the weight of the stores being eliminated by following the special procedure just mentioned; (4) 10 outgoing and 10 returning field bees caught at the hive entrances were weighed on the chemical balances daily, every hour the bees were working; and (5) daily weather observations were made and recorded. In 1915 the writers worked separately, but thereafter together, using both methods.

Because of unfavorable weather no definite and conclusive results were obtained at Roswell, N. Mex., Benton Harbor, Mich., and Winchester, Va., in 1915. Most of the samples of dead bees collected at Roswell contained arsenic in very small quantities, but no symptoms of arsenic poisoning were noticed, except in two hives, which contained poisoned pollen collected from cover crops the preceding year. The trees at Benton Harbor bloomed irregularly, so that their blossoms were sprayed in all stages, thus causing a light mortality among the bees, and most of the samples of dead bees contained small quantities of arsenic. There did not seem to be any unusual mortality among the bees at Winchester, and not one of the 21 samples collected contained arsenic. (See Tables 2 and 6 for weight records at Winchester.)

The experiments at Winchester, Va., in 1916, were conducted in three apiaries, surrounded by large commercial orchards. The first apiary consisted of 70 colonies, the second of 40, and the third of 5. For the weighing experiments the first and third apiaries were used. From the time the trees were almost in full bloom until all the petals had dropped, the weather was almost ideal, and the bees worked normally. When the trees were sprayed nearly all the petals had fallen, and by this time the bees had almost ceased visiting the trees. The results from the various sources did not indicate that the bees tested had been poisoned, although 17 of the 28 samples collected contained very small quantities of arsenic, too small to have been fatal to bees. (See Tables 3 and 6 for weight records.)

The experiments at Fennville, Mich., in 1916, were also conducted in three apiaries, surrounded by commercial orchards. The first apiary consisted of 12 colonies, the second of 14, and the third of 30. For the weighing experiments 6 colonies in the first apiary were used. During the entire period of the experiments the weather was almost ideal, the blossoms secreted more abundantly than they did at Winchester, and the bees worked well in the trees. When the trees were sprayed the bees had almost ceased visiting them and practically all the petals had fallen. The results taken together indicated that the bees tested had not been poisoned, although again 17 of the 28 samples collected contained small quantities of arsenic, too little to have been fatal to bees. (See Tables 4 and 6 for weight records.)

In regard to the spraying of fruit trees at the customary time, when 90 per cent or more of the petals had fallen, at Winchester, Va., and Fennville, Mich., in 1916, under the most certain conditions, which are usually rare, it appears for the following reasons that the bees tested were not injured: (1) The old adult bees died more rapidly before than after spraying was begun, as was shown both by the daily weight records and by the number of dead bees counted in the bee traps. (2) The gain in weight, after the spraying was begun, of all the old and young adult bees in two colonies tested was equal to the gain before the spraying was begun. (3) The results obtained from the chemical analyses of the samples of dead bees, collected after the spraying was begun, did not indicate that the bees had died of arsenic poisoning. And (4) no symptoms of arsenic poisoning were noticed among the bees under observation.

The experiments at Winchester and Fennville were repeated on a small scale in 1917 at Drummond, Md., where the bee culture laboratory of this bureau was then located. Eleven apple trees were sprayed when about 90 per cent of the petals had fallen and when bees were to some extent still visiting these blossoms. Of the 40 samples of dead bees collected and analyzed only 3 showed the presence of arsenic, and these samples came from colonies which apparently had been suffering for some time from bee paralysis. No arsenic was found in samples of pollen taken from these hives. The other results obtained agree with those obtained at Winchester and Fennville in 1916. (See Tables 5 and 6 for weight records at Drummond.)

Some of the samples of dead bees collected when the trees were sprayed in full bloom contained on an average as much as 0.0004 milligram of arsenic (As) per bee. Of course, some of the individual bees contained less and some more than this quantity, yet it was not definitely known whether that quantity had actually killed them. A series of laboratory experiments in which definite quantities of several arsenicals were fed to bees decided this question in the affirmative, established the minimum fatal dosage of arsenic (As) per bee to be about 0.0004 or 0.0005 milligram, and showed that the symptoms of arsenic poisoning of bees in confinement were like those of the bees poisoned in the orchards. (See Table 7 for details.)

LITERATURE CITED

(1) Brose, C. M.
1888. Bees fed with sirup containing arsenic. *In* Colo. Agr. Exp. Sta. 1st Ann. Rpt., pp. 233–234.

(2) Cook, A. J.
1889. Spraying with the arsenites. *In* Mich. Agr. Exp. Sta. Bul. 53, pp. 260–264.

(3) ———
1891. How strong shall we [illegible]e London purple? *In* 30th Ann. Rpt. Mich. State Bd. Agr., 189[illegible]91, p. 1[illegible]

(4) Cook, F. C., and N. E. McIndoo.
1923. Chemical, physical, and insecticidal properties of arsenicals. U. S. Dept. Agr. Bul. 1147, 57 pp.

(5) Doane, R. W.
1923. Bees vs. spraying. *In* Jour. Econ. Ent., vol. 16, pp. 527–531.

(6) Felt, E. P.
1900. Bees and spraying—a warning. *In* Country Gent., vol. 65, p. 470.

(7) Gates, B. N.
1914. An inquiry into the spraying laws of North America in their relation to beekeeping interests. *In* 61st Ann. Rpt. Mass. State Bd. Agr., 1913, pp. 281–284.

(8) Holland, E. B.
1916. Detection of arsenic in bees. *In* Jour. Econ. Ent., vol. 9, pp. 364–366.

(9) McIndoo, N. E.
1916. Effects of nicotine as an insecticide. *In* Jour. Agr. Research, vol. 7, pp. 89–122, illus.

(10) ———
1923. Effect on honeybees of treating cotton plants with calcium arsenate. Amer. Bee. Jour., vol. 63, No. 6, p. 285.

(11) Merrill, J. H.
1924. Bees vs. spraying. *In* Amer. Bee Jour., vol. 64, p. 134.

(12) Price, W. A.
1920. Bees and their relation to arsenical sprays at blossoming time. *In* Ind. Agr. Exp. Sta. Bul. 247, 15 pp., illus.

(13) Webster, F. M.
1892. Spraying with arsenites vs. bees. *In* Insect Life, vol. 5, pp. 121–123.

(14) ———
1894. Spraying with arsenites vs. bees. *In* Insect Life, vol. 7, pp. 132–134.

(15) Woodworth, C. W.
1914. Entomology. *In* Calif. Agr. Exp. Sta. Rpt., 1913–14, pp. 109–118, illus.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1369

Washington, D. C. ▼ April, 1926

THE CATTLE GRUBS OR OX WARBLES, THEIR BIOLOGIES AND SUGGESTIONS FOR CONTROL

By

F. C. BISHOPP, Entomologist, E. W. LAAKE, Associate Entomologist, and H. M. BRUNDRETT Assistant Entomologist, and R. W. WELLS, Entomologist, Investigations of Insects Affecting the Health of Animals, Bureau of Entomology

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1369

Washington, D. C. ▼ April, 1926

THE CATTLE GRUBS OR OX WARBLES, THEIR BIOLOGIES AND SUGGESTIONS FOR CONTROL

By F. C. BISHOPP, *Entomologist*, E. W. LAAKE, *Associate Entomologist*, and H. M. BRUNDRETT, *Assistant Entomologist*, and R. W. WELLS,[1] *Entomologist*, *Investigations of Insects Affecting the Health of Animals, Bureau of Entomology*

CONTENTS

The cattle grubs (*Hypoderma lineatum* De Villers and *H. bovis* De Geer [2]) are among the most widespread and injurious insects with which our livestock are beset. Nearly every owner of cattle is familiar with these larvæ, which are found under the skin on the backs of cattle in the early spring. Few, however, connect them with the adult insects which are known as heel flies or warble flies. Still fewer people have ever seen a heel fly, and many stockmen say, "I have heard all of my life of the heel fly and have seen the cattle run from it but I have never seen one." This has led many to regard the fly with something akin to superstition or to consider its existence a myth.

Among scientific workers there is also a very meager knowledge of the true life history or importance of these insects. Although a considerable number of veterinarians, zoologists, and entomologists have made observations and published articles, much of this work has been of a fragmentary character and most of the important biological facts have been established during the last decade. It is the writers' desire to set forth briefly the knowledge gleaned to date, and especially to present facts yet unpublished regarding the life his-

[1] Resigned July 24, 1923.

[2] Order Diptera, family Oestridae.

58252°—26——1

tories, habits, injuriousness, and means of repression of these two species, as obtained during this investigation.[3]

HISTORY

The heel flies or warble flies, or at least the effects of their attacks, have been known to man from time immemorial. The writings of Virgil and Shakespeare contain statements which undoubtedly refer to these pests. Their peculiar and injurious habits have attracted the attention of many naturalists, zoologists, and veterinarians, and the results of the observations and deductions beginning with the articles on this subject published in 1710 and 1713 by the Italian naturalist Vallisnieri (*102*, *103*)[4] make very interesting reading. Linné (*61*), in 1739, published information on the related reindeer bot (*Oedemagena tarandi* L.) and expressed his opinion that the eggs were attached to the skin or hairs and were not pushed through the skin as was believed by all previous writers, and as some subsequent writers have believed.

In 1797 Clark (*20*) published a notable account for that day of the Oestridæ, including observations on the habits of the cattle grubs. His modified and amplified views were published in 1827 (*21*) and 1843 (*22*).

In 1863 the Austrian entomologist Brauer (*8*) published his monograph of the Oestridæ, which added much to the knowledge of the species. He describes the last two stages of the larvæ, and in a subsequent article (*9*) he indicates a simple method of differentiating the last larval stages of *H. lineatum* and *H. bovis*.

Most writers up to the time of Clark's observations, and in fact many subsequent writers, were of the opinion that the flies place their eggs under the skin of the host. This idea probably originated from the fact that the cattle are driven to a frenzy by the ovipositing flies, the conclusion being that the flies must sting when laying the eggs—this, despite Linnaeus's statement in 1739 regarding the placement of the reindeer bot eggs on the hairs.

Up to the publication in 1888 by Hinrichsen (*41*) on the finding of Hypoderma larvæ in the spinal canal, only the subdermal or last larval stages were known. Hinrichsen reported the common occurrence of these (now known to be third-stage) larvæ in the spinal canal of cattle in December, January, March, May, and June. He also concluded, apparently without having seen the egg or the fly ovipositing, that the hosts take up the eggs with grass and that the young larvæ reach the spinal cavity from the diges-

---

[3] The present studies have been carried on incidental to other projects for a number of years and during the last seven years have received major consideration. During the prosecution of the work the writers have been materially assisted by many individuals and organizations, to whom thanks are extended. The Bureau of Animal Industry, through its various agents, has aided by sending immature stages. Dairymen, especially in the vicinity of Dallas, Tex., and Herkimer and Middletown, N. Y., have assisted materially by permitting the use of their cattle in the writers' experiments. Many specimens and much information have been obtained from correspondents, including dairymen, cattle raisers, hide dealers, butchers, packers, and others interested in the problem. The management of the leading packing plants in Dallas and Fort Worth, Tex., have been especially courteous in furnishing material for examination and in permitting examination of cattle during slaughter. Of necessity, a number of entomologists have been more or less associated with the writers in the carrying out of the observations and experiments. The following men have contributed materially to the results as herein given: D. C. Parman, O. G. Babcock, Oscar Pool, E. E. Wehr, H. P. Wood, and W. E. Dove.

[4] Numbers in italics refer to "Literature cited," p. 114.

tive tract, thence migrating up to the subcutaneous tissues of the back. In 1889 one of these early-stage larvæ found in the brain of a horse by Poulson was described by Boas (*5*) as a first-stage Hypoderma larva. From this time on the veterinarians, especially of Denmark and Germany, made important contributions regarding the young stages within the bodies of cattle.

During the decade beginning in 1884, the English entomologist Ormerod made a number of contributions to the literature of this subject culminating in reports published in 1894 (*71*) and 1900 (*72*). In these articles much valuable information is presented, especially as regards losses. This writer entertained the old idea that the larvæ penetrate through the skin of the backs of the cattle.

In America, interest in this pest began to be evident during the eighties; and articles were contributed by Riley (*82*, *83*) in 1889. In 1890 Cooper Curtice published a note (*24*) reporting the finding of larvæ 10 to 15 millimeters long in the walls of the esophagus, in the pleura near the eleventh rib, in the subcutaneous tissues of the back, and in subcutaneous tumors which opened through the external skin. He states that the finding of larvæ in the early stages in these situations suggests that—

> It is possible that the eggs or young larvæ are licked by the cattle from the back; that the larvæ made their way into the esophageal walls and from thence, during the proper season, through the back in the neighborhood of the eleventh rib, to the skin.

Curtice gives in 1891 (*25*) a full account of his work along this line. This hypothesis was based upon the finding of these immature stages in the submucous membranes of the gullet and in other tissues of the body, often months before the larvæ appeared on the back and cut holes through the skin. He also observed that the larvæ and inflammation disappeared from the gullet by the end of January or early in February. Apparently no observations were made on the actual habit of oviposition of the flies. In 1892 Riley (*84*) published a very good résumé of the knowledge of the life history and habits of *H. lineatum* up to that date. He concluded from an examination of material from various sources that *H. lineatum* was the predominant if not the only species found in the United States. In this article he also incorporated an account, based on observations of G. Schaupp and others, regarding the actual method of oviposition of this species, and the true first stage was described for the first time. He accepts Curtice's theory of the entrance via the mouth, and concludes that an additional link in the chain of circumstantial evidence pointing toward this method of ingress is supplied by the fact that the eggs are laid largely on the legs and that the cattle lick themselves in that region. In 1897 Marlatt (*64*) presented a concise summary of the information available at that time.

Horne, working largely on the immature stages within the bodies of cattle, published in Norway in 1894 (*45*) observations showing that the larvæ are truly migratory. He observed them in various situations, including the spinal column from one end to the other, sometimes under the pleura, in the abdominal cavity, and on the surface of the kidney. The following year the veterinarian Ruser (*86*) published his observations on the occurrence of the larvæ in the spinal canal and reported that he had found traces of larval tracks in the muscles of the back. In 1898 Koorevaar (*54*), working in Holland, gave definite proof that the small larvæ found in the spinal column of cattle were really Hypoderma. Some of these were introduced under the skin of a goat, and 12 days afterwards swellings appeared, from which later *H. bovis* was reared. In the same article he also described experiments in which 26 larvæ from the spinal canal of cattle were introduced under the skin of a dog. When the animal was examined two weeks later some of the larvæ were found in various parts of the animal, including the gullet and spinal canal. Similar larvæ fed to dogs and introduced into the gullet of a rabbit through a tube were not recovered. From these tests Koorevaar concludes that in bovines the larvæ reach the gullet or spinal canal after extensive wanderings from the place where they bored through the skin, and that they do not reach the gullet by way of the mouth. Further studies on the migration and seasonal occurrence of the larvæ within the host were published the same year by Koorevaar (*55*).

Following the publication by Curtice and the subsequent one by Riley, practically all scientists accepted Curtice's theory. In 1903 Koch (*53*) published a very valuable contribution as the result of several years' study of the larvæ of Hypoderma within the bodies of cattle. He shows that the young larvæ are widely distributed within the body cavity and in the intermuscular tissues of the back, and that larvæ as small as 2.2 millimeters in length may be found in the submucous tissues of the gullet. He concludes from the data presented that—

> It will presumably be apparent that the entrance of Hypoderma larvæ to the bodies of the cattle takes place through the alimentary system and not through the skin, and further that the larvæ migrate through the œsophagus and vertebral canal to the skin.

In 1907 Jost (*52*) reviewed the life history of *H. bovis.* He concluded that the eggs hatch in the gullet and that the larvæ bore through the mucous lining of it. He also makes the erroneous statement that the life cycle requires about nine months. Sörensen (*93*) in 1908 discussed the literature and concluded that the larvæ enter by mouth.

During the period 1908 to 1922, Carpenter and his associates in Ireland published a series of papers (*12* to *19*) dealing especially with experiments with the muzzling of calves in an effort to prevent their infestation. The earlier results were conflicting and the authors changed their viewpoint from year to year. In 1914, however, Carpenter, Hewitt, and Reddin (*17*) published the results of their observations on the penetration through the skin of larvæ of both *H. lineatum* and *H. bovis.* They first noticed soreness and scabs in the regions near where eggs of Hypoderma were attached. Beneath these they found holes indicating penetration and from one of these was squeezed, along with serum, a first-stage larva of *H. lineatum* which had evidently penetrated through the skin at the spot. They followed this with tests of newly hatched larvæ of *H. bovis* placed on clipped hair on a calf and found that they quickly passed down the hair and began to burrow into the skin immediately. They conclude:

> We believe therefore that no further doubt is possible as to the entrance of young Hypoderma larvæ into its host through the skin close to wherever the eggs may have been laid, and the results of the muzzling experiments show that entrance by the mouth is unlikely.

They have also expressed the opinion that it is not improbable that the larvæ may go from the legs to the gullet and thus to the back. Hadwen, working in British Columbia, has also made some valuable contributions to our knowledge of Hypoderma. In a paper published in 1912 (*32*), he presents data on the injuriousness of the cattle grubs in Canada and adds some valuable information on the method of egg laying of *H. bovis*.

The seriousness of injury by cattle grubs in Germany led to the appointment of a commission to study all phases of this subject. Several years were spent in this investigational work and the results were published in parts in the years 1912 to 1919 (*67*). A large amount of information was obtained on the losses due to the pests, relative numbers of the two species, life histories and habits, and control work.

C. Stub (*95–99*) carried on observations on cattle grubs in Denmark and published his records in 1912, 1913, 1915, and 1919. He added to the information on the life history and habits of the insect and reported that, in collaboration with Prof. Phil Boas, he found beneath a number of eggs a burrow through the skin which they interpreted as the entrance hole of a newly hatched larva. Stub also found larvæ from 2 to 7 millimeters long in the subdermal connective tissue of calves. In early records, he concluded that the larvæ burrow directly through the skin, but was under the erroneous impression that the eggs are laid on the back. In 1919 (*99*) he definitely traced the course of young larvæ from the inside of the right tibia to the esophagus.

Hadwen published further observations on the life history and seasonal development of both species in 1915 (*33*). In this paper he showed that larvæ removed from the gullet and placed under the skin on the leg of calves would work upward rapidly through the connective tissues and ultimately reach the back. In 1916, Hadwen and Bruce (*38*) attempted to trace the larvæ as they left the gullet and suggested that they pass up the crura of the diaphragm or along the posterior borders of the ribs to the neural canal and out through the posterior foramen to the subcutaneous tissues of the back. In another paper (*34*), in 1916, Hadwen added further data on the seasonal development of the larvæ and demonstrated the ability of the newly hatched larvæ to penetrate bovine skin. He also described lesions on cattle chargeable to the penetration of Hypoderma larvæ. Later a concise account of the cattle grub problem was issued by Hadwen (*36*).

In 1920 Carpenter and Hewitt (*18*) described in detail a successful experiment with warble eradication on Clare Island, Ireland; and in 1922 in the sixth report (*19*) on the problem, Carpenter, Phibbs, and Slattery presented further information on the life and seasonal history of both species of Hypoderma and further experimental evidence that larvæ enter the host through the skin only and not by way of the mouth. This report also summarizes tests with various dressings applied to the backs of cattle to kill the grubs, especially tobacco-powder wash. The biologies of Hypoderma and other aspects of the grub problem were summarized by Seymour-Jones (*91*) and Warburton (*110*) in 1922.

LIFE HISTORY IN BRIEF

There are two distinct species of cattle grubs and these of course present differences in appearance and habits in each of their stages. In a general way, however, the life histories of the two are similar, and the following summary of that of *Hypoderma lineatum* will serve as an illustration. Beginning with the large grubs which are well known to practically everyone who handles livestock, the life may be traced as follows:

As the grubs reach maturity in the subdermal tissues of the back during the late fall, winter, spring, or early summer, the holes through the skin gradually become larger and finally the grubs crawl out and drop to the ground. They seek protection under any loose material at hand and the outside skin shrinks, becoming hard, and within this the flies develop, emerging from 30 to 60 days later. These flies mate soon after emerging and without partaking of food begin to deposit eggs on cattle. The eggs are laid for the most part on the legs, probably the majority of them being below the knee or hock joint. The eggs hatch in from 2½ to 6 days, depending upon the temperature. The young larvæ crawl down the hair to the skin and immediately begin burrowing into it. At the point of entrance serum usually exudes and rather characteristic scabby and tender areas remain for a few days. After penetration little is known of the minute larvæ from the time they pass through the skin until they appear in the body cavity, especially in the submucous layers of the gullet of the host, having increased considerably in size and become more opaque, and evidently having passed through a molt. They spend several months in the host, mainly in the tissues between the mucous membranes and the muscular walls of the gullet, and evidently, as shown by one of the writers (Laake, *57*, *58*), pass through a molt in that situation or en route to the back. Growth continues during the summer months, and in the fall or winter the grubs have attained a length of from 15 to 17 millimeters and are ready to start on their migration to the back. Here again the exact route followed is not absolutely known; but these larvæ, which are of sufficient size to be found easily, have been met with in various places in the chest and abdomen and on the diaphragm. Not infrequently they are observed in the spinal canal and a little later are to be found in the connective tissues beneath the skin along the back. A hole is cut through the skin almost immediately after the larva reaches that situation and within 2 to 6 days the larva again molts and a wall of tissue begins to form around it in the form of an encystment sac. The next molt takes place about 24 days later, and the insect is now in its final larval stage. The duration of this stage averages about 30 days. It is thus seen that the development requires approximately a year's time, there being one generation during the year. The major part of this time, from 9 to 11 months, is spent within the body of the host.

DISTRIBUTION

The distribution of the two species of Hypoderma affecting cattle has received comparatively little attention, certainly not as much as the subject deserves. It appears that the grubs reach their maximum development in numbers in parts of Germany. They are known to be abundant in Switzerland, Denmark, Holland, and the British Isles, and probably occur throughout Europe. They are abundant throughout the greater part of the United States and southern Canada.

It is very doubful if either species of Hypoderma will ever become an established pest in the Tropics or subtropics. Both have been repeatedly introduced there with cattle, but there are no records of subsequent breeding. It is true, however, that positive information is very meager as to the presence of Hypoderma in parts of the world other than those in which it is a pest. A. H. Ritchie informs the writers that in the West Indies he has never seen the warble except in four animals imported from the United States.

No records are known to the writers of the occurrence of Hypoderma in South America. The genus is replaced in tropical America by Dermatobia, and its similar injury to hides leads some to think Hypoderma is present there.

Hypoderma is not indigenous to South Africa and apparently has never become established through introductions. Lounsbury (*62*) and Hutcheon (*47*) state that they have no knowledge of the occurrence of either species of Hypoderma in native cattle in the Union of South Africa. Lounsbury says in a letter: "Now and then warbles are found under the skin of animals imported within a matter of months, but I have never heard of any being found in animals bred in the country or here for a number of years."

Howard (*46*) reports the finding of larvæ of *H. lineatum* in Mozambique, East Africa, but does not say if from native or imported cattle.

James Bequaert has informed the writers that in his extensive work in Belgian Congo he has never seen or heard of an authentic case of the occurrence of either species of Hypoderma in that country. He also directs attention to the statement of Roubaud (*85*), who has paid special attention to dipterous parasites of mammals in Belgian Congo and French West Africa, that he has never seen Hypoderma on cattle in that region. In northern Africa, Hypoderma evidently occurs. E. E. Austen writes that the British Museum contains a male of *H. bovis* from Algeria near Bône, collected May 5, 1896, by A. E. Eaton. Vaney (*104*) in 1911, states that *H. bovis* occurs in Algeria. Willcocks (*112*), in 1918, says that *H. bovis* occurs in Egypt, but whether or not it is a common pest is not known.

In Australia, likewise, neither species seems to have gained a foothold. Tryon, in 1906 (*100*), and again in 1912 (*101*) reported the apparent stamping out of a local introduction in the Richmond district. Pound (*79*) describes the appearance of warbles in imported stock and adds, "It is difficult to assign any definite reason why the cattle grub fly has not become established in Queensland. Evidently the conditions of environment are unfavorable." Smit (*92*) states that *H. bovis* imported into the Dutch East Indies from Holland apparently failed to establish itself, as no records in native cattle have been made.

Regarding the nonoccurrence of Hypoderma in Hawaii, Van Dine and Norgaard (*108*) write: "One and possibily both of the bot flies attacking cattle have been brought to Hawaii with imported cattle. So far neither of them seem to have become established here."

Hypoderma bovis is essentially a northern form. This point has been brought out by a number of writers. Glaser (*29*) found that in Germany *bovis* predominated over the northern part of the empire while *lineatum* was more in evidence in the southern part. It is also worthy of note that Hypoderma larvæ are much more abundant in northern than in southern Germany (*56*). A writer (*1*) in Germany has pointed out that, with the interruption of the control work in that country due to the war, the insect had spread to previously uninfested areas. In Denmark, although *lineatum* is present, *bovis* is far more prevalent. Bequaert (in litt.) says:

In Belgium and France *H. bovis* is by far the most common species, and in some regions quite abundant. I do not know of any record of *H. lineatum* in Belgium. In France that species is very rare and of recent introduction; it was not known there at the time Joly (*51*) wrote his monograph, 1846.

In fact *H. lineatum* was not recorded from France until 1894 (*80*). Brauer (*8*, *9*) states that *H. bovis* is distributed from Scandinavia to the southern part of Europe and over Asia, Africa, and North America. He writes that this is the only species found in upper and lower Austria, Styria, and Hungary. He records the distribution of *H. lineatum* as South Russia, Norway, the Balkans, the Caucasus, and England. Vaney (*104*) reports *H. bovis* to be common in the Lyonnaise region in France. He and his associates (*59*, *60*, *105*, *107*) observed the number of grubby hides to range during the height of the season from about 12 to 21 per cent in different years. Vaney reports the occurrence of *H. bovis* only in the Lyonnaise region. Third-stage specimens, however, which he sent the writers from the gullets of cattle of that region, prove to be *H. lineatum*. In England and Ireland both species are common but sufficient data are not at hand to show their relative numbers. Hadwen (*36*) states that in Canada the two species have equal distribution, but that their distribution in the northern part of the country has not been determined. He makes no definite statement, however, regarding the relative abundance of the two.

A. Gansser, chairman of the Warble Fly Commission of Basel, Switzerland, states in correspondence that both *H. lineatum* and *H. bovis* are present in that country. *H. bovis* apparently constitutes about 60 per cent of the total number. The insects appear to be very abundant in certain sections of that country. Gansser states that they are generally distributed in the Alps and Jura Mountains up to 6,000 feet. He mentions heavy injury in the cantons of Valais, Vaud, and Grisons. Bornand (*7*) also comments on the abundance of *H. bovis* in cattle of the Jura and the Alps.

Until recently practically nothing definite has been known of the occurrence of Hypoderma in India. Maxwell-Lefroy and Howlett (*66*) write:

It seems probable that Hypoderma, the common European genus, is confined to western India from the Punjab southward probably as far as Gugerat. O'Quinlan (superintendent, C. V. D., Bengal) informs us that he has rarely or never seen warbles in Bengal cattle, and this agrees with our experience.

Patton (*75*) secured a specimen of *H. lineatum* from Doctor Annandale from India in 1922 and later others were sent him by Capt. H. E. Cross, who at the same time sent to the writers specimens of several larval stages of *H. lineatum* from the Punjab. He also furnished data showing an infestation of slightly over 35 per cent of some 41,000 head of cattle which he examined in different parts of the Punjab. C. W. Howard has written that he has never seen Hypoderma larvæ in southern China, except in cattle that were being imported. C. P. Clausen made some inquiry regarding the occurrence of Hypoderma in Manchuria in 1923. He informed the writers that although cattle in that Province were not infested, those from Mongolia were heavily infested. Clausen's informant stated that although many infested cattle were brought into Manchuria from Mongolia, they became free from grubs in one year. Clausen also learned from Dr. H. Okamoto that near Sapporo, Japan, there is a small locality in which this pest has become established, probably through introductions of cattle from America. Doctor Mat-

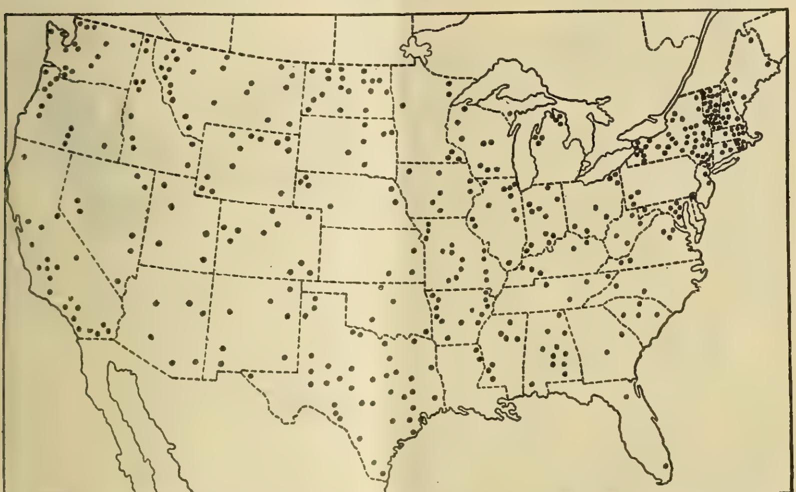


FIG. 1.—Distribution of *Hypoderma lineatum* in the United States. Each dot represents a locality where this species has been collected during this investigation

sumura also informed Clausen that *H. bovis* occurs on cattle in the vicinity of Akita.

Through correspondence and by personal examinations by agents of the bureau, the distribution of the cattle grubs in the United States and their relative abundance have been determined with fair accuracy. A summary of the information on this subject was published by one of the writers in 1915 (*4*), and Mote (*69*) has made a valuable contribution regarding the distribution of Hypoderma in Ohio. A study of the accompanying maps (figs. 1 and 2) will best illustrate the distribution of the two species of Hypoderma in the United States. It is apparent that *H. lineatum* is much more widely and generally distributed in this country than is *H. bovis;* in fact, the entire area where *H. bovis* occurs is also infested with *H. lineatum.* The former species had never been recorded in the United States up to 1910 (*50*). Riley (*84*), basing his information on a number of collections mainly from the Central and Southern States, concluded that probably *H. bovis* did not occur in this country. Hadwen (*32*) in 1912 showed that *H. bovis* occurred in abundance in southern British Columbia, and further evidence of the distribution is given by Hewitt (*42*) in 1914. Hence it is problematical as to just when that species was introduced, if in fact it is not a native. Records indicate, however, that it has been introduced rather recently. *H. lineatum*, on the other hand, has been known in this country for many years and has been bred from the native bison, suggesting the possibility that that form may be in reality an American species and not introduced from Europe. As indicated by the map, *H. bovis* is now generally distributed in the Northern States from Illinois to Maine and occurs in more or less isolated areas throughout the Northern States to the Pacific.

As stated by one of the writers (*4*) in regard to *H. bovis*, this species "must have some well-marked climatic barriers which have

FIG. 2.—Distribution of *Hypoderma bovis* in the United States. Each dot represents a locality where this species has been collected during this investigation. The points shown in the Southern States are collections of larvae shipped in in cattle

prevented its general dissemination through the country." As also pointed out in the publication referred to, there are certain areas in the United States which are almost, if not entirely, free from grubs. The most notable example of this is in the valley of the Red River of the North. In the southern two-thirds of Florida grubs are apparently not to be found except in imported animals. This condition may be due to some combination of natural-control factors, as humidity, salt spray, and drainage. In eastern Massachusetts, the coastal area of New Hampshire, and parts of southwestern Illinois, grubs are relatively scarce. Similar areas of scarcity have been noted by Hadwen in Canada, and he has also observed that the warbles are more abundant in the western Provinces than in the eastern. The writers' observations and reports from stockmen indicate that there is a marked variation in the abundance of grubs in different localities even when not distinctly separated. Sufficient data are not at hand for drawing final conclusions in regard to the areas of unusual abundance or scarcity; but it is believed that the effect of drainage, soil conditions, and the presence of certain types of vegetation are factors. In general, the lighter soils and good drainage, especially in the areas of heavy rainfall, appear to be favorable to the development of grubs. The presence of timber or moderately heavy vegetation also seems to favor them. There appears also to be an inhibiting influence existent along the coast, especially on the Atlantic.

It has not been possible to determine any special correlation between altitude and the abundance of grubs. It has been noted, however, that they seem to thrive admirably in fairly high altitudes. This is especially true with *H. lineatum*, which is known to be abundant at elevations above 7,000 feet. Some reports received from hide dealers indicate that they think grubs relatively fewer in numbers in the mountain ranges, but the writers' observations do not bear this out.

The evidence seems clear that in general where cattle are kept on the range, especially during the spring months, the grubs are more abundant. This condition is associated with the care the cattle receive, the absence of protection from the flies by barns and sheds, and the lack of cultivation of large areas. It is also probable that the poor and weak condition of stock on the range during early spring gives the flies a better opportunity of successfully depositing their eggs on them. Cultivation is apparently destructive to many of the larvæ, although the reduction in the number of grubs may be brought about by the combination of conditions which usually accompany intensive cultivation of large areas.

There is considerable variation in abundance of grubs from year to year in any given region, but in general this variation does not prevail throughout the entire country. Statistics on the percentage of grubby hides during the years 1921 to 1923, inclusive, furnished by some of the leading meat packers as recorded at their principal plants, show a distinct increase (average of 10 per cent) in grubbiness during this 4-year period. At first thought this might be attributed to seasonal conditions; but the fact that this increase was greatest and most consistent in the North, where *H. bovis* is known to be gaining a foothold, indicates that it may really be due in part at least to the spread of that species. If this is true, a very considerable further increase in percentage of grubby hides and degree of infestation may be expected.

ECONOMIC IMPORTANCE

That grubs are highly injurious to cattle is generally conceded. Opinions vary greatly, however, as to the exact extent of the injury, and it is a difficult matter to determine with any degree of accuracy the ill effects caused through the activity of the various stages of these insects. Injury is produced in a number of different ways. These may be classed in two general groups—(1) annoyance caused by the flies during the deposition of eggs, and, (2) irritation produced by the larvæ within the bodies of the hosts. The first group, of course, varies with the abundance of the insects and also with the species present. *Hypoderma bovis* causes the most excitement to stock and hence, where it occurs, produces the greatest damage in this respect. Losses caused by this annoyance include marked reduction in milk flow, failure to put on flesh normally, mechanical injury due to the wild efforts of the animals to escape attacks; and not infrequently loss from the miring down of cattle when they rush into ponds or mud holes, or their injury or destruction when running over embankments or cliffs. These attacks usually occur at a time when the stock are in a weakened condition in early spring, hence the danger of miring and abortion is increased. The exasperation and often death loss resulting from stampedes caused by heel flies is well known to stockmen. The second group may be divided into four sections: (1) The soreness and pain produced by the penetration of the young larvæ through the skin; (2) the irritation produced in the gullet and in other internal organs due to the migrating larvæ; (3) inflammation produced along the spinal cord and on the main branches of the nervous system by the burrowing of the larvæ along the spinal canal and the ingress and egress of that canal; and (4) the irritation produced by the later larval stages in the subdermal tissues of the back, with accompanying pus formation.

The exact extent of loss produced by these various stages and activities of the insect can not be determined, but it may be well to point out some facts along this line. Considering the loss produced by the flies at the time they are depositing eggs, many dairymen affirm that they know immediately by reduced production of milk when the heel flies become active. Of course the amount of loss at this time depends to a large extent upon the number of flies, the quantity of feed supplied the cattle, and the protection afforded them during the day. In regions where the grubs are abundant some dairymen estimate the milk loss at from 10 to 25 per cent during the period of fly activity. The season when the adult flies are active varies, lasting from one to four months. It can be well understood how this marked reduction in milk flow is brought about when the frantic efforts of the cattle to escape attack are observed. They are frequently seen standing closely bunched in the shade or in the middle of a pond or stream during the major part of the day when they should be grazing.

The annoyance produced by the penetration of the young larvæ through the skin is by no means small, although the period when it occurs is comparatively short. This irritation is indicated by the violent licking of the heels and other parts where the penetration is taking place, accompanied by intermittent kicking and stamping of the feet. There are also extensive external lesions, their location indicated by hair matted and rough from the exuding serum and sometimes by rather extensive areas denuded of hair or even by sloughed areas. This injury is more severe in the case of *H. lineatum* than with *H. bovis*, owing to the fact that with the former many larvæ penetrate the skin at nearly the same spot, the eggs from which they emerged having been laid together, whereas the eggs of the latter are placed singly.

Little is known as to the annoyance produced by the migration of the first-stage larvæ after they have passed through the skin. It is possible, however, that this is of minor importance. As the larvæ increase in size, and especially when they are numerous, there is no doubt that their migration through the body influences the productivity and health of the host. When the larvæ reach the esophagus in numbers, however, marked irritation is often in evidence. The submucous tissues are edematous, usually yellowish, and sometimes bloody in the region of the larvæ. Cases are on record in which heavy infestations of the esophagus produced edematose conditions with large swellings. Instances are also recorded in which the larvæ burrowing along the spinal canal have caused paralysis of the posterior parts, although this seems to be unusual, considering the large number of cases in which infestation of the canal occurs.

Abundant testimony is at hand as to the injurious effect of the last-stage larvæ under the skin in the backs of cattle. Many stockmen believe, and their opinion in most cases seems well founded, that heavy infestations of the grubs in the backs of calves are a prime factor in causing their death. It has been observed repeatedly that where these larvæ are removed, the calves begin to "pick up" promptly. The effect of heavy infestations in the backs of dairy cattle is also responsible for decreased milk flow. Danish literature contains a reference to a case observed by Boas (*6*), in which a cow producing daily from 30 to 32 pounds of milk increased the yield to 40 pounds a few days after 80 larvæ had been extracted from the back. Feeders frequently comment on the difficulty of fattening animals in which a considerable number of grubs are present. Those who feed steers on an extensive scale during the winter have informed the writers that in most cases when an animal is not making proper gains, it will be found upon examination to have a heavy infestation of grubs in the back. When these are extracted the animals usually respond well to the feed. Exact information on this subject is meager. Schöttler and Glaser (*88*) have reported upon an experiment which they performed in Germany on the effect of grubs on the fattening of cattle. The grubs were extracted from one-half of the herd and the other half kept as a check. The portion from which the grubs were removed showed a gain in weight of 5.16 per cent over the infested portion of the herd.

Aside from the damage produced by the holes cut in the skin, there is other injury produced to the host itself by the grubs while located in the subdermal tissues of the back. When the young larvæ first reach the subcutaneous tissues along the back, marked swellings are often produced. These are evidently painful, as indicated by the action of the host when they are touched. Just how much irritation is produced after this is problematical. Undoubtedly the spiny armature of the fourth and fifth stages causes considerable irritation, but it is supposed that the encystment sac surrounding the larger larvæ is practically free from nerves, and for this reason the host probably does not experience any considerable amount of pain or annoyance. Not infrequently, however, pus organisms gain entrance to the openings, and often large abscesses are formed under the skin. These are associated usually with the death of the larva, either by crushing or by its imprisonment and suffocation from the firm plugging up or scabbing over of the hole in the skin. In a number of instances abscesses have been observed which were half as large as the crown of a man's hat and very sore. If these are well opened and drained they soon heal, but where they are not properly drained they may discharge for considerable periods, and sometimes large encystments occur which may form a permanent blemish on the animal.

Another injury of distinct type, but directly connected with the infestation with grubs, has been discussed by Hadwen and Bruce (*39*). They have shown that the injection of the juice of a few grubs into a bovine may cause death by anaphylactic shock in a few minutes, and that the crushing of a number of grubs in the back of an animal may cause marked anaphylactic symptoms. Their explanation of this is that when an animal has been infested with larvæ of Hypoderma it becomes sensitized, and if the contents of grubs are introduced either by absorption through natural crushing of the larvæ in the back or by injection into the animal, anaphylactic symptoms are produced. In nature cases of anaphylactic shocks are probably rather rare, though they might follow the crushing of a considerable number of larvæ in the back of an animal, as sometimes happens.

In addition to the direct effect of the larvæ on the host itself, there is also an influence on the value of the meat as human food. The presence of the larvæ in the connective tissues of the back produces a very repulsive if not actually injurious condition in that portion of the carcass. This necessitates the trimming off of the affected parts, frequently resulting in the loss of 2 pounds of meat and at best leaving the carcass unattractive and hence less salable. This infiltrated edematous tissue is yellowish and more or less bloody, and appears watery or jelly-like. It is seldom that more than the connective tissue and fat immediately under the skin are affected.

The loss in the value of hides due to the holes cut by the larvæ is one which can be more nearly figured in dollars and cents than any other. Furthermore, this loss is constantly brought to the attention of hide dealers. Some very interesting information has been gleaned from the replies of about 100 packers, butchers, hide dealers, and tanners in all parts of the country through a questionnaire sent out in 1920. It has been computed from these replies that 19 per cent of all hides handled are classed as "grubby" and over 50 per cent of the hides taken off in grub season are so classed. The method of classing grubby hides varies considerably in different sections of the country. Most packer hides are sold on a grub-selection basis. The percentage of grubby hides is determined by the individual inspection of a sample of each lot of hides. Any grub injury which will permit of a skewer being pushed through is considered a grub hole. Country hides are usually sold "flat for grubs;" that is, the percentage of grubby hides is not determined by inspection, but the price is reduced during the grub season sufficiently to cover the lowered value of the hides.

On the Chicago market it is the custom of the trade to inspect, for grubs, branded cow hides and Texas steer hides from November 1 to June 1, Colorado steer hides from December 1 to June 1, and all other classes except bull hides from January 1 to June 1. It is obvious that these periods do not fully cover the seasons of grub damage; for instance, in the Northern States where *H. bovis* occurs, some grubs are present throughout the summer. Bull hides and calf-skins are seldom classified as regards grubs. On this market it is customary to place all packer hides with five or more grub holes in grade No. 2 and discount them 1 cent per pound. With a country

FIG. 3.—"Grubby" hide after being tanned, practically ruined by holes made by cattle grubs in most valuable part

hide, one grub hole makes a No. 2. Some recognize a No. 3 grade, placing in it all hides with more than 10 grub holes. Extremely grubby hides are frequently called "pepper boxes" (fig. 3) and are sold as glue stock at one-half price. The discount for grub holes in leather varies considerably, but usually ranges between 3 and 10 cents per pound, according to the number of grub holes in the side.

Practically all those concerned in the hide and leather business agree that the scars resulting from grub attack are not desirable in leather, but the opinion as to the percentage of injury produced differs considerably. Some say that even when completely healed grubby hides are undesirable in their business, on account of appearance, weaker fiber, etc.

It is generally agreed that the nominal discount of 1 cent per pound applied to grubby hides (grade No. 2) by trade custom is far too low. Many tanners state that they would gladly pay double the 1 cent per pound additional charged for hides of No. 1 grade if they could obtain grub-free hides. In fact, tanners of hides for certain purposes make every effort to avoid the grub season in purchasing their stocks; and this practice, in addition to tying up considerable capital for several months, introduces another indirect loss. Under present methods of storing green salt hides there develops in them, when held for several months, a condition known as "salt stain" which materially damages them. This loss is in a large measure chargeable to the warble. There are also a number of tanners who are purchasing Argentine and other foreign hides primarily to avoid grub damage. Grub holes are especially to be avoided when the leather is to be used for certain purposes; for instance, in upholstery leather even one or two holes coming in the center, as they usually do, would cause the entire hide to be discarded for that purpose.

Estimates of the actual monetary loss in hides and leather in the United States due to the grubs run from $5,000,000 to $10,000,000 annually. Although the percentage of infested hides varies somewhat from year to year and the number of cattle slaughtered also varies, it is thought that the figures for the winter of 1921–22 are about normal. In the period from November 1 to June 1 of these years, 4,448,793 cattle were slaughtered under the inspection of the Bureau of Animal Industry. It is estimated that about 40 per cent of the cattle killed in the United States that year were under inspection. Thus, the total number of cattle slaughtered in the United States during the period mentioned would be 11,121,980. Accepting the estimate that 50 per cent of these hides are infested with at least 5 grubs each and hence are placed in grade No. 2, we would have 5,560,990 of this grade. At an average of 40 pounds each and applying the nominal 1 cent per pound discount the loss would amount to $2,224,396. During the same period the number of calves slaughtered under inspection was 2,277,165. By the same method of figuring as for cattle, but considering only 30 per cent of the skins infested and the average weight at 20 pounds, there would be experienced a loss of $341,575, or a total annual loss among cattle hides and calf skins of $2,565,971.

Taking into consideration the number of hides which are damaged but not taken off during the season of grub classification, the number which are perforated by less than five grubs, the number which are placed in grade No. 2 or thrown into glue stock at one-half price owing to extreme infestation, the loss through salt stains in storage, and the increased cost of handling in making grub selections of the hides, side leather, and cut leather, and accepting the statement of hide dealers and tanners that the discount of 1 cent per pound is really too small, we may reasonably place the total loss to the hide, tanning, and leather industries of the United States at $5,000,000 each year. Coppens (*23*), in connection with a discussion of losses produced by this insect in Europe, states that the War Ministry at Brussels found that the wearing properties of grubby hides as leather is only 30 per cent of that of sound hides. Mason (*65*) also touches on the importance of grubs to the tanning industry. De Vries (*27*) and Ostertag (*74*) also discuss losses in Europe due to these insects.

After a careful consideration of the various losses brought about by the cattle grubs the writers have concluded that they are conservative in placing the annual loss in the United States chargeable to them at $50,000,000.

INJURY TO MAN

Many cases are on record in which larvæ of Hypoderma have been extracted from man. They are found usually in the subdermal tissues, where they produce what is often called "creeping myiasis." There seems to be a tendency for the larvæ to work upward and most of them are finally extracted from the head, face, or upper extremeties. These migrations are often extensive and rather rapid, accompanied by considerable pain. In some cases the larvæ appear under the mucous membranes of the mouth.

The source of these infestations in man is not known, but most of them have been in children and usually the affected individuals have been more or less associated with the cattle. It is probable that the flies occasionally oviposit on the hair of the heads or legs of children or on their clothing and the larvæ penetrate the skin upon hatching. In the experience of Glaser (*29*, *No. 5*, *p. 35*) while experimenting with the grub, there is an example of the deposition of an egg on woolen clothing. In this case the resulting larva hatched and penetrated the skin of the leg. Some time later its presence in the gastric and esophageal regions was detected by an uncomfortable feeling. The larva apparently passed up the esophagus and was later extricated at the base of one of the lower molar teeth.

Hamilton [5] records a case of a boy who was suffering for some months from swollen glands on the neck, accompanied by a fetid ulceration around the back teeth on the lower jaw. After three months of unsuccessful treatment a well developed tawny warble larva was discovered in the ulcer at the root of the tongue. The case resulted fatally.

The writers have obtained through W. A. Riley, of the University of Minnesota, the clinical history, as prepared by O. A. Kimble, of a case of dermal myiasis. As this case is typical, and as opportunity has been afforded of examining the larva, a résumé of the case is given. A child 6 years old, living on a farm, was brought to Doctor Kimble's office during the first week in November, 1920. She complained of a swelling of the left forearm with

---

[5] Hamilton, John. Medico-entomology. *In* Ent. News, vol. 4, pp. 217-219, 1893.

some stiffness and pain in the wrist. The pulse and temperature and general physical condition were normal. Three weeks later the child exhibited a swelling of a similar nature in the lumbar region on the left side. This lasted only a few days. During the first week in December the child was again brought in with a slightly edematous area, about the size of the palm of the hand, on the left side in the midaxillary region. Two or three days later this area showed two small perforations of the skin about an inch apart. A similar area next occurred on the lower border of the right scapula. Pain was felt in the area and a few hours later two punctures appeared. A few days later the child's father saw a larva moving in a hole which appeared on the upper angle of the left scapula following a similar clinical experience. Two days later a larva was pressed from a puncture which appeared at the base of the mastoid process of the left temporal bone. This larva was found by the writers to be *H. lineatum* in the third stage.

Another interesting case has been brought to the writers' attention by R. A. Cooley. Dr. O. E. Patterson, who attended this case, and the mother of the infested child have kindly furnished a very complete history of the case. This infestation occurred in a child of 5 years who lived on a stock farm near Moiese, Mont. From late November, 1921, to March 1, 1923, 14 larvæ were removed from the patient. Seven of these appeared on the head and face, one each from the neck, arm, shoulder, and chest, and one each from the thigh and from the calf of the leg. The symptoms accompanying the appearance of each larva were very similar but most acute with those on the face. Several hours (sometimes 24) preceding the appearance of each larva there was malaise and pain in the stomach, accompanied later with marked fever. These symptoms then gave way to retarded heart action, cold limbs, and drowsiness. When these symptoms had practically disappeared a local pain and swelling occurred in the region where the larva came to the surface. The duration of each attack ranged from one and one-half to four days. After several larvæ had been expelled symptoms of neuritis began to manifest themselves in stiffness of the legs, weakness of the leg muscles, and finally almost complete paralysis of the lower extremities, which lasted several weeks, only subsiding after practicaly all larvæ had come to the subdermal region. A year later this paralytic condition had not completely disappeared. These symptoms suggest that some of the larvæ may have entered the spinal canal and produced lesions there.

The writers have examined two of the specimens from this case and found them to be third-stage larvæ of *H. lineatum*.

Riley (*84*) has given a rather complete account of the infestation of a child in Pennsylvania. A physician was called to attend this child, which was supposed to be suffering from erysipelas. The child, a boy of 3 or 4 years, was suffering sufficient pain from something working under the skin to prevent his sleeping at night. This larva had been noticed five months before under the skin near the sternal end of the right clavicle, and during the intervening time it had traveled up and down the chest, in front down one arm to the elbow, and over one side to the back. Prior to the calling of the physician no serious annoyance had been experienced. This larva after removal was positively identified by Riley as *H. lineatum* in the next to the last stage.

Schöyen (*89*) has presented a résumé of a large number of cases which have been encountered in Norway and elsewhere. He states that he has examined many of these grubs and that they are without doubt *H. bovis.* He further says:

As a rule they have accomplished long ramblings under the skin, always in an upward direction previous to their appearance through an open tumor on the upper part of the body, head, neck, shoulders, etc. All of them have lived in this manner for months and came out in the course of the winter months, but were always still too young to go through their transformation. It is especially with persons who look after or take care of cattle in the summer months that such grubs are to be found during the winter.

It is of course conceivable that these larvæ in their migrations may cause some rather serious symptoms, which in many cases may not be attributed to the larvæ at all.

COMMON NAMES AND POPULAR IDEAS

It is not surprising, considering the wide distribution and common occurrence of Hypoderma on cattle, that the insects should have come to the attention of nearly all of the cattle raisers of the country. As with most other insect pests, various colloquial names have been applied to them. In the Southern States the larvæ are commonly spoken of as "wolves" and sometimes as "grubs." In the North and West the term "warbles" is commonly used for the larvæ although they are frequently spoken of as "grubs." By butchers, hide dealers, and tanners throughout the country, the name "grub" is applied very generally to the larvæ of both species and the infested hides are spoken of as "grubby." Certain individuals sometimes also speak of the larvæ as "worms" and others call them "cattle bots" or simply "bots." The term "heel fly" is commonly applied to the adult insect throughout the United States, but in most cases the stockmen do not connect the heel fly with the grub in the backs of the cattle. The term "heel fly" is very appropriate, especially for *Hypoderma lineatum*, as it fittingly describes the habit of the fly in attacking the lower extremities, particularly the heels, during oviposition. "Warble fly" is applied to the adult insect by some stockmen, especially those from England, and "gad fly" is used for it in some localities. The use of the last name is not desirable, as it is more frequently applied to the horse flies (Tabanidae).

In Great Britain the term "ox warble" is used for both species. In Germany the words "Dasselfliege" and "Dasselbeule" are applied specifically to the fly and the larvæ in the back of the host, while "Dasselplage" refers to infestations. In France the word "varron" is used.

There is need for common names to designate the two species. The propriety of adopting the name "ox warble" for the two forms might be open to question, on the ground that the use of the word "ox" as applied to cattle is almost obsolete in this country and that the word "warble" is more aptly applied to the swelling produced by the larva *in situ* and is essentially an English term.

Owing to the aptness and general use of the term "cattle grub," the adoption of this name for the larval stages of the two species is advised. Since *H. bovis* is not to be found in the South but thrives in the North, the term "northern cattle grub" is suggested for this species; and since *H. lineatum* is abundant and widely distributed throughout the country it may be termed the "common cattle grub." When referring to the adult the word "fly" could be added after either of the names and thus the habits of the larvæ would be suggested; but the well-established term "heel fly," with the modifying words "northern" or "common" preceding it when it is desired to refer definitely to one species, is preferable.

The most prevalent idea as to the cause of the grubs in the backs of cattle is that the animals are stung by the large black horse fly (*Tabanus atratus* Fab.) (fig. 4). This idea originates from the observation that these flies attack the cattle primarily along the back where the grubs occur and that they annoy the stock considerably. A good many stockmen are of the opinion that the running of cattle in the spring is caused by the pain produced by the grubs in the back, especially at the time they are dropping out. This erroneous supposition is, of course, correlated with the fact that the heel flies are seldom seen in action, owing to the rapidity with which the cattle leave a spot when the heel fly appears. There are many different notions held by stock raisers as to how grubs get into the backs of cattle and what causes them. These are often colored by the theories propounded by naturalists as reviewed in the preceding historical sketch.

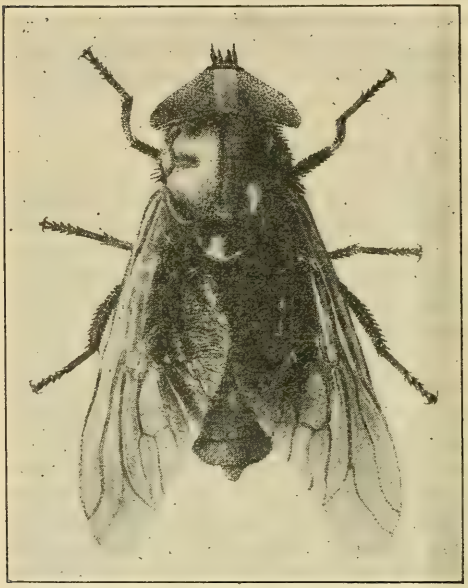


FIG. 4.—The black horse-fly (*Tabanus atratus*), often erroneously thought to be the cause of cattle grubs. Much enlarged

HOSTS

The normal host of *Hypoderma bovis* and *H. lineatum* is cattle, *Bos taurus*. The American bison, *Bos bison*, is known to be infested at times with *H. lineatum*, but bison do not appear to be so heavily infested as are cattle raised under similar conditions in the same regions. The migration and development in bison appear to be practically the same as in cattle.

A number of reports are at hand of the occurrence of *H. lineatum* larvæ in the subdermal tissues of the backs of horses. A few specimens of larvæ from this host have been examined by the writers and found to be *H. lineatum*. Most of those seen were in the fifth stage. Stockmen have informed the writers that occasionally one of their cow ponies becomes infested with as many as 10 or 15 grubs. These sometimes produce abscesses, probably due to the crushing of the larvæ by the saddle. The writers have no authentic records of the complete development of larvæ within a horse, but this probably occurs occasionally.

Brauer (*8*) has described a Hypoderma larva from the horse and was uncertain of its identity. Ormerod (*71*) gives considerable information on the occurrence of Hypoderma larvæ in horses in England, but none were positively identified. It is very probable that *H. bovis* or *H. lineatum* was concerned in these cases.

The writers have made but a single test of the development of Hypoderma larvæ in a horse. On March 15, 1922, and the following day two flies (*H. lineatum*) caught in nature were permitted to oviposit on the hairs, on the feet, and at the base of the tail of a horse. Five days later most of the eggs had hatched and the larvæ had penetrated the skin as indicated by a copious exudation of serum, some of which was slightly tinged with blood. There was also some swelling in the region where the larvæ penetrated at the base of the tail. However, the animal did not show any indication of irritation at the time the penetration took place. In about a week the heavy scab formed by the dry serum loosened. Frequent examination of the host during the next year failed to reveal the presence of a single larva.

Since it appears that Hypoderma larvæ may occasionally develop in the goat (*Capra* sp.), several tests were made of this possibility with Angora goats. In 1921, 25 eggs were placed by a fly upon a goat's heels. Three days later some of these were observed to be hatched and the larvæ penetrating, but the animal showed no special uneasiness. During the following spring about 86 eggs of *H. lineatum* were placed on the legs of another goat. Some of these were ready to hatch when the hairs bearing them were cemented on the animal. Other eggs of this lot were shown to be viable by incubator tests, but no lesions could be found on the host. Unfortunately one of these goats was lost the following summer, but the other failed to develop any larvæ. On April 10, 1923, a fly was induced to deposit 61 eggs on the legs of a kid. Although the eggs from this fly were fertile, the host showed no uneasiness and exhibited no lesions of penetration. Apparently the eggs were lost before hatching. No special difficulty was experienced in getting the flies to lay eggs on this host.

On December 22, 1920, 30 larvæ, 10 to 15 millimeters in length, taken from the gullets of cattle, were inserted under the skin between the knee and the hip of an Angora goat. A few days later a careful examination of the skin showed the presence of small objects a few inches from the point of insertion, which were thought to be some of the larvæ. On January 17, 1921, two of the larvæ reached the back in the lumbar region and perforated the skin. These soon scabbed over, however, and on March 4 the lumps were considerably reduced in size, and the larvæ were found to be dead.

Two Angora goats were infested on November 29, 1922, by means of an incision on the lower part of the thigh. One of these received 18 and the other 20 larvæ of *H. lineatum*, averaging 13.2 millimeters in length, from the gullets of cattle. On the former of these two goats 3 larvæ appeared under the skin of the back in the lumbar region, 2 on December 12, and 1 on December 19; and on the latter

2 larvæ appeared on the back December 12, also in the lumbar region. Each larva had cut a hole through the skin, and from these holes there was an extensive discharge of serum which hardened, matting the hair over the grub, thus indicating a marked reaction on the part of the host against the larvæ. All evidence of the presence of the larvæ disappeared in a few days.

During 1922 H. E. Cross forwarded a series of Hypoderma larvæ from goats on the Punjab, India. Most of these proved to be *H. crossi* Patton, but there were two larvæ of *H. lineatum*, one in the fourth and one in the fifth stage.

Peter (*76*) placed 45 larvæ, removed from the spinal canals of cattle, under the skin of two goats; a single larva finally completed its development.

Koorevaar (*54*) showed that it is possible for larvæ of *H. bovis* to complete development in a goat after their removal from the spinal canal of cattle and introduction under the skin of the goat.

Brauer (*8*) records sheep (*Ovis aries*) as a host for Hypoderma larvæ, stating that Winnertz had seen a number of flies following a flock and that Schwabs asserted that grubs occur under the skin of shorn sheep. These he pronounced to be *H. bovis*. It is noteworthy that Brauer placed a question after *Ovis aries* as a host. The writers have never observed a larva of Hypoderma on a sheep in nature, nor have they seen any indication of the attack of sheep by heel flies.

The writers have carried out a few experiments to illustrate how larvæ will develop in sheep. The flies seem averse to laying eggs on the wool, but oviposit readily on the hairs of the legs. Forty eggs attached by a fly above the hoof of a sheep apparently did not hatch, or at least no lesions indicating penetration were observed. These eggs were known to be viable. During the spring of 1922 about 75 eggs were deposited on the legs of a sheep; subsequent examinations failed to indicate that hatching or penetration had taken place. Some of the eggs of this lot were known to be fertile. During the spring of 1923 at least a few eggs of a number deposited on the leg of a sheep hatched and the larvæ penetrated, as indicated by the presence of lesions.

Two grade Shropshire sheep were infested November 29, 1922, by inserting under the skin a few inches above the right hock 20 *H. lineatum* larvæ averaging 13.2 millimeters in length, taken from cattle gullets. These were probably all second-stage larvæ when introduced. On December 7 one larva appeared on the back of one of the sheep, and on December 9 one came up on the other host. Larvæ continued to reach the subdermal tissues of the backs of both sheep at intervals of a few days until January 3, 1923, when a total of 11 had reached the back of each animal. They were rather generally distributed over the backs, but more numerous in the lumbar region. There was more or less exudate from the grub holes, and in no case did the larvæ remain longer than about 10 days before succumbing. Several dead larvæ, all in the fourth stage, were found at different times in the wool.

Many people are of the opinion that Hypoderma larvæ are to be found in small domestic and wild mammals. There are no published records of such occurrence in nature, and the examination of many small mammals in the course of the work leads to the belief that

Hypoderma seldom, if ever, develops in them. Cats are not infrequently infested with oestrid larvæ, but so far as known these all belong to another genus, Cuterebra.

Many dogs kept under conditions which would favor an infestation by Hypoderma larvæ have been examined with negative results. In one instance three adults of *H. lineatum* were permitted to oviposit upon the legs of a dog. About 50 eggs were placed in this way; although the eggs were viable, no penetration appeared to take place. Unfortunately, the dog was lost before an opportunity was had for the larvæ to reach the back.

Koorevaar (*54*) found that larvæ from the spinal canal of a calf, introduced under the skin of a dog, had migrated extensively when the animal was dissected two weeks later. Some were found in the gullet and some in the spinal canal.

Four tests of the possibility of the development of *H. lineatum* in rabbits were made by allowing the flies to oviposit upon the hairs of different parts of the rabbit. Three of these 4 hosts developed lumps on the body within 45 to 100 days after being infested. Some of these had openings through the skin, but the presence of the larvæ in them was not definitely determined, and none persisted for more than a week or two. In one instance several newly hatched larvæ of *H. lineatum* were introduced into the eye of a rabbit. They were watched for over an hour, but none burrowed into the tissues.

Two experiments were made with the introduction of larvæ of *H. lineatum* from the gullets of cattle into rabbits. On December 22, 1920, 15 larvæ measuring from 11 to 15 millimeters in length were introduced into an incision near the left hip joint of a Belgian hare. The rabbit died from infection two days later. Upon dissection four dead larvæ were found, but none of these were far from the point of introduction.

On November 15, 1922, 10 larvæ of *H. lineatum* from the gullets of cattle were introduced under the skin of a rabbit on the left side of the back in the lumbar region. The average length of these was 14 millimeters. The following morning the rabbit was ill, and had considerable swelling below the point of incision. The infiltrated area extended down the side and under the belly where there was a considerable accumulation of serous material, which was drained. On the second morning the animal was worse, with fever, labored breathing, stiff hind quarters, and an accumulation of puslike material in the eyes. In the afternoon the animal, which was very low, was chloroformed and dissected. Four living and one dead larva were recovered. Two of these were in the connective tissue from 1½ to 2 inches from the point of introduction. One was on the surface of the large intestine about opposite the kidney, and the fourth was rather deeply imbedded in the connective tissue on the inside of the left leg at the knee joint. It was possible to trace this larva with considerable certainty by an infiltrated path down the side to the median line of the belly, thence backward between the legs and upward to the pin bone, and thence to the inside of the leg, the point at which it was found. Thus this specimen had traveled 6 or 7 inches in the subdermal tissue.

In an experiment carried out by Peter (*76*), several larvæ were placed under the skin of two rabbits. In one of these four living larvæ were found four months later, but they were not seen subsequently.

A few tests have been made to determine if *H. lineatum* larvæ will develop in guinea pigs. Flies were induced to deposit nearly 100 eggs on 2 guinea pigs on April 10 and 11, 1923. Eggs from these females were shown to be fertile by tests in an incubator, but both guinea pigs apparently lost all the eggs before hatching began.

Several larvæ of *H. lineatum* from cattle gullets were introduced through an incision of the skin on the backs of two guinea pigs. Both animals were somewhat stiff and inactive the following day and the female soon became very sick. An edematous swelling developed on the belly. This finally broke and the animal slowly recovered, but there was no evidence of the presence of the larvæ. The male guinea pig recovered rapidly and a few weeks later developed a small lump with a hole through the skin over it, just behind the shoulders. This was a typical grub lesion, but the larvæ could not be seen. This disappeared in a few days and no further evidence of the infestation was seen.

As is shown in the discussion of "injury to man," infestations of humans, especially children, by Hypoderma are not uncommon, although it appears that man is not a favorable host.

ACTIONS OF CATTLE WHEN ATTACKED BY ADULT HYPODERMA

The reactions of cattle to the attack of these insects is so remarkable and so much discussed that a brief statement on this subject seems warranted.

As with the reactions of a host to various other stimuli, we find a marked variation in the effect of Hypoderma attack on different individuals. This is, however, mainly a matter of degree of violence of reaction rather than of kind. As has been mentioned, the fright produced by *H. bovis* is much more pronounced than that produced by *H. lineatum*, but the latter often causes a wild stampede.

In the case of both of these species the female has a very flexible telescopic ovipositor, in no way fitted for pricking the skin. In fact it can scarcely be felt on one's hand when it is extended by the fly. Convincing evidence of this is also afforded in the fact that flies have frequently been seen to approach an animal unnoticed and deposit many eggs without any annoyance whatever.

Careful observations among cattle during heel-fly activity will soon convince anyone that it is the attack of the fly which produces the fright. The writers agree with Hadwen (*36*) that this fear is produced mainly by the persistent attack of the fly. This is particularly true in the case of *H. bovis*. When the fly first attacks cattle at the beginning of the season the reaction against it is usually not very violent. The animal kicks or shakes the foot, but the immediate return of the enemy alarms the cow and she starts walking away; being pursued, the fright becomes more pronounced and she may run a short distance and begin walking again. The fly immediately resumes its attack and then the animal dashes away in terror (fig. 5, *b*), with the insect often at its heels, in the fashion of a dog. There is reason to believe that the fear of this insect is to some extent instinctive; also that, as the areas of attack become sore and tender from the penetration of the larvæ, the animals are more easily aroused and terrorized.

After a herd has been attacked for a few days in spring, it is only necessary to have a single fly begin to oviposit on an animal in order to start the whole herd from pasture to some protected place. When water is at hand it furnishes the preferred and most effective pro-

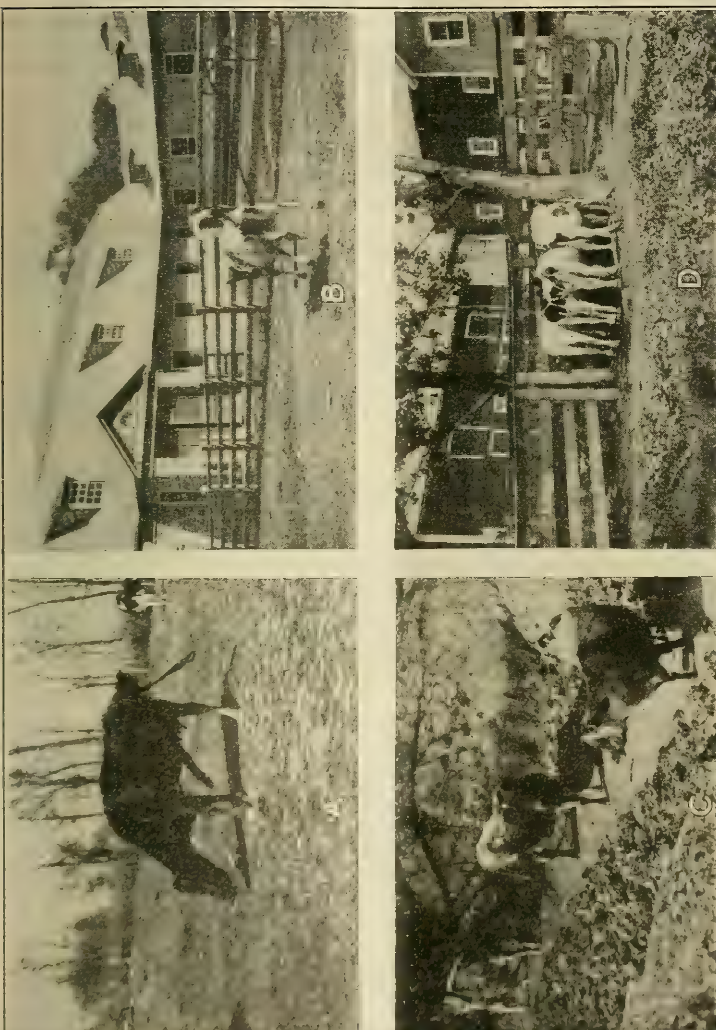


FIG. 5.—Actions of cattle when attacked by adult Hypoderma: *a*, Cow showing attitude assumed when heel fly (*Hypoderma lineatum*) first attacks; *b*, heifer attacked by *Hypoderma bovis* making wild dash for protection; *c*, cows standing in stream to escape heel-fly attack; *d*, calves crowding into shade to escape heel-fly attack

tection. Animals have been observed to remain standing in the water practically all day when adults of *H. lineatum* were numerous, and apparently without ever being molested by flies (fig. 5, *c*), even though the water was not more than a few inches deep. Shade offers considerable protection and is usually sought in the absence of water. (Fig. 5, *d*.) *H. bovis* is less easily repelled either by water or shade than is *H. lineatum.* Frequently cattle will run for a knoll if shade is not at hand, and when the breeze is strong the grouping of the stock on high ground seems to give some immunity from attack. When these natural protections are not accessible the flies, especially *H. bovis*, will keep up their attack intermittently, causing the cattle to run from one part of the pasture to another, in small pastures causing them to run round and round until they froth at the mouth, breathe heavily, and even drop from exhaustion. Under range conditions the stock usually have better opportunity of escaping, but the tendency to a general stampede is increased, especially if cattle are being worked in large herds.

When grazing, cattle usually detect the presence of a fly very quickly, largely by sight and hearing, but also by touch. Cattle readily differentiate between the presence of a heel fly and other insects. The listening attitude assumed when a fly is in the vicinity is characteristic, as is also the action of shaking the foot (fig. 5, *a*) to dislodge a fly, the rolling action of the tail, and the look of fright when a fly attacks in earnest.

DESCRIPTION OF STAGES

THE EGG

The egg of *Hypoderma lineatum* (fig. 6, *a*; fig. 7) is dull yellowish white and the surface is smooth and shining. It is narrowly ovoid, slightly larger at the base than at the tip, and its greatest diameter is at the middle. The average length of the egg proper is 0.76 millimeter and the average diameter at its greatest thickness is 0.21 millimeter. The unattached end of the egg has a slight ridge across it from side to side along which the egg splits when hatching takes place. (Fig. 6, *b*.) This ridge crosses the end slightly on the side toward the hair and the micropyle is located centrally at the apex. The clasp with which the egg is attached to the hair is oval in outline. The average length of the base attached to the hair is 0.31 millimeter. The petiole averages 0.1 millimeter in length. It is flat and curved and very narrow when viewed from the side. The position of the eggs when attached in a row is at an angle of about 45° to the axis of the hair, except the last one toward the tip of the hair, which is usually more nearly parallel with it.

The eggs of *H. bovis* are similar to those of *H. lineatum* except in size, measuring 0.81 millimeter in length and 0.29 millimeter in width. The clasping base is slightly more truncate at the end toward the tip of the hair and the petiole arises from the clasp more nearly at its middle than in *H. lineatum.* The most striking difference between the eggs of these two species is the attachment of the petiole to the base of the egg. With *H. lineatum* the attachment is on the side of the base of the egg away from the hair whereas with *H. bovis* the attachment is more nearly in the middle of the base and the petiole is more elbowed. (Fig. 8.) Furthermore, the eggs of *H. lineatum* are normally attached to the hair in rows, whereas with *H. bovis* the eggs are always laid singly.

THE LARVA

FIRST STAGE

The larva of *Hypoderma lineatum* when hatched from the egg measures from 0.55 to 0.65 millimeter in length and from 0.15 to 0.18 millimeter in width at its greatest diameter. The width is greatest at the posterior end and the larva tapers to the head. It is creamy or dull white in color, and densely covered with spines on all segments, the anterior borders bearing the heaviest spines in transverse rows, followed usually by six rows of spines, more or less regularly placed, and slightly decreasing in size toward the posterior border of the segment. The anal segment differs from all those preceding in that it bears spines of three distinct types. The posterior spiracles, which are represented by two dark circular spots, are protected by two or three rather large, triangular spines located near their borders. The cephalo-

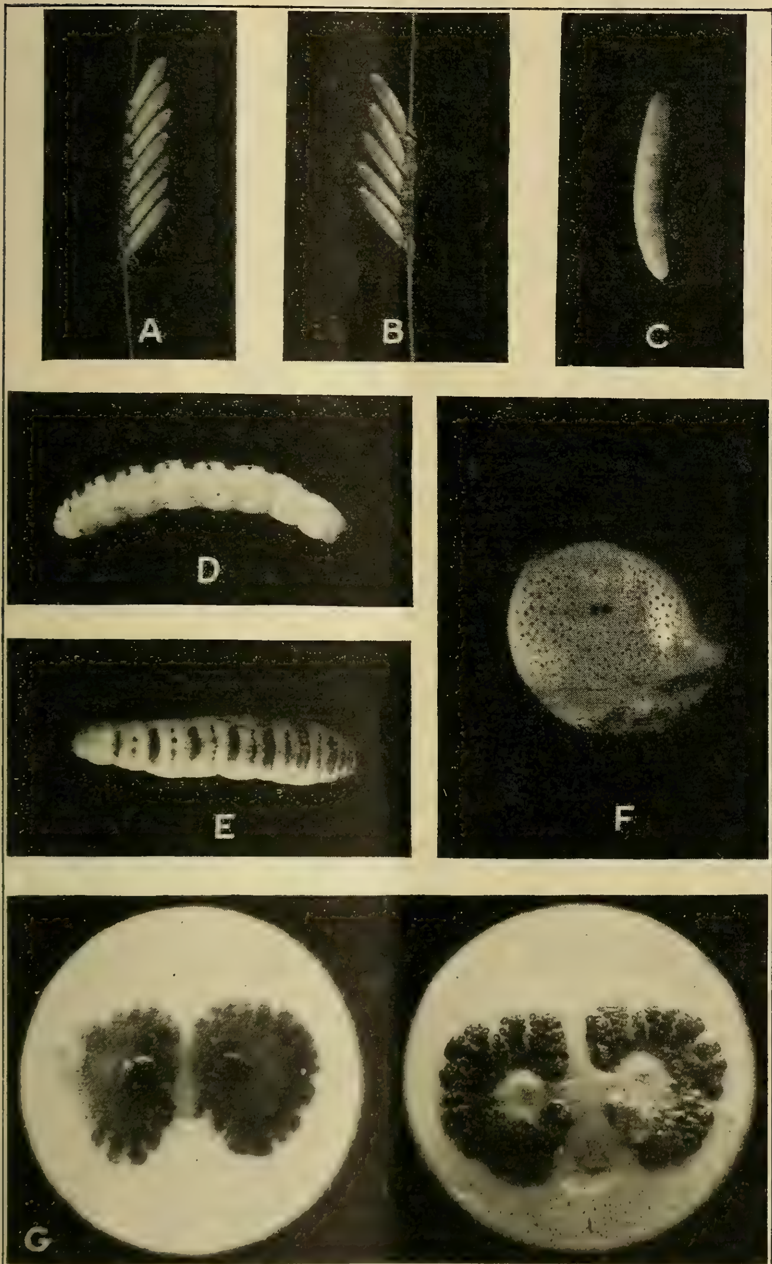


FIG. 6.—*Hypoderma lineatum:* *a*, Unhatched eggs attached to hair; *b*, hatched eggs on hair; *c*, third-stage larva, side view; *d*, fourth-stage larva, side view; *e*, fourth-stage larva, ventral view; *f*, posterior end of third-stage larva; *g*, posterior end of fourth-stage larva, just before molting (note fourth-stage spiracles in center with fifth-stage spiracles showing beneath); *h*, posterior spiracles of fifth-stage larva. All much enlarged

pharyngeal skeleton is composed of two long and nearly parallel rods slightly curved outward at the tip on which two crescent-shaped mouth hooks articulate. The hooks are pointed at each end, especially the forward one, which terminates in a sharp point. A prominent inward-curving tooth is located about one-third the length of the entire hook from the anterior tip (figs. 9 and 10). A stout, sharp spine directed forward projects slightly between the mouth hooks. The anterior spiracles appear as two minute circular elevations above the mouth parts and at the tip of the head.

FIG. 7.—*Hypoderma lineatum:* Row of eggs attached to hair. Greatly enlarged

The armature and spiracles of the first-stage larva of *H. bovis* do not differ materially from those of *H. lineatum*, but the larvæ are slightly larger. The outstanding difference is that the mouth hooks of *H. bovis* are well forked at the anterior end and more truncate at the posterior end. The articulation of the mouth hooks is on a small knob extending laterally nearly at right angles to the axis of the pharyngeal skeleton, which is not curved at the anterior tip like that of *H. lineatum.*

SECOND STAGE

The second or next known larval stage of *H. lineatum* found in the esophagus of cattle (fig. 11) varies in length from less than 3 millimeters up to 13 millimeters or sometimes even longer. It is cylindrical in form and tapers slightly at both extremities. The spinous armature is present on all segments. On the body segments the spines are arranged in transverse rows beginning with the heaviest spines along the anterior border and extending well back toward the posterior border. The spines are more numerous per row, thinner, and longer than those of the corresponding segments of the first stage.

The posterior half of the anal segment is covered with stout, sharp-pointed, curved spines; unlike the spines in this group on first-stage larvæ these are provided with a heavily chitinized, large, circular, elevated base.

The second-stage larva of *H. bovis*, which was first described by Phibbs (*78*), is remarkably similar to that of *H. lineatum* in the same stage excepting the cephalopharyngeal skeleton and mouth hooks, which exhibit the same differences as in the first stage.

THIRD STAGE

The third-stage larva of *H. lineatum* (fig. 6, *c*), sometimes found in the gullet just before migration to the back, and later immediately after puncturing the skin of the host, is from 12 to 16 millimeters long and from 2.5 to 3.5 millimeters wide. It is cylindrical, with the ends tapering and often with the anal end slightly curved toward the dorsal side. With few exceptions segments 2 to 10 inclusive are free from spines, and at the anterior end only the group of spines below the mouth parts is present. The posterior half of the anal segment is thickly dotted with spines having heavy circular bases greater in diameter than the length of the spine and nearly three times as great as that of the second stage (fig. 6, *f*). The posterior spiracles measure 14 microns in diameter, and the triangular spines on the border of the spiracles are greatly reduced in size. The form of the mouth hooks, although heavier than in the preceding stages, remains the same.

FIG. 8.—*Hypoderma bovis:* Egg attached to hair. Greatly enlarged

The third-stage larva of *H. bovis* is slightly larger than that of *H. lineatum*, but the spinous armature shows no material differences. The cephalopharyngeal skeleton and mouth hooks show the same specific characteristics as in the earlier stages (figs. 12 and 13).

FOURTH STAGE

The fourth-stage larva of *Hypoderma lineatum* (fig. 6, *d*, *e*, *g*) is from 13 to 18 millimeters long and from 3.5 to 6 millimeters wide. It tapers considerably from the fourth, fifth, or sixth segments to the posterior extremity. The spinous armature varies greatly with different specimens.

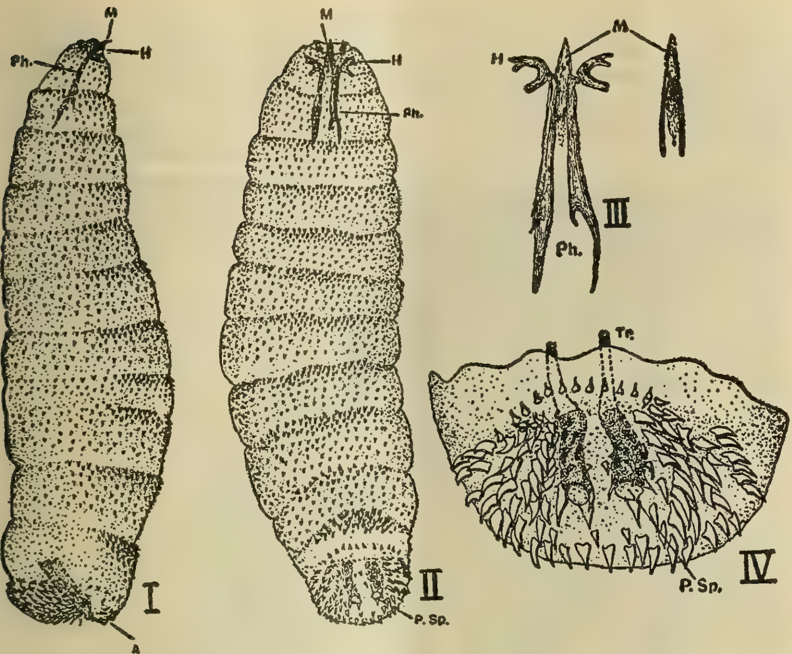


FIG. 9.—*Hypoderma bovis:* First-stage larva. I, Lateral view; II, ventral view; III, cephalopharyngeal skeleton with spine and mouth hooks; IV, caudal segment. *Ph*, Skeleton of pharynx; *H*, mouth hooks; *M*, spine; *Tr*, air tubes; *P. sp.*, posterior spiracles (Carpenter and Hewitt)

Ventrally segments 2 to 9 are provided fairly constantly with a heavy band of spines along the posterior border, but it is not uncommon to find specimens in which segment 10 is also armed and others with segment 9 naked. The spines on the anterior borders of the segments, ventrally, vary even more, and usually end on the eighth or ninth segment. Laterally the armature is very irregular and rarely extends behind the sixth segment on the ventrolateral or the fourth segment on the mediolateral and dorsolateral areas. Dorsally the armature is almost entirely wanting. The greater part of the anal segment posteriorly is thickly covered with small spines surrounding the posterior spiracles, but the triangular spines are no longer present. The two posterior spiracles may be round or very irregular in outline. They consist of a group of circular rings or disks. The color of the stigmal plate is orange or yellowish brown, and the disks are separate or loosely connected in groups but always very distinct in individual outline. The number of disks varies from 12 to over 30, but usually with specimens collected in Texas it is from about 18 to 25 (fig. 14).

The fourth-stage larva of *H. bovis* is similar to that of *H. lineatum*, but when grown it is slightly larger. The only specific distinguishing characters that can be relied upon are the posterior stigmal plates. In *H. bovis* the stigmal plates are composed of disks or rings that are dark brown or black in color, and usually the whole group is closely fused together. The number of disks in *H. bovis* is usually considerably higher than in *H. lineatum*, running from 29 to above 40, with the normal number about 32 to 37 (fig. 15).

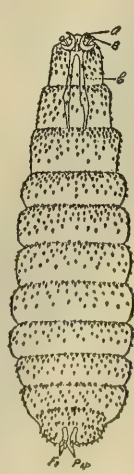


FIG. 10.—*Hypoderma lineatum:* Ventral view of first-stage larva. *A*, Mouth hooks; *B*, anterior spiracles; *C*, cephalopharyngeal skeleton; *Fs*, flattened spines on border of posterior spiracles; *P. sp.*, posterior spiracles. × 121 (Laake)

FIFTH STAGE

The fifth or last larval stage of *H. lineatum* (fig. 16, *a–c*) tapers considerably toward the anterior extremity from about the eighth segment. The size of the larva varies from about 16 to 26 millimeters in length and from 7 to 11 millimeters in width. The surface is more rugged than in the preceding stages, especially on the sides. The spinous armature is heavy; and, although varying greatly with different specimens on the dorsal and lateral sides, it is constant

FIG. 11.—Second-stage larva of *Hypoderma lineatum* in submucous tissues of gullet. Enlarged

ventrally on the posterior borders of segments 2 to 10, inclusive, and presents an excellent distinguishing characteristic for this species. The posterior stigmal plates are somewhat kidney shaped, flat, or slightly excavated toward the pseudostigmatic orifice, and have radiating furrows which are very distinct in the younger specimens (figs. 16, *d;* 17).

The fifth-stage larva of *H. bovis* is slightly larger, but otherwise very similar in shape to that of *H. lineatum*. The armature arrangement is similar to that of *H. lineatum*, except ventrally, where only segments 2 to 9, inclusive, are armed; very rarely a specimen is found with armature on the tenth segment and with a single or a few spines on the anterior border only. In *H. lineatum* there is always a fairly broad band of spines on the posterior border. The posterior stigmal plates of *H. bovis* are deeply excavated or funnel shaped toward the pseudostigmal orifice. This character is very reliable for distinguishing the species in this stage (fig. 18).

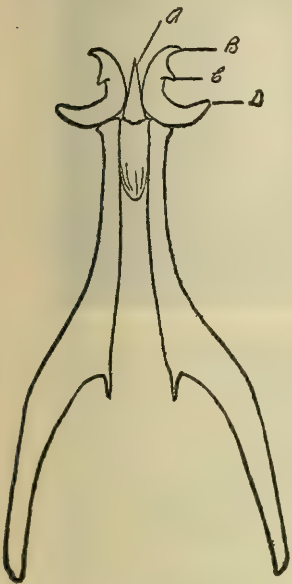


FIG. 12.—*Hypoderma lineatum*: Cephalopharyngeal skeleton and mouth hooks of third-stage larva. *A*, spine; *B*, anterior end, and *D*, posterior end of mouth hooks; *C*, tooth. Greatly enlarged (Laake)

FIG. 13.—*Hypoderma bovis*: Cephalopharyngeal skeleton and mouth hooks of third-stage larva. *A*, spine; *B*, anterior end, and *C*, posterior end, of mouth hooks. × 125 (Laake)

THE PUPARIUM

The puparium retains all the larval characters, except that it assumes a different shape and darkens in color to almost black. Its dorsal side is nearly straight and flat, with the anterior end plainly showing the operculum (fig. 16, *d–f*). The flat stigmal plates of *H. lineatum* and the funnel-shaped plates of *H. bovis* remain the same as in the mature larva and serve to distinguish the two species.

THE ADULT

The adult of *H. lineatum* (fig. 19) measures from 12 to 13 millimeters in length and has a wing expanse of from 23 to 25 millimeters. The female with ovipositor fully extended measures 17 millimeters in length. The general color of the adult is black, banded with yellowish and orange hair. The shade of the colors varies somewhat with different specimens and also changes according to the position and light in which the insect is viewed. The front, sides, and back of the head are covered with yellowish-white hairs. The thorax is clothed with yellowish hairs except dorsally, where the posterior part of the prothorax and the mesothorax are more thinly covered with black and some yellow hairs. On this area there are four distinct longitudinal lines which are nearly naked and shining. The basal segments of the abdomen are covered with grayish-yellow hairs, the middle segments are brownish black, and the terminal segments are clothed in orange-yellow hairs. The femora are black and the tibiæ and tarsi brown. The entire legs are well covered with black and orange-colored hairs. The wings are slightly fuscous and the veins are dark brown to black.

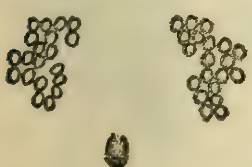


FIG. 14.—*Hypoderma lineatum*: Posterior stigmal plates of fourth-stage larva. Greatly enlarged (Laake)

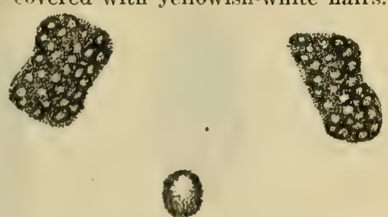


FIG. 15.—*Hypoderma bovis*: Posterior stigmal plates of fourth-stage larva. Greatly enlarged (Laake)

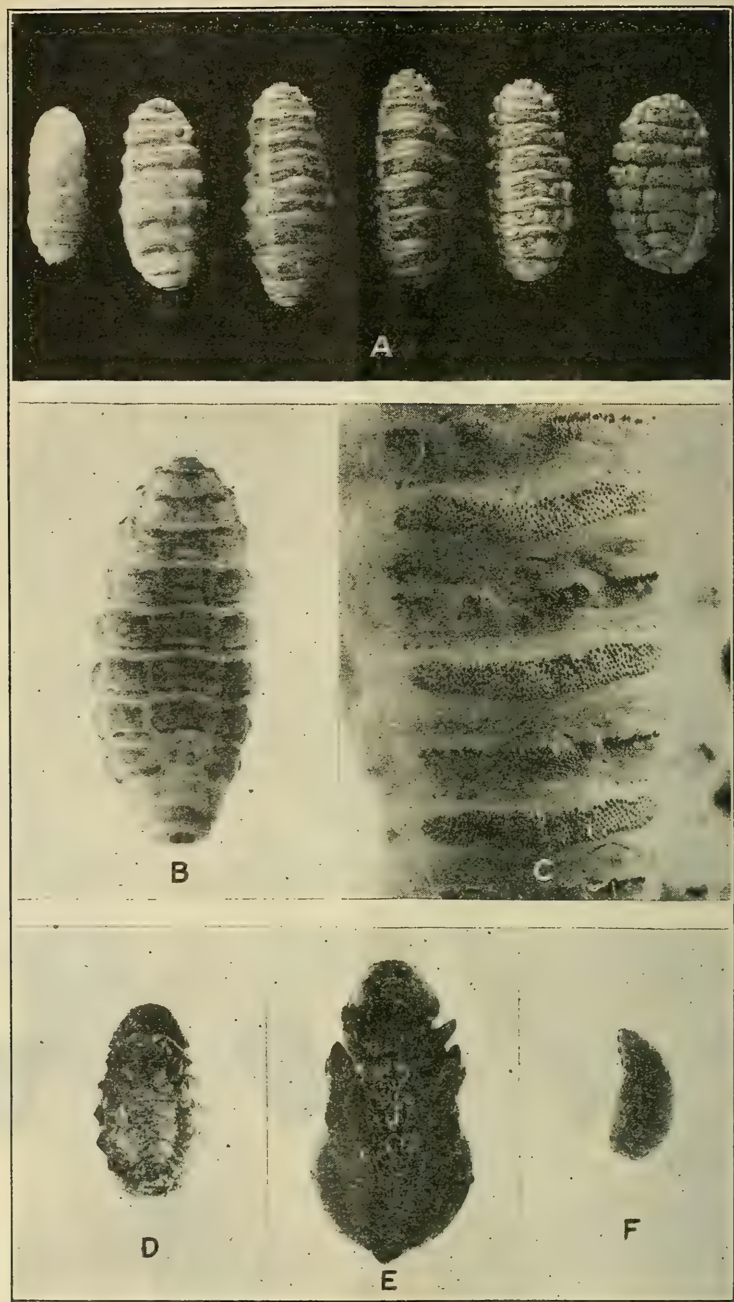


FIG. 16.—*Hypoderma lineatum: a,* Fifth-stage larvæ, newly molted to mature (ventral view, except mature larva, which is dorsal); *b,* fifth-stage larva, dorsal view; *c,* section of ventral side of mature larva; *d,* puparium after emergence of fly, dorsal view; *e,* ventral view of pupa; *f,* puparium, side view

The fly of *H. bovis* (fig. 20) is considerably larger and much stouter than that of *H. lineatum.* This is especially true of the thorax, which is much broader. The color is similar to that of *H. lineatum*, but the band of yellowish hairs across the prothorax dorsally is markedly wider and the shade slightly deeper than in *H. lineatum.* The shiny longitudinal lines of the thorax are obscured anteriorly by the hair. The color of the abdominal vestiture is similar to that of *H. lineatum* except on the terminal segments, which have a wider and more sharply defined band of lemon yellow, distinctly paler than in *H. lineatum.* The wing veins of *H. bovis* are of a reddish-brown color. The femora and the tibiæ are black and well covered with black and yellow hairs, and the tarsi are brown and much less hairy than in *H. lineatum.*

FIG. 17.—*Hypoderma lineatum:* Posterior stigmal plates of fifth-stage larva. Greatly enlarged (Laake)

HOW THE LARVÆ OF HYPODERMA LINEATUM GAIN ENTRANCE TO THE HOST

The method of ingress of various animal parasites is often a point of considerable economic importance. As has been indicated in the historical sketch, the opinions held by various investigators in regard to the way in which Hypoderma larvæ enter the host have been at wide variance; and even up to the present time there are but few who feel certain of the method of ingress of these parasites.

During 1916 plans were laid at the Dallas laboratory to carrry out a series of tests to determine accurately the way in which the larvæ enter the host. These tests have been continued along similar lines up to date. Since a full knowledge of the habits of oviposition of adult *H. lineatum* has been gained, it is evident that there are really only two ways in which the larvæ might get into the host, one of these being by direct penetration through the skin and the other by being taken in by mouth in the egg or young larval stage.

The following plan, with slight modification, was carried out in all of the tests: Certain animals were placed in fly-proof cages and thus protected from all possibility of attack by heel flies during the season of fly activity. To these animals were administered by mouth the eggs of newly hatched larvæ. Most of these were applied to the tongue or inside of the lips of the host, but some were placed in capsules and the host made to swallow them. Certain of these animals were dissected at a time when the larvæ should be present in the gullets or other portions of the carcass commonly infested, to ascertain if possible whether any of them escaped from the digestive tract. Others were kept and watched the following fall, winter, and early spring for the appearance of larvæ in the subdermal tissues of the back. At the time that these animals were being fed with the larvæ and eggs, others were infested on the legs or elsewhere by allowing flies captured in nature or reared in cages to deposit eggs upon

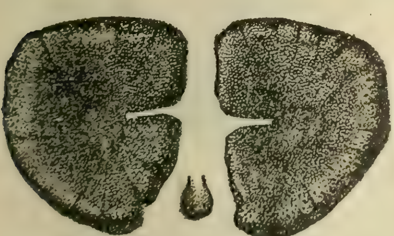


FIG. 18.—*Hypoderma bovis:* Posterior stigmal plates of fifth-stage larva. Greatly enlarged (Laake)

them. These hosts were kept securely muzzled throughout the season when flies were likely to be about, except for the time that they were being fed, when they were placed in specially constructed stanchions which would not allow them to lick any part of themselves. The muzzles used were made of heavy wire, extending well up the nose and covered with closely woven ducking, except for two small holes above the nostrils.

FIG. 19.—Dorsal view of adult male of *Hypoderma lineatum*. Much enlarged.

As will be seen by reference to Table I, during 1917 three animals (Nos. 164, 169, and 176) were infested by allowing flies to oviposit on them. One of these received the eggs on the heels and thigh, another on the legs, shoulder, and neck, and the third on the back. In each of these a considerable number (45, 27, and 10, respectively) of grubs came to the subdermal tissue and cut holes through the skin of the back the following fall and winter. Another animal (No. 174) was given, by way of the mouth, 36 newly hatched larvæ and 82 eggs which were about ready to hatch. Nine of these larvæ were administered down the throat in a capsule. No grubs appeared on the back of this animal during the fall and winter, although it was shown that it was a favorable host by the fact that it had a good infestation during the previous year.

FIG. 20.—Dorsal view of adult female of *Hypoderma bovis*. Much enlarged

In 1918 three animals were used, two of these (Nos. 212 and 217) receiving infestations on the heels and one (No. 214) by way of the mouth. Both of those having eggs deposited on the heels developed grubs in the back. One had 45, with about an equal number on each side of the backbone, and the other had 2 when the animal was disposed of on December 23. Possibly other grubs would have come up later. The animals to which the young larvæ were fed was observed throughout the fall and winter and no larvæ whatever came to the back.

In 1919 11 animals were used in the tests. Four of these (Nos. 411, 412, 413, and 415) received eggs on the heels and front feet, one near the hips (No. 419), and three on the heels and elsewhere (Nos. 409, 410, and 414). Three (Nos. 416, 417, and 418) were fed eggs and newly hatched larvæ. One of those receiving eggs on the heels and elsewhere (No. 410) was killed shortly after the eggs began to hatch in an effort to determine the presence of larvæ in or under the skin. No larvæ were found but some small holes were clearly visible in the skin beneath one group of the eggs, and the connective tissue under the eggs was yellowish and edematous, just as it appears when the larvæ are present. On July 9, one of those animals which received eggs on the heels, front feet, hock, and side of abdomen (No. 409) was killed and examined; 76 larvæ were found along the gullet. One of the animals which received eggs on the heels and front feet (No. 411) was killed October 7 and no larvæ were found owing, it is believed, to the fact that the eggs were infertile. In the case of this animal no irritation or lesions indicating penetration were observed, after what should have been a normal period of incubation. All of the 112 eggs deposited on this animal were laid by one fly and some of the eggs clipped from the host and placed in an incubator failed to develop larvæ. Of the other three receiving eggs on the heels and front feet, all showed moderate infestations of grubs (average of 14.3) in the back the following fall and winter. The animal receiving the eggs on the hips only (No. 419) developed a total of 13 grubs the following winter, and the one having the eggs placed on the hock, front feet, and udder (No. 414) developed a total of 20. On the other hand, two of the animals (Nos. 417 and 418) which received fertile and well-incubated eggs, as well as healthy larvæ, by way of the mouth, failed to develop a single grub during the subsequent fall and winter. The third (No. 416) was killed July 9, and a careful dissection failed to reveal the presence of a single larva in the gullet or elsewhere.

In the tests begun in the spring of 1920 10 experimental animals were employed. Three of these (Nos. 167, 159, and 417) were infested on the legs, mostly on the hind ones from the hock down; one received eggs only on the top of the shoulders; two (Nos. 158 and 22) had the eggs placed on the front and rear legs and on the belly near the flank; and two (Nos. 160 and 414) received larvæ and eggs by way of the mouth. Two other animals (Nos. 92 and K23) were used to test the migratory tendencies of the second-stage larvæ, which were removed from the gullets of slaughtered cattle. These were inserted in pockets cut under the skin near the hock.

TABLE 1.—*Determination of method of ingress of Hypoderma lineatum into host*

No.	Animal	Age	Infested				Results
			Date	Stage	Place and method	Number used	
			1917				
164	Steer	7 months	Mar. 7 to 14	Eggs	Heels and thigh	235	45 larvæ perforated skin on back Nov. 20 to Dec. 31.
169	Cow	6 years	Mar. 12 to 15	do	Legs, neck, and shoulder	220	27 had perforated skin on back Nov. 26.
174	do	3 years	Mar. 17 to 31	Larvæ and eggs	In mouth, naked [1] and in capsules.	118	No larvæ perforated skin on back.
176	do	2 years	Mar. 17	Eggs	On back	85	10 had perforated skin on back Dec. 20.
			1918				
212	Cow	3 years	Mar. 5 to 12	do	Heels	127	45 perforated skin on back Nov. 22, or before, to Jan. 8.
217	Steer	1½ years	Mar. 19	do	Heel	75	2 had perforated skin on back Dec. 23, when host was lost.
214	Cow	4 years	Mar. 18 to 29	First-stage larvæ	In mouth on tongue, naked [1]	28	No larvæ perforated skin on back.
			1919				
410	Steer	6 months	Mar. 10 to 20	Eggs	Heels, abdomen, flank, and by anus.	186	Dissected Mar. 24. Holes in skin and induration beneath.
409	Bull	5 months	Mar. 10 to 16	do	Heels, legs, abdomen	168	July 9, slaughtered, 76 larvæ in gullet.
411	do	15 months	Mar. 17	do	Heel, front feet	112	Oct. 7, dissected, no larvæ found.
416	Cow	3 years	Mar. 20 to 22	Eggs and larvæ	In mouth, on tongue	80	July 9, dissected, no larvæ found.
417	do	2 years	Mar. 22 to Apr. 5	Larvæ, first stage	In mouth, on tongue, and inside lips.	136	No larvæ perforated skin on back.
418	Heifer	1 year	Mar. 23 to Apr. 5	Eggs and first-stage larvæ	In mouth, on tongue and lips	94	Do.
414	Cow	8 years	Mar. 16	Eggs	Feet, legs, and udder	62	20 perforated skin on back Nov. 17, or before, to Dec. 29.
415	do	3½ years	do	do	Feet	67	22 perforated skin on back Nov. 17, or before, to Dec. 4.
419	Heifer	1 year	Mar. 27	do	Each side near hip	77	13 perforated skin on back Nov. 19, or before, to Jan. 5.
412	do	2 weeks	Mar. 17 to 27	do	Heel, front foot	64	10 perforated skin on back Dec. 1, or before, to Dec. 23.
413	do	6 weeks	do	do	do	49	11 perforated skin on back Dec. 6 to Jan. 2.
			1920				
160	Cow	4½ years	Mar. 19 to 22	Eggs and first-stage larvæ	In mouth, naked [1]	248	No larvæ perforated on back.
167	Heifer	1 year	Mar. 12	Eggs	Heels	200	3 perforated skin on back Nov. 21, or before, to Dec. 9.
163	do	do	Mar. 10 to 18	do	Top of shoulder	152	1 perforated skin on back Dec. 1.
159	do	2 years	Mar. 10 to 19	do	Heels	115	17 perforated skin on back Nov. 15 to Jan. 10.

414	Cow	9 years	Mar. 17 to 19	First-stage larvæ	In mouth, inside lips and on tongue, naked.[1]	70	Nov. 26 dissected and no larvæ found.
158	Heifer	2 months	Mar. 6 to 13	Eggs	Heels, belly, and near udder	138	Oct. 25, killed by train, not examined.
417	Cow	3 years	Mar. 2 to 19	do	Hock and heel	280	Do.
K23	Heifer	1 month	Dec. 22	Larvæ from gullet	Thigh under skin by incision	15	9 perforated skin on back Dec. 14–17, all to rear.
22	Bull	6 months	Mar. 22 to 28	Eggs	Heel and belly	340	July 3, dissected, 40 larvæ found.
92	Heifer	27 months	June 16	Larvæ from gullet	Hock, under skin by incision	60	32 perforated skin on back Nov. 21, or before, to Jan. 4.
			1921				
92	Heifer	38 months	May 3	Larvæ from gullet	Under skin, hind leg	25	13 perforated skin on back Oct. 20, or before, to Nov. 28.
22D	do	1 month	Mar. 15 to 18	Eggs and first-stage larvæ	Right and left heels. On skin right front foot.	160	8 perforated skin on back Nov. 9 to Dec. 24.
K23	do	4 months	Mar. 3	Eggs	Left hock and foot	45	Apparently none hatched.
			Mar. 16	do	Right heel and front foot	65	64 perforated skin on back Oct. 27 to Jan. 4.
24-D	Calf		Mar. 29	First-stage larvæ	On skin, left hind foot	5	None perforated skin on back.
160	Cow	5½ years	May 3	Larvæ from gullet	Hind leg under skin	30	3 perforated skin on back Oct. 20, or before, to Oct. 27.
25-D	do	29 months	Aug. 26	do	Behind right ear under skin	26	15 perforated skin on back Oct. 17 to Dec. 11.
167	Heifer	30 months	do	do	Under skin on back	26	2 perforated skin on back Nov. 8 to Nov. 12.
159	Cow	3 years, 5 months	do	do	Under skin hind leg	26	4 perforated skin on back Oct. 17 to Dec. 3.
167-1	Bull	5 months	do	do	do	26	Oct. 17, dissected, 10 larvæ recovered.
418-1	do	1 month	Nov. 16	do	do	14	9 perforated skin on back Nov. 30 to Dec. 22.
			1922				
25-D	Cow	3 years	Mar. 7	Eggs	Heels on hind legs	80	26 perforated skin on back Nov. 1, or before, to Dec. 7.
K-23	Heifer	16 months	Mar. 7 and 8	do	Back and rump	134	9 perforated skin on back Nov. 21, or before, to Jan. 2.
418-1	Bull	5 months	Mar. 8 and 16	do	Hind heels	131	Dipped in creosote dip; 1 perforated skin on back Dec. 4.
23-D	Cow	13 months	Mar. 8 to 16	do	do	134	Dipped in derris solution; 1 perforated skin on back Dec. 14.
92	do	4 years	Mar. 10 to 25	First-stage larvæ	Placed on tongue	89	None perforated skin on back.
1	Horse	12 years	Mar. 15 and 16	Eggs	Rear and front heels and base of tail.	175	Do.
160-1	Heifer	2 weeks	Mar. 20	First-stage larvæ and eggs.	Placed on skin and hair, hind heels.	[2] 42 [3] 35	15 perforated skin on back Nov. 15, or before, to Jan. 12.
167	Cow	3 years, 4 months	do	Eggs	Both rear heels	125	8 perforated skin on back Nov. 25, or before, to Jan. 8.
			1923				
92-1	Bull	1 month	Nov. 14	Gullet larvæ	Under skin, hind legs	20	Dissected Nov. 19, 15 recovered.
25D-1	do	3 weeks	Nov. 14 and Dec. 28	Larvæ from gullet	Under skin both hind legs	36	25 perforated skin on back Nov. 27 to Jan. 22.
25D	Cow	3¾ years	Dec. 28	do	Under skin right hind leg	29	8 perforated skin on side and back Jan. 7, or before, to Jan. 18.
			1924				
92	Cow	4 years, 10 months	Jan. 4	Larvæ from gullet	Under skin right hind leg	21	14 perforated skin on leg, flank, and back Jan. 8 to Jan. 22.

[1] "Naked" means without use of a capsule or other covering. [2] Larvæ [3] Eggs.

Of the three animals receiving the eggs on the legs, one (No. 417) was accidentally killed by a train during the late summer and no examination could be made. In November, larvæ first appeared under the skin on the backs of the other two cows (Nos. 167 and 159), and during the fall and winter one of them had 3 larvæ to reach the back, while the other had 17. With the animal infested on the shoulders (No. 163), a single larva appeared on the back during the following winter; but it had been observed that many of the eggs on this animal were infertile and had failed to hatch. One of the two animals with infestations on the legs and belly (No. 158) was also killed by a train and not examined, but the other (No. 22) was slaughtered and carefully dissected on July 3. A total of 40 second-stage larvæ were found on the viscera and along the gullet. One of the two hosts infested by way of the mouth (No. 414) was dissected on November 26 and no larvæ were found in the gullet or elsewhere. The other animal (No. 160) was observed carefully and repeatedly during the fall and winter and not a single larva came to the back. The two animals (Nos. K23 and 92) receiving the second-stage larvæ through incisions cut near the hock showed 9 and 32 larvæ, respectively. These appeared along the backs during the fall and winter.

During the spring of 1921 two heifers were infested by flies which deposited eggs on their hind legs. One of these (No. K23) received about 110 eggs on the feet, but apparently none of the 45 eggs hatched which were deposited on this animal on March 3. The first larva came to the back on October 27, and a total of 64 larvæ appeared during the winter. The other heifer (No. 22D) received far more eggs on the legs but developed only 8 larvæ on the back, the first appearing November 9.

During the season seven bovine hosts were infested by placing, in pockets cut under the skin, larvæ of *H. lineatum* removed from gullets of slaughtered animals. Two of the hosts (Nos. 92 and 160) were infested May 3 with larvæ (4.5 to 5.5 millimeters in length) inserted above the hock. Each developed an infestation in its back in the fall. The first larva reached the back October 20 or shortly before. Four cattle were infested with 26 gullet larvæ per animal on August 26; two received them in the right hind leg, one behind the ear, and one in the back about 8 inches behind the shoulder and 3 inches from the spinose processes; this was in order to compare the dates of appearance of larvæ on the back and the number successfully reaching that region.

One of the two hosts infested on the leg (No. 159) had larvæ present on the back on October 17, and at that time the other animal (No. 167–1) was killed and dissected. On a post-mortem examination 10 larvæ were recovered, 3 in the subdermal connective tissue of the back (but no holes had been cut through the hide), 1 under the spleen on the paunch, 1 on the paunch near the esophagus, 3 in the mesentery of the colon, and 2 in the submucous tissue of the gullet. One of the latter was near the paunch end of the gullet and measured 13.7 millimeters in length; the other was in the middle of the gullet and measured 11.6 millimeters. Both were headed toward the paunch.

In the case of the cow infested at the base of the ear (No. 25–D) the first larva reached the back October 17, and a total of 15 came to that region; with the cow infested on the back (No. 167) only two appeared (November 8 to 12). On November 16 a bull calf was infested in the hind leg by inserting in the skin 14 larvæ taken from the gullet of a slaughtered animal. These larvæ measured 11 to 15 millimeters in length and the first appeared on the back November 30. Nine of the 14 succeeded in coming to the back for normal development.

In the calf (No. 24–D) five first-stage larvæ were applied for a study of penetration. Although some of these were observed to penetrate the skin, none reached the back.

During 1922 seven cattle were used in the tests. One of these (No. 92) was protected from flies, but fed 89 newly hatched larvæ by placing them on the tongue and in the lips. In this animal not a single larva reached the back the following fall and winter. Of the other six hosts, five were infested on the heels and legs and muzzled to prevent ingress of newly hatched larvæ through the mouth. In all of these animals larvæ reached the back, the number per host varying from 1 to 26, despite the fact that two of the animals had the legs immersed in insecticides every day. The other animal (No. K–23), which received eggs on the back, developed nine larvæ in that region. The date of first appearance of larvæ in the subdermal tissue was not influenced materially by the date of infestation or by the point of ingress into the animal.

On November 14, 1923, 20 larvæ taken from the gullets of slaughtered cattle were placed beneath the skin by incision, on each of two calves (Nos. 92–1 and 25D–1). The point of introduction was about 6 inches above the hock joint on the outside of the right hind leg. The larvæ averaged slightly over 12 millimeters in length. On November 19 the older calf (No. 92–1) (1 month old) was dissected and 15 larvæ were recovered. Most of these were ranging upward in the connective tissue under the skin where there was marked infiltration, and one had passed between muscles on the rear of the thigh and was apparently following a large nerve, being only 3 inches from the spinal canal. In the other calf (No. 25D–1) 6 larvæ had reached the back and had perforated the skin, 4 on the right and 2 on the left side. On December 28 another lot of 16 larvæ from gullets were put under the skin of this calf on the left hind leg just above the hock. These were from 12 to 16 millimeters in length. Immediately preceding January 8, 12 grubs had reached the back and had punctured the skin. These were about equally distributed on each side of the spine; 7 others reached the back by January 22, making a total of 25. On December 28, 29 larvæ from 12 to 16 millimeters in length were introduced in an incision through the skin on the right hind leg of a cow, just above the hock. On January 7, or shortly before, the first larva appeared behind the right hip, and 7 others cut holes through the skin during the period up to January 18. One of these was only 7 inches above the point of introduction and the last one was on the left side just in front of the hip, a distance of about 33 inches from the point of introduction.

On January 4, 1924, 21 larvæ from 11 to 16 millimeters in length, from gullets, were introduced subcutaneously above the hock of another cow. On January 8 one larva cut through the skin 5½ inches above the incision. On the following day 5 others punctured the skin, one of these being 30 inches above the point of introduction. The following day 3 others appeared, 1 of these being near the spinal column on the right side about 7 inches behind the shoulder, a distance of 40 inches in a line from the incision. A total of 14 grubs perforated the skin, all being on the right side.

It appears from these tests that when larvæ which are ready to leave the gullet are introduced subcutaneously they may not travel far from the point of introduction before puncturing the skin, and that they appear to pass upward under the subdermal connective tissue without penetrating deeply into the tissues as occurs when young larvæ from the gullet are introduced.

To recapitulate, in the tests carried out at the Dallas laboratory, 28 animals were infested by allowing flies to oviposit on the legs and bodies and were prevented from reaching any part of their bodies with tongue or mouth. Of these 28 animals, 2 were accidentally killed and not examined. In one of those slaughtered for dissection no larvæ were found, but in this case no hatched eggs were observed on the animal and other evidence indicated that none of the eggs placed upon it were viable. One of the other animals was killed immediately after the eggs hatched and, although no larvæ were found, there were strong indications of the penetration of larvæ through the skin. Two of the other animals killed showed an abundance of grubs along the gullet and on the viscera. Twenty of these animals were kept for observation during the fall and winter, and in every one of them grubs came to the back during the normal grub season. In all of the 11 cattle which were infested by introducing larvæ from the gullets of slaughtered cattle under the skin on the legs, behind the ear, and on the back, larvæ appeared under the skin at the usual time during the following fall and winter. Larvæ were also recovered in 2 animals which were dissected after larvæ had been introduced under the skin in this way. On the other hand, among the 8 animals to which larvæ and eggs were given by mouth, neither of the 2 which were carefully dissected showed the presence of larvæ, and in not a single instance among the 6 cattle held for observation did a grub appear along the back.

In 1922 Carpenter, Phibbs, and Slattery (*19*) report similar results in experiments carried out in Ireland. No grubs were recovered in calves to which numerous larvæ were fed but heavy infestations developed in carefully muzzled calves exposed to the oviposition of flies.

The fact that the larvæ penetrate through the skin is established by the following evidence:

1.—The eggs are usually laid on the hairs comparatively close to the skin, which would favor penetration. They are firmly attached and the eggshells, after the larvæ have escaped, remain attached to the hair.

2.—The eggs are not fitted with an operculum as in the case of the horse bots, the ends merely splitting as the larvæ emerge.

3.—It is not necessary to apply friction to the eggs to cause them to hatch, as the larvæ have been observed in many instances by the writers and others to crawl from the shells when their development was completed, provided the proper temperature was maintained.

4.—Much skin irritation in areas where eggs have been attached to the hairs is in evidence about four days after the eggs have been deposited. It has been observed repeatedly that violent stamping, kicking, and licking of the affected parts by the host occur soon after the hatching of the eggs begins, and a few days later soreness and the formation of scabs due to the exudation and hardening of serum are apparent. When these scabs are removed, a cluster of hatched eggs is usually found attached to the hair in their midst. (Fig. 21.)

Fig. 21.—Scab removed from a lesion on a cow, caused by penetration of newly-hatched larvæ of *Hypoderma lineatum.* Note the three hatched eggs on the hair

5.—The actual penetration of a number of larvæ soon after hatching has been observed by the writers and their associates. This process will be described later.

6.—Stub (*95*) has been able to trace the route pursued by young larvæ from the inside of the right tibia over the shoulder and around the muscles of the neck to the connective tissue of the esophagus.

Taking the evidence set forth herein and considering the observations of other investigators whose work entirely corroborates it, there seems now to be no doubt that the normal method of ingress for the larvæ of both *H. lineatum* and *H. bovis* is directly through the skin at the point where the eggs are attached, and proves that there is comparatively little likelihood of infestation occurring by means of larvæ taken in by the mouth. It is desirable to stress at this point the demonstration given, by the slaughtering of some of the animals as above outlined, that the larvæ entering cattle through the skin on the lower legs may be found in the gullet in considerable numbers during the succeeding months. This proves the fallacy of the suggestion frequently made by investigators that those larvæ which are found in the gullet were probably taken in by the mouth and that they may perish and never reach the back. It should be noted that the writers have shown herein that larvæ of *H. lineatum* removed in the second instar from the gullets of cattle and introduced under the skin of uninfested bovines will not only appear under the skin on the backs of the new hosts in the proper season, but may and probably usually do pass again into the body cavity and even return to the gullet before going to the back.

DEVELOPMENT AND HABITS

NUMBER OF EGGS ON HAIR

The eggs of *H. lineatum* are usually laid in a series of from 5 to 12 and occasionally as many as 20 may be attached to a single hair. The number depends to some extent upon whether the fly is disturbed during the process of oviposition and also upon the length of the hair. In the case of *H. bovis* the eggs are always deposited singly on the hair.

DISTRIBUTION OF EGGS ON HOST

H. lineatum shows a marked tendency to oviposit on the heels of cattle which are standing, the favorite place apparently being the short hair overhanging the rear of the hoof and between the hoof line and the dewclaws. Many eggs, however, are deposited higher on the legs in the region of the hocks and a few above the hock line. Some eggs are also deposited on the belly, flanks, and forelegs, and occasionally on the sides, shoulders, and neck. In practically all of the writers' observations of depositions on cattle which are not lying down, it seems evident that many of the eggs deposited elsewhere than on the heels are laid after the fly has been disturbed by the actions of the host. Many eggs are also deposited along the escutcheon, on the outside of the thighs, on the tail, and on the base of the udder, and some along the side and on the forelegs in the region of the elbow joint. Infestations in these regions are especially common among quiet stock, oviposition taking place while they are lying down. In one instance over 200 fresh eggs were found attached to the hair on an area not over 2 inches square just behind the upper end of the scapula. The writers' observations on flies in nature and upon those placed on hosts in captivity indicate that they prefer the short, comparatively coarse hairs to the long, dense, silky ones.

H. bovis also prefers the heel or lower leg for a place of attachment for its eggs, but since this species frightens the animals much more, and since the flies continue to follow the cattle, depositing eggs while pursuing the rapidly running animals, a much larger percentage of eggs is deposited higher on the legs, especially in the region of the thighs and on the rump. Although a considerable number of eggs are laid on other parts of the body, especially along the sides, they tend to be concentrated on the hind quarters.

METHOD OF ATTACHMENT OF EGGS

As has been indicated under its description, the egg is provided with a definite attachment area or clamp. In addition to the placement of the clamp around the hair, each egg appears to be provided with a cement which when dry firmly glues it to the hair. Eggs have been observed to remain attached on the host for several weeks, sometimes the distal end gradually breaking away so as to leave only a portion of the shell. As shedding of the winter coat usually takes place about the time the eggs are deposited, many of them are shed off and perish before they have had an opportunity to hatch.

The eggs are nearly always attached very close to the skin, and this renders them inconspicuous, as they are usually covered by the overhanging hair. This is particularly true of *H. bovis.*

INCUBATION

The incubation period of *H. lineatum*, as observed in many lots of eggs kept under varying conditions, was found to range from

64 hours to 10 days. It is evident that the period of incubation is markedly affected by temperature. With eggs deposited on a host this would vary according to their proximity to the skin and the insulation from air temperatures by the hair. With normally placed eggs the basal ones on the hair are usually very close to the skin, but in the case of eggs deposited on fairly long hair the distal ones may be half an inch away from the skin.

Table 2 sets forth a number of observations on the period of incubation of eggs of *H. lineatum*. Many of the records are only approximate, the time of hatching having been determined largely by the irritation of the host produced by penetration of the larvæ. It will be observed that in one instance irritation was evident approximately 2¾ days from the time the eggs were deposited on the legs of a calf. This incubation period was almost exactly the same as that observed on a portion of the same batch of eggs placed in an incubator at approximately 98° F. The writers' observations indicate that the usual incubation period on the host is from 3 to 6 days, probably most of the eggs hatching toward the end of the third day and early in the fourth.

TABLE 2.—*Incubation of eggs of Hypoderma lineatum in situ and in incubator at Dallas, Tex.*

Deposited	Number of eggs	Place and method	Date of hatching	Incubation period	Air temperature: Maximum	Air temperature: Minimum	Air temperature: Mean
				Days	*° F.*	*° F.*	*° F.*
1917			1917				
Mar. 7, 4.30 p. m.	100	Calf's leg	Mar. 11 [1]	4−	84	30	65.6
Mar. 8, 4.30 p. m.	20	do	do	3−	84	30	63.4
Mar. 14	175	Incubator Mar. 15–18	Mar. 17 to 18	3+	87	85	86
Mar. 23 [2]	100	do	Mar. 25	2+	87	85	86
1918			1918				
Mar. 16 [2]	160	do	Mar. 18, a. m. to p. m.	2+	97	96	96.5
Mar. 26, p. m. [2]	20	do	Mar. 29, a. m.	2¾+	99	97	98
1919			1919				
Mar. 10	65	Calf's leg	Mar. 16 [1]	6−	77.5	37.5	60.5
Mar. 10, 5 p. m.	175	Calf's belly	do	6−	77.5	37.5	60.5
Mar. 12 [2]	40	Vest pocket and incubator.	Mar. 22 to 24	10+	81	37.5	62.7
Mar. 14 [2]	40	do	Mar. 22	8+	81	40.5	63.8
Mar. 16, p. m.	60	Cow's legs and body	Mar. 20 [1]	4−	79	40.5	61
Mar. 19, 5 p. m.	100	Incubator	Mar. 22, 2.30 p. m., to Mar. 23, 11 a. m.	3 to 4	90	90	90
Do	25	Calf's belly	Mar. 22	3	81	40.5	63.2
Do	37	Calf	Mar. 22, p. m.	3−	81	40.5	63.2
Mar. 20, 1 p. m.	3	On calf and in incubator.	Mar. 24	4−	90	90	90
Mar. 21, 11 a. m. [2]	231	Incubator	Mar. 23, 7 p. m. to Mar. 24, a. m.	2–3+	90	90	90
Mar. 27, 2.30 p. m.	260	do	Mar. 30, 6 p. m. to 10 p. m.	3+	90	90	90
Mar. 27, p. m.	77	Cow's body	Mar. 31, p. m.	4−	93	35.5	60.3
Do	7	Calf's leg	Mar. 31 [1]	4−	93	35.5	60.3
1920			1920				
Mar. 6, 4 p. m.	80	Calf's heel and belly	Mar. 9, 5 p. m. [1]	3−	55	20.5	38
Do	200	Calf at hock	Mar. 9, p. m. [1]	3−	55	20.5	38
Mar. 10, 5 p. m.	52	Calf's shoulder	Mar. 15, a. m., [1] one-half hatched.	4¾−	76	36	61.1
Mar. 12, 5 p. m.	200	Calf's heels	Mar. 16 [1]	4−	76	36	61
Mar. 18, 5 p. m.	100	Calf's shoulder	Mar. 22, a. m. [1]	3¾−	81.5	42	63.4
Mar. 22, 5 p. m.	250	Calf	Mar. 26 [1]	4−	80	46	61.7
Mar. 28, 5 p. m.	95	Calf's legs and belly	Mar. 31, 6.30 p. m., to Apr. 1, 3.15 a. m.	3–3.5	90	40	63.7

[1] Hatching determined by the kicking and rubbing of host, some checked by actual examination.
[2] Collected from animals infested under natural conditions. Exact time of deposition unknown.

TABLE 2.—*Incubation of eggs of Hypoderma lineatum in situ and in incubator at Dallas, Tex.*—Continued

Deposited	Number of eggs	Place and method	Date of hatching	Incubation period	Air temperature Maximum	Minimum	Mean
1921			1921	*Days*	° *F.*	° *F.*	° *F.*
Mar. 15, 11.30 a. m.	70	Incubator	Mar. 18, 9 a. m to p. m.	3−	98	98	98
Do	155	Calf's feet	Mar. 18, 9 a. m.[1]	3−	87	63.5	74.6
Mar. 16, 5 p. m.	40	Calf's leg	Mar. 19, a. m.[1]	2¾−	87	63.5	74.5
Do	16	Incubator	Mar. 19, 9 a. m. to 12 m.	2¾−	98	98	98
1922			1922				
Mar. 15, 4.15 p. m.	15	Incubator	Mar. 18, 1 to 2 p. m.	3−	90	90	90
Mar. 16, 2.30 to 2.45 p. m.	45	do	Mar. 19, 10 a. m. to 4.40 p. m.	3	90	90	90
Mar. 20, 12.50 to 1.10 p. m.	85	Cow's heels	Mar. 24, 10.30 a. m.	4−	84	36	64.8
Do	74	Incubator	Mar. 23, a. m. to p. m.	3	90	90	90
Mar. 15, 3.13 to 3.15 p. m.	32	do	Mar. 18, 11 a. m. to 1 p. m.	3−	90	90	90
Mar. 28, 3.15 to 3.30 p. m.	72	do	Mar. 31, 8 a. m. (before) to 8.15 a. m.	2½	90	90	90

[1] Hatching determined by the kicking and rubbing of host, some checked by actual examination.

Glaser (*29*), without making it clear whether he is dealing with *H. bovis* or *H. lineatum*, states that he has observed the incubation period of eggs clipped from the host to be 12 days. He also says that on living animals development is completed in less than 3 full days. Hadwen (*36*), basing his statements on observations in Canada, states that the eggs when removed from the host hatch in about 7 days, the shortest period being from 4 to 5 days, but apparently he made no observations on the incubation of eggs on the host.

The writers have made few exact observations on the incubation period of *H. bovis*. At Middletown, N. Y., 2 out of a lot of 6 eggs deposited on a calf June 8 at 3.30 p. m. had hatched on June 11 at 12.15 p. m., a period of approximately 3 days. These were left on the host. In one instance in which eggs were sent by mail from a northern State to the Dallas laboratory and placed in an incubator they hatched in less than 7 days after collection. Carpenter (*17*) observed eggs attached to a host to be hatched in slightly less than 4 days.

The writers, in their work with reared flies, have obtained a considerable number of eggs from females which were not associated with males, and in none of the cases was there any hatching, indicating that parthenogenesis does not occur in this species. The percentage of viable eggs deposited by fertilized females seems to vary considerably. In some instances a hatch of almost 100 per cent has been observed, whereas in other cases the examination of a series of eggs showed a hatch of less than 50 per cent. It seems certain that the percentage of the hatch is higher when the eggs are deposited and allowed to remain on a host than when they are removed and placed in an incubator, although in a few instances a hatch of above 90 per cent was obtained among eggs kept in an incubator.

In general it appears that the eggs attached lowest on a hair hatch slightly earlier than those toward the distal end. When this occurs it is probably due to the fact that the lower eggs, being closer to the skin, are kept at a slightly higher temperature.

Several hours before hatching, the segmentation and rows of spines are distinctly discernible through the shell. The larva becomes active shortly before hatching and can be observed through the eggshell pressing the mouth parts forward against the end of the egg. Finally the suture across the end of the egg is ruptured and the larva crawls out rather rapidly.

LARVAL ACTION AFTER HATCHING

The larva of *H. lineatum* after hatching usually crawls directly down the hair which bears the egg and after feeling about with the mouth parts begins to burrow directly into the skin at the base of the hair. The body is usually more or less extended along the hair, and during the initial efforts there is considerable twisting, expansion, and contraction. After the first few segments have been worked into the skin the larva becomes more quiet. The burrowing is slow but usually rather steady in case of vigorous specimens. Progress is retarded as the middle body segments reach the surface of the skin, and usually it is slightly accelerated when the larva has become almost completely imbedded. The time occupied for a larva to disappear after it has begun burrowing has been observed to be about one and one-half hours and sometimes considerably longer.

In nature it appears that several larvæ frequently enter the host through the same hole, and this no doubt greatly facilitates the penetration after the first larva has gained entrance.

Considerable difficulty was experienced in watching the penetration of the larvæ into the skin, mainly owing to the difficulty of holding a host quiet for considerable periods of time but also to the fact that the larvæ, on account of their small size and delicate structure, are very easily lost sight of. Most of the writers' observations on penetration were made with freshly hatched larvæ taken from an incubator. Even with the most careful handling there was a high mortality, apparently much greater than when the eggs are attached to the host in the natural way. It was observed repeatedly that larvæ removed from an incubator and placed on hair would wander about for a time before attempting to burrow and in so doing it seemed that they became more sensitive to drying, probably through the rubbing off of the gelatinous material with which their bodies are covered when they first emerge from the egg. Many larvæ put on hosts in this manner began burrowing, but perished during the process. In making observations a calf was usually placed on a table and firmly held or even strapped down so that the actions of the larvæ could be followed under hand lenses or binoculars. Where the hair had been clipped closely, early tests with the penetration of larvæ through the skin were unsuccessful, and all subsequent observations on penetration were made on hair one-fourth inch long or longer. In order to reduce the chances of escape without detection, it was the usual practice to clip closely or shave a narrow area around a tuft of hair and to place the larvæ upon this tuft.

Several attempts were made to observe the penetration of larvæ on the hands or arms of man. Usually the larvæ were watched for periods of from 10 to 30 minutes, but they were not allowed to remain indefinitely. Although some of the larvæ made slight attempts to penetrate into hair follicles, in no case did they succeed in making much progress. In one instance a number of larvæ were placed on the conjunctiva of the eye of a rabbit. They moved about actively for some time and could be seen for an hour or more in the conjunctival region, but apparently they made no effort to penetrate, and produced only a very slight irritation to the eye.

The writers have made no observations on the penetration of larvæ of *H. bovis*, but have frequently observed the lesions produced by the burrowing of this species.

In 1914 (*17*) Carpenter, Hewitt, and Reddin recorded observations on the penetration of *H. lineatum* through the skin of cattle at points where eggs were attached. In addition to finding lesions at those points they succeeded in squeezing from the penetration holes along with serum a newly hatched maggot of this species. In the same publication the authors record observations on the penetration of first-stage larvæ of *H. bovis*, stating that it required about six hours for them to get into the skin. Prior to this Glaser (*29*) had failed in attempts to get the young larvæ to penetrate through the shaven skin, but in one case previously mentioned the larvæ penetrated through the skin on his own leg. The time occupied from the detection of the presence of the larva until it had disappeared was one and three-fourths hours.

In 1916 (*33*) Hadwen published a number of observations on the action of larvæ, both on living hosts and on pieces of skin freshly cut from cattle. He failed to observe the penetration of larvæ on living animals, but in a number of tests on hide removed from a bovine he observed larvæ to burrow partially, and in a few cases completely out of sight.

LESIONS PRODUCED BY THE PENETRATION OF FIRST-STAGE LARVÆ

The presence of exudate and pimples on cattle immediately under the eggs of Hypoderma from which the larvæ had emerged was first recorded by Carpenter, Hewitt, and Reddin in 1914 (*17*). Hadwen (*33*) has rather fully described the skin lesions of the two species of Hypoderma. He proposes the name "hypodermal rash" for the condition resulting from larval penetration.

When the newly hatched larvæ have burrowed into the skin and when their posterior segments are about flush with the skin surface there begins to appear a watery secretion, presumably blood serum. After the larva disappears this exudate increases in quantity and several hours later small pimples form which in some instances, at least, have been found to contain pus. In the case of *H. lineatum* where a number of larvæ often penetrate near one another, the inflammation and exudate become more marked and often the hair is matted, making a scab. With *lineatum* this irritation is often very marked, the entire area near where the penetration occurs becomes swollen, and in certain instances where a large number of larvæ have penetrated the heels of a calf the hind leg from the hock down has been observed to be swollen. These swollen areas are more apparent when large numbers of eggs are deposited along the back of the thighs, on the escutcheon (fig. 22), or on the base of the udder. A number of instances have been observed where the soreness and swelling extended down the rear quarters to the udder and the tenderness made milking difficult.

Beneath the skin these swellings are similar in appearance to the "licked-beef" condition ordinarily found along the back when the last-stage larvæ reach that region. The connective tissue around the point of penetration is edematous, tinged with yellow, and sometimes slightly bloody.

The scabs become dry within a few days and can be removed. Usually a small quantity of hair comes off with them and a number of pits are left in the skin indicating the points where the larvæ have penetrated. If the scabs are not removed artifically they disappear in the course of a week or two. Animals slaughtered during the period of larval penetration have the hides more or less damaged at points where the larvæ penetrate, and slight infiltrated areas are visible on the carcass.

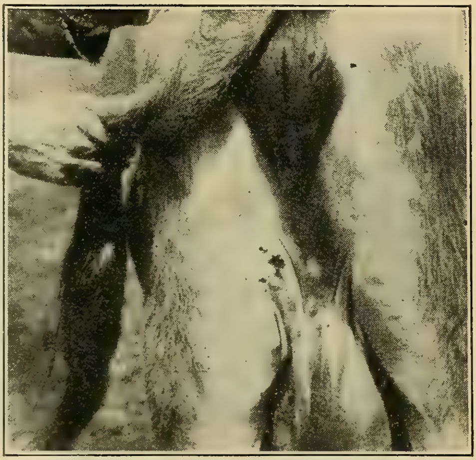


FIG. 22.—Lesions on escutcheon of cow, caused by penetration of newly-hatched larvæ of *Hypoderma lineatum*

As has been stated by other writers, these lesions may serve as portals through which disease organisms, such as anthrax or tuberculosis, may enter.

The actions of the animals at the time the larvæ penetrate have been mentioned in a general way. The first inclination of an animal, after penetration on the heel begins, is to shake the foot. This is usually followed by licking (fig. 23), which is often very vigorous and prolonged, and animals have been observed to continue it for two minutes without stopping. When the individuals are not allowed to lick the heels they usually twist, squirm, kick, and stamp, thus showing marked pain or irritation.

OCCURRENCE IN THE GULLET AND BODY CAVITY

On account of the minute size and translucent appearance, it is not surprising that various investigators have been unable to observe the course followed by the first-stage larvæ after penetration of the skin. Stub (*95*), working in Copenhagen, has given us the only definite record. In a post-mortem he observed an infiltrated area in the superficial connective tissue on the inside of the right tibia, and succeeded in following the track over the shoulder, around the muscles of the neck to the tissue on the esophagus, where it enters the thoracic cavity. Here he found a number of larvæ in close proximity and measuring 1 to 2 millimeters in length. Hadwen (*40*) has observed the tracks of the larvæ up the tendons to the knees or hocks in the elbow and patellar regions and in some cases farther up the legs; no larvæ, however, were recovered in these regions.

For many years it has been known that larvæ of the genus Hypoderma are found in considerable numbers in the connective tissue between the mucous lining and the muscular coat of the gullets of cattle. Since one of the writers (*57*) has found a method of determining accurately the species of the larvæ in any stage of their development, numerous collections of specimens have been examined from the gullets of cattle in regions where *H. bovis* occurs plentifully, and only one specimen of that species has been found. These observations involved the examination of 1,140 larvæ removed from the gullets of 563 cattle, and during every month of the year when they were found to be present in that part of the host. It is safe to conclude from these observations that the larvæ of this species do not have the habit of going to the gullet and spending some time

FIG. 23.—Cow licking heel where larvæ of *Hypoderma lineatum* are penetrating

there as occurs with *H. lineatum.* The single larva of *H. bovis* found in a gullet was taken at Chester, N. Y., on December 19, 1922. It was 10 millimeters long and was found lying loose on the tissue at about one-fourth the length of the gullet from the pharynx.

Since it appears that *H. bovis* does not frequent the gullet it may be taken for granted that all, or practically all, of the published statements of the occurrence of Hypoderma in the gullet appertain to *H. lineatum*, and the following discussion relates to that species only:

The principal data appertaining to the occurrence of the larvæ in the gullets are given in Tables 3 and 4. It will be observed that there is a gradual increase in the average size of the larvæ from their first appearance to their migration from the gullet. The range in sizes is observed by the writers to be from 1.5 to 16.9 millimeters. Among the larvæ found in the gullet only a small percentage are in the third stage, the others being in the second. Hadwen (*40*) reports finding in the submucosa of the gullet of a heifer a larva at least 2 millimeters long which he considered in the first stage.

TABLE 3.—*Number, size, and direction of travel of larvæ of Hypoderma lineatum in each of 10 divisions of gullets of cattle examined during each month at Dallas, Tex.*

	March	April	May	June	July	August	September	October	November	December	January	Total
Number of larvæ headed toward pharynx and paunch in each of 10 divisions of the gullet from pharynx to paunch:												
First—												
Pharynx	0	2	1	1	10	10	14	5	4	0	0	47
Paunch	0	3	0	1	4	6	16	4	4	1	0	39
Second—												
Pharynx	0	6	0	1	5	16	18	11	10	0	0	67
Paunch	1	2	1	0	5	13	15	7	6	1	0	51
Third—												
Pharynx	1	1	0	0	8	26	14	13	8	0	0	71
Paunch	0	2	0	2	13	21	27	14	16	2	0	97
Fourth—												
Pharynx	2	1	0	0	17	35	23	14	22	1	0	115
Paunch	0	2	1	1	4	22	30	12	16	4	0	92
Fifth—												
Pharynx	0	2	2	0	15	29	30	21	30	1	0	130
Paunch	0	0	0	5	8	25	35	16	25	3	0	117
Sixth—												
Pharynx	0	8	5	3	15	36	41	19	22	2	0	151
Paunch	1	4	3	3	16	31	41	20	16	7	0	142
Seventh—												
Pharynx	1	4	9	1	24	42	39	22	25	4	0	171
Paunch	0	9	5	4	14	49	34	10	21	5	1	152
Eighth—												
Pharynx	1	16	7	6	33	60	32	21	22	2	0	200
Paunch	3	21	7	3	31	49	50	12	24	6	0	206
Ninth—												
Pharynx	3	8	10	4	26	70	41	17	22	1	0	202
Paunch	1	12	8	2	32	65	52	20	31	3	0	226
Tenth—												
Pharynx	2	2	6	2	26	43	43	9	18	3	0	154
Paunch	2	4	3	2	17	48	37	11	16	1	0	141
Total number of larvæ headed toward—												
Pharynx	10	50	40	18	179	367	295	152	183	14	0	1,308
Paunch	8	59	28	23	144	329	337	126	175	33	1	1,263
Grand total	18	109	68	41	323	696	632	278	358	47	1	2,571
Length of larvæ (millimeters):												
Minimum	2.6	1.5	3.4	(1)	3.6	3.8	6.0	6.0	8.0	9.6	12.0	-----
Maximum	4.9	6.9	5.2	----	12.4	14.0	15.5	15.9	16.9	15.8	12.0	-----
Average	3.98	3.7	4.4	----	6.7	7.4	10.3	11.9	12.9	13.4	12.0	-----
Number of gullets examined	33	119	21	8	30	60	29	22	46	182	146	697
Average number of larvæ per gullet	0.55	0.92	3.24	5.13	10.77	11.60	21.79	12.64	7.78	0.26	0.01	3.69

[1] Larvæ not measured.

By reference to Table 3 it will be seen that throughout the season the majority of the larvæ occurred in the paunch half (last five divisions) of the gullet, the percentage of the total number in this half being 67.87. It was hoped that some indication of the place of entrance into and exit from the gullet might be given by a study of the postion and direction of travel of the larvæ during different seasons but one can draw no definite conclusions from an analysis of the figures. During the first five months the number of larvæ heading toward the pharynx was greater than the number heading toward the paunch. This, together with the fact that 76 per cent of the larvæ present during the first 5 months of infestation were in the lower half of the gullet clearly indicates that the larvæ do not enter the gullet at the pharynx end. The evidence, however, is not clear that the larvæ enter or leave the gullet tissue at the paunch end. It is possible that some of them reach the connective tissue by penetrating the muscle along the sides of the gullet. The writers' observations indicate that there is considerable variation in the size of the larvæ at the time they reach the gullet, and that the larvæ continue to reach the gullet over a much longer period than is covered by the entrance of the larvæ into the host.

TABLE 4.—*Number, size, and direction of travel of larvæ of Hypoderma lineatum in each of 10 divisions of gullets of cattle examined during each month in New York State.*

Month	June	July	August	September	October	November	December	January	February	March	April	May	Total
Number of larvæ headed toward pharynx and paunch in each of 10 divisions of the gullet from pharynx to paunch:													
First pharynx	0	0	6	0	2	0	2	2	1	0	0	0	13
First paunch	0	0	7	1	0	0	0	1	0	0	0	0	9
Second pharynx	0	0	5	2	2	0	3	1	3	0	0	0	16
Second paunch	0	0	5	0	1	0	1	1	2	1	0	0	11
Third pharynx	0	0	3	1	6	0	0	2	3	0	0	0	15
Third paunch	0	0	4	1	3	0	1	0	0	0	0	0	9
Fourth pharynx	0	0	2	3	7	0	2	4	4	5	0	0	27
Fourth paunch	0	0	4	2	7	0	2	5	6	0	0	0	26
Fifth pharynx	0	0	1	3	17	----	1	8	2	1	0	0	33
Fifth paunch	0	0	3	6	14	----	3	4	5	0	0	0	35
Sixth pharynx	0	1	0	6	17	0	1	6	7	2	0	0	40
Sixth paunch	0	0	11	3	25	0	4	7	8	2	0	0	60
Seventh pharynx	0	0	8	14	18	0	2	12	9	2	0	0	65
Seventh paunch	0	0	8	6	22	0	3	4	8	3	0	0	54
Eighth pharynx	0	0	16	11	19	0	2	17	5	1	0	0	71
Eighth paunch	0	0	11	10	37	0	1	9	6	2	0	0	76
Ninth pharynx	0	1	15	14	22	0	0	20	14	1	0	0	87
Ninth paunch	0	2	17	8	48	0	1	15	11	2	0	0	104
Tenth pharynx	0	2	14	7	23	0	0	19	7	1	0	0	73
Tenth paunch	0	1	14	5	46	0	1	25	9	1	0	0	102
Total number of larvæ headed toward—													
Pharynx	0	4	70	61	133	0	13	91	55	13	0	0	440
Paunch	0	3	84	42	203	0	17	71	55	11	0	0	486
Doubtful	0	0	7	1	0	1	3	2	8	3	0	0	25
Grand total	0	7	161	104	336	1	33	164	118	27	0	0	951
Length of larvæ (millimeters):													
Minimum	----	3.5	3.0	3.0	4.0	5.0	7.3	6.5	8.7	10.0	----	----	----
Maximum	----	4.0	6.0	7.3	8.0	5.0	11.1	14.7	14.9	15.6	----	----	----
Average	----	3.82	4.62	5.52	6.08	5.5	8.69	9.97	12.13	13.65	----	----	----
Number of gullets examined	15	61	68	28	25	15	21	27	72	88	5	15	440
Average number of larvæ per gullet	0	.11	2.37	3.71	13.44	.07	1.57	6.07	1.64	.31	0	0	2.16

Table 4 presents some of the data obtained during the examination of gullets in several localities in New York. Most of them were taken from cattle kept in the vicinity of Ithaca, Chester, Albany, and Buffalo. The combining of the records obtained in several different localities makes the figures more irregular than those obtained at Dallas. The figures show that about 77 per cent of the larvæ were found in the posterior half of the gullet. It will be noted that there is considerable irregularity in the average number of larvæ per gullet, there being a marked decline in the number in November and December, where it seems almost certain from analogy that the maximum should have occurred. The low average in these two months can be explained by the fact that the gullets were taken from a very few lots and were probably from a very small number of herds of cattle. It is well known that the extent of infestation varies in different herds.

The occurrence of larvæ, varying considerably in size, on the surface of various abdominal organs has been noted by a number of investigators. For instance, Koch (*53*) records having found larvæ on the pleural side of the gullet as well as under the mucous coats; on the surface of the spleen; some on the paunch and one between the muscular and mucous layers of it; a few among the intestines; and some in the connective tissue of the thoracic cavity just below the vertebral column. Horne (*45*) has on several occasions observed several larvæ in the connective tissue around the kidneys, and Hadwen and Fulton (*40*) have observed several larvæ on the pericardium. Berg (*3*) has found larvæ in the connective tissue between the small loin muscles and the muscle of the hip, and Koch (*53*) has observed a single larva in the intermuscular tissue of the back. Many writers have recorded the finding of larvæ, sometimes in considerable numbers, in the spinal column throughout the greater portion of its length and also passing through the posterior foramina. Hadwen and Bruce (*38*) state that larvæ observed by them in the spinal canal were found in the areolar tissue which surrounds the dura mater. Their presence was accompanied by evidences of green pigmentation and gelatinous infiltration at different points along the cord.

In the writers' own work they have encountered larvæ in nearly all of the locations where they have been reported by others. It is

Fig. 24.—*Hypoderma lineatum:* Diagram showing position, direction of travel, and length of larvæ in millimeters in gullet of calf (No. 22)

not at all uncommon for the larvæ to be present just under the pleura along the esophagus. The larvæ found in that region were practically of the same size as those in the submucous connective tissue of the gullet. Wide distribution of the larvæ within the abdominal cavity has been noted in the case of the experimental animals infested at one definite period, indicating that there is a general scattering of the larvæ of the same age. On account of the interesting distribution of the larvæ observed in experimental calf No. 22 the location of the larvæ will be briefly summarized. This animal had about 300 eggs deposited upon it by flies on March 22 and 28. Most of these were laid in the region of the dewclaws on the hind legs. On July 3 the animal was killed and carefully dissected. In the connective tissue beneath the mucous lining of the gullet 17 larvæ were found. One of these was crushed and its position not noted. The position of these larvæ in the gullet and direction they were headed are shown in Figure 24. Their size ranged from 3.6 to 6 millimeters in length, the average being 5.3 millimeters. On the paunch 12 larvæ were found. Six of these were almost immediately under the spleen, but none were attached to that organ when it was peeled off. The other six were scattered over the rumen at widely varying distances from the gullet entrance. These ranged in size from 5.8 to 8 millimeters, with an average of 6.8 millimeters. Some of these had the anterior end pointing toward the gullet entrance, others were pointing directly away from it, and others were pointing in various directions. Some of those closest to the gullet entrance were headed toward it. A number were along the line of attachment of the first and second stomachs. On the surface of the second stomach a single larva, 7 millimeters long, was found. On the surface of the colon, about 15 inches from the anus, one larva, 7 millimeters long, was taken headed forward. Seven larvæ were taken in various places in the mesentery of the small intestines. Six of these were 7 millimeters and the other 6.8 millimeters long. One larva, 6.1 millimeters long, was found on the surface of the sixth rib, just under the pleura, about half way between the sternum and the vertebra. This larva was headed ventrally and was rather slender. One larva, 6 millimeters long, was found free on the basal portion of the twelfth rib after the muscular tissue had been stripped off. A careful examination of the other internal organs, diaphragm, muscular tissues of the back, and muscles of the legs was made without finding any indication of the presence of larvæ.

It is noteworthy that the larvæ in the gullet averaged smaller than those in the paunch or elsewhere in the abdomen. This of itself might suggest that the older larvæ were passing backward from the gullet to the paunch or elsewhere. When consideration is given to the fact that larvæ much larger than these are found in considerable

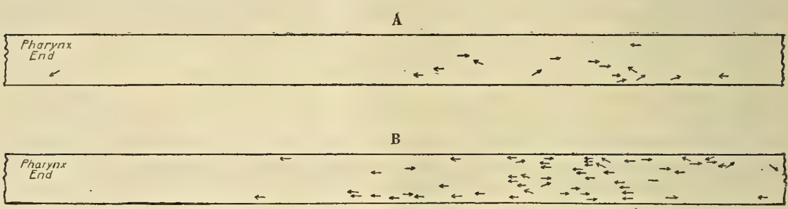


FIG. 25.—*Hypoderma lineatum:* Diagram showing position and direction of travel of larvæ in gullet of calf (No. 409) : *A*, pleural side ; *B*, mucous side

numbers in the gullet during the latter part of summer and throughout the fall, however, the drawing of such a conclusion is hardly justified.

Another experimental calf (No. 409, fig. 25) which was infested with about 268 eggs on the abdomen and hind legs on March 10 and 16 was slaughtered on July 9. A cursory examination of the viscera, walls of the diaphragm, chest, and abdominal cavities failed to reveal any larvæ. On the gullet, however, in the submucous tissue 60 larvæ were found and on the muscle side of the gullet 16 larvæ were taken in the stroma beneath the pleura. These larvæ ranged in length from 5 to 5.6 millimeters, but only a few were carefully measured. The length of those on the pleural side of the gullet was practically the same as those on the mucous side. Of those in the submucous tissue 17 were pointing toward the stomach, 40 toward the pharynx, and 2 were not noted. On the pleural side 9 were pointed toward the stomach and 7 toward the pharynx. The diagram (fig. 25) shows the distribution and the direction of pointing of these larvæ.

The exact course followed by the larvæ in passing from the body cavities to the back has not been determined with accuracy, though the presence of larvæ followed by greenish and gelatinous streaks indicates the lines of migration and the probable routes. The finding of larvæ along the ribs, on the diaphragm, and in the neural canal indicates that they pass from the gullet across the diaphragm to the ventral ends of the ribs and thence follow the connective tissue beneath the pleura up to the back. Some probably work their way between the muscles and pass directly up the diaphragm from the gullet to the back. A number of these no doubt gain entrance to the neural canal, later pass out through the posterior foramen, and then go up to the connective tissue beneath the skin along the back. Both of these routes are probably followed in migrating from the gullet to the back.

The writers' observations indicate that the migration from the gullet to the back is rather rapid. The first larvæ begin to appear in the subdermal tissues of the back very soon after the maximum size has been reached in the gullet. As soon as the number of larvæ are observed to decrease in the gullet they are observed to appear on the back, with practically no increased growth.

Unfortunately it has not been possible carefully to dissect animals infested only with *H. bovis* so as to determine just where the larvæ occur from the time they enter the host until they appear on the back. In New York, where both species are present, the neural canals of 140 slaughtered animals were examined and all the larvæ found were *H. bovis.* Thirty specimens were located, with a maximum of four in one canal. Larvæ were found in this situation during the months of October to March inclusive. The size ranged from 6.5 to 14 millimeters, the larger ones being found later in the season.

At Dallas, Tex., where *H. lineatum* only occurs, about 75 beeves were examined rather carefully as they were dressed. Only one Hypoderma larva was found in the neural canal, a third-stage specimen located in the central portion of the second lumbar vertebra and measuring 14 millimeters in length.

This observation indicates that the larvæ of *H. bovis* enter the neural canals of cattle more frequently than do those of *H. lineatum.* It seems unlikely, also, that all larvæ found in this situation are en route directly to the back, as the larvæ found during October were only from 6.5 to 9 millimeters long, and never have such small larvæ been encountered in the subdermal tissues of the back. Furthermore, the larvæ did not begin to appear under the skin of the backs of cattle in that locality for over three months after these larvæ were taken in the neural canals.

PREPARATION FOR THE EGRESS OF FULLY DEVELOPED LARVÆ

The appearance of third-stage larvæ under the skin on the back is frequently accompanied by considerable local inflammation, indicated by edema of the connective tissue and sometimes marked swellings and soreness.

Certain cattle are more prone to such manifestations and show swellings as large as 10 inches in diameter around each larva as it comes to the subcutaneous tissue of the back. From one to three days after the appearance of one of these swellings a minute hole is cut by the larva near the center, after which the swelling soon subsides. Although no conclusive evidence is at hand, the writers are of the opinion that the holes are cut through the skin almost immediately after the larvæ reach it, and never more than three days later. Usually the first indication of a break in the skin is in the nature of a minute, irregular hole which is usually accompanied by slight bleeding. Within a day or two after the first break is made the edges of the hole become more smooth and round. In several instances the writers have observed a circular plug of skin about 2 millimeters in diameter and bearing hair, seated in a freshly cut hole. In two cases these plugs were still attached at one side as though the cutting process was not complete.

The only evidence to indicate which end of the larva does the cutting is that in every case where larvæ have been extracted the posterior end is always outward. This has been found even before the cutting of the hole was completed. It is conceivable that the larvæ may do the major part of the cutting with the mouth parts and then turn around and complete the enlarging of the hole with the posterior end. When these early stages are removed by pressure they appear to be in a position perpendicular to the skin rather than lying horizontally under it as is the normal position in subsequent stages.

DEVELOPMENT OF THIRD-STAGE LARVÆ

The first molt under the skin, from the third to the fourth stage, takes place soon after the hole is completed. The determination of this period with exactness is very difficult, but the records of the writers show that the molt in *H. lineatum* may take place in about 24 hours after the hole is completed, or the stage may last from 6 to 8 days. The average period, based on 17 records made at Dallas, Tex., with considerable exactness, is 4.5 days, and the average period based on 13 records made in New York is 4.26 days. The period from the cutting of the hole in the skin to the molt in *H. bovis*, as observed in New York, ranged from 1 to 6 days with an average of 3.35 days.

For several hours prior to the molt the spiracles of the fourth stage can be seen beneath the skin of the larvæ. The exuvia are very delicate, but seem to be shed almost in their entirety at one time. The break in the larval skin is very irregular. The posterior ends of the tracheal tube where they join the spiracles are rather highly chitinized and they are shed along with the skin.

The writers' observations show that not infrequently the third-stage larva may move to a new location under the skin, usually within a few inches of the first, and cut a second hole or even a third hole before it molts.

ENCYSTMENT AND DEVELOPMENT OF FOURTH-STAGE LARVÆ

It appears that about simultaneously with the molt to the fourth stage the tissues of the host change their form of resistance from an active leucocytosis to a segregation of the insects by the formation of encystment sacs (fig. 26). With the development of these pouches the general inflammation of the connective tissue subsides. The skin of the third stage remains in the sac, which is formed very rapidly, and gradually the walls of the sac become thicker as the growth of the larva continues. During this and all subsequent stages the larva remains with its posterior spiracles toward the hole in the skin, usually keeping them just a short distance below the surface. During the course of development of the fourth stage the hole may be completely closed by scabs, but an effort is always made to keep it open. This frequently results in the formation of what the writers have called "a perforated plug." This apparently consists of secretions which harden within the hole, becoming somewhat free from its edges, and the larva maintains a minute hole through the center of the mass.

During the development of the fourth stage the body is nearly horizontal, the dorsal side outward, and the posterior end bent upward so that the spiracles are close to the aperture in the skin.

The duration of the fourth stage of *H. lineatum* at Dallas, Tex., has been observed in one instance to be from 5 to slightly more than 13 days, and in another from 10 to 13 days. It is thought, however, that the minimum periods mentioned are possibly erroneous, owing to the chance of failure to record the molt to the fourth stage with accuracy, and that 15 days is nearer a true minimum for this stage. The maximum period recorded in one instance was between 44 and 53 days. The average duration of this stage based upon 21 individuals as recorded at Dallas was 24.5 days. The duration of this stage in the backs of cattle in New York is practically the same as in Texas. Some of the records for this stage are given in Table 7.

In *H. bovis* the length of the fourth stage was observed with fair accuracy in 18 specimens in New York. The minimum period among these was 21+ days, the maximum period 35 to 38 days, and the average 27.1 days (see Table 5).

TABLE 5.—*Duration of fourth stage of Hypoderma bovis in New York*

Locality	Larvæ molted to fourth stage	Larvæ molted to fifth stage	Duration of fourth stage
	1921	1921	*Days*
Herkimer	May 10 (before)	June 1	22+
Do	do	June 7	28+
Do	do	June 9	30+
Do	May 15 (before)	do	25+
Do	May 17	do	23
Do	May 19 (before)	do	21+
Do	May 24 (before)	June 17	24+
Do	May 25 (before)	June 18	24+
Do	do	June 20	26+
Do	May 29	June 27	29
Do	June 2 (before)	June 25	23+
Do	do	July 3	31+
Do	June 6 (before)	July 11	35+
	1922	1922	
Middletown	Apr. 1 to 3	May 8 to 9	35 to 38
Do	Apr. 8 to 9	May 5 to 6	26 to 28
Do	Apr. 15 to 17	May 15 to 16	28 to 31
Do	Apr. 19 to 20	May 14 to 15	24 to 26
Do	Apr. 22 to 24	May 20 to 24	26 to 32

The molting of the fourth instar is apparently preceded by a short period of comparative inactivity. The fifth-stage spiracles appear as pale yellow objects deep beneath the integument two or three days before the molt takes place. As the time for molting approaches the spiracles become more distinct in outline and just prior to the molt their details of structure are well defined beneath the skin of the fourth stage (fig. 6, *g*). As in the preceding molt, the rupture in the integument seems to be irregular and does not

FIG. 26.—Under side of hide just removed, showing cysts, some of which are cut open to expose cattle grubs

always occur in the same place. The exuvium remains in the cysts and can often be removed by continued pressure after the fifth-stage grub has been forced out.

DURATION AND DEVELOPMENT OF THE FIFTH STAGE

Immediately after molting, the larvæ are more or less translucent and the integument comparatively tender. The spiracles at first appear more or less iridescent and are yellowish with a slight orange tinge. Growth in this stage is rapid. The integument becomes heavier and tougher and the spiracles darker. This darkening begins on the rims and gradually the entire spiracles become dark brown to almost black. Along with the darkening of the spiracles and the rapid growth of the larvæ, there is a general darkening of the entire integument. Just prior to emergence from the host the grub becomes shorter and broader. Along with this change comes the darkening of the integument to a deep brown or black.

The duration of the fifth stage is extremely variable. At Dallas, Tex., the minimum length of this stage in *H. lineatum* has been observed to be between 18 and 21 days. More than 100 larvæ were observed. In another instance there was a period of from 19 to 21 days, but it appears that very few complete this stage in less than 23 days. The average, based on 71 records made at Dallas, Tex., was 30.3 days. Some of these records are given in Table 7.

The length of the fifth stage was recorded in six larvæ of *H. lineatum* at Herkimer, N. Y. The maximum was 47 days, the minimum 29 days, and the average 38.5 days. In 1922 in Orange County, N. Y., the length of the instar was determined in 19 larvæ. The maximum was 39, the minimum 16, and the average 29.5 days.

The duration of the fifth stage of *H. bovis* was determined in the case of 58 larvæ at Herkimer, N. Y., in 1921, and in the case of 19 larvæ at Middletown, N. Y., in 1922. The maximum, minimum, and average in the former were 62, 26, and 39.6 days, and in the latter 45, 35, and 40.1 days. Some of these records are presented in Table 6.

TABLE 6.—*Duration of fifth stage of Hypoderma bovis in New York*

Locality	Larvæ molted to fifth stage	Mature larvæ emerged from host	Duration of fifth stage	Locality	Larvæ molted to fifth stage between dates	Mature larvæ emerged from host between dates	Duration of fifth stage
	1921	1921	*Days*		1922	1922	*Days*
Herkimer	May 13	June 27	45	Middletown	Apr. 1 and 3	May 11 and 13	38 to 42
Do	May 18	June 20	33	do	Apr. 10 and 13	May 20 and 24	37 to 44
Do	do	June 18	31	do	Apr. 19 and 20	June 1 and 3	42 to 45
Do	May 19	do	30	do	Apr. 24 and 22	June 3 and 5	42 to 45
Do	do	June 14	26	do	Apr. 22 and 24	May 31 and June 3	37 to 42
Do	do	June 28	40	do	do	June 1 and 3	38 to 42
Do	May 21	July 4	44	do	Apr. 25 and 26	June 7 and 9	42 to 45
Do	May 25	June 20	26	do	Apr. 26 and 27	June 5 and 7	39 to 42
Do	May 27	July 4	38	do	do	June 7 and 9	41 to 44
Do	May 31	July 7	37	do	Apr. 26 and 28	do	40 to 44
Do	June 2	July 14	42	do	do	do	40 to 44
Do	June 4	July 16	42	do	Apr. 27 and 28	June 3 and 5	36 to 39
Do	June 6	Aug. 7	62	do	do	do	36 to 39
Do	June 9	July 17	38	do	Apr. 29 and May 1	June 5 and 7	35 to 39
Do	June 10	July 20	40	do	May 1 and 2	June 7 and 9	36 to 39
Do	do	July 25	45	do	May 4 and 5	June 12 and 14	38 to 41
Do	June 27	Aug. 4	38	do	May 5 and 6	June 14 and 16	39 to 42
Do	June 29	Aug. 9	41	do	May 12 and 13	June 19 and 21	37 to 40

It is in this fifth or last larval stage that stockmen usually observe the presence of the grubs, as the sizes of the lumps increase with the growth of the larvæ. The sizes of the openings through the skin vary considerably, but they are usually much larger after the molt to the fifth stage, and measure from 3 to 4.5 millimeters in diameter (fig. 27). It is seldom that any scabbing or other obstruction is found in the aperture over a fifth-stage larva. There is usually to

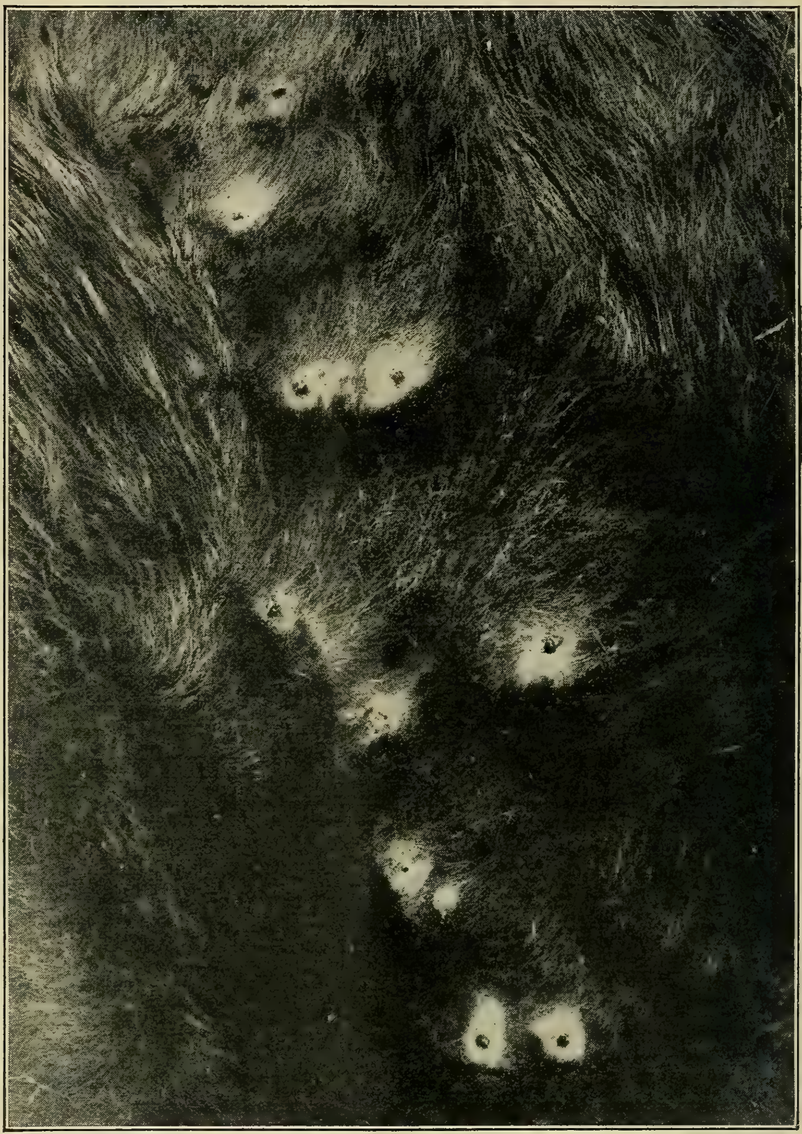


FIG. 27.—Close view of portion of cow's back infested with cattle grubs. Hair is clipped from around holes

be seen a rim of exudate, part of which is considered to be excrement, around the outside edge of each hole.

The position of the larva is similar to that in the fourth stage. The posterior end of the segments is bent slightly so as to bring the spiracle to the hole and almost perpendicular to it. Thus the hole in the skin is always near the posterior end of the larva, which may have the anterior portion in any direction. The majority of the cysts have the aperture near the upper side.

TOTAL DEVELOPMENTAL PERIOD IN THE BACKS OF CATTLE

As with other stages of Hypoderma, there is a variation in the total period required for the development of the larvæ from the time the holes are cut through until the larval growth is completed. The determination of this period with accuracy is of much importance in control and especially in eradication work, since the interval between treatments should be governed by such data.

In a large number of cattle of several breeds warbles of both species were followed through their entire development in the subdermal tissue. Owing to the high mortality among the larvæ, especially when examined repeatedly to determine molts, etc., only a comparatively few records of complete development were obtained among the hundreds of warbles observed.

FIG. 28.—Headlight outfit used in examining cattle grubs in cysts

In order that the duration of the larval stages might be determined various individual cattle were observed from the time warbles began to appear until all grubs had made a normal egress. These observations were made as frequently as time would permit, usually once each day. Through practice the touch was developed to a high degree and one could readily detect the first indication of a foreign object under the skin or a minute amount of exudate from a puncture of the skin.

In making the examinations a headlight was developed which proved of great value (fig. 28). It consisted of a shortened flash light attached to a head band, and served by two dry cells carried on a belt. The focus was adjusted to permit the observer to use a hand lens.

With the younger stages of the larvæ in particular it was found necessary to apply pressure around them to force them toward the surface, where they could be seen distinctly. Not only the time of molting was observed in this way but the changes in color of the last stage could be observed and the approach of complete development noted and emergence watched for.

In order to eliminate any possible adverse effect on the development of the larvæ by these repeated observations, the appearance in the subdermal tissues of several hundred third-stage larvæ was determined by the method indicated, following which they were not disturbed except to make occasional notes on their presence until about the date of emergence from the host. The average time for the development in the case of those larvæ examined for molts, etc., was practically the same, however, as in the case of those which were not disturbed.

As a method of checking up on the observations on the various larvæ it was found best to make a rough diagram of the backs of the hosts, indicating the position of each larva and assigning it a number. In order to facilitate the location of each larva the position on the animal's back was indicated by clipping the hair. In the early observations the hair was clipped close to the skin immediately over the warble hole. Later, as it was thought that the development might be interfered with by exposure, clips were made in the hair of the host just above or below the position of the warble.

The minimum period of development of larvæ of *H. lineatum* in the backs of cattle at Dallas, Tex., based on about 200 records, was between 35 and 47 days. Another period noted was 38 to 40 days, and still another 39 to 46 days. In several other cases the period ranged between 39 and 50 days. The maximum period was between 78 and 89 days. The average total developmental period, based on 104 warbles examined at frequent intervals, was 56.3 days. A few representative records of the development in the backs of cattle are given in Table 7.

The average period of development of 222 other larvæ of *H. lineatum* in which the date of appearance under the hide and the date of emergence from the host were determined without disturbing the larvæ by making observations on molts was 57.74 days.

At Uvalde, Tex., D. C. Parman recorded the duration of the larval period in the backs of cattle for larvæ of *H. lineatum*. The minimum period noted was 43 to 45 days, the maximum 54 days, and the average 49.4 days.

Six accurate records of the period of development of *H. bovis* in the backs of cows were made in New York. The maximum was 77 days, the minimum 65 days, and the average 72.8 days.

Apparently the duration of development in the backs of cattle is not influenced by individual, breed, or age of the host. The writers' records indicate that the development may be slightly shorter at Uvalde, Tex., than at Dallas, and that the time spent in the subdermal tissues of cattle averages slightly longer in the case of larvæ coming up to the backs in the early part of the season. For example, the average period of those which appeared in the subdermal tissue in October and early November was about 58 days, whereas in those which appeared during the latter part of December and in January it was about 51 days.

TABLE 7.—*Development of Hypoderma lineatum in backs of cattle, Dallas, Tex.*

Larvæ appeared between dates	Larvæ molted to fourth stage between dates	Duration of third stage [1]	Larvæ molted to fifth stage between dates	Duration of fourth stage [1]	Duration of third and fourth stages [1]	Emerged from host between dates	Duration of fifth stage	Total period in back of host [2]
1919–20	1919–20	*Days*	1919–20	*Days*	*Days*	1920	*Days*	*Days*
Oct. 27 and Nov. 3	Dec. 11 (before)		Dec. 20 and 22		47 to 56	Jan. 20 and 24	29 to 35	78 to 89
Nov. 12 and 19			Dec. 24 and 26		35 to 44	Jan. 24 and 28	29 to 35	66 to 77
Nov. 19			Dec. 15		26	Jan. 14	30	56.
Nov. 19 and 26			Dec. 17 and 18		21 to 29	Jan. 12 and 16	25 to 30	47 to 58
Do			Dec. 13 and 16		17 to 27	do	27 to 34	47 to 58
Nov. 20 and 28	Dec. 11 (before)		Dec. 12 and 15		14 to 25	Jan. 6 and 8	22 to 27	39 to 49
Dec. 1 and 2	Dec. 12 (before)		Dec. 22 and 24		20 to 23	Jan. 20 and 24	27 to 33	49 to 54
Dec. 2 and 3	Dec. 6 (before)	3 to 4				Jan. 26		54 to 55
Dec. 2 and 5	Dec. 13 (before)	8 to 11	Jan. 3 and 8		29 to 37	Feb. 3 and 7	26 to 35	60 to 67
Dec. 3 and 4	Dec. 12 (before)	8 to 9	Dec. 27	+15	23 to 24	Jan. 24 and 28	28 to 32	51 to 56
Dec. 3 and 5	Dec. 13 (before)	8 to 10	Dec. 23 and 26	10 to 13	18 to 23	Jan. 20 and 24	25 to 32	46 to 52
Dec. 4 and 5	Dec. 9	4 to 5	Dec. 24 and 26	15 to 17	19 to 22	Jan. 24 and 28	29 to 35	50 to 55
Do	Dec. 8 (before)	3 to 4	Dec. 22 and 23	14 to 15	17 to 19	Jan. 20	23 to 29	46 to 47
Dec. 5	Dec. 17 (before)		Dec. 31 and Jan. 2	+14 to 16	26 to 28	Jan. 28 and Feb. 3	26 to 34	54 to 60
Dec. 6 and 8	Dec. 11	3 to 5	Dec. 26 and 29	15 to 18	18 to 23	Jan. 24 and 28	26 to 33	47 to 53
Do			Jan. 6		29 to 31	Jan. 29	23	52 to 54
Dec. 6 and 9	Dec. 9 (before)	−3	Dec. 29 and 31	20 to 22	20 to 25	Jan. 28 and Feb. 3	28 to 36	50 to 59
Do	Dec. 13 (before)	4 to 7	Jan. 8 and 12	26 to 30	30 to 37	Feb. 7 and 11	26 to 34	60 to 67
Do	do	4 to 7	Dec. 18 and 26	+5 to 13	9 to 20	Jan. 20 and 24	25 to 37	42 to 49
Dec. 9 and 11	Dec. 11 and 13	0 to 4	Jan. 3 and 6	21 to 26	23 to 28	Feb. 7 and 11	32 to 39	58 to 64
Do	Dec. 16 (before)	5 to 7	Dec. 24 and 26		13 to 17	Jan. 24 and 28	29 to 35	44 to 50
Dec. 12 and 15	Dec. 20	5 to 8	Dec. 31 and Jan. 6	11 to 17	16 to 25	Jan. 28 and Feb. 3	22 to 34	44 to 53
Dec. 12 and 16	Dec. 16 (before)	−4	Dec. 22 and 26			Jan. 24 and 28	29 to 37	39 to 47
Dec. 24 and 26	Dec. 26 and 29	0 to 5	Jan. 20	22 to 25	25 to 27	Feb. 20 and 28	31 to 39	56 to 66
Dec. 31 and Jan. 2	Jan. 2 and 6	0 to 6	Jan. 20 and 24	14 to 22		Feb. 20 and 24	27 to 35	49 to 55

[1] Duration of stages includes shortest and longest possible periods.

[2] Figured from date larvæ appeared to date of dropping from the host and not from addition of days in each stage, as it was impossible to get accurate records on the duration of larval stages.

THE METHOD OF EGRESS OF GRUBS FROM BACKS OF CATTLE

When the fifth-stage larvæ complete their growth they become more active and the posterior segments are extended and forced into the openings through the skin and then quickly withdrawn. With this action the sides of the holes are cleaned of the rim of exudate and more or less covered with the pus forced up by the larvæ. When the actual process of emergence begins the posterior segments are forced into the aperture and the larvæ slowly work their way out by expansion and contraction of the body rings. The actual process of emergence of the grubs takes from one to

FIG. 29.—Diagram showing hours when larvæ of *Hypoderma lineatum* emerge from the host for pupation

three minutes, but the preparatory activities may be begun several hours before the grubs make a serious attempt to escape.

TIME OF EMERGING FROM HOST

With *H. lineatum* fairly accurate observations have been made on the time of day when 181 warbles emerged from the host, and less accurate observations on 211 others. Glaser (*29*) pointed out that he observed in Germany a large percentage of warbles dropped in the early morning hours, the percentage being from 49.4 to 68.2 between the hours of 5 and 7 a. m. The writers' observations do not agree closely with his in this respect, for, as is shown on the accompanying diagram (fig. 29), the largest number dropped in the middle of the forenoon from 8 to 10 a. m., and the emergence was greatly reduced in the middle of the day, increasing again in the middle of the afternoon.

The number of larvæ recorded as dropping in the earlier morning hours is undoubtedly too small, as fewer examinations were made between 8 and 9 a. m. than in later periods, and a much smaller number still between 7 and 8 a. m. It is believed, however, that by adding all of those which may have dropped between 7 and 9 a. m. the total would not nearly equal the number which dropped between 9 and 10 a. m. Of the 269 larvæ the hour of emergence of which was noted with considerable accuracy, 140, or 52 per cent, left the host between 8 a. m. and noon, and 129, or 48 per cent, between noon and 6 p. m. There is undoubtedly a greater disparity than these percentages indicate, as the number of hours in the forenoon period was smaller than the number in the afternoon. Also, as stated above, some warbles that dropped in the early morning hours were not recorded.

The percentage of grubs dropping in the night was comparatively small. Considering the entire 392 larvæ upon which the writers have records, only 88, or 22.4 per cent, dropped out during the 12 hours from 6 p. m. to 7 a. m. As a matter of fact, this percentage is too high, as in it are included larvæ which on several occasions were found to have dropped from animals when they were first examined in the morning; sometimes this examination being made as late as 8 or 9 o'clock.

From their observations and the study of the data accumulated the writers are led to believe that the activity of the host has much to do with the dropping of the larvæ. Feeding of the animals usually took place between 8 and 9 a. m. and up to about that time the animals were comparatively quiet, usually lying down. In the noon period following the morning feeding they again became quiet and lay down much of the time, until 4 or 5 p. m., when feeding again took place. Just how activity of the host should influence the dropping of the larvæ it is not easy to see. Possibly the muscular movements stimulate them. There is a possibility also that the warming up of the back of the animals by the sun following the cool night may tend to stimulate dropping. In the instances cited by Glaser it appears that feeding took place very early in the morning and hence his observations may tend to substantiate this hypothesis.

DISTRIBUTION OF THE LARVÆ ON THE BACKS OF CATTLE

As is well known, the larvæ occur in the greatest numbers along each side of the spinous processes from the shoulder to the hip bones. In diagraming the backs of hundreds of cattle the writers have observed that this distribution is very irregular, sometimes several larvæ being in one group and the rest of the back comparatively free, while in other cases they are widely scattered over the entire area. It seems certain, however, that this is simply a matter of chance. In summarizing their figures on the distribution of the larvæ the writers find that about 50 per cent of them occur in the region of the dorsal vertebræ and the other 50 per cent in the lumbar region. As a rule they are more concentrated in the area over the last three ribs. Although it is not unusual to find grubs on the shoulders, that is, above the scapulas or behind the hip bones, the percentage occurring in these regions is comparatively small, the writers figures indicating slightly less than 1 per cent for the latter. Occasionally grubs are met with on the tail 3 or 4 inches below its base, and also on the neck some inches in front of the shoulders. One instance of the occurrence of a grub below the point of the pin bone has been observed by the writers. Laterally most of the grubs are confined to a strip about 1 foot on each side of the backbone in grown animals, but it is not especially unusual to find them on the ribs half way down the side of the animal. The midline of the back is comparatively free (fig. 30).

The writers' experiments show that there is no relation between the distribution of the eggs on the host and that of the late stages

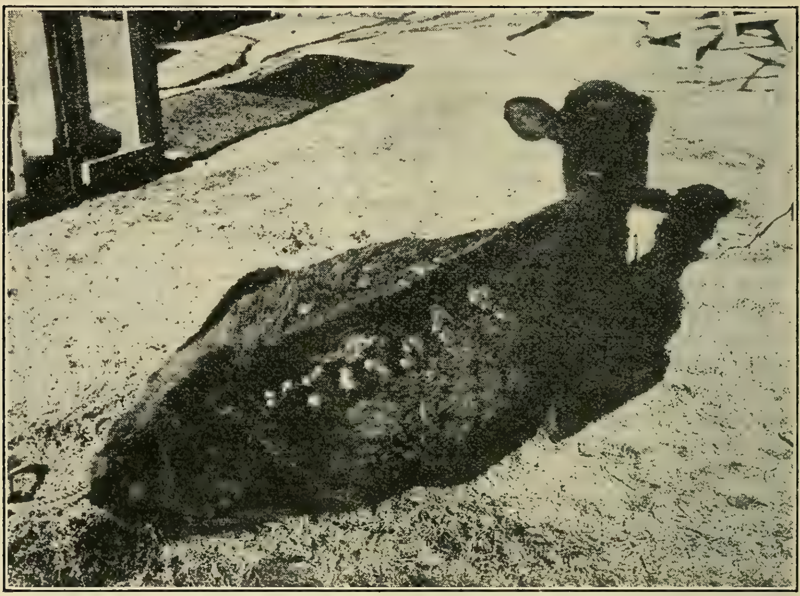


Fig. 30.—Cow with back infested with cattle grubs. Hair is clipped from around holes

of the larvæ resulting therefrom. As the larvæ are known to migrate freely all through the host, such a relationship would not be expected.

PUPATION AND DURATION OF THE PUPAL STAGE OF HYPODERMA LINEATUM

When the larvæ have freed themselves from the hole in the skin in the back of the host they begin contracting and expanding and soon roll off on the ground. For the collection of larvæ as they emerged from the hosts, burlap bands were placed around the bodies of cattle, as shown in Figure 31. They are not very active and their progress in crawling is very slow. There is a tendency for the larvæ to crawl under any loose objects which may be at hand and which would offer some protection; but ordinarily they do not go more than a short distance from the place where they drop, and their tendency to dig into the ground is not very marked. Not infrequently specimens will bury themselves in loose débris, such as straw and broken leaves, but they do not burrow into compact soil or sand to any extent. The larvæ show marked negative heliotropism, and one was observed to crawl more than 10 feet, seeking shade in which to pupate. Usually within a few hours they become quiet and within 1 to 12 days the integument hardens and changes its shape into the typical puparium form. The average prepupal period recorded in the case of 238 larvæ of *H. lineatum* was 3.4 days. Representative records are presented in Table 8. The prepupal stage observed among 7 specimens, kept in a screened insectary in Middletown, N. Y., in 1922, ranged from 1 to 4 days. This period may vary several days in the case of larvæ leaving the host the same day, but the total time required for their transformation to adult is not increased to that extent.

It is evident that where the larvæ drop normally the prepupal period is markedly influenced by temperatures.

The pupal period at Dallas, Tex., ranged from 16 to 75 days, the average being 38.2 days, as recorded for 196 specimens. Representative data are given in Table 8.

TABLE 8.—*Duration of prepupal and pupal stages of Hypoderma lineatum at Dallas, Tex.*

Larvæ emerged from host		Pupated		Prepupal period	Flies emerged			Pupal period	Period from dropping to adult	Temperature dropping to adult		
Date	Number	Date	Number		Date	Number of males	Number of females			Max.	Min.	Average daily mean
				Days				*Days*	*Days*	*°F.*	*°F.*	*°F.*
1916		1916			1916							
Feb. 17	1	Feb. 21	1	3½	Mar. 21		1	+29	33	91.5	23.7	58.26
Feb. 18	1	do	1	3	Mar. 20	1		28	31	91.5	23.7	57.71
Feb. 21	1	Feb. 22	1	¾	Mar. 21	1		+28	29	91.5	23.7	58.94
Do	1	Feb. 23	1	2	Mar. 22		1	28	30	97.9	23.7	59.68
Feb. 22	3	Feb. 24	3	2	do	2	1	27	29	97.9	23.7	59.80
Mar. 4	1	Mar. 6	1	2	do	1		16	18	97.9	28.0	64.65
Mar. 6	1	Mar. 7	1	1	Mar. 28		1	21	22	97.9	34.0	64.32
Mar. 7	1	Mar. 8	1	1	do	1		20	21	97.9	34.0	63.77
1917		1917			1917							
Jan. 31	1	Feb. 3	1	3	Mar. 13	1		38	41	93.0	9.5	50.92
Feb. 13	2	Feb. 17	2	4	Mar. 20	1	1	31	35	93.0	25.0	56.22
Mar. 10	1	Mar. 11	1	1	Mar. 31	1		20	21	87.5	32.0	63.31
1918		1918			1918							
Jan. 20	2	Jan. 25	2	5	Mar. 11	2		45	50	97.5	33.5	49.46
Jan. 31	2	Feb. 6	2	6	Mar. 13	1	1	35	41	97.5	12.5	53.86
1920		1920			1920							
Jan. 6	1	Jan. 8	1	2	Mar. 18	1		70	72	81.0	19.0	48.67
Jan. 7	1	Jan. 18	1	11	do		1	60	71	81.0	19.0	48.83
Jan. 9	1	Jan. 16	1	7	Mar. 25		1	69	76	81.0	19.0	51.31
Feb. 6	1	Feb. 9	1	3	do	1		45	48	81.0	19.0	52.46
Feb. 18	1	Feb. 20	1	2	Mar. 27		1	36	38	81.0	19.0	54.08
Feb. 23	1	Mar. 1	1	7	Mar. 25		1	24	31	81.0	19.0	52.61
1921		1921			1921							
Jan. 11	1	Jan. 15	1	4	Mar. 1	1		45	49	83.0	26.0	52.03
Do	1	Jan. 17	1	6	Mar. 3		1	45	51	83.0	26.0	52.44
Jan. 28	1	Jan. 29	1	1	Mar. 12	1		42	43	83.0	27.0	54.91
Feb. 5	2	Feb. 7	2	2	Mar. 15	1	1	36	38	83.0	28.0	56.89
Feb. 6	1	Feb. 8	1	2	do	1		35	37	83.0	28.0	56.94
Do	1	Feb. 10	1	4	do	1		33	37	83.0	28.0	56.94
Feb. 13	2	Feb. 14	2	1	Mar. 16	1	1	30	31	83.0	28.0	58.90

58252°—26——5

Only four adults of *H. lineatum* were bred out in Middletown, N. Y. Among these the pupal period ranged from 26 to 41 days, and the period from date of leaving the host to emergence of the adult ranged from 27 to 42 days. At Dallas, Tex., this period of transformation ranged between 18 and 77 days, with an average of 41.7 days in the case of 221 specimens kept out of doors.

The average period of transformation was slightly shorter in males than in females, being 42 days in the former and 44.4 in the latter, as computed on 92 males and 80 females.

Hadwen (*33*) has presented records of the duration of the pupal stage of *H. lineatum* of from 13 to 19 days when the specimens were kept in an incubator at 32° C., and Glaser (*30*) records a pupal period in Germany for this species of 23 to 38 days. Carpenter (*12*, *17*) states that he has observed the pupal period to be about 7 to 8 weeks in Ireland.

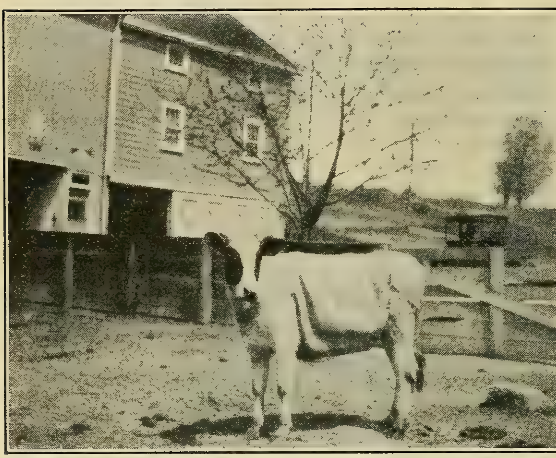


FIG. 31.—Heifer with bagging around body, for purpose of collecting cattle grubs as they emerge from host

PREPUPAL AND PUPAL STAGES OF HYPODERMA BOVIS

Mature larvæ of *H. bovis* show about the same degree of activity after emergence from the host as those of *H. lineatum*, but they seem to have a stronger tendency to burrow into the soil. The larvæ of this species also show a great desire to escape from direct sunlight, and one was observed to crawl 12 feet to a deep shadow, where it pupated. If placed on loose soil, most of them will bury themselves in a short time. Some burrow down about an inch, but most of them go just below the surface.

When the weather is warm the prepupal period is very short. At Dallas records were kept on several larvæ which emerged normally from cattle. All of these pupated, and 4 produced adults. The prepupal period of these larvæ was in every case somewhat less than a day, and the pupal period of the 4 which emerged was from 14 to 15 days, making a total period from emergence from the host to the appearance of the adult insects of from 15 to 16 days. Among 24 larvæ extracted from cattle at Dallas, Tex., and kept for rearing, 14, or 58.3 per cent, pupated and only 1 (4.2 per cent) produced an adult. In the case of this specimen the prepupal period was slightly more than a day, and the pupal period 14 days, a total transformation period of 15 days. The writers succeeded in breeding out 4 adults from 8 mature larvæ extracted from cattle at Herkimer, N. Y. (Table 9). The prepupal period among these was 10 hours to 1 day, and the pupal period from 15 to 24 days. The total developmental period from extraction of the larvæ to the emergence of the adults was 16 to 25 days. All of these records were made in midsummer, and the specimens reared in New York were kept in a building in which the temperature was warmer than outdoors, hence the periods shown are probably shorter than would occur normally.

TABLE 9.—*Duration of prepupal and pupal stages of Hypoderma bovis*

Locality	Date dropped or extracted from host	Date pupated	Duration of prepupal stage	Adults emerged			Duration of pupal stage	Period from dropping to adult	Temperature during period from dropping to adult		
				Date	Number of males	Number of females			Max.	Min.	Average daily mean
	1918	1918	*Days*	1918			*Days*	*Days*	°*F.*	°*F.*	°*F.*
Dallas, Tex.	May 15	May 16	1	May 30	------	1	14	15	98.4	54.0	78.28
Do.	May 24	May 25	1	June 8	1	1	14	15	96.0	63.1	81.62
Do.	May 27	May 28	1	June 12	------	1	15	16	97.0	65.0	81.37
	1921	1921		1921							
Herkimer, N. Y.	June 24	June 24	½	July 11	------	1	16½	+17	------	------	------
Do.	July 14	July 15	1	July 30	------	1	15	16	------	------	------
Do.	July 17	July 17	½	Aug. 5	------	1	18½	+19	------	------	------
Do.	Aug. 3	Aug. 4	1	Aug. 28	1	------	24	25	------	------	------
	1922	1922		1922							
Middletown, N. Y.	Apr. 20	Apr. 27	7	June 4	1	------	38	45	85.0	28.0	58.6
Do.	Apr. 21	do.	6	do.	1	1	38	44	85.0	28.0	59.1
Do.	Apr. 23	do.	4	do.	1	1	38	42	85.0	32.0	60.0
Do.	Apr. 26	do.	1	do.	1	3	38	39	85.0	32.0	60.9
Do.	Apr. 28	May 1	3	do.	2	1	34	37	85.0	33.0	61.4
Do.	do.	do.	3	do.	3	------	34	37	85.0	33.0	61.4
Do.	Apr. 29	do.	2	do.	1	3	34	36	85.0	33.0	61.9
Do.	do.	do.	2	June 5	1	2	35	37	85.0	33.0	62.1
Do.	Apr. 30	do.	[1] 1½	June 4	1	1	33½	35	85.0	33.0	62.1
Do.	May 4	May 8	4	June 6	1	------	29	33	85.0	40.0	62.8
Do.	do.	do.	4	June 7	6	------	30	34	85.0	40.0	63.2
Do.	do.	do.	4	June 8	1	2	31	35	89.0	40.0	63.6
Do.	May 8	May 9	1½	June 7	5	------	28½	30	85.0	40.0	63.8
Do.	do.	May 10	2	June 9	------	2	30	32	91.0	40.0	64.6
Do.	May 12	May 13	1	June 8	3	------	26	27	89.0	40.0	64.5
Do.	do.	do.	1	June 9	3	4	27	28	91.0	40.0	64.9
Do.	do.	do.	1	June 10	1	1	28	29	92.0	40.0	65.3
Do.	May 14	May 15	1½	June 9	3	1	24½	26	91.0	41.0	65.0
Do.	do.	do.	1½	June 10	1	------	25½	27	92.0	41.0	65.5
Do.	do.	do.	1½	June 11	------	1	26½	28	92.0	41.0	65.8
Do.	May 17	May 19	1½	do.	1	------	23½	25	92.0	41.0	66.5
Do.	do.	do.	1½	June 12	------	1	24½	26	92.0	41.0	66.8
Do.	May 20	May 21	1	June 11	1	------	21	22	92.0	41.0	67.8
Do.	do.	do.	1	June 12	------	1	22	23	92.0	41.0	68.2
Do.	May 25	May 26	1	June 16	2	------	21	22	92.0	41.0	68.3
Do.	May 27	May 29	2	June 19	1	------	21	23	92.0	41.0	68.1

[1] Half days are given to approximate more closely the time required for transformation.

At Middletown, N. Y., during 1922, a large number of adults were reared from larvæ which emerged normally from the backs of cattle. These pupæ were kept in a screened, roofed insectary out of doors. The prepupal period ranged from about 10 hours to 7 days, with an average of 1.7 days; the pupal period, from 21 to 38 days with an average of 29.4 days. The time from leaving the host to emergence of adults varied from 22 to 45, with an average based on 167 records of 31.34 days. The longest period (Table 9) occurred in the spring. As some larvæ left hosts in 1922 about April 1, it is probable that some periods longer than the maximum shown might have occurred among the larvæ dropped earlier in the spring.

In Canada, Hadwen (*34*) observed a period of 30 to 40 days to intervene from the emergence of the larvæ to the appearance of the adult, the average for several being 34.7 days, and Glaser (*29*) records this period as being 37 to 56 days in Germany. Under just what conditions these pupæ were kept is not known, but presumably they were out of doors. Vaney (*106*) in Lyons, France, has observed that the period of transformation requires from 3 to 4 weeks. In the vicinity of Paris, France, Lucet (*63*) records an average pupal period of 32.9 days, the range being from 29 to 40 days. In Ireland, Carpenter, Phibbs, and Slattery (*19*) record a pupal period of 32 to 46 days. Stub (*97*), working in Copenhagen, found the pupal period to be from 40 to 53 days.

MORTALITY IN THE PREPUPAL AND PUPAL STAGES

Among larvæ which drop normally a considerable percentage fail to produce flies, even under what might be thought to be optimum conditions. The percentage of the larvæ which pupate is rather high. Among 559 larvæ of *H. lineatum* which were noted at Dallas, Tex., 514, or 92 per cent, formed pupæ and 337, or 65.6 per cent, of the pupaæ emerged as adults, or 60.3 per cent of the total number. Both species of Hypoderma are very dependent upon proper conditions for completion of their development. Larvæ removed from the backs of cattle before they are ready to emerge are subject to a high percentage of mortality. It is conceivable that by forcing them through the holes in the hide they may be injured, but the writers' experience indicates that immaturity and not injury is the cause of death. Among 325 well-developed larvæ of *H. lineatum* extracted by hand and kept under optimum conditions for pupation and adult emergence, only 113, or 34.8 per cent, pupated, and out of this number 26, or 23 per cent, produced adults. This was 8 per cent of the total number of the larvæ extracted and observed. All of these larvæ had practically attained their full growth.

Among 221 larvæ of *H. bovis* which emerged normally from hosts and were kept in a screened insectary in Middletown, N. Y., 186, or 84 per cent, produced adults.

Excessive moisture produces a high mortality among pupæ. This point will be discussed under natural control.

EMERGENCE OF ADULT FROM PUPARIUM

In the case of both *H. lineatum* and *H. bovis* the flies appear mature within the puparia several hours before they emerge. The majority of the adults reared by the writers have been found to escape from the puparia during the early morning hours.

The cap of the puparium is first forced open by the head of the fly, and in some cases it is broken off completely. The fly then crawls out, and this process takes less than half a minute. Within a few minutes after the fly escapes it usually walks away from the puparium and begins to unfold its wings. Usually this process requires about five mintues. The ptilinum is completely retracted and the wings straightened to normal position in about 15 minutes after emergence. The abdomen is conspicuously distended, showing that the insect is provided with an ample supply of food from the larval stage. An occasional droplet of excrement is voided during the drying process. Immediately after the wings are dried the abdomen is extended and retracted and the insect makes clumsy attempts at flight. Within half an hour after emergence it is able to sustain itself on wing, though rather clumsily.

The adults evince a very strong positive heliotropism. In captivity their main energies are devoted toward escaping. Very few flies have been recovered in nature unless in the act of attacking cattle, and just what place they choose for resting is not known. Apparently, however, they remain on the ground or on grass and shrubbery close to the ground.

PROPORTION OF SEXES

The sexes were noted in the case of 284 reared adults of *H. lineatum*. Of these, 147, or 51.8 per cent, were males. The males usually emerge from the puparia slightly before the females, although this is not uniformly the case. Among 172 adults of *H. bovis* which were reared and the sex noted, 81, or 47.1 per cent, were males.

FOOD OF THE ADULT

Mention has been made of the supply of food carried over to the adult stage from the larvæ. This appears to be sufficient to meet the needs of the adult insect throughout its life. The writers have repeatedly attempted to feed reared adults in captivity on fruit, sirup, and water, but have never observed any indication that they would partake of such substances. The mouthparts are degenerate and probably not capable of functioning in feeding.

MATING

Many reared flies of *H. lineatum* have been kept in various types of breeding cages, usually supplied with sticks or branches of green trees, and in the much greater number of these cases mating was not observed to take place. Although a number of these reared females were induced to oviposit, in most instances the eggs were infertile. In four cases mating was closely observed. The act usually took place immediately after the males and females were placed in the same small cage. In each instance the male seized the female as soon as they met, but in one case the male went through some preliminary courting actions. He crawled over the female's back and head, then worked rearward on the back of the female and mating began. The details of mating appear to be about the same as with many other Diptera. The duration of the act ranges from one to three minutes. In two instances mating was repeated a second time immediately after the first. In two of the four instances of mating observed in *H. lineatum* both the male and female were 1 day or more old. In the other instance, however, which occurred at 10.45 a. m., the male had emerged shortly prior to 9. a. m. of the same day, and the female was observed to crawl from the puparium at 10 a. m.; thus mating took place when the female had been out only 45 minutes. It is interesting to note in this connection that this female upon being placed on a calf 20 minutes after mating deposited a considerable number of fertile eggs.

H. bovis evidently mates much more freely in captivity than *H. lineatum*. The act has been observed in many instances to take place among reared specimens. Among a large number of adults of *H. bovis* which emerged early in the morning and were kept in lantern globes, many pairs were observed in copula about 10 a. m. as the temperature rose. The duration of the act ranged from two to two and one-half minutes.

OVIPOSITION

Reference has been made already to an instance of a fly beginning oviposition within about an hour of the time she emerged. The writers' observations in the field indicate that if favorable weather conditions prevail oviposition usually begins on the same day the adults emerge. It also appears that with flies in the field and with those captured and placed on experimental animals the majority of the eggs deposited by an individual are laid during a single day. In several instances flies deposited a large number of eggs during one day and a moderate number during the second day, but in no case have specimens oviposited during three successive days.

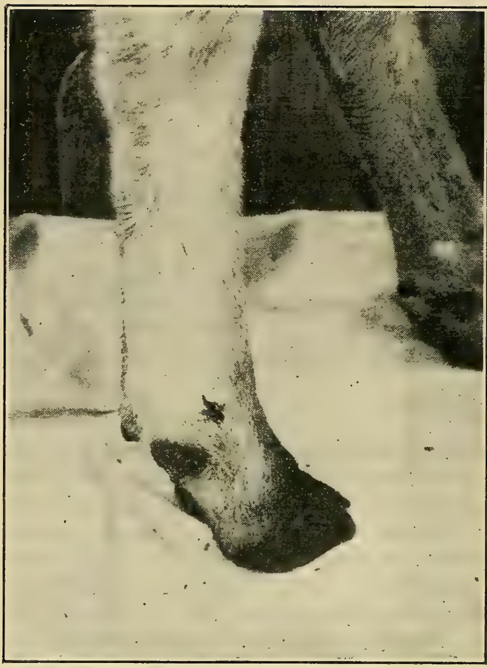


FIG. 32.—Heel fly (*Hypoderma lineatum*) ovipositing upon leg of cow

As has been pointed out by Hadwen and other authors, the methods of oviposition are very different in *H. lineatum* and *H. bovis.* The former attacks more stealthily than the latter, and several eggs are usually placed on a single hair, while with *H. bovis* the eggs are laid singly. This difference in the action of the flies during their oviposition is intimately associated with the fright produced among cattle, as will be discussed later.

In the field when cattle come in the vicinity of a resting female of *H. lineatum* the insect is observed to approach them on the wing, usually alighting on the ground close to an animal and frequently approaching the hind legs of the host by a series of short flights which resemble jumps. She sometimes lights directly on the heel, usually below the dewclaws, and immediately begins to extend the ovipositor, grasping the hair and cementing on her eggs (fig. 32). In other instances if the animal is not moving she may come close to the heel of the host, turn around, and back up to the rear of the hoof with the ovipositor extended. In this way the short hairs between the hoofs are reached and the eggs are placed in position while the fly remains on the ground. When the animal moves, the fly usually follows, flying behind close to the ground, and when the opportunity offers she may alight on the host, commonly on the hind legs below the hock. Under such conditions the animal is usually aware of the presence of the fly and often kicks at it, frequently knocking it to the ground, in which case it usually arises promptly and starts again after the host. With animals disturbed in this way the fly is more likely to attack higher on the legs and not infrequently on the sides, especially in the region of the flank or on the forelegs or shoulders.

In many instances the writers have observed females of *H. lineatum* to oviposit on cattle while they were lying down. When not disturbed the fly usually deposits a series of eggs, possibly 50 to 60, in rapid succession and then rests for a minute or two. Sometimes she moves slightly to a new position and then repeats the operation.

Flies of *H. lineatum* captured by means of a net while attacking cattle in nature are readily induced to oviposit on experimental animals kept under control; in fact, this was the method followed in obtaining eggs with which to infest experimental animals and for other purposes. After the flies were captured they were usually placed in small tubes or jars and brought immediately to the laboratory and placed upon experimental hosts. To accomplish this the female was usually placed in a glass vial with the open end placed against the host. Usually as soon as the fly comes in contact with the hair of the animal she begins extending the ovipositor and starts laying eggs. After she has once begun it is often unnecessary to keep the restraining vial over her.

H. bovis attacks the animals viciously, usually approaching them about the height of the hock, and very seldom lights on the ground. On account of its more persistent and ferocious attack the animals are put to flight with the first period of oviposition. The fly strikes the animal a number of times in rapid succession, cementing an egg on a hair in nearly every instance. After a number of these strikes at the animal the fly may leave for a few minutes and then return and repeat the process as persistently as before. Frequently when the host is active the fly may follow it around a small pasture, attacking repeatedly when it catches up to the fleeing animal.

Great difficulty was experienced in getting females of *H. bovis* to deposit eggs after they had been captured. Hawden's reports indicate that he had no difficulty in getting females caught while ovipositing in nature to deposit under an insect net held to a bovine or when released near a tethered animal. In Illinois and New York, however, a number of flies captured in the field by the writers and applied in various ways to hosts under control gave very discouraging results. Only a few eggs were secured and these for the most part were dropped free in the hair.

During the summer of 1922 a large number of flies of both sexes of *H. bovis* were reared at Middletown, N. Y., and many attempts were made to secure eggs from them. Although they mated freely, as has been stated, they persistently refused to oviposit. Some were kept in glass containers held against a calf; others were placed in small screen cages attached to the host; and still others were liberated in cages containing calves. But in no case were any eggs deposited normally.

On account of the fact that *H. lineatum* deposits its eggs in series on the same hair, the rate of egg laying is somewhat faster than with *H. bovis*. In some instances the eggs of *H. lineatum* have been seen to be deposited at the rate of nearly 2 per second, and 30 or 40 may be deposited in a minute.

NUMBER OF EGGS DEPOSITED

The number of eggs deposited, especially by *H. bovis*, is very difficult to determine. The maximum number observed by the writers for *H. lineatum* was 446. These were deposited by a female taken in the act of ovipositing on a cow in a pasture, and hence this fly may have laid many eggs before capture. Glaser (*29*) has observed a female *H. lineatum* to deposit 538 eggs, and estimates the total number deposited by this female as 550. In many instances from 200 to 300 eggs have been obtained from a female caught in the field in the act of oviposition. Females dissected after they have become too weak to deposit more eggs usually have a good number of ova left in the abdomen, although many of these appear to be only partially developed.

CONDITIONS UNDER WHICH OVIPOSITION TAKES PLACE

Both species of Hypoderma are stimulated to oviposition by bright sunlight and usually egg laying takes place largely in the sunshine. Both species have been observed, however, to deposit eggs in the shade, and occasionally when the sun was fairly well covered with clouds, especially if there were occasional bursts of sunshine. Oviposition rarely takes place when the sky is heavily clouded, and dense shade such as under large sheds appears to be shunned by the females of both species. Females of both *H. bovis* and *H. lineatum* have been observed to be active on days when the temperatures were comparatively low, provided the sun was shining brightly. No doubt in their protected places close to the ground reflected heat and sunshine stimulate them to activity when the general temperatures are very low. In one instance oviposition of *H. lineatum* was observed when the temperature was between 40 and 45° F. The minimum temperature at 7 o'clock that morning was 20.5° F. and the maximum for the day 46° F. at 3 p. m. It is difficult to say just what is the optimum temperature, as large numbers of flies have been observed ovipositing under a wide range of temperature conditions. Females of this species oviposit freely when the temperatures range between 55 and 85° F. provided the sun is shining.

Apparently the range of temperature in which females of *H. bovis* will oviposit is narrower than in *H. lineatum*, although, in localities where both species occur, females of *H. bovis* usually experience higher temperature, since they emerge later in the season.

High winds and even fresh breezes tend to check egg laying of both species. Occasionally, however, the flies will oviposit on windy days when the cattle are standing in the sunshine in protected places.

LONGEVITY OF ADULTS

Owing to the fact that the adults of Hypoderma are very restless when in captivity and since there seems to be no means of keeping records of specimens in nature, the writers' observations on the length of life of the adults may give erroneous ideas. The longevity of reared adults of *H. lineatum* is shown in Table 10. It ranged from 1 to 25 days and averaged somewhat longer for males than for females. The markedly greater longevity observed among about 50 adults reared in the laboratory during the spring of 1924 than had been noted previously indicates clearly the probability that certain individuals which emerge prior to periods of uniformly cool weather may live for a considerable time. The specimens referred to were hastened in their emergence by being kept in a warmed room. After emergence the adults were transferred to lantern-globe cages and kept in an unheated room. The temperatures given in Table 10 for these records for 1924 were those recorded in a standard weather shelter out of doors, and hence undoubtedly show a much greater range of temperature than was actually experienced. There is no question but that in nature the flies would seek the sunshine and warmer places which would stimulate activity, and thus we should not expect to find such long periods of existence as those referred to above. The writers' observations in the field also bear out this assumption. It seems certain that when the weather is warm and the adults are active their lives are uniformly very short.

TABLE 10.—*Adult longevity of Hypoderma lineatum at Dallas, Tex.*

Date adults emerged	Number of males	Number of females	Record of death	Longevity	Temperature Min.	Temperature Max.	Temperature Average	Remarks
1915			1915	*Days*	°*F.*	°*F.*	°*F.*	
Apr. 12	------	1	Apr. 19, a.m.	7	48.0	83.5	67.6	In cage 1 foot by 1 foot by 1 foot, with leaves.
Apr. 19	------	1	Apr. 22, p.m.	3	54.0	82.0	69.0	In small cage, with leaves.
1916			1916					
Mar. 20	1	3	Mar. 21, 2 ♀; Mar. 22, 1 ♀; Mar. 23, 1 ♂.	1 to 3	61.5	97.9	80.2	In cage 1 foot by 1 foot by 1 foot in sun.
Mar. 22	10	10	Mar. 23, 1 ♀; Mar. 24, 1♂, 2 ♀; Mar. 25, 3♂, 5♀; Mar. 27, 2♀, 1 ♂; Mar. 28, 2♂; Mar. 29, 3♂.	1 to 7	38.0	88.0	61.7	In small and large cages and on cow.
Mar. 27	2	2	Mar. 28, 1 ♀; Mar. 29, 2 ♂, 1 ♀.	1 to 2	39.5	88.0	66.3	Do.
1918			1918					
Feb. 25	2	------	Feb. 27, 1 ♂; Feb. 28, 1 ♂.	2 to 3	38.0	97.5	66.2	In laboratory.
Feb. 26	1	5	Feb. 28, 1 ♂, 3 ♀; Mar. 1, 2 ♀.	2 to 3	38.0	87.0	58.2	Do.
Feb. 27	------	1	Mar. 1	2	38.5	87.0	56.2	Do.
Mar. 11	3	1	Mar. 14, 2 ♂, 1 ♀; Mar. 19, 1 ♂.	3 to 8	33.7	90.0	60.9	In 1-inch tubes (♀ deposited).
Mar. 13	2	1	Mar. 15, 1 ♀; Mar. 19, 2 ♂.	2 to 6	33.7	90.0	56.5	In 1-inch tubes with leaves.
1921			1921					
Mar. 7	8	1	Mar. 14, 2 ♂; Mar. 15, 4 ♂, 1 ♀; Mar. 16, 2 ♂.	7 to 9	36.0	87.0	63.4	In lantern globes with leaves.
Mar. 8	8	1	Mar. 12, 1 ♀; Mar. 13, 1 ♂; Mar. 15, 1♂; Mar. 16, 4 ♂; Mar. 17, 2 ♂.	4 to 9	36.0	87.0	64.0	
Mar. 12	10	8	Mar. 13, 1 ♂; Mar. 15, 1 ♂; Mar. 18, 7 ♂, 8 ♀; Mar. 20, 1 ♂.	1 to 8	51.0	87.0	71.7	In cage 1 foot by 1 foot by 1 foot, with leaves.

TABLE 10.—*Adult longevity of Hypoderma lineatum at Dallas, Tex.*—Continued

Date adults emerged	Number of males	Number of females	Record of death	Longevity	Temperature Min.	Temperature Max.	Temperature Average	Remarks
1921			1921	*Days*	°*F.*	°*F.*	°*F.*	
Mar. 13	1	2	Mar. 16, 1 ♂, 1 ♀; Mar. 17, 1 ♀.	3 to 4	52.0	87.0	71.1	In lantern globes, with leaves.
Mar. 14	6	3	Mar. 16, 1 ♀; Mar. 17, 2 ♂, 1 ♀; Mar. 18, 3♂, 1 ♀; Mar. 19, 1 ♂.	2 to 5	52.0	87.0	74.5	Do.
Mar. 15	9	2	Mar. 17, 1 ♂; Mar. 21, 5 ♂, 2 ♀; Mar. 22, 3 ♂.	2 to 7	43.0	87.0	72.1	In lantern globes, with leaves. Copulated.
1924			1924					
Feb. 7	2	------	Feb. 13, 1 ♂; Mar. 3, 1 ♂---	6 to 25	26.5	82.5	51.25	In lantern globes in cool room. Outdoor temperatures are given.
Feb. 9	2	------	Feb. 27, 1 ♂; Mar. 1, 1 ♂---	18 to 21	26.5	82.5	50.93	Do.
Feb. 14	3	1	Feb 27, 1 ♀; Mar. 4, 2 ♂; Mar. 8, 1 ♂.	13 to 23	26.5	82.5	52.55	Do.
Feb. 16	2	1	Mar. 5, 1 ♂; Mar. 8, 1 ♀; Mar. 10, 1 ♀.	18 to 23	25.0	77.5	51.10	Do.
Feb. 18	5	5	Feb. 27, 2 ♂; Mar. 1, 3 ♀; Mar. 3, 1 ♂; Mar. 4, 1 ♀; Mar. 5, 1 ♂; Mar. 6, 1 ♂, 1 ♀.	9 to 17	26.5	77.5	50.37	Do.
Feb. 25	5	3	Mar. 6, 1 ♂; Mar. 7, 1 ♂, 2 ♀; Mar. 10, 1 ♀; Mar. 17, 3 ♂.	10 to 21	25.0	77.5	49.41	Do.

The longevity of *H. bovis* apparently does not differ much from that of *H. lineatum*. Specimens reared at Dallas, Tex., lived from 2 to 4 days in cages. In Middletown, N. Y., a number of adults were kept in cages in the shade and supplied with green leaves. These lived from 4 to 10 days with an average of 6 days. Specimens of both species captured in nature live in confinement only 1 or 2 days.

SEASONAL HISTORY

There are some distinct differences in the seasonal development of *H. bovis* and *H. lineatum*. These must be considered in control undertakings and they will be pointed out under the several topics following. Both species are essentially single brooded.

SEASON OF ADULT ACTIVITY

Adults of *H. lineatum* appear under usual conditions during the first warm days of spring. The actual date necessarily varies with latitude and altitude as well as with local climatic conditions. It appears that in the southern range of *H. lineatum* the period during which adults of that species are active is longer than in any other portion of the country. Not infrequently in southwestern Texas adults begin to emerge in December and continue to appear during warm periods throughout the winter. In this section the maximum abundance of adults apparently occurs about the middle of February. Observations made by D. C. Parman at Uvalde, Tex., indicate that during some years, at least, adults may continue to appear until about April 1, thus extending the period of adult activity over about four months. At Dallas, Tex., the adults rarely, if ever, emerge before February 1 or after April 15. The maximum abundance usually occurs between February 20 and March 15. In the plateau region of southwestern Texas in certain instances larvæ have been found to mature early enough in the fall to permit of the issuance of a considerable number of heel flies in the fall. It has not been possible to determine if this really takes place, but the finding of a young larva in the gullet of a cow on January 4 is fairly conclusive proof that some eggs are deposited in October or November. It is certain that some heel flies emerge and attack cattle during December, and heel-fly activity has been observed on numerous occasions in January. The season of adult activity in New Mexico, Arizona, and California appears to be about the same as observed at Dallas. Throughout the central belt of States—that is, between the latitudes 35 and 45° N.—the period of activity is approximately between March 15 and May 1, and in the northern tier of States between April 1 and June 30. These dates are only approximate, and vary much during different years, as well as with altitude and local conditions.

In New York adults of *H. lineatum* may begin oviposition as early as the middle of April, are most abundant during the first three weeks of May, and cease activity about the end of June. In the territory where *H. bovis* occurs it is difficult to determine the date of cessation of activity of the adults of *H. lineatum*, since their seasons of activity overlap.

In New York considerable numbers of adults of *H. bovis* begin to oviposit during the first week in June and apparently some emerge during the latter part of May. The flies are very annoying to cattle during June and the first half of July, are less so during the remainder of July and the first half of August, and during the remainder of August and up to the middle of September only stragglers are abroad. Since normal larvæ have been found in the backs of cattle in New York after September 1, some fly activity is possible throughout that month. No flies have been seen, however, nor have the effects of their attack been noted, after September 14.

Hadwen (*36*) states that at Agassiz, British Columbia, adults of *H. bovis* appear in the early part of June and continue up to the beginning of August, and that adults of *H. lineatum* were out from April 15 to April 24. Carpenter (*19*) records the emergence of adults of *H. bovis* in June and July, and deposition of eggs of *H. lineatum* on May 8 and June 16, at Athenry, Ireland.

The season of oviposition of both species is about coincident with that of adult emergence.

SEASONAL DEVELOPMENT OF LARVÆ

Rather abundant data regarding the seasonal occurrence of larvæ of *H. lineatum* in the gullets and viscera of cattle are presented on page 47 and Tables 3 and 4. In general, approximately two and one-half months elapse between the deposition of eggs and the earliest appearance of larvæ in the gullets.

In the vicinity of Dallas, Tex., the larvæ first appear in the submucosa of the gullets of cattle at about the end of March and continue to enter that organ until the maximum is reached during September. There is then a gradual reduction in numbers until about January 1, when all have migrated from the gullet.

In southwestern Texas the larvæ begin to reach the gullets distinctly earlier than at Dallas, thus closely conforming with the earlier appearance of adults in that region. The earliest larva observed by the writers to appear in a gullet was a single specimen 4.2 millimeters in length taken from an animal slaughtered in a Fort Worth, Tex., packing house on January 4, 1924. This specimen evidently developed from eggs deposited the previous fall.

At Herkimer, N. Y., larvæ began to appear in the gullet about the middle of July and the last larvæ left that organ about April 1. Thus it is certain that the larvæ are to be found in the gullets for about nine months.

The seasonal prevalence of larvæ in the subcutaneous tissues of the backs of cattle is closely correlated with the time when the larvæ reach the maximum size attained by them in the gullet, and to some extent with the period of adult activity. Knowledge of this subject is of vital importance in connection with any control procedure, yet the information published is meager in the extreme.

The earliest appearances in the United States of larvæ of *H. lineatum* in the backs of cattle occur in the plateau region of western Texas. On August 10, 1919, at Roosevelt, Tex., O. G. Babcock observed grubs in considerable numbers in the backs of cattle. A few collected on August 12 showed some to be in the early fifth stage. Thus they must have appeared on the backs about July 15. In 1923 fifth-stage larvæ were found by Mr. Babcock at Sonora, Tex., on August 22. These must have reached the backs of the cattle about July 30. At Uvalde, Tex., records made by D. C. Parman during several years show that the first appearance of larvæ in the backs of cattle is later than it is in the plateau region to the north. The earliest appearance noted at Uvalde was on August 12, 1918. The larvæ in this case evidently had been present about 10 days.

Mr. Parman's records at Uvalde indicate that larvæ usually begin to appear under the skin about the middle of September. Some years, however, they may appear as late as October 9, as was observed in 1920. During that season the maximum number present was noted on January 15.

At Dallas, Tex., fairly accurate records of the earliest appearance of larvæ in the subdermal tissue have been made in 10 different years, during the period from 1907 to 1922. These dates have been rather uniform, ranging from about October 10 in 1914 and 1918 to October 30 in 1916. The year 1923 was an exception, as in that year the larvæ appeared about September 8.

At Herkimer, N. Y., the date of appearance of larvæ of *H. lineatum* in the subdermal tissue of the backs of cattle was found in 1920 to be about March 1, and in 1922 about February 6. At Middletown, N. Y., in 1920 larvæ of *H. lineatum* came to the backs about February 12, and in 1923 about February 1. At Watertown, N. Y., in 1920 the date of earliest appearance was about March 3. In Kane County, Ill., C. C. Compton found a single small larva in one of 200 cattle examined on February 7, 1924, thus showing the earliest appearance to be soon after February 1. Subsequent collections made by Mr. Compton indicate that this date is substantially correct for that section in 1924. W. H. Brittain has sent the writers specimens collected by W. E. Whitehead at intervals during the spring of 1924 from cattle at Truro, Nova Scotia. In an examination of a large number of cattle by Doctor Whitehead on March 24 only 3 grubs were found. The largest one had been in the back about 10 days. Records sent the writers by C. J. Drake on collections of larvæ made by E. W. Dunnam and others at Ames, Iowa, indicate that larvæ of *H. lineatum* first reached the backs in 1923 about January 8, and in 1924 about January 20.

Hundreds of collections have been made by the writers and by correspondents throughout the country, and with these records as a basis the dates of appearance of the earliest larvæ of *H. lineatum* have been estimated and the accompanying map (fig. 33) constructed. Unfortunately, as the number of accurate records of the time of first appearance is small, many discrepancies will be found, but it

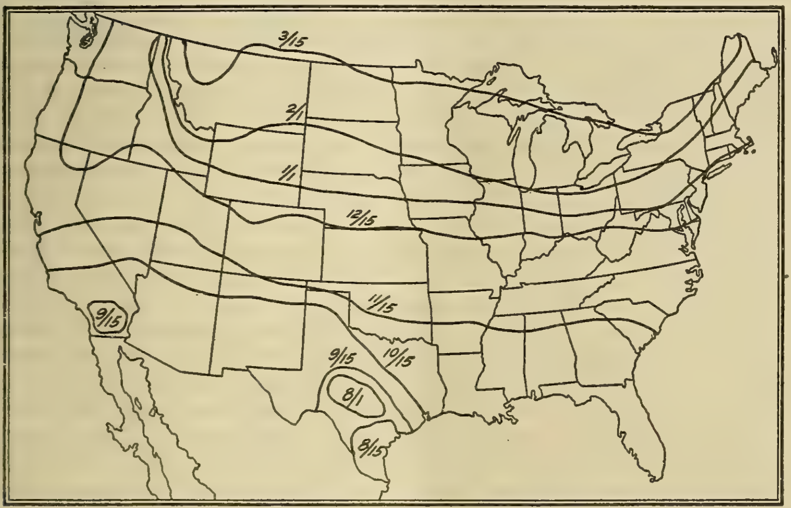


FIG. 33.—*Hypoderma lineatum:* Date zones of first appearance of grubs in backs of cattle, in the United States

is hoped that the data available will serve a useful purpose in control undertakings and also stimulate others to add to these much needed records.

The date when the first larvæ become mature and leave the host is an important one from an economic point of view. This date is necessarily closely correlated with the date when the first grubs of the season reach the back. It seems extremely rare for these earliest grubs to complete their development in the minimum time, hence the first emergence of larvæ from the cattle should be expected to take place about 45 days after the grubs first reach the back. At Dallas the earliest larvæ become mature and begin leaving the host between December 1 and 15 during average years. The following are the approximate dates when mature larvæ began emerging from cattle at Middletown, N. Y.: In 1920, March 26; in 1922, March 16; and in 1923, March 19.

The time of maximum abundance of larvæ in the backs of cattle varies considerably in different herds and during different years. At Dallas, Tex., this maximum usually occurs, on the average, about January 10, and at Uvalde, Tex., about December 15.

The date when the last grub leaves the cattle varies considerably in different herds, as well as in different localities and during a series of years. This point is of little economic importance for *H. lineatum* in those States where *H. bovis* also occurs, for the latter always persists in the hosts later in the season, and the two species must be dealt with as a unit. At Dallas, Tex., the date when cattle become free from grubs in their backs has been determined during several years. In 1915 this date was March 20; in 1916, April 12; in 1917, March 18; in 1919, March 15; in 1921, March 20; and in 1922, March 16. At Uvalde, Tex., Mr. Parman has observed the cattle to become free of grubs between January 20 and April 12. It is interesting to note that Mr. Babcock found two specimens of *H. lineatum* in the back of a cow at San Angelo, Tex., on March 20, 1924. These larvæ would not have been mature in less than 15 days. Since the grubs of this generation began to appear in the backs of cattle in that region about August 2, there is a remarkable and very unusual period of infestation of the backs of cattle of about eight months. Thus it appears that there is a wider variation from year to year in this respect in southwestern Texas than occurs elsewhere. A very general idea of the time when all larvæ of *H. lineatum* have emerged from the cattle may be gained from the following dates: March 1, southern Arizona and southern California; March 15; Alabama, Georgia, North Carolina, Oklahoma, and southern New Mexico; April 15, Maryland, Missouri, and Nevada; May 1, Pennsylvania, Indiana, Colorado, Idaho, and Washington; June 1, North Dakota and Michigan; June 15, New York and Montana. Observations made by W. E. Dove in 1924 indicate that all larvæ of *H. lineatum* would have left the cattle in the vicinity of Aberdeen, S. Dak., about May 5, and at Minot and Dickinson, N. Dak., and at Moorhead, Minn., about May 10. The season, however, was more advanced that spring than usual. On May 1, 1924, all grubs were found to have emerged from cattle at Sioux Falls, S. Dak.

In general the duration of the infestation of the backs of cattle in *H. bovis* is longer than in *H. lineatum*. This is brought about through the longer developmental period of the larvæ in this situation and the wider spread of time between the date the first larvae of *H. bovis* reach the back and the date the last ones appear there. The writers' records indicate that the earliest larvæ of *H. bovis* reach the subcutaneous tissues from one to two weeks after those of *H. lineatum*. On the other hand, the larvæ of *H. lineatum* arrive in that portion of the host in much larger numbers proportionately during the first month or six weeks following their first appearance.

The writers have checked closely the earliest appearance of larvæ of *H. bovis* in the subdermal tissues, as well as the time of dropping of the last grubs in herds of cattle in New York during three seasons. The earliest appearance of *H. bovis* was February 2 in 1923 in Orange County, N. Y. In 1920 they appeared about February 26, and in 1922 about February 22. At Herkimer they first reached the subdermal tissues about March 8 in 1920, April 15 in 1921, and

February 20 in 1923. The last date on which a third-stage larva was observed to reach the region of the back was June 6, 1922, at Middletown, N. Y. The record of earliest dropping of a mature grub of this species at Middletown was April 11, in 1923. Emergence from the host probably begins rather later than this on the average. In New York the maximum number of grubs of this species in hosts occurs about May 1.

Judging by collections and observations made in other States the seasonal occurrence of *H. bovis* tallies rather closely with that noted in New York. One record of earlier appearance has been made in western Pennsylvania, where in 1916 the grubs reached the back about January 25. That year grubs seemed to have been exceptionally early, especially in the Northeastern States. The dates of earliest appearance in the backs of cattle as calculated from observations and collections in some of the infested territory are as follows: Maine, February 15; New Hampshire, February 8; Vermont, February 20; New Jersey, February 10; Ohio, February 8; Indiana, February 3; Illinois, February 5; Michigan, February 25; Wisconsin, March 2; Iowa, February 15; Wyoming, February 15; Washington, February 8. These dates are presented to give a general idea of the time of earliest appearance of larvæ of *H. bovis* in the subdermal tissues. It is recognized that they are not based on continuous accurate observations and that they will vary in different parts of a State and during different seasons.

The date when all the grubs leave the host has been found to vary widely and in general to be much later than has been supposed. In New York in both Orange and Herkimer Counties most of the grubs are out of the backs of cattle by August 1, but healthy specimens have been taken as late as September 2 in 1922 at Middletown and August 30 during the same year at Herkimer. Collections of *H. bovis* made by W. E. Dove at Aberdeen, S. Dak., on April 21, 1924, indicate that the cattle would be free from grubs in that locality about May 15.

It is worthy of note that the development of grubs in cattle infested in the North and shipped into the South agrees closely with that which occurs in the native habitat of the species. For instance, infested cattle shipped to Miami, Fla., from Syracuse, N. Y., during the winter showed a good infestation of well matured grubs on May 25. Larvæ of *H. bovis* in cows shipped from Michigan to Dallas, Tex., continued to develop and emerge normally up to June 3, when the last one dropped.

In Ireland, Carpenter, Phibbs, and Slattery (*19*) record the presence of larvæ of *H. lineatum* in the backs of cattle on March 29, and a few larvæ of *H. bovis* were still present on June 10. Lehmann (*59*) and Vaney (*105*) found the highest percentage of grubby hides to occur in July in the Lyonnaise region of France.

NATURAL CONTROL

The combined action of all agencies of natural control has a marked effect on the abundance of both species of Hypoderma. This is true even in areas where the pest is at its worst.

DESTRUCTION BY BIRDS AND MAMMALS

Birds undoubtedly destroy many larvæ as they drop to the ground after emerging from the backs of cattle. The pupæ also are subject to attack, since they often remain exposed on the surface of the soil or only slightly covered. Several instances were observed in New York in which robins (*Planesticus migratorius*) devoured larvæ of *H. bovis* with avidity. In one case a larva under observation as it burrowed into the soil was seen by a robin sitting on a fence. The robin flew down, picked up the larva, and escaped with it before the bird could be frightened away. This larva was almost covered by the soil as it burrowed in. Species of the larger ground birds undoubtedly destroy many larvæ. Henry Polson of Mountainview, Wyo., makes the following statement: "Sometimes magpies pick holes in the backs of the cattle, trying to get the grubs out, causing sores." In rather extensive observations made by one of the writers in areas where magpies (*Pica pica hudsonia*) abound, this action has not been seen, hence it is thought to be rare.

Many larvæ which emerge from cattle in the barnyards where poultry range are destroyed by fowls. Chickens have been observed to devour greedily considerable numbers of mature larvæ when fed to them.

It is probable that small rodents destroy many larvæ and pupæ. Stegmann (*94*) states that the pupæ on the ground are destroyed by moles.

INSECT ENEMIES

No predacious insects have been observed to attack the larvæ or pupæ of Hypoderma in the United States, and it is thought that they are not an important factor in control.

No parasites have been found in nature, but very few pupæ have been recovered after exposure in fields. The writers have reared a considerable number of specimens of *Nasonia brevicornis* Ashm. from pupæ kept in screen cages in an outdoor insectary, in more or less close association with parasitized pupæ of muscoid flies.

A. Gansser, of the Warble Committee of Switzerland, states in a letter that he thinks that a hymenopterous parasite which has not been determined is an important factor in control in that region.

FUNGOUS GROWTHS

The writers have observed the growth of molds on and in the puparia of Hypoderma, and there is some reason to believe that the insects may be attacked in some cases. Lucet (*63*) expresses the opinion that in France certian fungi destroy the pupæ.

EFFECT OF SUBMERGENCE ON LARVÆ AND PUPÆ

In 1921 a considerable number of extracted larvæ of *H. lineatum* were submerged in water for periods ranging from 3 to 23 hours. These periods apparently had very little effect on the larvæ; at least the percentage found dead at the end of three days was not greater than in the untreated groups. During 1922 five mature larvæ were submerged from 1½ to 19 hours. The larva submerged the shortest period produced an adult in normal time, but the four submerged

6½ to 19 hours failed to transform. In 1924 six larvæ which had emerged normally from a host were submerged in lots of two for 24, 30, and 40 hours. Adults emerged from all of these in normal time. Two pupæ were also submerged for 30 hours and both transformed to adults.

Six mature larvæ of *H. bovis* were submerged in water for periods ranging from 49 to 122 hours. All except one, which was submerged for 121 hours, produced adults in about the normal length of time.

From these tests it is clear that these stages are not easily drowned, and this might enable them to survive carriage for considerable distances by flood waters.

CLIMATIC CHECKS

Climatic conditions undoubtedly have a marked effect on the distribution and abundance of Hypoderma. The relationship between climate and the distribution of the two species of Hypoderma has been discussed in a general way under the heading "Distribution."

One of the writers (*4*) has made the statement that he believes that climatic barriers have prevented the general dissemination of *H. bovis* throughout the United States. He says,

> One explanation of this possible barrier will be found in the fact that *H. bovis* is generally later in emerging from the backs of cattle than *H. lineatum*. The grubs emerging from the backs of cattle shipped to the Southern States would, on account of their later emergence, encounter excessively hot weather, and this may account in part at least for the failure of the species to establish itself in the warmer portions of the country.

No facts appear to have come to light since the publication of the foregoing statement which would tend to disprove this conclusion. *H. lineatum* establishes itself in new sections with less difficulty, and uninfested areas are less general with this species. It must be recognized, however, that meteorological conditions are potent factors in limiting its abundance as a parasite of cattle.

Climatic conditions appear to have very little direct effect upon the development of the grubs within the host. Climatic influences are therefore restricted to the portion of the year when the insects are separated from their hosts; that is, while they are in the pupal and adult stages.

Among the several meteorological factors which affect Hypoderma, rainfall and humidity during the pupal and adult stages are probably the most important. It has been found that where the soil beneath pupæ is kept very moist the mortality is extremely high. Under such conditions some of the insects appear to die before development has proceeded very far, and others transform to adults but are unable to escape from the puparia. This appears to be due to the large size of the abdomens, which are not reduced sufficiently through evaporation to allow them to be withdrawn from the puparia. Heavy rains coming at the time the adults emerge may destroy many of them, and continuous rainy or even very cloudy weather after the emergence of the adults will prohibit oviposition. Since the longevity of the flies is limited, adverse weather conditions of comparatively short duration will prevent individuals from ovipositing. Owing to the fact that large numbers of flies usually emerge at approximately the same time, regardless of the time the pupæ may have been formed, rainy weather immediately after emergence of one of these large groups of flies may affect materially the infestation of the following year.

Clouds have been mentioned as being a factor in repressing oviposition. Their influence is felt only by the adult insect, as cloudy weather in the absence of unusual precipitation does not seem to affect the development of the pupæ, except possibly to prolong slightly the pupal stage.

Winds apparently have a double influence: In the first place they cause a more rapid drying of the surface soil, which would benefit the pupæ; and secondly they have an adverse effect upon oviposition, since the flies, especially those of *H. lineatum*, will not oviposit freely in a strong wind. This influence is less potent than the others, however, since it is not so generally operative. Cattle congregated in places protected from the wind are frequently attacked by heel flies.

Temperature conditions probably rank next to precipitation in their effect on these species. Periods of unusually warm weather in the winter or early spring often tend to cause the emergence of flies which are destroyed by succeeding days of cold or rainy weather.

As is generally known, warm bright days are most favorable for the activity of *H. lineatum*. It is probable, however, that during periods of high temperature, that is, when the daily maxima run above 95° F., the total number of eggs laid by a fly is reduced. When such higher temperatures are reached, oviposition occurs mostly before the hottest part of the day. The destructive effect of the direct rays of the sun on both *H. lineatum* and *H. bovis* is apparent when caged flies are placed in the sun during moderately warm weather. They become very active and fly most of the time, soon weakening and falling to the bottom of the cage where they die, sometimes very suddenly.

Oviposition of *H. lineatum* takes place at surprisingly low temperatures if the sun in shining. Often adults are active during the day when the minimum temperature in the morning ranges between 19 and 22° F. Flies have been observed to oviposit when the temperature was as low as 45° F., the maximum temperature for the day being 46° F. There seems to be no doubt that heat is an important factor in restricting the southern spread of *H. bovis*.

Mature larvæ and pupæ can withstand rather low temperatures. The pupæ appear to be more resistant to cold than the larvæ. A considerable number of observations have been made by the writers on the effect of cold on these stages of *H. lineatum* at Dallas, Tex., but the minimum fatal temperature has not been determined with accuracy. In 1918, when a minimum temperature of 3.5° F. was reached, the larval and pupal transformations of a number of specimens was under observation. Considerable protection was afforded these and a good percentage of adults emerged. Among a number of larvæ and pupæ exposed to 9.5° F. an adult emergence of 54.5 per cent was secured. In other series of specimens which experienced minimum temperatures of about 19° F. approximately 68 per cent produced adults. This is not much below the percentage of emergence under outdoor conditions where the temperatures do not drop below freezing. A mature larva of *H. lineatum* placed in a freezing room for 24 hours at a temperature of about 7° F. failed to pupate, whereas a fresh pupa exposed in the same way produced a normal adult. Nine mature larvæ of *H. bovis* subjected for from 24 to 26 hours to temperatures in a freezing room of 7 to 9° F. failed to pupate. Five larvæ of this species placed in the room at 25 to 29° F. for 26 hours gave an adult emergence of 80 per cent, and five larvæ kept at from 32 to 33° F. for 14 days pupated promptly upon removal and 60 per cent emerged.

SOIL CONDITIONS AND DRAINAGE

Naturally soil character and drainage are linked with rainfall in their relationship to Hypoderma. The writers' observations indicate that porous, well-drained soils are more favorable for Hypoderma than heavy, flat-lying lands.

In the valley of the Red River of the North, where Hypoderma seldom occurs, there is probably a soil condition which prevents fully developed larvæ from producing adults. It is known that animals infested with Hypoderma have been shipped into that section, but the pest has never become well established.

HOST RESISTANCE AND OTHER CONTROL FACTORS

The great disparity in the number of grubs found in different cattle in the same herd is well known. The writers' investigations indicate that this difference in degree of infestation is brought about by a combination of several causes. Probably the main reason why one animal will show a heavy infestation of grubs while another will be free from grubs or comparatively so, is that there was a marked difference in the number of eggs which were attached to them. The reason why one animal may receive a much larger number of eggs than another, however, is not altogether apparent. Certainly the element of chance enters here strongly. The individual idiosyncracies of the animals are also factors. Some animals seem more able to detect the presence of flies than others and secure protection from them.

A large series of observations made on individual animals year after year shows that the extent of infestation may vary greatly. The writers have found, however, that certain animals are uniformly resistant to the grubs from the time the eggs hatch to the time the larvæ complete their development or die within the host. This individual resistance is probably due in a large measure, as pointed out by Hadwen (*35*, 40), to eosinophilia. That there is a very definite reaction against the larvæ is apparent when they penetrate the skin of such resistant hosts. The exudate at the point of entrance is usually more profuse than ordinarily, and the infiltration of the connective tissue beneath is pronounced. Apparently this strong reaction against the invading parasite is present throughout its course in the body of the animal. It is after the larvæ have reached the subcutaneous tissues of the back, however, that the destruction of the larvæ is most apparent. The reaction against the larvæ appears to differ considerably in different hosts. In some, large swellings occur; in others, the reaction seems to be more localized. In the latter case there is a tendency for the skin to close the grub opening and cut off its air supply. In certain animals there is also a strong tendency to form pus in and about the cyst, and in such cases the grubs usually die. The writers' observations show that the mortality in the subcutaneous tissues of the back is very high. Their figures indicate that 60.5 per cent of those which have cut holes through the skin die before reaching maturity. Of this percentage approximately 16 per cent succumb in the third stage, 46 per cent in the fourth stage, and 38 per cent in the fifth stage. It appears also that occasionally third-stage larvæ which reach the subdermal tissues die before they succeed in cutting through the skin.

There is a marked difference in the degree of infestation of animals of different ages. Young stock, notably animals from 1 to 3 years old, almost always show a higher percentage of infestation than mature animals. There is also some reason to believe that as cattle become very old the degree of infestation is again increased. Seymour-Jones (*91*) advances the theory that in young stock the tenderness of the muscle (*panniculus carnosus*) immediately under the skin enables the grubs to penetrate them, whereas in older cattle they do not all get through.

Hadwen (*35*, *40*) is of the opinion that the difference in degree of infestation between young and matured animals may be explained by a gradual development of immunity following the repeated attacks of parasites. He believes that a first invasion of parasites in an unresisting host stimulates the production of both antisubstances and eosinophiles to neutralize their cast-off products, and in addition to this, that there must be a third substance which is antagonistic to the parasites themselves; he believes that this substance is secreted by the eosinophiles, and that it paralyzes or kills the parasites which are surrounded by the eosinophiles in the tissues.

The writers believe that the difference in the number of grubs found in young and old cattle may be explained in part by this reaction, but that other factors enter into the question. In general, young animals are more exposed to the attack of the flies, both because they are not housed so long in the spring and because they are seldom placed in barns during the time when the flies are ovipositing. It is also true that the young stock are frequently not as well fed as the older animals. The statement is made frequently by dairymen and stockmen that poor animals are more heavily infested than fat ones. The writers have observed many instances in which very fat animals were fairly well infested with grubs, but their observations indicate that the poor cattle are usually more heavily infested. It appears logical to believe that well fed, healthy animals have more natural resistance to grubs than those in poor flesh and with lower vitality. It is also certain that cattle in an extremely impoverished condition will fall more ready prey to the flies at the time of oviposition. It seems evident, however, that the presence of a large number of grubs, especially in cattle not receiving an optimum amount of feed, will reduce flesh condition.

No marked difference in susceptibility seems to exist in different breeds. When water or shade is readily available it serves as a means of partially protecting from infestation the stock which have access to it. Large numbers of grubs and pupæ are destroyed by the walking of the cattle, especially in pastures where the animals are concentrated.

ARTIFICIAL CONTROL

In considering control or eradication it should be borne in mind that the flies do not feed, nor have any habits been noted which could be utilized in accomplishing their destruction. The flies also do not seem to be sensitive to the presence of foreign materials on the host, and therefore are not easily repelled. The egg stage is comparatively short, hence any treatment directed against it must be applied frequently. During the greater part of the year the larvæ are protected within the body of the host; that is, from the time of penetration immediately after the hatching of the eggs to the appearance of the third-stage grubs in the subdermal tissues of the back. There is, however, a rather definite period, usually not exceeding four months, during the fall, winter, and spring, varying according to latitude, during which the grubs are localized in the backs of the cattle where they may be reached through the apertures in the skin. The fact that both species are practically incapable of developing in hosts other than cattle is also a point of distinct advantage in any control procedure attempted.

POSSIBILITIES OF CHECKING THE SPREAD OF HYPODERMA

No effort has been made in this country to check the spread of either species of Hypoderma. In fact *H. lineatum* appears to have long since established itself in all parts of the United States where it is capable of existing. *H. bovis*, on the other hand, is much more restricted in distribution and it appears that it is capable of becoming much more widely disseminated in this country.

It is probable that *H. bovis*, which at this time occurs west of the Mississippi River only in scattered localities in the Northern States, may cover that region solidly and extend its range well south along the mountain ranges. Hewitt (*42*, *43*, and *44*) and others have stated that Hypoderma appears to be increasing in abundance in Manitoba. The importance of *H. bovis* as a cattle pest is sufficient to warrant serious consideration of ways and means of checking its spread in this country. It may not be advisable to take legal steps to meet the situation, but certainly stock raisers should recognize the danger of bringing cattle infested with *H. bovis* into regions where that pest does not exist, and take due precautions to destroy all grubs which reach the subcutaneous tissues of the backs during the spring and summer following the arrival of the cattle. Certain uninfested foreign countries have enacted legislation designed to prevent the establishment of Hypoderma. Australia (*2*), for instance, has a law prohibiting the introduction of cattle from the United States, the British Isles, and other infested countries except during the period from December 1 to May 31. Present knowledge of the seasonal history of Hypoderma shows clearly that such a restriction would not give a complete protection against the introduction of the pests. It would appear, however, that some system by which the animals could be kept under surveillance and all grubs destroyed during the period of one full year after importation would be effective.

EFFECT OF BURIAL ON LARVÆ AND PUPÆ

It is difficult to say just what degree of control is effected through plowing. From reports on the abundance of grubs in cattle in the Central States in the eighties as compared with the number of grubs in the same regions now, it apears that there has been a decrease in abundance. Many think that the restriction of pastures to comparatively small areas and more general and intensive cultivation are largely responsible for this. It is reasonable to suppose that plowing fields where larvæ and pupæ occur would destroy many of them.

Several mature larvæ and freshly formed pupæ of *H. lineatum* were buried in sand and black clay soil, at depths of from 2¼ to 4 inches. In most instances the larvæ worked their way to the surface in a short time and pupated on top of the soil. In the black clay the flies emerged in about the normal time and pushed out of the soil even when the pupæ were buried to a depth of 4 inches. In the fine sand, however, the flies were found to have emerged and worked upward about half an inch from the puparia, where they died and were found later with a comparatively hard cell of sand formed around them.

Many larvæ in pastures undoubtedly become covered with manure, as are those that drop in barns and are shoveled out with the dung. To test the effect of burial under such conditions four mature larvæ were placed on a board and a large fresh cow dropping was laid on them. None of them moved from where they were placed. Three of them died without pupating and the other died as a half-developed fly. This preliminary test probably indicates that burial in fresh cow manure is very destructive and that many larvæ are destroyed in this way, since often a large percentage of the grubs leave the hosts in the barns.

Some larvæ of *H. bovis* buried from 1 to 6 inches in both clay and sand came to the surface, while others pupated near where they were buried. Some flies emerged from pupæ buried to a depth of 6 inches, but apparently the burial below 3 inches was detrimental, especially if the soil was very moist.

PROTECTION OF CATTLE BY HOUSING AND NATURAL BARRIERS

There are abundant examples of the great reduction of infestations effected by housing the herd during the periods of fly activity. Some dairymen leave their barns open or provide sheds which the cattle can enter when attacked by the flies. The flies, however, have considerable opportunity to deposit eggs on the cattle before they can get into the buildings. Such an arrangement has the advantage of allowing the cattle to excape from continued annoyance and fright, which is inevitable when no protection is afforded. Since the flies will oviposit in the broken shade supplied by trees, the presence of woods in a pasture will not greatly reduce infestation, but is beneficial in that the worry to the catttle is lessened. Streams afford effective protection against *H. lineatum*, but less against *H. bovis*. The excitement, however, is greatly relieved and milk flow maintained when cattle have access to streams or ponds. There is danger of some injury to cattle, however, from standing in mud and water for long periods when weather is favorable for continued fly activity.

The construction of sheds is advisable where they will perform the double service of protecting the stock against heel flies and from adverse climatic conditions.

REPELLENTS AGAINST HEEL FLIES

For many years various ill-smelling applications have been used with the view of protecting cattle from the attack of heel or warble flies. Prior to the last few years, during which our knowledge of the life history of these pests has clearly showed that the eggs are not deposited on the backs of the cattle, it was the custom to use various repellent smears and washes upon the backs of cattle. As it is now known that the eggs are deposited largely on the legs and lower portions of the body, the futility of this practice is at once evident. Inquiry into the results of the application of fly sprays has led the writers to conclude that the claims that they are efficient against grubs are unfounded.

The fact that the adults of Hypoderma do not partake of food would suggest that their reaction toward attractant and repellent chemicals or other substances would be less than in those species which have the senses developed to aid them in finding food or breeding places. The writers' experiments and observations along this line seem to bear out this conclusion. It appears probable that the application on the animals of materials which tend to cover the hair or mat it together may affect oviposition more than those materials possessing various odors supposed to be repellent. The experiments in this field, however, have not been sufficiently extensive to enable final conclusions to be drawn.

During 1919 a dairy herd of 61 animals was used in tests of the application of repellents and solvent solutions, as follows: 2 per cent compound solution of cresol, 10 per cent solution of acetic acid, undiluted fuel oil (petroleum), and a mixture of 1 gallon of fish oil with 1 pint of commercial pine tar. These materials were applied to the legs of cattle, some with a spray pump and others with a brush. The applications were made at about 4-day intervals during the period when heel flies were active. While the treatments were being administered heel-fly eggs were found on several of the treated animals. Some were even present on the legs of those treated with petroleum, and on those treated with a mixture of fish oil and pine tar.

Observations made incidentally in the experiments discussed under "Destruction of eggs or larvæ by the use of wading vats" indicate that the application of 2 per cent coal-tar creosote dips at 4-day intervals has no marked effect in repelling flies. The same is true of wading-vat experiments with arsenical solutions.

On a number of occasions where cattle waded and got their feet and legs well covered with mud the flies were found to deposit their eggs freely on the legs above it. The application of gummy materials to the entire animal has not been tried, but this would hardly seem feasible from a practical viewpoint.

DESTRUCTION OF EGGS OR LARVÆ BY THE USE OF WADING VATS

The fact that a considerable percentage of the eggs of Hypoderma are laid on the lower legs at once suggests the possibility of destroying the eggs or young larvæ as they hatch, by applying insecticides to those portions. One of the most convenient and effective methods of accomplishing this is through the utilization of shallow vats. In 1918 experiments were begun to determine the effect on the infestation of dairy cattle of the use of standard arsenical solution. One-half of the cows in a dairy herd was allowed to pass through a wading vat containing the solution about 1 foot deep, at invervals of four days. The other half of the herd was not treated, being kept as a check. In the first year's test 16 cows were treated and the following season these were found to be infested to almost identically the same degree as the 16 cows which were not treated. In 1919 the same herd was utilized in a test under similar conditions, a standard sodium arsenite solution containing about 19 per cent arsenic trioxide being used in the vat. The following season the dipped cows had an average infestation of 7.18 grubs per animal and the untreated cows showed an average of 5.65 grubs per animal. During the spring of 1920 the same herd was again utilized in the same way, except that 18 cows were treated. For charging the vat in this experiment a commercial arsenical dip was used which in concentrated form was said to contain about 9 per cent of cresol salts. In the first two treatments the strength of the solution was about 0.19 per cent arsenious oxide. Subsequently this was raised to approximately 0.22 per cent. The following spring the treated cattle showed an average infestation of 2.5 grubs per head and the untreated ones an average infestation of 3.33 grubs each. During the spring of 1919 another dairy herd was utilized. Thirteen cows representative of the herd in age and breeding were passed through a wading vat at 4-day intervals and 14 cows were utilized as a control. In this case the vat was charged with a commercial coal-tar creosote dip diluted to about 2 per cent. The following season a careful check of the grubs in the treated cattle showed an average of 6.58 per animal, and the untreated animals showed an average of 3.84 grubs each. The following year a similar test was carried out at the same dairy. A count of the grubs present in the treated and untreated groups made on December 30 showed an average of 6 per animal in the case of the former group and 8.14 in the latter. In a subsequent examination made on February 7, the treated animals showed an average infestation of 2.75 grubs each and the untreated animals an average of 2.67 each.

It is possible that better protection would be afforded should the dipping be done every day. It would not be feasible, however, to dip so frequently with the strengths of solutions used and endeavor to cover a greater portion of the legs by having the solution deeper in the vats. In the experiments mentioned, the walking of the cows through the vats, which were 10 feet long at the bottom and 18 feet long at the top, brought the material into contact with the legs considerably higher up than the actual depth of the dip (1 foot). In fact it was found that the udders and bellies of the cattle were fairly well drenched, especially on the cows that were inclined to hurry through the vat.

Imes and Schneider (*48*) have published results of tests with the application of used automobile cylinder oil, sodium silicate, and coal-tar creosote dip by spraying and wading the cattle through vats similar to those used in the experiments described above. They concluded that the treatments had a very material effect on the infestation the following season. Since only 10 animals were used in the test the great variation in the degree of infestation may readily be due to causes other than the effect of the treatments. Subsequent experiments conducted by the Bureau of Animal Industry, however, are said to show that a satisfactory degree of control may be brought about in range cattle through the use of wading vats (*68*).

Studies of the distribution of the eggs of both species of Hypoderma made by the writers show that a large percentage of the eggs are deposited elsewhere than on the legs. This is particularly true with *H. bovis*, which deposits many eggs above the hock joint. It is also the case with the deposition of eggs on dairy or quiet farm cattle by *H. lineatum*. As has been pointed out in preceding pages, the flies often approach such cattle while lying down and deposit large numbers of eggs on the escutcheon, tail, and elsewhere, all of which would be unaffected by dips applied in wading vats.

LABORATORY TESTS OF DIPS ON EGGS OF HYPODERMA LINEATUM

Several authors have suggested the use of sprays or washes containing materials designed to dissolve the attachment of eggs of certain species of Oestridae. Acetic acid is one of those which has been advocated for this purpose. Tests were conducted during 1919 in which eggs of *H. lineatum* were submerged in a 10 per cent solution of acetic acid for periods varying from 3 minutes to 5 days. Following this treatment the eggs were allowed to dry for periods ranging from 30 minutes to 13 days, and then the firmness of attachment of the eggs to the hairs was tested by scraping and pulling them with a dissecting needle or forceps. In every instance the eggs were found to be firmly attached. In most cases the eggshells would tear in two without their attachment to the hair being disturbed.

Hairs bearing eggs of *H. lineatum* were also submerged for a few seconds in 2 per cent coal-tar creosote dips and kept in incubators to determine if the eggs would be destroyed. In one of these tests 29 eggs were submerged three times for an instant in 2 per cent creosote dip at 3 p. m. and then placed in an incubator at 90° F. The following morning one larva had hatched and was very active. During the day a total of 21 larvæ hatched from these eggs and were apparently normal. Twenty eggs from the same lot mentioned above were given three dippings as in the previous lot and on the following morning they were again dipped in 2 per cent creosote dip and returned to the incubator. These did not begin hatching until the afternoon of March 25, a full day later than those in the previous lot which were submerged but once. Sixteen or seventeen larvæ, however, hatched from the 20 eggs and all were apparently normal. Another series of 26 eggs which were about one-half through their normal period of incubation were dipped in a 2 per cent solution of a coal-tar creosote dip and placed in an incubator. From these, 19, or 73.08 per cent, of the eggs hatched normally. In still another test 34 eggs were dipped in 2 per cent creosote dip before they were due to hatch. An hour later 10 larvæ had hatched and were active. No other larvæ emerged, thus making a hatch of 29.4 per cent, whereas in a check lot the hatch was 31.3 per cent.

In 1923 two series of tests were made. In the first of these 192 eggs deposited April 10 on cow hair were divided into four lots, each of which was kept in an incubator at about 90° F. The check lot contained 99 eggs. These began hatching on April 13, and 45 per cent of them hatched. The other three lots were submerged for one minute after they had been incubated for 1 hour, 25 hours, and 49 hours, respectively. The respective percentages of larvæ which hatched in these three lots were 42, 45, and 57.5. All of these lots began hatching on the same date as the check.

The second series contained 74 eggs deposited on April 11, 1923; 18 of these were submerged for three minutes in a 2 per cent solution of a coal-tar creosote dip on April 13. These began hatching in the incubator on April 14, and 44 per cent of the larvæ emerged. The other eggs were kept in an incubator except for the time required to submerge them for one minute in crank-case oil, drained from an automobile. Of the 22 eggs dipped immediately after oviposition none hatched, of the 23 eggs dipped 24 hours after being laid 26 per cent hatched, and of the 11 submerged 65 hours after oviposition none hatched.

ATTACK DIRECTED AGAINST HYPODERMA LARVÆ IN THE BACKS OF CATTLE

A number of facts point to the practicability of combating this pest by destroying the larval stages while in the subcutaneous tissues of the back. Control by this procedure is favored (1) by the fact that the species confine their attack almost entirely to cattle, (2) by the fact that there is a rather definite and somewhat restricted seasonal occurrence of the larvæ in that situation, (3) by the presence of an aperture through the hide immediately over the grub during its entire existence in the subdermal tissue, and (4) by the fact that the larvæ are limited in their distribution to the back of the host between the withers and tail. In order to proceed intelligently against the species in this situation it is necessary to have very definite information regarding its seasonal occurrence in the subdermal tissues in each section where control work is undertaken, as also a knowledge of the developmental period in the subcutaneous tissues, particularly as to the minimum time required.

The possibilities of attacking the species in this situation appear to have been recognized in a general way many years ago. Work along this line, however, has been of a very superficial and sporadic nature, with the exception, perhaps, of that carried on in certain districts in Denmark (*6*), Holland, and Germany (*67* and *77*.)

EFFECT OF MATERIALS ON LARVÆ REMOVED FROM HOSTS

In order to determine the toxicity of various insecticides and other materials to the larvæ of Hypoderma, a series of tests was carried out in which larvæ in different stages of development were removed from the backs of cattle and submerged in these materials. This method of testing the insecticidal value of various chemicals is open to objection, owing to the fact that the conditions are abnormal. Another objection to the use of larvæ extracted from hosts is that practically none of them will produce adults even though kept under the most favorable conditions, hence there is difficulty in determining the percentage of mortality chargeable directly to the treatment. The tests made show clearly, however, that Hypoderma larvæ, especially in the later stages of their development, are very resistant to contact insecticides. In these tests some 25 or 30 different materials were used. Those were selected which would seem to be adapted to use in the destruction of grubs in the cysts in the backs of the hosts. The period of submergence in most cases was about two minutes.

Mention will be made of only a few of the results obtained, since it appears impractical to determine by this method the efficiency of the various materials when applied to the warbles in the cysts. In these experiments it appeared that the saponified coal-tar creosote products gave the highest percentage of mortality within the first 24 hours. Tincture of iodine U. S. P. also gave a high percentage of kill soon after treatment. Certain other materials such as iodoform with neutral carriers and 5 per cent solutions of silver nitrate destroyed a high percentage of the grubs but the action was slower. To illustrate the resistance of the larvæ to the action of certain insecticides it might be mentioned that submergence for two minutes in such materials as crude petroleum and spirits of turpentine killed a comparatively small number.

APPLICATION OF MATERIALS TO GRUBS IN THE BACKS OF CATTLE

Many years ago the application of various smears to the backs of cattle was advocated by many, including such authorities as Ormerod (*71*) in England. The object in view, however, was not the destruction of the larvæ in the subcutaneous tissues but the prevention of infestation. In connection with their work the present writers have learned of the use by farmers and dairymen of the injection of such substances as kerosene oil and turpentine into the cysts for the purpose of destroying the grubs. Some men have practiced this method for years and are well pleased with the results. In Germany the warble commission (*67*) advocated the application of birch tar oil to the grubs individually in the backs of cattle. In Ireland and England, as a result of experiments carried out by Carpenter (*18*), the application of a tobacco decoction in the form of a wash has been advocated. Rène (*81*) advises, among other methods of control, the injection of 1 cc. of tincture of iodine into the warble.

Attempts to employ gas against the grubs in the backs of cattle have been reported on by Greve (*31*) and Duncan, Hewitt, and Jardine (*28*). The results were not encouraging.

In their own work, experiments along these lines have been carried out by the writers on a rather extensive scale since 1918. Most of these tests have been conducted in a way which made it possible to secure accurate records on the percentage of grubs destroyed by the various treatments. In this work various dairy herds were utilized in the vicinity of Dallas and other points in Texas, in Peoria, Ill., and in Orange and Herkimer Counties, N. Y.

Three different classes of materials were employed—powders, ointments, and liquids. The powders were usually applied directly into the grub holes by means of a shaker can. The ointments were in most cases applied with the fingers, care being taken to press some of the material into the apertures in the skin (fig. 34). The liquids were applied with hypodermic syringes, a blunt needle being used and care being taken not to injure the grub; with oil cans (fig. 35); with eye droppers; or in the form of a general wash thoroughly applied to the backs of the cattle with a stiff brush. In preliminary tests with all of the materials the cattle were numbered and a diagram made of the distribution of the grubs on the back, each grub being numbered and the stage of development determined before the application was made. In some instances the hair was clipped from around the openings in the hide; but the results in each case were checked afterwards by the treatment of other infestations in

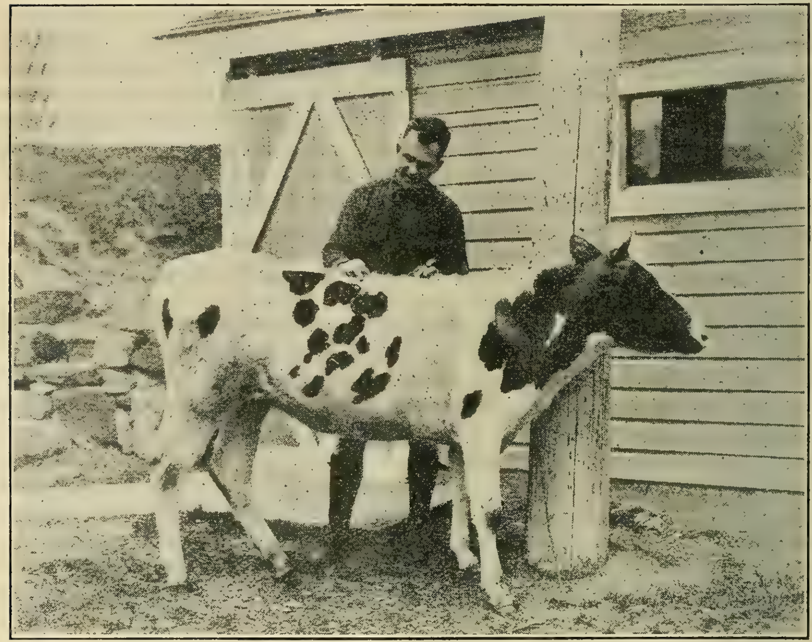


FIG. 34.—Applying ointment to grubs in back of heifer

which the hair was left undisturbed immediately around the holes and the position of the grubs marked by clipping the hair below each of them. In injecting the materials into the cysts an effort was made to fill the cavity around the grub with the liquid. The average quantity used was something less than 1 cubic centimeter per grub. In order to determine the results of the treatment in the early experiment, each grub was carefully examined from four to six days after the treatment was made. Then the larvæ were extracted and notes made on their condition and the condition of the lesions produced by them. Following the preliminary tests, large numbers of grubs were treated without determining the stage they were in or otherwise interfering with them before the application. The percentage of mortality in some cases was determined merely by continued observation of the larvæ *in situ.* In such cases the observations were continued for several weeks to determine the effect on the host of the destruction of the grubs by this method. In order to make accurate observations on the killing power of the various materials used, most of these were administered after the major part of the grubs had reached the fifth or last stage. In most cases a sufficient number of grubs were in the younger stages so that the effect of the various materials upon them could be determined. The tests indicated that, although the younger stages may be more susceptible to the action

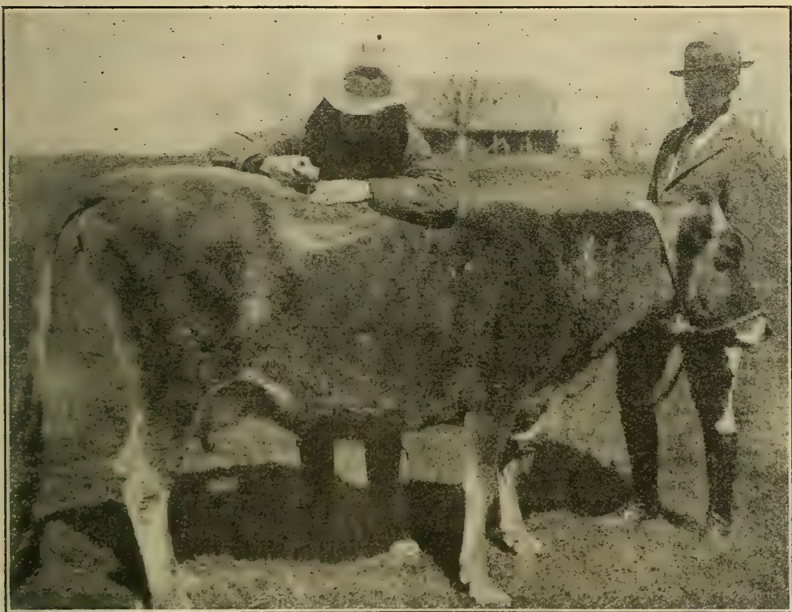


FIG. 35.—Injecting Hypoderma cysts with chemicals by means of an oil can

of the insecticides, in those stages they are probably more protected against the materials, since the apertures in the skin are usually much smaller.

Most of the tests in which the results were carefully checked are given in Tables 11 and 12. It will be observed from a study of the results that a number of the materials will produce a mortality above 80 per cent. The writers are of the opinion that materials which will not accomplish the destruction of at least 80 per cent of the grubs present should not be considered as practicable. On the other hand, some of these materials which gave a very high percentage of destruction are not adapted to use in general practice on account of the cost.

TABLE 11.—*Treatment of Hypoderma lineatum in the backs of cattle, Dallas, Tex., 1918–1924*

Material and strength	How applied	Number of cows treated	Number of grubs treated	Number of grubs killed			Number of grubs not killed			Number of grubs doubtful			Number of grubs gone			Percentage killed based on dead and alive
				Stage			Stage			Stage			Stage			
				3	4	5	3	4	5	3	4	5	3	4	5	
Argyrol, 10 per cent solution	Dropper, in hole	2	6	0	0	6	0	0	0	0	0	0	0	0	0	100.00
Arsenical solution, 0.182 per cent As_2O_3.	Syringe, in hole	17	57	0	0	3	0	0	28	0	0	21	0	0	5	9.68
Arsenical solution, 0.222 per cent As_2O_3.	do	14	28	0	0	7	0	0	3	0	0	16	0	0	2	70.00
Do	Wash on back	2	61	0	1	0	0	31	29	0	0	0	0	0	0	1.65
Do	Wash, 2 applications, 2 days apart.	14	100	2	10	11	0	21	56	0	0	0	0	0	0	23.00
Arsenical solution, 0.237 per cent As_2O_3.	Wash on back	7	39	0	0	1	0	0	36	0	0	0	0	0	2	2.70
Benzol, 90 per cent	Injected with oil can	8	115	0	11	88	0	1	5	0	0	0	0	0	10	94.29
Benzol, 100 per cent	do	56	240	0	31	189	0	0	8	0	0	3	0	0	9	96.49
Borax, saturated solution	Injected with syringe	13	72	0	0	3	0	6	20	0	18	16	0	0	9	10.34
Boracic acid, saturated solution	do	12	63	0	0	3	0	10	23	1	9	9	0	0	8	8.33
Carbolated petrolatum, 1½ per cent	Pressed into holes	5	62	1	0	4	1	31	25	0	0	0	0	0	0	8.06
Carbon tetrachloride	Injected with oil can	71	375	0	31	298	0	0	8	1	0	10	0	2	25	97.63
Chloroform, C. P.	Injected with syringe	6	24	0	0	16	0	0	0	0	0	8	0	0	0	100.00
Copper sulphate, saturated solution	do	10	59	1	1	31	0	0	1	0	5	20	0	0	0	97.06
Carbolic acid, crude, 1 part; paraffin oil, 10 parts.	Injected with oil can	11	65	0	5	20	0	2	26	0	0	0	0	0	12	47.17
Creosote oil (wood)	do	23	77	0	4	25	0	0	28	0	0	0	0	0	20	50.88
Cresol compound, U. S. P., 1 part; water, 10 parts.	do	9	52	0	0	19	0	0	7	0	7	19	0	0	0	73.08
Cresol compound, U. S. P., 1 part; water, 5 parts.	do	7	122	0	2	16	0	3	65	0	0	0	0	0	36	20.93
A cresol compound, 1 part; water, 10 parts.	Injected with syringe	45	136	0	12	91	0	1	18	0	2	3	0	0	9	84.43
Do	Injected with oil can	8	19	0	0	12	0	0	7	0	0	0	0	0	0	63.16
Do	Injected with syringe	15	79	0	4	54	0	0	7	0	5	9	0	0	0	89.23
A cresol compound, 1 part; water, 5 parts.	Injected with oil can	17	185	1	19	108	0	0	33	0	0	0	0	0	24	79.50
Creosote dip (coal-tar), 1.66 per cent solution.	Wash on back	18	115		[1] 9			[1] 78		0	0	0		[1] 28		10.34
Creosote dip (coal-tar), 8 per cent solution.	Injected with syringe	6	46	0	5	27	0	0	2	0	2	10	0	0	0	94.12
Cresol ointment, full strength	Pressed into holes	12	90	0	2	51	0	0	7	0	1	29	0	0	0	88.33
Derris extract (proprietary), 1 part; water, 10 parts, plus 4 ounces soap per gallon.	Injected with oil can	15	97	0	14	81	0	0	0	0	0	0	0	0	2	100.00
Derris extract (proprietary), 2 per cent in water, plus 4 ounces soap per gallon.	Wash on back	18	108	0	6	7	0	3	80	0	0	1	0	0	11	13.54
Derris powder, dry	Dusted into hole	22	133	0	7	110	0	0	6	0	2	1	0	0	7	95.12
Derris powder, 1 part; paraffin oil, 5 parts.	Injected with oil can	9	24	0	5	19	0	0	0	0	0	0	0	0	0	100.00
Derris powder, 1 part; petrolatum, 2 parts.	Pressed into hole	76	234		[1] 220			[1] 5		0	0	0	0	0	8	97.77
Derris powder, 1 part; petrolatum, 5 parts.	do	21	82	0	3	76	0	0	1	0	0	0	0	0	2	98.75
Derris powder, 1 part; petrolatum, 10 parts.	do	33	123	5	41	66	0	0	3	0	0	1	0	0	7	97.39
Derris powder, 1 part; petrolatum, 15 parts.	do	15	92	2	43	40	0	0	3	0	0	2	0	0	2	96.59
Derris powder, 1 part; petrolatum, 20 parts.	do	3	82	2	55	25	0	0	0	0	0	0	0	0	0	100.00
Derris powder, 8 ounces; soap, 4 ounces; water, 1 gallon.	Wash on back, 2 applications.	9	11	0	0	7	0	0	0	0	0	0	0	0	4	100.00
Do	Wash on back, 1 application.	18	109		[1] 65			[1] 34		0	0	0		[1] 10		65.66
Derris powder, 12 ounces; soap, 4 ounces; water, 1 gallon.	Wash on back, 2 applications.	8	21	0	1	19	0	0	0	0	0	0	0	0	1	100.00
Do	Wash on back, 1 application.	26	191	1	51	137	0	0	2	0	0	0	0	0	0	98.95
Derris powder, 16 ounces; soap, 4 ounces; water, 1 gallon.	do	55	503		[1] 495			[1] 7		0	0	0	0	0	1	98.61
Do	Wash on back, 2 applications; first application, 4 ounces of derris.	5	92		[1] 89		0	0	0	0	0	0	0	0	3	100.00

[1] Includes all stages. Mostly fifth-stage larvæ, but all stages not determined.

TABLE 11.—*Treatment of Hypoderma lineatum in the backs of cattle, Dallas, Tex., 1918–1924*—Continued

Material and strength	How applied	Number of cows treated	Number of grubs treated	Number of grubs killed			Number of grubs not killed			Number of grubs doubtful			Number of grubs gone			Percentage killed based on dead and alive
				Stage 3	Stage 4	Stage 5	Stage 3	Stage 4	Stage 5	Stage 3	Stage 4	Stage 5	Stage 3	Stage 4	Stage 5	
Derris powder, 12 ounces; water, 1 gallon.	Wash on back, 1 application.	11	78		[1] 47			[1] 31		0	0	0	0	0	0	60.26
Gasoline	Injected with syringe	9	34	0	10	14	0	0	1	0	1	8	0	0	0	96.00
Do	Injected with oil can	19	91	0	6	34	0	2	17	0	0	6	0	0	26	67.80
Hellebore, dry	Dusted into hole	1	20	0	3	8	0	1	4	0	1	3	0	0	0	68.75
Iodine, tincture, U. S. P., 25 per cent.	Injected with syringe	1	12	0	0	5	0	0	7	0	0	0	0	0	0	41.66
Iodine, tincture, U. S. P., 100 per cent.	do	68	437	0	0	204	0	0	111	0	27	95	0	0	0	64.76
Iodoform, 1 part; petrolatum, 10 parts.	Pressed into hole	57	255	0	12	197	0	0	12	0	0	2	0	0	32	94.57
Iodoform, 1 part; petrolatum, 5 parts.	do	88	480		[1] 410			[1] 37		0	0	1		[1] 32		91.72
Do	Rubbed on bumps	12	21		[1] 12			[1] 6		0	0	0		[1] 3		66.66
Iodoform, 1 part; petrolatum, 3 parts.	Pressed into holes	10	67	0	1	42	0	0	0	0	0	0	0	0	24	100.00
Iodoform, 1 part; petrolatum, 1 part.	do	41	223	1	8	179	0	3	16	0	1	4	0	0	11	90.82
Kerosene emulsion, 22.2 per cent oil	Wash on back, 2 applications.	13	41	0	2	8	0	1	30	0	0	0	0	0	0	24.39
Kerosene, 25 per cent; lard, 75 per cent.	Pressed into holes	9	60	0	1	11	0	0	17	0	0	31	0	0	0	41.38
Kerosene	Injected with oil can	10	67	0	0	32	0	1	14	0	0	3	0	0	17	68.09
Lime-sulfur solution, 1.92 per cent active ingredients.	Wash on back, 2 applications 24 hours apart.	22	147		[1] 44			[1] 100			[1] 2		0	0	1	30.56
Lubricating-oil emulsion	Oil can, 1 application	6	59	1	5	6	0	17	27	0	0	1	0	0	2	21.43
Nicotine sulfate, 0.08 per cent; soap, 2 ounces per gallon.	Wash on back, 2 applications 36 hours apart.	28	73	0	0	14	0	1	29	0	0	0	0	0	29	31.82
Nicotine sulfate, 0.1 per cent; soap, 2 ounces per gallon.	Wash on back 2 applications 48 hours apart.	14	52	0	0	5	0	1	28	0	0	0	0	0	18	14.71
Nicotine sulfate, 0.4 per cent nicotine.	Injected with syringe	2	10	0	3	1	0	0	4	0	0	0	0	0	2	50.00
Nicotine dust, 2 per cent	Dusted into hole	27	77	0	0	74	0	0	0	0	0	0	0	0	3	100.00
Nicotine, free, 0.2 per cent	Injected with syringe, 1 application.	14	88	0	7	15	1	11	42	0	0	2	0	0	10	28.95
Nicotine, free, 0.52 per cent	do	18	164	0	17	63	0	23	42	0	0	1	0	0	18	55.17
Nicotine, free, 0.52 per cent; soap	do	14	100	0	17	54	0	1	12	0	0	1	0	0	15	84.52
Nitrobenzene	Injected with syringe	20	68	0	16	34	0	1	7	0	0	1	0	0	9	86.21
No chemical used	Stiff brush, hard rub	2	10	0	0	1	0	0	6	0	0	0	0	0	3	14.29
Paraffin oil	Injected with syringe	18	88	0	0	55	0	0	33	0	0	0	0	0	0	62.50
Petroleum (fuel) oil	do	8	30	0	0	5	0	0	9	0	1	15	0	0	0	35.71
Pine-tar oil, crude, ¾ per cent phenol.	Injected with oil can, 1 application.	13	163	3	125	18	0	7	6	0	2	0	0	0	2	91.82
Pine-tar oil, refined	do	20	162	0	34	55	0	0	42	0	0	0	0	0	31	67.94
Pine tar	Rubbed on bumps	6	35	0	0	13	0	0	8	0	0	14	0	0	0	61.90
Pine-tar oil, commercial, 2 parts; furfural, 1 part; 90 per cent benzol, 1 part.	Dropped in holes	3	14	0	2	6	0	0	6	0	0	0	0	0	0	57.14
Pine tar, 1 part; paraffin oil, 1 part	Injected with syringe	4	14	0	2	6	0	0	0	0	1	5	0	0	0	100.00
Potassium permanganate, 25 per cent of a saturated solution.	do	4	4	0	0	4	0	0	0	0	0	0	0	0	0	100.00
Potassium permanganate, 50 per cent of a saturated solution.	do	1	6	0	0	5	0	0	1	0	0	0	0	0	0	83.33
Potassium permanganate, saturated solution.	do	24	146	0	5	101	0	0	34	0	0	6	0	0	0	75.71
Pyrethrum flowers, 2 pounds; grain alcohol, 96 per cent, 1 gallon.[2]	Injected with oil can	21	75	1	30	12	0	4	24	0	0	1	0	0	3	60.56
Pyrethrum flowers, 2 pounds; alcohol (denatured, formula 5), 1 gallon.[2]	do	2	19	0	14	5	0	0	0	0	0	0	0	0	0	100.00
Pyrethrum flowers, 2 pounds; alcohol (grain, denatured, formula 5), 1 gallon.[2]	Wash on back	21	111	0	11	41	0	1	39	0	0	4	0	0	15	56.52
Pyrethrum flowers, 2 pounds; benzol (90 per cent), 1 gallon.[2]	Injected with oil can	11	126	1	74	49	0	0	1	0	0	1	0	0	0	99.20

[1] Includes all stages. Mostly fifth-stage larvæ, but all stages not determined.
[2] Open pyrethrum flowers. Macerated for 24 hours and strained.

TABLE 11.—*Treatment of Hypoderma lineatum in the backs of cattle, Dallas, Tex., 1918–1924*—Continued

Material and strength	How applied	Number of cows treated	Number of grubs treated	Number of grubs killed, Stage 3	Number of grubs killed, Stage 4	Number of grubs killed, Stage 5	Number of grubs not killed, Stage 3	Number of grubs not killed, Stage 4	Number of grubs not killed, Stage 5	Number of grubs doubtful, Stage 3	Number of grubs doubtful, Stage 4	Number of grubs doubtful, Stage 5	Number of grubs gone, Stage 3	Number of grubs gone, Stage 4	Number of grubs gone, Stage 5	Percentage killed based on dead and alive
Pyrethrum flowers, 2 pounds; carbon tetrachloride, 1 gallon.[2]	Injected with oil can	24	107	8	63	35	0	0	0	0	0	0	0	0	1	100.00
Pyrethrum flowers, 2 pounds; kerosene, 1 gallon.[2]	do	20	173	6	110	47	0	2	8	0	0	0	0	0	0	94.22
Pyrethrum-kerosene extract,[2] emulsified with soap and water, 0.44 pound per gallon of emulsion containing 0.22 per cent oil.	Wash on back, 1 application.	12	91	0	6	9	0	9	58	0	0	0	0	0	9	18.29
Pyrethrum powder (open flowers), 1 part; petrolatum, 2 parts.	Pressed into holes	22	100	0	8	76	0	0	0	0	0	1	0	0	15	100.00
Pyrethrum powder (open flowers), 1 pound; soap, 4 ounces; water, 1 gallon.	Wash on back, 1 application.	8	87	0	2	9	0	2	57	0	0	0	0	0	17	15.71
Pyrethrum powder (open flowers)	Dusted into holes	1	22	0	2	2	0	1	7	0	3	7	0	0	0	33.33
Silver nitrate, 5 per cent	Injected with syringe	4	30	0	0	15	0	0	0	0	0	15	0	0	0	100.00
Silver nitrate, saturated solution	do	1	20	0	0	20	0	0	0	0	0	0	0	0	0	100.00
Silvol, 10 per cent	do	2	13	0	0	12	0	0	1	0	0	0	0	0	0	92.31
Soap, 4 ounces; water, 1 gallon	Wash on back	1	21	0	0	0	0	19	0	0	0	0	0	0	3	00.00
Sodium chloride, saturated solution	do	3	21	0	0	3	0	0	18	0	0	0	0	0	0	14.29
Sodium chloride, dry	Dusted into holes	16	91	0	0	14	0	2	45	0	0	30	0	0	0	22.95
Sodium fluoride, 75 per cent, saturated solution.	Injected with syringe	6	22	0	1	9	0	0	6	0	3	3	0	0	0	62.50
Sodium fluoride, dry	Dusted into holes	1	3	0	0	0	0	1	1	0	0	1	0	0	0	00.00
Sodium hypochlorite, 1 ounce; water, 16 ounces.	Injected with oil can	6	46	1	1	8	1	2	33	0	0	0	0	0	0	21.74
Sulfur, 1 part; petrolatum, 2 parts	Pressed into holes	15	45	1	16	8	0	10	10	0	0	0	0	0	0	55.55
Tobacco dust, fine, 1.08 per cent nicotine.	Dusted into holes	36	146	0	3	105	0	1	18	0	0	0	0	0	19	85.04
Tobacco dust, 1 part; petrolatum, 2 parts; 0.33 per cent nicotine.	Pressed into holes	28	231	0	60	147	0	14	4	0	0	0	0	0	6	92.00
Tobacco-dust infusion No. 1[3]	Injected with oil can	12	97	0	22	15	0	19	29	0	0	1	0	0	11	43.53
Tobacco-dust infusion No. 2[3]	Wash, 2 applications on successive days.	4	27		[1] 17			[1] 9		0	0	0	0	0	1	65.38
Tobacco-dust infusion No. 3[3]	do	5	87	0	9	57	0	4	16	0	0	0	0	0	1	76.74
Tobacco-dust infusion No. 4[3]	Wash, 1 application	5	77	0	4	27	0	10	33	0	0	0	0	0	3	41.89
Tobacco-dust infusion No. 5,[3] 0.22 per cent nicotine.	Wash, 4 applications; 2 on successive days; 2 weeks apart.	39	360	0	128	103	0	32	69	0	4	6	0	0	18	69.58
Tobacco-dust infusion No. 6,[3] 0.22 per cent nicotine.	Wash, 2 applications 2 weeks apart.	39	275	0	90	56	0	16	77	0	8	5	0	0	23	61.09
Tobacco-dust infusion No. 7,[3] 0.22 to 0.32 per cent nicotine.	Wash, 5 applications 1 week apart.	44	336	0	134	115	0	13	44	0	4	3	0	0	23	81.37
Tobacco-dust infusion No. 8,[3] 0.52 per cent nicotine.	Wash, 1 application	18	101	0	6	34	0	8	40	0	0	0	0	0	13	45.45
Tobacco-dust infusion No. 9,[3] 0.51 to 0.54 per cent nicotine.	Wash, 3 applications, 1, then 2 one week later.	21	95	0	5	53	0	2	8	0	0	0	0	0	27	85.29
Turpentine spirits, undiluted	Injected with syringe	7	78	0	0	60	0	0	4	0	0	14	0	0	0	93.75
Do	Injected with oil can	50	213	0	2	80	0	2	54	0	1	2	0	0	72	59.42
Disinfectant (phenol, boracic acid, alum).	Injected with syringe	3	14	0	0	9	0	0	0	0	0	5	0	0	0	100.00

[3] These tobacco infusions, Nos. 1 to 9, were made with ingredients in the following proportions: No. 1, 4 pounds of tobacco dust, sufficient water to make 1 gallon; No. 2, 1 pound of English tobacco dust, 4 ounces of stone lime, sufficient water to make 1 pint; No. 3, for first application, 1 pound of tobacco dust, 1 ounce of lime, sufficient water to make 1 gallon; for second application, three-fourths pound of tobacco dust, 1 ounce of lime, sufficient water to make 1 gallon; Nos. 4, 5, 6, and 7, 4 pounds of tobacco dust, 1 pound of lime, sufficient water to make 1 gallon; Nos. 8 and 9, 8 pounds of tobacco dust, 4 pounds of lime, sufficient water to make 1 gallon.

TABLE 12.—*Treatment of Hypoderma lineatum and H. bovis in the backs of cattle, Orange County, N. Y., 1922*

Chemicals used	How applied	Number of cows treated	Number of grubs treated	Number of grubs killed — Stage 3	4	5	Number of grubs not killed — Stage 3	4	5	Number of grubs doubtful — Stage 3	4	5	Number of grubs gone — Stage 3	4	5	Percentage killed based on dead and alive	Species
Derris, 1 part; petrolatum, 10 parts.	Rubbed in, 1 application.	4	64		[1] 64		0	0	0	0	0	0	0	0	0	100.00	Hypoderma bovis and H. lineatum.
Derris, 1 pound; soap, 4 ounces; water, 1 gallon.	Wash on back, 1 application.	9	91		[1] 63			[1] 21			[1] 7		0	0	0	75.00	Do.
Derris, 1 ounce; water, 300 ounces; soap, 5½ ounces.	do	2	43	0	0	0	0	0	43	0	0	0	0	0	0	00.00	H. bovis.
Derris extract, 1 part; water, 100 parts; soap, 1 part.	do	6	23	0	0	2	0	0	17	0	0	0		[1] 4		10.53	Do.
Iodoform, 1 part; petrolatum, 5 parts	Rubbed in, 1 application	19	206		163			[1] 42		0	0	0		[1] 1		79.51	H. bovis and H. lineatum.
Nicotine (free), 0.1 per cent solution.	Wash on back, 1 application.	6	100		[1] 14			[1] 69			[1] 2			[1] 15		16.87	H. bovis.
Tobacco dust, dry	Rubbed in, 1 application.	4	67		[1] 3			[1] 60			[1] 1			[1] 3		4.76	Do.
Tobacco infusion: Tobacco dust, 4 pounds; lime, 1 pound; water, 1 gallon.	Wash on back, 2 applications 24 hours apart.	3	115		[1] 19			[1] 56			[1] 21			[1] 19		25.33	Do.
Sodium hypochlorite, 2 ounces; water, 16 ounces.	do	1	5	0	0	2	0	0	3	0	0	0	0	0	0	40.00	Do.

[1] Includes all stages. Mostly fifth-stage larvæ, but all stages not determined.

Several different methods were considered of computing the percentage of the grubs destroyed by the various materials, but it was finally decided to make this computation on the basis of the number of grubs found alive or dead at the time of examination. This gives considerable advantage to those materials which had low killing power, as in many cases the mature larvæ which were uninjured would leave the host before the results were checked. Furthermore, in the case of those substances which were very toxic, especially the ointments, many of those grubs recorded as gone were no doubt killed or were so weakened as never to produce adults. Those recorded as doubtful were, for the most part, larvæ which were extracted four or five days after treatment. In the case of some of the substances it was found difficult to determine for certain in every case whether the grubs were dead or alive when observations upon them were made so soon after treatment. From six to eight days proved to be the most satisfactory interval between treatment and determination of result.

In general it may be stated that in the case of those materials which gave a very high percentage of mortality relatively few grubs were gone at the time of examination. Some of the ointments may be noted as exceptions to this, as they were found to facilitate the emergence of the grubs from the skin even though the grubs were dead.

Attention is especially directed to the results secured by the use of the following materials: Benzol and carbon tetrachloride when injected into the cysts; derris used in dry form, as an ointment with petrolatum, or in suspension in water when injected into the cysts, or applied as a wash (*111*); iodoform and petrolatum, also pyrethrum and petrolatum, when applied as an ointment; and very fine tobacco dust and nicotine dust used in powder form.

The results of the writers' work seem to indicate rather clearly that the percentage of mortality is not so high in the case of *H. bovis* as with *H. lineatum*.

The treatment of cattle in practice requires the application of a method which will be as effective as possible under adverse conditions. When treatments are given by the livestock owners themselves, washes applied to the entire back of the animal are probably the most dependable, in that the inexperienced operator is more likely to treat all of the grubs than if the latter have to be found individually. On the other hand, there may be some objection to the use of washes on the entire back of the animal under certain adverse weather conditions. An objection to the use of the syringe is that the instrument is an item of expense and may be broken even if carefully handled. This tends to commend the oil can if the grubs are to be injected individually. In the writers' experience they have found that an oil can with a comparatively slender curved point is the most convenient to use. If the aperture in the spout is not too large the spout can be utilized to advantage in finding the grub hole. One advantage in the use of an ointment such as iodoform-petrolatum is that the operator can easily recognize which grubs have been treated. The use of powders is favored by those who do not wish to wet the animals during the winter, but some objection might be had to them on account of the possibility of the dust getting into the buckets during milking. With certain washes, however, the dust is left in the hair after the animal has dried. A careful application of dust to the backs of cattle is almost as certain to reach all grubs as the use of a wash.

Tobacco infusion has been advocated for the destruction of grubs in the backs of cattle by Carpenter, Phibbs, and Slattery (*19*). Although results of the writers' preliminary tests with similar infusions were not satisfactory, they continued their experiments after receiving Carpenter's favorable reports. In his early publications he gave no idea of the strength of the decoctions he used, and it appears that he must have employed infusions with a higher percentage of nicotine than the writers were able to obtain from American tobacco dusts by using his formula. When, however, tobacco dust from the same source as that employed by Carpenter (see Table 11, tobacco infusion No. 2) was used, the mortality obtained (65.38 per cent) was not nearly so high as reported by Carpenter. With most of American tobacco dusts, which run from 1 to 1½ per cent nicotine, great difficulty was found in obtaining an infusion containing 0.5 per cent of nicotine. In order to get such a percentage the amount of tobacco dust advised in Carpenter's formula was doubled, being 8 pounds of tobacco dust, 4 pounds of stone lime, and 1 gallon of water. In preparing this the lime was first slaked in the water, and then the tobacco dust was stirred in and allowed to stand about 24 hours. The mass was then placed in a sack and pressure applied at times with two boards hinged at one end. From 1 gallon of water usually not more than 3 pints of infusion was obtained. Serious objections to the use of this decoction are the labor involved in preparing it and the great variability in the strength of the infusion obtained. These objections would cause the investigator or stockman to turn to the standardized solutions of free nicotine or nicotine sulfate, but the results obtained with these substances when used at strengths which would not endanger the host were unsatisfactory. Nicotine sulfate at a strength of 0.4 per cent when injected into the cysts of the grubs gave a mortality of only 50 per cent, and free nicotine at a strength of 0.52 per cent with soap added resulted in a mortality of 84 per cent. These strengths are greater than would be advisable for use as general washes on the backs of cattle.

The toxicity, to larvæ in different stages, of materials applied to the backs of cattle is a point of importance. It is necessary, of course, to kill a high percentage of all stages of larvæ present at the time of treatment, but for several reasons it is desirable that treatment be made with a view of destroying the grubs while small. To gain some information on this question a study of the percentage of mortality among the different stages was made. For comparison the percentages of mortality among the grubs in the fourth and fifth stages treated with fairly effective larvicides were compared. The materials used were grouped according to method of treatment. These groups and the mortality of the larvæ in each were as follows: Cysts injected with syringe or oil can, fourth stage 91.01 per cent, fifth stage 81.21 per cent; ointments applied to the opening in the skin, fourth stage 84.34 per cent, fifth stage 93.32 per cent; dusts applied to the openings in the skin, fourth stage 83.33 per cent, fifth stage 88.05 per cent; washes applied to backs of cattle, fourth stage 90.29 per cent, fifth stage 68.77 per cent. These figures should not be taken to indicate the relative merits of the different methods of treatment. They are of value, however, because they clearly show that the ointments and powders are relatively more effective against the larvæ of the fifth stage than against those of the fourth, probably owing to the larger apertures in the skin, which permit the materials more readily to gain access to the larvæ; but, on the other hand, that the percentage of mortality is higher in larvæ of the fourth stage than in those of the fifth when the insecticides are injected into the cysts or applied as washes to the backs of the cattle. It appears that the younger stages are somewhat more easily killed than the fifth-stage larvæ when they are actually brought into contact with the insecticide. Exact observations on the mortality among third-stage larvæ have not been made in a sufficient number of specimens to form a reliable basis for conclusions, but for the purpose of comparing the relative susceptibility of the three stages to various treatments, it may be said that the mortality runs about 92 per cent in the third stage, 89 per cent in the fourth stage, and 83 per cent in the fifth stage.

EXTRACTION OF GRUBS BY HAND

It is the common belief that the cattle grubs must be fairly well matured before they can be successfully removed by hand. The expression is often heard, "the grubs are not yet ripe."

In the writers' experience they have found that grubs may be extracted at any time during the course of their development in the backs of the cattle. They have found that, by removing the small scabs which usually develop around the apertures cut by the young or third-stage larvæ, they can be pressed out with great ease. There seems to be a period in the fourth stage during which extraction is more difficult. By using care, however, practically every grub can be removed by hand. (Fig. 36.)

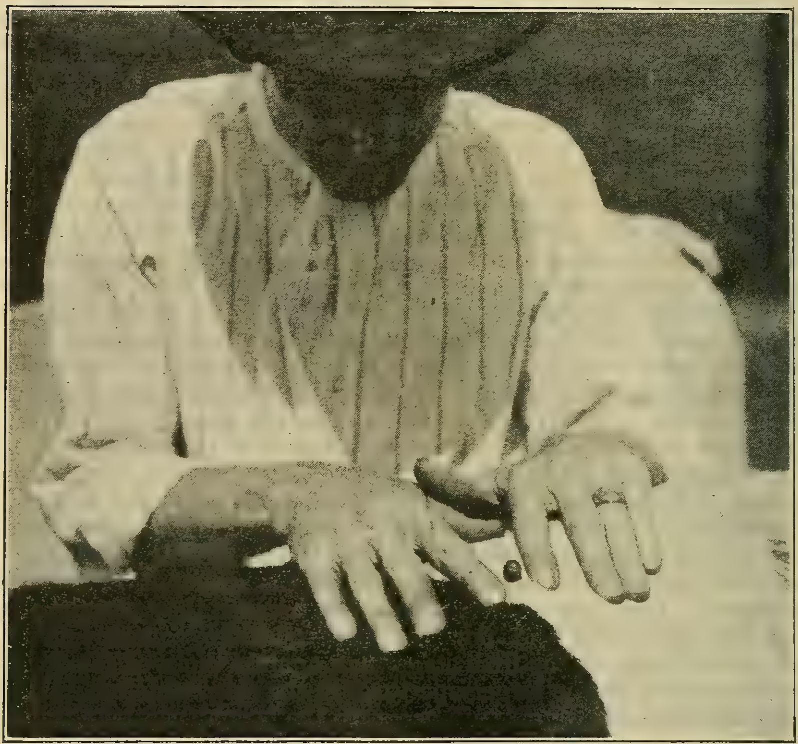


FIG. 36.—Extracting Hypoderma larva from cow by pressing down around cyst opening

There is a very marked difference in the ease with which grubs may be etxracted from the backs of cattle of different breeds. In the case of the island breeds the skin appears more flexible and elastic, and extraction is comparatively easy. Very often with the Holstein-Friesian and certain beef breeds it is almost impossible to squeeze the grubs out by hand. The condition of flesh of the host also has a considerable effect on the ease of extraction. Very poor or extremely fat cattle are more difficult to treat than those in fair condition.

The method of procedure in extracting grubs may be modified to suit the individual and also the character of the skin of the host under treatment. Inexperienced people often find extraction extremely difficult; but those who have considerable experience are able to remove the grubs with comparative ease, and they seldom break the cyst and allow the larva to escape. Certain writers have advocated the application of salt water or soapy water to the backs of cattle before extraction is begun. It is probable in the case of cattle with elastic skins that a weak saline solution applied to the backs some time before extraction is undertaken will aid the work. In the present writers' experience, however, washes have not been found materially to facilitate extraction. (See further discussion under "Cost of treatment or extraction of grubs," p. 106.)

MECHANICAL EXTRACTION OF GRUBS

One often hears of the old-fashioned method of placing the mouth of a heated bottle over the aperture of the grub. Some larvæ may be extracted by this method, but it is extremely slow. It suggests, however, the possibility of utilizing suction and pressure in extraction work. For several years the writers have given considerable attention to the question of developing an implement for removing the grubs from the backs of cattle by suction. One of the principal difficulties encountered is in obtaining an airtight cup to fit over the warble and to generate, without unduly complicated and expensive apparatus, a sufficient vacuum to suck the grubs out of the cysts. Brodersen (*11*), a veterinarian in Denmark, has devised and patented a small suction pump operated by hand which he considers a success for the removal of grubs. The principle employed is a combination of pressure and suction. The end of the pump barrel is fitted with a rubber cup which is applied to the back of the animal over the grub hole. This is pressed down against the animal while the plunger is being pulled out, thus creating a partial vacuum. Doctor Brodersen has very kindly furnished the writers with one of these instruments, but in their experiments it has not worked well, especially on animals with inelastic skins. In certain instances, even though tremendous pressure was applied and the plunger raised a great many times, the grubs could not be pulled out of their cysts. Before receiving Brodersen's extractor, the writers had developed a similar instrument made from an old automobile-tire pump (fig. 37). This, probably owing to a larger barrel capacity, gave even better results than the imported extractor. There is certainly some advantage in using an instrument of this kind if it can be developed to a point where a large percentage of the grubs can be removed without consuming too much time. It would be less trying on the fingers than hand extraction and the operator would not have the disagreeable experience, which often comes from squeezing the grubs out by hand, of having pus, or the contents of the grub, squirted into the face. Furthermore, it is probable that the chance of breaking the cysts or bruising the tissues would be less than might result from hand extraction, especially by an inexperienced operator.

The use of forceps to assist in the extraction of larvæ naturally comes to mind. The writers have investigated the possibility of using various types of forceps in this work. One of the principal difficulties is in obtaining a pair of forceps with sufficiently fine points to enter the small holes in the hide and at the same time with enough strength to extract the larvæ and not get out of order. One of the most successful forms of forceps tried is the alligator-jaw type (fig. 38). These permit one to place the tips well into the hole and then to open them and secure a firm hold on the grub. Another type which has been found very successful is a simple forceps with stout shanks and provided at the tip with minute mouse-teeth. These, however, often puncture the grub, which might be considered objectionable by some.

The enlargement of the grub holes in the hide by cutting, is a method suggested by some, especially by veterinarians. It has been found that in most cases this practice causes the host too much discomfort. There is also the possibility of cutting through the cyst, if the incision is made too deeply, and thus allowing some of the foreign matter to enter the tissues of the host.

Certain stockmen have for years practiced the plan of puncturing the grub before attempting to extract it. This led the writers to

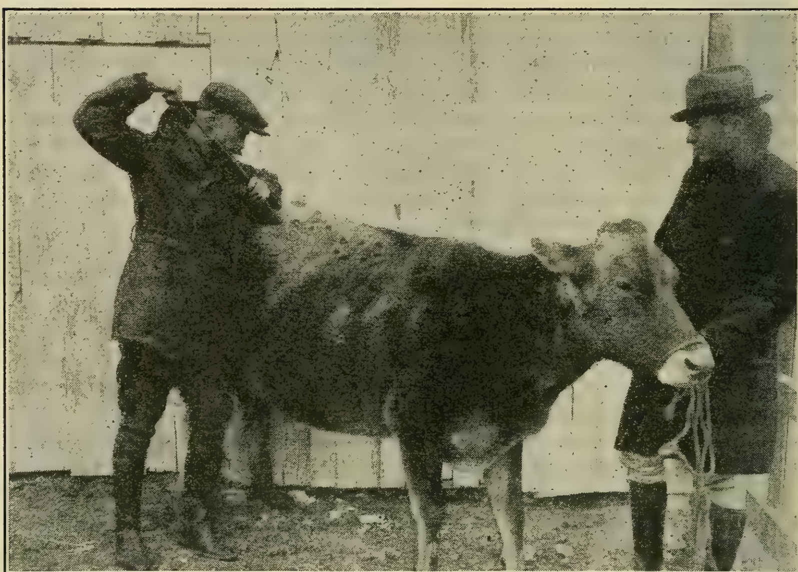


FIG. 37.—Removing Hypoderma larvæ from back of cow by means of suction pump of the Brodersen type

make a series of tests of this method. One of the procedures followed was to press firmly around the grub, thus bringing it up to the aperture in the skin, and then to clip the posterior end with a pair of fine-pointed scissors. A small amount of pressure applied to the cyst will expel the contents of the larva, after which the skin of the grub may be easily extracted by pressure, or better, with a pair of forceps. In certain instances grubs punctured in the way described were left in the host. In a short time it was found that the skins of most of these grubs had protruded some distance from the holes in the skin, thus enabling one to remove them easily with the fingers.

EFFECT ON HOST OF DESTRUCTION AND EXTRACTION OF GRUBS

Despite the very general practice of extracting grubs by hand which has been employed for many years, not until recently have any definite ill effects been attributed to this method. Brodersen (*10*), working in Denmark, reports his observations upon a semiacute malady which he terms "Rosenfeber." He records several cases in which he has seen the sick cows very soon after the grubs had been squeezed out. The description he gives of the sickness indicates clearly that it is of an anaphylactic nature similar to that described by Hadwen and Bruce (*38*), Jensen (*49*), and Van Es and Schalk (*109*) in cases where they injected the juice of larvæ into animals sensitized by natural infestations. Brodersen's cases were acute but not serious. Apparently the general depression, rapid pulse, and puslike secretion from the mucous membranes completely subsided within a few hours. In the cases cited it appears that the grubs were squeezed out by men hired for the purpose and apparently the work was done in a very crude way. The experience, however, directs attention to the danger of handling cattle roughly during the extraction process and further emphasizes the need of a proper understanding of the best method of removing the grubs. It should be noted also that in cases in the writer's experience in which the grubs have been removed from large numbers of cattle, some of them very heavily infested, no instance in which any ill effects whatsoever were noticeable has ever been observed. The principal danger seems to lie in the improper application of pressure around the grub, which causes the cyst to break and the grub, after being crushed, to be forced back into the connective tissue.

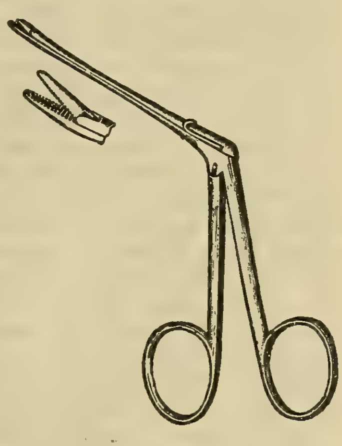


Fig. 38.—Alligator forceps, a type well adapted for use in extracting grubs from the backs of cattle

To lessen the danger of anaphylactic shock to cattle following hand extraction of grubs, Hadwen (*37*) has advised that the back of the animal be washed off with cold water. In very valuable animals and show herds, it is suggested that the warble cysts be washed out with a hypodermic syringe or oil can, using a normal saline solution or a 2 per cent carbolic wash.

Aside from the anaphylactic reaction mentioned above it is claimed by some that there is occasional formation of pus abscesses in the subcutaneous tissue following extraction. The writers' observations indicate, however, that with even moderate care in hand extraction the chance of pus formation in the backs of stock is lessened rather than increased by removing the grubs. Great numbers of cases have been encountered in which cows had developed large abscesses without having been treated for grubs, usually because of the closing of the orifice of the grub cyst before the grub reaches maturity. In most cases this results in the death of the insect. Such abscesses are always greatly relieved by discharging them as soon as they are observed.

Realizing the fact that the leaving of foreign bodies in a host is not good surgical practice, the writers were at first rather skeptical about the advisability of destroying the grubs in the backs of cattle by the application of insecticides. The difficulty of removing the grubs from certain breeds, however, led them to give very serious consideration to this method of treatment. As a result of rather extended experiments and practical demonstrations of this method, it became evident that no ill effects were visible in the host. It is true that certain materials may be used in the destruction of the grubs which are detrimental to the host, as, for instance, copper sulfate. In the writers' tests this material gave decidedly bad local effects. Abscesses were developed in a considerable percentage of the cysts treated. On the other hand, with many of the most effective larvicides tried, pus formation in the cysts was checked and the size of the lump caused by the grub was rapidly reduced.

With some treatments, notably those with carbon tetrachloride, and with derris in various forms, the exit holes of the grubs were observed to close rather rapidly and there was little tendency for the host to expel the insect. In most instances the grubs were found to disintegrate rather rapidly under such conditions, especially if they were not in the late stages of development. At times some of the grubs, especially in the late fifth stage, were found to rise in the aperture in the skin and the posterior segments to harden, thus retarding the closing of the hole in the skin.

When the grubs are not further developed than the early part of the fifth stage, they are promptly absorbed after being killed by substances applied to the back of the host. After the skin and spines have become thoroughly chitinized their elimination by the host is more difficult. Some collapse and work out or are licked out of the skin. Most of them are reduced in bulk by absorption and the skin heals up smoothly over them. A considerable percentage of these mature grubs may remain in the skin for several months. This shows the advisability of applying treatments while the grubs are young; furthermore, at this time the holes in the hides are much smaller and heal up more quickly.

When ointments such as iodoform, derris, or pyrethrum and petrolatum are used, the writers have found that a considerable percentage of the grubs are expelled from the cysts after their death. Some of them are found completely emerged from the skin of the host two days after treatment and they continue to be thrown off for about two weeks. Some project slightly from the skin and may remain so for weeks if not mechanically removed. The percentage of grubs which are expelled after treatment varies widely, apparently differing with the character of the skin of the host.

In order to determine the effect on the host and the rapidity of healing of the grub holes, some special observations were made on herds (1) where grubs left the hosts normally, (2) where the larvæ were punctured and pulled out, (3) where they were extracted by hand, and (4) where various materials were applied to the backs of the cattle. The rapidity of healing of the grub holes was found to vary much in different animals, both when the grubs emerged normally and when they were extracted or destroyed *in situ.* It was found that the time required for healing of holes where the grubs emerged normally ranged from about 13 to 76 days. The scars from the skin injury often persist for several months. The presence of foreign material in the form of a plug in the grub aperture often retards healing. This may contain the exuviæ of the larvæ, but usually it seems to be composed of dried excretions from the cyst. As the opening heals about this tough material there often remains a pit containing a minute hole which can be located with a pointed instrument.

Observations have been carried on to determine the rapidity of healing of grub holes in the skin when the grubs are killed by the application of insecticides or are extracted by hand. It has been observed that where grubs are squeezed out, or even drop normally, the old cyst and other material left within it require several weeks for absorption. Grubs were extracted on one side of the backs of cattle and on the corresponding side they were killed with insecticides. Two weeks later these animals were slaughtered and examined. The condition of the connective tissue around the grub cysts was practically identical on both sides. When the skin was removed no discolored or infiltrated tissue was left on the carcass, but the former position of the grubs could be located on the under side of the hide. The holes in the hide had healed to about the same degree with the exception of a few cases in which portions of the bodies of the dead larvæ were in the grub openings, thus preventing the closing of the apertures.

In several herds in which insecticides were administered to the backs of the cattle, a number of subsequent examinations were made to determine the general condition of the infested areas and the rapidity with which the skin healed. In most of these herds the grubs were not treated until many of them were nearly mature. Seventy-seven days following the treatment it was found that between 42 and 62 per cent of the grub holes had healed, and the fact that the animals had been infested with larvæ could not then be determined by touch. One hundred and twelve days following treatment 75 per cent of the grub holes were completely healed and smooth. At this time only 2 per cent remained open and in no case was more than a very slight quantity of pus present. In one herd treated with benzol it was found that the healing was less advanced at the end of 77 days. Only 30 per cent of the grub holes were healed and smooth, and 48 per cent of the holes were still open. The presence of the grubs was apparent in 25 per cent of the cysts. In all cases, however, the warbles were distinctly reduced in size.

Since in certain animals extraction is greatly facilitated by puncturing the grubs and squeezing out their contents before removing the grub skin, the writers have treated over 200 head in this way. In no instance did the condition of the lesions and the rapidity of the healing of the holes in the skin show any difference from those in cases in which the grubs were extracted by squeezing. In a number of cattle the grubs were punctured and left in the cyst after the body contents had been pressed out. No ill effects were observed, but healing of some of the holes in the skin was retarded, owing to the hardening in them of the skins of the grubs. One animal treated in this way had 60 well-developed grubs in its back. Six days after the puncturing, about 10 of the grubs were projecting from the skin. These were shrunken and hardened, and seven of these were pulled out. There was no more pus in any of the cysts than would occur with living larvæ. Twelve days later six projecting grubs were pulled out; the cysts under these were small and the animal had improved noticeably in condition of flesh. At this time more than one-half of the holes were healed. When the grubs are punctured before they are extracted the cattle are worried much less than when extraction by the usual method is practiced. Schöttler (*87*) states that in Germany a crochet needle has been used for puncturing and extracting grubs, but that this method had been found to be undesirable because the juice from the grubs may cause nettle fever.

COST OF TREATMENT OR EXTRACTION OF GRUBS

To gain information on the expense of treating cattle for grubs, records were kept on the time required in applying the different treatments, the quantity of the material used, and its cost.

It was found that for cattle of the island breeds hand extraction was the most economical. The time consumed in extraction varied considerably with the breed and with the local conditions under which the work was done, as well as with the experience of the operator. The rate of extraction per hour ranged from 38 grubs in Holsteins to 191 in a dairy herd of mixed breeds. It appears that with the average herd of Jerseys or mixed breeds, not Holsteins, the grubs can be extracted carefully and thoroughly at the rate of about 125 per hour. Naturally the degree of infestation affects the rate, as in very light infestations much time is occupied in going from one animal to another and in very heavy infestations more care is necessary to avoid missing some grubs.

In tests in which the backs of the cattle were thoroughly moistened with soap solution the average number of larvæ extracted per hour was 119, and where normal salt solution was applied prior to the extraction the grubs were removed at the rate of 100 per hour. These tests therefore seem to indicate that the wetting of the backs of the cattle in the case of island or mixed breeds, not Holsteins, tends to retard the rate of extraction.

In tests of the method of extracting the grubs after puncturing them and expelling the contents, the average number of grubs removed per hour was slightly over 88. This work was done without special forceps, which if used would have hastened the work. Although this rate of extraction is considerably slower than that of the hand extraction in Jersey or mixed herds it is decidedly more rapid than hand extraction in Holsteins.

The rate of treatment when injecting the cysts with a hypodermic syringe ran about 170 grubs per hour. The time consumed in injecting the material by means of an oil can varied considerably, ranging from 74 to 240 grubs per hour. The very slow record mentioned was probably due to the fact that a large number of the grubs had dropped, and it was necessary to examine each cyst to determine if the larva was still present. Under good conditions in a dairy it is thought that by the oil-can injection method 225 grubs per hour might be readily treated.

The application of such general treatments as dusts and washes is considerably more rapid than the individual treatment of grubs. The thoroughness with which either of these methods must be carried out, however, causes more time to be consumed in the treatment than would be supposed. On an average it required an hour to treat about 98 grubs by the application of ointments, such as iodoform-petrolatum to cysts in the backs of cattle. Undoubtedly this work could be done much more rapidly in herds showing a fairly heavy infestation.

The cost of materials and equipment should be considered, especially if large herds are to be treated. The fact that no instruments or materials are needed for the ordinary hand extraction commends that method. With the use of ointments, powders, and washes practically no equipment is required. The cost of forceps or scissors for the puncturing and pulling method of extraction is not great, but this method requires rather more care and a higher degree of training for the work than is necessary for using the oil-can injection method or for applying washes and powders.

The cost of the chemicals used varies considerably with the material, and there is also considerable difference between the wholesale and retail prices of each. Iodoform-petrolatum ointment costs about 8¼ cents per ounce at the usual wholesale price. The retail price is about 15 cents per ounce. An ounce will treat between 125 and 200 grubs, thus making the retail cost of the ointment about 12 cents per 100 grubs. Pyrethrum ointment is much cheaper, as it costs about 5 cents per 100 grubs. The only objection to this ointment is that the pyrethrum powder must be fresh to be potent.

With such materials as carbon tetrachloride and benzol, it was found that a pound of either would treat about 500 warbles. Since these materials are comparatively inexpensive the cost is extremely low.

As yet derris is not available on the open market in this country, but it is probable that it will retail at approximately $1 per pound. Tobacco dusts of all grades are very much cheaper, but they do not appear to be equally effective in any strength, and furthermore their strength as well as mechanical make-up varies considerably. It is probable that if further tests prove that very fine tobacco dust with a fairly high percentage of nicotine is as effective as the writers' preliminary experiments indicate, this material may be standardized for this purpose.

CONTROL THROUGH INDIVIDUAL EFFORT

The results of control measures applied by an individual cattle owner when he is more or less closely surrounded by livestock are likely to be disappointing. Three tests have been made by the writers in which the grubs have been destroyed rather systematically for periods of from two to four years. It is true that all grubs were not destroyed each year, but the work was probably done as thoroughly as it would have been if left to the cattle owners. The pastures where the treated cattle ranged were in close proximity to others in which untreated stock were kept. In none of these tests was a striking reduction observed in the number of grubs during the year following.

The most thorough work along this line was done on the dairy and breeding farm of J. T. Orr, near Dallas, Tex. From 45 to 100 head of cattle were carried on this place. During the grub season of 1920–21 the cattle were examined and grubs destroyed only once, on January 29. The average number of grubs per head then was

5.13. In 1921–22 the cattle were all examined and grubs extracted on December 16 and January 17, the average per head being 3.55. In 1922–23 the grubs were all extracted on November 28, December 28, January 29, and March 21, the average per head for the year being 11.30. During 1923–24 the cattle were gone over four times and an average for the year of 7.5 grubs per animal was found. During the last three seasons the work was done very thoroughly, yet it appears that enough flies entered the pasture from adjoining farms to keep up the infestation. It is thought that this is a rather peculiar case, however, on account of certain local conditions.

Duncan, Hewitt, and Jardine (*28*) have reported a similar experience on a farm in Ireland. The average number of grubs was materially lowered after the first year's destruction, but for several succeeding years it remained rather constant, though relatively low.

The writers have observed a number of instances, however, where well-isolated dairymen and breeders have largely, if not completely, eradicated the pest from their herds by systematic destruction of the grubs.

In attempting to control the insect on the individual farm it is important to destroy the grubs in the young stock, and also to kill those larvæ which reach the backs rather late in the season.

POSSIBILITIES OF ERADICATION BY SYSTEMATIC DESTRUCTION OF GRUBS

For many years the possibilities of completely eliminating this destructive pest from given areas have been presented. In 1896 Osborn (*73*), after discussing methods of destroying the grubs, says:

> While it is certain that this insect could be practically exterminated in the United States in a single year, we realize fully the great difficulty in getting every person owning cattle to know or appreciate the need of using the necessary means . . . We can not close this sketch of remedies without presenting a plan which, though it may be styled fanciful or ideal, must if carried out result in the extermination of the pest and the saving, we believe, of not less and probably more than $50,000,000 per year to the farmers of the United States.

He then briefly outlines his plan of having all cattle examined and the grubs extracted or destroyed by chemical treatment. Other authors have presented somewhat similar suggestions, but until recently it would appear that the knowledge of the seasonal history of the two species of grubs in this country has been too meager to make possible the formulation of very definite plans. From studies which have been made in various parts of the world on this problem it appears certain that eradication from considerable areas, if not from entire countries, can be accomplished and that such effort would be very remunerative to the dairy and livestock industries. In considering the possibilities for eradication the following facts should be borne in mind:

1. Both species of Hypoderma confine their attack almost exclusively to domestic cattle. It is probable, however, that in vicinities where bison range these grubs might readily be carried over in numbers in such herds. Horses and goats are the only other hosts which would have to be considered at all, and the writers' observations clearly indicate that they would not play a part in perpetuating this species if all grubs were destroyed in bovines.

2. Every individual of both species of Hypoderma is present in the subcutaneous tissues of the backs of the cattle for a period in excess of 35 days, and while in this situation it is constantly amenable to treatments applied to the backs of the cattle or to extraction.

3. The larvæ are present in the subcutaneous tissues of the back during a fairly well-defined and comparatively limited period of the year.

The difficulty of carrying out systematic extraction or the application of ointments or washes under range conditions is at once apparent. In the farming and dairying sections, however, where the cattle are fairly gentle, systematic treatment would be fully warranted even under present conditions.

No definite experiments have been possible to show the distance the flies may travel, but circumstantial evidence indicates that they do not go far from the place where they hatch out, and this lends further encouragement to the efforts toward control. The writers' experience with the systematic destruction of grubs among animals on a single farm surrounded by infested cattle clearly indicates the futility of the individual attempting to secure a high degree of control, to say nothing of eradication. Cooperative community action is therefore clearly called for. Such an undertaking in Denmark is reported by Boas (*5*). On a farm in the center of an area where systematic grub extraction was carried out by a dairy association, the following numbers of grubs were found present and destroyed on seven succeeding years, beginning in 1889: 832, 215, 65, 229, 64, 0, 0. Complete eradication was not accomplished toward the edges of the areas covered by this effort, but the grubs were greatly reduced in numbers.

The stock raiser who has comparatively few grubs in his cattle has not been given sufficient consideration in connection with the sale of his cattle or hides, owing to the fact that it is the custom of the hide buyers of a section known to be infested by grubs to make a horizontal discount for grubbiness without determining the degree of infestation of the hides and even without the knowledge of the producer. With the inauguration of systematic control work there seems to be little doubt that hide buyers would pay a premium for hides from areas practicing control work, and also that butchers would slightly favor cattle from those areas.

In the initial undertaking of systematic control or eradication work it would seem desirable that the plan be attempted on a considerable area. Such a plan has been under consideration by the writers for several years, although funds have not been forthcoming to put it into effect (*70*). The writers believe that a large amount of educational work must be done in advance of any actual control work, and in this connection all organizations of business men and farmers should be thoroughly in sympathy with the undertaking. In an initial attempt it is thought best to have all of the work of destroying the grubs carried out by men specially trained in the procedure, and not to depend upon the volunteer efforts of the stock owners. It is probable that such an undertaking would have to be carried on during about three years, as inevitably a few grubs would escape destruction even in the most carefully executed plan. It appears that the mortality of grubs under natural conditions is high, and there is the possibility that with only an occasional grub maturing the male and female flies would fail to emerge at the same time and mating would not be possible. In carrying out such a plan it is imperative that an exact knowledge of the seasonal development of the grubs be obtained in advance, so that the date for be-beginning the work will be known with a fair degree of accuracy. Where both species of Hypoderma occur at least four treatments will be required. The first should be completed some days before the time of maturity of the earliest larvæ. All cattle exposed to fly attack should be carefully examined. In the greater part of the United States calves under 6 months old would not be found infested, but under certain conditions animals as young as 5 months of age may be infested.

The experiment carried out by Carpenter and his associates (*18*) on Clare Island, County Mayo, Ireland, amply demonstrates the possibility of complete eradication of grubs, provided all cattle are systematically treated.

The fact that a few cases of temporary sickness have resulted in cattle from careless hand extraction should not be allowed in any way to interfere with the work of destroying grubs in the backs of cattle. These cases are comparatively rare and the good accomplished by grub destruction far outweighs any loss which might be sustained.

LEGISLATION ON GRUB CONTROL

A very active interest is being shown in various parts of the world in the matter of grub control. Great Britain has for many years given attention to this problem, but her efforts took on more systematic form recently when the English Ministry of Agriculture in collaboration with the Scottish Board and the Department of Agriculture for Ireland formed a commission of experts to devise methods of control or eradication of the pest. It seems that there is a very strong sentiment in Great Britain in favor of the passage of laws to bring about the systematic destruction of the grubs. In Switzerland and France similar commissions have been organized recently; Germany (*67*) has had its commission functioning for several years; and in Denmark (*26*) a law was passed in 1923 by Parliament, looking toward the destruction of all grubs in cattle during the years 1923 and 1924 with a view to complete eradication throughout the nation.

This action by the legislative authorities of Denmark, it should be remembered, followed years of individual or community effort against the pest.

It is doubtful if any legislation on the part of our own country is advisable at present. After there have been large-scale demonstrations of what may be accomplished in the direction of grub eradication through well-organized cooperative work, however, appropriate legislative enactments will no doubt be called for.

SUMMARY

Cattle grubs of the genus Hypoderma are abundant throughout the greater part of the United States and southern Canada, and in

Germany, Switzerland, Denmark, Holland, and the British Isles, and probably occur throughout the remainder of Europe. They have been reported also from North Africa, western India, Mongolia, and parts of Japan. Of the two species, *H. bovis* De Geer is essentially a northern form as shown by its distribution, both in the United States and in Europe. In the United States *H. lineatum* is much more widely distributed than *H. bovis*, has been known for many more years, and has been bred from the native bison; possibly, therefore, it may be an American species, although now occurring in other parts of the world. *H. bovis*, on the other hand, appears to have been introduced into the United States from Europe rather recently.

Injury to cattle by these insects comes from (1) the annoyance caused by the flies during egg deposition and (2) the irritation produced by the larvæ within the bodies of the hosts. The yearly loss to the hide, tanning, and leather industries of the United States caused by these grubs is estimated at $5,000,000 and the yearly losses to the people of the United States at $50,000,000.

Cattle are the normal hosts for both *H. bovis* and *H. lineatum*. The American bison is also a host of *H. lineatum*. Although horses are attacked, in nature very few larvæ ever reach maturity in them. Goats may occasionally serve as hosts but in experiments with them, as also with sheep, dogs, rabbits, and guinea pigs, no larvæ were successfully reared. Several cases are known of the infestation of man by these parasites.

In several series of experiments with cattle controlled by muzzles and cages it was determined that the larvæ upon hatching from the eggs penetrate through the skin at the points where the eggs are laid and do not enter the host by the mouth, either in the egg or larval stage.

It was found that the place where the eggs are laid on the host has no apparent effect either on the place where the larvæ reach the subdermal tissues or on the time of their appearance. Larvæ entering the skin of an animal on the legs may go to the submucous layers of the gullet, as may also larvæ removed from the gullets and introduced by incision under the skin on the leg of a bovine.

H. lineatum prefers the heels as points for the attachment of its eggs, but eggs may be found on many other parts of the host. *H. bovis* oviposits on the legs, but more eggs are laid on the thighs and about the rumps of the cattle than with *H. lineatum*.

H. lineatum attaches its eggs in rows on the hairs; *H. bovis* deposits its eggs singly.

The usual incubation period for *H. lineatum* is from 3 to 6 days; for *H. bovis*, about 3 days.

After penetrating the skin the larvæ apparently work upward in the connective tissue and begin to appear in the chest and abdominal cavity about two months after penetration. Although many larvæ enter the connective tissue of the gullet it appears that many may never enter that organ. This is particularly true of *H. bovis*, as only one larva of this species was found among 1,140 specimens removed from 563 gullets in regions where this species abounds. Of 3,522 larvæ removed from 1,137 gullets, the majority were in the second stage, only a few being in the third.

The distance from the gullet and viscera to the subcutaneous tissues of the back is apparently traversed very rapidly by the larvæ. Soon after the larvæ reach the back they cut a hole through the skin. The duration of the third stage of *H. lineatum* after the skin of the back is punctured averaged 4.5 days at Dallas, Tex., and 4.26 days in New York; in *H. bovis* it averaged 3.35 days in New York. The average duration of the fourth stage of *H. lineatum* was 24.5 days and of *H. bovis*, 27.1 days. The development of the fifth stage of *H. lineatum* required an average of 30.3 days in Dallas, Tex., and that of *H. bovis* about 40 days in New York.

The total developmental period in the backs of cattle has been determined with fair accuracy in many individuals at points in Texas and New York. The three shortest developmental periods recorded at Dallas, Tex., were between 35 and 47, between 38 and 40, and between 39 and 46 days, respectively. The average at Dallas, Tex., was 56.3 days in one series and 57.7 days in another, whereas at Uvalde, Tex., it was 49.4 days. The developmental period of *H. bovis* in the backs of cattle in New York was 77 days (maximum), 65 days (minimum), and 72.8 days (average).

Mature larvæ may emerge from the host at any time of day or night, but the largest number as recorded by the writers emerged during the middle of the forenoon. The time from emergence from the host to appearance of the flies of *H. lineatum* at Dallas, Tex., ranged from 18 to 77 days, with an average of 41.7 days. In the case of *H. bovis* at Middletown, N. Y., this period ranged from 22 to 45 days, with an average of 31.34 days.

Mating of the adults of *H. lineatum* takes place very soon after emergence, and oviposition may begin a few minutes after copulation. There are some distinct differences in the habits of oviposition of *H. lineatum* and *H. bovis*. Among other things the flies of the latter species are more persistent in their attack on the cattle and induce greater fear in them. *H. lineatum* may ovipost at a temperature as low as between 40 and 45° F., but oviposits freely between 55 and 85° F.

The adults of *H. lineatum* lived in captivity from 1 to 25 days. The average life of the adults of this species is about 5 or 6 days and *H. bovis* has a similarly brief life span.

The seasonal history of *H. lineatum* varies widely according to latitude and other conditions. In southwestern Texas the flies may appear and lay eggs in the fall or early winter so that the whole life cycle may be correspondingly earlier than elsewhere in the country. As the higher latitudes and altitudes are approached the various stages in the life history are later. In the northern edge of the United States the adults do not begin to emerge until about April 1. The seasonal development of the larvæ is closely correlated with that of oviposition; for instance, in southwestern Texas the earliest grubs may reach the backs of the cattle in July, at Dallas, Tex., in September or October, at Ames, Iowa, during January, and at Herkimer, N. Y., in February. The earliest appearance of the larvæ of *H. bovis* in the backs of cattle is somewhat later than that of *H. lineatum*. The dates in different regions when the earliest larvæ become mature and leave the host, and the dates when the last larva has reached the back, are matters of much importance in connection with control and have been determined and mapped with a fair degree of accuracy in several parts of the country. In general the duration of infestation of the backs of cattle with *H. bovis* is longer than with *H. lineatum*, owing to the longer developmental period required by *H. bovis*.

Temperature, humidity, cloudiness, and drainage are important factors in natural control. Host resistance as acquired by age is also an important factor in holding down the abundance of Hypoderma. No important insect enemies or diseases affecting Hypoderma have been found.

The most effective time for the practice of control procedure is during the period of development of the larvæ in the subcutaneous tissues of the back. Destruction of the larvæ may be accomplished by hand extraction with or without the aid of forceps. In the case of certain breeds of cattle extraction of the grubs is very difficult.

Tests of the application of washes, powders, and ointments to the backs of the cattle and also the injection of substances into the cysts containing the larvæ show that each of these methods of treatment is effective if certain materials are used. Among the most effective should be mentioned: Derris used as a wash, as an ointment, or as a powder; iodoform used as an ointment; pyrethrum applied as an ointment; benzol and carbon tetrachloride injected into the grub cysts; fine tobacco applied in powder form and nicotine dust applied dry.

No adverse effects on the host have been observed in this country from the destruction of the grubs in the backs of cattle with suitable insecticides.

The cost of extraction or treatment depends on the skill of the operator but in all cases it is small compared with the benefits derived.

Experiments with the application to the feet and legs of cattle of certain insecticides and repellents by means of wading vats show that with the materials used control was not brought about, and indicate that attack directed against the eggs or young larvæ in this way will not be successful.

Results of individual effort against cattle grubs is likely to be disappointing, especially if the work is not thoroughly done and if untreated cattle are in close proximity to the treated herd.

Systematic treatment of all infested cattle in a neighborhood either by extraction or by the use of insecticides appears to be a practical method of control or eradication. Although these methods are best adapted to dairy or farm conditions it is probable that they may be modified so as to be applied successfully to range cattle.

In order successfully to combat the insects by destroying the larvæ in backs of cattle it is necessary to treat all infested cattle at intervals of not to exceed 35 days. The first treatment must be given before the earliest larvæ have matured and left the host. In most parts of the United States it is necessary to treat the animals four times during a season to reach all of the larvæ. The time of beginning the treatments in different parts of the country is indicated in the discussion of seasonal history.

58252°—26——8

LITERATURE CITED

(1) ANONYMOUS.
1919. Die Dasselplage (Hypoderma bovis). *In* Ztschr. Angew. Ent., Bd. 6, pp. 176–180.

(2) AUSTRALIA, COMMONWEALTH of.
1923. Quarantine Proclamation No. 108. *In* Commonwealth of Australia Gazette, No. 21, March 22, p. 398, Melbourne.

(3) BERG, J.
1895. Lidt om vandrende Bremselarver hos Kvæget. *In* Maanedsskr. Dyrlæger, 7. Bind, pp. 129–135.

(4) BISHOPP, F. C.
1915. The distribution and abundance of the ox warbles, Hypoderma lineata and H. bovis in the United States. *In* Ann. Ent. Soc. Amer., vol. 8, pp. 359–364, illus.

(5) BOAS, J. E. V.
1889. Bemærkninger til ovenstaaende Iagttagelse. *In* Tidsskr. Veterinærer, 19. Bind, pp. 76–83, illus.

(6) ———
1906. Om Oksebremsen og Midlerne til dens Udryddelse. Udgivet af Landbrugsministeriet. 14 pp., illus. Copenhagen.

(7) BORNAND, M.
1920. L'hypoderme du boeuf et ses conséquences au point de vue économique. *In* Bul. Soc. Vaud. Sci. Nat., vol. 53, Procés-Verbaux, pp. 55–58.

(8) BRAUER, F.
1863. Monographie der Oestriden. Herausgegeben von der K. K. Zool. Bot. Gesell. Wein. vi+292 pp., illus.

(9) ———
1890. Ueber die Feststellung des Wohnthieres der Hypoderma lineata Villers durch Dr. Adam Handlirsch und andere Untersuchungen und Beobachtungen an Oestriden. *In* Verhandl. K. K. Zool. Bot. Gesell. Wien, Bd. 40, pp. 509–515, illus.

(10) BRODERSEN, L.
1919. Om Rosenfeber hos Kvæg. *In* Maanedsskr. Dyrlæger, 31. Bind, pp. 321–323.

(11) ———
1922. Om Oksebremsens Bekæmpelse. *In* Maanedsskr. Dyrlæger, 34. Bind, pp. 305–310, illus.

(12) CARPENTER, G. H., and J. W. STEEN.
1908. The warble fly. Experiments on cattle as to its treatment and life history. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 8, pp. 227–246, illus.

(13) ———, and W. F. PRENDERGAST.
1909. The warble flies. Further experiments as to life-history and treatment. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 9, pp. 465–476, illus.

(14) ———, and T. H. CORSON.
1910. The warble flies. Third report on experiments as to life-history and treatment. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 10, pp. 642–650, illus.

(15) ———
1910. Notes on the Oestridae. *In* Extrait du 1er Congrès International d'Entomologie, pp. 289–294, illus.

(16) ———, and T. R. HEWITT.
1914. Some new observations on the life-history of warble-flies. The entrance of the maggot into the host's body. *In* Irish Nat., vol. 23, pp. 214–221.

(17) ———, ———, and T. K. REDDIN.
1914. The warble flies. Fourth report on experiments and observations as to life-history and treatment. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 15, pp. 105–132, illus.

(18) ———, and J. O. Hewitt.
1920. The warble flies. Fifth report on experiments and observations as to life-history and treatment. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 20, pp. 452–459, illus.

(19) ———, G. Phibbs, and T. Slattery.
1922. The warble flies. Sixth report on experiments and observations as to life-history and treatment. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 22, pp. 14–25.

(20) Clark, B.
1797. Observations on the genus Oestrus. *In* Trans. Linn. Soc. London, vol. 3, pp. 289–329, illus.

(21) ———
1827. Of the insect called Oistros by the ancients . . . *In* Trans. Linn. Soc. London, vol. 15, pp. 402–411.

(22) ———
1843. An appendix or supplement to a treatise on the Oestri and Cuterebrae of various animals. *In* Trans. Linn. Soc. London, vol. 19, pp. 81–94.

(23) Coppens, A.
1913. L'affection hypodermique du boeuf.—Le varon. *In* Ann. Méd. Vét. ann. 62, pp. 309–328, 384–388.

(24) Curtice, Cooper.
1890. The larvae of Hypoderma bovis, De Geer. *In* U. S. Dept. Agr., Div. Ent., Insect Life, vol. 2, pp. 207–208.

(25) ———
1891. The ox warble of the United States. *In* Jour. Compar. Med. and Vet. Arch., vol. 12, pp. 265–274, illus.

(26) Denmark, Kingdom of.
1923. Om Foranstaltninger til Udryddelse of Oksebremsenlarven. *In* Lovtidenden, No. 65, pp. 351–352, Copenhagen. (Not seen.)

(27) De Vries, H. J.
1910. Ein Beitrag zur Illustration des durch die Dasselfliege verursachten Schadens, und die Bekämpfung derselben beim Rindvieh. *In* Inaug.-Diss. Univ. Bern, 63 pp., illus.

(28) Duncan, J. L., T. R. Hewitt, and D. S. Jardine.
1914. The destruction of warble maggots. *In* Jour. Dept. Agr. Tech. Instr. Ireland, vol. 15, pp. 119–132, illus.

(29) Glaser, H.
1912–13. Über Dasselfliegen. *In* Mitteilungen des Ausschusses zur Bekämpfung der Dasselplage, No. 2, pp. 1–16, illus; No. 3, pp. 29–37, illus.; No. 4, pp. 1–26; No. 5, pp. 1–39, illus. Berlin.

(30) ———
1914. Le varon. *In* Ann. Méd. Vét., ann. 63, pp. 358–364.

(31) Greve, C.
1922. Zur Bekämpfung der Dasselplage mit giftigen Gasen. *In* Deut. Tierärztl. Wchnschr., Jahrg. 30, pp. 639–640.

(32) Hadwen, S.
1912. Warble flies. The economic aspect and a contribution on the biology. Canada Dept. Agr., Health of Animals Branch, Bul. 16, 20 pp., illus.

(33) ———
1915. Warble flies. A further contribution on the biology of Hypoderma lineatum and Hypoderma bovis. *In* Parasitology, vol. 7, pp. 331–338, illus.

(34) ———
1916. A further contribution on the biology of Hypoderma lineatum. Canada Dept. Agr., Health of Animals Branch, Sci. ser. Bul. 21, 10 pp., illus.

(35) ———
1918. Natural occurrence of oesinophilias. *In* Jour. Parasitology, vol. 4, pp. 135–137.

(36) ———
1919. Warble flies. Hypoderma lineatum, Villers and Hypoderma bovis, De Geer. Canada Dept. Agr., Health of Animals Branch, Sci. ser. Bul. 27, 24 pp., illus.

(37) ———
1922. Effects following improper methods of extracting Hypoderma larvae from the backs of cattle. *In* Jour. Amer. Vet. Med. Assoc., vol. 60, n. s. vol. 13, pp. 724–728.

(38) ———, and E. A. Bruce.
1916. Observations on the migration of warble larvae through the tissues. Canada Dept. Agr., Health of Animals Branch, Sci. ser. Bul. 22, 14 pp., illus.

(39) ———
1917. Anaphylaxis in cattle and sheep produced by the larvae of Hypoderma bovis, H. lineatum and Oestrus ovis. *In* Jour. Amer. Vet. Med. Assoc., vol. 51, n. s. vol. 4, pp. 16–44, illus.

(40) ———, and J. S. Fulton.
1924. On the migration of Hypoderma lineatum from the skin to the gullet. *In* Parasitology, vol. 16, pp. 98–106, illus.

(41) Hinrichsen.
1888. Ueber einen neuen Parasiten im Rückenmarkskanal des Rindes. *In* Arch. Wiss. u. Prakt. Thierheilk., Bd. 14, pp. 219–223.

(42) Hewitt, C. G.
1914. The occurrence of the warble fly Hypoderma bovis De Geer in Canada. *In* Canad. Ent., vol. 46, pp. 1–2.

(43) ———
1917. Report of the Dominion Entomologist for the year ending March 31, 1917. Canad. Dept. Agr., 24 pp. Ottawa.

(44) ———
1920. Report of the Dominion Entomologist and Consulting Zoologist for the two years 1917 and 1918. Canad. Dept. Agr., 23 pp., illus.

(45) Horne, H.
1894. Bremserlarver i rygmarkskanalen og kjődet hos oxen. *In* Norsk Veterinær-Tidsskr. [Kristiania], VII. Bind, pp. 33–40. (Not seen.)

(46) Howard, C. W.
1912. Insects directly or indirectly injurious to man and animals in Mozambique, East Africa. *In* Bul. Ent. Research, vol. 3, pp. 211–218.

(47) Hutcheon, D.
1914. Bots or "paapjes." *In* Agr. Jour. Union S. Afr., vol. 8, pp. 194–200.

(48) Imes, M., and F. L. Schneider.
1921. Experimental treatment of cattle to prevent ox warble infestation. *In* Jour. Amer. Vet. Med. Assoc., vol. 59, n. s. vol. 12, pp. 722–727.

(49) Jensen, C. O.
1919. Bemærkninger om Hypodermalarvernes Forhold til Rosenfeber. *In* Maanedsskr. Dyrlæger, 31. Bind, pp. 324–326.

(50) Johnson, C. W.
1910. Some additions to the dipteran fauna of New England. *In* Psyche, vol. 17, pp. 228–235.

(51) Joly, M. N.
1846. Recherches zoologiques, anatomiques, physiologiques et médicales sur les Oestrides en général, et particulièrement sur les oestres qui attaquent l'homme, le cheval, le boeuf et le mouton. *In* Ann. Sci. Phys. Nat. d'Agr. d'Ind. [Lyon], tome 9, pp. 157–305, illus.

(52) Jost, H.
1907. Beiträge zur Kenntnis des Entwicklungsganges der Larve von Hypoderma bovis De Geer. *In* Ztschr. Wiss. Zool., Bd. 86, pp. 644–715.

(53) Koch, T. P.
1903. Om Oksebremsen Hypoderma bovis. Specielt Larvens Udvikling og Vandring i Kvægets Legeme. *In* Maanedsskr. Dyrlæger, 15. Bind, pp. 129–159.

(54) Koorevaar, P.
1898. De larvetoestand van Hypoderma bovis. *In* Tijdschr. Nederland. Dierk. Ver., (2) deel 5, pp. 29–34. Translated in Ann. and Mag. Nat. Hist., (7) vol. 4, pp. 69–73, 1899.

(55) ———
1898. Hypoderma bovis und ihre jüngsten Larven. *In* Centbl. Bakt. [etc.], Abt. 1, Bd. 23, p. 888–892.

(56) Krause, R.
1912. Dasselschäden und Abdasselung. *In* Mitteilungen des Ausschusses zur Bekämpfung der Dasselplage, No. 1, pp. 1–28. Berlin.
(57) Laake, E. W.
1921. Distinguishing characters of the larval stages of the ox-warbles Hypoderma bovis and Hypoderma lineatum, with description of a new larval stage. *In* U. S. Dept. Agr., Jour. Agr. Research, vol. 21, pp. 439–457, illus.
(58) ———
1924. Further observations on the molts of the ox bots Hypoderma bovis De Geer and H. lineatum Villers. *In* U. S. Dept. Agr., Jour. Agr. Research, vol. 28, pp. 271–274.
(59) Lehmann, N., and C. Vaney.
1911. Pourcentages et qualités des peaux attaquées par les larves de l' Hypoderma du boeuf dans la région lyonnaise. *In* Compt. Rend. Acad. Sci. [Paris], tome 152, pp. 1343–1345.
(60) ———
1911. Relations entre les conditions climatériques et la fréquence des larves de l'Hypoderme du boeuf. *In* Compt. Rend. Acad. Sci. [Paris], tome 152, pp. 1508–1510.
(61) Linné, K. von.
1739. Om Renarnas broemskulor i Lapland. (Oestrus.) *In* K. Svenska Vetensk. Akad. Handl., vol. 1, pp. 119–130.
(62) Lounsbury, C. P.
1914. Warble flies. A danger with imported cattle. *In* Agr. Jour. Union S. Afr., vol. 8. pp. 61–64, illus.
(63) Lucet, A.
1914. Recherches sur l'évolution de l'Hypoderma bovis De Geer et les moyens de le détruire. *In* Compt. Rend. Acad. Sci. [Paris], tome 158, pp. 812–814, 968–970.
(64) Marlatt, C. L.
1897. The ox warble. U. S. Dept. Agr. Div. Ent. Cir., 2d ser., 25, 10 pp., illus.
(65) Mason, F. A.
1921. Biology and its relationship to the leather industry. *In* Leather Trades' Yearbook, 13th ed., pp. 98–108, illus.
(66) Maxwell-Lefroy, H. M., and F. M. Howlett.
1909. Indian insect life. A manual of the insects of the plains (Tropical India). xii+786 pp. Calcutta, 1909.
(67) Mitteilungen des Ausschusses zur Bekämpfung der Dasselplage. 1912–1919. 7 reports. Berlin. (See references *29*, *76*, *87*, and *88*.)
(68) Mohler, J. R.
1922. Report of the Chief of the Bureau of Animal Industry, U. S. Dept. Agr., 62 pp. Washington.
(69) Mote, D. C.
1917. Observations on the distribution of warble flies in Ohio. *In* Ohio Jour. Sci., vol. 17, pp. 169–176, illus.
(70) O'Kane, W. C.
1922. One year of the Crop Protection Institute. *In* Jour. Econ. Ent., vol. 15, pp. 209–213.
(71) Ormerod, E. A.
1894. Observations on warble fly or ox bot fly, Hypoderma bovis, De Geer. 62 pp., illus. London.
(72) ———
1900. Flies injurious to stock, being life-histories and means of prevention of a few kinds commonly injurious, with special observations on ox warble or bot fly. pp. viii+80, illus. London.
(73) Osborn, H.
1896. Insects affecting domestic animals. . . . U. S. Dept. Agr., Div. Ent., n. s. Bul. 5, 302 pp., illus.
(74) Ostertag, R.
1906. Die Dasselfliegenplage und ihre Bekämpfung durch ein Gesetz. *In* Ztschr. Fleisch u. Milchhyg., Jahrg. 16, pp. 407–413.
(75) Patton, W. S.
1924. Note on the occurrence of Hypoderma lineatum Villers in the Punjab. *In* Indian Jour. Med. Research, vol. 11, pp. 961-962.

(76) PETER, B.
1912. Versuche mit Hypodermenlarven. *In* Mitteilungen Ausschusses zur Bekämpfung der Dasselplage, No. 3. 18 pp., illus. Berlin.

(77) ———
1923. Gegenwärtiger Stand in der Bekämpfung der Dasselplage. *In* Berlin. Tierärtzl. Wchnschr., Jahrg. 39, pp. 207–210.

(78) PHIBBS, G.
1922. The larval mouth-hooks of Hypoderma. *In* Irish Nat., vol. 31, pp. 25–30, illus.

(79) POUND, C. J.
1915. Report of the Government bacteriologist. *In* Dept. Agr. Stock Queensland Ann. Rpt. (1914–15), pp. 62–68.

(80) RAILLIET, A.
1894. Recherches sur l'origine des larves d'oestridés de l'estomac du chien. *In* Compt. Rend. Soc. Biol. [Paris], (sér. 10, tome 1), tome 46, pp. 541–543.

(81) RÈNE, C.
1917. Les larves d'oestres chez les animaux. *In* Progrès Agricole [Amiens], 31e ann., pp. 410–411. (Not seen.)

(82) RILEY, C. V.
1889. The bot-fly of the ox, or ox warble. *In* U. S. Dept. Agr., Div. Ent., Insect Life, vol. 2, pp. 156–159, illus.

(83) ———
1889. The ox warble (Hypoderma bovis De Geer). *In* Insect Life, vol. 2, pp. 172–177, illus.

(84) ———
1892. The ox bot in the United States. Habits and natural history of Hypoderma lineata. *In* U. S. Dept. Agr., Div. Ent., Insect Life, vol. 4, pp. 302–317, illus.

(85) ROUBAUD, E.
1914. Études sur la faune parasitaire de l'Afrique Occidentale Française. Fasc. 1. Les producteurs de myiases et agents similaires chez l'homme et les animaux. 251 pp., illus. Paris.

(86) RUSER, WILHELM.
1895. Ueber das Vorkommen von Oestruslarven im Rückenmarkskanal des Rindes. *In* Ztschr. Fleisch u. Milchhyg., Jahrg. 5, pp. 127–129.

(87) SCHÖTTLER, DOCTOR.
1912. Über Abdasseln. *In* Mitteilungen des Ausschusses zur Bekämpfung der Dasselplage, No. 3, pp. 19–28. Berlin.

(88) ——— and H. GLASER.
1914. Der Abdasslversuch. *In* Mitteilungen des Ausschusses zur Bekämpfung der Dasselplage, No. 6, pp. 1–31. Berlin.

(89) SCHÖYEN, W. M.
1886. Om Forekomsten af Dipterlarver under Huden hos Mennesker. *In* Ent. Tidskr., årg. 7, pp. 171–187, illus.

(90) SEYMOUR-JONES, A.
1921. Warble flies and their maggots in cattle. *In* Leather Trades' Year Book, 13th ed., pp. 169–188, illus. London.

(91) ———
1922. The warble fly problem. *In* Jour. Amer. Leather Chem. Assoc., vol. 17, pp. 15–26.

(92) SMIT, H. J.
1922. Parasitologische Studien in Nederländisch-Indien. 11. Gastrophiluslarven in Nederländisch-Indien. *In* Deut. Tierärztl. Wchnschr., Jahrg. 30, pp. 546–547.

(93) SÖRENSEN, W.
1908. Hvorledes lever Larven af Hypoderma bovis De Geer? *In* Ent. Tidskr., årg. 29, pp. 65–116, illus.

(94) STEGMANN, P.
1920. Die Bekämpfung der Dasselfliege. 23 pp. Berlin.

(95) STUB, C.
1912. Bidrag til Oksebremsens Biologi. *In* Maanedsskr. Dyrlæger, 24. Bind., pp. 409–410.

(96) ———
1913. Udklækning af Oksebremser. Oksebremsens Ophold og Æglægning paa den levende Okse. Hypoderma-Larvers Forekomst hos Kalve. Hypoderma lineatum's Forekomst in Danmark. *In* Maanedsskr. Dyrlæger, 25. Bind, pp. 336–340, illus.

(97) ———
1913. Bidrag til Oksebremsens Biologi. *In* Maanedsskr. Dyrlæger, 25. Bind, pp. 482–487, illus.

(98) ———
1915. Bidrag til Oksebremsens Biologi. *In* Nordisk Garvertidende, 38. Bind, No. 21, p. 23. (Not seen.)

(99) ———
1919. Hypodermalarvers Indtrængen gennem Oksens Hud. *In* Maanedsskr. Dyrlæger, 31. Bind, pp. 230–231.

(100) Tryon, H.
1906. Report of the Entomologist and Vegetable Pathologist. *In* Dept. Agr. Stock Queensland Ann. Rpt. (1905–1906), pp. 64–73.

(101) ———
1912. Report of the Entomologist and Vegetable Pathologist. *In* Dept. Agr. Stock Queensland Ann. Rpt. (1911–12), pp. 94–104.

(102) Vallisnieri, A.
1710. Considerazioni ed esperienze intorno alla generazione de vermi ordinarj del corpo umano. 160 pp., illus. Padova.

(103) ———
1713. Esperienze ed osservazioni intorno all'origine, sviluppi e costumi di varj insetti. 232 pp., illus. Padova.

(104) Vaney, C.
1911. Le développement de l'hypoderme du boeuf. *In* Assoc. Française pour le Destruction du Varron [Bul.] No. 1, pp. 24–38, illus. Paris.

(105) ———
1911. Recherches sur la developpement de l'hypoderme du boeuf (Hypoderma bovis de Geer). *In* Compt. Rend. Acad. Sci. [Paris], tome 152, pp. 283–286.

(106) ———
1920. Conference sur le varron. *In* Extrait Bul. Assoc. Française Destruction du Varron. Juin. (Not seen.)

(107) ———, and G. Tainturier.
1911. Dégénérescence de quelques formes larvaires de l'hypoderme du boeuf (Hypoderma bovis de Geer). *In* Compt. Rend. Acad. Sci. [Paris], tome 152, pp. 1192–1194.

(108) Van Dine, D. L., and V. A. Norgaard.
1908. Abstract of preliminary report on insects affecting live stock in Hawaii. *In* Rept. 5th Ann. Meeting Hawaiian Livestock Breeders' Assoc., pp. 19–70.

(109) Van Es, L., and A. F. Schalk.
1917. Notes on parasitic anaphylaxis and allergy. N. Dak. Agr. Exp. Sta. Bul. 125, pp. 149–193, illus.

(110) Warburton, C.
1922. The warble flies of cattle, Hypoderma bovis and H. lineatum. *In* Parasitology, vol. 14, pp. 322–341, illus.

(111) Wells, R. W., F. C. Bishopp, and E. W. Laake.
1922. Derris as a promising insecticide. *In* Jour. Econ. Ent., vol. 15, pp. 90–95.

(112) Willcocks, F. C.
1918. Notes on some insects found in Egypt of medical and veterinary interest. *In* Bul. Soc. Ent. d'Egypte, ann. 10, pp. 79–90.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

March 23, 1926

Secretary of Agriculture	W. M. Jardine.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	————
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Information	Nelson Antrim Crawford.
Director of Personnel and Business Administration	W. W. Stockberger.
Solicitor	R. W. Williams.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Agricultural Economics	Thomas P. Cooper, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	W. B. Greeley, *Chief.*
Bureau of Chemistry	C. A. Browne, *Chief.*
Bureau of Soils	Milton Whitney, *Chief.*
Bureau of Entomology	L. O. Howard, *Chief.*
Bureau of Biological Survey	E. W. Nelson, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Bureau of Dairying	C. W. Larson, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. Cottrell, *Director.*
Office of Experiment Stations	E. W. Allen, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*
Insecticide and Fungicide Board	J. K. Haywood, *Chairman.*
Packers and Stockyards Administration	John T. Caine, *in Charge.*
Grain Futures Administration	J. W. T. Duvel, *in Charge.*

This bulletin is a contribution from

Bureau of Entomology ---------- L. O. Howard, Chief.

120

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
25 CENTS PER COPY
▽

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1371

Washington, D. C. ▼ January, 1926

EFFECTIVENESS AGAINST THE SAN JOSE SCALE OF THE DRY SUBSTITUTES FOR LIQUID LIME-SULPHUR

By

W. S. ABBOTT, Entomologist, and JULIAN J. CULVER, Assistant Entomologist,
Enforcement of the Insecticide Act, Bureau of Entomology, and
W. J. MORGAN, Associate Chemist, Insecticide and Fungicide Laboratory,
Miscellaneous Division, Bureau of Chemistry

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1371

Washington, D. C. ▼ January, 1926

EFFECTIVENESS AGAINST THE SAN JOSE SCALE OF THE DRY SUBSTITUTES FOR LIQUID LIME-SULPHUR

By W. S. ABBOTT, *Entomologist*, and JULIAN J. CULVER, *Assistant Entomologist, Enforcement of the Insecticide Act, Bureau of Entomology*, and W. J. MORGAN, *Associate Chemist, Insecticide and Fungicide Laboratory, Miscellaneous Division, Bureau of Chemistry*

CONTENTS

INTRODUCTION

Several dry substitutes for liquid lime-sulphur have been on the market for a number of years, but their value as remedies against the San Jose scale (*Aspidiotus perniciosus* Comstock) appears to be a disputed point. A brief abstract of the published experiments covering this point is given below.

The Arkansas station in 1921 (*4, p. 13*) [1] summarizes its work with certain sprays against the San Jose scale by stating that barium-sulphur,[2] calcium-sulphur, and sodium-sulphur "while highly effective in the season of 1921, were not so satisfactory during the two previous years, and can not yet be given as strong a recommendation as lime-sulphur."

In the annual report of the State entomologist of Colorado for 1922 (*25, p. 47*) experiments with a dry calcium-sulphur used on plots 6, 7, and 8, respectively, at the rate of 49, 50, and 56 pounds to 200 gallons of water are summarized as follows:

> In the dry lime-sulphur plots, plot No. 8 shows a 3.08 per cent better kill than plot No. 6. This difference might possibly be attributed to the nozzle holder as different men did the work. Plot No. 7 shows perfect control, but the infestation was so light that a satisfactory count could not be made.

The Connecticut station in 1923 (*5, p. 330*) reports the following results of experiments against the San Jose scale: Liquid lime-sulphur, 77.3 per cent killed; barium-sulphur, 72.6 per cent killed; calcium-sulphur, 74.9 per cent killed.

[1] Reference is made by number (roman) to "Literature cited," pp. 25 and 26.

[2] For convenience in discussion the substitutes for liquid lime-sulphur are referred to as calcium, sodium, and barium sulphurs.

The Idaho station in 1918 (*9, p. 9*) says, "Dry lime-sulphur manufactured by the * * * company was added to the experiment in 1917. It gave very encouraging results, but we are not prepared at this time to make any recommendations regarding this spray."

On page 15 results with a sodium-sulphur are given as follows: 1915, 20 pounds to 100 gallons of water, 64 per cent killed; 1916, 25 pounds to 100 gallons of water, 82 per cent killed; 1917, 25 pounds to 100 gallons of water, 93 per cent killed.

In the summary it is stated that the sodium-sulphur "gave fairly good results in 1917, but we can not recommend its use over lime-sulphur."

The Illinois station in 1919 (*6, p. 4*) records tests made with a sodium-sulphur, a barium-sulphur, and two calcium-sulphurs, showing the following results: Sodium-sulphur, excellent control; barium-sulphur, fair to good control; calcium-sulphurs, excellent control.

In Bulletin XIII of the Division of Natural History Survey for November, 1920 (*10, pp. 341–342*), additional tests are reported for one orchard as follows: Sodium-sulphur, good control; barium-sulphur, good control; calcium-sulphur No. 1, good to excellent control; calcium-sulphur No. 2, good control; calcium-sulphur No. 3, poor to fair control.

For another orchard: Sodium-sulphur, fair to good control; barium-sulphur, fair to good control; calcium-sulphur No. 1, good control; calcium-sulphur No. 2, good control; calcium-sulphur No. 3, very poor control.

The general conclusions are:

> The results of two years' work with these materials seem to show that some dry sulphur compounds, if used at sufficient strength, are effective in controlling the San Jose scale. From the results of the past season where * * * dry lime-sulphur was used at a strength of 12½ pounds to 50 gallons of water, it is apparent that these materials should not be used at a less rate than 15 pounds to 50 gallons of water.

In 1922 (*22, p. 2*) it is stated that "the diluted spray must contain 15 pounds of sulphur in 50 gallons," and in 1924 (*2, p. 8*) the following recommendation is made: Each 50 gallons of dormant spray should contain * * * or 15 [3] to 28 [4] pounds of dry lime-sulphur * * *.

In its annual report for the year 1919 (*7, p. 44*) the Kentucky station says:

> *Use of dry lime-sulphur in sprays.*—Four samples of dry lime-sulphur were submitted by the department of horticulture for analysis. It had been noted that the use of the particular samples did not give the results expected.

The Missouri station in 1920 (*13, p. 7*) states:

> Some report good results with dry lime-sulphur used at the rate of about 1 pound to 4 gallons of water. However, the writer's experience leads him to believe that in their present form the brands of dry lime-sulphur will not control this pest as effectively as the better brands of lime-sulphur solution.

In 1922 (*14, p. 62*) are reported tests with three calcium-sulphurs, one barium-sulphur, and one sodium-sulphur used at the rate of 12 and 20 pounds to 50 gallons. In no case were the dry materials as effective as liquid lime-sulphur, and the following conclusions are drawn: "The above results show that it was practically impossible to eradicate San Jose scale from infested peach trees by means of

[3] Recommendation for points north of Hancock and Vermilion Counties.
[4] Recommendation for Hancock and Vermilion Counties and points in same latitude or south.

a spray, but the proper application of most of the materials listed gave good control."

In 1923 (*15, p. 2*) it is stated:

During the past three years most growers in this State have controlled the scale with lime-sulphur, though some have lost faith in it. Dry lime-sulphur preparations have failed in our experiments to give satisfactory control.

The New Mexico station in its annual report for 1918–19 (*12, p. 15*) says:

5. *San Jose scale.*—Dry lime-sulphur and concentrated lime-sulphur were used as sprays for the above scale. The dry lime-sulphur dissolves readily, with little or no residue, is much more easily prepared, saves time, and is just as effective. Many of the chemical spray companies think the prices will be so reduced in another year that every farmer and orchardist will be able to use it. Between the two above sprays, the dry lime-sulphur is the coming insecticide for the San José scale.

In the report of the New York station for 1923 (*20, p. 41*) is found the following statement:

In this season's efforts provision was made for tests of various commercial sulphides in a powdered or granular state in comparison with lime-sulphur solution at standard strength. On the basis of the initial killing of the San Jose scale on old apple trees, the dry sulphides were noticeably inferior to lime-sulphur, while oil emulsions gave better control of the pest than lime-sulphur.

In the monthly bulletin of the Ohio station for February, 1920 (*16, pp. 50–51*), tests are reported with one calcium-sulphur, one sodium-sulphur, and one barium-sulphur, and it is stated that "commercial or practical control" was obtained.

In a later issue (*1, p. 25*) the following statement is made:

The powdered lime-sulphur has not yet been sufficiently tested to warrant us in recommending it as a perfect substitute for the liquid lime-sulphur, but we have cleaned an orchard badly encrusted with San Jose scale by applying it in the spring, 12 pounds to 50 gallons of water. * * * Until more extensively tested we do not recommend it as being so reliable for cleaning badly infested orchards as liquid lime-sulphur or miscible oil, but believe it can be safely used for a few seasons, at least, as a dormant spray in orchards only slightly or not at all infested with scale. For dormant use, mix 15 pounds with 50 gallons of water.

The Oregon station in 1924 (*21, p. 8*) states that barium-sulphur "has been shown to be a fairly effective contact poison, but it possesses no distinct advantage over the lime-sulphur solution except that it is in powder form and convenient to handle," and sodium-sulphur "is similar to lime-sulphur except that lye is used instead of lime in its preparation. As a dormant spray it has been found satisfactory, but it has no superiority over the lime-sulphur."

In reference to calcium-sulphur this bulletin says:

When dry lime-sulphur is used either for the dormant spray or for the summer sprays it should be applied in amounts equivalent to the liquid lime-sulphur in order to obtain equivalent protection. Since each gallon of lime-sulphur solution contains 3.4 pounds of active ingredients it would take 4 pounds of a dry lime-sulphur having 85 per cent active ingredients to be equivalent to 1 gallon of liquid lime-sulphur. Therefore, in making dilutions for the various sprays 4 pounds of the dry lime-sulphur should be used for each gallon of liquid lime-sulphur, Baumé 33°, necessary. While this amount is much higher than is recommended by the manufacturer, field experiments carried on in different parts of the country have indicated conclusively the need of using larger amounts than the manufacturers have recommended in the past, particularly when weather conditions favor the development of serious disease epidemics.

The Texas station in 1920 (*24, p. 7*) summarizes the results of tests made with a sodium and a calcium-sulphur and a commercial liquid lime-sulphur as follows:

The fact that infestation increased heavily on all the trees in the check rows while at the same time there was nearly perfect control in the case of the sprayed trees, shows that all three materials were very effective in controlling the San Jose scale under the conditions of this experiment. So far as we could determine, there was very little if any difference in the effectiveness of the three materials.

It is realized, of course, that this is only a preliminary experiment and that further tests should be made with such mixtures before final recommendations can be made.

Numerous experiments with dry sulphur preparations are reported by the Washington station (*17; 18, p. 21*) and the conclusions are drawn that in certain parts of the State none of the sulphur sprays are effective against the San Jose scale.

In the April, 1924, issue of the Journal of Economic Entomology (*8, p. 288–289*), J. J. Davis, of Purdue University, reports a large series of tests made with various preparations against the San Jose scale, and says:

Results.—We have concluded from these tests and many scattered observations, that the dry lime-sulphur is inefficient against the San Jose scale as it occurs at the present time in southern Indiana when used at label strength. The liquid concentrate proved ineffective under the conditions which have prevailed in southern Indiana the past few years. These results are corroborated by results secured where the scale could not be checked even when 1–6 strengths were used thoroughly. Even with a 90 per cent kill, the 10 per cent live scales on moderately or heavily infested trees are able to increase and encrust a vigorous tree by fall. The dry lime-sulphur when used at twice label strength was about equal in effectiveness to the liquid concentrate.

The lack of agreement in the conclusions reached by the investigators quoted above may be explained in several ways:

(1) The results were taken in many different ways and, in some cases, the methods used apparently do not correctly represent the effect of the treatment on the hibernating scale.

(2) These experiments cover a period of six years, and it is generally recognized by entomologists that the virility of this scale in a given locality may vary greatly in the course of several years, and, moreover, some of these tests were made when the vitality of the scale was very low. This has been well shown in Arkansas (*3*) where, prior to 1918, the scale had been kept in check by one dormant treatment with liquid lime-sulphur. From 1919 to 1922 this pest became so virulent that liquid lime-sulphur could no longer be relied on, even when two applications at greatly increased strengths were used. That this was not the result of faulty spraying is shown by experiments of the Bureau of Entomology at Bentonville, Ark., in 1921 and 1922.

(3) It is also a well-established fact that the vitality of this species of scale varies with the locality, and some of these experiments were made in sections where the scale is not difficult to control. This regional variation in resistance has been demonstrated by the work of A. L. Melander (*19*) in Washington.

(4) In many cases only the percentage of dead or living scale is given and such results are very misleading if the number of dead scales in the untreated plats, or checks, is not taken into consideration.[5]

[5] See "Percentage of control," p. 6.

In view of these very conflicting data, further experiments were deemed necessary, and the entomologists of the Insecticide and Fungicide Board, working under the direction of the Bureau of Entomology, have, therefore, very carefully tested a representative series of the dry substitutes for liquid lime-sulphur, as dormant sprays against the San Jose scale.[6]

These preparations have been tried at several dilutions under practical orchard conditions as dormant sprays against the San Jose scale on peach trees in Mississippi and Alabama and on apple trees in Indiana and Virginia. In every case unsprayed trees and trees sprayed with liquid lime-sulphur were included as controls.

The tests, which cover a period of three years and have been carried on in four different States, form the basis of this report and they are confirmed by numerous other experiments that have been made in cooperation with the writers in other parts of the country.[7]

MATERIALS USED

All of the materials used in these experiments were purchased in the open market, analyzed, and kept under seal until tested. New samples were collected each year and nothing but fresh material, which had not been exposed to the air, was used. Although the different samples vary slightly in chemical composition, they are, on the whole, very similar and typical of the dry substitutes for liquid lime-sulphur now being sold. The analyses of the preparations tested are given in tables preceding each set of experiments.

LIQUID LIME-SULPHUR

A good commercial liquid lime-sulphur solution should test from 32 to 33° Baumé (sp. gr. 1.283 to 1.295), and analyze approximately as follows: Calcium polysulphide 30 to 32 per cent; calcium thiosulphate 1.5 to 2.5 per cent; traces of calcium sulphate; impurities from the lime; and the remainder water. A comparison of the composition of the liquid and dry lime-sulphurs shows that the latter contain roughly about twice as much calcium polysulphides; from three to five times as much calcium thiosulphate; and, in addition, from 8 to 14 per cent of free sulphur, which does not occur in liquid lime-sulphur solution.

Since a gallon of commercial liquid lime-sulphur (32° Baumé) weighs about 10.7 pounds and contains approximately 32 per cent of calcium polysulphides, a dilution of 6.66 gallons to 50 gallons of spray (1 to 7.5), which was the strength used in the tests here reported, will furnish approximately 22.8 pounds of calcium polysulphides in each 50 gallons of spray material.

RECORDS TAKEN

Two kinds of records were taken in these experiments, one on the hibernating scales and one on the young scales settling on new wood.

In order to determine the effect of the treatment on the hibernating scales, a number of twigs and branches were cut from all parts of the

[6] The field experiments were under the direct supervision of J. J. Culver, who also made nearly all of the records.

[7] A. J. Ackerman in Arkansas, O. I. Snapp in Mississippi, J. J. Culver in Georgia, and J. E. Fouser and J. J. Davis in Indiana.

record trees. These were placed under a binocular, the scale covering was lifted with a needle, and the scale examined to determine whether it was living or dead. Two thousand scales were counted from each plat, except from those used in the 1921 experiments in Indiana, where only 1,000 were counted. In this examination only the hibernating females were recorded, the last season's dead scales and the young scales, which would not in any case survive the winter, being disregarded. These counts were made approximately one month after treatment.[8]

In addition to the examination of the hibernating scale to determine the percentage actually killed by the spray, a careful count of the newly settled scale on 80 linear inches of new wood was made. This was done for the first and second generations on peach trees and for the first generation on apple. These records show the continued effect of the dormant spray as well as the value of the treatment in preventing reinfestation of the treated trees.

For this purpose a number of twigs with a total length of 80 linear inches were selected from each plat, care being taken to secure representative twigs from branches with approximately the same original infestation. The number of newly settled scales on these 80 inches of wood was counted and the average number per inch taken as a measure of the reinfestation resulting from the scale not killed by the dormant spray.

PERCENTAGE OF CONTROL

In computing the actual value of a given treatment against an insect where it is possible to make an accurate count of the living and dead individuals and no satisfactory data can be obtained to show the effect of the infestation on the host plant or the crop produced, it is necessary to take into account the number of dead insects in the untreated check. In the following experiments the figure designated "percentage of control" is obtained as follows:

Let X = per cent living in the untreated check.

Let Y = per cent living in the treated plat.

Then $X-Y$ = per cent actually killed by the treatment.

The ratio of the percentage actually killed by the treatment ($X-Y$) to the percentage living in the check (X) will give the actual efficiency of the spray, or $\frac{X-Y}{X} \times 100$ = per cent control.

DRY CALCIUM-SULPHURS

These so-called dry lime-sulphurs, which are sold as substitutes for liquid lime-sulphur solutions, are of comparatively recent development, and their sale has reached large proportions. The great quantity of water in lime-sulphur solutions makes this product objectionable as a commercial preparation from the standpoint of packing and shipping. Many efforts have been made to eliminate this feature and to obtain a lime-sulphur product in dry form that is at the same time susceptible to ready solution. Several "dry" methods of preparation have been tried, but in general the method of manufacture

[8] A. L. Melander (*19*) has shown that an examination made at this time gives the most reliable index of the efficiency of a dormant spray against the San Jose scale.

is first to prepare commercial lime-sulphur solution in the usual manner, then to add a "stabilizing" substance (usually cane sugar), and finally to evaporate the solution to dryness, either in vacuo or at atmospheric pressure in the presence of an inert gas. Several patents have been issued for the preparation of a dry lime-sulphur,[9] but practically all of that produced at the present time is made by the process of evaporation under reduced pressure in the presence of a "stabilizer."

CHEMICAL COMPOSITION

Commercial dry calcium-sulphur, or dry lime-sulphur as it is usually called, contains a relatively large percentage of insoluble matter, consisting chiefly of free sulphur and smaller amounts of calcium sulphite and lime. This high percentage of insoluble matter is objectionable because it decreases the active ingredients and tends to clog the nozzle of the spraying apparatus. The average composition of six different brands of dry lime-sulphurs,[10] representing the principal brands on the market, are given in Table 1.

TABLE 1.—*The chemical composition of representative dry lime-sulphurs*

Brand	Average percentage found				Number of samples averaged
	Calcium polysulphides [1]	Calcium thiosulphate [2]	Free sulphur	Other ingredients (diff.) [3]	
A	67.31	6.96	8.44	17.29	10
B	64.67	9.66	10.31	15.36	10
C	70.59	8.72	8.09	12.60	4
D	59.68	8.15	11.79	20.38	5
E	60.82	6.42	14.08	18.68	4
F	64.69	9.09	8.87	17.35	10
Weighted average	64.90	8.34	9.86	16.91	43

[1] The sum of the polysulphide sulphur and the polysulphide calcium.
[2] Thiosulphate sulphur calculated to calcium thiosulphate, CaS_2O_3.
[3] Mainly water, sugars, calcium sulphite and insoluble impurities.

EXPERIMENTS IN 1921

For the experiments made in Indiana in 1921 an old apple orchard at Washington, Ind., badly infested with the San Jose scale, was used. This was divided into plats of three to five trees, each with approximately the same infestation. A dormant spray was applied on March 22 and 23, using a power sprayer maintaining a pressure of 225 pounds, with two spray guns. From 9 to 12 gallons of spray were applied to each tree.

The composition and dilutions of the essential materials used are given in Table 2.

[9] United States patents Nos. 460,227; 997,601; 1,186,561; 1,231,741; 1,254,908; 1,336,957; 1,338,678; 1,374,951; 1,422,977; and 1,423,605.
[10] Material purchased on the open market.

TABLE 2.—*Composition of the dry calcium-sulphurs tested in experiments against the San Jose scale in 1921*

Material used	Per cent of— Calcium polysulphide	Per cent of— Calcium thiosulphate	Per cent of— Free sulphur	Quantity used in 50 gallons of spray	Quantity of polysulphides in 50 gallons
					Pounds
Dry lime-sulphur A	71.87	7.38	4.70	13.5 lbs.	9.70
Do	71.87	7.38	4.70	20 lbs.	14.37
Do	71.87	7.38	4.70	27 lbs.	19.40
Dry lime-sulphur B	64.80	8.81	11.15	12.5 lbs.	8.10
Do	64.80	8.81	11.15	19.5 lbs.	12.63
Do	64.80	8.81	11.15	25 lbs.	16.20
Dry lime-sulphur C	73.92	9.35	4.09	13.5 lbs.	9.97
Do	73.92	9.35	4.09	19 lbs.	14.04
Do	73.92	9.35	4.09	27 lbs.	19.95
Liquid lime-sulphur [1]	31.57	1.95	----------	6.66 gals.	22.75
Do	31.57	1.95	----------	3.25 gals.	11.10

[1] Sp. gr. 1.30; Baumé 33.4°.

On April 23, twigs were taken from all parts of the trees and a count of 1,000 hibernating scales was made for each plat. The results of these experiments are given in Table 3.

TABLE 3.—*Results of tests against the San Jose scale made on apple trees at Washington, Ind., in 1921*

Material used	Quantity in 50 gallons of spray	Hibernating scale Dead	Hibernating scale Control
	Pounds	*Per cent*	*Per cent*
Dry lime-sulphur A	13.5	75.2	14.5
	20	83.6	43.5
	27	80.4	32.4
Dry lime-sulphur B	12.5	78.3	25.2
	19.5	84.0	44.8
	25	83.1	41.7
Dry lime-sulphur C	13.5	71.2	.7
	19	89.6	64.1
	27	84.0	44.8
	Gallons		
Liquid lime-sulphur	6.66	88.4	60.0
	3.25	70.4	0
Check	(1)	71.0	----------

[1] Untreated.

The results shown in Table 3 indicate that at dilutions of 12.5 to 13.5 pounds to 50 gallons these dry lime-sulphurs were of no practical value against the San Jose scale, and when the strength was increased they did not furnish a practical control. Liquid lime-sulphur used at the rate of 3.25 gallons to 50 gallons of water, which is roughly equivalent to the weaker strength of the dry materials, was of no value.

EXPERIMENTS IN 1922

The experiments on apple trees in 1922 were conducted at Bicknell, Ind., in a scale-incrusted orchard, which was divided into plats of three to five record trees. The application was made on March 15, using a power sprayer which maintained a pressure of 250 to 275 pounds with one spray gun and one rod. From 9 to 10 gallons of spray were used per tree. The composition and dilution of the essential materials in the sprays are shown in Table 4.

TABLE 4.—*Composition of the dry calcium-sulphurs tested in experiments against the San Jose scale in 1922*

Material used	Percentage of— Calcium poly-sulphides	Calcium thio-sulphate	Sulphur	Quantity used in 50 gallons of spray	Quantity of poly-sulphides in 50 gallons
				Pounds	*Pounds*
Dry lime-sulphur A	70.72	8.76	3.35	13.5	9.54
Do	70.72	8.76	3.35	20	14.14
Do	70.72	8.76	3.35	27	19.09
Dry lime-sulphur B	72.43	9.33	6.50	12.5	9.05
Do	72.43	9.33	6.50	19.8	14.34
Do	72.43	9.33	6.50	25	18.10
Dry lime-sulphur C	69.16	12.53	6.03	13.5	9.33
Do	69.16	12.53	6.03	20	13.83
Do	69.16	12.53	6.03	27	18.67
				Gallons	
Liquid lime-sulphur [1]	31.71	1.80		6.66	22.87
Do.[1]	31.71	1.80		3.25	11.16
Liquid lime-sulphur [2]	30.59	1.88		6.66	21.88
Do.[2]	30.59	1.88		3.25	10.68

[1] Used in Mississippi; sp. gr. 1.30, Baumé 33.4°.
[2] Used in Indiana; sp. gr. 1.29, Baumé 32.6°.

On April 26 a careful count was made of 2,000 scales on twigs taken from all parts of the trees in each plat. On June 29, 80 linear inches of new wood from each plat were examined and the number of young scales of the first generation recorded. The results of these counts are given in Table 5.

TABLE 5.—*Results of tests against the San Jose scale made on apple trees at Bicknell, Ind., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scales: Dead	Hibernating scales: Control	Infestation of young scales on 80 linear inches new wood: Total scale	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Dry lime-sulphur A	13.5	65.5	23.3	3,801	47.51	42.8
	20	80.5	56.6	2,882	36.02	32.5
	27	84.6	65.7	2,459	30.73	27.7
Dry lime-sulphur B	12.5	69.8	32.8	5,008	62.60	56.4
	19.8	75.1	44.6	3,684	46.05	41.5
	25	79.8	55.1	2,471	30.88	27.8
Dry lime-sulphur C	13.5	60.7	12.6	4,806	60.07	54.2
	20	78.5	52.2	3,111	38.88	35.1
	27	81.3	58.4	2,279	28.49	25.7
	Gallons					
Liquid lime-sulphur	6.66	97.6	94.6	175	2.19	2.0
	3.25	70.8	35.1	3,547	44.34	40.0
Check	Untreated.	55.0		8,873	110.91	

APPLE TREES, 1922

In the 1922 experiments, as in those of 1921, the weaker solution failed to give any practical control of scale. Although a much higher percentage of control was obtained with the greater strengths, it was still much lower than that secured with liquid lime-sulphur and can not be considered satisfactory. Liquid lime-sulphur at 3.25 gallons to 50 gallons of water was a little more effective than the weaker strengths of the dry lime-sulphurs.

These results are confirmed by the counts of young scales that settled on the new wood, since the average number of scales found on the twigs treated with the weaker solutions of the three dry lime-sulphurs was 25.9 times the number found in the liquid lime-sulphur plat and approximately 50 per cent of the number found on the untreated check. The strongest solutions of the dry materials gave an average of 59.7 per cent control and an average of 27 per cent as many young scales on the new wood as were found on the untreated checks.

PEACH TREES, 1922

The same spray materials (see Table 4) were tested against the San Jose scale on peach trees at Canton, Miss., where plats of five trees each were given a dormant spray on February 12 and 13. A barrel pump, maintaining a pressure of 100 to 125 pounds with a rod and disk nozzle, was used and an average of 1½ gallons of spray material was applied to each tree.

The count of hibernating scales was made on March 7 and the counts of the newly settled scales of the first and second generations were made from June 1 to 3 and from August 10 to 12. The results of these tests are given in Table 6.

TABLE 6.—*Results of tests against the San Jose scale on peach trees at Canton, Miss., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scales on 80 linear inches new wood					
				First generation			Second generation		
		Dead	Control	Total scale	Average per inch	Per cent of check	Total scale	Average per inch	Per cent of check
	Pounds	*Per cent*	*Per cent*						
Dry lime-sulphur A	13.5	41.9	27.1	403	5.04	27.1	899	11.23	42.4
	20	45.4	31.5	336	4.20	22.7	683	8.53	32.2
	27	54.1	42.4	194	2.42	13.1	671	8.38	31.6
Dry lime-sulphur B	12.5	43.3	28.9	375	4.69	25.3	732	9.15	34.5
	19.8	49.0	36.0	292	3.65	19.7	629	7.86	29.7
	25	57.2	46.4	202	2.53	13.6	643	8.03	30.3
Dry lime-sulphur C	13.5	39.1	23.7	376	4.70	25.4	688	8.60	32.4
	20	48.6	35.6	275	3.44	18.5	588	7.35	27.7
	27	56.2	45.1	145	1.81	9.8	420	5.25	19.8
	Gallons								
Liquid lime-sulphur	6.66	77.6	71.9	37	.46	2.5	117	1.46	5.5
	3.25	31.2	13.8	437	5.46	29.5	600	7.50	28.3
Check	Untreated.	20.2		1,483	18.54		2,121	26.51	

In the experiments reported in Table 6 the weaker solutions of the dry lime-sulphur gave an average control of 26.6 per cent, and the stronger solutions 44.6 per cent, as compared with a control of 71.9 per cent for liquid lime-sulphur.

On the new wood the weaker strengths of the dry materials showed an average of 4.8 scales of the first generation per linear inch. The strongest solutions gave 2.25 per inch and the liquid lime-sulphur 0.46. The untreated checks showed an average of 18.5 scales per inch.

In the second generation the weaker strengths showed about 36.4 per cent and the greater strengths about 27 per cent, as many young scales as were found on the untreated check. These figures show an infestation 6.6 and 4.9 times as great as where the liquid lime-sulphur was used.

EXPERIMENTS IN 1923

APPLE TREES

The tests on apple trees were conducted at Stuart, Va., in an 18-year-old orchard moderately infested with scale. Plats of five trees each were given a dormant spray on March 8, using a power sprayer which maintained a pressure of 225 pounds with one spray gun. An average of 12 gallons per tree was used. The composition and dilutions of the essential materials in these sprays are shown in Table 7.

TABLE 7.—*Composition of the dry calcium-sulphurs tested in experiments against the San Jose scale in 1923*

Material used	Percentage of—			Quantity used in 50 gallons of spray	Pounds of polysulphide in 50 gallons of spray
	Calcium polysulphides	Calcium thiosulphate	Free sulphur		
				Pounds	
Dry lime-sulphur A	72.09	9.45	1.42	15	10.81
Do	72.09	9.45	1.42	27	19.46
Dry lime-sulphur B	68.68	11.18	6.40	15	10.30
Do	68.68	11.18	6.40	27	18.54
Dry lime-sulphur C	78.78	9.00	.86	15	11.81
Do	78.78	9.00	.86	26	20.48
				Gallons	
Liquid lime-sulphur [1]	30.34	2.04		6.66	21.53

[1] Specific gravity 1.28, Baumé 31.8°.

The count of hibernating scales was made on April 11 and the first generation of the scale on new wood was counted on June 27. The results of these experiments are shown in Table 8.

TABLE 8.—*Results of tests against the San Jose scale made on apple trees at Stuart, Va., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches new wood		
		Dead	Control	Total scale	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Dry lime-sulphur A	15	48.7	33.6	289	3.61	35.9
	27	69.1	60.0	124	1.55	15.4
Dry lime-sulphur B	15	59.2	47.2	294	3.68	36.6
	27	74.6	67.1	117	1.46	14.6
Dry lime-sulphur C	15	50.0	35.3	258	3.23	32.1
	26	71.4	63.0	132	1.65	16.4
	Gallons					
Liquid lime-sulphur	6.66	97.0	96.1	51	.64	6.34
Check	(1)	22.7		804	10.05	

[1] Untreated.

In the experiments reported in Table 8 the dry lime-sulphurs at the rate of 15 pounds to 50 gallons of water gave an average control of 38.7 per cent, and at 26 and 27 pounds to 50 gallons an average control of 63.4 per cent as compared with 96.1 per cent for liquid lime-sulphur.

The average number of young scales per linear inch of new wood for the same experiments was 3.5, 1.55, and 0.64. Although the number of young scales found per inch of new wood was rather small, it should be noted that the 15-pound treatment allowed 5.5 times as many scales to settle as did the liquid lime-sulphur; and the 26 and 27 pound treatments 2.4 times as many.

PEACH TREES, 1923

The same materials (see Table 7) were tested against the San Jose scale on peach trees at Canton, Miss., in the same orchard that was used in 1922, although the infestation was not so heavy as that of the previous season. From five to seven trees were used per plat, and these were sprayed on February 14, using a barrel pump which maintained a pressure of 100 to 125 pounds with a rod and disk nozzle. An average of 1½ gallons per tree was applied.

The hibernating scales were counted on March 23 and the counts of the first and second generations were made on June 27 and October 4. The results of these experiments are shown in Table 9.

TABLE 9.—*Results of tests against the San Jose scale on peach at Canton, Miss., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches new wood					
				First generation			Second generation		
		Dead	Control	Total scales	Average per inch	Percentage of check	Total scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*						
Dry lime-sulphur A	15	53.2	44.2	215	2.69	21.0	627	7.84	49.7
	27	69.7	63.8	157	1.96	15.4	425	5.31	33.7
Dry lime-sulphur B	15	55.9	47.4	206	2.58	20.2	487	6.09	38.6
	27	75.0	70.2	151	1.89	14.8	249	3.11	19.7
Dry lime-sulphur C	15	50.7	41.2	242	3.03	23.7	500	6.25	39.6
	26	70.1	64.3	136	1.70	13.3	289	3.61	22.9
	Gallons								
Liquid lime-sulphur	6.66	96.4	95.7	39	.49	3.8	92	1.15	7.3
Check	(1)	16.2		1,022	12.78		1,262	15.78	

[1] Untreated.

When used on peach trees at the rate of 15 pounds to 50 gallons of water the average control obtained with the dry materials was 44.27 per cent. When the strength was increased to 26 or 27 pounds the control rose to 66.10 per cent, but this does not compare very favorably with the 95.7 per cent control obtained with liquid lime-sulphur concentrate. The 15-pound applications showed an average of 42.6 per cent and the 27-pound spray an average of 25.4 per cent as many young scales of the second generation as were found on the untreated check, which is 5.9 and 3.5 times as many as were present in the liquid lime-sulphur plat.

DISCUSSION OF FIELD EXPERIMENTS WITH DRY CALCIUM-SULPHURS

The experiments already described show that when these dry lime-sulphurs were used at dilutions from 12.5 to 15 pounds to 50 gallons of water the average control on hibernating scale was only 29.16 per cent. When the strength was increased to 25 or 27 pounds the average control was increased to 54.68 per cent. In the same series of tests standard liquid lime-sulphur gave an average control of 83.66 per cent. These figures show that the dry materials tested did not give a control against hibernating scale which approximated that obtained with liquid lime-sulphur, or one that could be considered of very much practical value.

If the efficiency of these dry substitutes is measured by the number of young scales that settle on the new wood, the same lack of control is found. On apple trees the weaker sprays showed an average of 2,409 scales of the first generation on each 80 linear inches of new wood examined, or 30 scales to the inch. The stronger sprays gave an average of 1,263.6 scales per 80 inches, or 15.8 per inch. These treatments should be compared with liquid lime-sulphur which allowed an average of 1.4 scales per inch to settle.

The counts of second-generation scales on peach showed an average of 8.19 scales per inch of new wood where the weaker sprays were used, 5.61 for the stronger sprays, and 1.3 for liquid lime-sulphur.

These experiments cover a variety of conditions, since they were carried on in Indiana, Virginia, and Mississippi. In 1922 the orchards treated were incrusted and the scale was increasing very rapidly, whereas in 1923 orchards only moderately infested, in which the scale was not increasing very rapidly, were used. Although the dry lime-sulphurs, in all cases, show some effect on the scale, the apparent control was never great enough to justify their being used as remedies for the San Jose scale under general orchard conditions.

S. A. Forbes has estimated (*11, p. 549*) that the theoretical number of the progeny from one hibernating female San Jose scale might, under ideal or optimum conditions, in one season, reach the astonishing total of 32,791,472. If the actual increase under natural conditions is even as low as 1 per cent of the theoretical it is still very evident that a treatment which does not kill more than 50 per cent or 60 per cent of the hibernating scales, and allows from three to six scales to settle on each inch of the new wood, can not be considered satisfactory, since it would not prevent an immediate reinfestation and the resulting damage to the trees.

EXPERIMENTS IN 1924

The experiments conducted in 1924 were primarily for the purpose of determining the relative value of the ingredients found by chemical analysis to be present in the dry and liquid lime-sulphurs.

Based on the analyses of more than 100 commercial lime-sulphur solutions the average molecular ratio $\frac{\text{Polysulphide sulphur}}{\text{Polysulphide calcium}}$ is 4.68, indicating a predominating percentage of the higher sulphide, CaS_5, whereas from the analyses of 38 samples of dry lime-sulphur the molecular ratio $\frac{\text{Polysulphide sulphur}}{\text{Polysulphide calcium}}$ is 3.53, indicating that the polysulphides are mainly the lower sulphides, CaS_4 and CaS_3.

From these observations it was thought that there might be a difference in the efficacy of the products on account of the fact that the polysulphide sulphur in the dry lime-sulphur was not in as high a ratio to the polysulphide calcium as the polysulphide sulphur to polysulphide calcium in the lime-sulphur solution.

With this in mind, solutions were prepared having the same molecular ratio of sulphur and lime as calcium trisulphide, calcium tetrasulphide, and calcium pentasulphide. These solutions were diluted so that the total polysulphide content, when applied as a spray, was the same as the total polysulphide content of the lime-sulphur solution and dry lime-sulphur when applied as sprays. Calcium thiosulphate, calcium sulphite, and sulphur were also prepared and tested.

The essential materials used and the results of these experiments are shown in Table 10.

TABLE 10.—*Effectiveness of the ingredients of dry and liquid lime-sulphur used in experiments against the San Jose scale*

Experiment No.	Material used	Dilution	Dead	Control
			Per cent	*Per cent*
1	Liquid lime-sulphur (32 per cent calcium polysulphide).	6.66 gallons to 50 gallons	95.95	94.98
2	Same, with 1.11 pounds of sugar to 50 gallons	do	95.90	94.92
3	Same, with 10 pounds of sugar to 50 gallons	do	93.00	91.33
4	Liquid lime-sulphur A	Equivalent to No. 1[1]	89.75	87.30
5	Same, with 1.11 pounds of sugar to 50 gallons	do	88.00	85.14
6	Dry lime-sulphur A	do	50.40	38.58
[2] 7	do	do	59.0	35.94
[2] 8	Same with all sludge removed	do	96.0	93.75
9	Calcium pentasulphide (CaS_5) [3]	do	93.10	91.46
[4] 10	do	do	95.20	94.27
11	Calcium tetrasulphide (CaS_4) [3]	do	89.5	87.00
[4] 12	do	do	93.5	92.24
13	Calcium trisulphide (CaS_3) [3]	do	43.4	29.91
14	Calcium thiosulphate	1 ounce to 1 gallon	13.4	0
15	do	24 ounces to 1 gallon	18.45	0
16	Calcium sulphite	½ ounce to 1 gallon	19.37	.15
17	do	12 ounces to 1 gallon	16.55	0
18	Sulphur	Equivalent to No. 1[1]	19.45	.25
19	Check, untreated		19.25	

[1] Based on polysulphide-sulphur content.
[2] Check, 36 per cent dead.
[3] Calcium polysulphides are so prepared that the molecular ratio of calcium to sulphur equals 1 to 5, 1 to 4, and 1 to 3, respectively.
[4] 1923 experiments; check, 16.2 per cent dead.

With the exception of Nos. 7, 8, 10, and 12, the experiments considered in Table 10 were carried on in a moderately infested peach orchard in Opelika, Ala. A dormant application was made on January 28 and 29, using a wheelbarrow sprayer having a vertical agitator and maintaining a pressure of about 100 pounds. The counts of hibernating scales were made on March 7, 8, 9, and 10.

Experiments 7 and 8 were made on small, badly infested peach trees near Vienna, Va. The sprays were applied with a knapsack sprayer on March 17 and the scale count was made on April 17.

Experiments 10 and 12 were a part of the 1923 series on apple trees, the details of which are given on pages 11 and 12.

Experiments 2, 3, and 5 mentioned in Table 10, which were made with liquid lime-sulphur and granulated sugar, indicate that the addition of sugar, at the rate of 1.11 pounds and 10 pounds to 50 gallons of spray solution, does not materially reduce the effectiveness against the San Jose scale.

Experiments 6 and 7 show that dry lime-sulphur A, even when used at a strength (33 pounds to 50 gallons) which furnishes an amount of polysulphide sulphur equivalent to that found in standard liquid lime-sulphur, can not be considered an effective remedy against this scale.

Dry lime-sulphur A, at the rate of 33 pounds to 50 gallons of water, was used for experiments 7 and 8.

After this material had been mixed a part of the solution was carefully filtered to remove the insoluble portions. One-half of this filtrate was used for experiment 8. Half of the insoluble sludge that had been removed was added to the remaining filtrate and this was used in experiment 7.

The 93.75 per cent control obtained with the filtered material (experiment 8) compared with the 35.94 per cent control obtained with the part containing the sludge (experiment 7) indicates that the insoluble matter present, when this dry lime-sulphur was used at the rate of 33 pounds to 50 gallons of water, greatly reduced the effectiveness of the spray.

This detrimental effect of the sludge also explains why, in the field experiments when the amount of dry lime-sulphur was doubled, there was not a corresponding increase in effectiveness.

The experiments with the three polysulphides, prepared to represent calcium pentasulphide, tetrasulphide, and trisulphide, respectively, show that the pentasulphide and the tetrasulphide furnish a satisfactory control of the scale and the trisulphide is of very little practical value. The calcium thiosulphate, calcium sulphite, and free sulphur, at the strength used, were found to be of no value.

DISCUSSION OF RESULTS

The foregoing experiments show that the three dry lime-sulphurs tested were not staisfactory remedies against the San Jose scale, even when used in excessive quantities.

A study of the chemical analyses of the dry and liquid lime-sulphurs shows the following differences:

The dry lime-sulphurs contain sulphur and calcium in the proportions to form calcium trisulphide (CaS_3) and calcium tetrasulphide (CaS_4), they contain considerable amounts of calcium thiosulphate and free sulphur, and, at increased strengths, an objectionable quantity of insoluble sludge.

Liquid lime-sulphur contains polysulphide sulphur in such proportions as to form calcium tetrasulphide (CaS_4) and calcium pentasulphide (CaS_5), with the latter predominating; very little calcium thiosulphate, no free sulphur, and no insoluble sludge.

If Shafer's theory (*23*) that the efficacy of a lime-sulphur solution against scale insects is due to an oxidizing action is correct, it naturally follows that the higher polysulphides (CaS_5 and CaS_4) would be more effective than the lower (CaS_3) since, per molecule, they would furnish a larger quantity of nascent sulphur to act as an oxidizing agent.

The experiments given in Table 10 show that the calcium thiosulphate and the free sulphur are of no practical value against scale.

Experiments 6 and 7 in Table 10 show that the presence of a considerable amount of insoluble sludge greatly reduces the effectiveness of these dry preparations. It is thus clearly evident that there are adequate chemical and physical reasons for the failure of these dry lime-sulphurs to control the San Jose scale.

SUMMARY

(1) The dry lime-sulphurs used were found to be of little practical value against the San Jose scale.

(2) The addition of sugar did not materially reduce the effectiveness of liquid lime-sulphur.

(3) Calcium polysulphides corresponding to the pentasulphide and tetrasulphide were found to be effective and that corresponding to the trisulphide of very little value against the San Jose scale.

(4) Calcium thiosulphate, calcium sulphite, and free sulphur were of no practical value.

(5) The lack of effectiveness in the dry lime-sulphurs may have been caused by the following:

(*a*) When the water is removed from liquid lime-sulphur to produce the dry calcium-sulphur, the calcium polysulphides are changed from the mixture of polysulphides 5 (CaS_5) and 4 (CaS_4) with the 5 predominating, which is found in liquid lime-sulphur, to a mixture of polysulphides 4 (CaS_4) and 3 (CaS_3) in approximately equal proportions. This change would, according to the experiments given in Table 10, reduce the effectiveness of the dry calcium sulphurs since the higher polysulphides were found to be more effective than the lower ones.

(*b*) The calcium thiosulphate, sulphite, and free sulphur present are not effective.

(*c*) The presence of a considerable amount of insoluble sludge apparently reduces the effectiveness of these materials against the San Jose scale.

DRY SODIUM-SULPHUR COMPOUNDS

The dry sodium-sulphur compounds, which are also sold as substitutes for lime-sulphur solution, are likewise of comparatively recent development. Patents [11] covering several methods for the manufacture of these preparations have been obtained. However, the method most generally employed consists in heating or fusing together sulphur and sodium carbonate (soda ash), or sulphur and caustic soda.

CHEMICAL COMPOSITION

The results of the chemical analysis of 15 samples of sodium-sulphur compounds, obtained in the open market and including the principal brands, are given in Table 11.

[11] United States Nos. 1,044,452; 1,132,476; and 1,457,652.

TABLE 11.—*The chemical composition of representative dry sodium-sulphurs*

Sample No.	Sodium polysulphide [1]	Sodium thiosulphate [2]	Free sulphur	Other ingredients by difference [3]	Sample No.	Sodium polysulphide [1]	Sodium thisoulphate [2]	Free sulphur	Other ingredients by difference [3]
	Per cent	*Per cent*	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	55.11	41.93	0.13	2.83	9	41.13	50.52	0.67	7.68
2	58.21	39.20	.54	2.05	10	40.91	49.43	.35	9.31
3	72.00	7.67	.99	19.34	11	43.55	29.39	20.03	7.03
4	60.18	25.87	1.25	12.70	12	41.99	41.45	10.33	6.23
5	52.83	40.74	.48	5.95	13	61.53	29.35	.34	8.78
6	56.84	36.56	3.38	3.22	14	2.12	60.00	18.94	18.94
7	68.30	10.80	1.39	19.51	15	10.96	61.60	17.54	9.90
8	55.13	40.80	1.56	2.51					

[1] Polysulphide sulphur calculated to sodium polysulphide (Na_2Sx).
[2] Thiosulphate sulphur calculated to sodium thiosulphate ($Na_2S_2O_3$).
[3] Mainly water.

It will be noted that these products are extremely variable in composition, the sodium polysulphide varying from 2.12 to 72 per cent, sodium thiosulphate from 7.67 to 61.6 per cent and free sulphur from 0.13 to 20 per cent.

A comparison of the composition of the liquid lime-sulphurs and the sodium-sulphur compounds shows that the latter contain roughly about 1½ times as much polysulphides; from 15 to 25 times as much thiosulphates; and, in addition, varying quantities of free sulphur, which does not occur in liquid lime-sulphur solution.

The analysis of more than 100 commercial lime-sulphur solutions indicates the presence of a predominating percentage of the pentasulphide (CaS_5). In the case of the sodium-sulphur preparations they show such wide variations in composition that no general statement can be made in regard to the sodium polysulphide that may predominate, although some of them apparently contain sulphur in the pentasulphide form.

Table 12 gives the chemical composition of the dry sodium-sulphur preparations that were tested in experiments against the San Jose scale. These experiments were carried on under the same general conditions as those described for the dry calcium-sulphur tests which have already been discussed. For the details of these tests reference should be made to the dry calcium-sulphur experiments under the corresponding locality and date.

TABLE 12.—*The chemical composition of the dry sodium sulphur preparations tested*

Sample No.	Percentage of—					Pounds used in 50 gallons of spray	Pounds of polysulphides in 50 gallons
	Sodium polysulphides	Sodium thiosulphate	Free sulphur	Sodium sulphate	Insoluble residue and water		
1	59.71	25.79	2.54	3.72	8.24	12.5	7.46
1	59.71	25.79	2.54	3.72	8.24	19.	11.34
1	59.71	25.79	2.54	3.72	8.24	25	14.92
2	61.26	23.95	6.54	6.09	2.16	12.5	7.65
2	61.26	23.95	6.54	6.09	2.16	19	11.63
2	61.26	23.95	6.54	6.09	2.16	25	15.31
3	60.53	22.76	3.07	9.21	4.43	12.5	7.56
3	60.53	22.76	3.07	9.21	4.43	27	16.34

EXPERIMENTS IN 1921 [12]

In these tests dry sodium-sulphur No. 1 was used against the San Jose scale on apple trees at Washington, Ind. The results of these tests are shown in Table 13.

TABLE 13.—*Results of tests with dry sodium-sulphur sprays against the San Jose scale on apple trees at Washington, Ind., in 1921*

Material used	Amount in 50 gallons of spray	Hibernating scale	
		Dead	Control
	Pounds	*Per cent*	*Per cent*
Sodium-sulphur No. 1	12.5	79.0	27.6
Do	19	83.8	44.1
Do	25	84.4	46.2
	Gallons		
Liquid lime-sulphur [1]	6.66	88.4	60.0
Check	----------	71.0	----------

[1] Baumé 33.4°.

The tests recorded in Table 13 show clearly that, even when a large percentage of the scales die from natural causes, dry sodium sulphur does not serve as an effective remedy. They also show that when the conditions are such that the standard liquid lime-sulphur treatment falls below what can be considered an effective control this preparation is even less effective. Although increasing the dosage increased the efficiency of the dry sodium-sulphur, in no case was an effective control obtained.

EXPERIMENTS IN 1922 [13]

Dry sodium-sulphur No. 2 was tested against the San Jose scale on apple at Bicknell, Ind., and on peach at Canton, Miss. The results of these tests are given in Tables 14 and 15.

TABLE 14.—*Results of tests with dry sodium-sulphur sprays against the San Jose scale on apple trees at Bicknell, Ind., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood		
		Dead	Control	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Sodium-sulphur No. 2	12.5	63.4	18.7	4,086	51.1	46.0
Do	19	73.7	41.6	2,528	31.6	28.5
Do	25	85.4	67.6	1,140	14.3	12.8
	Gallons					
Liquid lime-sulphur [1]	6.66	97.6	94.7	175	2.19	2.0
Check	----------	55	----------	8,873	110.91	----------

[1] Baumé 32.6°.

Table 14 gives the results of tests in an orchard where the scale was increasing very rapidly. Under these adverse conditions liquid lime-sulphur gave a very good control but the dry sodium-sulphur spray

[12] For details of these tests see p. 7-8. [13] For details of these tests see pages 8-11.

even at the rate of 25 pounds to 50 gallons could not be considered satisfactory. The weakest spray not only failed to give a good control of hibernating scale, but allowed almost half as many young scales to settle on the new wood as were counted on the untreated trees.

TABLE 15.—*Results of tests with dry sodium-sulphur sprays against the San Jose scale on peach trees at Canton, Miss., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood					
				First generation			Second generation		
		Dead	Control	Number of scales	Average per inch	Percentage of check	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*						
Sodium-sulphur No. 2	12.5	34.4	17.8	362	4.53	24.5	783	9.79	36.9
Do	19	48.9	36.0	278	3.48	18.7	540	6.75	25.5
Do	25	58.8	48.4	178	2.23	12.0	419	5.24	19.8
	Gals.								
Liquid lime-sulphur [1]	6.66	77.6	71.9	37	.46	2.5	117	1.46	5.5
Check		20.2		1,483	18.5		2,121	26.51	

[1] Baumé 33.4°.

In the experiments reported in Table 15 the dry sodium-sulphur failed to show a control that could be considered satisfactory, even when used at the rate of 25 pounds to 50 gallons of water. Although the liquid lime-sulphur was not satisfactorily effective, it gave much better control than did the dry substitute.

EXPERIMENTS IN 1923 [11]

The tests with dry sodium-sulphur No. 3 were made at Stuart, Va., and Canton, Miss. The results of these experiments are given in Tables 16 and 17.

TABLE 16.—*Results of tests with dry sodium-sulphur sprays against the San Jose scale on apple trees at Stuart, Va., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood		
		Dead	Control	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Sodium-sulphur No. 3	12.5	55.6	42.6	216	2.7	26.9
Do	27	72.8	64.8	145	1.81	18.0
	Gallons					
Liquid lime-sulphur [1]	6.66	97.0	96.1	39	.49	4.9
Check		22.7		804	10.05	

[1] Baumé 31.8°.

The experiments reported in Table 16 indicate the same lack of control that has been noted in the earlier tests. Although the

[11] For details of these experiments see p. 11-12.

greater strength was more effective this increase was not in the same ratio as the increase in dosage.

The infestation in this orchard was not very heavy but even under these favorable conditions the 12.5-pound dosage allowed over 5.5 times as many young scales to settle on the new wood as did the liquid lime-sulphur.

TABLE 17.—*Results of tests with dry sodium-sulphur sprays against the San Jose scale on peach trees at Canton, Miss., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood					
				First generation			Second generation		
		Dead	Control	Number of scales	Average per inch	Percentage of check	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*						
Sodium-sulphur No. 3	12.5	53.0	43.9	353	4.41	34.5	525	6.56	41.6
Do	26.625	71.0	65.4	247	3.09	24.2	365	4.56	28.9
	Gallons								
Liquid lime-sulphur [1]	6.66	96.4	95.7	39	.49	3.8	92	1.15	7.3
Check		16.2		1,022	12.78		1,262	15.78	

[1] Baumé 31.8°.

The experiments discussed in Table 17 were carried on during a season when the scale was not increasing so rapidly as in 1922, and all of the treatments gave better control than in the previous season, but the relative efficiency is much the same.

It is of interest to note that in the first experiment, in spite of the 43.9 per cent control, the second count of young scales showed 41.6 per cent, as many as were found on the untreated checks.

DISCUSSION OF RESULTS

When used at the strength ordinarily employed (12.5 pounds to 50 gallons) the average control on hibernating scales was 30 per cent. When this dosage was increased to 25 to 27 pounds the control only rose to 58.3 per cent. In the same set of experiments liquid lime-sulphur gave an average control of 83.6 per cent.

These figures are supported by the counts of first and second generations of young scales on the new wood, since in every case many more were found in the sodium-sulphur plats than where liquid lime-sulphur was used.

SUMMARY

The experiments with the dry sodium-sulphur sprays show, on the whole, results that are very similar to those obtained with the dry calcium-sulphurs. In no case were they as effective as liquid lime-sulphur, even when used at greatly increased strengths, and it can not be considered that they furnished a satisfactory control of the San Jose scale.

These experiments covered a period of three years, and were carried on in three different States under widely varying conditions.

DRY BARIUM-SULPHUR COMPOUNDS

The dry barium-sulphur compounds, which are sold as substitutes for lime-sulphur solution, are of comparatively recent origin. Several methods for their preparation have been developed, and patents [15] granted covering some of these processes, but all, or practically all, of those produced at the present time consist simply of a mixture of "black ash" (a crude barium-sulphide, BaS, made by heating barium sulphate with coal in a furnace) and sulphur.

CHEMICAL COMPOSITION

Commercial dry barium-sulphur contains—in addition to barium sulphide and sulphur—chemically combined water, some barium sulphate, siliceous material, carbon, and small quantities of other impurities. These impurities are objectionable in that they decrease the percentage of active ingredients, impede their action, tend to clog the nozzle of the spraying apparatus, and the graphitelike residue from the coal is very destructive, on account of its abrasive action, to the spray pumps and nozzles.

The results of analyses of nine samples of commercial dry barium-sulphurs purchased in various parts of the United States are given in Table 18.

TABLE 18.—*Chemical composition of representative dry barium-sulphurs*

Sample No.	Barium-sulphide (BaS)	Free sulphur	Barium-thiosulphate (BaS_2O_3)	Other ingredients, by difference [1]	Sample No.	Barium-sulphide (BaS)	Free sulphur	Barium-thiosulphate (BaS_2O_3)	Other ingredients, by difference [1]
	Per cent	*Per cent*	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	34.81	38.64	3.46	23.09	6	38.00	34.01	3.97	24.02
2	32.84	36.24	4.32	26.60	7	39.76	34.88	2.96	22.40
3	35.30	32.03	4.55	28.12	8	39.41	33.66	1.28	25.65
4	46.66	37.11	1.98	14.25	9	38.10	34.60	4.09	23.21
5	41.22	31.05	7.47	20.26	Gen. av.	38.46	34.69	3.79	23.07

[1] Chiefly barium sulphate, siliceous material, carbon, and moisture.

The dry barium-sulphurs, when diluted according to directions (12 to 14 pounds to 50 gallons of water), leave an insoluble residue which on filtering and drying at 105° C. amounts to about 34 per cent of the product. The soluble portion has a specific gravity of about 1.014 and contains approximately 2 per cent of barium-polysulphide in solution. The ratio of sulphur to barium indicates that the polysulphide is largely the tetrasulphide (BaS_4). This will furnish approximately 8.5 pounds of barium-polysulphide in each 50 gallons of spray material.

Commercial liquid lime-sulphur (32° B.) at a dilution of 6.66 gallons to 50 gallons of water (1 to 7.5), which was the strength used in the tests here reported, will furnish approximately 22.8 pounds of calcium-polysulphides in each 50 gallons of spray material.

The experiments with dry barium-sulphur were a part of the series of tests with the various dry substitutes for liquid lime-sulphur. These tests were made under the same general conditions as those already described.

[15] United States Nos. 1,263,856 and 1,457,652.

Table 19 gives the chemical composition of the essential materials in the dry barium-sulphur sprays used against the San Jose scale.

TABLE 19.—*The chemical composition of the dry barium-sulphur preparations tested*

Sample No.	Percentage of—				Pounds used in 50 gallons of spray	Pounds of sulphides in 50 gallons
	Barium-sulphide	Barium-thiosulphate	Free sulphur	Barium-sulphate and siliceous material		
1	41.22	7.47	31.05	[1] 18.32	13	5.35
1	41.22	7.47	31.05	[1] 18.32	19.5	8.03
1	41.22	7.47	31.05	[1] 18.32	26	10.71
2	38.00	3.97	34.01	24.43	13	4.94
2	38.00	3.97	34.01	24.43	19.5	7.41
2	38.00	3.97	34.01	24.43	26	9.88
3	39.41	1.28	33.66	25.14	14	5.51
3	39.41	1.28	33.66	25.14	31	12.21

[1] 1.94 per cent undetermined.

EXPERIMENTS IN 1921 [16]

Dry barium-sulphur No. 1 was tested against the San Jose scale on apple trees at Washington, Ind. The results of these tests are shown in Table 20.

TABLE 20.—*Results of tests with dry barium-sulphur sprays against the San Jose scale on apple trees at Washington, Ind., in 1921*

Material used	Quantity in 50 gallons of spray	Hibernating scale	
		Dead	Control
	Pounds	*Per cent*	*Per cent*
Barium-sulphur No. 1	13	75.2	14.5
Do	19.5	80.0	31.0
Do	26	91.6	71.0
	Gallons		
Liquid lime-sulphur [1]	6.66	88.4	60.0
Check	----------	71.0	----------

[1] Baumé 33.4°.

The above experiments show that at the rate of 13 or 19.5 pounds to 50 gallons of water this material did not furnish a satisfactory control of the scale. When 26 pounds was used, it apparently gave much better results than the liquid lime-sulphur, but, since such effectiveness was not shown in any of the later experiments, it seems probable that some other factor influenced these results.

EXPERIMENTS IN 1922 [17]

Dry barium-sulphur No. 2 was tested against the San Jose scale on apple at Bicknell, Ind., and on peach at Canton, Miss. The results of these tests are shown in Tables 21 and 22.

[16] For general conditions in these experiments see pp. 7–8.
[17] For details of these experiments see pp. 8–11.

TABLE 21.—*Results of tests with dry barium-sulphur sprays against the San Jose scale on apple trees at Bicknell, Ind., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood (first generation)		
		Dead	Control	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Barium-sulphur No. 2	13	72.1	38.0	3,796	47.45	42.8
Do	19.5	81.9	59.8	2,296	28.70	25.9
Do	26	86.9	70.8	1,181	14.76	13.3
	Gallons					
Liquid lime-sulphur [1]	6.66	97.6	94.7	175	2.19	2.0
Check		55.0		8,873	110.91	

[1] Baumé 32.6°.

The results given in Table 21 show that dry barium-sulphur, even when used at the rate of 26 pounds to 50 gallons of water, did not furnish a control of hibernating scale that could be considered effective, or one that approached the effectiveness of the liquid lime-sulphur. If the value of the treatment is measured by the number of young scales that settle on the new wood the same lack of control is shown since 13 pounds to 50 gallons allowed almost half as many young scales per inch as settled on the untreated check and over 21 times as many as were found in the liquid lime-sulphur plat.

Even the maximum strength showed over six times as many young scales as were present on the twigs sprayed with standard liquid lime-sulphur.

TABLE 22.—*Results of tests with dry barium-sulphur sprays against the San Jose scale on peach trees at Canton, Miss., in 1922*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood					
				First generation			Second generation		
		Dead	Control	Number of scales	Average per inch	Percentage of check	Number of scales	Average per inch	Percentage of check
	Lbs.	*Per cent*	*Per cent*						
Barium-sulphur No. 2	13.5	42.4	27.8	343	4.29	23.1	573	7.16	27.0
	Gals.								
Liquid lime-sulphur [1]	6.66	77.6	71.9	37	.46	2.42	117	1.46	5.5
Check		20.2		1,483	18.50		2,121	26.51	

[1] Baumé 32.6°.

Only one strength of the dry barium-sulphur spray was used in these experiments, and this failed to show an effective control when either the hibernating scale or the young scale on new wood is considered. Although the liquid lime-sulphur gave rather poor control, it was relatively much better than the dry material.

EXPERIMENTS IN 1923 [18]

The tests with dry barium-sulphur No. 3 were made at Stuart, Va., and Canton, Miss. The results of these experiments are shown in Tables 23 and 24.

TABLE 23.—*Results of tests with dry barium-sulphur sprays against the San Jose scale on apple trees at Stuart, Va., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood (first generation)		
		Dead	Control	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*			
Barium sulphur No. 3	14	54.9	41.7	233	2.91	28.9
Do	31	79.6	73.6	148	1.85	18.4
	Gallons					
Liquid lime-sulphur [1]	6.66	97.0	96.1	51	.64	6.3
Check		22.7		804	10.05	

[1] Baumé 31.8°.

The tests reported in Table 23, although made where the scale was not very abundant, show the same lack of control, in spite of the fact that, in one case, the barium-sulphur was used at the rate of 31 pounds to 50 gallons. Even this strength showed 22.5 per cent less control on the hibernating scale and almost three times as many young scales per inch when compared with the trees sprayed with liquid lime-sulphur.

TABLE 24.—*Results of tests with dry barium-sulphur sprays against the San Jose scale on peach trees at Canton, Miss., in 1923*

Material used	Quantity in 50 gallons of spray	Hibernating scale		Infestation of young scale on 80 linear inches of new wood					
				First generation			Second generation		
		Dead	Control	Number of scales	Average per inch	Percentage of check	Number of scales	Average per inch	Percentage of check
	Pounds	*Per cent*	*Per cent*						
Barium-sulphur No. 3	14	56.7	48.3	298	3.73	29.2	468	5.85	37.1
Do	31	71.4	65.9	173	2.16	17	231	2.89	18.3
	Gallons								
Liquid lime-sulphur [1]	6.66	96.4	95.7	39	.49	3.8	92	1.15	7.3
Check		16.2		1,022	12.78		1,262	15.78	

[1] Baumé 31.8°.

The experiments in Canton, Miss., show the same lack of control by barium-sulphur that was noted in previous tests. A strength of 31 pounds to 50 gallons gave a control of only 65.9 per cent on the hibernating scales and allowed 4.5 times as many scales to settle on the new wood as did the standard liquid lime-sulphur.

[18] Details of these experiments are given on pages 11 and 12.

DISCUSSION OF RESULTS

When used at the rate of 13 or 14 pounds to 50 gallons the dry barium-sulphur gave an average of only 34 per cent control of hibernating scale. When the strength was increased to 26 or even 31 pounds the effectiveness did not approach that obtained with standard liquid lime-sulphur. The same lack of control is shown by the counts of the first-generation scales on the new wood.

SUMMARY

The dry barium-sulphurs tested failed to show a satisfactory control of the San Jose scale at any of the strengths used. In a general way this material was about as effective as the other dry substitutes that were tested.

GENERAL SUMMARY

The experiments here considered include 39 tests with dry calcium-sulphur, 13 tests with dry sodium-sulphur, and 11 tests with dry barium-sulphur. They were conducted under practical orchard conditions in four different States and cover a period of three years. Both apple and peach trees were used and conditions varied from a moderate infestation to incrustation. Conditions in the different orchards were such that the natural increase of the scale varied from very rapid to moderate.

Under the conditions mentioned the results obtained are sufficient to warrant the drawing of a general conclusion, at least for the localities in which these experiments were made.

The foregoing tests show that the commercial samples of dry calcium, sodium, and barium sulphurs, even when used at strengths much greater than ordinarily employed, do not furnish a satisfactory control of the San Jose scale.

LITERATURE CITED

(1) Anonymous.
1922. Spraying programs for the orchard and fruit garden with directions as to sprays to be used. *In* Ohio Agr. Exp. Sta. Mo. Bul., vol. 7, pp. 19–38.

(2) ———
1924. Directions for spraying fruits in Illinois. Ill. Agr. Exp. Sta. Circ. 277, 24 pp., illus.

(3) Ackerman, A. J.
1923. Preliminary report on control of San Jose scale with lubricating-oil emulsion. U. S. Dept. Agr. Circ. 263, 18 pp., illus.

(4) Baerg, W. J.
1921. Spraying for San Jose scale. Ark. Agr. Exp. Sta. Bul. 177, 19 pp., illus.

(5) Britton, W. E.
1923. Tests of sprays to control the San Jose scale. *In* Conn. Agr. Exp. Sta. Bul. 247, pp. 329–331.

(6) Brock, W. S., and W. P. Flint.
1919. Field experiments in spraying for control of San Jose scale, 1919. Ill. Agr. Exp. Sta. Circ. 239, 4 pp.

(7) Cooper, T.
[1920]. Use of dry lime-sulphur in sprays. *In* Ky. Agr. Exp. Sta. Ann. Rpt. 32 (1) (1919), pp. 44–45.

(8) Davis, J. J.
1924. Comparative tests with dormant sprays for San Jose scale control. *In* Jour. Econ. Ent., vol. 17, pp. 285–289.

(9) Edmundson, W. C.
1918. Sprays for the control of San Jose scale. Idaho Agr. Exp. Sta. Bul. 108, 16 pp., illus.
(10) Flint, W. P.
1920. Further tests of dry sulphur compounds for the control of the San Jose scale. *In* Ill. Div. Nat. Hist. Survey Bul. 13, pp. 339–343.
(11) Forbes, S. A.
1915. Observations and experiments on the San Jose scale. Ill. Agr. Exp. Sta. Bul. 180, pp. 545–561, illus.
(12) Griffith, J. G.
[1919]. San Jose scale. *In* N. Mex. Agr. Exp. Sta. Ann. Rpt. 30 (1918/19), pp. 15–16.
(13) [Haseman, L.]
1920. Nursery and orchard insect pests. Mo. Agr. Exp. Sta. Bul. 176, 35 pp., illus.
(14) ——— and K. C. Sullivan.
1922. An investigation to determine what insects are injurious to nursery stock in the State, their life histories, distribution, injury, and methods of control. *In* Mo. Agr. Exp. Sta. Bul. 197, pp. 62–63.
(15) ——— ———
1923. Controlling San Jose scale with lubricating oil emulsion. Mo. Agr. Exp. Sta. Circ. 109, 4 pp., illus.
(16) Houser, J. S.
1920. Recent tests of materials to control San Jose scale. *In* Ohio Agr. Exp. Sta. Mo. Bul., vol. 5, pp. 49–51.
(17) Melander, A. L.
1922. Per cent of San Jose scale alive after treatment with various insecticides. *In* Wash. Agr. Exp. Sta. Bul. 167 (1921), p. 26.
(18) ———
1922. San Jose scale. *In* Wash. Agr. Exp. Sta. Bul. 175, pp. 21–22.
(19) ———
1923. Tolerance of San Jose scale to sprays. Wash. Agr. Exp. Sta. Bul. 174, 52 pp., illus.
(20) Parrott, P. J.
[1924]. Sulphide sprays for control of San Jose scale. *In* N. Y. State Agr. Exp. Sta. Ann. Rpt. 42 (1923), p. 41.
(21) Robinson, R. H.
1924. The preparation of spray materials. Oreg. Agr. Exp. Sta. Bul. 201, 15 pp., illus.
(22) Ruth, W. A.
1922. An explanation of recent failures in San Jose scale control. Ill. Agr. Exp. Sta. Circ. 252, 4 pp.
(23) Shafer, G. D.
1915. How contact insecticides kill. Mich. Agr. Exp. Sta. Tech. Bul. 21, 67 pp., illus.
(24) Tanquary, M. C., and M. E. Hays.
1920. Commercial sulphur products as dormant sprays for control of the San Jose scale. Tex. Agr. Exp. Sta. Circ. 24, 7 pp., illus.
(25) Yetter, W. P., Jr.
1923. Lime-sulphur tests. *In* Ann. Rpt. State Ent. Colo. 14 (1922), pp. 45–47.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

JANUARY 14, 1926

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	————.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	THOMAS P. COOPER, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This bulletin is a contribution from

Bureau of Entomology	L. O. HOWARD, *Chief.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
△

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1372

Washington, D. C. ▼ March, 1926

TRANSMITTING ABILITY OF TWENTY-THREE HOLSTEIN-FRIESIAN SIRES

By R. R. Graves, *Specialist in Dairy Cattle Breeding, Bureau of Dairying*

CONTENTS

BREEDING STUDIES ON DAIRY CATTLE

Dairy-cattle breeding experiments were initiated by the Bureau of Dairying in 1918 with the object of determining what method of mating would give the most uniformly good results in the transmission of large milk and butterfat producing ability. These experiments included the comparison of line breeding with outbreeding, also of close inbreeding with outbreeding. Another project was the use, for generation after generation, of sires which have shown by the producing ability of their daughters that they are prepotent in transmitting the capacity for uniformly high milk and butterfat production. In addition to these experiments, studies are being made of the inheritance, for milk and butterfat production, of the animals in the advanced registry and register of merit of the dairy breeds.

The last-mentioned research has included a genealogical study to determine what families are most likely to transmit large milk and butterfat production (*1*).[1] Such studies, however, give very little information on the laws governing the transmission of milk and butterfat producing ability. In the following pages a study is made of the comparative milk and butterfat producing ability of the daughters, compared with their dams, of each Holstein-Friesian sire having six or more daughters with yearly records, all out of dams also having yearly records. This includes all sires on record up to and including volume 29 of the Advanced Register Yearbook.[2]

[1] Figures in italics in parentheses refer to "Literature Cited," p. 32.

[2] The writer desires to give credit to T. W. Gullickson, formerly with this bureau, for compilations in connection with the studies presented in this bulletin.

60980°—25†——1

SCOPE OF THE STUDY

The following questions are discussed in this bulletin in connection with the comparative records of daughters and their dams, which are given in Tables 2 to 25, inclusive.

1. What is the method of inheritance of production of milk and butterfat in dairy cattle? Is it through the factors determining production, contributed by each parent? Is it a blending inheritance—are the records of the daughters of a sire an average between his inherent transmitting ability and that of the dam of the daughter?
2. Can a sire be prepotent or dominant in impressing his characteristics, or his standard of production, on his daughters regardless of the standard of production of the dams of those daughters?
3. Can a sire be prepotent in influencing both the milk yield and the percentage of butterfat?
4. What influence has the dam's producing ability and the method of breeding on the prepotency of the sire?
5. Which parent has the greater influence on the yield of milk? Which has the greater influence on the percentage of butterfat in the milk? Is this percentage of butterfat correlated with or independent of the milk yield?
6. Which is the greater sire—one that sires daughters capable of making much larger records than their medium-producing dams, or one that sires daughters capable of slightly larger, or, at least, as large records as their high-record dams?

HOW THE SIRES WERE SELECTED

In the list of 126 Holstein-Friesian sires given in another study (*1*) just 20 sires had 6 or more yearly record daughters whose dams also had yearly records. There were only three other sires in the breed, outside the above-mentioned list, up to Volume 29 of the Advanced Register Yearbook, that came within the category mentioned. The records of the daughters of these 23 sires, compared with their dams' records, provide the best material available in the Holstein-Friesian breed for the study of the transmitting ability of the sire. In choosing these sires for study the minimum number of six daughters was decided upon because it was felt that this number was the smallest which could be used in drawing conclusions relative to the correlation between the production of the daughters of any one sire and the production of their dams.

In checking over the records of the daughters of these 23 sires it was found that 1 of the 6 daughters of 1 sire had a record of 568.3 pounds of butterfat in 305 days, while her dam's record was 350.8 pounds of butterfat made in 207 days. These records did not offer a fair comparison and were not included. Consequently, one of the sires appearing in the records has only five daughters with yearly record dams. Three of the 23 yearly record daughters of another sire were taken out for the same reason.

To facilitate the study of the comparative records of the daughters and their dams, the milk as well as the butterfat was computed to maturity, when the records were made under 5 years of age. Table 1 gives the percentages and ages used in calculating records to maturity.

TABLE 1.—*Ages and per cent used in calculating production records to maturity*

Age, calculated to nearest whole month	Mature record equivalent	Age, calculated to nearest whole month	Mature record equivalent
	Per cent [1]		*Per cent* [1]
2 and under 2¼ years	70.0	3¾ and under 4 years	87.5
2¼ and under 2½ years	72.5	4 and under 4¼ years	90.0
2½ and under 2¾ years	75.0	4¼ and under 4½ years	92.5
2¾ and under 3 years	77.5	4½ and under 4¾ years	95.0
3 and under 3¼ years	80.0	4¾ and under 5 years	97.5
3¼ and under 3½ years	82.5	5 years and over	100.0
3½ and under 3¾ years	85.0		

[1] The percentages used for calculating records to maturity correspond very closely to the percentage differences of the average production in the various classes for the Holstein-Friesian breed. Aside from the corrrection for differences in age, other factors that might cause variation between the records of the daughters and their dams, such as number of times milked per day, were not considered, as the information is not available.

PRODUCTION RECORDS OF DAUGHTERS AND THEIR DAMS

Table 2 shows detailed production records of the daughters of these 23 sires, together with the production of their dams; the dam's record in every case is given on the same line as that of her daughter. Averages are stated also, to facilitate comparison. Other figures show the average quantity of milk, percentage of butterfat, and pounds of butterfat by which the daughters exceed their dams or are exceeded by their dams. Plus and minus signs indicate excess or deficiency of the average daughter's performance compared with the average dam's performance.

The object of the investigation was to study the hereditary transmission of production, not to point out the good or the poor sires of the breed; hence the sires in these lists have been designated by letter and not by name. The records are arranged in the order of the daughters' butterfat records, beginning with the highest record.

TABLE 2.—*Production records of daughters and their dams*

SIRE A

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	22,757.0	3.43	779.7	10,928.3	3.30	361.4
2	22,515.2	3.21	723.1	18,290.1	3.03	554.7
3	21,260.8	3.20	678.6	13,285.0	3.40	451.8
4	16,266.0	3.47	564.7	17,287.3	3.32	575.0
5	15,079.7	3.60	543.4	12,533.4	3.12	391.8
Average of 5	19,575.7	3.36	657.9	14,464.8	3.23	466.9
Increase (+) of daughters over dams	+5,110.9	+0.13	+191.0			
Per cent increase	+35.3	+4.02	+40.9			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE B

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	28, 575. 5	3. 39	970. 5	14, 562. 4	3. 44	501. 6
2	23, 924. 4	3. 81	912. 1	20, 202. 9	3. 33	674. 6
3	22, 674. 8	3. 74	848. 8	17, 066. 8	3. 57	610. 1
4	22, 235. 3	3. 69	821. 2	14, 454. 0	3. 19	462. 1
5	23, 840. 9	3. 37	804. 5	16, 508. 6	3. 39	560. 8
6	22, 817. 1	3. 43	784. 2	17, 046. 4	3. 08	526. 3
7	21, 539. 7	3. 45	745. 0	20, 105. 1	3. 36	676. 1
8	23, 265. 9	3. 17	738. 6	14, 245. 7	3. 14	448. 5
9	20, 622. 8	3. 52	727. 5	20, 202. 9	3. 33	674. 6
10	18, 520. 6	3. 71	688. 3	18, 125. 0	3. 66	663. 7
11	18, 724. 7	3. 33	623. 7	15, 655. 1	3. 35	525. 9
12	13, 959. 4	3. 71	517. 9	17, 597. 7	3. 73	658. 0
13	15, 857. 8	3. 19	506. 1	17, 027. 3	3. 39	577. 4
Average of 13	21, 273. 8	3. 50	745. 3	17, 138. 5	3. 39	581. 5
Increase (+) of daughters over dams	+4, 135. 3	+0. 11	+163. 8			
Per cent increase	+24. 1	+3. 24	+28. 2			

Eleven daughters exceeded dams in milk.
Eleven daughters exceeded dams in butterfat.
Eight daughters exceeded dams in percentage of butterfat.

SIRE C

1	26, 497. 6	3. 46	917. 4	21, 309. 5	3. 42	730. 7
2	22, 498. 2	3. 97	893. 4	17, 577. 1	3. 26	574. 5
3	26, 059. 6	3. 42	891. 6	23, 714. 2	3. 76	892. 7
4	20, 147. 3	4. 28	862. 7	10, 755. 1	3. 76	404. 5
5	24, 055. 5	3. 43	825. 8	18, 068. 2	3. 51	635. 6
6	23, 626. 1	3. 32	784. 5	19, 410. 7	3. 26	633. 1
7	23, 238. 1	3. 35	779. 9	17, 958. 6	3. 37	605. 5
8	21, 928. 2	3. 54	777. 6	20, 255. 9	3. 62	735. 2
9	21, 650. 7	3. 58	775. 7	20, 255. 9	3. 62	735. 2
10	20, 464. 6	3. 60	738. 0	17, 367. 8	3. 39	588. 9
11	17, 225. 0	3. 50	604. 1	17, 958. 6	3. 37	605. 5
12	17, 504. 9	3. 36	588. 6	19, 410. 7	3. 26	633. 1
Average of 12	22, 074. 6	3. 56	786. 6	18, 670. 2	3. 47	647. 9
Increase (+) of daughters over dams	+3, 404. 4	+0. 09	+138. 7			
Per cent increase	+18. 2	+2. 59	+21. 4			

Ten daughters exceeded dams in milk.
Nine daughters exceeded dams in butterfat.
Seven daughters exceeded dams in percentage of butterfat

SIRE D

1	28, 753. 6	2. 93	844. 0	18, 882. 7	3. 03	572. 4
2	24, 450. 6	3. 13	767. 0	17, 703. 8	3. 62	642. 1
3	21, 647. 5	3. 43	744. 1	24, 397. 1	3. 46	846. 3
4	19, 988. 9	3. 56	712. 8	14, 022. 4	3. 45	485. 0
5	21, 379. 2	3. 32	711. 9	23, 027. 2	2. 76	637. 5
6	21, 308. 1	3. 16	675. 0	16, 577. 1	3. 14	520. 9
7	21, 564. 5	3. 10	670. 4	18, 138. 2	3. 00	544. 4
8	17, 529. 1	3. 22	565. 2	14, 053. 5	3. 02	425. 1
9	15, 540. 4	3. 26	507. 7	11, 425. 9	3. 39	388. 2
Average of 9	21, 351. 3	3. 23	688. 7	17, 580. 9	3. 20	562. 4
Increase (+) of daughters over dams	+3, 770. 4	+0. 03	+126. 3			
Per cent increase	+21. 4	+0. 94	+22. 4			

Seven daughters exceeded dams in milk.
Eight daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE E

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	24, 941. 0	3. 73	930. 3	19, 539. 4	3. 24	634. 4
2	26, 949. 8	3. 33	899. 5	22, 377. 0	3. 05	684. 6
3	24, 872. 1	3. 19	794. 3	22, 377. 0	3. 05	684. 6
4	25, 301. 6	2. 92	739. 2	22, 377. 0	3. 05	684. 6
5	17, 684. 0	3. 91	691. 6	17, 173. 9	3. 90	670. 5
6	21, 056. 1	3. 07	648. 4	16, 422. 0	3. 79	622. 4
Average of 6	23, 467. 4	3. 34	783. 9	20, 044. 4	3. 31	663. 5
Increase (+) of daughters over dams	+3, 423. 0	+0. 03	+120. 4			
Per cent increase	+17. 1	+0. 91	+18. 1			

All daughters exceeded dams in milk.
All daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE F

1	26, 692. 2	4. 04	1, 079. 8	20, 847. 6	3. 98	830. 2
2	28, 316. 8	3. 07	871. 6	19, 043. 5	3. 34	636. 9
3	23, 061. 2	3. 58	826. 0	18, 177. 8	3. 73	678. 3
4	21, 029. 1	3. 60	758. 4	16, 366. 3	3. 55	581. 2
5	21, 617. 7	3. 45	745. 7	25, 455. 7	3. 04	772. 7
6	19, 781. 7	3. 65	722. 3	15, 036. 6	3. 79	569. 3
7	20, 364. 0	3. 24	660. 4	20, 646. 0	3. 24	670. 0
8	18, 102. 0	3. 30	598. 1	17, 629. 5	3. 35	592. 1
9	16, 833. 9	3. 45	580. 9	16, 483. 8	3. 22	531. 4
Average of 9	21, 755. 4	3. 49	760. 3	18, 854. 1	3. 45	651. 3
Increase (+) of daughters over dams	+2, 901. 3	+0. 04	+109. 0			
Per cent increase	+15. 4	+1. 16	+16. 7			

Seven daughters exceeded dams in milk.
Seven daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE G

1	24, 690. 0	4. 31	1, 065. 4	15, 032. 6	4. 30	647. 1
2	23, 044. 6	4. 21	972. 2	28, 090. 0	3. 25	913. 9
3	18, 831. 0	4. 25	801. 1	17, 591. 5	3. 61	636. 1
4	22, 097. 8	3. 43	760. 0	22, 287. 0	3. 60	802. 6
5	22, 695. 8	3. 32	753. 8	19, 753. 7	3. 52	696. 3
6	15, 657. 2	4. 39	687. 4	15, 735. 4	3. 83	602. 8
7	13, 945. 5	3. 81	531. 8	14, 971. 7	3. 88	581. 8
Average of 7	20, 137. 4	3. 95	795. 9	19, 066. 0	3. 66	697. 2
Increase (+) of daughters over dams	+1, 071. 4	+0. 29	+98. 7			
Per cent increase	+5. 6	+7. 92	+14. 2			

Three daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Four daughters exceeded dams in percentage of butterfat.

SIRE H

1	20, 516. 2	3. 66	752. 1	18, 235. 9	3. 74	683. 1
2	21, 246. 0	3. 37	716. 7	17, 027. 3	3. 39	577. 4
3	23, 056. 6	3. 04	701. 6	17, 046. 4	3. 08	526. 3
4	16, 566. 8	3. 75	622. 3	17, 290. 0	3. 72	643. 3
5	19, 422. 1	3. 13	609. 1	14, 245. 7	3. 14	448. 6
6	18, 430. 2	3. 01	554. 6	17, 898. 1	2. 92	523. 3
Average of 6	19, 872. 9	3. 32	659. 4	16, 957. 2	3. 34	567. 0
Increase (+) or decrease (−) of daughters over dams	+2, 915. 7	−. 02	+92. 4			
Per cent increase or decrease	+17. 2	−. 60	+16. 3			

Five daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE I

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	22, 308. 8	3. 54	791. 3	17, 514. 6	3. 59	629. 6
2	23, 477. 1	3. 33	782. 4	13, 700. 7	3. 49	479. 3
3	23, 229. 5	3. 22	748. 3	17, 514. 6	3. 59	629. 6
4	22, 149. 5	3. 04	675. 2	14, 178. 1	3. 53	500. 9
5	11, 553. 6	3. 77	436. 6	14, 178. 1	3. 53	500. 9
6	12, 051. 7	3. 01	362. 8	15, 720. 1	3. 24	510. 7
Average of 6	19, 128. 4	3. 31	632. 8	15, 467. 7	3. 50	541. 8
Increase (+) or decrease (−) of daughters over dams	+3, 660. 7	−0. 19	+91. 0			
Per cent increase or decrease	+23. 7	−5. 43	+16. 8			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
One daughter exceeded dam in percentage of butterfat.

SIRE J

1	29, 053. 2	3. 40	988. 2	25, 227. 1	3. 46	875. 3
2	25, 345. 3	3. 80	965. 1	13, 447. 5	3. 61	485. 9
3	23, 359. 5	4. 04	945. 0	25, 227. 1	3. 46	875. 3
4	21, 837. 5	4. 29	937. 6	11, 006. 9	3. 42	377. 2
5	24, 741. 6	3. 77	933. 1	20, 877. 2	3. 28	684. 9
6	26, 331. 0	3. 39	895. 2	26, 134. 2	3. 27	856. 6
7	22, 424. 6	3. 70	830. 9	23, 340. 1	3. 58	835. 9
8	23, 853. 6	3. 24	774. 0	27, 762. 5	3. 60	1, 000. 3
9	19, 045. 8	3. 78	720. 1	19, 602. 3	3. 59	704. 3
10	18, 569. 0	3. 79	703. 8	23, 485. 6	3. 45	811. 2
11	18, 759. 8	3. 66	688. 3	27, 762. 5	3. 60	1, 000. 3
12	18, 804. 3	3. 59	676. 0	15, 788. 4	3. 29	519. 5
13	18, 826. 5	3. 59	677. 4	15, 788. 4	3. 29	519. 5
14	19, 080. 8	3. 48	665. 2	25, 227. 1	3. 46	875. 3
15	17, 585. 5	3. 61	635. 7	11, 337. 3	3. 70	419. 7
16	15, 401. 7	3. 70	570. 1	8, 891. 4	4. 01	357. 1
17	16, 264. 4	3. 44	561. 0	11, 006. 9	3. 42	377. 2
18	15, 104. 5	3. 55	536. 7	21, 796. 6	3. 33	725. 9
19	14, 894. 0	3. 55	530. 2	12, 266. 6	3. 55	436. 2
20	11, 412. 9	4. 14	473. 3	12, 266. 6	3. 55	436. 2
Average of 20	20, 034. 8	3. 67	735. 3	18, 912. 1	3. 48	658. 7
Increase (+) of daughters over dams	+1, 122. 7	+0. 19	+76. 6			
Per cent increase	+5. 9	+5. 46	+11. 6			

Eleven daughters exceeded dams in milk.
Fourteen daughters exceeded dams in butterfat.
Fifteen daughters exceeded dams in percentage of butterfat.

SIRE K

1	21, 689. 0	3. 59	777. 8	20, 690. 2	3. 55	734. 6
2	19, 132. 7	3. 71	709. 3	14, 562. 4	3. 44	501. 6
3	20, 558. 8	3. 19	655. 1	17, 046. 4	3. 09	526. 3
4	14, 146. 2	4. 34	614. 8	17, 027. 3	3. 39	577. 4
5	16, 570. 7	3. 26	539. 4	14, 245. 7	3. 15	448. 6
6	12, 413. 2	3. 51	436. 8	14, 562. 4	3. 44	501. 6
Average of 6	17, 418. 4	3. 57	622. 2	16, 355. 7	3. 35	548. 3
Increase (+) of daughters over dams	+1, 062. 7	+0. 22	+73. 9			
Per cent increase	+6. 5	+6. 57	+13. 5			

Four daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
All daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE L

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	23, 451. 5	3. 35	786. 5	22, 449. 5	3. 50	785. 8
2	21, 183. 7	3. 39	718. 4	15, 967. 8	3. 66	584. 2
3	21, 892. 1	3. 13	684. 4	18, 716. 3	3. 53	660. 7
4	19, 693. 0	3. 47	683. 1	14, 096. 2	3. 77	531. 9
5	18, 355. 0	3. 51	644. 0	14, 946. 5	3. 61	539. 9
6	18, 214. 5	3. 45	627. 9	16, 133. 9	3. 36	541. 3
7	15, 972. 4	3. 74	597. 5	14, 096. 2	3. 77	531. 9
8	18, 236. 5	3. 25	593. 5	18, 716. 3	3. 53	660. 7
9	17, 350. 5	3. 38	586. 7	14, 096. 2	3. 77	531. 9
10	14, 815. 3	3. 75	555. 7	14, 946. 3	3. 61	539. 9
11	12, 196. 6	3. 13	382. 0	11, 593. 3	3. 96	459. 0
Average of 11	18, 305. 6	3. 41	623. 6	15, 978. 0	3. 62	578. 8
Increase (+) or decrease (−) of daughters over dams	+2, 327. 6	−0. 21	+44. 8			
Per cent increase or decrease	+14. 6	−5. 80	+7. 7			

Nine daughters exceeded dams in milk.
Nine daughters exceeded dams in fat.
Two daughters exceeded dams in percentage of butterfat.

SIRE M

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	16, 465. 6	3. 69	608. 4	12, 480. 8	3. 88	483. 9
2	15, 429. 6	3. 44	531. 0	12, 445. 7	3. 40	423. 1
3	14, 918. 3	3. 56	530. 8	12, 470. 8	3. 68	458. 7
4	14, 925. 1	3. 49	521. 2	12, 470. 8	3. 68	458. 7
5	14, 972. 0	3. 33	499. 8	21, 746. 2	2. 98	649. 0
6	12, 240. 9	3. 68	450. 1	12, 480. 8	3. 88	483. 9
Average of 6	14, 825. 2	3. 53	523. 5	14, 015. 8	3. 52	492. 9
Increase (+) of daughters over dams	+809. 4	+0. 01	+30. 6			
Per cent increase	+5. 8	+0. 28	+6. 2			

Four daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

SIRE N

	Daughters Milk (Pounds)	Daughters Butterfat (Per cent)	Daughters Butterfat (Pounds)	Dams Milk (Pounds)	Dams Butterfat (Per cent)	Dams Butterfat (Pounds)
1	18, 218. 0	3. 87	705. 6	11, 311. 8	3. 81	431. 4
2	18, 456. 8	3. 77	695. 0	12, 529. 7	3. 55	445. 2
3	19, 973. 4	3. 40	678. 4	15, 357. 5	3. 54	543. 1
4	17, 300. 3	3. 75	648. 7	19, 258. 8	4. 41	849. 2
5	16, 756. 9	3. 78	632. 9	14, 913. 7	3. 54	527. 9
6	15, 826. 2	3. 48	550. 3	11, 649. 3	3. 94	458. 4
7	16, 017. 2	3. 38	541. 6	17, 882. 3	4. 32	773. 2
8	13, 761. 6	3. 71	510. 4	14, 241. 8	3. 71	528. 5
9	15, 096. 2	3. 33	502. 3	17, 022. 3	4. 41	750. 0
Average of 9	16, 822. 9	3. 61	607. 2	14, 907. 5	3. 96	589. 7
Increase (+) or decrease (−) of daughters over dams	+1, 915. 4	−0. 35	+17. 5			
Per cent increase or decrease	+12. 8	−8. 84	+2. 9			

Five daughters exceeded dams in milk.
Five daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE O

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	14, 173. 8	3. 02	428. 5	13, 615. 1	3. 42	466. 3
2	12, 336. 0	3. 81	469. 7	10, 546. 0	3. 47	366. 3
3	19, 162. 7	4. 21	806. 6	19, 316. 4	4. 17	805. 9
4	21, 578. 0	3. 13	674. 5	15, 708. 5	3. 27	513. 1
5	13, 329. 5	3. 52	469. 7	15, 901. 4	4. 03	640. 9
6	13, 479. 7	3. 63	489. 1	13, 615. 1	3. 42	466. 3
Average of 6	15, 676. 6	3. 55	556. 3	14, 783. 7	3. 67	543. 1
Increase (+) or decrease (−) of daughters over dams	+892. 9	−0. 12	+13. 2			
Per cent increase or decrease	+6. 0	−3. 27	+2. 4			

Three daughters exceeded dams in milk.
Four daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

SIRE P

1	18, 355. 7	3. 70	678. 7	18, 670. 1	3. 23	603. 5
2	19, 861. 0	3. 03	602. 7	18, 762. 6	3. 08	577. 5
3	14, 776. 1	3. 71	547. 9	15, 223. 1	3. 65	556. 2
4	14, 634. 5	3. 64	533. 9	16, 510. 8	3. 06	505. 4
5	13, 167. 6	3. 31	435. 9	15, 754. 3	3. 28	516. 1
6	12, 713. 1	3. 10	393. 9	13, 051. 4	3. 04	396. 3
Average of 6	15, 584. 6	3. 41	532. 2	16, 328. 7	3. 22	525. 8
Increase (+) or decrease (−) of daughters over dams	−744. 1	+0. 19	+6. 4			
Per cent increase or decrease	−4. 6	+5. 90	+1. 2			

One daughter exceeded dam in milk.
Three daughters exceeded dams in butterfat.
Five daughters exceeded dams in percentage of butterfat.

SIRE Q

1	22, 552. 5	3. 21	723. 8	17, 893. 0	3. 80	679. 5
2	20, 267. 7	3. 55	719. 0	14, 122. 2	3. 34	472. 3
3	20, 895. 6	3. 28	686. 4	14, 630. 0	3. 58	523. 2
4	19, 048. 2	3. 51	667. 9	19, 999. 8	3. 27	654. 4
5	18, 463. 0	3. 28	605. 0	17, 879. 1	3. 35	598. 2
6	18, 300. 4	3. 13	573. 4	16, 497. 4	3. 33	549. 0
7	16, 654. 4	3. 30	549. 6	16, 497. 4	3. 30	544. 4
8	13, 245. 5	3. 69	488. 7	18, 509. 7	3. 60	666. 4
9	15, 807. 8	3. 07	484. 9	14, 755. 6	3. 23	475. 9
10	14, 547. 4	3. 29	478. 0	21, 063. 0	3. 43	723. 0
11	13, 966. 8	3. 34	466. 1	17, 894. 8	3. 35	598. 9
Average of 11	17, 613. 6	3. 33	585. 7	17, 249. 3	3. 42	589. 6
Increase (+) or decrease (−) of daughters over dams	+364. 3	−0. 09	−3. 9			
Per cent increase or decrease	+2. 1	−2. 63	−0. 7			

Seven daughters exceeded dams in milk
Eight daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE R

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	15,458.3	3.23	499.8	17,287.3	3.33	575.0
2	17,718.1	2.75	487.7	15,387.8	2.74	423.1
3	13,285.0	3.40	451.8	12,258.9	3.53	433.0
4	15,688.1	2.61	409.7	15,387.8	2.74	423.1
5	11,975.8	3.20	383.2	12,258.9	3.53	433.0
6	10,928.3	3.31	361.4	11,367.8	3.25	368.9
Average of 6	14,175.6	3.05	432.3	13,991.4	3.16	442.7
Increase (+) or decrease (−) of daughters over dams	+184.2	−0.11	−10.4			
Per cent increase or decrease	+1.3	−3.48	−2.3			

Three daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat

SIRE S

1	14,064.6	4.30	604.2	10,300.0	4.44	457.6
2	16,728.5	3.27	546.6	18,329.6	3.34	611.8
3	13,594.9	4.00	541.9	16,355.5	3.88	634.2
4	15,168.5	3.28	496.9	15,068.3	3.63	546.4
5	14,897.0	3.18	473.2	14,069.5	3.24	456.2
6	11,831.1	3.88	458.8	15,669.8	3.22	505.1
7	11,779.5	3.44	405.1	16,032.5	3.37	540.5
Average of 7	14,009.2	3.60	503.8	15,117.9	3.55	536.0
Increase (+) or decrease (−) of daughters over dams	−1,108.7	+0.05	−32.2			
Per cent increase or decrease	−7.3	+1.41	−6.0			

Three daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Three daughters exceeded dams in percentage of butterfat.

SIRE T

1	23,050.3	3.32	765.9	18,511.7	3.67	679.9
2	19,737.4	3.53	697.6	19,074.8	3.70	706.1
3	18,347.6	3.61	662.3	16,977.6	3.58	607.1
4	18,057.7	3.31	596.8	17,809.8	3.92	697.4
5	16,702.7	3.56	595.4	19,074.9	3.70	706.1
6	17,417.4	3.29	572.3	21,611.7	3.37	728.0
7	16,481.0	3.35	551.6	18,619.5	3.63	675.7
Average of 7	18,542.0	3.42	634.5	18,811.4	3.65	685.8
Decrease (−) of daughters over dams	−269.4	−0.23	−51.3			
Per cent decrease	−1.4	−6.30	−7.5			

Four daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
One daughter exceeded dam in percentage of butterfat.

60980°—26†——2

TABLE 2.—*Production records of daughters and their dams*—Continued

SIRE U

	Daughters			Dams		
	Milk	Butterfat		Milk	Butterfat	
	Pounds	*Per cent*	*Pounds*	*Pounds*	*Per cent*	*Pounds*
1	13,994.8	3.35	468.5	12,691.9	3.88	492.9
2	14,990.5	3.07	459.7	15,071.8	3.78	569.5
3	14,239.6	3.41	485.2	15,559.1	3.27	508.6
4	13,580.1	3.16	429.2	16,335.1	3.46	565.8
5	14,913.1	3.23	481.1	9,555.6	3.68	351.7
6	14,727.0	3.06	451.6	19,002.6	3.20	608.1
7	11,881.9	3.29	390.8	14,446.3	3.30	477.4
Average of 7	14,046.7	3.22	452.3	14,666.0	3.48	510.5
Decrease (−) of daughters over dams	−619.3	−0.26	−58.2			
Per cent decrease	−4.2	−7.47	−11.4			

Two daughters exceeded dams in milk.
One daughter exceeded dam in butterfat.
One daughter exceeded dam in percentage of butterfat.

SIRE V

1	16,971.7	3.54	601.2	17,148.8	3.29	563.7
2	16,687.4	3.32	554.1	18,670.1	3.23	603.5
3	14,973.1	3.44	515.5	15,754.3	3.28	516.1
4	14,135.2	3.42	483.7	20,108.2	3.26	656.2
5	18,049.3	2.62	472.1	13,815.9	3.02	417.4
6	15,237.6	3.06	466.2	17,343.6	3.27	566.6
7	12,126.5	3.82	463.1	20,108.2	3.26	656.2
Average of 7	15,454.4	3.29	508.0	17,564.2	3.24	568.5
Increase (+) or decrease (−) of daughters over dams	−2,109.8	+0.05	−60.5			
Per cent increase or decrease	−12.0	+1.54	−10.6			

One daughter exceeded dam in milk.
Two daughters exceeded dams in butterfat.
Five daughters exceeded dams in percentage of butterfat.

SIRE W

1	21,208.6	3.71	786.4	15,652.5	3.76	589.1
2	23,088.1	3.40	785.8	20,407.7	3.94	804.3
3	19,502.2	3.48	678.8	20,323.0	3.51	712.4
4	19,652.2	3.36	660.2	18,510.7	3.67	679.9
5	18,640.6	3.50	653.8	17,562.0	3.60	632.7
6	18,251.3	3.53	643.8	20,407.6	3.94	804.3
7	17,330.0	3.71	643.0	17,809.8	3.92	697.4
8	17,421.4	3.63	632.0	17,478.9	3.96	692.5
9	19,799.0	3.18	629.6	16,668.2	3.88	646.5
10	16,511.8	3.71	613.2	17,478.9	3.96	692.5
11	17,285.7	3.53	610.4	20,323.0	3.51	712.4
12	18,562.4	3.18	589.6	24,858.1	3.07	762.7
13	16,796.1	3.40	570.4	18,619.5	3.63	675.7
14	15,058.2	3.52	530.3	18,676.8	3.64	680.1
15	13,278.0	3.65	484.6	15,701.7	3.73	586.2
16	13,296.8	3.22	428.2	21,611.7	3.37	728.0
Average of 16	17,855.1	3.48	621.2	18,880.6	3.67	693.5
Decrease (−) of daughters over dams	−1,025.5	−0.19	−72.3			
Per cent decrease	−5.4	−5.18	−10.4			

Five daughters exceeded dams in milk.
Two daughters exceeded dams in butterfat.
Two daughters exceeded dams in percentage of butterfat.

Table 3 is a summary of Table 2 showing the increase or decrease in yield of milk, percentage of butterfat, and yield of butterfat of the daughters of each of the 23 sires as compared with the records of their dams. Comparisons are made in pounds of milk, pounds of butterfat, and fat tests, with the per cent of increase or decrease in each case.

TABLE 3.—*Summary of sires having six or more yearly-record daughters whose dams have yearly records, in order of relative increase in pounds of butterfat, by daughters over dams*

Sire	Increase (+) or decrease (—) of daughters over dams.					
	Milk		Butterfat test		Butterfat	
	Pounds	Per cent	Amount	Per cent	Pounds	Per cent
A	+5, 110. 9	+35. 3	+0. 13	+4. 02	+191. 0	+40. 9
B	+4, 135. 3	+24. 1	+0. 11	+3. 24	+163. 8	+28. 2
C	+3, 404. 4	+18. 2	+0. 09	+2. 59	+138. 7	+21. 4
D	+3, 770. 4	+21. 4	+0. 03	+0. 94	+126. 3	+22. 4
E	+3, 423. 0	+17. 1	+0. 03	+0. 91	+120. 4	+18. 1
F	+2, 901. 3	+15. 4	+0. 04	+1. 16	+109. 0	+16. 7
G	+1, 071. 4	+5. 6	+0. 29	+7. 92	+98. 7	+14. 2
H	+2, 915. 7	+17. 2	−0. 02	−0. 60	+92. 4	+16. 3
I	+3, 660. 7	+23. 7	−0. 19	−5. 43	+91. 0	+16. 8
J	+1, 122. 7	+5. 9	+0. 19	+5. 46	+76. 6	+11. 6
K	+1, 062. 7	+6. 5	+0. 22	+6. 57	+73. 9	+13. 5
L	+2, 327. 6	+14. 6	−0. 21	−5. 80	+44. 8	+7. 7
M	+809. 4	+5. 8	+0. 01	+0. 28	+30. 6	+6. 2
N	+1, 915. 4	+12. 8	−0. 35	−8. 84	+17. 5	+2. 9
O	+892. 9	+6. 0	−0. 12	−3. 27	+13. 2	+2. 4
P	−744. 1	−4. 6	+0. 19	+5. 90	+6. 4	+1. 2
Q	+364. 3	+2. 1	−0. 09	−2. 63	−3. 9	−0. 7
R	+184. 2	+1. 3	−0. 11	−3. 48	−10. 4	−2. 3
S	−1, 108. 7	−7. 3	+0. 05	+1. 41	−32. 2	−6. 0
T	−269. 4	−1. 4	−0. 23	−6. 30	−51. 3	−7. 5
U	−619. 3	−4. 2	−0. 26	−7. 47	−58. 2	−11. 4
V	−2, 109. 8	−12. 0	+0. 05	+1. 54	−60. 5	−10. 6
W	−1, 025. 5	−5. 4	−0. 19	−5. 18	−72. 3	−10. 4

METHOD OF INHERITANCE

A study of the records of the daughters and their dams in Table 2 shows a remarkable variation. Note the following instances:

The highest-record daughter of sire A is out of the dam that has the lowest record of the five. His lowest-record daughter is out of the dam with the next lowest record. The one daughter which failed to make a larger record than her dam was from the dam with the highest butterfat record, and yet this daughter's record is 6,491 pounds of milk and 215 pounds of butterfat lower than his highest-record daughter.

Sire B's highest-record daughter is out of a dam with the third from the lowest record, and his daughter with the next to lowest record is from the fourth highest dam. There are two full sisters in his list of daughters. One is second in the list of 13 daughters, the other is ninth, the latter with 3,301 pounds of milk and 184 pounds of butterfat less than her sister.

Sire C has 12 daughters whose dams have yearly records. The highest-record dam, which produced 892 pounds of butterfat, has a daughter with the third highest record, or 891 pounds of butterfat; whereas the lowest-record dam, with 404 pounds of butterfat, has a daughter with the fourth highest record, or 862 pounds of butterfat. His highest-record daughter produced 917 pounds of butterfat and her dam 730 pounds. The next highest daughter, which produced 893 pounds of butterfat, is from a dam with 574 pounds.

The lowest-record dam in the list of sire D produced 388 pounds of butterfat; her daughter, sire D's lowest-producing daughter, has a record of 507 pounds of butterfat, an increase of 119 pounds. Sire D's highest-producing daughter produced 844 pounds of butterfat and her dam produced 572 pounds, an increase by the daughter of

272 pounds over the dam. The highest-record dam produced 846 pounds of butterfat and her daughter 744 pounds, or a 102-pound decrease. This daughter of the highest-record dam has a record that is 100 pounds lower than that of the highest-record daughter, whose dam's record, 572 pounds of butterfat, is 274 pounds less than that of the highest-record dam.

The highest-record daughter of sire F was out of a dam with the highest record of any of the dams, 20,847 pounds of milk and 830 pounds of butterfat; yet this daughter's record is larger than the dam's by 5,845 pounds of milk and 249 pounds of butterfat. His lowest-record daughter was out of the lowest-record dam. This dam has a record of 16,483 pounds of milk and 531 pounds of butterfat. Her daughter's record is larger by 350 pounds of milk and 49 pounds of butterfat. Note the difference between this increase from a low-record dam and the increase from the highest-record dam. Two of his other daughter's records were lower than those of their dams.

The highest-record dam of the daughters of sire G has a record of 913 pounds of butterfat. The daughter of this dam exceeded this record by 59 pounds. This increase was due to a rise of almost 1 per cent of butterfat. The yield of milk of the daughter was less by 5,046 pounds. The lowest-record dam produced 581 pounds of butterfat and her daughter 531 pounds, a decrease of 50 pounds. This decrease was due to both a lower yield of milk and a lower percentage of butterfat in the milk. The one other daughter of this sire that had a lower butterfat record than her dam was out of a dam which produced 802 pounds of butterfat.

Included in the list of six daughters of sire I are two pairs of full sisters. The dam of one of these pairs had a record of 17,514 pounds of milk and 629 pounds of butterfat. Both daughters of this dam made more milk and more butterfat than the dam. One daughter exceeded her dam's production by 4,794 pounds of milk and 162 pounds of butterfat and had nearly the same test as the dam. The other daughter produced 5,715 pounds of milk more than the dam, but the percentage of butterfat in her milk was 0.37 less than that of her dam and her increase in total butterfat was only 119 pounds. The dam of the other pair of sisters has a record of 14,178 pounds of milk and 500 pounds of butterfat. One of these sisters increased the yield of milk 7,971 pounds, lowered the percentage of butterfat 0.49 (from 3.53 to 3.04) and increased the total butterfat 175 pounds. The other sister decreased the yield of milk 2,625 pounds, raised the percentage of fat 0.24 and decreased the total butterfat 64 pounds.

Such examples as those mentioned may be cited in the records of the daughters of every sire in the list. A careful study of the comparative records of each sire will show great variations in the records of the daughters of the same sire, and between the records of the daughters and their dams. Instances are found of the highest-record daughters coming from the lowest-record dams. There are other instances in which both the highest-record and the lowest-record dams have daughters which show increases, whereas other dams coming in between these extremes have daughters showing decreases.

It seems clear that the daughters' records are not a blend between the production ability of sire and dam, and it also seems clear that the increase or decrease of the records of a sire's daughters over or under the records of their dams will not be uniform; nor is the size of the record of the dam a criterion of the size of the record of the daughter.

THE BLENDING-INHERITANCE THEORY

Many investigators and breeders believe that the inheritance of milk and butterfat production is of the blending type. It has been suggested, in accordance with this theory, that the true measure of a sire's inherent ability might be calculated by adding the average increase of the daughters over their dams to the average record of the daughters, the result being the true inherent transmitting ability of the sire for milk and butterfat production. The assumption is that the capacity of the daughter is halfway between that of her sire and that of her dam. Thus, if the sire's inherent transmitting ability is 800 pounds of butterfat and he is bred to a 600-pound-butterfat cow, the daughter should have the ability to make an average between the two, or 700 pounds of fat.

This theory was tried out by taking the average butterfat records of the daughters of sire B and their dams. The average of the daughters was 745 pounds of butterfat; the average of their dams was 581 pounds of butterfat. The difference between the average of the daughters and the average of the dams was 164 pounds. This added to the average of the daughters gives the sire an inherent transmitting ability of 909 pounds of butterfat. With the inherent transmitting ability of the sire a known quantity, as is also the record of the cow to which he is mated, it should be possible to predict the producing capacity of a particular daughter by halving the sum of the sire's standard and dam's record, the resulting average being the daughter's producing capacity. But when this system is applied to the individual daughters of sire B the results do not check well with the actual records in Table 2. The comparison is shown in Table 4.

TABLE 4.—*Butterfat records of daughters of sire B, showing butterfat production predicted by blending-inheritance computation, and that actually produced*

Daughter No.	Butterfat predicted	Butterfat produced	Difference of predicted from actual production	Daughter No.	Butterfat predicted	Butterfat produced	Difference of predicted from actual production
	Pounds	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
1	705.3	970.5	−265.2	8	678.8	738.6	−59.8
2	791.8	912.1	−120.3	9	791.8	727.5	+64.3
3	759.6	848.8	−89.2	10	786.4	688.3	+98.1
4	685.6	821.2	−135.6	11	717.5	623.7	+93.8
5	734.9	804.5	−69.6	12	783.5	517.9	+265.6
6	717.7	784.2	−66.5	13	743.2	506.1	+237.1
7	792.6	745.0	+47.6				

It is true that where there have been crosses between two distinct breeds of dairy cattle that have a considerable difference between their milk flow and their range of butterfat percentage, such as the Holstein-Friesian cross on Guernsey or Jersey, it has been observed that the resulting progeny have a milk flow and a percentage fat that are intermediate between those of the two parents. In these crosses between distinct breeds there are probably so many independently inherited factors having a bearing on the milk flow and the percentage fat in each parent, that it is almost impossible to bring about, in any limited number of animals, a segregation of factors that will result in the exact reappearance of either of the parental characters. For crosses within a breed, however, there is not the same evidence of intermediate milk flow and percentage fat. The great variation in records between the daughters of a sire, and also the variation between records of the daughters and their dams, do not indicate a blended inheritance of the type shown by crosses between distinct breeds.

There are several explanations that may be given to account for this great variation in the production capacity of the daughters of a sire: (1) The factors that determine high-producing capacity may be dominant over those determining a low-producing capacity. (2) Each individual sire and dam may have a double nature in its hereditary make-up. The dam may be a good producer, because of dominant factors for high production received from one parent, but she may also possess recessive factors for low-producing capacity that she received from her other parent; and, consequently, she may transmit to a part of her offspring an inheritance for high-producing capacity and to the other part an inheritance for low-producing capacity. (3) The cumulative or multiple factor hypothesis is based on the theory that quantitative characters are produced by cumulative factors; that is, when a factor is added to another similar factor, the cumulation affects the degree of development of that character.

WHAT IS A GREAT SIRE OF PRODUCTION?

Which is the greatest sire of production? Is it (1) one that gets daughters that are as good as their high-producing dams; (2) one that gets daughters that make considerably larger records than good dams; (3) one that gets daughters that make much larger records than their low or medium-producing dams; (4) one that gets daughters with the greatest average increase of milk and butterfat over their dams; (5) one whose daughters have the highest average yield of butterfat and milk regardless of the dam's average; (6) one that has the greatest proportion of his daughters better than their dams regardless of the amount of the increase; or (7) one that has daughters showing the greatest uniformity of production?

If sires were judged solely by the average increase in yield of their daughters over their dams, some sires having only one-third of their daughters better than their dams would appear better than other sires with two-thirds of their daughters better than their dams. Nor can a sire be judged entirely by the number of his daughters that are better than their dams, for if the dams were low producers and the increase of the daughters was small, the sire would not have great merit.

It seems desirable to take into consideration all the following factors in judging the comparative merits of several sires: The average yield of their daughters; the average increase in the yield of the daughters over that of their dams; and the number of daughters that were better than their dams.

The 23 sires studied are given comparative rankings in Table 5 with respect to average milk yield of their daughters, average butterfat yield, average increase of milk, average increase of butterfat, and the percentage of daughters that were better than their dams in milk and in butterfat yield; in the last column is the sum of his rankings in the various classes.

TABLE 5.—*Ranking of the 23 sires in various classes based on the comparative production of their daughters*

Sire	Relative rank in this group	Number of daughters	Rank according to— Average milk yield of daughters	Average butterfat yield of daughters	Average increase of milk	Average increase of butterfat	Percentage of daughters making increase in milk	Percentage of daughters making increase in butterfat	Total of rankings
E	1	6	1	3	5	5	1	1	16
B	2	13	5	5	2	2	2	3	19
C	3	12	2	2	6	3	3	8	24
D	4	9	4	7	3	4	6	2	26
A	5	5	9	9	1	1	5	6	31
F	6	9	3	4	8	6	6	7	34
H	7	6	8	8	7	8	3	4	38
G	8	7	6	1	12	7	13	10	49
I	9	6	10	11	4	9	7	12	53
L	10	11	12	12	9	12	4	5	54
J	11	20	7	6	11	10	11	11	56
K	12	6	15	13	13	11	7	4	63
N	13	9	16	15	10	14	10	13	78
Q	14	11	14	16	16	17	8	9	80
T	15	7	11	10	18	20	9	16	84
M	16	6	20	19	15	13	7	12	86
O	17	6	17	17	14	15	12	12	87
P	18	6	18	18	20	16	16	14	102
W	19	16	13	14	21	23	14	18	103
R	20	6	21	23	17	18	12	15	106
S	21	7	23	21	22	19	13	16	114
U	22	7	22	22	19	21	15	17	116
V	23	7	19	20	23	22	17	16	117

No sire has the same rank in all classes. Several have the same rank in three classes. The smallest total of the rankings in the six classes indicates the sire having the best general rank.

This method of comparing the merit of several sires for their ability to transmit milk and butterfat producing capacity to their daughters is not without its faults. Probably the most serious fault is in allowing average production of milk and of butterfat to have equal weight with the average increase of milk and butterfat yield and the percentage of daughters that were better than their dams. These last two qualifications would appear to measure fairly the influence of the sire; but the first qualification, the average yield of daughters, may be due to a very great extent to the influence of the dams.

An illustration of the influence that the high average production may have in the final rankings is shown in sires Q, T, M, O, and P, whose final relative rankings are near together. The average productions of milk and butterfat of the daughters of these sires are given in Table 6.

TABLE 6.—*Production of daughters (and their dams) from five sires with comparative rankings shown*

Sire	Rank	Daughters Milk	Daughters Fat	Dams Milk	Dams Fat
		Pounds	*Pounds*	*Pounds*	*Pounds*
Q	14	17, 613. 6	585. 7	17, 249. 3	589. 6
T	15	18, 542. 0	634. 5	18, 811. 4	685. 8
M	16	14, 825. 2	523. 5	14, 015. 8	492. 9
O	17	15, 676. 6	556. 3	14, 783. 7	543. 1
P	18	15, 584. 6	532. 2	16, 328. 7	525. 8

Thus sires Q and T, who decreased the average butterfat yield of their daughters, have a higher ranking than do sires M, O, and P, who increased the average butterfat yield of their daughters. This is brought about largely through the much higher average yield of milk and butterfat of the daughters of the sires Q and T, though the relative ranking among these five sires in the percentage of daughters better than their dams is high for sire Q in both milk and butterfat and for sire T in milk.

Such inconsistencies do not appear in the rankings of the other sires, though the final ranking is not always in the same order as the amount of the average increase or decrease of the daughters for any one class.

THE STANDARD DEVIATION AND COEFFICIENT OF VARIABILITY FOR BUTTERFAT YIELD OF THE DAUGHTERS OF THE 23 SIRES AND OF THEIR DAMS

Judging by the records of the daughters of the 23 sires in this study, it is not to be expected that any sire, at this stage of breed improvement, will get daughters all of which will have the capacity to make uniform records of any certain standard. This is true regardless of how uniform the production records may be of the dams to which a sire is mated. A study of the detailed records given in Table 2 readily shows the great variation in the producing capacity of each sire's daughters. It is not strange that there should be such a great variation when the double nature of the hereditary make-up of each individual is considered and when we realize how few matings are made where the animals are known to be homozygous or pure in their inheritance for the desired characters. If a sire's inheritance for a character, such as milk and butterfat producing capacity, is not homozygous, so that he can not transmit to each of his offspring the same capacity for production, and then if this sire is mated to a group of dams, each of whose 30 ancestors in 4 ancestral generations show varying degrees of producing capacity, it is not surprising that the offspring should show a wide variation in producing ability.

It would seem that a prepotent sire, mated to a group of cows having a considerable range in producing capacity, would get daughters showing greater uniformity of production. The standard deviation [3] and the coefficient of variability of the butterfat yields of daughters, and of their dams, as given in Table 7, does not show that the sires who decrease the coefficient of variability were any more prepotent in increasing production as measured in Table 5, than were the sires who increased the variability of the butterfat producing capacity of their daughters. The dams to which sire N was mated had a standard deviation of 148 pounds butterfat, whereas his daughters had a standard deviation of only 76 pounds butterfat—a decrease in the coefficient of variability from 25.22 per cent for the dams, to 12.57 per cent for the daughters. Yet sire N ranks thirteenth in prepotency for producing capacity as measured in Table 5.

On the other hand sire I's daughters show a standard deviation of 170 pounds butterfat as compared with a standard deviation of only 62 pounds butterfat in their dams. The coefficient of variability is increased from 11.56 per cent for the dams to 26.91 per cent for the

[3] "Standard deviation" is a term used in statistical calculations to denote a mathematical measure of the variability of the items in a group from the mean, or average, of the whole group. "Coefficient of variation" is an index of variability appearing in the form of rate per cent.

daughters. Sire I ranks ninth in prepotency among the 23 sires as measured in Table 5. The daughters of sire E, who ranks first in prepotency for production capacity in Table 5, show a greater coefficient of variation than do their dams. This is also true of the daughters of sire B, who ranks second, but the daughters of sires C, D, and A who rank third, fourth, and fifth, respectively, in Table 5, all show a smaller coefficient of variation than do their dams. Thus it will be seen that greater or less uniformity of production of a sire's daughters as compared with that of their dams is no indication of the sire's prepotency for producing capacity.

The smallest variation of production in butterfat in any group of daughters is found in the daughters of sire U, that have a standard deviation of only 30 pounds butterfat and a coefficient of variation of 6.68 per cent. Sire U ranks twenty-second in the 23 sires for prepotency, according to Table 5. Sire I's daughters show the greatest variation—standard deviation 170 pounds butterfat—in any group of daughters, as well as the greatest increase in coefficient of variation as compared with that of their dams. The daughters of sire G show the second greatest standard deviation among the groups of daughters, with 161 pounds. Sire G ranks eighth among the 23 sires. Neither the greatest nor the least variations among the groups of daughters, nor the amount of variation among daughters as compared with that of their dams, is indicative of the prepotency of the sire in transmitting producing capacity. This will probably be true as long as the sires and dams that are mated are heterozygous in their hereditary factors controlling producing capacity.

TABLE 7.—*Standard deviation and coefficient of variation of butterfat records of the daughters of each of the 23 sires, and of the dams of the daughters; also the increase or decrease of coefficient of variation of the daughters of each sire as compared with that of their dams; and the rankings of the sires as in Table 5*

Sire	Daughters		Dams		Increase or decrease in coefficient of variation	Rank of sires
	Standard deviation	Coefficient of variation	Standard deviation	Coefficient of variation		
	Pounds	*Per cent*	*Pounds*	*Per cent*		
A	90.9	13.81	85.0	18.20	−4.39	5
B	131.9	17.69	80.6	13.85	+3.84	2
C	100.8	12.81	113.4	17.50	−4.69	3
D	95.6	13.88	128.9	22.94	−9.06	4
E	103.1	13.15	25.6	3.85	+9.30	1
F	144.7	19.03	92.6	14.22	+4.81	6
G	161.9	20.34	110.5	11.54	+8.80	8
H	68.7	10.42	78.5	13.84	−3.42	7
I	170.3	26.91	62.7	11.56	+15.35	9
J	158.0	21.48	217.7	33.05	−11.57	11
K	107.4	17.25	91.2	16.63	+0.62	12
L	99.0	15.88	86.1	14.87	+1.01	10
M	47.0	8.98	72.7	14.73	−5.75	16
N	76.3	12.57	148.7	25.22	−12.65	13
O	136.7	24.58	142.9	26.31	−1.73	17
P	95.7	17.98	66.9	12.70	+5.28	18
Q	95.8	16.35	80.3	13.61	+2.74	14
R	51.5	11.90	63.1	14.25	−2.35	20
S	61.0	12.09	64.3	12.00	+0.09	21
T	71.2	11.22	35.5	5.16	+6.06	15
U	30.2	6.68	78.0	15.28	−8.60	22
V	48.5	9.55	77.7	13.66	−4.11	23
W	89.4	14.39	61.6	8.59	+5.80	19

PREPOTENCY OF THE SIRE

The available records do not indicate whether a sire can be completely prepotent in raising the production of his daughters, for the reason that comparatively few of the tested daughters of the various sires have dams that have been tested. Then, too, the lowest-producing daughters of a sire may not be tested, for it is doubtful whether some breeders would test a low-producing daughter of their herd sires. When the dam of a tested daughter does have a record, information is not available to show whether the dam's record was made under as favorable conditions as was the daughter's record. Although the information relative to the conditions under which the dams and daughters were tested is not available, and it is not known whether the poorer-producing daughters of these sires were tested, the information contained in Table 8 should be of interest. It shows the number of each of the 23 sires' daughters that increased and the number that decreased the yield of milk and butterfat, and the percentage of butterfat in the milk as compared with the yields of their dams.

Table 8.—*Number of each sire's tested daughters that increased or decreased the milk and butterfat yield and the percentage of butterfat, as compared with their dams*

Sire	Number of daughters with tested dams	Milk yield		Percentage of butterfat		Total butterfat	
		Increased	Decreased	Increased	Decreased	Increased	Decreased
A	5	4	1	4	1	4	1
B	13	11	2	8	5	11	2
C	12	10	2	7	5	9	3
D	9	7	2	4	5	8	1
E	6	6	0	4	2	6	0
F	9	7	2	[1]4	[1]4	7	2
G	7	3	4	4	3	5	2
H	6	5	1	2	4	5	1
I	6	4	2	1	5	4	2
J	20	11	9	[1]15	[1]4	14	6
K	6	4	2	6	0	5	1
L	11	9	2	2	9	9	2
M	6	4	2	2	4	4	2
N	9	5	4	[1]3	[1]5	5	4
O	6	3	3	3	3	4	2
P	6	1	5	5	1	3	3
Q	11	7	4	[1]3	[1]7	8	3
R	6	3	3	2	4	2	4
S	7	3	4	3	4	2	5
T	7	4	3	1	6	2	5
U	7	2	5	1	6	1	6
V	7	1	6	5	2	2	5
W	16	5	11	2	14	2	14

[1] One daughter had same test as dam.

In Table 8, the second column gives the number of daughters of each sire that have yearly records and have dams with yearly records. In the column headed "Milk yield" is shown, on the left side, the number of daughters that made larger milk yields than their dams, and on the right side the number of daughters that made smaller yields than their dams. Similar comparisons are given in the columns headed "Percentage of butterfat" and "Total butterfat." In the column headed "Percentage of butterfat," it will be noted that the number of daughters increasing and the number of daughters decreasing the percentage of fat does not always equal the number of tested daughters given in the first column. The difference represents the number of daughters that had same test as their dams.

No sire in this list is completely prepotent; that is, no sire has all his tested daughters better than their dams in yield of milk, percentage of butterfat, and yield of butterfat. Sire E is the only one that increased the milk and butterfat yield of all his tested daughters over the yields of their dams, but only four of his daughters had a higher percentage of butterfat than their dams. Several sires increased the milk yield of a great majority of their daughters. For example, one sire increased the milk yield of 4 out of 5 daughters; another sire increased the milk yield of 11 out of 13 daughters; another 10 out of 12 daughters; another 9 out of 11 daughters; and another 7 out of 9 daughters.

Some sires were also prepotent in decreasing the milk yield; for example, one sire decreased the milk yield of 5 out of 6 daughters; another, 6 out of 7 daughters; another, 11 out of 16; and another, 4 out of 7 daughters.

Four sires were prepotent in influencing the percentage of butterfat in the milk of their daughters. One sire's daughters had higher percentages of butterfat than their dams in every case. On the other hand, two sires had 6 out of 7 daughters with lower percentages of butterfat than their dams, and another sire had 14 out of 16 daughters with lower percentages.

Only nine sires had a majority of their daughters with higher percentages of butterfat than their dams. There were 15 sires that had over half their daughters with a larger yield of milk than their dams, and 16 sires had over half their daughters with a larger yield of butterfat than their dams.

This study indicates that some sires are capable of increasing in the great majority of their daughters both the yield of milk and the percentage of butterfat in the milk over that of the dams. Some sires may increase the yield of milk in the majority of their daughters and decrease the percentage of butterfat. Several sires decreased both yield of milk and percentage of butterfat in the milk. Fewer sires were prepotent in increasing the percentage of butterfat in the milk of their daughters than in increasing the milk yield of their daughters. No sire in the list increased both the milk yield and the percentage of butterfat in the milk of all his daughters, or decreased the milk yield and the butterfat percentage in the milk of all his daughters.

METHOD OF BREEDING AND RECORD OF DAM AS INDICATIONS OF A SIRE'S BREEDING ABILITY

Table 9 shows the 23 sires listed in the order in which they were ranked on the basis of comparative production of milk and butterfat of their daughters, as in Table 7. The record of the dam of each sire is given first. The next column shows whether the sire was inbred, line bred, or outbred; and the last two columns give this same information for his sire and his dam. The figures in the last three columns refer to the popular expression "common blood," meaning the percentage of common ancestry that appeared on the sire's and dam's side of the pedigree in five ancestral generations.

TABLE 9.—*Method of breeding of each of 23 sires and records of their dams*

Sire	Record of his dam			How this bull was bred	How his sire was bred	How his dam was bred
	Time	Milk	Butterfat			
		Pounds	*Pounds*			
E	No record			Line bred (28.1 [1])	Line bred (25 [1])	Line bred (31.2 [1]).
B	7 days	567.9	25.04	Outbred (18.75 [1])	Outbred	Outbred.
C	do	534.5	22.1	Line bred (34.37 [1])	Inbred (50 [1])	Line bred (25 [1]).
D	do 1 year	545.1 20,174.6	22.1 724.7	Line bred (34.37 [1])	Outbred	Outbred.
A	7 days	539.1	19.5	Outbred	Line bred (43.75 [1])	Do.
F	do	638.7	24.4	Inbred (56.24 [1])	Line bred (25 [1])	Inbred (50 [1]).
H	do	520.1	20.2	Outbred	Outbred	Outbred.
G	do	568.9	20.0	do	Line bred (26.31 [1])	Do.
I	do	707.6	24.6	do	Outbred	Do.
L	do	480.3	24.7	do	do	Do.
J	do 1 year	535.4 15,972.2	28.4 593.8	do	Outbred (18.75 [1])	Outbred (18.75 [1]).
K	No record			Outbred	Outbred	Outbred.
N	7 days	523.7	16.7	Line bred (23.12 [1])	do	Line bred (43.75 [1]).
Q	No record			Outbred	do	Outbred.
T	7 days	469.2	14.4	do	do	Do.
M	7 days 1 year	478.0 [2] 16,679.0	19.2 [2] 522.5	Line bred (31.25 [1])	do	Do.
O	7 days	437.6	15.87	Inbred (65 [1])	Line bred (21.87 [1])	Line bred (25 [1]).
P	do	533.6	21.0	Outbred	Outbred	Outbred.
W	do	581.7	22	Inbred (62.49 [1])	do	Inbred (75 [1]).
R	do	558.5	20.4	Outbred	do	Outbred.
S	do	514.1	20.3	Outbred (12.5 [1])	do	Do.
V	do	437.1	16.2	Outbred	do	Do.
U	do	423.7	19.42	Line bred (31 [1])	do	Do.

[1] Per cent common blood. [2] At 11 years 1 month.

On the basis of the dam's records one would hardly be able to select the best breeding sire from the first group of 10. These records, however, average higher than the records of the dams of the 10 poorest sires. The records of the dams of the 10 poorest sires do not follow any more closely the ranking of the sire according to merit than is the case with the 10 best sires.

It is hardly to be expected that the mere fact of an individual, his sire, or his dam, being line bred or inbred would cause him to be more prepotent than if he were outbred; that is, without any concentration of blood lines. In order that the line breeding or inbreeding may have a favorable effect on prepotency it would seem necessary that the individual which appears more than once in the ancestry be an animal of superior breeding ability. It is a common belief, however, that the mere fact that a sire is outbred militates against the chances of his being prepotent. Three of the five sires heading the list in Tables 7 and 9 were line bred, the second and fifth each being outbred. Fourteen of the 23 sires are classed as outbred. Six of the first 10 sires are in this class and 6 of the last 10 sires are also classed as outbred.

The pedigree of any individual is only an indication of what the transmitting ability of that individual, for milk and butterfat production, may be. Until such time as we have pedigrees in which the sires have a sufficient number of tested daughters from tested dams, so that their breeding performance can be analyzed, as has been done with these 23 sires, predictions can not be made with much certainty as to the transmitting ability of any untried individual. When animals are produced with pedigrees in which all the sires for several generations have ability to transmit, such as sires E, B, and C displayed, then it will be fairly certain that the majority of the bulls bred will be prepotent. It is more difficult to judge the transmitting power of the dams, because of their limited number of offspring, and also because very often many of the offspring will be by one sire. On the other hand, the sire has a considerable number of offspring, usually from different dams, so that his transmitting ability can be more accurately gauged.

A sire's transmitting ability is determined by the chance inheritance of factors governing production, which he received at the time of his conception. Should he by chance have received all his inheritance governing production from some of his ancestry which carried only factors for low production, then he will transmit only low production to his offspring, regardless of how many high-producing ancestors he may have.

Once a bull has proved himself to be a poor sire it would seem that there is little chance of his transmitting any of the ability of his more worthy ancestors.

WHICH PARENT HAS THE GREATER INFLUENCE ON MILK YIELD, BUTTERFAT PERCENTAGE, AND BUTTERFAT YIELD?

A study was made of the correlation between the daughters and their dams, with respect to total yield of butterfat, for each of 23 sires having 6 or more tested daughters from tested dams. The results of this study are shown in Table 10. The correlation coefficients range from -0.39 for sire N to $+0.90$ for sire P.[4]

---

[4] Perhaps a brief explanation of the meaning of correlation should be made before discussing Table 10. A correlation coefficient shows to what extent the variation in one character follows or is coordinated with the variation in some other character. For example, many are of the opinion that in order to get high production in dairy cows we must have large cows If this assumption is true, then there should be a positive correlation with respect to production and size. If milk and butterfat were produced more economically with small cows then there would be a negative correlation with respect to economical production and size. Or, a correlation coefficient may indicate to what degree the same character, such as yield of milk or butterfat, exists between parent and offspring; and that is the thing intended to be determined in this table.

This relation of the yield of milk and butterfat between parent and daughters is expressed as a coefficient. If a high yield of milk or fat in the dam is followed by a correspondingly high yield in the daughter, the correlation would be perfect and the coefficient would be 1. If, on the other hand, the highest-yielding daughters all came from the lowest-yielding dams, and the lowest-yielding daughters all came from the highest-yielding dams, then there would be a perfect negative correlation and the coefficient would be -1. Again, if there is no relation between the yield of the daughter and the yield of her dam, indicating that there is no correlation, then the coefficient would be 0. It is seldom that a perfect correlation is found; usually the correlation is between 0 and $+1$, or between 0 and -1.

The correlation coefficient is arrived at by a rather complicated mathematical formula. It expresses in mathematical terms the extent of the relation which exists between two characters, or the extent to which a character is common to two individuals. If the coefficient is low, it indicates that there is very little relation; if it is high, there is a close relationship; and if it is so high as to indicate a perfect correlation, then it may be said that one is probably the cause of the other. The correlation coefficient when expressed in writing is followed by the probable error; that is, the amount to be added to or subtracted from the correlation coefficient to get the two limiting figures within which there is an even chance that the true value will lie.

The following rules are suggested in Babcock and Clausen (*2*) for the interpretation of coefficient of correlation:

1. If r (the coefficient of correlation) is less than the probable error, there is no evidence whatever of correlation.
2. If r is more than six times the size of the probable error, the existence of correlation is a practical certainty.
3. In cases where the probable error is relatively small:

a. If r is less than 0.3, the correlation can not be considered at all marked.
b. If r is above 0.5, there is decided correlation.

TABLE 10.—*Correlation between daughters of each sire and their dams with respect to total yield of butterfat*

Sire	Number of daughters with yearly records	Average production of butterfat		Standard deviation				Correlation between daughters and dams
		Daughters	Dams	Daughters		Dams		
		Pounds	*Pounds*					
A	5	657.9	466.9	90.9	±19.3	85.0	±18.1	−0.09±0.30
B	13	745.3	581.5	131.9	±17.4	80.6	±10.7	−0.23±0.18
C	12	786.6	647.9	100.8	±13.9	113.4	±15.6	+0.17±0.19
D	9	688.7	562.4	95.6	±15.2	128.9	±20.5	+0.60±0.14
E	6	783.9	663.5	103.1	±20.1	25.6	±5.0	+0.15±0.27
F	9	760.3	651.3	144.7	±23.0	92.6	±14.7	+0.71±0.11
G	7	795.9	697.2	161.9	±29.2	110.5	±19.9	+0.43±0.21
H	6	659.4	567.0	68.7	±13.4	78.5	±15.3	+0.48±0.21
I	6	632.8	541.8	170.3	±33.2	62.7	±12.2	+0.47±0.22
J	20	735.3	658.7	158.0	±16.8	217.7	±23.2	+0.34±0.13
K	6	622.2	548.3	107.4	±20.9	91.2	±17.8	+0.67±0.15
L	11	623.6	578.8	99.0	±14.2	86.1	±12.4	+0.71±0.10
M	6	523.5	492.9	47.0	±9.2	72.7	±14.2	−0.22±0.26
N	9	607.2	589.7	76.3	±12.1	148.7	±23.6	−0.39±0.19
O	6	556.3	543.1	136.7	±26.6	142.9	±27.8	+0.51±0.30
P	6	582.2	525.8	95.7	±18.6	66.9	±13.0	+0.90±0.05
Q	11	585.7	589.6	95.8	±13.8	80.3	±11.5	−0.15±0.20
R	6	432.3	442.7	51.5	±10.0	63.1	±12.3	+0.66±0.16
S	7	503.8	536.0	61.0	±11.0	64.3	±11.6	+0.09±0.25
T	7	634.5	685.8	71.2	±12.8	35.5	±6.4	−0.27±0.24
U	7	452.3	510.5	30.2	±5.5	78.0	±14.1	−0.23±0.24
V	7	508.0	568.5	48.5	±8.7	77.7	±14.0	+0.06±0.25
W	16	621.2	693.5	89.4	±10.7	61.6	±7.3	+0.06±0.16

The number of tested daughters that these 23 sires have is rather small for the determination of a coefficient of correlation that is really indicative. A study of the coefficients of correlation between the daughters and their dams indicates that with the daughters of three sires there is a marked correlation. These three decided correlations are between the daughters and their dams of sire L (+0.71 ±0.10), sire F (+0.71 ±0.11), and sire P (+0.90 ±0.05). The last is the most significant of the three. In Table 2 it may be noted how closely both the milk and butterfat yields of the daughters of sire P follow those of the dam (from the highest daughter out of the highest dam down to the lowest daughter out of the lowest dam). The ranking of the records of the dams according to size of record does not follow that of the daughters so closely with the other two sires, though the similarity of sequence is very apparent.

The daughters of four other sires show evidence of correlation with their dams with respect to yield of butterfat, though the probable error is rather high. These four sires are: Sire D (+0.60 ±0.14); sire H (+0.48 ±0.21); sire K (+0.67 ±0.15); sire R (+0.66 ±0.16).

A study of the records of the daughters of these bulls and their dams indicates somewhat the same general ranking of the dams' records with reference to size as that of the daughters; for instance, with 2 of the 4 sires the lowest-record daughter is out of the lowest-record dam, and with 3 of the 4 sires the highest-record daughter is out of the highest-record dam.

Of the three sires whose daughters have a distinct correlation with their dams relative to butterfat yield, all have daughters with a greater average yield than their dams, though in the case of the daughters of sire P this average increase amounts to only 6.4 pounds, whereas the average milk yield of his daughters is somewhat less than that of their dams. The four sires whose daughters show evidence of correlation have daughters with rather a large average increase in both milk and butterfat yield over their dams, excepting in the case of sire R, whose daughters show a decrease in butterfat, owing to a lower percentage of fat in the milk. With sires whose daughters had smaller average yields of butterfat than their dams, the daughters show no correlation at all with their dams with respect to butterfat yield.

Does the correlation coefficient indicate the relative influence of the parent on the offspring? Does the fact that the daughters of sire P show a correlation of +0.90 to their dams in butterfat yield indicate that the dams had far greater influence on their producing capacity than did sire P? Where there is no significant correlation between daughters and dams, meaning that the size of a daughter's record does not have any particular relation to the size of her dam's record, does this indicate that the sire is exerting greater influence on the producing capacity of the daughters than are the dams? If so, what would a marked negative correlation indicate, a case where the lowest-producing daughters were from the highest-producing dams, and the highest-producing daughters from the lowest-producing dams? The daughters of sire N are the only ones showing any significant negative correlation, though the probable error is so great as to neutralize its significance. The relative rank of the coefficients of correlation of the daughters of each sire to their dams in butterfat yield is shown in Table 11, and in comparison is shown the relative rank among the 23 sires as given in Table 5. The sires are ranked in this table according to the size of the coefficient of correlation without regard to the significance of the probable error. It should also be remembered that in ranking the sires in Table 5 milk yield as well as butterfat yield were considered.

TABLE 11.—*Rank of sires according to coefficient of correlation between daughters and dams with respect to butterfat production, and the comparative ranking of sires as in Table 5*

Sire	Coefficient of correlation of daughters to dams	Rank of sires in Table 5	Sire	Coefficient of correlation of daughters to dams	Rank of sires in Table 5
P	+0.90 ±0.05	18	E	+0.15 ±0.27	1
F	+0.71 ±0.11	6	S	+0.09 ±0.25	21
L	+0.71 ±0.10	10	W	+0.06 ±0.16	19
K	+0.67 ±0.15	12	V	+0.06 ±0.25	23
R	+0.66 ±0.16	20	A	−0.09 ±0.30	5
D	+0.60 ±0.14	4	Q	−0.15 ±0.20	14
O	+0.51 ±0.30	17	M	−0.22 ±0.26	16
H	+0.48 ±0.21	7	U	−0.23 ±0.24	22
I	+0.47 ±0.22	9	B	−0.23 ±0.18	2
G	+0.43 ±0.21	8	T	−0.27 ±0.24	15
J	+0.34 ±0.13	11	N	−0.39 ±0.19	13
C	+0.17 ±0.19	3			

The sires in Table 11, ranked according to the size of the apparent correlation coefficients of their daughters with respect to butterfat yields, are divided in Table 12 into the three following groups:

(1) Eight sires in group, from sire P, coefficient of correlation +0.90 to sire H, coefficient of correlation +0.48.

(2) Eight sires in group, from sire I, coefficient of correlation +0.47, to sire V, coefficient of correlation +0.06.

(3) Seven sires in group, from sire A, coefficient of correlation −0.09, to sire N, coefficient of correlation −0.39.

In each group, the sires are arranged in the order of their ranks as found in Table 5, and with each sire is given the average increase or decrease in pounds of butterfat.

TABLE 12.—*Sires divided into three groups according to correlation of daughters and dams, showing increase or decrease in butterfat production of daughters (each group in order of ranking)*

Group 1			Group 2			Group 3		
Sire		Change in butterfat production	Sire		Change in butterfat production	Sire		Change in butterfat production
Letter	Rank		Letter	Rank		Letter	Rank	
		Pounds			*Pounds*			*Pounds*
D	4	+126.3	E	1	+120.4	B	2	+163.8
F	6	+109.0	C	3	+138.7	A	5	+191.0
H	7	+92.4	G	8	+98.7	N	13	+17.5
L	10	+44.8	I	9	+91.0	Q	14	−3.9
K	12	+73.9	J	11	+76.6	T	15	−51.3
O	17	+13.2	W	19	−72.3	M	16	+30.6
P	18	+6.4	S	21	−32.2	U	22	−58.2
R	20	−10.4	V	23	−60.5			

In Group 1, where the apparent correlation between daughters and dams with respect to butterfat yield is most marked, and where it might have been expected that the dams were exerting greater influence than the sires on the producing capacity of the daughters, the sires are found to be fully as effective in increasing the producing capacity of their daughters as are the sires in Group 2, where apparently little correlation between the daughters and the dams exists, or in Group 3, where the correlation between daughters and dams is apparently negative. Indeed, some of the best and some of the poorest sires are found in each group.

In this study the fact that the records of the daughters of a sire do or do not follow the relative size of the records of their respective dams seems to indicate nothing as to the relative influence of the sire and dams on the daughter's producing capacity.

TABLE 13.—*Rank of 23 sires according to the average yield of butterfat of their daughters, and rank of same sires according to yield of milk of their daughters*

Sire	Average butterfat yield		Sire	Average milk yield	
	Daughters	Dams		Daughters	Dams
	Pounds	*Pounds*		*Pounds*	*Pounds*
G	795.9	697.2	E	23,467.4	20,044.4
C	786.6	647.9	C	22,074.6	18,670.2
E	783.9	663.5	F	21,755.4	18,854.1
F	760.3	651.3	D	21,351.3	17,580.9
B	745.3	581.5	B	21,273.8	17,138.5
J	735.3	658.7	G	20,137.4	19,066.0
D	688.7	562.4	J	20,[illegible]34.8	18,912.1
H	659.4	567.0	H	19,872.9	16,957.2
A	657.9	466.9	A	19,575.7	14,464.8
T	634.5	685.8	I	19,128.4	15,467.7
I	632.8	541.8	T	18,542.0	18,811.4
L	623.6	578.8	L	18,305.6	15,978.0
K	622.2	548.3	W	17,855.1	18,880.6
W	621.2	693.5	Q	17,613.6	17,249.3
N	607.2	589.7	K	17,418.4	16,355.7
Q	585.7	589.6	N	16,822.9	14,907.5
O	556.3	543.1	O	15,676.6	14,783.7
P	532.2	525.8	P	15,584.6	16,328.7
M	523.5	492.9	V	15,454.4	17,564.2
V	508.0	568.5	M	14,825.2	14,015.8
S	503.8	536.0	R	14,175.6	13,991.4
U	452.3	510.5	U	14,046.7	14,666.0
R	432.3	442.7	S	14,009.2	15,117.9

The ranking of these sires in the order of average butterfat yield does not place them in the same order as when they are ranked according to the average milk yield. Table 13 shows that the better-producing daughters were on the average out of the better-producing dams.

It will be noted that there is a gradual decline in average milk yield of the dams in somewhat the same order as that of the daughters, though the decline is not uniform. The average production of butterfat of the daughters of the 10 sires at the head of the list is 724 pounds, and the average production of their dams is 618 pounds. The average production of the daughters of the 10 sires at the bottom of the list is 532 pounds and the average production of their dams 549 pounds. The same comparison holds with the milk yield, showing that on the average the sires at the head of the list were mated with better cows than the sires at the bottom of the list, and that the dams as well as the sires are contributing to the inheritance that determines the producing capacity of the daughters.

The number of cases, however, in which sires raise or lower the production of the great majority of their daughters (see Table 2) regardless of the production of their dams, apparently indicates that if the sire is homozygous for the factors that govern high or low milk yield he is likely to have more influence on the production of a group of daughters than have the dams, because of the probability of some or all the dams being heterozygous in their inheritance governing production capacity.

Even in the case of the sire who improves approximately half his daughters and lowers the production of the other half, the production of neither the poorer nor the better daughters seems to follow very closely that of the dams. Take the case of sire N; 5 of his 9 daughters are better than their dams and the other 4 are poorer. Here there is something of a negative correlation between the daughters and their dams with respect to production; that is, his better daughters on the whole are from the lower-producing dams and his lower-producing daughters from the higher-producing dams.

In the list of a small number of daughters of a sire, the production of the daughters may not follow very closely that of the dams, owing perhaps to the sire's being more homozygous for the factors that will govern high-producing ability than the dams with which he is mated. But when a large number of daughters and dams are considered, the higher-producing daughters will as a rule be found to have good dams. This is to be expected, for the high-producing dam is certain to have at least a part, if not all, of her germinal factors governing production, those that will determine high production, and she will therefore transmit high production to a part or all of her offspring.

The evidence seems to point to both parents' contributing equally to the inheritance governing the milk and butterfat producing capacity of their daughters. But if one parent is homozygous or pure for the hereditary factors determining high production and the other parent is heterozygous in its inheritance, then the homozygous parent will have the greater influence on the producing capacity of the daughter; yet this daughter will transmit to a part of her progeny the inheritance for low production that she may receive from her heterozygous parent. From two heterozygous parents, it is to be expected that the daughters will show a great range in producing capacity, from very poor to very good.

THE PERCENTAGE OF BUTTERFAT

Roberts (*3*) found a significant negative correlation between the percentage of butterfat and the yield of milk for Jerseys, Guernseys, and Holsteins, but did not find so significant a correlation for Ayrshires. That is, as the yield of milk increased, the percentage of butterfat in the milk decreased. Wilson (*4*) studying Ayrshire records, concluded that the yield of milk and the percentage of butterfat were independent of each other. Pearson (*5*) also found a small but significant negative correlation between percentage of butterfat and yield of milk.

The material for the study by Roberts was made up largely of advanced-register and register-of-merit records of the various breeds. The animals in each breed were classed according to age, and the correlation was between the milk yield and the percentage of butterfat for the group of animals in each class. The negative correlation was significant for the Jerseys and Guernseys; but the coefficient for the Holsteins, when judged by the probable error, was not significant in any of the classes.

Evidence on the question whether a bull which has the ability to increase the milk yield of his daughters can also increase the percentage of butterfat in the milk, or whether if he increases the milk yield he will decrease the percentage of butterfat (as is indicated in the results obtained by Roberts with Jersey and Guernsey records), is offered in Tables 14 and 15. These tables show that most of the sires making the greatest increase in milk yield also increased the average percentage of fat very materially, whereas a few sires that increased the average milk yield of their daughters decreased the percentage of fat. Several sires whose daughters showed an average decrease in milk yield also had a decrease in percentage of fat. In those cases where the daughters showed the greatest decline in milk yield (see sires S and V), the increase in percentage of fat was very small. In the daughters of sire G, the sire showing the greatest average increase in percentage of fat, there was an average increase in milk, as was also the case with the daughters of sire N, the sire showing the greatest decrease in percentage of fat. These data show that the percentage of fat and the milk yield in Holstein-Friesian cattle are inherited independently, and that it is entirely possible for a sire to increase both the milk yield and the percentage of butterfat.

TABLE 14.—*Sires with daughters showing greatest percentage increase in milk yield and their percentage increase or decrease in butterfat test*

Sire	Average increase (+) or decrease (−) in milk yield o. daughters compared with dams	Average increase (+) or decrease (−) of daughters compared with dams in fat test	Sire	Average increase (+) or decrease (−) in milk yield of daughters compared with dams	Average increase (+) or decrease (−) of daughters compared with dams in fat test
	Per cent	*Per cent*		*Per cent*	*Per cent*
A	+35.3	+4.02	J	+5.9	+5.46
B	+24.1	+3.24	M	+5.8	+0.28
I	+23.7	−5.43	G	+5.6	+7.92
D	+21.4	+0.94	Q	+2.1	−2.63
C	+18.2	+2.59	R	+1.3	−3.48
H	+17.2	−0.60	T	−1.4	−6.30
E	+17.1	+0.91	U	−4.2	−7.47
F	+15.4	+1.16	P	−4.6	+5.90
L	+14.6	−5.80	W	−5.4	−5.18
N	+12.8	−8.84	S	−7.3	+1.41
K	+6.5	+6.57	V	−12.0	+1.54
O	+6.0	−3.27			

TABLE 15.—*Distribution of daughters of each sire with respect to corresponding increases and decreases in both yield of milk and percentage of butterfat*

Sire	Number of daughters				
	Total	Yield of milk increased; percentage of butterfat increased or left unchanged	Yield of milk increased; percentage of butterfat decreased	Yield of milk decreased; percentage of butterfat increased or left unchanged	Yield of milk decreased; percentage of butterfat also decreased
A	5	3	1	1	0
B	13	8	3	0	2
C	12	5	5	2	0
D	9	4	3	1	1
E	6	4	2	0	0
F	9	3	4	2	0
G	7	2	1	2	2
H	6	1	4	1	0
I	6	0	4	1	1
J	20	8	3	8	1
K	6	4	0	2	0
L	11	1	8	1	1
M	6	1	3	1	1
N	9	3	2	1	3
O	6	1	2	2	1
P	6	0	1	5	0
Q	11	2	5	2	2
R	6	1	2	1	2
S	7	0	3	3	1
T	7	1	3	0	3
U	7	0	2	1	4
V	7	0	1	5	1
W	16	0	5	2	9
Total	198	52	67	44	35

In those daughters where both the milk yield and the percentage of butterfat were increased over those of their dams, and in those daughters where both the milk yield and the percentage of butterfat were lower than those of their dams, there may be said to be evidence of a positive correlation between the yield of milk and percentage of butterfat. That is, the percentage goes up or down with the yield of milk, though whether or not in the same ratio only a correlation coefficient would determine.

On the other hand, in those daughters whose percentage of butterfat increased, but the milk yield decreased, and in those daughters whose percentage of butterfat decreased and the milk yield increased, there may be said to be evidence of a negative correlation. That is, as the milk yield increases the percentage of butterfat decreases, and as the milk yield decreases the percentage of butterfat increases.

Of the 198 daughters of these 23 sires (Table 15), 52 are better than their dams in milk yield and as good in percentage of butterfat; 67 have a larger milk yield and a lower percentage of butterfat than their dams; 44 have a lower milk yield and either an increased or an equivalent percentage of butterfat as compared with their dams; and 35 have both a lower milk yield and a lower percentage of butterfat than their dams. This would seem to offer fairly good evidence that the milk yield and the percentage of butterfat are independent in Holstein-Friesian cattle, though the total number of daughters inclined toward a negative correlation, 111, is somewhat greater than that of those inclined toward a positive correlation, 87. The uniform distribution of the daughters of each sire in these several classes would seem to indicate that but few of these sires were prepotent in controlling the percentage of butterfat. No sire has all his daughters in any one of these classes, and only four sires have their daughters in only two classes, whereas nine sires have their daughters in all four classes.

Coefficients of correlation between the daughters of 23 sires and their dams, with respect to percentage of butterfat, are given in Table 16. These indicate the extent to which high or low production in the dam is followed by similar production in the daughter. The correlation coefficients range from -0.39 for sire N to $+0.98$ for sire H.

TABLE 16.—*Correlation between daughters and dams relative to per cent of butterfat*

Sire	Number of daughters	Correlation of daughters to dams		Sire	Number of daughters	Correlation of daughters to dams	
		Coefficient	Probable error			Coefficient	Probable error
A	5	−0.07	±0.30	M	6	+0.93	±0.04
B	13	+0.49	±0.14	N	9	−0.39	±0.19
C	12	+0.34	±0.17	O	6	+0.65	±0.16
D	9	+0.32	±0.20	P	6	+0.59	±0.18
E	6	+0.49	±0.21	Q	11	+0.11	±0.20
F	9	+0.75	±0.10	R	6	+0.94	±0.03
G	7	+0.31	±0.23	S	7	+0.75	±0.11
H	6	+0.98	±0.01	T	7	+0.06	±0.25
I	6	+0.47	±0.21	U	7	−0.06	±0.25
J	20	+0.15	±0.15	V	7	+0.79	±0.09
K	6	+0.52	±0.20	W	16	+0.56	±0.12
L	11	−0.001	±0.20				

Because the daughters of most of these sires are so few in number, allowance should be made in interpreting the coefficients derived.

There is a significant correlation between the daughters and their dams with respect to percentage of butterfat in the cases of the following seven sires (Table 17):

TABLE 17.—*Sires between whose daughters and their dams there is a significant correlation*

Sire	Correlation	Sire	Correlation
F	+0.75 ±0.10	S	+0.75 ±0.11
H	+0.98 ±0.01	V	+0.79 ±0.09
O	+0.65 ±0.16	M	+0.93 ±0.04
R	+0.94 ±0.03		

This marked correlation is easily seen when the percentages of butterfat of daughter and of dam are placed side by side and ranked according to the size of the daughters' tests, as shown in Table 18 for the daughters of sires S, H, and R.

TABLE 18.—*Percentage of butterfat of daughters of sires S, H, and R, and their dams, showing positive correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Per cent*		*Per cent*	*Per cent*		*Per cent*	*Per cent*
S	4.30	4.44	H	3.75	3.72	R	3.40	3.53
	4.00	3.88		3.66	3.74		3.31	3.25
	3.88	3.22		3.37	3.39		3.23	3.33
	3.44	3.37		3.13	3.14		3.20	3.53
	3.28	3.63		3.04	3.08		2.75	2.74
	3.27	3.34		3.01	2.92		2.61	2.74
	3.18	3.24						

These figures show, as does the coefficient of correlation, that the butterfat test of the daughters of these sires follows very closely that of their dams. The average percentage of butterfat of the daughters was very close to the average percentage of butterfat of the dams, with each of these three sires. The average percentage of butterfat of the daughters of sires R and H were slightly less than the average of the dams, whereas the average for the daughters of sire S was slightly greater. On the other hand a comparison of tests of the daughters of other sires and their dams shows that the test of the daughters does not follow that of their dams. The comparative tests of the daughters of the two sires G and J and their dams, shown in Table 19, illustrate this point.

TABLE 19.—*Per cent of butterfat of daughters of sires G and J and their dams, showing no correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Per cent*		*Per cent*	*Per cent*
G	4.39	3.83	J (continued)	3.70	3.58
	4.31	4.30		3.70	4.01
	4.25	3.61		3.66	3.60
	4.21	3.25		3.61	3.70
	3.81	3.88		3.59	3.29
	3.43	3.60		3.59	3.29
	3.32	3.52		3.55	3.55
J	4.29	3.42		3.55	3.33
	4.14	3.53		3.48	3.46
	4.04	3.46		3.44	3.42
	3.80	3.61		3.40	3.46
	3.79	3.45		3.39	3.27
	3.78	3.59		3.24	3.60
	3.77	3.28			

The daughters of sire N show stronger indications of a negative correlation with respect to percentage of butterfat between daughters and dams than the daughters of any other sire. To some extent this is also true of his daughters with respect to their milk yield and butterfat yield, as stated before. The comparative percentages of butterfat of his daughters and their dams are shown in Table 20.

TABLE 20.—*Percentage of butterfat of daughters of sire N and their dams, indicating negative correlation*

Sire	Daughters	Dams	Sire	Daughters	Dams	Sire	Daughters	Dams
	Per cent	*Per cent*		*Per cent*	*Per cent*		*Per cent*	*Per cent*
N	3.87	3.81	N	3.75	4.41	N	3.40	3.54
	3.78	3.54		3.71	3.71		3.38	4.32
	3.77	3.55		3.48	3.94		3.33	4.41

It will be observed that, in general, the higher-testing daughters of sire N come from the lower-testing dams and the lower-testing daughters from the higher-testing dams.

WHICH PARENT HAS THE GREATER INFLUENCE ON THE PERCENTAGE OF BUTTERFAT?

There are a larger number of significant correlation coefficients between dams and daughters with respect to percentage of butterfat than with respect to fat yield. As explained under fat yield, it is doubtful to what extent a significant correlation indicates dependence on either parent, because of the lack of homozygosity of the parents for yield or percentage of fat. There are other indications than the correlation coefficient showing that the dams do contribute to the daughters' inheritance for percentage of fat. A study was made of all dams to which these sires were mated that had extremes of percentage of butterfat of 3.3 or below, and 3.8 or above, and the percentage of butterfat of the daughters of the dams in these two classes. There were 57 dam-daughter pairs, representing 19 sires, in the class for dams having 3.3 per cent butterfat or less. The average percentage of fat for these 57 dams and daughters was 3.155 for the dams and 3.314 for their daughters. There were 33 dam-daughter pairs representing 13 sires in the class for dams having 3.8 per cent or over. The average percentage of fat for these 33 dams and daughters was 3.966 for the dams and 3.633 for the daughters. This would seem to show that the dams do contribute to the inheritance for the percentage of fat of their daughters. It further shows, as does Table 15, that the sires also contribute to the inheritance of their daughters for percentage of fat.

The tables giving the production records of the daughters of each sire and their dams have seemed to show that the daughters' percentage of fat follows that of the dams fairly closely. This might be due to the following reasons:

(1) There may be less variability in the percentage of fat than in the milk yield.

(2) The inheritance for percentage of fat may be better fixed (purer) than is the inheritance for the milk yield.

The fact that the percentage of fat and the milk yield are inherited independently, at least within limits, and that both the sire and dam contribute to the inheritance of their daughters, governing both milk yield and percentage of fat, indicates that improvement in yield of butterfat can be brought about by selection for both milk yield and percentage of fat.

SUMMARY

A study of the transmitting ability for milk yield, percentage of butterfat, and butterfat yield, of 23 Holstein-Friesian sires each having six or more daughters with yearly records, out of dams with yearly records, brought out the following results:

1. A remarkable variation between the records of the daughters of any sire and their dams is evidenced. Prepotency in a sire is not indicated by the size of the coefficient of variability of his daughters.

2. No sire in the list shows a complete prepotency in raising or lowering both the milk yield and the percentage of butterfat of all his daughters. Some sires are capable of raising both the milk yield and the percentage of butterfat; some raise one and lower the other; and some lower both. Not so many sires are prepotent in increasing the percentage of butterfat as are prepotent in increasing the milk yield.

3. The coefficient of correlation for butterfat yield between daughters and dams varies widely for the different sires, regardless of whether the daughters of the sires are better or poorer than their dams. For only three sires is there a marked correlation; one of these sires has daughters that made an average increase of some 15 per cent in both milk and butterfat production over their dams; another of these three sires had daughters that showed an average increase of 14.6 per cent in milk, but owing to a decrease in percentage of butterfat, there was only about half that average increase in total butterfat; the third sire's daughters varied little from their dams in the production of either milk or butterfat.

The fact that there is a correlation between the daughters and their dams with respect to yield of milk and butterfat does not mean that the sire is not prepotent in either raising or lowering the yield. It only indicates that where a number of daughters and dams are considered, the record of the daughter will be of the same relative size as that of her dam, though it may be larger or smaller. For instance, if a sire is mated with a cow of 10,000 pounds capacity and to another cow of 20,000 pounds capacity, the daughter of the first cow is likely to be in the 10,000 class, though she may produce from 8,000 to 12,000 pounds, depending upon the germinal make-up of the sire with reference to milk yield; the daughter from the second cow is likely to be in the 20,000-pound class, though she may produce from 16,000 to 24,000 pounds.

4. When the records of a large number of daughters are compared with the records of their dams there is a limited correlation or a tendency for the high-record daughters to come from high-record dams. The breeding record of each individual sire indicates, however, that a sire may be prepotent in increasing the milk yield and decreasing the percentage of butterfat of his daughters as compared with the production of their dams, or he may be prepotent in lowering

the yield of milk and increasing the percentage of butterfat, or he may be prepotent in either raising or lowering both the milk yield and the percentage of butterfat.

This ability of the sire seems to depend upon the combination of factors governing the yield of milk and percentage of butterfat that he has inherited from his parents. If he is homozygous for dominant factors that will determine high milk yield and high percentage of butterfat, he will be prepotent in impressing these characters on his offspring. If he and the dams he is mated with are heterozygous for these factors, as most sires and dams are, a variety of combinations in the different offspring will follow, and they will be of varying degrees of producing ability.

5. The percentage of butterfat and the milk yield seem to be inherited independently in Holstein-Friesian cattle. This is contrary to the findings of other investigators. The theory generally accepted is that, as the milk yield increases, there will be a decrease in the percentage of butterfat. Though this study showed that in the majority of cases there was a tendency toward a negative correlation, there was a sufficient number showing a tendency toward a positive correlation to indicate that the two are independent of each other. It is also shown that it is possible for a sire to increase both the milk yield and the percentage of butterfat of his daughters.

6. A great sire of production is one whose daughters have a high average yield of milk and butterfat, a high average increase in milk and butterfat yield over the yield of their dams, and a high percentage of their number better than their dams. All these things must be considered. No one of them alone offers sufficient evidence of the sire's worth. The production of each sire's daughters must be considered in comparison with the production of other sires' daughters. Provided a sufficient number of tested daughters are available for each sire the ranking system shown in this bulletin seems to indicate the comparative merit of the sires in a group.

7. The production records of the dams of the 10 highest-ranking sires average higher than the records of the dams of the 10 lowest-ranking sires. In neither of these cases, however, does the rank of the sire follow the size of the record of his dam.

8. Six of the 10 highest-ranking sires and 6 of the 10 lowest-ranking sires are classed as outbred. This seems to indicate that the mere fact that an individual, his sire, or his dam, is line bred, inbred, or outbred is not indicative of the prepotency of that individual for high production.

LITERATURE CITED

(1) Graves, R. R. A genealogical study of Holstein-Friesian sires. (In unpublished manuscript.)
(2) Babcock, E. B., and Clausen, R. E. 1918. Genetics in relation to agriculture.
(3) Roberts, Elmer. Journal of Agricultural Research, vol. 14, no. 2.
(4) Wilson, James. Sci. Proc. Royal Dublin Soc., vol. 12, no. 33.
(5) Pearson, Karl. Biometrika, vol. 7, no. 4.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1926

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1374

Washington, D. C. ▼ March, 1926

STUDIES OF THE PINK BOLLWORM IN MEXICO

By

W. OHLENDORF, Plant Quarantine Inspector
Federal Horticultural Board

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

Bulletin No. 1374, United States Department of Agriculture, "Studies of the Pink Bollworm in Mexico," by W. Ohlendorf.

CORRECTION SLIP.

Page 3, line immediately below legend of Figure 2. For "San Carolos" read "San Carlos."

Page 8, Fig. 4. After the first sentence the legend should read, "Top row shows type of winter cocoons, and bottom row type of summer cocoons."

Page 14, Table 13, sixth column. For "2.0" read "20."

Page 24, line 1. For "Figure 3" read "Figure 9."

Page 24, line 8. For "these" read "there."

Page 35, line 3 from bottom. For "infested" (last word in sentence) read "parasitized."

Page 38, line 22. For "20 weeks" read "two weeks."

Page 59, Fig. 15. For "Average number of worms per acre" read "Average number of worms per boll."

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1374

Washington, D. C. ▼ March, 1926

STUDIES OF THE PINK BOLLWORM IN MEXICO

By W. Ohlendorf, *Plant Quarantine Inspector, Federal Horticultural Board*

CONTENTS

INCEPTION AND SCOPE OF THE WORK [1]

Since its introduction into Mexico in 1911 the pink bollworm[2] has established itself firmly in the Laguna district and has made its appearance in several less important cotton-growing sections in Mexico, as well as at several points in the United States. The United States Department of Agriculture began research work on the pink bollworm in the Laguna district of Mexico in 1918. The results of the work of 1918 and 1919 were reported by Loftin, McKinney, and Hanson.[3] After an interruption of one year the work was resumed in March, 1921, at a new station at Tlahualilo, Durango, Mexico, on a large cotton plantation.[4]

In considering the results of the research work dealt with in this report, it must be recalled that the climate in the Laguna district (fig. 1) is very dry, the average annual rainfall being only about 8

[1] This report is based on two years' work in the Laguna, conducted by the Federal Horticultural Board under the authority given, in the appropriation for the eradication of the pink bollworm, to investigate in Mexico or elsewhere the pink bollworm as a basis for control measures. This investigation has been conducted under the general direction of the chairman of the board and W. D. Hunter, a member of the board. In accordance with the policy established by this board with respect to any research work on insect pests which it becomes necessary for the board to conduct, the results of this investigation are presented as a contribution through and in collaboration with the Bureau of Entomology. The field and laboratory work has been under the charge of W. Ohlendorf, assisted at various times by the following agents of the Federal Horticultural Board: F. F. Bibby, A. C. Johnson, C. R. Roitsch, R. B. Lattimore, J. C. Woodward, W. R. Sudduth, and D. M. McEachern.

[2] *Pectinophora gossypiella* Saunders.

[3] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Report on investigations of the pink bollworm of cotton in Mexico. U. S. Dept. Agr. Bul. 918, 64 pp., illus. 1921.

[4] Special thanks are due the Tlahualilo Agricultural & Colonization Company for extending all facilities that could in any way assist in the research work. To the Testamentaria de Carlos Gonzales also thanks are due for many courtesies extended in connection with numerous observations made in fields on their properties, as well as to many other planters in the Laguna district who at all times willingly cooperated in any investigations made in the district generally. The Comision Inspectora de Plagas at Torreon, charged with the enforcement of the regulations of the Mexican Government relating to the pink bollworm, cooperated in a most satisfactory manner. This commission is under the direction of Dr. R. Ramirez of Mexico City, with Juan Antuna in charge at Torreon.

60776—26†——1

inches. Cotton production is possible only by irrigation, and owing to lack of reservoirs the irrigation water which comes from the Nazas River must be put on the land whenever the water is available. As the greater part of the irrigation water usually arrives in the fall and winter, the general practice is to flood the fields (fig. 2) to a depth of from 1 to 3 feet at that time of the year. This often represents all the water that the following year's crop receives except for what little rain may fall during the growing season.

The work of 1921 and 1922 supplemented that of 1918 and 1919. As the life history and the habits of the pink bollworm under Laguna conditions were rather thoroughly studied in the previous research work, the greater amount of attention during the last two years was devoted to studies aimed more directly at control.

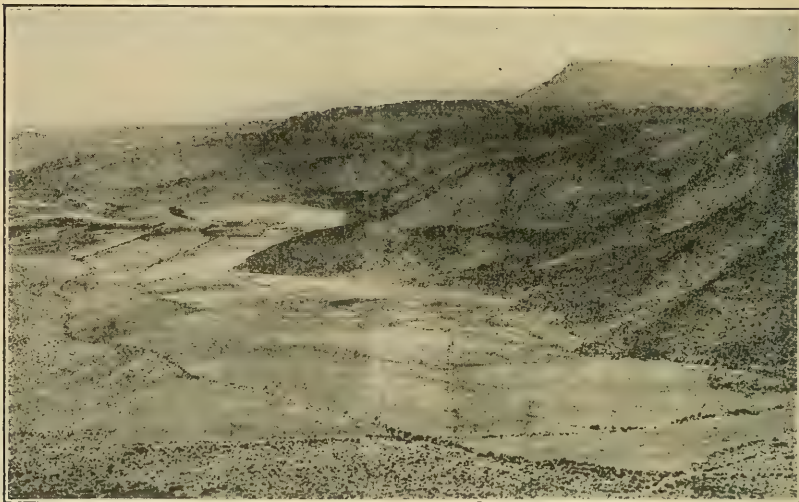


FIG. 1.—Typical Laguna district scenery, showing character of country surrounding the valley

DISTRIBUTION OF THE PINK BOLLWORM

Since the report on the 1918 and 1919 work was published, new and important records of the occurrence of the pink bollworm in various parts of the world have been made. The species is now known to occur in India, Palestine, Mesopotamia, Ceylon, Burma, Siam, Straits Settlements, China, Japan, Korea, the Philippine and Hawaiian Islands, East Africa, Zanzibar, Egypt, Sudan, West Africa (southern Nigeria, Angola, Sierra Leone), Italian Somaliland, Brazil, West Indies, and Mexico, and in Texas, New Mexico, and Louisiana in the United States.

The occurrence of the insect in the West Indies is of special interest. It was first reported from Montserrat and St. Kitts in November, 1920. Later it was reported from Anguilla, St. Croix, and Porto Rico. In July, 1921, it was reported to occur throughout the Leeward and British Virgin Islands, but not south of Montserrat.

In the United States, progress has been made in the eradication of the insect. There has been no recurrence of the two infestations in Louisiana for two years. The infestation at Hearne, Tex., has not reappeared since 1917. In 1922 there was no recurrence in the large Trinity Bay area, where all or parts of seven counties were found infested in 1917.

In extreme western Texas and New Mexico, conditions have prevented any attempt toward eradication. The infestation is being controlled, however, by quarantines, the disinfection of all cottonseed, and other means, so that it is still at a low ebb and the danger of spread from this area to other parts of the country has been minimized.

DISTRIBUTION IN MEXICO

A new infestation has been found in Mexico, at Monclova in the State of Coahuila. The previously known infestations in Mexico were the entire Laguna district, Santa Rosalia, State of Chihuahua,

FIG. 2.—Distant view of cotton plantation in the Laguna district, showing flooded fields.

San Carolos, approximately 40 miles west of Eagle Pass, Tex., Allende and Santa Monica in the State of Coahuila, about 40 miles from the nearest point on the Rio Grande, and several points in the Rio Grande Valley opposite Presidio County, Tex., and El Paso County, Tex.

The Mexican records to which reference has been made deal only with infestations in growing cotton. The insect is constantly being brought to the border towns in Mexico in cottonseed scattered in freight cars, and living specimens are frequently found under such conditions by the inspectors of the Federal Horticultural Board.

HABITS

POSITION OF EGGS ON THE PLANT

According to observations made by Loftin [5] on plants growing in the field in the Laguna, 51.7 per cent of the eggs of the pink bollworm are deposited on the green bolls, the remainder on other parts of the

[5] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

plant. Willcocks [6] on the other hand reports only 12 per cent of the total eggs deposited on the bolls in Egypt, stating, however, that these data are based on too few records. No doubt the percentage of eggs deposited on different parts of the plant depends to a great extent on the state of growth of the plant and the ratio of bolls to foliage.

In the summer of 1921 observations were made on plants growing in the field to determine the number of larvæ reaching the bolls from eggs deposited on parts of the plant other than the bolls. These tests were begun August 20. Three sets of plants, two plants per set, were selected, and all bolls then on the plants were removed. Thus the bolls as well as the larvæ considered in the experiment were produced after the experiment began. After a sufficient number of bolls were set, no more were allowed to form. Every two days all eggs were removed from the bolls on one plant in each set. The other plant served as a check. On September 14 all the bolls were removed from the plants and examined for larvæ and exit holes.

The results of this test are given in Table 1.

TABLE 1.—*Infestation of green bolls from which all pink bollworm eggs had been removed and of bolls on check plants*

Plant No.	Number of bolls	Number of eggs removed	Total number of larvæ and exit holes	Number of larvæ and exit holes per boll—		Percentage difference
				Test plants	Check plants	
1	19	1,326	104	5.47		2.3
2	15	0	84		5.60	
3	18	722	111	6.17		26.5
4	18	0	151		8.39	
5	11	741	51	4.64		52.0
6	12	0	116		9.67	
Average per boll		[1] 58.1		5.54	7.80	28.9

[1] Bolls on check plants not included.

The most striking points about these results are the great number of eggs removed per boll and the comparatively little reduction (28.9 per cent) in infestation brought about thereby. The proportion of eggs deposited in other places than on the bolls is likely to have been higher in the case of these plants than is normal, because of the limiting of the number of bolls that grew on them. Considering, however, Loftin's [7] figures (51.7 per cent), first referred to, it would appear that even with only an equal chance for the larvæ hatching from eggs on the bolls to enter the bolls, the infestation should be reduced by at least 50 per cent by the removal of all eggs from the bolls.

From these observations it must be assumed either that the position of the egg on the plant has little to do with the ability of the young larva finally to enter the bolls, or that in this particular experiment, with such a number of eggs present, many of them were so near the bolls that the young larvæ hatching from them were in almost as favorable a position as those hatching from eggs on the

[6] F. C. Willcocks. The insect and related pests of Egypt. Volume I. The insect and related pests injurious to the cotton plant. Part I. The pink bollworm. 335 pp., illus. Cairo. 1916. (Sultanic Agr. Soc.)

[7] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

boll itself. The great excess of the number of eggs on the bolls above the number of larvæ in the bolls shows that the failure of many young larvæ to enter the bolls must be assigned to causes other than distance from the bolls at time of hatching.

The favorite position of the eggs on the bolls is between the wall of the boll and the calyx. A cluster of eggs in this characteristic position is shown on the calyx of the boll in Figure 3.

ENTRANCE OF THE YOUNG LARVA INTO THE BOLL

The entrance hole made by the young larva into the boll is very small but quite distinguishable. Numbers of these punctures are shown on the boll in Figure 3. The young larva seems to show no particular preference as to where it attempts to enter the boll. Some counts were made on October 11 and 14, 1921, to determine whether any appreciable number of larvæ enter the boll at points covered by the calyx. The results are shown in Table 2.

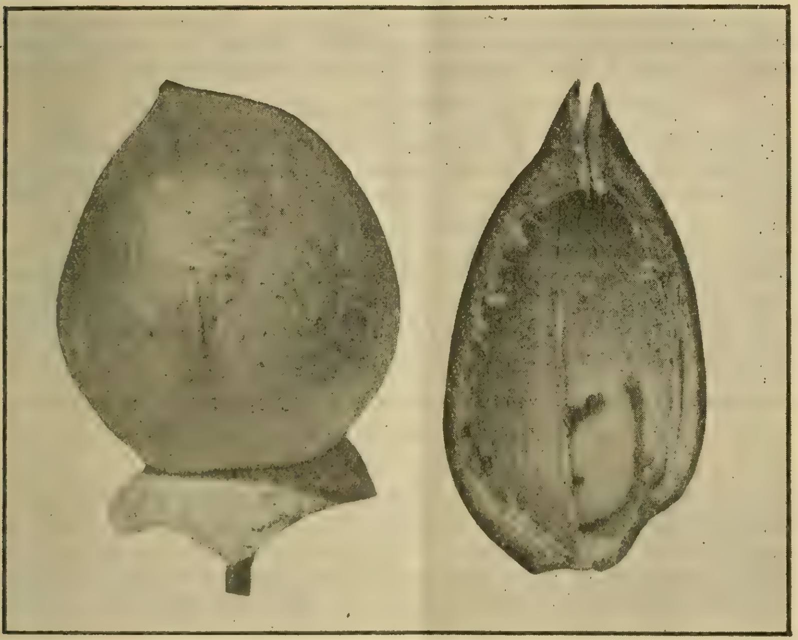


FIG. 3.—Work of pink bollworm on cotton boll. At left: Cotton boll showing entrance holes of young pink bollworm larvæ and cluster of eggs on calyx. At right: Carpel showing characteristic tunneling by young larvæ under inner surface of wall before entering lock

TABLE 2.—*Punctures by the pink bollworm under the calyx and at other points on the boll*

Number of bolls	Number of entrance holes— Under calyx	Above calyx	Total	Per boll	Percentage under calyx
89	113	5,678	5,791	65	1.95

The great number of punctures counted on the bolls is very striking. These particular bolls were not examined further to determine the number of larvæ inside, but three field examinations made on October 5, 13, and 20, respectively, gave an average of 5.64 larvæ and exit holes per boll. So it may be assumed that the infestation of the bolls on which Table 2 is based was somewhere near this figure.

In some cases the young larva goes directly through the entire wall of the boll and into the lock of cotton inside. In this case the point where it passed through the inner wall is only slightly raised and may be somewhat colored. Very frequently, after passing through the greater part of the wall of the boll, it tunnels for some distance just underneath the inner surface of the wall. In this case the tunnel usually extends until either the suture or the partition wall is reached, at which point the larva then enters the lock. This tunneling occurs more commonly in nearly mature bolls, where the inner wall is harder. Some of these types of entrances are shown in Figure 3.

ISSUANCE OF FULLY DEVELOPED LARVÆ FROM BOLLS

In the fall of 1922, a test was conducted in the laboratory to determine the time of the day mature larvæ leave the green bolls. Fifty green bolls were placed in a screen-bottom tray, with a trap underneath to catch any emerging larvæ. All larvæ were removed from the trap each day at 8 a. m. and at 8 p. m. Of 172 larvæ taken out of the trap from September 29 to October 17, 160 were removed in the afternoon and 12 in the morning. According to this, the larvæ, at least under laboratory conditions, prefer to leave the bolls during the daytime.

TRANSFORMATION AND HIBERNATION OF THE PINK BOLLWORM IN THE SOIL

PUPATION DURING SUMMER

In the Laguna district the pink bollworm passes the pupa stage during the summer in shed blooms and bolls, under or attached to leaves on the surface of the soil, and in the soil. Rarely are pupæ found in bolls on the stalks. None were ever found in green bolls. One hundred and seventy-four open bolls on stalks examined during the period from July 7 to November 28, 1921, showed neither pupæ nor pupal cases, but a total of 358 larvæ and exit holes. The last figure, however, does not represent the total infestation, since larvæ issuing from the bolls after opening do not as a rule cut exit holes through the wall. Open bolls on stalks during the latter part of November and in December, 1922, averaged about 8 pupæ and pupal cases per hundred.

VARIATIONS IN NUMBERS IN THE SOIL

A considerable number of field examinations were made during 1921 and 1922 in a study of the transformation of the pink bollworm in the soil. In making these examinations, samples of soil, usually 1 square yard to the depth of 6 inches, were taken from heavily infested cotton fields and the number of pink bollworms in each sample determined. The square yard was laid off so as to have a row of cotton running through its middle. The soil was first sifted through a sieve of which the mesh was too small to allow the passage of pink bollworms. The coarse remaining material was taken to the laboratory and washed through other sieves, leaving finally only particles of plant material and other coarse matter, which was allowed to dry and was then examined. In examinations where forms on the plants and on the surface of the soil were considered, only those forms on the same square yard as that in which the soil sample was taken were included.

Table 3 gives a record of the number of pupæ found in and attached to forms on the surface of the soil, and in the soil. The totals, 34 and 136, show that the larva prefers to enter the soil for pupation.

TABLE 3.—*Pupæ of pink bollworm (live and dead) found per square yard in forms and plant material on the surface of the soil and in the soil*

Date	On the surface	In the soil
1921		
July 21	2	7
Aug. 4	29	96
Sept. 6	2	28
25	1	1
Oct. 18	0	0
29	0	2
Nov. 28	0	2
Total	34	136

DEPTH TO WHICH LARVÆ ENTER SOIL

Larvæ often enter the soil to a depth of 6 inches, but the majority are found within the first 2 inches. In a number of soil examinations made in 1921 cotton fields, the soil was taken up in three 2-inch layers. A record of these examinations is given in Table 4. As will be noted, 70.6 per cent of all stages are found in the first 2 inches, 21.3 per cent in the second 2 inches, and 8.1 per cent in the third 2 inches.

TABLE 4.—*Total larvæ, pupæ, and pupal cases found per square yard at different depths in the soil*

Date	First 2 inches	Second 2 inches	Third 2 inches
1921			
Aug. 4	101	23	3
19	65	33	17
Sept. 6	50	20	10
Oct. 18	41	2	0
29	15	4	0
Dec. 16	19	9	0
1922			
Jan. 3	25	3	3
20	16	0	5
Feb. 28	7	8	1
Total	339	102	39
Percentage of total	70.6	21.3	8.1

Both larvæ and pupæ are found more abundantly in the soil immediately under the plants than in that between the rows. This is shown by the results of some of the soil examinations made in 1921 cotton fields, in which each square yard taken as a sample was divided into two areas. The first area consisted of a strip immediately under the plants, 1 foot wide and 3 feet long, running lengthwise with the row, and the second, 2 strips of the same size as the first and on either side of it. The inner area was thus only half as large as the outer. Table 5 shows the results of these examinations, 67.1 per cent of the stages being found immediately under the plants and only 32.9 per cent between the rows.

TABLE 5.—*Total larvæ, pupæ, and pupal cases found in the soil immediately under the row and between the rows*

Date	Under the row	Between the rows
1921		
Aug. 19	60	55
Sept. 6	69	11
25	18	6
Oct. 18	33	10
29	9	10
1922		
Mar. 23	18	1
Do	28	16
Do	27	19
Do	6	4
Do	13	6
Total	281	138
Percentage of total	67.1	32.9

RESTING-STAGE LARVÆ IN THE SOIL

Not only does the larva of the pink bollworm, in the Laguna district, go to the soil during the summer for transformation into the

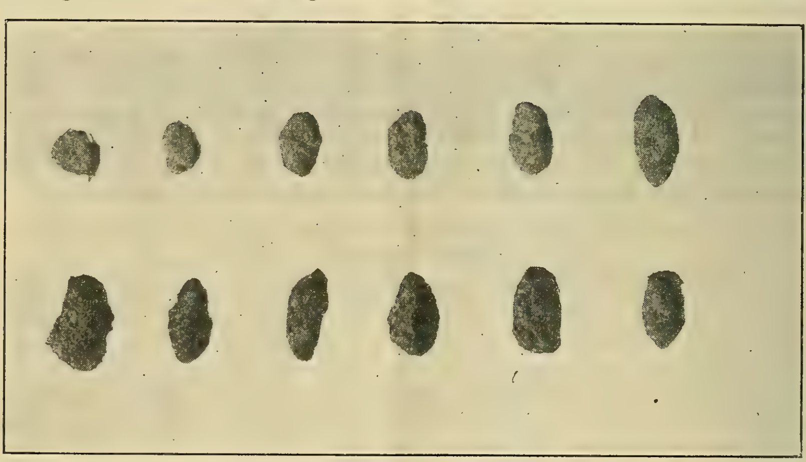


FIG. 4.—Cocoons spun by the pink bollworm in the soil. Top row shows type of summer cocoons and bottom row type of winter cocoons

adult, but to a certain extent it also passes the winter there in the resting stage. The summer larva, after entering the soil, spins a light oblong cocoon in which it pupates. Later, in the fall, some cocoons of a much heavier texture and more spherical in form are noticed in the soil (fig. 4). In these the larvæ are found in the same characteristic curled-up position that they assume on passing the winter in double seeds. Observations have shown that when disturbed, unless it is unusually cold, the larva readily leaves this cocoon.

In Tables 6 and 7 are given the results of all the soil examinations made in 1921 and 1922 cotton fields. The maximum number of living stages found at any time is shown in the second examination of 1921 when a total of 83 living larvæ and pupæ were found in 1 square yard of soil. This sample was taken from a heavily infested field of very large cotton on loose sandy soil.

TABLE 6.—*Soil examinations for pink bollworms, 1921 cotton fields*

Date examined	Number of square yards examined	Living stages found in soil			Dead larvæ and pupæ	Pupal cases
		Larvæ	Pupæ	Total per square yard		
1921						
July 21	1	4	1	5	9	0
Aug. 4	1	9	74	83	24	15
19	1	5	5	10	20	85
Sept. 6	1	44	7	51	24	5
25	1	12	0	12	5	7
Oct. 18	1	2	0	2	0	41
29	1	5	0	5	2	12
Nov. 28	1	27	0	27	3	2
Dec. 16	1	11	0	11	4	13
1922						
Jan. 3	1	15	0	15	6	10
20	1	10	0	10	2	9
Feb. 6	1	15	0	15	5	5
15	1	4	0	4	6	10
28	1	9	0	9	4	3
Mar. 21	[1] 4	33	0	8.25	33	4
23	5	83	0	16.6	49	6
Apr. 17	5	43	0	8.6	18	1
May 1	5	42	0	8.4	20	0
17	5	22	0	4.4	21	1
30	5	16	0	3.2	12	1
June 12	5	9	0	1.8	13	2
26	5	2	3	1	8	5
July 10	5	0	0	0	0	1
24	5	0	0	0	1	0
Aug. 8	5	0	0	0	1	1

[1] This examination and all subsequent ones, except that on Mar. 23, include some samples from plats cultivated in March and April, 1922.

TABLE 7.—*Soil examinations for pink bollworms, 1922 cotton fields*

Date examined	Number of square yards examined	Living stages found in soil			Dead larvæ and pupæ	Pupal cases
		Larvæ	Pupæ	Total per square yard		
1922						
Aug. 8	4	1	0	0.25	1	1
15	4	1	1	.50	2	0
22	4	11	1	3	23	1
29	4	31	1	8	22	3
Sept. 5	4	14	1	3.75	30	5
12	4	31	3	8.5	44	11
21	4	10	0	2.5	7	4
Oct. 7	3.33	15	7	6.6	0	0
23	3.33	11	4	4.5	21	0
Nov. 2	.83	3	0	3.6	4	2
10	.83	4	0	4.8	4	4
17	.83	10	0	12.0	5	9
23	10	52	0	5.2	31	8
Dec. 5	5	108	0	21.6	23	10
13	5	102	3	21.0	29	23
20	5	57	0	11.4	30	3
27	5	103	0	20.6	28	14
1923						
Jan. 3	5	75	0	15.0	23	10
10	5	81	0	16.2	19	16
17	5	66	0	13.2	30	12
24	5	79	0	15.8	21	13
Feb. 1	5	49	0	9.8	30	4
7	5	70	2	14.0	15	18
14	5	57	0	11.4	17	6
21	5	45	1	9.2	30	17
28	5	65	0	13.0	10	22
Mar. 7	5	32	0	6.4	11	12
14	5	62	1	12.6	36	9
21	5	45	1	9.2	20	33
28	5	27	0	5.4	16	20
Apr. 4	5	28	0	5.6	13	24
11	5	22	0	4.4	20	22

60776—26†——2

It will be noted that the records for 1921 fields show no living pupæ at any time during the period from September 25, 1921, to June 12, 1922, inclusive. This would indicate that any larvæ that enter the soil after about the middle of September prepare to hibernate. No doubt some pupæ were killed by the sifting and washing; but, if any number of living pupæ had been present, some certainly would have been found, considering that during this period 44 square yards of soil were examined and 358 living larvæ found. Some of the larvæ that hibernated in the soil must have pupated long before the time of the first record of living pupæ, June 26, 1922. The records for 1922 show living pupæ in samples of soil as late as October 23, and again on December 13. In fact, there are indications that pupation occurred throughout the winter, and living pupæ were found on February 7 and 21. In another experiment a living pupa was found in a cocoon in the soil on January 22, 1923. The consistent finding of a rather large number of pupal cases throughout December, January, and February, shown in Table 7, also points to some pupation throughout this period.

FIG. 5.—Bolls placed on surface of soil to determine extent to which larvæ will leave these bolls and enter soil for hibernation

NUMBERS OF STAGES IN SOIL AND IN BOLLS ON SURFACE OF SOIL AND ON STALKS DURING WINTER COMPARED

An experiment was begun at the end of November, 1922, to determine the relative importance of soil, bolls on the surface of the soil, and bolls on stalks as hibernating quarters for the pink bollworm. Although this experiment has not been completed and so does not show the results at the end of the hibernating period, it indicates the extent to which the pink bollworm enters the soil for hibernation under the different conditions. Bolls were collected from standing stalks in the field at the end of November. These were divided into lots of 100 bolls each. One lot examined on November 28 showed the extent to which the bolls were infested then. On the following day 15 lots were placed on the surface of the soil in the garden (fig. 5), where there had been no cotton and consequently no larvæ in the soil.

The bolls were placed in a single layer and the lots widely enough separated from one another to allow ample room for the examination of 1 square yard of soil with each lot of bolls. Then, at first weekly and later biweekly examinations of one lot of bolls and the square yard of soil underneath, to the depth of 6 inches, were made, with results as given in Table 8.

TABLE 8.—*Entrance of pink bollworm larvæ from bolls on the surface of the soil into soil for hibernation*

Date examined	Found in bolls: Larvæ and pupæ— Living	Found in bolls: Larvæ and pupæ— Dead	Found in bolls: Pupal cases	Found in soil: Larvæ and pupæ— Living	Found in soil: Larvæ and pupæ— Dead	Found in soil: Pupal cases
1922						
Nov. 28[1]	228	13	11			
Dec. 5	162	12	3	23	1	0
11	152	35	6	9	0	0
18	144	14	1	14	1	0
25	125	25	0	29	3	0
1923						
Jan. 8	143	16	1	12	0	0
22	120	49	0	30	1	0
Feb. 5	76	30	3	14	2	0
20	65	43	1	21	5	0
Mar. 5	[2] 30	[2] 55	1	22	1	0
19	19	60	6	32	4	0
Apr. 2	5	43	3	9	3	0
Averages	94.6	34.7	2.3	19.5	2.0	0
	131.6			21.5		

[1] This represents examination of bolls at start of experiment, as a check, and is not included in averages.
[2] Only 97 bolls in this examination.

The procedure followed in the experiment with bolls or stalks (Table 9) was the same as that in the experiment just described, except that instead of placing the bolls on the surface of the soil they were supported on stakes above the ground in such a way as to represent the same conditions that they would be under were they still on the stalks in the field. These bolls were set out on December 2 and 4 and examinations were made biweekly.

TABLE 9.—*Entrance of pink bollworm larvæ from bolls on stalks into the soil for hibernation*

Date examined	Found in bolls: Larvæ and pupæ— Living	Found in bolls: Larvæ and pupæ— Dead	Found in bolls: Pupal cases	Found in soil: Larvæ and pupæ— Living	Found in soil: Larvæ and pupæ— Dead	Found in soil: Pupal cases
1922						
Nov. 28[1]	228	13	11			
Dec. 7	227	20	12	4	1	0
19	279	7	5	3	0	0
1923						
Jan. 1	285	9	6	2	0	0
16	232	13	5	7	0	0
30	248	17	1	6	2	0
Feb. 13	133	22	4	Ant nest in soil (no larvæ)		
27	130	15	3	1	1	0
Mar. 13	136	24	4	0	0	0
27	131	48	3	3	0	0
Apr. 10	129	29	2	2	1	0
Averages	193	20.4	4.5	3.1	0.6	0
	217.9			3.7		

[1] This represents an examination of bolls at the start of the experiment, as a check, and is not included in the averages.

A very sudden decrease in the number of living larvæ after the end of January without a compensating increase in the number of dead larvæ is noted in both Tables 8 and 9. Few pupal cases were found in any of the bolls, so this does not explain the disappearance of the larvæ; neither was there any increase in numbers found in the soil. On January 30 the first rain, 0.34 inch, fell since the experiment was started. This may have caused many larvæ to leave the bolls; but, owing to the condition of the soil immediately after the rain, they did not enter the soil readily. Many of them were probably destroyed by birds or crawled beyond the area of soil that was examined.

Tables 8 and 9 indicate that very few larvæ left the bolls on the stalks to go to the soil. With the larvæ in the bolls placed on the surface of the soil the proportion leaving the bolls was much greater. As shown in Table 8, most of this entrance of larvæ from the bolls into the soil must have taken place shortly after the bolls were placed on the soil. The first examination, six days after the bolls were placed, showed as many larvæ in the soil as the average for all the examinations. That this may have been due to the heat of the sun is indicated by the experiment about to be described.

EFFECT OF EXPOSURE TO SUN ON ENTRANCE INTO SOIL

On December 11, 1922, 100 bolls were placed on the surface of the soil in each of two boxes filled with soil. One of these boxes was kept in the shade and the other in the sun, both outdoors. Every week the soil was taken from each box and carefully examined for pink bollworms. Fresh soil was then put into the boxes and the same bolls replaced on the surface thereof. The results of this test are shown in Table 10.

TABLE 10.—*Number of larvæ leaving 100 bolls on the surface of the soil in the shade and in sun, and entering the soil*

Date examined	Number of larvæ in the soil	
	In the shade	In the sun
Dec. 18	0	2
25	0	6
Jan. 1	0	3
8	0	0
15	0	0
22	0	0
29	0	1
Feb. 5	0	2
12	0	1
19	0	1
Feb. 26	0	4
Mar. 5	0	1
12	0	0
19	0	0
26	0	0
Apr. 2	0	0
9	0	0
Total	0	21

The total of 21 larvæ found to have entered the soil from the bolls in the sun, with none from the bolls in the shade, shows clearly the effect of exposure to the sun. Below (Table 11) is given a record of the precipitation and the maximum daily temperature reached at the surface of the soil during the time these experiments were conducted, as well as the maximum daily air temperature.

TABLE 11.—*Precipitation and maximum daily temperatures of the air and the surface of the soil.*

Date	Maximum daily temperatures		Precipitation	Date	Maximum daily temperatures		Precipitation
	Air	Surface of the soil			Air	Surface of the soil	
1922	°*F.*	°*F.*	*Inches*	1923	°*F.*	°*F.*	*Inches*
Dec. 11	80	116	0	Jan. 1 to 7	82	120	0
12	80	119	0	8 to 14	82	123	0
13	81	116	0	15 to 21	83	122	0
14	84	124	0	22 to 28	86	128	0
15	81	120	0	29 to Feb. 4	86	127	0.34
16	81		0	Feb. 5 to 11	85	125	0
17	78		0	12 to 18	87	130	0.21
18 to 24	79		0	19 to 25	80		0
25 to 31	79		0	26 to Mar. 4	86		0.15
				Mar. 5 to 11	96		0

THE PRACTICAL IMPORTANCE OF HIBERNATION IN THE SOIL

In a series of experiments reported in Department Bulletin 918,[8] it was found that the survival of the larvæ in the soil is greatly decreased as the amount of moisture increases. In nonirrigated plots it was found that 12.8 per cent of the larvæ were alive or had emerged as moths during May and June, whereas in several irrigated plots no larvæ whatever survived the winter. It was also found that in Mexico the infestation of the season generally starts from material, such as old bolls, left on the surface of the ground. These facts show the reason for the effectiveness of the clean-up measures followed in the United States, where all of the possibly infested material on the surface of the soil is removed and burned and such infestation as remains in the soil dies out on account of the heavy winter rains.

LONGEVITY OF RESTING LARVÆ

Studies to determine the longevity of the resting larvæ were carried on during 1921 and 1922. On March 8, 1921, several thousand heavily infested, open bolls were gathered from standing stalks of the 1920 crop. These bolls were stored in a box in the laboratory, and monthly examinations were made to determine the mortality of the larvæ. In the latter part of the same month several thousand double seed were collected from a large quantity of 1920 seed stored in an oil mill at Gomez Palacio, Durango. These were placed in a cloth bag and stored with a quantity of other seed in a sack in the laboratory. Monthly examinations were also made of these seed.

The results of these studies are given in Table 12.

[8] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

TABLE 12.—*Longevity of resting pink bollworm larvæ*

Date examined	Bolls of 1920 crop: Number examined	Number of living larvæ	Dead larvæ and pupæ	Per cent living	Double seed of 1920 crop: Number examined	Number of living larvæ	Dead larvæ and pupæ	Per cent living
1921								
March	100	109	15	87.90	100	29	68	29.89
April	100	48	21	69.56	100	28	58	32.56
May	100	55	25	68.75	100	14	73	16.09
June	100	52	41	55.91	100	4	87	4.39
July	100	28	46	37.84	100	3	89	3.26
August	100	9	64	12.33	100	0	86	0
September	100	2	14	12.50	200	0	196	0
October	100	2	39	4.88	1,000	1	818	.12
November	100	4	64	5.88	975	0	750	0
December	100	1	57	1.72				
1922								
January	100	4	73	5.19				
February	300	1	143	.69				
March	100	[1] 1	50	1.96				
April	600	0	550	0				
May	700	0	481	0				
Maximum longevity	16¾ months.				Maximum longevity	11½ months.		

[1] This larva was placed in a pill box. It pupated and a perfectly developed moth emerged on Apr. 10, 1922.

Some of the larvæ in the bolls survived longer than those in the seeds. The larvæ in both lots of material were attacked by mites, which probably reduced the maximum longevity considerably. In obtaining the figure for maximum longevity given at the foot of the table, the date of the first killing frost in 1920 was used as the starting point.

Table 13 gives the results of the examination of bolls and seed of the 1921 crop. The bolls were gathered in the field on November 11, 1921, and stored on the veranda of the laboratory in sacks. The seed came from cotton picked on November 1 and ginned November 4, 1921. Part of this was stored in sacks in a warehouse, and was examined later as a whole. Other parts were stored over winter in a seed house and in a railroad car, and in the spring the double seed were picked out and stored in glass jars in the laboratory.

TABLE 13.—*Longevity of resting pink bollworm larvæ*

Date examined	Bolls of 1921 crop: Number examined	Number of living larvæ	Dead larvæ and pupæ	Per cent living	Seed of 1921 crop: Quantity examined	Number of living larvæ	Dead larvæ and pupæ	Per cent living
1921					*Ounces*			
November	100	296	8	97.37				
1922								
March	15	51	6	89.47				
April	30	39	14	73.58				
May	100	93	59	61.18				
June	95	29	71	29	8	6	94	6
July	67	2	97	2.02	7	2	99	1.98
August	60	0	116	0	1.6	1	218	.46
September	140	1	299	.33	6.5	1	99	1
October	135	1	352	.28	2.0	1	3,608	.03
November	175	1	403	.25	25.5	1	3,382	.03
December	449	1	836	.12	14	1	2,000	.05
1923								
January	700	1	1,366	.07	7	1	1,057	.09
February	1,100	1	2,945	.03	58	1	10,564	.009
March	1,200	1	3,184	.03	9	0	1,658	.0

NOTE.—The first four lots of seed examined consisted of both single and double seeds; the remaining lots consisted entirely of double seeds.

Bolls of the 1921 crop are still available at the present writing (April, 1923), so Table 13 is incomplete, but the records now indicate a longevity of over 16 months.

DAMAGE CAUSED BY THE PINK BOLLWORM

DAMAGE TO IMMATURE FORMS

As pointed out by Loftin,[9] the young pink bollworm often enters a square and reaches maturity therein without causing shedding, and the larva may develop to maturity in the bloom without causing abnormal development of the boll. Just what amount of damage the pink bollworm does by feeding on the immature forms on the cotton plant is difficult to determine, owing to the usual heavy natural shed of forms at about the same time that the pink bollworm becomes very numerous. Under conditions prevailing in the Laguna district during 1921 and 1922, the damage done to squares, blooms, and very young bolls early in the season certainly was entirely negligible This point is brought out in Figure 6, in which it will be noted that the rapid fruiting early in the season quickly outstrips the multiplication of the pink bollworm in the blooms.

Under normal climatic and cultural conditions in this district the fruiting of the cotton is very rapid, once it has well begun. Then a point is reached at which, owing to lack of moisture, all young forms begin to shed off. Later the cotton makes a second growth, which may be very little, or very considerable in case the field receives spring or early summer irrigation. This is illustrated in Figure 6, in which all records after August 21 represent counts in irrigated fields only.

The results of observations on the relation of shedding to infestation made in a field at Tlahualilo during 1922 are given in Table 14. These observations were discontinued early on account of the appearance of the leafworm. The table shows the number of forms on 100 plants on the dates indicated, the number of shed forms found under these plants at the same time, and the percentage of these shed forms that were infested. The field in which these observations were made was cultivated on July 18 and irrigated on July 20. On the 27th it was again cultivated. Many of the shed forms were therefore either covered up or floated away, which made the figure for shed forms on July 29 unusually low, and not representative of the entire shed since July 14.

TABLE 14.—*Relation of shedding of immature forms from cotton plants to pink bollworm attack, Tlahualilo, 1922*

[Number of forms on and under 100 plants]

Date	Forms on plants		Shed forms	
	Bolls	Squares and blooms	Total	Percentage attacked by the pink bollworm
July 14	1,586	712	834	3.5
29	994	49	488	2.5
Aug. 9	947	11	132	4.5
16	1,008	127	10	0
29	1,038	932	12	33.3
Sept. 6	1,162	1,319	36	61.3
14			212	69.8

[9] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

The data in this table are shown graphically in Figure 7. In the graph the figures of Table 14 are reduced to number of forms per plant. A fourth line in the graph shows the development of the infestation in mature green bolls on the plants during the same period of time. A great decrease occurred in the number of forms on the plants between the middle and the end of July. Reference to Table 14 shows that this was due to both shedding and absence of new fruiting. Following the irrigation, however, there was a

FIG. 6.—Daily average number of total blooms and blooms infested with the pink bollworm per acre, 1921 and 1922 records

great increase in fruiting, and shedding practically ceased for a time.

The early infestation (fig. 7) was so light that, even if it caused shedding, this could have had no appreciable effect on the total shed, which was very great at that time. During the period of the second growth a much greater part of the shed forms was infested. Comparing this, however, with the infestation of blooms on the plants (fig. 6), it will be noted that an equally high percentage of the blooms on the plants was infested. This indicates that even at that time little of the shedding of the young forms could be attributed to the pink bollworm.

An experiment was conducted in another field in 1922, in which both infested and uninfested freshly opened blooms were tagged and kept under observation to determine the final percentage of the forming bolls that was shed. Two kinds of infested blooms were considered, those that on the day of opening contained mature larvæ and those that contained immature larvæ. The blooms were tagged on July 19 and 20. In Table 15 are given the results of this test.

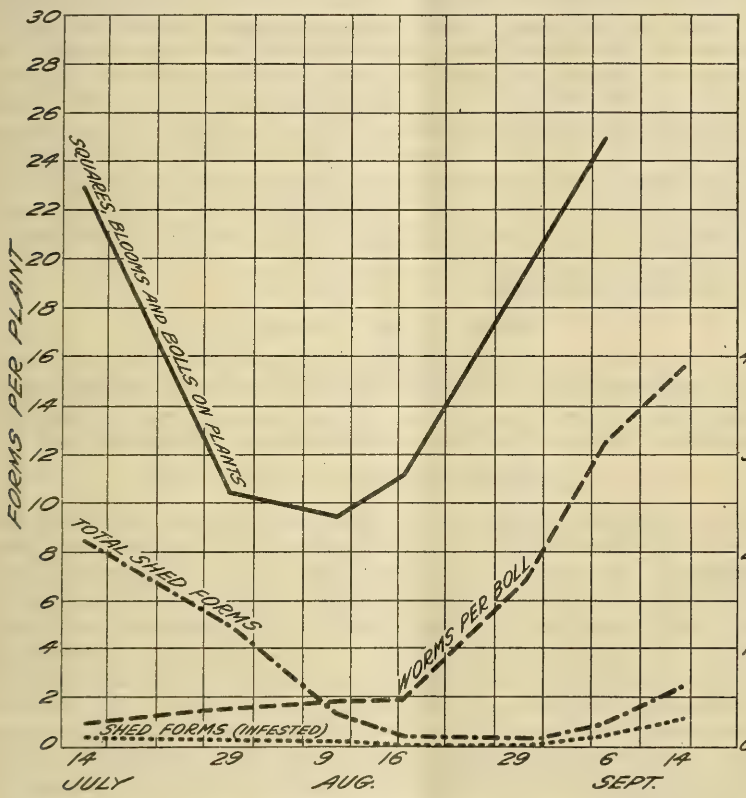


FIG. 7.—Relation of the infestation of immature forms on the cotton plant to shedding

TABLE 15.—*Boll shed due to infestation of the bloom*

Kind of bloom	Number tagged	Per cent of bolls shed
Uninfested	200	61
Infested (immature larvæ)	200	93.1
Infested (mature larvæ)	200	93.74

The only difference noted during the experiment between the shedding of the bolls of the two kinds of infested blooms was that those of the last group in the table were shed sooner than those of the second group. The average of the last two (93.42 per cent) shows an increase of 32.42 per cent in shedding of bolls of the infested blooms above that of the uninfested.

This does not seem to check with the data on which Figure 7 is based. In that case, as has been pointed out, the percentage of infested blooms on the plants (fig. 6) is equally as great as the percentage of infested fallen forms (fig. 7). These data, however, do not offer a basis for direct comparison. In the first place, the experiments were carried out in two different fields in which the rate of natural shed may have been quite different at the time. Then again, Figure 7 represents all shed forms, not indicating what proportion of them were blooms. And, lastly, it is possible that the feeding of the larva in the bloom may cause bolls to shed even though the larva does not touch the young boll itself, in which case an examination of the shed boll only, after the bloom has dropped off, would not reveal the fact that its shedding was due to the pink bollworm. The figure, 32.42 per cent increase in the shedding of the bolls of infested blooms, or an increase of 53.1 per cent above that of the uninfested blooms, compares with Loftin's figures [10] of a difference of 26.8 per cent in shed due to the pink bollworm, or an increase in shedding of bolls of infested blooms of 65.7 per cent above that of bolls of uninfested blooms.

DAMAGE TO MATURE BOLLS

The damage done by the pink bollworm to bolls that reach maturity has been separated into damage to picked cotton and cotton rendered unpickable. The latter is the cotton which is left in the field by the pickers, because it is too greatly damaged to be worth picking.

DAMAGE TO PICKED COTTON

In 1921 a number of samples of cotton were picked from different fields and experimental plats to obtain samples of lint and seed and to determine the extent to which they were damaged. These samples were obtained by selecting average stalks and picking all pickable bolls from each of these stalks. One hundred bolls were picked for each sample. To obtain a check sample, a number of locks corresponding to 100 bolls and apparently not injured by the pink bollworm were selected, and picked lock by lock. All of these samples were then ginned on a 10-saw hand gin. The damage to the seed was determined by examination at Tlahualilo. After repeated disinfection, the lint samples were sent to the Bureau of Markets at Washington for classification and testing.

DAMAGE TO SEED

From the seed of every one of the above samples a certain volume, averaging about 1,000 seed, was taken. These samples were carefully examined, the damaged seed was separated from the sound seed, each part was counted and weighed, and from these figures the damage was calculated, expressed as percentage of reduction in weight of the samples due to pink bollworm feeding. This method should give approximately the damage to the seed of the picked cotton. The results of this calculation are given in the column under "Percentage reduction in weight" in Table 16. This gives the loss in quantity of seed only. There was in addition a loss in quality, but what this amounted to was not determined.

[10] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

TABLE 16.—*Comparison of average pick and check samples of lint and seed, 1921 experiments*

Sample or variety No.	Lint												Seed	
	Grade		Length of staple		Uniformity (length)		Tensile strength				Percentage of lint		Percentage reduction in weight	
							Grams		Per cent deviation					
	Check	Average pick	Check	Average pick	Check	Average pick	Check	Average pick	Check	Average pick	Check	Average pick	Check	Average pick
			Inches	*Inches*										
Unirrigated:														
Blue Ribbon	SGM	SGM	7/8	7/8	Regular	Regular	5.12	5.08	40.6	50.6	34.63	38.88	0.81	5.80
019-020	GM	GM	7/8	15/16	do	do	4.83	4.47	43.3	46.1	35.00	33.33	.45	1.07
021-022	MF	GM	7/8	15/16	do	do	5.58	4.78	28.3	37.7	37.21	30.55	.86	5.56
023-024	SGM	GM	15/16	1	do	do	4.67	5.35	41.1	36.1	34.29	30.55	.49	4.76
025-026	SGM	SM	15/16	15/16	do	do	5.02	4.92	43.6	35.5	34.88	34.37	2.85	7.37
Acala	MF	SM	1 1/16	15/16	Uniform	do	4.78	4.65	34.5	46.5	37.50	35.29	.45	4.26
Lone star	MF	SM	1	15/16	Regular	do	3.45	4.20	41.7	47.9	36.36	35.91	.87	5.86
Kasch	SGM	SM	15/16	7/8	do	do	[1] 5.28		[1] 41.9		38.85	40.91	.92	4.71
Truitt	MF	SM	1	7/8	do	do	[2] 4.66		[1] 40.8		37.50	37.98	.19	1.76
Webber-49-3	SGM	M	1 3/16	7/8 to 1 1/8	do	Wasty	4.68	3.25	30.1	44.0	31.25	30.26	.90	4.58
Webber-82-2	MF	M	1 1/8 to 1 3/16	1	Irregular	Regular	5.07	4.77	44.0	45.7	33.33	32.62	.30	3.12
Average			0.9856	0.9375			4.80	4.61	38.6	43.3	35.53	34.60	.83	4.44
Irrigated:														
Express	MF	M	1	1 to 1 1/16	Regular	Irregular	4.45	4.67	30.3	45.8	34.28	32.48	.64	4.40
Acala	MF	GM	1 1/16	1	do	Regular	6.08	5.07	43.3	45.6	33.33	34.30	.37	3.44
Lone Star	MF	M	1	15/16	do	Irregular	5.12	4.97	39.8	36.8	36.36	36.11	1.12	6.80
Kasch	SGM	M	1	7/8 to 15/16	do	do	6.20	5.28	32.6	38.1	40.00	41.21	1.62	4.28
Truitt	MF	SM	1	7/8 to 15/16	do	do	5.87	4.08	45.3	55.4	34.61	36.00	1.03	4.45
Webber-49-3	SGM	M	1 1/4	1 1/16 to 1 3/16	do	do	4.73	3.60	43.3	54.2	31.81	30.57	.73	5.76
Webber-82-2	MF	M	1 1/4	1 1/8 to 1 3/16	do	do	4.10	3.68	40.0	53.5	31.81	31.21	.41	6.58
Average			1.08	1.009			5.22	4.48	39.2	47.1	34.60	34.55	.85	5.10
Grand average			1.02	.96			4.98	4.55	38.9	45.0	35.17	34.58	.83	4.70
Percentage difference			5.9				8.6		15.7		1.7		[2] 3.87	

[1] These figures not included in averages.

[2] Difference in percentage.

NOTE.—All data in the above table, except those in columns headed "Percentage reduction in weight" (of seed), are taken from a report on these samples by the Bureau of Markets, U. S. Department of Agriculture. In their report the following descriptive notes are given: "*Uniformity:* 'Uniform' indicates unusual uniformity in length of fibers. 'Regular' indicates average uniformity. 'Irregular' indicates slightly below average. 'Wasty' indicates mixed length of fiber." The fiber (body) of all samples was classified in the report as "light." "Irrigated" and "unirrigated" in the table refer to early summer irrigation.

As will be noted, none of the check samples were entirely free from pink bollworm damage, the average percentage reduction in weight of seed of these samples being 0.83 of 1 per cent. This was due to the difficulty of determining from outside appearances that locks of cotton actually contained seed that had been damaged by the pink bollworm. The average percentage reduction in weight of the seed (4.7 per cent) would appear rather low. This was to be expected, however, as all the samples were of the first and only picking in the fields from which they were taken, no second crop of any consequence having been produced in these fields. This fact should also be taken into consideration in connection with the data on damage to the lint.

DAMAGE TO LINT

In Table 16 are given the results of tests of the lint samples submitted to the Bureau of Markets.

The first four headings under "Lint" come under "quality," whereas the "percentage of lint" shows the effect of the pink bollworm on the quantity of lint. There is more difference in the case of the unirrigated than in the irrigated cotton. The 1.7 per cent difference, however, is not the entire reduction in quantity of lint. It is based on the actual weight of the seed, and this had been reduced by the pink bollworm. Comparing with the calculated production of lint in the check samples, there is a reduction of the quantity of lint in the samples of average pick of 5.9 per cent. As in the case of the seed samples, however, the lint samples were possibly too small to be considered as accurately giving the lint turnout. This is indicated by the rather wide variations found in some of the samples. The averages given must therefore be considered only as approximations.

NONPICKABLE COTTON

In the foregoing discussion "nonpickable cotton" was referred to as representing part of the total damage done by the pink bollworm to the crop of bolls that actually reach maturity. Nonpickable cotton (fig. 8) is the open cotton left in the fields after the crop has been harvested on account of being too severely damaged by the pink bollworm to be picked. It is expressed as a percentage of the total crop matured and can be determined fairly accurately. In determining the percentage of nonpickable cotton, several representative points were selected in each field, and in 1921 counts were made of all bolls, both picked and unpicked, on a certain number of plants and the number of unpicked locks in these bolls, and in 1922 counts were made of a certain number of bolls both picked and unpicked on consecutive plants and the number of unpicked locks in these. The total bolls and the unpicked locks were then reduced to the same basis, using for the number of locks per boll a figure either arbitrarily set or determined by actual boll examinations in the fields in which counts were made. (In 1921 the first method was followed, the figure used being 4.5 locks per boll; in 1922, using the second method, an average of 4.43 locks per boll was obtained.) From these figures the percentage represented by the unpicked locks is calculated.

In Table 17 are given the percentages of nonpickable cotton separately for the irrigated and unirrigated fields for both 1921 and 1922 and for "zoca" (volunteer cotton) for 1922, based on counts made in a number of representative plantations in the Laguna. In 1921 the counts were made in November and the first part of December. In 1922 the counts in the unirrigated fields were made in

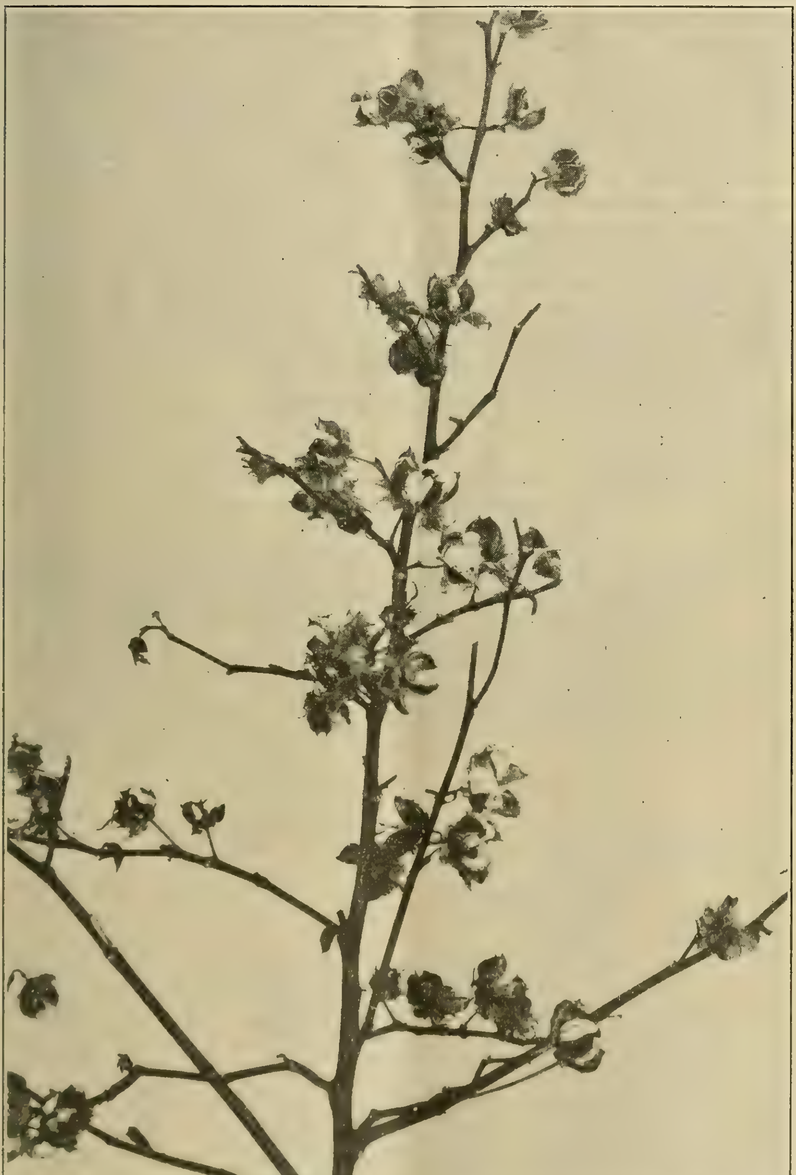


FIG. 8.—Characteristic pink bollworm damage, showing type of bolls classed as "nonpickable"

the latter part of September and the first part of October and those in the irrigated fields during the latter part of November. A frost on October 30, 1921, killed all the cotton and consequently no green bolls had to be taken into consideration in the counts that year. Frost in 1922, however, did not occur till December 19, and at the time the counts were made that season many nearly mature green bolls were still on the plants. These bolls were recorded at the same time the counts were made, and in this way the figure for "Percentage of crop open" was obtained. The percentage of nonpickable cotton, however, is based on open bolls only. Had the counts been postponed until after the frost, the amount of nonpicakble cotton would have been greater, for many of the green bolls would have had time to open, and they were all heavily infested. This would not have been comparable with 1921, on account of the lateness of frost. As it was, the results for irrigated cotton are more nearly comparable for the two years, since those in 1922 were made not very long after the time of the year when frost occurred in 1921. The extremely low figure for the unirrigated cotton in 1922 can be partly explained by the earliness of the counts. Had these been made at the end of October the percentage nonpickable would have more nearly approached that of the unirrigated fields in 1921.

TABLE 17.—*Nonpickable cotton, Laguna district, 1921 and 1922*

Plantation No.	Percentage nonpickable, 1921		1922								
			Irrigated "planta"			Unirrigated "planta"			"Zoca"		
	Irrigated cotton	Unirrigated cotton	Percentage of crop open	Percentage of open cotton nonpickable	Yield, bales per acre	Percentage of crop open	Percentage of open cotton nonpickable	Yield, bales per acre	Percentage of crop open	Percentage of open cotton nonpickable	Yield, bales per acre
1						80.8	1.33	0.56			
2		7.9									
3			80.9	16.22	0.64						
4		7.9							62.6	2.26	
5		6.1							74.9	10.13	0.12
6		[1] 11.9									
7			97.2	5.00		90.9	3.65	.58			
8		8.0									
9						86.2	5.42		97.9	4.50	
10			94.1	5.34	1.04	91.5	1.40				
11	13.2	6.2									
12	15.2										
13		[1] 13.3									
14		10.3									
15						98.6	1.34	.80			
16			93.1	9.41	1.21						
17		13.9									
18						81.3	.87	.76	70.9	7.66	
19	3.4	7.7	86.0	6.90	.80						
20			54.0	23.59		71.5	7.34				
21						86.0	1.19	.56			
22	14.5					93.9	1.16	.40	51.9	2.60	
23	27.3	14.4									
24									62.7	17.38	
25	16.7										
26	13.9	7.3							82.4	16.03	
27	7.5		96.4	2.04	.75						
28		9.8							90.2	17.18	
29		5.5									
30	29.8										
31	20.8	11.4	97.7	15.99	.79	94.6	3.94	.65	71.3	17.56	.03
Average	16.2	9.4	87.4	10.56	.87	87.5	2.76	.61	73.9	10.59	.07

[1] Zoca fields. "Planta" is planted cotton; "zoca," volunteer cotton.

Average nonpickable, all classes, 1921, 12.8 per cent: 1922, 7.97 per cent.

The great variations shown in the nonpickable cotton on different ranches are due to several things and will be taken up later. One point of note is the effect an infestation by the boll weevil has on the percentage of nonpickable cotton. This insect severely damaged several fields in 1921. When the attack occurs reasonably early and the weevil becomes abundant, it destroys the greater part of the late crop, allowing very few late bolls to remain on the plant. Then we have a condition represented by a short early crop only slightly damaged by the pink bollworm and very little nonpickable cotton on account of the lack of late bolls. This occurred in the case of plantation No. 19 in 1921, where the percentage nonpickable in the unirrigated field is twice as great as in the irrigated.

RELATION OF THE AMOUNT OF NONPICKABLE COTTON TO TOTAL DAMAGE

A seasonal variation in the ratio of nonpickable cotton to total damage may be looked for, because in seasons of high prices for the staple it will be picked cleaner than when low prices prevail. This variation was illustrated in 1921 and 1922. The infestation on the Tlahualilo plantation, as shown in Table 18, was equally as high in 1922 as it was in 1921, but the percentage of nonpickable cotton on this plantation (No. 31), as shown in Table 17, was 16.1 for 1921 and 9.96 for 1922 (taking the average of the irrigated and unirrigated fields). About the only explanation for this great difference is that the cotton was more closely picked in the latter season, a greater percentage of the severely damaged cotton being gathered and less "nonpickable" cotton left in the field. The price of picking at the end of the season and the price of low-grade cotton apparently substantiate this theory. The lowest grade of cotton (good ordinary) sold for 10 cents per pound during the 1921 season and for 15 cents per pound (Mexico City prices) during the 1922 season. At the same time the highest price paid for picking at the end of the season was 4 cents per kilo in 1921 and 6 cents per kilo in 1922. In this connection is presented Figure 9 to show the relation between nonpickable cotton and the price of cotton.

TABLE 18.—*Progress of infestation of green bolls, Tlahualilo plantation, 1921 and 1922*

Month	Week	Percentage of bolls infested		Number of worms per boll	
		1921	1922	1921	1922
June	Third		22.6		0.22
	Fourth		7.3		.08
July	First		5.2		.06
	Second	17	4.9	0.19	.06
	Third	29	16.3	.45	.23
	Fourth	32.1	15.8	.48	.20
August	First	34.3	27.6	.54	.37
	Second	43.7	31.1	.72	.48
	Third	68.3	59.0	1.57	1.05
	Fourth	87.9	84.1	2.46	2.47
	Fifth	96.4	99.3	3.42	5.13
September	First	95.5	99.9	4.03	6.48
	Second	99.1	100	4.36	7.15
	Third	99.3	100	5.25	7.16
	Fourth	100	100	5.82	6.13
October	First	100	100	5.84	8.57
	Second	100	100	6.98	7.48
	Third	100	100	4.05	5.87
	Fourth		100		4.97
November	First		99.2		4.42
	Second		100		3.16
	Third		100		5.26
	Fourth		100		5.62

In Figure 3 the upper curve represents the percentage of nonpickable cotton on the Tlahualilo plantation for the seasons from 1919 [11] to 1922, inclusive, and the lower curve the average price of "good ordinary" cotton on the Houston, Tex., market during the last three months of the years from 1918 to 1922, inclusive.

TOTAL DAMAGE

For an estimate of the total damage, considering matured bolls only, these are data, other than those showing the percentage of nonpickable cotton, only in the case of the test of seed and lint samples from fields on the Tlahualilo plantation in 1921. Referring to Table 16, there is a reduction in the weight of the seed of 4.7 per cent. In the absence of definite data, let the damage to the lint be considered the same. Figures in Table 17 indicate an average loss in

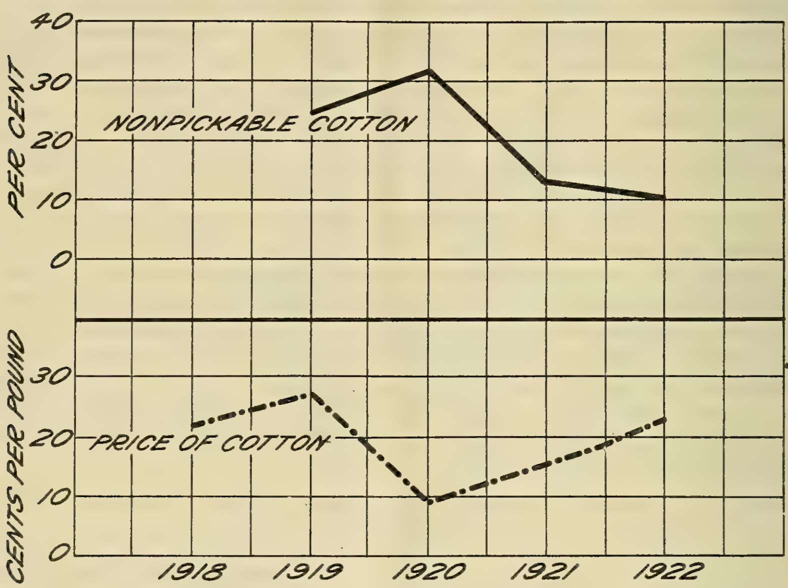


FIG. 9.—The relation between the price of cotton and the amount of "nonpickable" cotton left in the field

1921 on this plantation (No. 31) of 16.1 per cent in the form of nonpickable cotton. This leaves 83.9 per cent representing the crop picked; 4.7 per cent of this gives the damage to picked cotton amounting to 3.9 per cent of the total matured crop, which added to 16.1 gives a total average damage of 20 per cent. In 1921, however, only approximately one-third of the cotton at Tlahualilo received summer irrigation. So a weighted average on this basis, but not considering acreages in individual fields, would give the nonpickable cotton as 14.5 per cent of the total crop, the damage to the picked cotton as 3.9 per cent, and a total damage of 18.4 per cent.

The total loss for 1922 can not be calculated on the above basis, because, as was pointed out before, the figures for the percentage of nonpickable cotton for the two seasons are evidently not comparable.

---

[11] The figures for nonpickable cotton for 1919 and 1920 are from Loftin (Dept. Bul. 918 and a subsequent unpublished report by him).

In November and December of 1921, Schutz and Haskell of the Bureau of Markets and Crop Estimates of the United States Department of Agriculture made a survey of the Laguna district, to obtain data on the economic phases of the pink bollworm situation. By the use of questionnaires they obtained from plantation owners and managers data on the average loss due to the pink bollworm. From a total of 143 estimates of the losses during the period from 1915 to 1921, inclusive, they obtained an average yearly loss record of 23.4 per cent of the crop. Their averages were 22.4 per cent for 1921 and 30.4 per cent for 1920, based on 39 and 36 estimates, respectively.

CONDITIONS AFFECTING DAMAGE

SUMMER IRRIGATION

Cotton in the Laguna district which receives summer irrigation is usually more severely damaged by the pink bollworm than unirrigated cotton. The irrigation causes later fruiting, and this late crop becomes subject to attack at the time of the season when the pink bollworm is most abundant. Table 19 shows the progress of the infestation in irrigated and unirrigated fields in both 1921 and 1922.

TABLE 19.—*Average number of worms per green boll in irrigated and unirrigated fields*

Date	1921		Date	1922	
	Irrigated[1]	Unirrigated		Irrigated	Unirrigated
July 24	0.33	0.57	June 27	0.14	0.03
Aug. 2	.27	.45	July 8	.18	.02
9	.43	.30	18	.38	.11
16	1.22	2.34	28	.36	.14
23	1.81	2.27	Aug. 7	.60	.27
30	2.81	3.63	17	1.85	.77
Sept. 6	4.37	4.08	27	5.05	2.95
13	3.92	3.54	Sept. 5	6.87	4.55
20	5.37	5.20	16	[2] 8.32	
27	6.36	6.16	27	[2] 5.50	
Average	2.69	2.85	Average	1.93	1.10

[1] Dates of irrigation: 1921, July 24; 1922, July 11. [2] Not included in average.

According to these records the unirrigated cotton in the first part of the season of 1921 was a little more severely infested than the irrigated, but the condition became reversed in the latter part of the season, with a smaller percentage difference. In 1922 the irrigated cotton showed a heavier infestation throughout the season.

A few plantations in the Laguna have wells which supply summer irrigation water. Their irrigation practices differ from those on other plantations in that less water is applied in the fall and winter floodings and several irrigations are given during the summer. Plantations Nos. 16 and 27 in Table 17 are irrigated in this manner. An unusually low figure for the nonpickable cotton on plantation No. 27 is shown in 1921 and 1922. The figure for plantation No. 16 for 1922, however, is not unusually low. Possibly the low damage on the former was due to early maturity of the crops as a whole caused by timely irrigations, which prevented the usually very definite separation between the first and second crops found in fields that receive late irrigation of river water.

DISTANCE FROM COTTON FIELDS OF PREVIOUS YEAR

On the Tlahualilo plantation a system of rotation is practiced in which cotton is not planted on the same land two consecutive seasons. In addition a zoning system has been instituted providing the planting of cotton in fields more or less distant from cotton fields of the previous year. Studies were conducted in 1921 on the influence that distance from source of infestation has upon the damage caused by the pink bollworm. Regular boll examinations were made throughout the season in four selected fields on the Tlahualilo property, located at different distances from 1920 cotton fields. Data on this experiment are given in Table 20. The four fields are hardly comparable in one group, as fields Nos. 1 and 2 were west of old cotton fields and Nos. 3 and 4 were north. But field No. 1 is comparable with No. 2 and No. 3 with No. 4. Only a slight advantage is shown for the more distant fields.

TABLE 20.—*Pink bollworm infestation in 1921 fields located different distances from 1920 fields*

[Worms per boll]

Date	Field 1 (1,000 meters)[1]	Field 2 (2,750 meters)[1]	Field 3 (3,500 meters)[1]	Field 4 (6,250 meters)[1]
June 23	[2] 0.06	[2] 0.09		
30	.01	.015	0.075	0.02
July 8	.008	.024	.037	.002
15	.038	.006	.05	.026
22	.47	.08	.42	.23
29	.44	.15	.45	.35
Aug. 5	.54	.37	.60	.61
11	1.74	.80	1.07	1.12
18			1.74	1.69
26	2.84	3.15		
Sept. 1			3.55	3.32
9	6.02	4.50		
15			5.48	4.34
Averages	1.35	1.01	1.35	1.17

[1] Distance from 1920 fields. [2] Not included in average.

In Table 21 the results of nonpickable cotton counts made in 1921 at 47 different points in unirrigated fields on the Tlahualilo property are presented with reference to the distance of these points from 1920 cotton fields.

TABLE 21.—*Percentage of nonpickable cotton, 1921, in unirrigated fields, with reference to distance from 1920 cotton fields*

Number of points	Distance from 1920 fields (meters)		Percentage of cotton nonpickable	
	Average	Range	Average	Range
34	680	250–1,500	11.5	3 to 32
13	4,730	2,750–6,250	10.6	7 to 16

Here again only a slight advantage is shown in favor of the more distant fields. Comparisons of individual fields in each group bear this out also. The field in the first group that showed a damage of 32 per cent and another that showed only 3 per cent were both 250 meters from the 1920 fields. Loftin made some counts on this plantation in 1920, and some of his most heavily damaged fields were near fields that showed little damage in 1921.

A relatively heavy infestation was frequently noticed at the edge of a field. This would indicate either migration from a near-by field or possibly greater concentration of moths at the edge of the field on the side toward which flight directed them. The more or less simultaneous beginning of the infestation in different parts of large fields, noted at Tlahualilo in 1921, must be attributed either to a rather general flight of the moths first emerging in the spring or ineffectual fumigation of planting seed. As long as such possibilities remain, the data on distribution of the infestation can not be considered solely with reference to fields of the previous year or seed storehouses as sources of infestation.

VOLUNTEER COTTON (ZOCA)

Under favorable conditions in the Laguna district, volunteer cotton sprouts from stalks of the previous year to such an extent that a considerable crop has often been produced on such fields. This cotton is commonly called "zoca" and its destruction in the spring has in recent years been required by the Mexican Government in its program of pink bollworm control. On account of the extreme shortage of irrigation water in the fall and winter of 1921, the growth and cultivation of zoca was permitted in 1922 in order to offset to some extent the small acreage that could be planted.

The influence which zoca has on the damage of the pink bollworm to planted cotton probably depends greatly on seasonal conditions. With early zoca and late-planted cotton, early food is furnished the worm, and greater numbers of the insects are present when the planted cotton becomes subject to attack than if the zoca is kept down, causing many of the early emerging moths to die without finding cotton on which to deposit their eggs. On the other hand, if the zoca and the planted cotton begin fruiting at about the same time, the former, being on the insects' hibernating grounds, is attacked first and may retard the infestation in the planted cotton. But in that case a rapid increase in the infestation of the planted cotton may be expected when moths in the zoca become so abundant that they begin to seek other cotton.

In referring to the records of nonpickable cotton for 1922 (Table 17), it is noted that the percentage nonpickable for zoca is about the same as that for the irrigated planted cotton and much higher than for the unirrigated planted cotton. Also many more green bolls were left on the zoca than on the planted cotton at the time of the examinations. Ordinarily the stand of zoca is very poor and it has a heavy late growth, which accounts for a high percentage of nonpickable cotton. Although infestation develops early in zoca, it does not necessarily follow that severe damage occurs much earlier than in planted cotton. This is indicated in Table 22, in which the infestation of a field of zoca is compared with the average for three fields of planted cotton on a plantation near Torreon in 1921.

TABLE 22.—*Average number of worms per boll in planted cotton and in zoca, 1921*

Date	Planted cotton	Zoca
June 18	0.14	0.44
July 2	.07	.63
16	.67	1.47
30	1.31	2.79
Aug. 13	1.53	1.95
27	3.20	3.30
Sept. 10	4.08	2.72
26	----------	3.77
Oct. 8	----------	2.02

FOOD PLANTS

Experiments were conducted and observations made by A. C. Johnson on host plants other than cotton to determine the part these plants may be expected to play in the perpetuation of the pink bollworm in the absence of cotton or its spread beyond extensive areas in which there is no cotton. Dry okra plants containing a large number of heavily infested pods were placed under a large screen cage in the winter of 1921–22. The following spring both okra and cotton were planted under this cage, the old stalks being allowed to remain. The cotton bloomed about the middle of June and the okra still later, but no infestation developed on either.

On May 27, 1922, 200 okra pods were gathered from dry stalks that had been in the field all winter. An examination showed 3 living larvæ, 33 dead ones, and 1 pupal case. It is thus evident that under Laguna conditions the larva can survive the winter in okra pods on stalks in the field. In an okra pod, however, the larva is not so well protected against cold as in a cotton boll containing cotton.

Other malvaceous plants growing in the Laguna district were likewise studied with reference to their possible relation to the pink bollworm as host plants. A larva was found in a bloom of hollyhock (*Althea rosea*) as early as May 28 in 1922, and on June 7, 1921. Heavy infestation of hollyhock was never noted, and the larva was observed only in the bloom.

Three wild malvaceous plants are rather common in the Laguna district. These are *Sphaeralcea cuspidata* (Gray), *Sida hederacea* Torr., and *Malva parviflora* L. Quantities of these plants were collected repeatedly and placed in rearing cages, but no stages of the pink bollworm were ever found on them. In many cases these plants were collected immediately adjoining cotton fields. Larvæ of the lepidopteron *Noctuelia rufofascialis* Stephens were found in considerable numbers in the seed pods of these plants. This larva attains practically the same size as the pink bollworm and it is found occasionally feeding on cotton, both in the blooms and in the bolls. The pods of these malvaceous plants are large enough to enable the pink bollworm to reach maturity in them.

A few specimens of *Hibiscus coulteri* Harv. were found on the mountains near Tlahualilo, but they were not infested.

RELATION OF ALTERNATIVE FOOD PLANTS OF THE PINK BOLLWORM TO NONCOTTON ZONES

In the United States in the work of eradicating the pink bollworm the planting of cotton over extensive areas has been prohibited. This work appears to have been entirely successful in bringing about eradication in several large areas. In these areas, however, no effort was made to eliminate possible alternate food plants.

Very extensive searches have been made in the United States to find infestation by the pink bollworm in okra and other malvaceous plants growing in noncotton zones and in their immediate vicinity. In no case has any infestation ever been found in any of these plants.

The records from Mexico and those from Egypt and other countries have shown clearly that the insect can develop in plants other than cotton. Taking all the available information together, the conclusion seems to be warranted that, in the presence of enormous numbers of the insect, such as are found in Mexico and Egypt, there are occasional more or less aberrant individuals which attack plants other than cotton. With such an attenuated infestation as has occurred in the United States, the volume of the moths is so small that the chance of attack on other plants is negligible.

FIG. 10.—Group of cotton plants in tests to determine distance of flight, fenced for protection against animals

DISSEMINATION BY FLIGHT

In 1921 and 1922 F. F. Bibby conducted experiments to determine if possible the distance the pink bollworm moth would normally cover by flight. Small groups of plantings (fig. 10) were made at isolated points distant from cotton fields and kept under observation to determine whether they became infested. Seed free from pink bollworms was used.

In 1921, there were 8 small groups of plants at intervals of 1 mile to the north of the fields on the Tlahualilo plantation, which was the nearest cotton to these plantings. Each group consisted of about a dozen plants, which did not attain any great size and bore little fruit, making examination easy. Thorough examinations precluded the possibility of moths developing in one group of plants and infesting the next one. The results of the test are given in Table 23.

TABLE 23.—*Infestation of plantings in 1921 distance-of-flight tests*

Point	Distance from fields	Date first bloom	Date found infested	Larvæ per group of plants— First instar	Second instar	Third instar	Fourth instar	Total	Date plants were destroyed
	Miles								
No. 1	1	July 19 to 28	Aug. 25	8		1		9	Aug. 30
No. 2	2	July 13	Sept. 22	2	1	1		4	Sept. 22
No. 3	3	Aug. 18 to 25	Sept. 15	7				7	Sept. 18
No. 4	4	do	Sept. 1	1				1	Sept. 7
No. 5	5	Sept. 1 to 7	Sept. 7		2		1	3	Sept. 8
No. 6	6	July 28 to Aug. 4	Oct. 14	6				6	Oct. 14
No. 7	7	Aug. 18 to 25	Sept. 7	1			1	2	Sept. 8
No. 8	8	July 6 to 13	July 28 and Sept. 29	2				2	Oct. 2

All the groups of plants became infested, No. 8, which was 8 miles from the nearest cotton field, being the first. As only one small larva was found in this instance it was removed; but the plants were not destroyed. Close examinations showed that there was no connection between this infestation and the later one in this group of plants. In all other cases the plants were removed soon after the infestation was discovered, and all forms closely examined, with the results given in the table. Each group of plants in this test became infested independently of the others, with the nearest source of infestation as indicated in the table. Whether the moth reached any or all of the points by flight or through carriage by man can not be explained. There was no occasion of infested material being carried past these plantings but the moth may have been carried out in making inspections or by carts which occasionally passed near by. Still, with millions of moths in the fields, it would not seem strange had some of them been carried to these plantings by favorable winds, even though their power of flight is limited.

The following season (1922) plantings of small groups of plants were made in several directions from the source of infestation. Table 24 shows the arrangement of these plantings and the results obtained.

TABLE 24.—*Results in distance-of-flight plantings, Tlahualilo, 1922*

Point	Distance from cotton	Direction	Infestation	Remarks
	Miles			
No. 1	5	North	None	Fruited sufficiently for infestation.
No. 2	8	do	Late	
No. 3	5	West	Early	
No. 4	8	do	None	No fruit formed.
No. 5	5	East	do	Do.
No. 6	6	do	do	Do.

With the exception of the failure of the plants at point No. 1 to become infested, the results are about the same as in 1921.

In addition, two other plantings were made in 1922, one 25 miles northwest and the other 40 miles west of the nearest cotton in the Laguna district. These plantings were on cattle ranches and consisted of about 100 plants each. The first showed as heavy an infestation at the end of August as the average for the Tlahualilo fields at the same time. The cotton at the other point also developed a heavy infestation. A number of families of Mexicans lived at each of these ranches, and, although supposedly no material subject to infestation was ever brought there, it is extremely likely that infested seed or seed cotton was brought in with packing, bedding, or the like. This seems a more logical explanation, in view of the early development of heavy infestation, than the theory of flight.

NATURAL CONTROL

One of the characteristics of the pink bollworm under conditions in Mexico is the regularity of its attack. Equally as characteristic is the contrast between the enormous number of larvæ found in the fields in the fall and the slow development of the infestation in the spring. Though the latter is probably explained to a great extent by the practice of thoroughly cleaning the fields in the winter and fumigating the planting seed, still were there not a heavy natural mortality among both the hibernating larvæ and the newly hatched larvæ during the season much greater damage would be expected.

MORTALITY OF YOUNG LARVÆ

The great difference between the total eggs deposited and the number of larvæ found in the bolls was pointed out in connection with Table 1. A greater discrepancy occurs between the number of apparent entrance holes on the outside of the boll and the number of worms within the boll, as shown in Table 2. These facts point to a mortality of something like 90 per cent of the young larvæ before they enter the boll.

The mortality of the larvæ after the boll is once entered does not appear to be very high.

Data collected during 1921 on the transformation of the pink bollworm in the soil showed considerable mortality during this period. In a number of soil examinations separate records were kept of the findings in the soil immediately under the plants and those between the rows. For further explanation of this experiment see page 7. In other examinations the soil was divided into three 2-inch layers. The results of the former are given in Table 25.

TABLE 25.—*Mortality of the pink bollworm in the soil immediately under the plants and between the rows*

Date of examination	Under the plants			Between the rows		
	Larvæ and pupæ		Pupal cases	Larvæ and pupæ		Pupal cases
	Living	Dead		Living	Dead	
Aug. 19	7	12	41	3	8	44
Sept. 6	51	15	3	0	9	2
25	10	3	5	2	2	2
Oct. 18	0	0	33	2	0	8
29	2	0	7	3	2	5
Total	70	30	89	10	21	61
Total, all stages	189			92		
Percentage dead			15.9			22.8

A higher mortality among the larvæ and pupæ between the rows than among those immediately under the rows is noted.

Table 26 shows the relative mortality among pink bollworms at different depths in the soil. The mortality is greatest in the first 2 inches of soil, decreasing with the depth. An average for all depths in this table gives 19.7 per cent mortality.

TABLE 26.—*Mortality of the pink bollworm at different depths in the soil*

Date of examination (1921)	First 2 inches			Second 2 inches			Third 2 inches		
	Larvæ and pupæ		Pupal cases	Larvæ and pupæ		Pupal cases	Larvæ and pupæ		Pupal cases
	Living	Dead		Living	Dead		Living	Dead	
July 21	5	8	0	0	0	0	No examination.		
Aug. 4	70	18	13	16	5	2	2	1	0
19	3	17	45	5	3	25	2	0	15
Sept. 6	31	17	2	12	5	3	8	2	0
25	11	3	6	-------	-------	-------	1	2	1
Oct. 18	2	0	39	0	0	2	0	0	0
29	4	2	9	1	0	3	0	0	0
Total	126	65	114	34	13	35	13	5	16
Total, all stages	305			82			34		
Percentage dead	21.3			15.8			14.7		

MORTALITY OF LARVÆ IN THE RESTING STAGE

The pink bollworm larva passes its resting period in or about seed or seed cotton in gins and warehouses, in the bolls in the field, and in the soil. As the activity of the insect lessens in the fall, an increasing percentage of the larvæ spin up in the boll and assume the resting stage. This shows their normal preference for hibernating quarters. Larvæ that hibernate in the soil evidently do so because the boll in which they mature does not offer suitable quarters. It may either still be green when the larva is ready to make its cocoon, or it may have fallen to the ground, where the sun's heat becomes so excessive that the larva enters the soil.

MORTALITY OF LARVÆ IN BOLLS AND SEED IN STORAGE

One hundred bolls collected from standing stalks in the field on March 9, 1921, showed a total of 109 living larvæ and 15 dead ones. Bolls in storage furnish equally as good quarters for the resting larvæ. Of the larvæ in bolls that had been collected from the fields in the middle of November, 1921, and stored, 10 per cent were dead in March, 1922, and in others that were collected early in December, 1922, 7 per cent were dead on February 7, 1923. Usually the larvæ in seed or bolls in storage are attacked by mites, and mortality from this cause rises very rapidly in the spring.

Tables 12 and 13 give records of larvæ in stored seed and bolls of the 1920 and 1921 crops. According to these data, the larvæ survive longer in bolls than in the seed. As all this material was stored under the same conditions in the laboratory, the most likely explanation for the difference is that larvæ in loose seed are more accessible to mites than those in the bolls. The more rapid decrease of the percentage of living larvæ in the bolls of the 1921 crop than in those of 1920 may be explained in a similar way. The former were stored about four months earlier in the season than the latter and were therefore longer subjected to the attack of mites.

MORTALITY OF RESTING LARVÆ IN THE FIELD

An experiment is now under way which will give data on the mortality of resting larvæ in the field in bolls, both on the stalks and on the soil, as well as in the soil. Data on this experiment are given in Tables 8 and 9. Figure 11 shows graphically the results of the experiments with the bolls on the surface of the soil as recorded

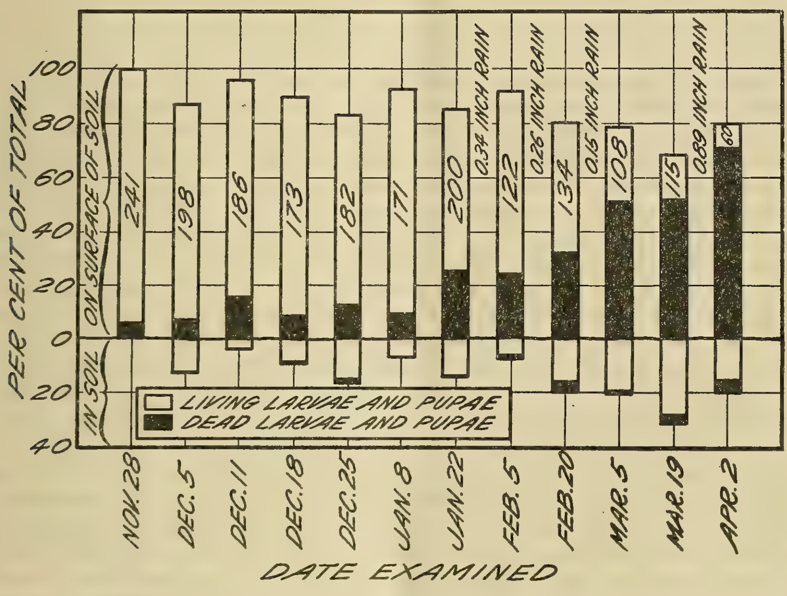


FIG. 11.—Comparative mortality of resting larvæ in bolls on the surface of the soil and of resting larvæ in the soil. Each bar represents the results of the examination of a separate lot of 100 bolls, that had been placed on the soil on November 28, and the soil underneath. The first examination shows the content of 100 bolls at the time they were placed on the soil but before any larvæ had left them to enter the soil

in Table 8, up to April 2. The rate of mortality is seen to be higher in the bolls than in the soil. This diagram does not take into consideration individuals that have emerged. This, however, appears not to have been great to the date of the last record, as will be observed in the record of pupal cases in Table 8. It would appear from this that larvæ left undisturbed in the soil during the resting period have a better chance of surviving than those in the bolls on the surface of the soil at the same time.

Another experiment, conducted in the winter of 1921–22, dealt primarily with the longevity of resting larvæ in seed and bolls on and in the soil of irrigated and unirrigated fields. The results of this experiment are discussed under "Irrigation" as a control method.

In Table 27 are given the percentages of the stages in the soil found to be dead during the winter and spring months in 1921 and 1922.

TABLE 27.—*Mortality of resting pink bollworms in the soil in the fields, 1921 and 1922*

Month	Percentage of mortality	
	1921–22	1922–23
November	10	38.9
December	26.6	22.8
January	24.2	26.4
February	34.9	26.1
March	41.4	33.1
April	29.5	--------
May	39.8	--------
June	60.0	--------
July	100	--------

These records are based entirely on actual field examinations, which explains their irregularity. In the first place there is an accumulation of dead larvæ and pupæ from the summer and fall. And as the larvæ assume the resting stage in the soil gradually, it is not possible to consider a certain percentage of the dead an accumulation of the summer stages and subtract this from all subsequent records. Again, a gradual decay of dead larvæ, which are consequently not found in the examinations, will make the figures for dead too low in the later examinations. Lastly, emergences of moths have not been considered at all in these figures, because pupal cases are to a great extent destroyed in preparing the soil for examination. The records for 1922–23 are based on examinations of more soil than those for 1921–22. Also the soil all came from the same field, which was not the case in 1921–22. Individual figures for the second season are therefore more comparable than for the first. The decrease in the percentage of dead for December, 1922, was due to the cutting of the cotton stalks at the end of November, which, as has been pointed out, caused the shedding of many bolls and a consequent issuance of many larvæ from these bolls and entrance into the soil. From data in Table 7, an increase is calculated in the average number of living larvæ and pupæ per square yard of soil from 6.4 for November to 18.6 for December.

The records in Table 27 give no indication of the total mortality during the resting period and the percentage of the larvæ that finally transform to the moth stage. In connection with an experiment on the effect of winter cultivation, some cages were placed in the field to catch moths emerging from the soil in the spring. This experiment is described in detail in this report, under "Winter plowing." A partly calculated record of an emergence of 2.2 moths per square yard from an uncultivated part of the field which averaged 14 living larvæ per square yard during March and April is given. This would show a mortality of about 84 per cent of the larvæ that pass the resting period in the soil.

PARASITES

In the spring of 1921 an experiment was started to determine whether daily picking of all infested blooms would reduce the pink bollworm infestation. A half-acre plat was selected for this test, and work was commenced June 17. After a few days a considerable mortality of the larvæ in the picked blooms was observed. This was found to be caused by parasites. Records were then kept of the parasitized larvæ also. The results of this test are shown in Figure 12.

The parasites more or less followed the course of the pink bollworm infestation at first, but afterward did not keep pace with its rapid increase.

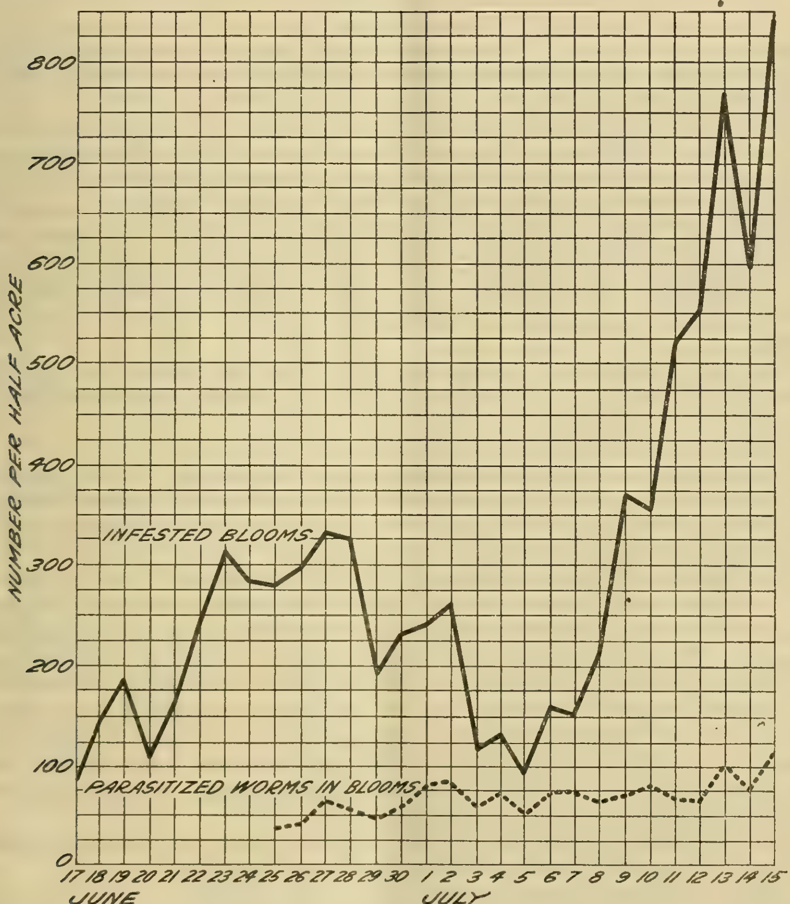


FIG. 12.—Parasitized larvæ in blooms and total blooms infested with the pink bollworm on a half-acre plat, 1921

The peak in blooming was reached on July 11. Regular counts were discontinued after July 15. On July 19 and August 2, two complete counts were made. In the first the maximum of 972 infested blooms and 114 parasites was reached. By August 2 the total number of blooms had dropped to 17 per cent of the maximum, with only 18 infested, and 3 parasitized larvæ. Few parasitized larvæ were found in blooms after this. Of 165 larvæ collected from infested blooms on October 1, none were found to be infested.

Two species of parasites were found to be common. These are *Microbracon mellitor* (Say) and *Habrobracon gelechiae* (Ashm.).

Their life history and habits were studied during the summer by A. C. Johnson and are here given briefly, so far as known.

Normally the female *M. mellitor* stings the pink bollworm larva while still in the square, paralyzing it, and deposits an egg on it. In all cases only a single egg was found on one larva. When placed in a cage the adult did not attack loose pink bollworm larvæ. The larva of the parasite feeds on the pink bollworm until nothing is left of the latter but a mass of dry skin.

The larval period of *M. mellitor* was found in the summer to be from 3½ to 4 days. The pupal period lasted 4 to 5 days. The adult of this species is apparently a nocturnal worker, as none were ever observed in the field in the daytime.

Habrobracon gelechiae is more common through the season than *M. mellitor*. In freshly opened blooms, larvæ of the pink bollworm attacked by this parasite were usually found paralyzed and with the eggs of the parasite on them. This indicates that the attack is made after the bloom opens, which appears likely also when we consider the short ovipositor of the adult. It is common to find 4 or 5 eggs on 1 larva, and as many as 10 have been observed. In some instances the adult attacked loose pink bollworm larvæ in cages.

The larval and pupal periods of *H. gelechiae* are about the same as those of *M. mellitor*. Many adults of the former were observed in the field in the daytime.

About two-thirds of all paralyzed pink bollworm larvæ found in blooms contained neither parasite eggs nor larvæ. It is possible that in such cases the eggs or larvæ were destroyed by other insects, or the adult of the parasite may often sting the pink bollworm without depositing eggs upon it.

On October 2, some clusters of cocoons and several living pupæ of *H. gelechiae* were found in dry blooms collected from the ground. Then 400 closed blooms from 2 to 5 days old were collected from plants. Ninety-seven of these were infested with pink bollworms, of which 10 were parasitized by *H. gelechiae*. About 2 per cent of the larvæ found in bolls in the fields in December, 1921, were parasitized by *H. gelechiae*. These observations show that *H. gelechiae* seems to prefer attacking larvæ in dry blooms and bolls in the fall to attacking them in fresh blooms. During 1921, *M. mellitor* was more abundant early in the season.

Several other species of parasites were reared from pink bollworm larvæ. These were rare and have not been identified.

General observations showed that the parasites were not so abundant in 1922 as in 1921. A few parasites apparently identical with *M. mellitor* were reared from malvaceous plants other than cotton in 1922, but what insects these parasites attacked was not determined. *H. gelechiae* was not observed emerging from these plants.

The more or less spasmodic attack of parasites on the pink bollworm observed in 1921 and 1922 indicates that under conditions existing in the Laguna district no appreciable control of the pest by parasites may be expected, even though a maximum of 33 per cent of the larvæ in blooms early in July, 1921, were parasitized. Climatic conditions are evidently much more favorable for the pink bollworm than for the parasites so far observed.

REPRESSION

CULTURAL CONTROL

The pink bollworm's habit of pupating in the soil during summer, and of passing the resting period there to some extent, suggests that considerable control may be expected from cultural methods designed to kill the larvæ and pupæ in the soil.

IRRIGATION

In the winter of 1921–22 F. F. Bibby conducted an experiment to show the effect of flooding on resting larvæ in the soil. Heavily infested bolls and double seed were placed in a garden under conditions as nearly as possible representing those normally found in the field. The material was arranged in plats part of which could be flooded. In these the seed and bolls were buried at several depths, one layer in the first inch of soil, another 3 inches beneath the surface, and a third 6 inches beneath the surface. A fourth layer was placed on the surface of the soil. The latter material floated when water was applied. One plat of each, bolls and seed, was flooded for a period of 18 days, another for 33 days, and a third for 64 days. Each plat was completely covered with water during this entire time. The floating bolls were kept in water for periods of 18 and 44 days and the seed for 17, 22, 33, and 56 days.

The data obtained in these experiments are summarized in Table 28. In preparing this table the average number of living larvæ found in the seed and bolls when the experiment was started was determined. This was considered as 100 per cent and the percentage of living larvæ and pupæ found in later examinations was calculated on this basis. Forty-seven days after flooding was discontinued on one of the 18-day plats 5 larvæ and pupæ were found loose in and on the surface.[12]

TABLE 28.—*Longevity of resting larvæ in bolls and seed in flooded and in dry fields*

Approximate date of examination	Time from beginning of treatment to examination	Larvæ surviving in bolls and seed				
		Buried from 1 to 6 inches in soil in field				Floating in water
		In dry plats	In plat flooded 18 days	In plat flooded 33 days	In plat flooded 64 days	
	Days	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dec. 26	0	100	100	100	100	100
Jan. 15	20					17.1
Feb. 4	40					.2
24	60		7.6			0
Mar. 6	70	50.9		1.2		
26	90				.06	
Apr. 5	100		4.8			
15	110	18.4				
May 24	149		1.5			
June 3	159	1.5		.4		

According to the data gathered in these experiments, the flooding of fields in fall and winter, as commonly practiced in the Laguna

[12] According to Willcocks, irrigation causes larvæ to leave bolls that are buried and seek the surface of the soil for pupation to a greater extent than they do in dry soil.

district (fig. 2, p. 3), whereby the fields remain under water for periods varying from one to two months and sometimes longer, will kill very nearly all the resting larvæ in the soil and in bolls on the surface. The flooding of heavily infested cotton fields just cleared, whenever it can be practiced, should materially retard the infestation in new cotton.

WINTER PLOWING

To determine the effect of winter plowing on resting larvæ in the soil, an experiment was conducted in 1922 in which plats in a field that was heavily infested with the pink bollworm late in the fall of 1921 were plowed in different ways. Five quarter-acre plats were laid off and the following treatments given:

Plat 1: Uncultivated.
Plat 2: Harrowed and cross-harrowed with disk harrow, March 9, 1922.
Plat 3: Plowed to a depth of about 6 inches, harrowed and cross-harrowed with disk harrow, March 9, 1922.
Plat 4: Plowed to a depth of 6 inches, March 9, 1922.
Plat 5: Zoca, soil thrown away from plants with two cultivator shovels, first week of April, 1922.

After this plowing, examinations of 1 square yard of soil to the depth of about 8 inches were made in each of these plats at intervals of about 20 weeks. Plat 5 was not included in the first examination, as it had not then been cultivated. The data obtained in this experiment are given in Table 29.

TABLE 29.—*Effect of different methods of plowing on the pink bollworm hibernating in the soil*

Date examined	Number of pink bollworms found per square yard of soil									
	Plat 1, check		Plat 2, harrowed		Plat 3, plowed and harrowed		Plat 4, plowed only		Plat 5, cultivated	
	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead
1922										
Mar. 22	10	5	4	11	3	6	16	11	No examination.	
Apr. 17	18	7	13	7	1	1	9	2	2	1
May 1	8	14	7	2	13	3	6	0	8	1
17	7	7	5	4	7	5	3	3	0	2
30	4	0	1	4	6	7	5	0	0	1
June 12	2	3	2	2	2	4	2	1	1	3
26	0	1	0	3	4	3	0	1	4	0
July 10	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	1	0	0	0	0
Aug. 8	0	0	0	0	0	0	0	1	0	0
Total	49	37	32	33	36	30	41	19	15	8
Average	4.9	3.7	3.2	3.3	3.6	3.0	4.1	1.9	1.67	.89
Percentage dead	--------	43.0	--------	50.77	--------	45.5	--------	31.7	--------	34.8

Considering only the total number of living individuals found per plat, there is a notable reduction in the plowed plats, especially the cultivated zoca. But the two harrowed plats show the highest percentage of dead individuals, and plat 4 is particularly low in this. Considering the individual examinations, the first one shows a very decided advantage for the two harrowed plats. Only 4 and 3 living specimens were found in these, compared with 10 in the uncultivated plat and 16 in the plat that was plowed only. However, some later examinations show up entirely differently. Thirteen living specimens were found in a square yard from plat 2 on April 17, and the same number in a square yard from plat 3 on May 1. It is evident that further experiments should be conducted.

In addition to the soil examination, three cages were placed on each plat (except plat 5) to catch any emerging moths. Each cage covered 1 square yard and had a trap arranged in the middle to catch emerging moths. Paper covers were placed on the cages at night, leaving only the traps exposed. It was thought that moths seeking light or free air would more readily enter the traps in this way. The cages were examined every second or third day with the following total results:

Plat 1. 2 moths, April 15.
2. 1 moth, April 15.
3. 0 moth.
4. 1 moth, April 30.

In August all these cages were removed and the surface of the soil under each one carefully examined for signs of any moths that might have emerged and not entered the traps. Only the following were found:

Plat 1. 1 dead pupa in cocoon on surface of ground, 1 pupal case under base of cage.
2. 1 pupal case under clod of earth.
3. 1 pupal case under clod of earth.
4. 1 pupal case under clod of earth.

The efficiency of the traps on the cages was tested. One cage was set up as it had been in the field, 20 moths were placed under it in the afternoon, and the paper cover was put on during the night. Only 6 of the 20 moths were found in the trap on the morning following. This indicates that probably only 30 per cent of the moths that emerged under the cages in the field were caught in the traps.

One striking point brought out is the difference between the number of moths that emerged and the number of living larvæ found in the soil. Table 29 gives an average for the first two examinations in plat 1 of 14 living larvæ per square yard. On this plat, in 2 cages, covering a total area of 3 square yards, only 2 moths were caught. If this was 30 per cent of the moths that actually emerged under the cages, there was a total of 6.67 moths, or an average of about 2.2 moths, emerging per square yard.

EMERGENCE OF ADULTS THROUGH SOIL

An experiment was conducted in the spring of 1922 to determine the depth of soil through which a moth can emerge. Two sets of sheet-iron cylinders were made. These were 5 inches in diameter and closed at the bottom and ranged in depth from 4 to 20 inches. Larvæ in cocoons from the soil and in cottonseeds were placed in the bottoms of the cylinders and covered with soil to different depths (see Table 30). The cylinders were taken to the field and sunk in an upright position in the ground so as to leave the surface of the soil in the cylinder on a level with the surface of the soil on the outside. Screen-wire traps were made to fit the tops of the cylinders, so that any emerging moths might be caught.

These cylinders were kept under observation throughout the summer and in October the soil was removed from them and carefully examined. Table 30 shows the results of this experiment.

TABLE 30.—*Emergences of moths and larvæ buried at different depths in soil in cylinders*

Larvæ buried		Emerged during summer			Found in soil (dead)		
Depth	Number	Larvæ	Pupæ	Moths	Larvæ	Pupæ	Pupal cases
Inches							
4	74	2	----------	1	17	3	4
8	74	----------	----------	----------	15	2	3
12	74	4	----------	----------	6	----------	1
16	74	1	1	----------	8	----------	4
20	73	3	----------	1	15	1	6

The larvæ recorded under "Emerged during summer" were found in the traps, evidently having issued from the soil and entered the screen-wire traps in searching for a place to pupate or trying to escape from the cylinders. This also accounts for the one that entered and later pupated. These larvæ and the pupa were all dead when found, having evidently been killed in the traps by the heat of the sun. The adult taken from the cylinder in which the larvæ were buried at the depth of 4 inches was alive and perfectly developed. The other adult was imperfectly developed and had been partly eaten by ants when found.

Considering the number of larvæ that were found to have issued from the soil, the most reasonable explanation of the emergence of the moths is that the larvæ first came to the surface, or near the surface, and then pupated. This explanation is much more reasonable than that a moth could issue from any great depth of soil unless it were of such nature that the moth would not have to burrow its way out. The experiment plainly shows that the pink bollworm, at least in the larva stage, can escape even if buried to a considerable depth by cultivation.

SUMMER CULTIVATION

It was shown in Tables 25 and 26 that during the summer the natural mortality of the pink bollworm in the soil is greater for individuals found between the rows than for those found immediately under the plants and that the mortality decreases with depth. This suggested that the heat of the sun might be responsible for the increased mortality, since larvæ between the rows, particularly near the surface, are more exposed to this heat. A few experiments were conducted to determine whether this is true.

Temperature readings were taken on several days in September, 1921, on the surface of the soil and 1 and 2 inches below the surface during the hottest part of the day. These readings are recorded in Table 31.

TABLE 31.—*Temperature, in degrees Fahrenheit, on surface of, and in, soil between cotton rows in the field*

Date	Hour	Surface	1 inch beneath surface	2 inches beneath surface	Maximum air temperature
1921		° F	° F	° F	° F
Sept. 13	12.30 p.m.	142	124	113	
	2.30 p.m.	141	123	112	95
	4.30 p.m.	123	116	108	
Sept. 14	10.00 a.m.	128	101	92	
	12.30 p.m.	146	115	106	96
	2.30 p.m.	138	124	111	
	4.30 p.m.	114	112	110	
Sept. 15	10.30 a.m.	128	102	94	
	12.30 p.m.	141	114	102	92
	2.30 p.m.	130	112	102	

A temperature sufficient to kill the pink bollworm in a very short time is reached on the surface of the soil, and the soil, even as deep as 1 inch below the surface, becomes hot enough on some days to kill in time. All these readings were taken between the cotton rows, where the soil was exposed to the direct rays of the sun.

Early in the morning of September 14, infested blooms were placed in and on the surface of the soil in direct sunlight and in the shade of cotton plants. These blooms had been collected from plants and allowed to dry several days in the laboratory. Ten blooms, each containing a living larva, were used in each experiment. Late in the afternoon the blooms were removed and examined. The results are given in Table 32.

TABLE 32.—*Effect of solar heat on pink bollworm larvæ in blooms in and on the surface of soil in sunlight and in shade*

Location	Sunlight	Shade
On surface	10 dead larvæ	4 live larvæ, 6 empty blooms.
2 inches beneath surface	6 live larvæ, 4 empty blooms	7 live larvæ, 3 empty blooms.
4 inches beneath surface	5 live larvæ, 5 empty blooms	2 live larvæ, 8 empty blooms.

All larvæ on the surface in the sun were killed. All larvæ in the other locations either lived or left the blooms. The maximum air temperature on this day was 96° F.

A similar experiment was conducted a few days later with pupæ in blooms. After exposure the pupæ were removed and placed in vials so that emergences of moths could be noted. The results are given in Table 33.

TABLE 33.—*Effect of solar heaton pupæ in shed blooms in and on the surface of the soil in sunlight and in shade*

Location	Sunlight		Shade	
	Total pupæ	Moths emerged	Total pupæ	Moths emerged
On the surface	14	0	14	9
2 inches beneath the surface	13	10	Test omitted.	
4 inches beneath the surface	12	11	Test omitted.	

If the pink bollworm normally remained in the blooms until they were shed, a considerable number of those in blooms falling between the rows should be killed by the heat of the sun. On September 26 some blooms containing larvæ were tagged for observation, to ascertain whether the larvæ remain in the blooms until they are shed. Some of these blooms were removed from the plants each day and examined, with results as follows:

Sept. 27. 20 blooms removed, 19 contained larvæ.
28. 20 blooms removed, 16 contained larvæ.
29. 20 blooms removed, 9 contained larvæ.
30. 18 blooms removed, 4 contained larvæ.

This shows that normally the majority of the larvæ leave the blooms before they are shed. Thus they may have a better opportunity to seek suitable shelter in the shade of the plants than they would have if they remained in the blooms until they are shed.

It would appear from the results of the foregoing tests that a method of cultivation during the summer in which the top layer of soil is thrown away from the plants might materially increase the mortality in the soil by exposing larvæ and pupæ to the sun. An experiment aimed at this point was conducted during the summer of 1922. Four plats of about 12 acres each were laid off and numbered. Plats 1 and 4 were checks, and plats 2 and 3 were cultivated every 6 days, plat 2 on 1 day and plat 3 on the following day. Cultivators with shovels set so as to throw the soil away from the plants were used. This work was continued from August 4 and 5 to September 14 and 15, a total of 8 cultivations being given each of the plats. When this experiment was begun, regular cultivation had been discontinued, so plats 1 and 4 received no cultivation whatever during this period. A 6-day interval was used between cultivations. This is the minimum pupal period at this time of the year, according to Loftin [13] and the purpose was to stir the soil at least once during the time each individual is in the pupa stage. The pupa would not be able to move about to any extent if exposed to the sun by the cultivator.

A square yard of soil from each plat was examined weekly and a sample of bolls from 2 points per plat every 10 days. The results of these examinations are given in Tables 34 and 35.

Table 34.—*Effect of summer cultivation on the pink bollworm in the soil*

[Living and dead larvæ and pupæ and pupa cases in 2 square yards of soil]

Date of examination	Plats 2 and 3 (cultivated)			Plats 1 and 4 (check)		
	Living	Dead	Pupal cases	Living	Dead	Pupal cases
Aug. 8		1		1		
15		3		1		
22	3	7	1	9	16	
29	18	12		14	10	3
Sept. 5	5	11	1	10	19	4
12	15	20	4	19	24	7
21	7	5	3	3	2	1
Total	48	59	9	57	71	15
Total		116			143	
Percentage dead			50.9			49.6

[13] U. C. Loftin, K. B. McKinney, and W. K. Hanson. Op. cit.

TABLE 35.—*Average number of worms per green boll in cultivated and check plats*

Date of examination	Plats 2 and 3 (cultivated)	Plats 1 and 4 (check)
Aug. 6	0.35	0.19
16	.65	.60
26	2.94	3.58
Sept. 5	5.35	5.86
15	5.86	6.18
25	6.05	6.47
Average	3.53	3.81

Although fewer living larvæ were found in the cultivated than in the check plats, there were also fewer dead ones. The proportion of living to dead was about the same in the two cases.

HEAVY WINTER KILLING IN WET SOILS

Earlier in this bulletin attention was directed to the fact that the survival of larvæ in the soil decreases as the amount of moisture increases. In unirrigated plats 12.8 per cent of the larvæ were alive or had emerged as moths during May and June, while in several irrigated plats no larvæ whatever survived the winter. This heavy mortality in wet or soaked soils during the winter indicates perhaps one of the most important possibilities of control of this pest wherever, through irrigation or the occurrence of winter rains, the soil becomes and remains for considerable periods thoroughly moistened. Under such conditions it seems probable that all of the pink bollworm larvæ entering the soil for hibernation will be killed. On the other hand, it is known that the larvæ in cotton bolls, either on standing plants or on the surface of the ground, survive the winter in large percentages. Such opportunity of carriage of the pest over winter can be very largely eliminated by thorough cleaning in the fields of all cotton plants, scattered bolls, or other rubbish, and the burning of such material. It would appear, therefore, that under the moisture conditions indicated and the thorough cleaning, a method of effective control will be available for irrigated districts and others where the winter rains are adequate to hold the soil fairly moistened for a considerable period. Undoubtedly, the effectiveness of the clean-up measures which have been carried out in the United States in the effort to eradicate the pink bollworm has been due quite as much to the mortality of the larvæ in wet soil as to the thorough collection and destruction by burning of all old plants and scattered bolls. This is particularly true in southeastern Texas and in Louisiana, where the winter rains are heavy.

EFFICACY OF CLEAN-UP METHODS

In the winter of 1922–23 an experiment was conducted to determine approximately what proportion of the resting larvæ in the field are destroyed by cutting and burning the stalks. As pointed out in the discussion of hibernation habits (Tables 7 and 8), many larvæ leave the bolls and enter the soil when the stalks are cut.

A field that was heavily infested late in the fall was selected and on November 23, 2 square yards of soil to a depth of 6 inches were examined at each of five different points. An average of 5.2 living larvæ per square yard were found in this soil. At the same time all bolls on the stalks growing on these 10 square yards of soil were removed and examined. There was a total of 122 dry and 50 green bolls, an average of 17.2 bolls per square yard, and these contained a total of 397 living larvæ (first and second instars not included), or an average of 39.7 per square yard.

At near-by points in this field two areas of 50 square yards each were staked off on November 25 and the bolls both on the plants and on the ground were counted. On November 28 and 29 the stalks were cut, and on December 1 they were raked up. On the following day the bolls on the surface of the ground in the same areas were again counted. The results are shown in Table 36.

TABLE 36.—*Number of bolls on stalks and on the ground on an area of 100 square yards, before and after cutting stalks*

Bolls	Before cutting stalks		After cutting stalks		Percentage shed in cutting
	On stalks	On ground	On stalks	On ground	
Green bolls	108	3	[1] 77	34	28.7
Open bolls	986	190	[1] 443	733	55.1
Total	1,094	193	[1] 520	767	52.5
Per cent of total on the ground		15.00		59.6	

[1] Calculated.

This shows that nearly 60 per cent of all the bolls were left on the ground after the fields were cleaned, and that 28.7 per cent of the green bolls and 55.1 per cent of the open bolls on the stalks were shed in cutting the stalks. Using the percentage of 15 for bolls on the ground before cutting and the figure of 17.2 bolls on stalks per square yard already mentioned, at the time the soil examination was made on November 23 there were on an average 3 bolls per square yard on the surface of the soil at the points where these examinations were made. On November 25, 100 bolls collected from the surface of the soil showed an average of 2.12 living larvæ per boll, which would make an average of 6.36 living larvæ in bolls on the surface of every square yard of soil. On each of December 2 and 5,100 bolls were collected from the surface of the soil and examined, giving an average of 1.41 living larvæ per boll. And on December 5 another square yard of soil was examined at each of the 5 points where examinations were made before, giving an average of 21.6 living larvæ per square yard in the soil. Then using the figures obtained in these two soil examinations and the percentages given in Table 36, the distribution of larvæ before and after the stalks were cut can be calculated. This calculation is summarized in Table 37.

TABLE 37.—*Distribution of bolls and larvæ before and one week after cutting of stalks in field*

[Number per square yard]

	Before cutting stalks			After removing stalks		
	On stalks	On surface	In soil	Removed with stalks	On surface	In soil
Bolls	17.2	3		[1] 8.2	12	
Larvæ	39.7	6.36	5.2	12.76	16.9	21.6
Per cent of total larvæ	77.5	12.4	10.1	24.9	33	42.1

[1] Difference between total of last two columns and total of first three.

Although this summary is a calculation based on several separate observations and must be considered as only approximate, it should be fairly reliable. The figure of 12.76 larvæ removed in 8.2 bolls gives an average of 1.56 larvæ per boll. Usually the larger and better-matured bolls remain on the stalks, and a higher worm content is found in them than in those that are shed. It seems safe to say, however, that in this field not more than from one-fourth to one-third of the total larvæ were destroyed by cutting and burning the stalks. The stalks were cut by hand and raked up with a hay rake. Afterward they were burned.

Soil examinations at the same five points in this field were continued weekly, and at each time 100 bolls were collected from the surface for examination. Table 38 summarizes the results of these examinations, including only those made after the stalks had been cut.

TABLE 38.—*Average number of living and dead larvæ per square yard in the soil and per boll in bolls on the soil after removal of stalks*

Date	Per boll on the surface		Per square yard in the soil		
	Living	Dead	Total living	Total dead	Living in bolls and locks in the soil (average)
Dec. 2	1.3	0.10			
5	1.54	.15	21.6	4.1	
13	1.18	.38	20.4	3.6	1.86
20	1.58	.27	11.4	3.6	
27	.82	.14	20.6	3.8	
Jan. 3	.72	.21	15.0	3.4	
10	.62	.15	16.2	3.0	1.4
17	.52	.18	13.2	4.8	
24	.51	.19	15.8	3.4	
Feb. 1	.30	.18	9.8	5.2	
7	.23	.15	14.4	2.2	
14			11.4	2.8	
21			9.2	4.8	
28			13.0	1.4	
Mar. 7			6.4	1.6	
14			12.6	7.2	
21			9.2	4.0	
28			5.4	3.2	
Apr. 4			5.6	2.6	
11			4.4	4.0	

These data show particularly the effect of pasturing after the stalks were cut. Between December 20 and 27, a herd of cattle was pastured in this field for a number of days. These cattle ate a considerable part of the bolls left on the surface of the soil. They picked up practically all the larger bolls, the sudden decrease in the number of larvæ found per boll on December 27 being due to the removal of the larger bolls, which contained the greater number of larvæ. Apparently there was no increase, or very little, in the number of larvæ in the soil to offset the decrease in living larvæ in bolls on the surface. The figures in the last column, giving the average number of the larvæ in the soil that are found within locks or open bolls, before and after pasturing, show that there can not have been much trampling of bolls into the soil by the cattle.

Early cleaning of fields in the fall, before a great part of the late unpickable bolls open, is recommended. In this way the number of bolls shed would be reduced. Grazing after cutting the stalks should be practiced, if possible, and it is possible that grazing before the stalks are cut is even more beneficial. If the stalks are not cut until all bolls are dry and open, it may even be advantageous to delay cutting until after cold weather has set in and the larvæ have spun up more completely. Then possibly there might not be any appreciable issuance of larvæ from shed bolls and entrance into the soil, and consequent pasturing would destroy a great part of the larvæ in the shed bolls.

TREATMENT OF SEED BY HEAT

Machines for killing the pink bollworm in seed by heat have been in use in Egypt for some years. The Egyptian seed is practically lintless, whereas that produced in Mexico and the United States is covered with lint. For this and other reasons it was necessary to devote considerable attention to methods of treating seed.

Laboratory tests were made to determine the amount of heat required to kill the pink bollworm in cottonseed, and the amount of heat to which seed may be exposed without injury. The latter point was determined by tests conducted by the Federal Horticultural Board at College Station, Tex., where laboratory facilities for this work were furnished by the college. These tests were conducted in February, 1921, with Texas seed. A Freas electric oven was used.

THERMAL DEATH POINT

The tests on the thermal death point were conducted at Tlahualilo, using a Freas oven also. At first several series of tests were conducted in which larvæ in double cottonseed were used. The procedure followed was to bring the oven to the desired temperature, which was maintained by thermostatic control. The seed, arranged in a single layer on a sheet of perforated cardboard, was then introduced. All larvæ upon removal from the seed were placed in pill boxes and kept under observation for several days. One hundred double seed were used in each test.

In one series of tests the seed was heated in dry air, that is, the normal air in the oven. In another series dishes containing water were placed in the oven. Evaporation from this water brought about a moist condition of the air.

The results of these tests are summarized in Table 39. All the tests with dry heat giving 100 per cent mortality, except those from 145° F. down, were repeated three or four times.

TABLE 39.—*Thermal death point of pink bollworm larvæ in double seed exposed to heat in Freas oven, with margin of safety for seed*

Period of exposure	Temperature required to cause 100 per cent mortality		Maximum temperature to which seed may be heated without injury to germination	
	Dry air	Moist air	Dry air	Moist air
Minutes	° *F.*	° *F.*	° *F.*	° *F.*
5	195	160	----------	----------
10	170	145	----------	----------
15	----------	----------	175	170
20	145	135	----------	----------
30	140	130	165	170
45	135	125	----------	----------
60	130	----------	160	160

In the tests with the larvæ in seed more heat was required than Willcocks[14] found necessary in his experiments. With dry air he found a 30-minute exposure at a temperature ranging from 121 to 129° F. to give 100 per cent mortality, and with moist air an exposure for 4 minutes at 159.8°. This difference is probably due to the fact that Egyptian seed is practically devoid of lint.

Following the tests that are given in Table 39, a series of experiments with unprotected larvæ was conducted in the Freas oven. These experiments differed further from the others in the fact that the larvæ were placed in the oven at approximately air temperature, and the temperature afterward raised. Two devices were finally decided upon as giving the most accurate results. The first was to place the larvæ in a cylindrical screen cage with a cardboard floor in the center, on which the larvæ rested. A thermometer was inserted centrally through this cylinder with the bulb partly above and partly below the cardboard floor. This cage with thermometer in position was hung in the oven and kept swinging like a pendulum until the desired temperature was reached. Then it was removed and the larvæ immediately cooled. In the second device the larvæ were placed in a shallow perforated blotter tray in the bottom of which a thermometer rested. The tray was set in the oven and the temperature raised until the desired point was reached. Then the tray was removed and the larvæ immediately cooled. The results of the tests conducted in these two ways are given in Tables 40 and 41.

[14] F. C. Willcocks. Op. cit.

TABLE 40.—*Thermal death point of unprotected pink bollworm larvæ exposed in swinging cage in Freas oven*

Number of larvæ exposed	Cage temperature at start	Time of exposure	Cage temperature at end	Mortality
	°*F.*	*Minutes*	°*F*	*Per cent*
10	88	13¾	135	60
8	80	11½	135	62.5
10	85	6¼	135	50
10	77	15¼	140	100
10	81	14½	140	100
10	80	13¾	140	100
10	82	10	140	100
10	82	9¾	140	100
10	83	9	140	100
10	84	8	140	100
5	81	7¼	140	100
10	80	7¼	140	100
10	83	7	140	100
10	82	7	140	100
10	86	6¾	140	100
10	83	7	140	100
10	84	6¼	140	100
10	82	6½	141	100
8	82	19	145	100
10	92	10¼	145	100
10	87	7¾	145	100
10	85	6¾	145	100
10	84	6	145	100
10	79	18½	150	100
10	84	7½	150	100
10	84	5½	150	100

TABLE 41.—*Thermal death point of unprotected pink bollworm larvæ exposed in blotter tray in Freas oven*

Number of larvæ exposed	Temperature in tray at start	Time of exposure	Temperature in tray at end	Mortality
	° *F.*	*Minutes*	° *F.*	*Per cent*
8	81	16½	135	87.5
7	91	13½	135	100
9	101	8½	136	100
8	81	18¾	140	100
10	90	12¼	140	100
7	100	11¾	140	100
8	99	10¼	100	100
8	100	8½	140	100
11	101	8½	140	100
10	102	8¼	140	100
8	102	8¼	140	100
9	100	8	140	100
9	90	12¾	142	100
10	99	9½	142	100

The air in the oven during all these experiments was dry. The thermal death point as indicated by these tests is 140° F., or between 135 and 140° for the conditions under which these tests were made. The results agree closely with those of Willcocks.[15]

COMMERCIAL DISINFECTING MACHINES

From the writer's experiments it appeared that the heating of cottonseed to a temperature sufficient to kill the pink bollworms contained therein and at the same time not to injure the seed, would be comparatively simple. The main difficulty in perfecting a com-

[15] F. C. Willcocks. Op. cit.

mercial machine was to obtain capacity equal to the output of an average gin and still to maintain the machine on an economical and effective basis. This matter was taken up actively by R. E. McDonald, of the Texas Department of Agriculture, and owing to his efforts rapid progress has been made in developing satisfactory machines.

Machines developed in the United States may be grouped in two general classes according to the principles on which they operate. In the machines of one group the seed is heated by hot air and to some extent by contact with heated parts of the machine. Machines of the other group inject live steam into the seed mass itself. Tests were conducted with one machine of each group at Tlahualilo, in 1922.

DRY HEAT PROCESS

In January, 1922, the Texas Department of Agriculture sent a machine of the dry-heat type to Tlahualilo and tested it there. This machine consisted of a large drum containing a group of steam pipes, all fixed on a central axle. It is set at a slight angle, and on operation the entire machine, drum and pipes, revolves. Flanges on the inside of the drum carry the seed up and drop it between the steam pipes. The seed moves forward through the drum on account of the tilt of the machine. As a result of exhaustive tests, McDonald and Scholl [16] reached the following conclusion: "Our tests indicate that cottonseed uniformly exposed to dry heat for three and one-half minutes and discharged at 145° F. will be rendered free of living pink bollworms." They found further, from numerous experiments detailed in their report, that injury to germination begins at a certain temperature which is somewhere near 165° F.

It should be mentioned that tests with commercial machines and laboratory tests in an electric oven do not give data directly comparable. In the practical operation of a disinfecting machine, the machine temperature will necessarily vary according to the temperature of the seed before treatment and the quantity of seed that passes through the machine at any one time, the object of course being to heat all the seed to a required temperature. Consequently the temperature of the seed on discharge must be used as the basis in the data obtained. With the laboratory tests, an oven in which constant temperature could be maintained was used, and the quantity of seed in any one test was so small that no accurate discharge temperatures were obtainable. Therefore, in these tests the oven temperature forms the basis of comparison.

The Texas Department of Agriculture left its machine at Tlahualilo when its tests were completed. Later, to reinforce the data, the writer independently conducted similar tests with the same machine.

In these tests seed taken directly from a seed house was used. It was fed into the hopper by hand. Irregularity in feeding is partly responsible for the irregular discharge temperatures obtained and the differences in steam pressure required to bring the seed to a certain temperature. A sample of from 1 to 2 bushels per test was caught as it came out of the machine and spread immediately on a wire screen, so that it cooled as quickly as possible. After cooling, all

[16] R. E. McDonald, and G. J. Scholl. Disinfecting cotton seed to prevent the spread of the pink bollworm. Texas Dept. Agr. Bul. 71, pp. 38, illus. 1922.

double seed and locks of cotton were picked out of this sample and examined for pink bollworms. The larvæ found were removed from the seed and kept in pill boxes for a time to make certain that none revived.

Results of one set of tests are given in Table 42.

TABLE 42.—*Tests conducted with a dry heat disinfecting machine for destruction of the pink bollworm in cottonseed*

[Time of exposure ranging from 2⅓ minutes to 6¾ minutes]

Test No.	Steam pressure	Time of exposure	Number of larvæ in test	Temperature of seed on discharge	Mortality	Germination
	Pounds	*Minutes*		*° F.*	*Per cent*	*Per cent*
212	8–4	2½–6	25	141 –136	100	----------
237	16–15	3 –6	34	138 –137	91.2	----------
216	15–11	2½–5½	29	142.5–138	93.1	----------
207	20–30	2¾–6	21	141 –138.5	90.5	----------
214	21–23	3 –6	25	141 –139	100	----------
233	11– 9	3 –6	26	139.5–139.5	100	----------
234	15–21	2¾–6	16	139.5–153	100	----------
217	20–20	3 –6	22	140 –140	86.4	----------
238	22–21	3 –6¼	29	143.5–140	100	----------
243	20–21	3 –6½	25	140.5–141	96	----------
218	20–21	3 –6	21	141 –144.5	100	----------
244	22–22	3 –6½	24	143 –142.5	100	----------
220	20–18	3 –6	27	143 –143	100	----------
242	18–18	2¾–6½	23	144 –143	100	----------
221	27–25	2½–6	26	146.5–143	100	----------
231	15–17	2½–6¼	23	143 –148	100	----------
229	14–17	2½–6	27	143 –153	100	----------
215	20–19	2¾–6	28	147.5–143.5	100	----------
211	24–22	2¾–6	25	148.5–144	100	----------
219	20–35	3 –5½	25	144 –149	100	----------
213	18–16	2½–6	22	146 –145	100	75.5
240	25–27	3 –6½	27	145 –146.5	100	75.0
236	15–21	2¾–5¾	33	145 –156	100	70.5
239	25–25	3¼–6¾	37	146 –145.5	100	81.0
222	26–26	3 –6	28	148 –145.5	100	71.0
245	22–22	3¼–6¾	30	146 –147	100	80.5
230	20–20	2¾–6	27	148.5–153	100	70.0
226	35–33	2⅓–6⅓	19	151 –149.5	100	73.5
210	25	2¾–6	26	150 –150	100	----------
232	18–18	2¾–6¼	30	150 –151	100	64.0
241	24–25	3 –6½	18	155.5–150.5	100	82.0
228	20–21	2½–6¼	21	150.5–158	100	61.5
209	35–30	3 –6	24	153 –151	100	----------
223	40–41	2½–6	12	154 –151.5	100	71.5
235	33–48	3¼–6¼	20	152.5–169	100	73.5
208	40	2½–6	31	153 –154	100	----------
227	32–33	2¾–6¼	19	156.5–158	100	72.5
224	63–59	3 –6½	28	161.5–163	100	68.0
225	44–40	3 –6	27	163 –166	100	----------
Average						72.6
Average 6 untreated checks						74.8

Steam pressure readings were taken at the beginning and at the end of each test. The difference between the two readings which usually occurred can be ascribed to difference in boiler pressure. The greater pressure required in some tests than in others, though the same discharge temperatures were obtained, was due either to difference in feeding or to absorption of heat by the machine, which usually took place for some time after steam was first applied each day. The time of exposure was ascertained by dropping a handful of colored seed into the hopper while the machine was in operation. The time required for the first and the last of these seed to pass through gave the two readings. Both extremes represent only single scattered seeds, the majority coming out within a period of about one minute. In the column "Number of larvæ in test" are included only larvæ that were alive before the seed was treated. Temperature records were obtained by catching one bucket of seed immediately before and one immediately after the sample for examination was taken, and determining the temperature of the seed in these buckets. The difference between the two temperatures in most of the tests can likewise be ascribed to differences in feeding and to variations in steam pressure. The temperature readings should more or less represent the minimum and maximum for each sample examined.

Next, a series of tests was conducted in which the period of exposure was decreased by lowering the discharge end of the machine. Otherwise the method of operation was identical with that in the first set of tests. The results are given in Table 43.

TABLE 43.—*Tests conducted with a dry-heat disinfecting machine for destruction of the pink bollworm in cotton seed*

[Time of exposure ranging from 1 minute to 3½ minutes]

Test No.	Steam pressure	Time of exposure	Number of larvæ in test	Temperature of seed on discharge	Mortality
	Pounds	*Minutes*		*Degrees F.*	*Per cent*
256	33–36	1¼–2½	(1)	130 –132.5	(1)
255	37	1¼–2¼	17	139 –138	70.6
257	39–39	1¼–2½	20	141 –140.5	100
252	26–26	1¼–3½	19	141.5–144	100
258	47–45	1¼–2¼	26	146.5–143	96.1
254	40–38	1 –2½	14	148 –143.5	100
259	49–48	1¼–2¼	36	148 –145	100
253	35–37	1 –2½	32	147 –151	100

1 No examination.

The result shown in these two tables tends to substantiate the conclusion, drawn by McDonald and Scholl,[17] that seed exposed to dry heat so that it attains a temperature of 145° F. in a period of 3½ minutes is effectively disinfected.[18] That 100 per cent mortality is not obtained by shorter exposures, even though a temperature of 145° is recorded, is no doubt due to the fact that the interior of individual seeds, when immediately cooled, does not attain the temperature recorded by the seed if bulked for a short time after exposure.

LIVE-STEAM PROCESS

The type of machine just discussed, although found to be effective, heats the seed rather slowly. Also, a machine of greater capacity was desired to meet the needs of large gins [19] where the installation of machines of the first type with proper capacity would be an expensive item. To meet these requirements a machine was developed in which the seed is heated by injecting live steam into the seed mass. Much more rapid heating is brought about in this manner. A machine of this type was sent to Tlahualilo and tested by J. C. Woodward.

The machine consisted of three inclosed 10-inch screw conveyors. The seed is fed into one end of the top conveyor and is discharged at the opposite end of the bottom conveyor. Immediately underneath each conveyor is a partly inclosed steam pipe. In the upper side of this pipe are a number of small perforations through which

[17] R. E. McDonald, and G. J. Scholl. Op. cit.

[18] In experiment No. 258, a temperature of 145° F. was reached, but the mortality was less than 100 per cent. It will be noted, however, that the exposure was only 2¼ minutes.

[19] Later experiments have shown that the capacity of the machine can be increased indefinitely by increasing its size.

steam is injected directly into the moving seed mass in the conveyor. A regulating valve controls the quantity of steam passing into the conveyors, and other valves serve to cut off the steam from any of the conveyors altogether, if desired. A thermometer with the bulb fixed near the discharge end of the machine records the temperature of the seed as it passes out of the machine.

In testing this machine it was learned that the seed is very unevenly heated while passing over the perforated pipes. Some seeds are hit directly by a jet of steam; others pass entirely through the conveyor without being hit directly. But at the same time the vapor is thoroughly mixed with the seed. When the seed is run directly from a heated conveyor into a sack, the temperature immediately rises very high, but soon drops again. The first high reading evidently is due to the vapor and the hot outside walls of the seed. When the seed is left in bulk for a short time, this heat penetrates to the inside of the individual seeds, causing a lower but more even temperature throughout the seed mass, and a consequent falling of the temperature. If this is true, it explains the fact that treatment in a single conveyor, even though giving a temperature in a sacked sample high enough to kill the pink bollworm, fails to kill if the seed is immediately cooled.

A number of series of tests were conducted with this machine operated at different speeds and steam pressures, and with steam injected into different conveyors. The procedure followed was similar to that with the dry-heat machine. The machine was fed by hand. Samples for examination were caught on a screen and immediately cooled, the double seed picked out and examined. Between each two samples for examination, a sample for temperature readings was taken. Thus in the records, with a few exceptions, two temperatures are given for each test, as in the tests with the other machine.

The results of these tests are given in Table 44.

TABLE 44.—*Results of treatment of cottonseed in live-steam disinfecting machine*

SERIES 1

[Speed of machine, 42 revolutions per minute. Time of exposure, 1 minute 5 seconds. Steam admitted into two upper conveyors only]

Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed	Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed
		°*F.*	*Per cent*			°*F.*	*Per cent*
18	6	136 –141	100	45	56	145 –149	100
47	65	143 –137	100	42	69	146 –145½	100
41	10	140 –138	80	34	42	151 –145½	100
19	7	141 –140	100	11	14	146	100
40	17	144½–140	100	23	22	148	100
37	11	141 –143	100	25	55	148	100
44	44	141 –145	100	22	20	150 –148	100
36	13	145 –141	100	13	6	148½	100
43	47	145½–141	100	21	16	149 –150	100
15	7	145½–141½	100	12	4	150	100
16	5	141½–146	100	24	54	150	100
14	8	142	100	28	54	150 –152	100
48	43	142½	[1] 97.6	27	41	154 –150	100
38	15	143 –144	100	33	33	152 –151	100
46	38	149 –143	100	30	48	154 –151	100
20	18	144	100	31	42	151 –155	100
39	13	144 –144½	100	29	56	152 –154	100
26	32	144 –154	100	32	46	155 –152	100
35	14	148 –145	100	17	5	153 –154	100

[1] The only living larva found in this sample was crawling on the treated sample and probably had not passed through the machine.

Table 44.—*Results of treatment of cottonseed in live-steam disinfecting machine*—Continued

SERIES 2

[Speed of machine, 50 revolutions per minute. Time of exposure, 55 seconds. Steam admitted into two upper conveyors only]

Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed	Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed
		°*F.*	*Per cent*			°*F.*	*Per cent*
52	103	138	100	55	141	146 –145	100
51	115	138 –138	100	53	98	145 –147	100
50	56	141 –138	100	123	44	145½–148	100
121	39	138½	94.8	120	40	146	100
127	22	139	100	54	84	147 –146	100
117	36	141	100	125	43	146½–147	100
49	89	149 –141	100	124	32	148 –146½	100
128	28	141½	100	122	27	147	100
118	33	142	100	126	32	147 –147	100
57	109	143 –142	99	119	22	149½	100
56	118	145 –143	100	130	24	152 –152½	100
129	26	144 –152	100	131	27	152½–152	100

SERIES 3

[Speed of machine, 55 to 56 revolutions per minute. Time of exposure, 49 seconds. Steam admitted into two upper conveyors only]

		°*F.*	*Per cent*			°*F.*	*Per cent*
106	46	140	100	109	32	152 –149	100
105	73	141 –140	100	108	57	150	100
104	101	146 –141	99	111	48	150 –155	100
102	61	145	100	114	50	151½–152	100
103	61	149 –146	100	113	24	153 –151½	100
116	44	148 –150	100	107	57	152	100
115	82	152 –148	96.3	112	43	155 –153	100
110	43	149 –150	100	101	57	154	100

SERIES 4

[Speed of machine, 60 revolutions per minute. Time of exposure, 47 seconds. Steam admitted into two upper conveyors only]

		°*F.*	*Per cent*			°*F.*	*Per cent*
58	143	136 –140	100	90	52	143 –145	100
98	91	138	90.9	92	42	146 –143½	100
99	57	138 –140½	94.7	95	41	149 –143½	100
100	61	140½–138	100	84	42	144 –145	97.6
62	108	141 –138	87.9	83	28	147 –144	100
73	62	138 –142	100	69	89	149 –144	100
72	85	143 –138	98.8	91	49	145 –146	100
85	45	145 –138	91	64	33	145 –146	100
86	32	138 –146	84.3	63	34	149 –145	100
71	94	142 –139	98.9	93	33	145½	100
82	33	139 –147	100	94	50	146	100
81	36	149 –139	97.1	65	68	146 –149	100
59	111	140 –141	94.5	68	49	149 –149	100
88	21	140½	95.2	66	46	149 –150	100
80	29	140 –149	100	67	60	150 –149	100
60	75	141 –142	100	75	82	152 –153½	100
61	57	142 –141	98.2	74	83	155½–152	100
97	67	142	100	78	47	153 –154	100
70	76	144 –142	97.3	77	60	155 –153	100
87	53	146 –142	98.1	76	70	153½–155	100
89	29	142½	100	79	30	154	100
96	30	143½–143	100				

SERIES 5

[Speed of machine, 40 revolutions per minute. Time of exposure,[1] 1 minute 8 seconds. Steam admitted into two lower conveyors only]

		°*F.*	*Per cent*			°*F.*	*Per cent*
138	27	137	81.4	141	76	144	84.2
135	22	138	100	134	20	154	100
139	30	138–142	93.9	136	28	160	96.4
142	59	139	89.8	132	33	162	100
137	36	140	100	133	37	166	100
140	64	142–147½	73.4				

[1] Actual exposure is only about 46 seconds on account of no steam reaching the seed until it entered the second section of conveyor.

TABLE 44.—*Results of treatment of cottonseed in live-steam disinfecting machine*—Continued

SERIES 6

]Speed of machine, 40 revolutions per minute. Time in machine, 1 minute 8 seconds. Steam admitted into top conveyor only]

Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed	Test No.	Number of larvæ in tests	Seed temperature on discharge	Larvæ killed
		°*F.*	*Per cent*			°*F.*	*Per cent*
165	26	137 –135	100	169	18	154 –146	100
163	16	136 –137	100	151	9	147 –147	100
162	30	142 –136	100	150	26	151½–147	100
164	8	137 –137	100	157	26	148	100
143	20	139	100	166	24	148	100
175	28	139½–140	100	145	14	148 –148	100
174	21	140 –139½	100	155	27	149 –148	100
173	22	140 –140	100	154	39	149	100
172	13	142 –140	100	144	21	149½	100
161	53	142 –142	100	146	17	150	100
159	29	142 –143	100	153	20	151½	100
160	19	143 –142	100	149	10	153 –151½	100
158	26	146 –142	100	167	18	153	100
171	20	147 –142	100	168	28	153 –154	100
170	33	143	100	148	24	157½–153	100
152	32	147 –144	100	147	24	158 –157½	100
156	29	148 –146	100				

SERIES 7

[Speed of machine, 50 revolutions per minute. Time of exposure, 55 seconds. Steam admitted into top conveyor only]

		°*F.*	*Per cent*			°*F.*	*Per cent*
186	17	138 –132	82.3	191	16	147 –140	100
178	25	133½–135	96	187	7	141½	100
179	17	135 –153	100	195	11	142½–146	100
177	33	136	96.9	194	8	147 –142½	100
176	13	136	100	182	13	143 –145	100
185	31	138 –138	100	181	22	151½–143	100
192	17	140 –138	94	190	10	144 –147	100
184	29	140 –138	100	189	15	147 –144	100
193	13	138 –147	100	188	13	147½	100
183	20	145 –140	100	180	19	153 –151½	100
196	11	146 –140	100				

SERIES 8

[Speed of machine, 60 revolutions per minute. Time of exposure, 47 seconds. Steam admitted into top conveyor only]

		°*F.*	*Per cent*			°*F.*	*Per cent*
206	8	138	100	200	10	143–143	100
207	10	139	100	201	16	143–145	93.7
208	16	139–140	93.7	199	10	145–143	100
209	16	140–142	100	205	22	150–143	100
213	30	141–141	100	218	22	150–143	100
214	22	141–141	100	197	10	144	100
215	25	141–141	100	198	9	145	100
219	15	143–141	100	202	9	145–147	100
212	12	144–141	100	203	12	147–147	100
216	18	141–150	100	204	13	147–147	100
210	20	142–142	100	217	10	150–150	100
211	17	142–144	100				

The record of time of exposure in all the series referred to the time required for the seed to pass entirely through the machines, regardless of which conveyors it was exposed to steam in. It was the purpose to show in these tests a range of temperatures from which the safe minimum temperature giving 100 per cent mortality at a given time of exposure might be determined. Owing to irregular boiler pressure and feeding, however, it was difficult to obtain a certain desired temperature in any one test, and the temperatures obtained in any series were usually very irregular. To this same irregularity in steam pressure and feeding can be ascribed the wide variations in temperature indicated in some of the individual samples.

In the tests recorded in series 1, 2, 3, and 4 steam was admitted into the upper two conveyors of the machine only. The results in these four series show the maximum temperatures that failed to give 100 per cent mortality for the respective periods of exposure to be as follows:

Series 1, 1 minute, 5 seconds, 142½° F.
Series 2, 55 seconds, 143° F. to 142° F.
Series 3, 49 seconds, 152° F. to 148° F.
Series 4, 47 seconds, 144° F. to 145° F.

In series 5 steam was admitted into the two lower conveyors only and the seed required 1 minute and 8 seconds to pass through the machine. This would of course be equivalent to a machine with two conveyors only and an exposure of about 46 seconds. In series 6, 7, and 8 steam was admitted into the top conveyor only. The results in these series show the maximum temperatures that failed to give 100 per cent to be as follows:

Series 5, 1 minute, 8 seconds (46 sec.), 160° F.
Series 6, 1 minute, 8 seconds (all 100 per cent).
Series 7, 55 seconds, 140° F. to 138° F.
Series 8, 47 seconds, 143° F. to 145° F.

These eight series throw considerable light upon the action of a machine of this type. In series 1 and series 5 the time of exposure is the same, or practically the same, and in each steam is admitted into two sections of conveyor. Under equal pressure this should heat the seed equally. Yet series 5 shows a failure at 160° F., and in series 1 142½° is the maximum that did not give 100 per cent mortality, and it is a doubtful record. Other tests in series 5 compare with those in series 1 in a similar way. This brings out the point already mentioned, that the record obtained immediately after exposure does not show the temperature attained by the inside of individual seeds.

From this it may be concluded that, in the test in series 5, enough steam had been injected into the seed mass to raise the seed to a temperature sufficient to kill the pink bollworm, were it bulked long enough to allow even heating throughout the mass by absorption. This at the same time explains the better results obtained when steam was admitted into the upper conveyors only, giving opportunity for absorption of heat while the seed was passing through the lower dry conveyors.

The results obtained in these tests warrant the conclusion that a machine of this type will be successful if operated so that the seed is discharged at a temperature of not less than 145° F. after an exposure of at least one minute, during the first half of which it is subjected to steam, the remaining time being allowed for penetration of the heat to the larva inside the seed. The temperature record should be obtained at a point near the discharge end of the machine.

EFFECT OF LIVE-STEAM TREATMENT ON GERMINATION

A number of germination tests with samples taken from the series of tests just discussed were made. The results are given in Table 45.

These tests were conducted a few days after the seed was treated. They show plainly that the treated seed was not damaged when cooled immediately.

TABLE 45.—*Percentage of germination of seed after treatment in live-steam machine*

Seed temperature on discharge	Time in machine	Germination: Heated seed	Germination: Check seed	Seed temperature on discharge	Time in machine	Germination: Heated seed	Germination: Check seed
°F	Min. sec.	Per cent	Per cent	°F	Min. sec.	Per cent	Per cent
136 –140	47	77	77	146	1 20	85	87
143	1 20	89	87	146	1 20	90	87
143 –145	55	80	85	148	1 20	82	76
144 –147	55	87	85	149. 5	1 8	88	85
145. 5–141. 5	1 5	84	85	150	1 20	79	76
145	1 20	79	76	150	1 5	92	91
145	1 20	81	87	151 –145. 5	1 5	80	78
145	1 20	87	87	152. 5–152	55	81	80
145	1 20	89	76	160	46	77	80
145	1 20	89	76				
145. 5	47	83	79	Average		83. 9	82. 0

An experiment was performed to determine the time required for seed to cool if bulked immediately after treatment. Several tons of seed were treated, admitting steam only into the top conveyor, and bulked in the corner of the seed house. The seed registered a temperature on discharge ranging from about 140 to 152° F. After bulking, a recording thermometer was inserted into the seed pile. The readings obtained are shown graphically in Figure 13. A curve showing the mean daily outside air temperature during the period is also given. The difference between the temperature at discharge and that after bulking was probably caused by absorption of heat after leaving the machine and by loss incurred while the seed was carried in sacks and emptied in the corner of the seed house.

Germination tests of some of this seed were made, using one untreated sample, one treated sample that was cooled immediately, and one sample that was kept in bulk from December 15 to 30. These germination tests to date of this writing (April, 1923) resulted as shown in Table 46.

TABLE 46.—*Percentage of germination of seed treated in live-steam machine*

Sample	January, 1923	February, 1923	March, 1923
	Per cent	Per cent	Per cent
Check	85	94	98
Cooled immediately	86	94	93
Bulked Dec. 15 to 30	87	92	97

According to the above results, no harm follows bulking of seed immediately after treatment with live steam.

AMOUNT OF MOISTURE ABSORBED BY SEED IN LIVE-STEAM TREATMENT

Several tests were made with the live-steam machine to determine the amount of water absorbed by seed on treatment. Quantities of seed were weighed before treating and again after treating. The results are given in Table 47.

TABLE 47.—*Absorption of moisture by seed treated in live-steam machine*

Time in machine	Steam pressure	Weight of seed— Before treatment	Weight of seed— After treatment	Gain in weight	
M. sec.	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Per cent*
1 5	50	1,137	1,172	35	3.08
1 5	50	781	814	33	4.2
55	55	782.8	804	21.2	2.7
55	70	846.6	861.2	14.6	1.7

In the first three tests steam was admitted into two sections of the conveyor, and in the last into only one. The temperatures recorded in these tests ranged from 144 to 150° F. It appears from the results

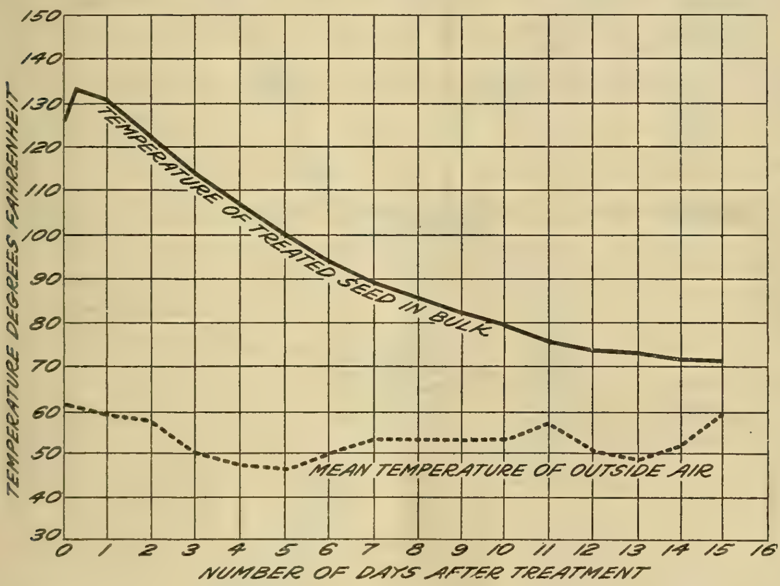


FIG. 13.—Cooling of seed treated with live steam and bulked immediately after treatment

that the amount of moisture absorbed decreases when the time of actual subjection to steam is reduced, even though the steam pressure has to be increased to give sufficient heat.

PRACTICAL USE OF DISINFECTING MACHINES

Under the State regulations, disinfecting machines were installed at all the gins during 1922 in all of the regulated zones in Texas. Twenty-three of these machines were of the dry-heat type and 14 of the live-steam type. Altogether about 23,000 tons of seed were treated. There were no interruptions and machines were found to be entirely practicable.

Dry-heat machines costing about $500 each had a capacity in the larger size as high as 10 bushels per minute. Three horsepower was required to operate this machine. The expense of operation ranged from 10 to 25 cents per ton of seed.

The live-steam machine was found under practical working conditions to have a capacity of 5 bushels per minute and required not more than two horsepower. The cost of operation was about the same as in the case of the dry-heat machine.

Continuous series of germination tests were made during the operation of these machines. There were no indications of any appreciable reduction in the vitality of the seed.

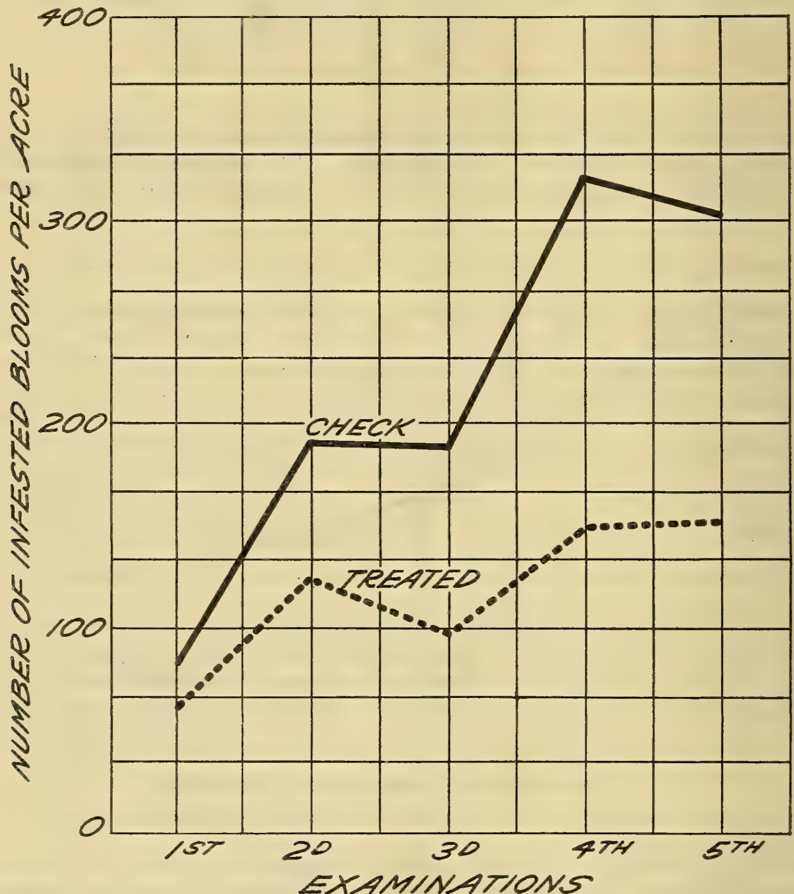


FIG. 14.—Number of infested cotton blooms per acre in poisoned and check plats, 1921 experiments, as shown by weekly examinations. First examination made six days after treatment began

POISONING EXPERIMENTS

The habits of the newly hatched pink bollworm larva suggest that there may be an opportunity to kill it by means of poison before it enters the boll or while it is attempting to enter. Experiments were instituted at Tlahualilo to determine whether any degree of control could be attained by dusting with arsenical poisons.

In 1921, nine separate plats in large cotton fields were treated, seven of these with calcium arsenate and two with arsenite of zinc. Records were kept at the same time on an equal number of check plats of equal size. As the purpose of these first experiments was to determine whether any control could be attained, no attempt was made to do the work on a commercially profitable basis. On the contrary, the plan followed was to keep the plants thoroughly covered with poison during the entire period of treatment. Some of the plats were dusted with hand guns and others with 2-row mule dusting machines.

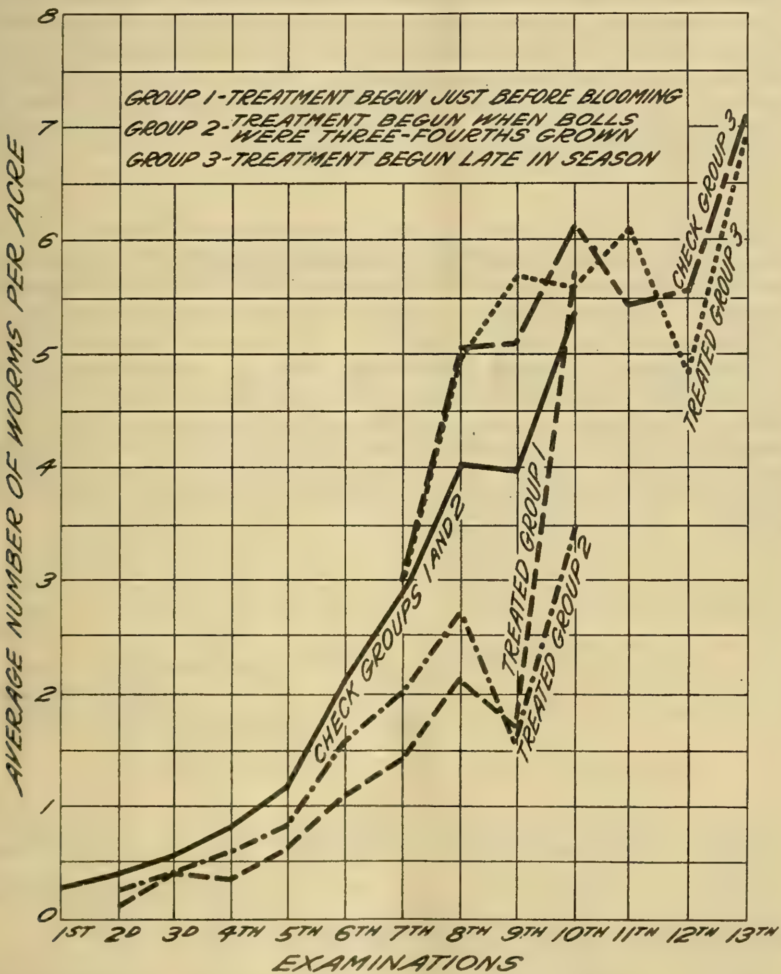


FIG. 15.—Progress of the infestation of green bolls in poisoned and check plats as shown by weekly examinations, 1921 poison tests

The air in the Laguna district is very dry and there is considerable wind. It was therefore found that applications must be made every five days in order to keep the plants fairly well covered with poison. Applications were repeated after rains. A period of calm lasting an hour, more or less, usually occurs at 5 or 6 o'clock in the morning, and the applications were made at that time. Dew was usually absent or so light as to be hardly noticeable. The conditions for dusting were therefore far from ideal.

The 1921 plats may be divided into three groups. Poisoning on those of the first group (plats 2, 6, 10, and 14) began about the middle of June, a few days before blooming started. Treatment of the plats in the second group (plats 4, 8, 12, and 16) began in the latter part of July. At that time the first bolls were about three-fourths grown. In the third group (plat 18) poisoning began near the end of August, when the infestation averaged 2.96 worms per boll. Applications were continued on all plats until nearly all bolls were open.

In the beginning, records of infestation were obtained by examining blooms. But after bolls developed this record was replaced by boll examinations, which were made weekly. Figure 14 shows the development of the infestation in blooms in the plats of group 1 and the corresponding check plats. According to this record the treatment caused a very noticeable check in the infestation.

The progress of boll infestation, by groups of plats, is shown graphically in Figure 15.

A general summary of the experiments is given in Table 48. These records show definitely that the infestation was reduced by poisoning. The earlier the treatment was commenced the greater the reduction obtained. Treatment begun very late had practically no effect, as shown in Group 3, plats 17 and 18. The sudden rise in numbers, of worms per boll in the plats of Group 2 (fig. 15) at the last examination was due to scarcity of bolls. Very few bolls were left on the plats at this time. This, however, was an abnormal record, not comparing with the previous showing of the plats. In the table, therefore, the next to the last instead of the last examination is given for plats 13, 14, 15, and 16, to show the maximum reduction in infestation due to the treatment.

TABLE 48.—*Summary of poisoning tests, 1921*

Plat No.	Treatment	Acres	Date of application		Number of applications	Pounds applied		Infestation last examination		Percentage nonpickable cotton	Classification of lint samples
			First	Last		Total	Per acre	Worms per boll	Percentage difference		
1	Check	1						3.46		9.3	Middling.
2	Calcium arsenate.	1	June 15	Aug. 23	16	152.5	9.5	1.92	44.5	3.3	Strict middling.
3	Check	1.11						3.82		6.9	Do.
4	Calcium arsenate.	1.11	July 20	Aug. 23	8	84.75	9.5	2.88	24.6	5.3	Good middling.
9	Check	1						3.22		8.0	Do.
10	Calcium arsenate.	1	June 15	Aug. 23	16	124.25	7.8	2.44	24.2	6.0	Do.
11	Check	1.11						4.04		7.7	Strict middling.
12	Calcium arsenate.	1.11	July 20	Aug. 23	8	84.75	9.5	3.72	7.9	7.5	Do.
13	Check	1.07						[1] 4.16		11.0	Do.
14	Calcium arsenate.	1.07	June 25	Sept. 14	19	181.25	8.9	[1] 1.66	60.1	6.8	Good middling
15	Check	1.07						[1] 3.68		9.0	Strict middling.
16	Calcium arsenate.	1.07	July 24	Sept. 14	12	112.0	8.7	[1] 1.52	58.7	4.5	Good middling.
17	Check	2.16						6.98		14.8	
18	Calcium arsenate.	2.16	Aug. 26	Sept. 30	9	229.0	11.8	6.8	2.6	10.8	
5	Check	0.66						4.8		6.7	Strict middling.
6	Arsenite of zinc.	0.66	June 15	Aug. 23	16	134.0	12.7	2.38	50.4	4.4	Good middling.
7	Check	0.66						4.18		7.0	Strict middling.
8	Arsenite of zinc.	0.66	July 19	Aug. 23	8	60.0	11.4	3.14	24.9	5.5	Good middling.

[1] These were the next to last examination.

Treatment of the cotton, particularly in the early plats, was followed by aphid infestation, which reduced the yield considerably. On this account the yields of the early-treated plats were for the most part lower than those of the check plats. There was a slight increase in yield of the treated plats of the second group.

Poisoning experiments were continued in 1922, but on a slightly different basis. Instead of making applications of poison on all plats till the end of the season, an equal number of treatments was given each plat, but during different parts of the season. Most of the plats were arranged in several six-plat series with two check plats to the series. Treatments on each series covered a period of 16 applications at five-day intervals. One such series then consisted of the following:

Plat 1, check.
2, first 7 applications.
3, applications Nos. 4 to 10, inclusive.
4, applications Nos. 7 to 13, inclusive.
5, applications Nos. 10 to 16, inclusive.
6, check.

Infestation records were kept on each plat throughout the season. In addition to the use of calcium arsenate and arsenite of zinc in different series, one entire series was treated with lead arsenate.

Although a considerable volume of data was obtained in the 1922 experiments, no very definite conclusions could be drawn other than those drawn from the 1921 experiments. The plats receiving the early applications showed a greater percentage reduction in infestation during the period of treatment than later ones, amounting in some individual examinations to more than 50 per cent. But after the period of treatment the infestation rose again. The later applications on the other hand caused a greater reduction in actual number of worms per boll, and an average of all the examinations in each plat showed a lower number of worms per boll in the later plats. This point is illustrated in Table 49, in which are summarized data from 2 complete and 1 incomplete 6-plot series.

TABLE 49.—*Summary of Series D, E, and G, 1922 poison tests*

Plat No.	Poison applications	Average number of worms per boll per examination	Daily average number of blooms per acre		Bolls per plant		Yield (pounds per acre)			Percentage non-pickable cotton
			First crop	Second crop	First picking	Second picking	First picking	Second picking	Total	
1 and 6	None	3.89	6,211	2,939	5.17	2.22	1,062	48	1,110	13.4
2	First 7	3.07	6,676	2,592	5.97	2.02	1,275	69	1,344	10.6
3	4 to 10, inclusive	3.04	6,687	3,363	5.56	2.54	1,172	142	1,314	13.2
4	7 to 13, inclusive	3.00	6,341	3,302	5.80	2.91	1,074	186	1,260	11.5
5	10 to 16, inclusive	2.89	6,128	3,154	5.50	3.04	1,076	138	1,214	13.3

Aphid damage in 1922 was checked by dusting with nicotine sulphate preparations. As many as three applications were necessary on some of the series. Whenever an application on one plat became necessary, all plats in the series were treated, checks included, so that any action of the nicotine on the pink bollworm would be the same for all plats.

The records show increases in yield for all the treated plats, the increase being greatest in the plats that received early treatment. Records of blooming and bolls produced should be considered in connection with the yields. Bloom counts were made weekly in each plat, and bolls were counted just before the first pick and shortly before the second pick. The individual plat averages for both blooms and bolls of the first crop are comparable among themselves about as the yields of the first pick in the same plats. This holds true, more or less, also with the second crop of blooms and bolls and the yields of the second pick. According to these records the increase in yield of the treated plats can not be ascribed entirely to reduction of the pink bollworm damage, but the poisoning evidently reduced the infestation.

Each boll count represents an average from 50 plants at each of 3 points per plat. The count of the first crop of bolls included only bolls that were open just before the first picking. All of the first-crop bolls were open at this time, but hardly any of those of the second crop. Boll counts for the second crop were made several weeks before the second picking and included both open and nearly grown green bolls. No doubt the shedding of some of these green bolls and the failure of others to open by the time of the second picking, the smaller size of the bolls of the second crop, and the non-pickable cotton practically all of which was of the second growth, all contributed toward the much greater difference that is found between the yields of the first and the second picking than that found between the records of total bolls of the first and of the second crop.

Of three other series of poison tests conducted in 1922, two showed increases in yield in treated plats. In the third there was a very slight decrease.

COMPARATIVE EFFECTIVENESS OF DIFFERENT POISONS

Reduction in infestation was brought about by all three poisons used in 1922. Sufficient experiments have not been made to determine whether one is more effective than the others. Because the 6-plat series treated with arsenite of zinc was left incomplete, a comparison of the effectiveness of the three kinds of poison can be based only on the results obtained in the two latest poisoned plats in each of three 6-plat series on which different poisons were used. This comparison of the poisons is shown in Table 50.

TABLE 50.—*Comparison of average infestation in plats treated with different kinds of poison*

Plat No.	Treatment	Average number of worms per boll per examination		
		Calcium arsenate	Arsenite of zinc	Lead arsenate
1 and 6	Check	[1] 5.13	[1] 5.13	[1] 5.13
4	Aug. 9 to Sept. 7	4.29	4.30	4.19
5	Aug. 22 to Sept. 26	4.07	4.17	4.15

[1] Average of checks, all series.

The differences here are so slight that the effectiveness of all the poisons must be considered about the same. In the records for 1921 (Table 48, plats 2, 4, 6, and 8) the effectiveness of calcium arsenate and that of arsenite of zinc compare in a similar way.

ACTION OF THE POISON ON THE PINK BOLLWORM

In the fall of 1922 experiments were begun to determine the manner in which the application of arsenicals to cotton reduces the pink bollworm infestation. It was planned to determine by applications of dust, in one case to the entire plant except the bolls, and in another to the bolls only, whether the young larvæ are killed while they feed on the foliage or while they attempt to enter the boll. A few plants were selected for each test and young bolls on them labeled, including bolls on separate plants to serve as checks. Applications of dust were made every five days and repeated after rains. An examination of 50 small bolls as a check at the beginning of the experiment showed an average of 0.38 worm per boll. The results of this experiment are summarized in Table 51.

TABLE 51.—*Effect on pink bollworm infestation of the application of calcium arsenate dust on bolls only and on the rest of the plant only*

Part of plant dusted	Period of treatment	Number of bolls	Eggs and eggshells on bolls			Larvæ and exit holes		Dead larvæ in bolls
			Total eggs	Total egg-shells	Average per boll	Total	Per boll	
Entire plant except bolls	Sept. 1 to 30	100	3	96	0.99	209	2.09	13
Check	None	82	46	227	3.33	277	3.38	17
Bolls only	Sept. 1 to Oct. 3	50	4	30	.68	185	3.70	6
Check	None	58	55	242	5.12	256	4.41	9
Average, both checks					4.07		3.80	

Reduction in infestation was brought about in both cases, but it was more marked where the foliage was dusted than where the bolls only were dusted. It would appear that young larvæ were killed both while feeding on the foliage of dusted plants and while entering the bolls. But the most striking point in the results is the great reduction in the number of eggs found on the bolls after dusting. This was found to be the case also in the examination of bolls from plats in the other poison tests. It suggests that the reduction in infestation may not have been brought about at all by killing of the larvæ, but by repelling the moths. This point should be closely studied in connection with further dusting experiments.

SUMMARY

An average annual loss of from 20 to 25 per cent of the cotton crop has been caused by the pink bollworm in Mexico, since the infestation attained maximum development. There is a reduction in both the quantity of the total crop picked and the quality of the lint and seed marketed.

The pink bollworm begins its attack on the early squares. From this beginning the numbers of the insect increase with regularity until at the height of the season four or more larvæ per boll is a common average and all late bolls are rendered practically valueless. The enormous numbers of larvæ that go into hibernation in stored seed and in the bolls and soil in the field insure the presence of sufficient adults to begin the attack the following spring.

In the summer the larva leaves the boll to pupate. About 80 per cent pupate in the soil, the remainder in and under plant material on the surface of the soil. (Table 3.) The majority of the larvæ are found within the first 2 inches of soil (Table 4), and more of them immediately under the plants than between the rows (Table 5). As many as 83 living larvæ and pupæ have been found in 1 square yard of soil. (Table 6.) Some larvæ hibernate in the soil. In some instances over 20 living larvæ were found per square yard of soil in the field in winter. (Table 7.)

The common manner of dispersal is through the carriage of infested seed by man. Experiments have shown that isolated plantings of cotton even as far as 40 miles from the nearest source of infestation readily became infested where chances of carriage by man were meager but by no means excluded.

The mortality among newly hatched larvæ is great (p. 31). Of the larvæ entering the soil for pupation during the summer, 19.7 per cent were found to die (p. 32). The attacks of parasites on the pink bollworm in Mexico are spasmodic and as yet have not proved of any importance (p. 36). The mortality of resting larvæ in the field during winter and early spring is great, and when fields are flooded in winter hardly any survive. (Table 28.)

When fields are cleaned in fall and winter and bolls that are shed remain on the soil, many larvæ leave these bolls and enter the soil for hibernation. (Table 37.) The survival of larvæ during the winter is much greater in bolls on stalks in the field than in bolls on the surface of the soil (Tables 8 and 9), showing plainly the advantage of cutting and burning old stalks.

The pink bollworm may be killed in cottonseed by heat without injury to the seed. Machines have been made in which the seed is treated either by dry heat or by contact with live steam. By the first method, seed can be disinfected by heating to a temperature of 145° F. in 3½ minutes. By injection of live steam into the seed mass the time of exposure required can be lessened.

The infestation of green bolls has been reduced as much as 60 per cent (Table 48) by repeated applications of arsenicals in the field. This indicates that there is some hope for practical control by this means, but a final conclusion on this point depends on future work.

O

U. S. DEPARTMENT OF AGRICULTURE
OFFICE OF INFORMATION
DIVISION OF PUBLICATIONS

DEPARTMENT BULLETINS
Nos. 1376-1400

WITH CONTENTS

PREPARED IN THE INDEXING SECTION

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1928

CONTENTS

Page

Department Bulletin No. 1382.—The Relation Between the Ability to Pay and the Standard of Living Among Farmers:

Department Bulletin No. 1383.—Single-bath Hot-water and Steam Treatments of Seed Wheat for the Control of Loose Smut:

Department Bulletin No. 1384.—The Effectiveness of Extension in Reaching Rural People. A Study of 3,954 Farms in Iowa, New York, Colorado, and California, 1923–24:

Page

Department Bulletin No. 1396.—A Comparison of Maize-Breeding Methods:

Department Bulletin No. 1397.—The Pink Bollworm, with Special Reference to Steps Taken by the Department of Agriculture to Prevent its Establishment in the United States:

Department Bulletin No. 1398.—Comparative Efficiency of Wire-Basket Bunkers in Refrigerator Cars:

Department Bulletin No. 1399.—Agricultural Survey of Europe: Germany:

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1393

Washington, D. C. ▼ May, 1926

THE GRANARY WEEVIL[1]

By E. A. BACK, *Entomologist in Charge*, and R. T. COTTON, *Associate Entomologist, Stored-Product Insect Investigations, Bureau of Entomology*

CONTENTS

INTRODUCTION

The granary weevil (*Sitophilus granarius* L.) (fig. 1) is well named, for of all the primary grain pests it is par excellence a pest in the granary or storehouse. Unlike its more successful and widespread rival, the rice weevil (*Sitophilus oryza* L.), the granary weevil possesses only rudimentary wings and does not appear to thrive in tropical and semitropical climates. Restricted as it is to the granaries of the colder climates, it seems to be finding it increasingly difficult to withstand the combined effect of limited numbers of generations due to cold and the modern methods of handling and protecting grain.

As late as the decade from 1860 to 1870 the granary weevil was the prevailing species of weevil in grain throughout the northern portion of the United States. E. A. Schwarz, of the Bureau of Entomology, states that *Sitophilus granarius* was the only grain weevil present among the insects collected by C. V. Riley in Missouri and later acquired by the United States National Museum. The writers, who have examined many samples of grain from various grain centers of this country, believe that the granary weevil is a minor pest as compared with the rice weevil, and that it is responsible for a relatively small amount of the damage caused by calandrid pests in this country, notwithstanding the numerous instances of serious injury that are constantly coming to one's attention. Keys distinguishing the larvae and adults of *granarius* and *oryza* have been given by Cotton (*13*).[2]

SYNONYMY

The granary weevil was described and named by Linné (*44, p. 378*) in 1758 as *Curculio granarius*. Numerous references to this weevil

[1] The biological data contained in this bulletin are based on work conducted in Florida from 1919 to 1921 and in Washington, D. C., from 1921 to 1923.

[2] Reference is made by number (italic) to "Literature cited," p. 32.

appeared in literature before this time. It was described in 1710 by Ray (*55*) under the name of Scarabaeus and again by Linné (*43*) in 1746 under the name of Curculio. In 1798 Clairville and Schellenberg (*59, p. 62*) erected the genus Calendra for the species *granaria* and *abbreviata*. Latreille (*41, p. 431*) in 1810 designated *abbreviata* Fab. as the type of the genus Calandra (*sic*), and in 1838 Schoenherr (*60, p. 967*) erected the genus Sitophilus to include the species *granarius* and *oryzae*. Hence, as noted by Pierce (*51, p. 26*) in 1919, the correct generic name for the granary weevil is undoubtedly Sitophilus and not Calendra or Calandra. The synonyms of the species are as follows:

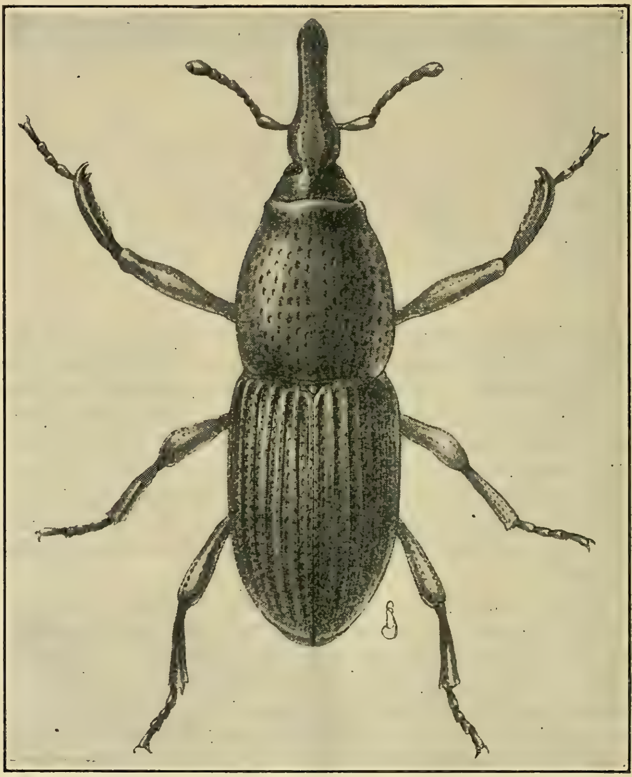


FIG. 1.—The granary weevil (*Sitophilus granarius*): Adult, dorsal view. Enlarged about 38 times

Sitophilus granarius Linné

Curculio granarius Linné, Syst. Nat., ed. 10, p. 378, 1758.
Curculio segetis Linné, Syst. Nat., ed. 10, p. 381, 1758.
Rhynchophorus granarius Herbst, Jablonsk. Natursystem., vol. 6, p. 14, Pl. 60, fig. 7, 1795.
Curculio policarius Voet, Col., ed. Panz., vol. 4, p. 54, Pl. 37, fig. 17, 1798.
Calendra granaria Clairville and Schellenberg, Helv. Ent., vol. 1, p. 62, 1798.
Curculio unicolor Marsham, Ent. Brit., p. 275, 1802.
Rhynchaenus segetis Latr., Hist. Nat., xi, 193, 1804.
Cordyle granarius Thunberg, Nova Acta Ups., vol. 7, p. 112, 1815.
Calandra frumentarius Stephens, Cat. Brit. Ins., pt. 1, p. 148, 1829.
Sitophilus granarius Schoenherr, Gen. Curc., vol. 4, p. 977, 1838.
Sitophilus remotepunctatus Gyll., Schh., Gen. Curc., vol. 4, p. 979, 1838.

ECONOMIC HISTORY

The granary weevil was well known as a pest in stored grain long before its description by Linné (*44*) in 1758, and numerous references to it are found in the publications of earlier writers. Remains of this weevil are said (*23*) to have been found in a vial in an ancient Gallo-Roman cemetery and also in a Marovingian tomb. Plautus (*52, pp. 251–252*), writing about 196 B. C., speaks of a curculio in stored grain which was presumably this species, and there seems to be little doubt that the *curculio* of Pliny and the Romans was this weevil. Von Schwenckfeld (*61, p. 527*) in 1603, Rango (*54*) in 1665, Commodus (*10*) in 1668, and Van Leeuwenhoek (*42*) in 1695 all referred to this weevil in their writings. Redi (*56*) published a figure of it in 1668. Since its description by Linné, innumerable accounts of the weevil have appeared.

The writers have over 300 references to the granary weevil. Naturally many merely pass on information previously published; surprisingly few contain real contributions to our knowledge. Only one paper, that by Strachov-Koltchin (*65*), contains a decided contribution to our knowledge of the various stages of the life cycle, as viewed from a modern standpoint. Although the work of this Russian was published in 1915, a translation [3] was not available for the writers until 1923; hence, the data hereinafter presented were secured uninfluenced by those of the work in Russia. Only a few of the more important papers, from an American standpoint, can be mentioned.

Duhamel du Monceau (*24*) published a short account of the granary weevil in 1761 and gave directions for combating the weevils and preserving the grain. In 1775 De Geer (*31, pp. 239–240*) stated that the weevils were commonly known as calandres. The same common name was used by Van Leeuwenhoek about a hundred years before, so it is probably of rather ancient origin. In 1790 Olivier (*48, pp. 442–444*) published a lengthy account that has served as a basis for a majority of the articles on the granary weevil up to recent times. He described the weevil and its habits and reported numerous experiments for its control. He came to the conclusion (amusing in these days) that fumigations only resulted in imparting a bad odor to the grain without seriously inconveniencing the weevils. He found that a temperature of from 167° to 190° F. would kill all stages of the insect but had a tendency to damage the wheat. He observed that when a pile of infested wheat was stirred up, the weevils crawled away in their endeavors to escape, and this suggested to him the following method for destroying them: "In the early spring before any eggs have been laid, several small piles of wheat should be formed near the large pile. The large pile should then be stirred and the weevils will leave the large pile and on encountering the small piles will enter them to seek shelter. The small piles should then be treated with boiling water to kill the weevils."

Latreille (*40, pp. 54–56*), in 1804, gave an extended account of the weevil, noting, among other things, that the period from egg to adult was about 40 days, and that one pair of weevils were capable of having 6,045 descendants in a single season. He also noted that

[3] A translation of this article by Strachov-Koltchin is on file in the Library of the Bureau of Entomology, United States Department of Agriculture

the weevils were very resistant to cold. Mills (*46*), in 1836, advocated the use of heat to kill the weevils, finding that a temperature of 130° to 140° F. would kill all stages without injuring the grain. He recommended using a room heated with hot-water pipes in which to treat infested grain. Gavit (*30*), in 1849, published a good account of the weevil, stating that the life cycle lasted from 40 to 45 days and that the adults lived for 1½ years or more.

Curtis (*14, pp. 323–328*), in 1860, published an interesting account of the insect in England, and Taschenberg (*68, pp. 63–65*), in 1865, gave a good account of the species in Germany. The latter author noted that badly weeviled wheat had a high temperature and stated that one female weevil was supposed to lay as many as 150 eggs. Taschenberg's observations in Germany have more recently been interestingly added to by Zacher (*71, 72*) and Teichmann and Andres (*69*). In 1869 Walsh and C. V. Riley (*70*) noted the vesicatory properties of the granary weevil. These properties were disproved in 1922 by W. A. Riley (*57*) and Defiel (*17*). In 1879 Ormerod (*49, 50*) wrote short articles on the granary and rice weevils and suggested trapping the beetles in vessels of water, and this idea was further developed by Dendy (*18*) in 1918. Kompfe (*39*), in 1879, recorded breeding the weevil from egg to adult in four weeks. Cotes (*12*), in 1888, while not discussing *granarius* as one of the grain pests of India, gives an interesting bibliography of grain weevils. Decaux (*16*), in 1890, published a few notes on the life history of the weevil and recorded rearing several species of chalcid parasites from it. Chittenden (*6, 7, 8*), in 1895 and 1896, published short accounts of the habits and depredations of this insect in North America.

Cole (*9*), in 1906, found that a fairly moist, ventilated atmosphere of about 80° F. was most satisfactory for the development of the granary weevil; that at 51° to 76° F. weevils were still alive after 48 days when kept in a moist atmosphere with food, but that when kept in a dry atmosphere they were dead by the end of the fourteenth day.

In 1915 Strachov-Koltchin (*65*) published an excellent account of the life history and habits of the granary weevil in Russia. He found that the length of the larval period is from 21½ to 84 days, according to the prevailing temperature, and that the length of the pupal stage is from 10 to 22 days. He gives data on oviposition based on adults reared from eggs laid in grain by females of unknown ages.

Dendy and Elkington (*19, 20, 21*), in a series of reports appearing in 1918 and 1920, discussed the effect of air-tight storage on the granary weevil and the vitality and rate of multiplication of this weevil.

Back and Cotton (*2, p. 5*), in 1922, stated that adult weevils may live for 10 months or more, and that in this period each female may lay from 200 to 300 eggs, these statements being summarized from actual data bearing upon the subject.

Chapman (*5*), writing in 1923, records experiments indicating that no stage of the granary weevil survives the process of milling semolina and that adults will not oviposit in semolina, with the natural result that macaroni is not infested as it comes from the press even though it is made from wheat badly infested.

A key to the principal insect pests of grain, including the granary weevil, was published by Zverezomb-Zubovski (*73*) in 1923, and is especially interesting because of the 78 illustrations, the keys, and the Russian bibliography of 72 entries dealing with grain pests. A translation of this paper is on file in the Library of the Bureau of Entomology, United States Department of Agriculture. Entomologists are directed to this paper in any study of the Russian literature.

ORIGIN AND DISTRIBUTION

The origin of the granary weevil is not definitely known, although it has been thought to have originated either in Asia or in the region bordering the Mediterranean Sea. Unlike the other members of the genus Sitophilus, which thrive best in a tropical or subtropical climate, the granary weevil is now distinctly a temperate-climate species.

Because of its habit of breeding in grains of all kinds, it has been carried by commerce to all parts of the civilized world. It does not thrive in warm climates, even though it is occasionally found there in apparently thrifty cultures. In tropical and subtropical climates it soon dies out. This seems true in spite of the fact that one of the best cultures seen by the writers came from Texas in chick-peas from Northern Mexico. Cotes (*12*) in 1888, Fletcher (*27*) in 1911, and Fletcher and Ghosh (*28*) in 1920, in their articles dealing with grain pests in India, do not mention *granarius* as a grain pest along with *oryza* and others.

In colonial days, the granary weevil appears to have been abundant and widespread over the United States and much more common than the rice weevil, *Sitophilus oryza*. Possibly there existed a confusion in the identification of these closely related weevils. At the present time, the granary weevil is common in all the northern States and is the predominating form in the States of the extreme north. It is not often found breeding farther south than North Carolina.

Cooley (*11, p. 127*), in 1914, in recording the presence of *granarius* in Montana, intimates that the species was not commonly found there, for he says, "The knowledge of its presence in Montana should put grain growers on their guard." Chapman (*4, p. 38*), in 1921, writes, "It is far more common in the south than in Minnesota. Its importance in the north is due to the fact that it is continually shipped in with southern wheat."

Swenk (*66, p. 366*), of Nebraska, in writing of the principal insects injurious to agriculture during 1908–9, says: "A really tremendous amount of grain is lost every year in Nebraska through the attack of stored-grain pests after the grain has been stored in the granary. Of course the insect most concerned in this destruction is the common grain weevil (*Calandra granaria*)." In 1922 Swenk (*67, pp. 3–4*) again states that the granary weevil is common throughout Nebraska, but refers to the presence also in southern Nebraska of *S. oryza*. Dean (*15, p. 198*), in 1913, lists the granary weevil along with the rice weevil and the Angoumois grain moth as the three principal pests in Kansas of whole grains. Girault (*32, p. 70*), in 1912, in discussing the granary weevil, says, "The species is widely distributed in the United States but is more common southward." Stedman

(*63, pp. 139–141*), of Missouri, in 1902, mentions *granarius* as the only true weevil in Missouri, while in 1915 Haseman (*36, p. 35*) of the same State records the granary weevil, and not the rice weevil, among the stored-grain pests of Missouri. On the Pacific coast the granary weevil is reported in 1915 by Essig (*26, pp. 305–307*) as very common throughout the State of California.

In the typically southern States, however, especially those bordering on the Gulf of Mexico, where weevil damage is greatest, the injury is caused not by the granary weevil but by the rice weevil. Quaintance (*53, p. 366*), in 1896, writes from Florida that "the granary weevil is not sufficiently abundant to be the cause of much damage," the rice weevil and the Angoumois grain moth being responsible for the greater part of the injury done to stored grain. Hinds (*38*), in 1914, in discussing the pests of stored corn in Alabama, does not mention the granary weevil. Smith (*63, p. 10*), in 1909, writing from North Carolina, states that the granary weevil "requires only passing mention here, for the rice weevil far surpasses it in numbers and destructiveness in the Southern States," and Sherman (*62*), in 1903, also of North Carolina, does not mention *granarius* in writing of common pests of grain. Back (*1*), in 1919, in discussing the conservation of corn from weevil attack in the Gulf Coast States, after an extended study of the stored-grain situation, did not consider *granarius* sufficiently important in that region to be mentioned.

It is accepted, naturally, that trade carries the rice weevil well into the territory of the granary weevil, particularly at the large ports such as New York and London (see reports of Durrant (*25*) in 1921), receiving cargoes of grain from warm climates. Riley and Howard (*58*), in 1888, reviewing a paper by R. A. Philippi on the changes in the fauna of Chile, caused by man, state that the two grain weevils occur, and that the damage done by *granarius* is often enormous. Doane (*22, p. 312*), in 1919, records the presence of *granarius* in Australian wheat brought into the United States through Pacific ports, but found that *oryza* was the more abundant. The writers, in examining Australian wheat brought into this country at Baltimore during the war period, found that it contained relatively few *granarius* as compared with *oryza*. Gurney (*35, p. 41*), in 1918, in discussing the insect pests of New South Wales, states that, while *oryza* was very abundant, *granarius* had been noticed twice only in imported grain. Froggatt (*29, p. 485*), in 1903, writes that *granarius* is a comparatively rare beetle: "I have met with it for the first time for over a year in a packet of macaroni left at the office, which was purchased at a Sydney grocer's." In South Africa, *oryza* and not *granarius* is the destructive species. Lounsbury (*45, p. 94*), writes in 1903, "The rice weevil is by far the more abundant species at the cape." The statement by Herrick (*37, p. 259*), in 1914, that *granarius* "is a more cosmopolitan species" than *oryza*, does not seem true to the writers, especially in these days (1923).

Since the granary weevil has no effective wings and is by nature not very active, it is found chiefly in granaries and other storehouses and has become now dependent upon man for its dissemination or spread. It seems very possible that, with the present-day tendency to treat all infested grain and to ship only clean grain, the granary weevil will become more and more scarce and may even be eliminated as a serious pest of stored grain in any part of America.

NATURE OF INJURY

The granary weevil is destructive to grain (figs. 2 to 4) and grain products (fig. 5) in both its adult and larval forms. The adults feed throughout their long lives and may occasion as much injury as their larvæ. The adults will feed upon many seeds and manufactured cereal products and are found in flour. They do not oviposit in any loose and finely divided grain particles too small to serve as food for the development of a single larva. Thus flour and similar materials, like semolina used in the manufacture of macaroni, may be fed upon by the adult weevil but not by the larvæ unless the substances become caked by long standing, in which case they are used by the adult weevils as suitable materials for the rearing of their young.

FIG. 2.—Injury to pearled barley resulting from development of larvæ and feeding of adult beetles of the granary weevil in making exit from kernels

Ordinarily when adult weevils are found crawling over sacks of flour and similar finely divided grain products they are migrating from near-by infested grain in the berry, and their presence will not cause injury except that uninformed buyers, on noting the presence of the weevils, may refuse to purchase or may insist on a lower price. The writers have known of instances where flour-mill owners have incurred considerable expense to hand-pick granary weevils from sacks of freshly manufactured flour standing overnight in the mill.

The adult weevil may become established and cause loss in cartoned grains like pearled barley (fig. 2). In an instance recently called to the attention of the writers a considerable shipment of pearled barley in small cardboard cartons was found to be infested with the granary weevil. The adults were not only causing a general infestation of the grain, but were opening the cartons to the attack of other grain pests by boring small holes in their efforts to escape, similar to those made in pill boxes and shown in Figure 6. The entire shipment was condemned.

Injury by the larvæ consists in the destruction, by feeding, of a larger or smaller part of the kernel, and in the fouling of the seed by their excrement. The development of one granary weevil larva will reduce the weight of a wheat kernel over 50 per cent and the adult before leaving the kernel may destroy even more. The destruction caused in all grains depends largely upon the abundance of the larvæ.

Fig. 3.—Wheat kernels damaged not only by development of larvæ but by continued feeding of adult beetles of the granary weevil. These kernels are reduced to mere skeletons and can be crushed flat as paper by the least pressure

Horses and other stock have been reported at times injured by being fed weeviled grain or other grain products filled with the feces and other débris left in the grains when these are infested. Recent investigation by Riley (*57*) and Defiel (*17*) show that the granary weevil has no poisonous qualities. The writers have seen very badly weeviled grain fed to animals without bad results and have yet to establish a clear instance in which injury to animals was caused by weevils.

Badly infested seeds, particularly wheat (fig. 3) are rendered worthless for seeding.

The destructive possibilities of the granary weevil were clearly shown during the World War when immense quantities of wheat were stored in Australia, a considerable quantity of it, owing to a lack of shipping, being held in storage for several years. This wheat became infested with weevils and only prompt treatment prevented very severe losses. Hundreds of thousands of tons of wheat were sterilized and screened and from every 2,500 bags of wheat so treated between 200 and 300 pounds of weevils were removed, an enormous number when one considers that there are about 442,000 weevils to the pound. Although three species of weevils predominated in this wheat, the granary weevil is said to have caused the most damage.

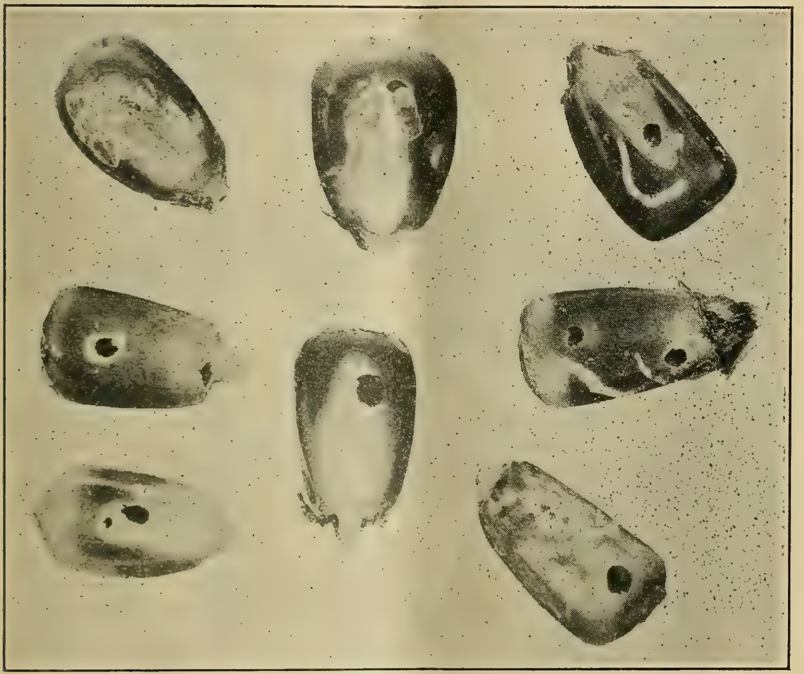


FIG. 4.—Corn kernels showing evidences of injury by the granary weevil. Note long white streaks on kernels to right. These indicate burrows of very young larvæ of the weevil just beneath surface of grain

TECHNICAL DESCRIPTION

THE BEETLE

(Fig. 1)

Elongate-oblong, feebly convex. Chestnut brown to piceous, moderately shining. Beak two-thirds as long as thorax, slender, cylindrical, finely and sparsely punctate. Thorax sparsely punctate, punctures coarse and on the disk more or less fusiform. Elytra deeply striate, striæ punctured at bottom, not serrate; intervals smooth, alternately wider and more elevated, especially toward the base; the sutural with a row of elongate punctures. Pygidium coarsely cribrate. Body beneath coarsely and less densely punctured than in *oryza*. Length 3 to 4 mm.

The original description of Linné follows:

"C. longirostris piceus oblongus, thorace punctate longitudine elytrorum."

THE EGG

(Fig. 7, *e*)

Egg opaque, shining, white, ovoid to pear-shaped in form, widest below middle, bottom broadly rounded, neck narrowing gradually toward top, which is somewhat flattened and bearing a small rounded protuberance that fits into a cap or plug cementing the egg in place.

Length 0.68 to 0.80 mm., width about 0.33 mm.

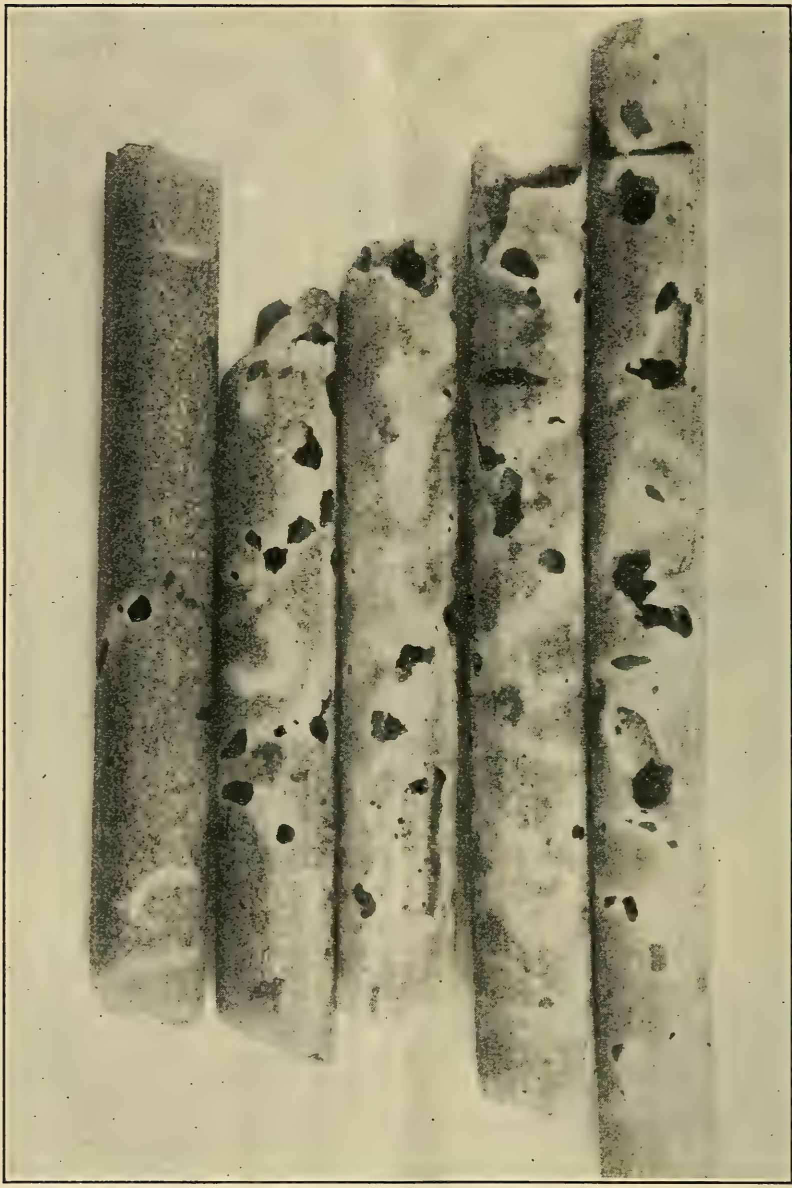


FIG. 5.—Injury to macaroni by the granary weevil. Macaroni is sometimes reduced to a powder by continued feeding of the weevil. The opaque whitened areas indicate progress of developing larvæ; the openings in the macaroni are caused by feeding of adult weevils

THE LARVA

(Fig. 7, *a* to *d*, *g* to *j*)

Mature larva (*f*) 2.5 to 2.75 mm. in length. A pearly white, fleshy grub, very thick bodied, the ventral outline being approximately straight, whereas the dorsal outline is almost semicircular. Ten abdominal segments; ninth small, tenth reduced, eighth and ninth forming a sort of pygidial plate.

Head (*b*) light brown in color, the anterior margin and mandibles much darker. Head longer than broad and somewhat wedge shaped, the sides broadly rounded from middle to apex, which is slightly angular. Sides nearly straight from middle to the anterior angles, and lateral area with an oblique, longitudinal, lighter stripe or area.

Epicranial and frontal sutures distinct and light in color; also two oblique, longitudinal, light stripes rising from frontal sutures and coalescing with epicranial suture near base of head.

Frons subtriangular, with a distinct, dark, median line indicating the carina running from the posterior angle to beyond the middle. Sutural margins irregular or sinuate. Frons provided with five pairs of large setæ, the sutural margins each bearing a large seta.

Clypeus attached in front of frons and broadly transverse, broad at base, sides narrowing toward the apical angles, slightly longer and broader than labrum, and bearing on epistomal margin two fine setæ on each side.

Labrum (*c*) distinctly broader than long, with two small lateral and a larger, rounded, median lobe. Labrum provided with six large dorsal setæ and two sensory spots, two marginal, short, thickened setæ on each lateral lobe, and six similar marginal setæ on median lobe.

Each epicranial lobe bearing the following setæ: One close to posterior angle of frons and located within the oblique, longitudinal stripe rising from the frontal suture; one very small seta posterior to this and near occiput; two anterior to it on disk of epicranium; two opposite middle of frons; one opposite middle of mandible; one opposite hypostomal angle of mandible; and one on hypostoma near base of mandible.

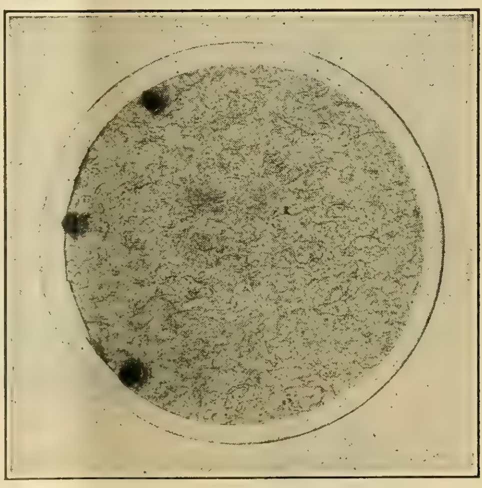


FIG. 6.—View of pill box, 1¼ inches in diameter, showing three exit holes bored by adults of the granary weevil in escaping from box. Cereal cartons may be thus opened to the attack of cereal pests

Eye represented by a single ocellus.

Antenna a fleshy two-jointed appendage located at the lateral angle of the frons, first joint broad and short, second slender and short.

Mandibles (*d*) stout, triangular, with the apex produced into a broad apical tooth; inner edge toward the apex provided with a subapical tooth and a small medial tooth; no molar part. Dorsal area of mandible provided with two stout setæ set apart.

Maxilla with cardo present and distinct. Maxillary mala (*g*, *h*) entire, tip obtuse, dorsal and ventral surfaces smooth, lightly chitinized, dorsal surface with a longitudinal row of six plain stout setæ, tip with two short and two longer setæ. Maxillary palp extending slightly beyond mala, two-jointed, proximal joint thick and rounded, bearing a single seta near apex; distal joint fingerlike, bearing several terminal papillæ. There are three other setæ on maxilla, two located on the vaginant membrane between palpus and palpifer and one, stouter and longer, midway between palpus and cardo.

Mentum, submentum, and maxillary articulating area fused into a fleshy region bearing three pairs of stout setæ. Eulabium posteriorly enforced by a median triangularly bent chitinization. Between the palpi a small slightly bilobed ligula. Labial palp short, conical, two-jointed, distal joint of palp with several small, fleshy, terminal papillæ. Eulabium bearing two setæ on ventral surface; ligula bearing four small setæ and two sensory spots on ventral side and one pair of setæ on dorsal side.

Paragnathal region or maxillular region with a median fleshy area and two setose lateral lobes.

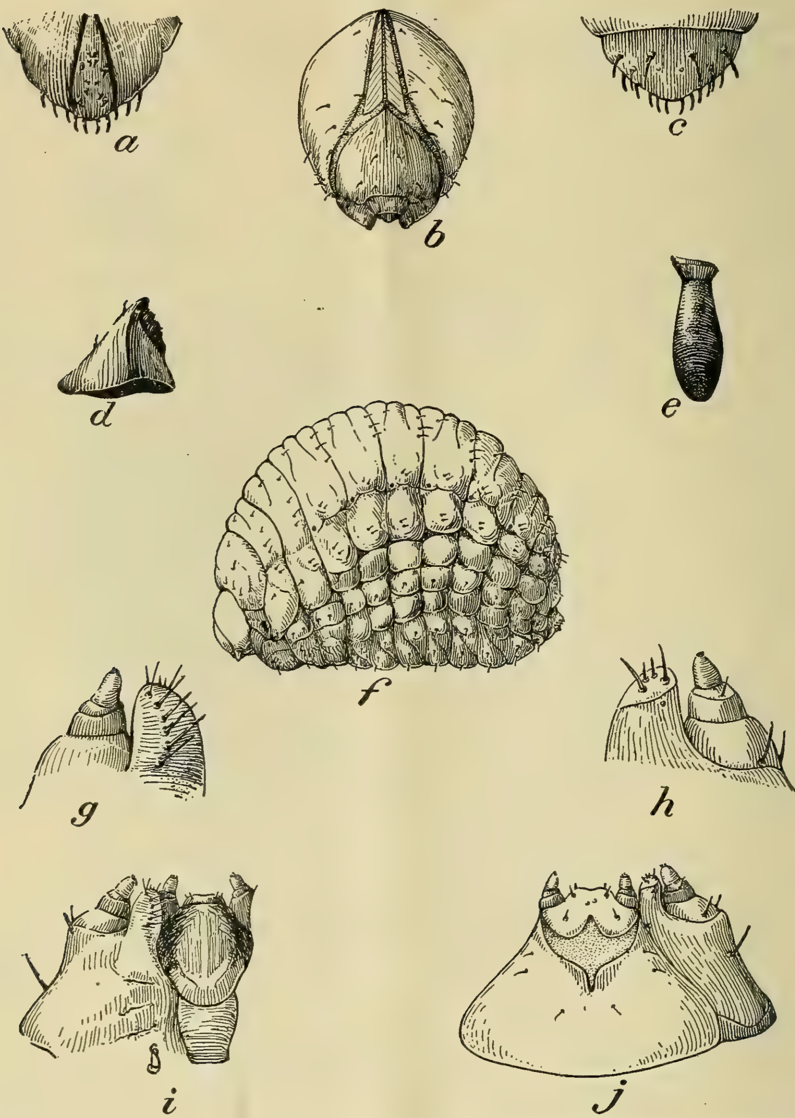


FIG. 7.—The granary weevil: *a*, Epipharynx of larva; *b*, head of same, dorsal view; *c*, labrum of same; *d*, mandible of same; *e*, egg; *f*, larva; *g*, mala of same, dorsal view; *h*, mala of same, ventral view; *i*, mouth parts of same, dorsal view; *j*, mouth parts of same, ventral view

Epipharynx (*a*) carrying a pair of narrow, longitudinal, chitinized, epipharyngeal rods approaching each other posteriorly. Between these there are usually 12 small setæ somewhat asymmetrically arranged, as follows: Two near anterior margin of epipharynx, a median group of four much smaller ones posterior to these, a pair of larger ones posterior to the group of four, and finally another median group of four very small setæ posterior to these.

Prothorax dorsally not divided, but two areas, præscutal and scuto-scutellar, are roughly indicated by rows of setæ. Præscutal area with six pairs of setæ, the last two of which occur on the alar lobe, scutoscutellar area with four pairs of setæ. The thoracic spiracle is located on a lobe pushed into the prothorax from the epipleurum of the mesothorax. It is bifore, elongate, larger than abdominal spiracles, and placed with the fingerlike air tubes pointing dorsad.

The mesothoracic and metathoracic segments are divided above into two distinct areas, a spindle-shaped præscutum provided with two pairs of minute setæ, and the scuto-scutellum and alar area. The scuto-scutellum has eight pairs of setæ and two pairs of hairs on each alar lobe. The epiplerum of the mesothorax and metathorax bears a pair of setæ. The sternum of the thorax consists of a median area or eusternum and two lateral lobes more or less connected medianly behind the sternum. The median portion is the sternellum and the lateral portions are the parasternal plates. Each thoracic sternum bears a pair of hairs, each coxal lobe of prothorax bears three pairs of hairs, and each coxal lobe of mesothorax and metathorax bears five hairs.

Each tergum of first four abdominal segments divided above into three distinct areas, præscutum, scutum, and scutellum. Each tergum of fifth to seventh abdominal segments divided above into only two areas, the first containing præscutal and scutal elements, the second representing the scutellum. Below these two areas and adjacent to the epipleurum is the alar area. Below a very indistinct and abrupt dorsolateral suture and above a well-defined ventrolateral suture is a large, not subdivided epipleurum. The abdominal epipleura are located considerably higher than the thoracic lobes. Below the ventrolateral suture is the hypopleurum, subdivided into three lobes, one directly below another. Below the hypopleurum is the coxal lobe and below that the sternum consisting of the eusternum and a posterior triangular area representing the parasternum or the parasternum fused with the sternellum. Abdominal segments provided with setæ, as follows: Each præscutum bears a pair of setæ; each scutellum bears three lateral setæ; each alar area bears a pair of setæ, and each epipleural lobe bears a pair of setæ. The second part of each hypopleural lobe bears a seta, each coxal lobe bears a seta, and there is a pair on the eusternum.

Eighth abdominal segment smaller than the typical segment; tergum declivous and without distinct tergal areas; ninth segment rather small; tenth ventral and very small. Abdominal spiracles placed anteriorly and in a small separate corner piece, probably of the alar area; spiracles bifore and found on abdominal segments 1 to 8, that on the eighth being located slightly more dorsad than the rest.

Measurements of larval stages

Stage	Width of larval head
	Mm.
1	0.25 to 0.26
2	.36 to .37
3	.47 to .48
4	.61 to .65

THE PUPA

Pupa (fig. 8) uniformly white when first formed; length 3.75 to 4.25 mm., width 1.75 mm. Tips of elytra attaining fifth abdominal segment, inner wings rudimentary and almost completely concealed by elytra. Tips of metathoracic tarsi extending beyond tips of elytra. Head rounded, beak elongate. Head with two prominent spines toward vertex, a group of two small spines and two spinules on each side above eyes, two pairs of small spines near anterior margin and one on each side of front between eyes, three pairs of spines on beak between frontal ones and base of antennæ, a pair of small ones on beak midway between base of antennæ and tip of beak, a pair on sides of beak between latter pair and tip of beak, and two pairs of minute spines on tip of beak. Prothorax provided with one pair of anteromarginal setigerous tubercles, one pair of anterolateral, two pairs of mediolateral, and four pairs of dorsal setigerous tubercles; also a pair of minute mediolateral ventral spines. Mesonotum and metanotum normally each provided with three pairs of spines; one or more pairs often missing. Abdomen with seven distinct dorsal tergites, the seventh being much larger than the rest. Dorsal area of each armed with a pair of large spines and a pair of smaller ones. Lateral area of each tergite bearing a spine, at base of which is a small seta. Epipleural lobes each obscurely armed with two minute setæ. Ninth segment armed as usual with two prominent pleural spines.

LIFE HISTORY AND HABITS

The granary weevil normally hibernates during the winter in either the adult or the larval form. The adult is resistant to low temperatures and will survive a very cold winter. Adults resume activity with the first warm weather of spring, and egg laying soon begins. Overwintering larvæ at that time begin pupating. Hibernating adults kept in the laboratory at Washington, D. C., resumed egg laying in the early part of March.

THE ADULT

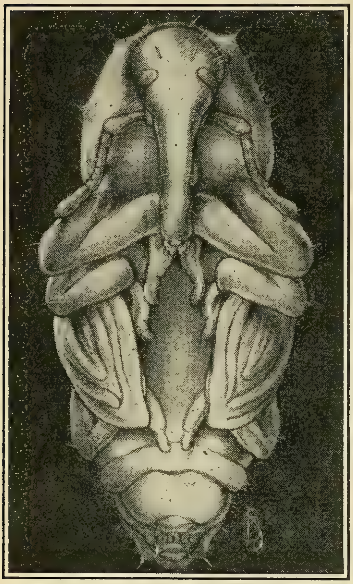


FIG. 8.—The granary weevil: Pupa, ventral view. Enlarged about 37 times

After transformation from the pupal to the adult form, the weevil remains within the seed for a short time until the body integuments harden and the color has changed to a dark chestnut brown. Some weevils remain to feed for a considerable time within the larger seeds. Shortly after emergence copulation takes place and is repeated at frequent intervals throughout the life of the weevil.

The weevils are rather sluggish in their actions and are very easily handled. If disturbed in any way they draw their legs up close to the body and remain motionless for some time. The females may be distinguished from the males by their smoother and more slender beaks.

PARTHENOGENESIS

Virgin females of the granary weevil have been observed to deposit an occasional egg, but none of these hatched.

DURATION OF ADULT LIFE WITHOUT FOOD

The granary weevil is capable of surviving without food for a considerable period, much longer than the closely related rice weevil, possibly because of its less active life and its restriction to a more temperate climate. The temperatures at which the insects were kept under observation had a very marked effect on their powers of resistance to starvation. Five lots of 50 weevils each were kept without food until they died. Each lot was placed in a separate compartment held at a constant temperature. These temperatures ranged from 55° to 85° F. and were maintained with but slight variation for the entire period and at a rather high humidity. The results are given in Table 1.

TABLE 1.—*Resistance of the granary weevil to starvation*

Date	Number of days starved	Number of adult weevils found dead at— 55° F.	60° F.	68° F.	76° F.	85° F.	Date	Number of days starved	Number of adult weevils found dead at— 55° F.	60° F.	68° F.	76° F.	85° F.
1920							1920						
June 24	7	0	0	0	12	28	July 12	25	0	7	0	------	------
25	8	5	0	11	12	0	14	27	0	6	3	------	------
26	9	0	0	5	4	4	15	28	0	2	0	------	------
27	10	0	0	0	2	0	16	29	3	0	4	------	------
28	11	0	4	0	14	0	17	30	0	7	0	------	------
29	12	7	7	0	3	7	18	31	2	0	0	------	------
July 1	14	3	0	7	2	2	19	32	0	0	3	------	------
2	15	0	5	0	0	0	20	33	0	3	0	------	------
3	16	0	3	0	1	7	21	34	1	0	2	------	------
4	17	5	2	4	------	1	23	36	0	1	------	------	------
6	19	3	0	0	------	1	29	42	1	------	------	------	------
7	20	2	0	0	------	------	Aug. 3	47	1	------	------	------	------
8	21	4	0	5	------	------	10	54	1	------	------	------	------
9	22	6	3	0	------	------	21	65	1	------	------	------	------
10	23	5	0	6	------	------							

The weevils subjected to a temperature of 85° F. were very active; more than 50 per cent died at the end of the first week of starvation, a few lingered on for some days, and one survived for 19 days. The weevils kept at 55° F. were sluggish; 50 per cent survived for three weeks and one for 65 days.

DURATION OF ADULT LIFE WITH FOOD

The average length of life with food, as indicated by the data in Table 2, is between 7 and 8 months.

This is the average of 35 females observed for oviposition records. Several individuals not included in this table lived considerably longer. Of a number of weevils that emerged on May 1, 1921, one female lived until July 2, 1922, and two females until July 10, 1922, a period of a little more than 14 months. The effect of a moderately low temperature, which permits occasional feeding but at which the adults are decidedly sluggish, is greatly to prolong life. Thus, of 30 adults placed, on September 18, 1921, in a refrigerator of the ordinary type, which maintained a temperature between 50° and 60° F., one lived two years and five months and four were still alive on January 15, 1924. Although adult life may be prolonged to cover a two-year period, it is not likely that conditions favoring such a long life obtain under normal warehouse conditions. The average length of life, as stated above, is about seven or eight months, with certain individuals living well over one year.

PREOVIPOSITION PERIOD

The data of Table 2 indicate that the granary weevil begins ovipositing from 6 to 148 days after emergence. In early spring females begin ovipositing about three weeks after emergences. Later, in the summer, the preoviposition period is reduced to approximately one week. Weevils emerging late in the fall have the longest preoviposition period, since they usually do not begin to oviposit until the following spring.

TABLE 2.—*Data concerning period of oviposition and adult longevity of the granary weevil*

No.	Date weevil emerged	Date first egg was laid	Length of pre-oviposition period	Date last egg was laid	Length of oviposition period	Number of eggs laid	Date of death	Length of life
	1920	1920	*Days*	1920	*Days*		1920	*Days*
1	Feb. 26	Mar. 19	22	June 14	87	152	June 18	113
2	---do----	Mar. 18	21	May 29	72	172	June 15	110
3	---do----	Mar. 24	27	June 11	79	150	June 23	118
4	---do----	Mar. 20	23	---do----	83	140	June 18	113
5	---do----	Mar. 19	22	Aug. 30	164	247	Sept. 1	188
6	May 25	June 2	8	Aug. 31	90	148	Sept. 2	100
7	June 17	June 23	6	Sept. 15	84	170	Sept. 20	95
				1921			1921	
8	Aug. 15	Aug. 27	12	June 10	287	254	June 27	316
9	Aug. 24	Sept. 4	11	Apr. 10	218	77	May 18	267
		1921						
10	Oct. 17	Mar. 3	137	June 30	119	141	Sept. 15	333
11	---do----	Feb. 24	130	July 22	148	144	Aug. 20	307
	1921			1922			1922	
12	Sept. 5	Sept. 18	13	Apr. 21	215	65	Apr. 25	232
13	Sept. 6	Sept. 19	13	May 12	235	71	May 24	260
14	---do----	Sept. 15	9	June 12	270	145	June 30	297
15	---do----	Sept. 18	12	May 8	232	128	May 15	251
16	---do----	Sept. 15	9	June 7	265	130	June 16	283
		1922						
17	Sept. 7	Feb. 2	148	May 7	94	98	May 25	260
18	Oct. 25	Jan. 28	95	Sept. 24	239	197	Oct. 8	348
19	---do----	Jan. 31	98	Apr. 21	80	36	May 1	188
20	---do----	Feb. 1	99	July 24	173	135	Aug. 4	283
21	---do----	Jan. 30	97	June 5	126	126	June 9	227
22	---do----	Feb. 1	99	July 28	177	234	July 31	279
23	---do----	---do----	99	June 9	128	181	June 12	230
24	---do----	Feb. 2	100	July 7	155	184	July 17	265
25	---do----	Feb. 1	99	May 27	115	74	July 10	258
26	---do----	---do----	99	Apr. 20	78	114	May 1	188
27	---do----	Feb. 2	100	June 9	127	200	June 12	230
28	---do----	Jan. 31	98	June 26	146	177	Aug. 7	286
29	---do----	Feb. 5	103	Aug. 2	178	166	Aug. 23	302
30	---do----	Jan. 31	98	May 29	118	210	June 5	223
31	---do----	Feb. 1	99	Apr. 13	71	95	Apr. 20	177
32	Nov. 7	Mar. 10	123	June 14	96	130	July 21	256
33	Nov. 8	Feb. 18	102	Aug. 6	169	242	Aug. 14	279
34	---do----	Mar. 19	131	May 25	67	78	June 1	205
35	---do----	Mar. 6	118	June 5	91	108	July 5	239

METHOD OF EGG LAYING

The beetles lay their eggs within the seeds of most of our common grains. A hole is excavated within the grain equal to the length of the slender proboscis of the female. When this is completed to the satisfaction of the beetle, she withdraws her proboscis and turning around swings the abdomen about until the cavity is located. The ovipositor is then thrust into the cavity and an egg deposited.

Before the ovipositor is withdrawn a translucent mass of gelatinous material is discharged on top of the egg and is tamped down level with the surface of the seed. This plug of gelatinous material quickly hardens, holding the egg in place and forming a protective covering for it.

The eggs are laid in all parts of the seeds but usually near one end. It is probably mechanically easier for the weevil to bore a hole at either end of the seed, owing to the need of a good foothold during the operation.

DAILY RATE OF OVIPOSITION

No data on the daily rate of oviposition of granary weevils of known age have ever been published. Strachov-Koltchin (*65*), after working with weevils of unknown ages and counting the adults emerging from kernels of grain with which they had been confined, published data from which he concluded that, when the average moisture content of the grain was from 15 to 17 per cent, a single egg is deposited at intervals of a few days at a temperature range of 59° to 65.5° F., one egg daily at 63.5° to 70° F., one to two eggs daily at 70° to 75° F., and two to three eggs daily at 75° to 82° F. As this author did not take into consideration the mortality among the immature stages, it is surprising how closely his data agree with those given in Table 3 based upon an actual count [4] of the eggs laid daily by females of known ages.

TABLE 3.—*Daily rate of oviposition of the granary weevil* [a, b, c]

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1921																									° *F.*
Sept 15			2		1																				78
16			1		1																				77
17			1		1																				79
18	1		1	1	1																				82
19		1	1	1	1																				75
20			1																						73
21			1		1																				75
22	1		1	1	1																				76
23				1	1																				75
24			1		2																				73
25	1		1	2	1																				75
26				2																					71
27				1	1																				69
28	2		1	1	1																				74
29					1																				78
30	1				1																				76
Oct. 1				1	3																				68
2					1																				67
3					1																				68
4					1																				66
1922																									
Jan. 28											1														71
30											1			1											61
31											1	1		1							1		1		75
Feb. 1											1		1	1	1	1		1	1		1		1	1	69
2						1						1		2	1	1	1	1	1	1				1	70
3											2			1		1	1		1	1	2		2	2	63
4						1					1	1		1	2		2	2	2	1	1		1		65
5														1	1	1	1	1	1	1	1	1		2	64
6											1	1		1		1	2		2	2		1	1		61
7															1	1	2	1	1	2		1		1	67
8											1	1			2	1	1	1	1	1	1	2	2		68
9											1				1		1	1	2	2	2	2	1		68
10						1					2			2	1	1	1	1	3	2		1		2	69
11												1		1	1	1	3		2	1	1	1	1	1	68
12												1				2	1		1			3	1	2	68
13						2					1	1		1	1	1	1		1	1		1	1		61
14												2		1			1		1		1	3		2	66
15											1			2	1	2	2		3		1	1	1		65
16						1					2	1		1		1	1		1	2		1	1		69
17						1					1			1	2	1			1		1		1	1	67
18								1			1	2		1	1	1	1	1		1	1	3	3	1	65

[a] No eggs were laid on dates omitted.

[b] Weevils emerged as adults as follows: Nos. 1 to 3 on Sept. 5, Nos. 4 and 5 on Sept. 6, No. 6 on Sept. 7, Nos. 7 to 10 on Nov. 7 and 8, and Nos. 11 to 24 on Oct. 25, 1921.

[c] Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24 of Table 3 are the same females recorded in Table 2 as Nos. 12, 13, 11, 15, 16, 17, 32, 33, 34, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, and 31, respectively.

[4] Two kernels of corn were inclosed with a pair of weevils and removed daily and examined beneath the binocular microscope.

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1922																									° F.
Feb. 19														1	1	1	1	1	1	1			1		66
20								1						1	1	1	1	1	1	1		1	2		58
21						2						1		1	2	1	1		2	2	1	1	1	2	69
22								1			1			1	1	1	1			1	1		3		62
23						2		1			1		1	2	1	2		1		1	1		2	1	69
24											2	1		1		1		1	4	2	1	2	1	1	70
25								1			1			2	1	1	1		2	2	1	1	3	1	67
26						1					1	1				1		1		1	1		1	1	60
27						1					1	1		1	1	1		1	1	1	1		2	2	67
28						1					3		1	1	2		2		4	1	1	1	3	1	67
Mar. 1						2		2		1	1			1	1	1		1	1		1	1	2		67
2						1		1			1		1	1	2	1		1	1	1	1	1	2	1	68
3								1		1	1				2		2		2		1		1		65
4								1		1	1	1		1	1		2	3	1	1	1	1		1	69
5								2		1		1	1		1	1	1	1	1		1		2	1	61
6											1	1			1	1		1	1	1	1	1	2	1	66
7								2		1	1			1	2	2	1		1	1	4		1	2	69
8	1					1		3		1	1	1		1	3	2		2	3	2	2	3	4		65
9	1			1				2		1	1	1		1	2	2	2		1	1		1	3	2	66
10	1		1	1	1	1	1	1		1	1			1	1		2	1		1	1	1			67
11	1		1	1	1	1	1	1		1	2		1	2	2		2		2	3			2	2	67
12	1		1	1	1	1	1	1		1				1		1	1		1	1	2			2	59
13			1	1	1	2	1	2		1			1	1	1	2	1	1	1	1	3		1	2	68
14		1	2	1	1	1	2	2		3				2	2	1	1			2	1	1	1	1	70
15	3	2	1	3	1	2	2	2		2	2			2	2	2	2	2	2	2	2		3	1	70
16	2	2	2		2	2	2	2		2	3	1	2	1	2	1	1	1	2	1	1		3	2	69
17	1	2	1	2	2	3	4	2		1	1		2	1	1	2	1		2	2	1	1	2	1	64
18	3	1		2	3	3	2	2		2	3	1	1	1	1	2	1	2		2	2		2	2	67
19	1	1	1	3	2	1	2	1	1	1				1		1				1			1	1	61
20	1	1	1	3	2	1	3	2	1	2				1	1	2			1	1	1		2	2	69
21	1	1	2	2	1	2	1	2	1	1	1	2		1	1	1		1		1			1	1	66
22	1	3	1	4	2	1		2		3	1			1	1	2	2		1	1	1		1	2	67
23		1	4	2	2	2	1	1	2	2					1	1	1	2	3	1	2		2	2	67
24	1	1	4	2	2	1		2	2	3					2	1	2	1	2	1	1		2	2	68
25	2	1	2	4	1	1		3		3	2		2		2	1	2		1	2	2	1	3	3	70
26	1	1		4	1	4		2	2	3				2	3	2	2		2	1	2		5	2	70
27	1	1		3	1	4		2	1	2		1	1	1	2	1	2	1	2	1	1	1	4	2	66
28	2	2	2	3	2	3	2	2		2	3		1		2	1	2	1	3	2	2	2		1	72
29	2	3	3	5	2	1	3	2	1	3	1		4	2	2	5	4	2	2	4	2	1	2	1	70
30		1	1	1		2	2	1		2	2		2	2		2	2	2	2	3	2		1	1	66
31	2	2	1	1	2	3	3	3	2	2	2		1		1	3	3		1	2	2	3	3	3	65
Apr. 1	1		3	1	1	2	1	4	1	2	1		1	2	2	2	2		2	3	2	2	2	2	68
2	2	2	1	2	2	1	2	2	2	1	2		2	2	1	2	1	2	2	3	2	2	2	1	58
3	1	1	2	3	2	2	2	3		2	1	1	1	1	2	3	2	1	2	2	2	1	3	3	65
4	1	2	1	2	3	2	1	2	1	2	1		3	1	3	3	2	2	1	2	3	2	2	2	69
5	2	1	2	2	2	1	3	2	2	1	2		2	2	2	2	3	3	2	2	2	2	5	3	68
6	2	3	2	3	2	3	3	5			1	1	2	1	2	2	2	2	2	3	2	3	2	1	69
7	2	2	2	2	1	2	2	2	2	3	2		2	2	1	1	1	3	3	2	3	2	2	1	68
8	1	2	3	2	2	2	3	2	2		2		3	2	2	2	3	1	2	5	2	2	3	2	75
9	2	1	1	1	2	2	2	1	1	2	1		2	1	2	2	2	2	2	2	2	1	1	2	79
10	2	3	2	3	1	1	2	2		2	2	1	2	2	2	3	2	2	3	2	1	2	4	2	80
11	3	2	2	2	1	2	2	2	2	2	2		1	2	3	2	2	2	2	2	3	2	2	3	80
12	2	2	2	2	2	2	2	3	2	1	1		3	2	2	1	3	1	1	3	2	2	2	2	72
13	2	2	2	2	3	3	2	2	2	2	2		2	1	2	2	2	2	2	2	2	2	3	2	72
14	1	1	2	2	1	1	2	1	1	1	1		1	1	2	2	2		1	2	2	1	2		72
15	1	1	1	3	1	1	2	2	1	1	1		1	1	2	1	1	1	1	3	2	1	1		69
16	1	1	1	2	1	2	2	2	1	1	1		1	1	2	2	2		1	3	1	1	2		66
17	1		2	2	1	1	2	1	1	1	1	1	1	1	2	2	2	1	1	3	2	1	2		68
18	1	2	1	3	2	1	1	2	2	2		2	1	3	2	3	1		1	3	1	2	4		67
19		1	1	2	1	1	1	2	1	1	1	1		2	2	2	1			2	1	1	3		69
20	1	1	1	2	2	1	2	2	2	2	2	1	2	1	1	2	3		1	2	1	2	2		67
21	1			1	2		2	1	1	1	1	1	2		1	2	2			2	1	1	1		68
22				1				1		1					1	1	1				1		1		67
23		1	1	1	1		1	2	1	1					1	1	1				2		2		59
24		1	1	2	1		1	2	1	1			1		2	2	1				2	1	2		64
25		1	1	2	1	1	1	2	1	1	2		2	1	3					2	1	1	2		69
26			1	2	1		3	1		1	2		2	1	2	1				3	1	1	2		73
27			1	1	1	1	3	1	1	1			1		2	1	1			1	1	1	3		71
28		1	1	2	2		1	3	2	1	1		1	1	1	1		1		1	1	1	2		69
29			1	3	1	1	1	2	1	1			1		1	1	2			1	1	1	2		70
30			2	2	2		1	3	1	2	1		1		1	1	1	1		1	1	1	2		67
May 1		1	2	1	2		1	3	1	2			1		1	1	2			2	1	2	3		68
2		1	3	1	1	1	2	2	1	1	2		1	1	1	2	1	1		1	2	2	2		70
3		1	3	1	1		2	2	1	1	1		2	2	1	2	2			1	2	2	3		70
4		1	1	1	1		1	1		1	1		1	1	3	2	2			2		1	2		70
5		1	1	1	1		1	1	1	1	1		1	1	2	2	1			2	1	1	1		71
6			1					2	1		2		1	1	1	1	1			1	1	1	2		71

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Daily mean temperature
1922																									° *F.*
May 7	-	-	2	1	1	1	1	2	1	1	1	-	2	1	1	1	1	-	-	2	1	1	1	-	73
8	-	-	1	1	1	-	1	2	1	1	2	-	1	1	1	1	1	-	-	1	1	1	2	-	73
9	-	1	1	-	1	-	1	3	1	1	-	-	2	-	1	1	1	-	-	2	3	1	2	-	72
10	-	1	1	-	1	-	1	2	1	1	1	-	1	1	1	1	1	1	-	2	3	1	3	-	72
11	-	1	2	-	2	-	2	2	3	1	3	-	2	3	2	2	2	-	-	2	1	2	1	-	76
12	-	1	3	-	1	-	2	2	3	1	2	-	2	2	2	2	1	1	-	3	1	2	1	-	75
13	-	-	3	-	-	-	-	2	1	-	1	-	1	2	2	-	1	-	-	3	2	1	1	-	74
14	-	-	3	-	1	-	1	2	1	-	1	-	1	2	1	1	1	-	-	3	2	1	2	-	75
15	-	-	3	-	1	-	1	2	1	-	1	-	1	1	2	1	1	-	-	3	2	1	1	-	74
16	-	-	2	-	-	-	-	3	1	1	2	-	2	-	2	2	-	-	-	2	-	2	2	-	73
17	-	-	1	-	1	-	-	2	1	-	2	-	2	1	1	2	1	-	-	2	1	2	1	-	72
18	-	-	2	-	-	-	1	3	1	-	1	-	-	1	2	-	2	-	-	1	-	2	2	-	74
19	-	-	2	-	1	-	-	2	1	-	1	-	-	1	1	1	1	-	-	1	1	2	2	-	70
20	-	-	1	-	1	-	1	2	1	-	1	-	1	-	1	2	2	1	-	1	1	2	2	-	72
21	-	-	2	-	1	-	2	1	2	-	1	-	2	1	2	1	1	-	-	2	1	1	1	-	75
22	-	-	2	-	1	-	1	2	1	-	2	-	-	1	1	2	2	-	-	1	1	2	1	-	78
23	-	-	1	-	-	-	2	2	2	-	1	-	-	1	2	2	2	-	-	1	2	2	2	-	79
24	-	-	1	-	-	-	1	1	1	-	1	-	2	-	2	2	1	-	-	2	1	2	1	-	77
25	-	-	2	-	1	-	2	1	1	-	1	-	1	1	1	1	1	-	-	1	1	2	1	-	76
26	-	-	1	-	-	-	2	2	-	-	2	-	1	1	1	2	2	-	-	1	1	1	1	-	79
27	-	-	2	-	1	-	2	3	-	-	1	-	-	1	2	1	1	1	-	1	2	2	2	-	74
28	-	-	2	-	1	-	1	2	-	-	1	-	2	-	1	2	2	-	-	2	1	2	1	-	67
29	-	-	1	-	1	-	2	1	-	-	1	-	1	-	1	2	1	-	-	1	1	2	1	-	69
30	-	-	1	-	1	-	1	2	-	-	1	-	2	1	2	1	1	-	-	1	1	2	-	-	73
31	-	-	2	-	1	-	1	1	-	-	1	-	2	1	2	1	2	-	-	1	1	2	-	-	75
June 1	-	-	1	-	1	-	2	1	-	1	1	-	1	1	1	2	1	-	-	1	1	2	-	-	74
2	-	-	-	-	-	-	-	2	-	1	1	-	1	-	1	2	2	-	-	1	1	1	-	-	76
3	-	-	-	-	1	-	-	1	-	1	1	-	1	1	1	1	1	-	-	1	2	-	-	-	78
4	-	-	-	-	-	-	-	2	-	1	1	-	1	-	1	2	1	-	-	1	1	-	-	-	77
5	-	-	-	-	1	-	-	1	-	1	1	-	1	1	1	1	1	-	-	1	1	1	-	-	79
6	-	-	-	-	1	-	1	1	-	-	1	-	1	-	1	2	2	-	-	2	2	1	-	-	80
7	-	-	-	-	1	-	1	1	-	-	1	-	1	-	1	2	2	-	-	2	2	1	-	-	83
8	-	-	-	-	-	-	-	3	-	-	2	-	1	-	-	1	3	-	-	2	-	-	-	-	83
9	-	-	1	-	-	-	1	3	-	-	2	-	1	-	1	1	2	-	-	2	-	1	-	-	82
10	-	-	-	-	-	-	1	1	-	-	1	-	-	-	2	-	1	-	-	-	2	1	-	-	84
11	-	-	-	-	-	-	-	1	-	-	1	-	-	-	2	-	1	-	-	-	1	1	-	-	86
12	-	-	1	-	-	-	1	1	-	-	1	-	-	-	2	-	1	-	-	-	2	1	-	-	79
13	-	-	-	-	-	-	-	1	-	-	1	-	-	-	1	-	1	-	-	-	-	-	-	-	73
14	-	-	-	-	-	-	1	1	-	-	1	-	-	-	1	-	1	-	-	-	-	-	-	-	70
15	-	-	-	-	-	-	-	2	-	-	1	-	-	-	1	-	-	-	-	-	1	-	-	-	73
16	-	-	-	-	-	-	-	2	-	-	1	-	-	-	1	-	-	-	-	-	1	1	-	-	78
17	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	1	1	-	-	79
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	-	-	79
19	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	1	1	-	-	78
20	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	1	1	-	-	79
21	-	-	-	-	-	-	-	2	-	-	2	-	1	-	2	-	-	-	-	-	-	2	-	-	78
22	-	-	-	-	-	-	-	2	-	-	2	-	1	-	2	-	-	-	-	-	-	1	-	-	74
23	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	1	2	-	-	73
24	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	1	1	-	-	79
25	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	82
26	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	80
27	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	79
28	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	81
29	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	79
30	-	-	-	-	-	-	-	1	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	82
July 1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	85
2	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	86
3	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-	84
4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	77
5	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-	1	-	-	70
6	-	-	-	-	-	-	-	2	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	73
7	-	-	-	-	-	-	-	2	-	-	1	-	1	-	1	-	1	-	-	-	-	-	-	-	72
8	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	79
9	-	-	-	-	-	-	-	2	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	80
10	-	-	-	-	-	-	-	2	-	-	1	-	1	-	1	-	-	-	-	-	-	1	-	-	79
11	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	82
12	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	88
14	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	75
15	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	73
16	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	77
17	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	79
18	-	-	-	-	-	-	-	1	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	80
19	-	-	-	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	80
20	-	-	-	-	-	-	-	1	-	-	1	-	1	-	2	-	-	-	-	-	-	-	-	-	78
21	-	-	-	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	76
22	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	79
23	-	-	-	-	-	-	-	1	-	-	1	-	1	-	2	-	-	-	-	-	-	1	-	-	82
24	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	87

TABLE 3.—*Daily rate of oviposition of the granary weevil*—Continued

Date of oviposition	Weevil number and oviposition record																								Daily mean temperature
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1922																									° F.
July 25	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80
26	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75
27	-	-	-	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	77
28	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	81
29	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79
30	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	79
31	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77
Aug. 1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	78
2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	77
4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	77
6	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80
8	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	78
9	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	72
23	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	75
25	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	76
Sept. 1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	76
3	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	75
5	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	80
9	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	77
10	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	78
14	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	74
15	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	77
17	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	70
19	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	68
20	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	69
23	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	70
24	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	73
Total eggs	65	71	145	128	130	98	130	242	78	108	197	36	135	126	234	181	184	74	114	200	177	166	210	95	-

During the experiments recorded in Table 3 the average moisture content of the grain (corn) was about 12 to 14 per cent. It will be noted that from one to five eggs were laid per day when oviposition took place; 58.4 per cent of the 2,199 records of oviposition were for one egg per day, 33.4 per cent for two eggs per day, 7 per cent for three eggs per day, 0.9 per cent for four eggs per day, and 0.3 per cent for five eggs per day. On the 5 days when five eggs per day were laid the mean temperatures were 70°, 70°, 68°, 69°, and 75° F. and not more than two of the females under observation deposited so large a number of eggs on any one day. On the 19 days when four eggs were deposited each day, the mean temperatures were 70°, 67°, 69°, 65°, 64°, 67°, 67°, 68°, 70°, 70°, 70°, 66°, 66°, 70°, 70°, 70°, 68°, 80°, and 67° F. The more usual number of eggs deposited per day appears to be one or two. In one instance when the mean temperature fell as low as 58° F., 6 females deposited one egg each, 16 females deposited two eggs each, and 1 female deposited three eggs. When these records were made (April 2) the female weevils were in the midst of spring activity. Earlier in the year, on February 20, when the mean temperature was 58° F., but at the beginning of spring oviposition, 9 females deposited one egg each and only 1 female two eggs. One female, No. 20, on two occasions deposited three eggs for four consecutive days when the temperature means were 69°, 66°, 68°, and 67° F., and 75°, 74°, 75°, and 74° F. It is interesting to note, however, that during the latter period of four days when a second female (No. 3) also deposited three eggs each day, other records show but one egg deposited in 32 instances, two eggs in 19 instances, and three eggs in only 1 instance. A female, No. 11, deposited only a single egg per day on the 39 oviposition days between June 23 and September 25, when she died, although the temperature means for this period ranged from 68° to 88° F. and averaged well above 70° F. This female, which began ovipositing on January 28, was therefore nearing the end of her life; still she deposited but one egg on each of 120 oviposition days, two eggs on each of 31 oviposition days, and three eggs on each of 5 oviposition days.

In the absence of definite data on the normal larval mortality, it is believed to be rather high, and this is thought by the writers to account for the somewhat higher daily rate of oviposition recorded in Table 3 as compared with the conclusion of Strachov-Koltchin (*65*).

DURATION OF OVIPOSITION

The duration of the oviposition period is influenced by several factors and varies considerably. (See Tables 2 and 3.) Those adults that emerge late in the season and commence egg laying in the fall have a long oviposition period. They cease ovipositing on the approach of cold weather and commence again in the spring, during February or March. Thus weevil No. 3, of Table 3, emerging on September 5, began ovipositing September 15, and oviposited almost daily until September 28, when she ceased laying until March 10, only to resume egg laying and to continue it almost daily until June 1, ceasing entirely on June 12. This record of duration of oviposition of 270 days is second only to that of 287 days, August 27, 1920, to June 10, 1921, by a female depositing 254 eggs. (No. 8, Table 2.)

Adults emerging in the spring have a shorter oviposition period, because they deposit all their eggs during a single season. The shortest oviposition period recorded in Table 3 is 67 days, Weevil No. 9, March 19 to May 25, 1922. Weevil No. 11 of Table 3, depositing a total of 197 eggs, emerged on October 25, 1921, but did not begin ovipositing until January 28, 1922, after which she laid eggs with considerable regularity until September 24, 1922, thus having an oviposition period of 239 days. Weevil No. 8, with an egg-laying capacity of 242, emerged November 7, 1921, began ovipositing February 18, 1922, and continued until August 6, 1922, an oviposition period of 169 days.

The average length of the oviposition period for adults emerging during the spring and early summer is between three and four months.

NUMBER OF EGGS DEPOSITED BY SINGLE FEMALES

The data of Strachov-Koltchin, which are the only data previously published on the egg-laying capacity of the granary weevil, were obtained with promiscuously captured females. From 11 females he secured 65, 78, 87, 107, 116, 121, 129, 135, 149, 153, and 167 eggs respectively. But he concluded that "since the females used were in most cases not young, it is possible to assume that a normal number of eggs deposited by a single female during her life is 135 to 167."

The 24 females of known ages, the oviposition records of which are given in Table 3, deposited totals of 36, 65, 71, 74, 78, 95, 98, 108, 114, 126, 128, 130, 130, 135, 145, 166, 177, 181, 184, 197, 200, 210, 234, and 242. The largest number of eggs deposited by any single female recorded is 254 (Table 2, No. 8). In Table 2 are recorded the total numbers of eggs deposited by 35 females, the daily oviposition records of 24 of which are given in Table 3.

THE EGG

INCUBATION PERIOD

Data on the incubation period of the granary weevil accompanied by the maximum, minimum, and mean temperatures for the period, have never been published. References to the length of the egg stage are very fragmentary except those by Strachov-Koltchin *(65)*, in which the day, but not the night, temperatures are given. This writer concludes that the incubation period may range from about 5 days at 75° F. to 15 days at 62° F. Observations made on individual eggs indicated that at 75° F. the incubation period might be 5 to 6 days; at 73° and 82° F., 6 days; at 69° F., 8 days; at 68° F., 9 days; and at 67° F., 9 to 10 days.

TABLE 4.—*Duration of the egg stage of the granary weevil*

No.	Date egg laid	Date egg hatched	Temperature for incubation period			Length of egg stage	No.	Date egg laid	Date egg hatched	Temperature for incubation period			Length of egg stage
			Maximum	Minimum	Mean					Maximum	Minimum	Mean	
	1919	1919	°F.	°F.	°F.	Days		1920	1920	°F.	°F.	°F.	Days
1	Sept. 30	Oct. 5	98	67	79.8	5	23	Sept. 2	Sept. 6	96	68	81.5	4
2	Oct. 1	do	98	68	78.0	4	24	Sept. 3	Sept. 8	95	68	82.8	5
3	Oct. 2	Oct. 6	98	68	83.1	4	25	Oct. 5	Oct. 12	89	50	70.9	7
4	Oct. 3	Oct. 7	98	67	83.1	4	26	Nov. 7	Nov. 13	88	57	72.1	6
5	Oct. 15	Oct. 19	94	67	80.4	4	27	Nov. 12	Nov. 17	79	57	68.5	5
	1920	1920						Nov. 15	Nov. 20	76	39	62.9	5
6	Mar. 18	Mar. 24	90	54	69.7	6	28	Dec. 4	Dec. 19	84	35	61.0	15
7	Mar. 25	Mar. 31	95	52	76.8	6	29	Dec. 15	Dec. 25	84	35	60.0	10
8	Mar. 26	Apr. 1	95	58	77.5	6	30	Dec. 16	Dec. 24	84	35	61.2	8
9	Mar. 28	Apr. 3	95	55	78.1	6	31	1921	1921				
10	Apr. 9	Apr. 15	85	46	66.6	6	32	Jan. 11	Jan. 20	80	34	61.2	9
11	Apr. 13	Apr. 18	90	46	68.7	5	33	Jan. 21	Jan. 30	84	43	62.6	9
12	Apr. 16	Apr. 21	92	54	76.1	5	34	Jan. 23	Feb. 1	84	43	64.0	9
13	Apr. 20	Apr. 25	93	62	78.9	5	35	Jan. 31	Feb. 12	88	43	67.6	12
14	June 23	June 27	93	69	79.9	4	36	Feb. 2	Feb. 14	88	39	66.2	12
15	June 26	June 30	93	66	78.6	4	37	Feb. 3	Feb. 15	88	39	66.5	12
16	July 3	July 7	96	70	82.9	4	38	Feb. 11	Feb. 23	86	39	65.2	12
17	July 14	July 18	94	68	81.0	4	39	July 26	July 30	----	----	85.4	4
18	July 15	July 20	94	68	81.3	5	40	July 30	Aug. 3	----	----	81.5	4
19	July 20	July 24	94	70	81.5	4	41	Aug. 2	Aug. 6	----	----	83.5	4
20	July 24	July 28	95	68	80.5	4	42	Aug. 15	Aug. 20	86	69	76.5	5
21	Aug. 5	Aug. 9	93	69	80.2	4	43	Sept. 26	Oct. 1	83	65	72.5	5
22	Sept. 1	Sept. 5	96	68	81.6	4							

Of the data presented by the writers in Table 4, those for 1919 and 1920 were secured under the semitropical conditions of Florida and those of 1921 under laboratory conditions at Washington, D. C. These data indicate that the minimum period for egg development is 4 days when the temperature means average about 78° to 80° F. The longest incubation period, 15 days, recorded in Table 4, covers a period when the daily temperatures ranged from a minimum of 35° F. to a maximum of 84° F., with a mean of 61° F. But at a mean of 60° F., with the same range in the maximum and minimum temperatures for the period, one egg (No. 30) required only 10 days for development. Certain eggs held for 28 days in refrigeration at

30° F., and then removed to a warm temperature, hatched 32 days after deposition. Although 4 days is the minimum period observed by the writers, eggs have been observed to hatch in 5 days after deposition when the temperature for the incubation period ranged from a mean of 68.7° F. (90° F. maximum, 46° F. minimum) and of 82.8° F. (95° F. maximum, 68° F. minimum).

Although the data of Table 4 indicate that the length of the incubation period is from 4 to 15 days under more normal conditions and may be extended over a period of at least 32 days during colder weather, there are dealers in grain who firmly believe that eggs are capable of passing through a very long period of development, and that they are capable of a suspended development when temperature conditions are unfavorable to growth, only later to resume normal development upon the return of favorable temperature conditions. It has been found that the female weevils do not begin to mate and lay eggs until the temperature is from 61° to 63° F., and that even at these temperatures eggs are not deposited every day. It is not until the temperature has risen to 66° to 68° F. that mating and oviposition occur daily. It would appear from observations that eggs are not deposited at temperatures below the minimum at which they can start development. Should the temperature drop to below 50° to 55° F. for a considerable period, there is every reason to believe that egg development is suspended indefinitely and that eggs perish for lack of warmth. No eggs were observed to hatch after the temperature of the grain had reached 95° F. or above.

THE LARVA

When the embryo is fully developed, its undulating movements cause a rupture of the thin eggshell, and the young larva emerges to find an abundance of food ready at hand. It immediately begins to feed, burrowing through the tissues of the seed, forming a winding tunnel that increases in size with the growth of the larva. The tunnel is often close to the surface of the seed, and in corn, particularly, the progress of the larva is sometimes distinctly visible through the seed coat (fig. 4).

FOOD OF THE LARVA

The larva breeds in all the common grains, such as corn (fig. 4), oats, barley (fig. 2), rye, wheat (fig. 3), kafir, buckwheat, millet, and also in chick-peas (fig. 9). It is said to breed in acorns, chestnuts, and sunflower seeds, although Strachov-Koltchin states that he failed to get them to breed in sunflower seeds. It is unable to breed in loose farinaceous material, such as flour and semolina used in making macaroni, but breeds readily in manufactured products of cereals, such as macaroni (fig. 5), noodles, and probably other similar products, and in milled cereals that have become badly caked from excess moisture. The larva feeds on all parts of the seed, but prefers the soft starchy portion. As it bores and tunnels through the seed it thrusts the borings and frass behind it, so that the mine it leaves behind is always filled. It has been found that larvae can feed in grain with a moisture content as low as 8 per cent, although feeding undoubtedly progresses more normally when the moisture content is about 14 to 16 per cent.

TABLE 5.—*Duration of larval stage of the granary weevil*

No.	Date larvæ hatched	Date of first molt	Length of first instar	Mean temperature	Date of second molt	Length of second instar	Mean temperature	Date of third molt	Length of third instar	Mean temperature	Date prepupal stage began	Length of fourth instar	Mean temperature	Date larva pupated	Length prepupal stage	Mean temperature	Length larval stage	Mean temperature: Maximum	Mean temperature: Minimum
	1919	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	1919	Days	°F.	Days	°F.	°F.
1	Oct. 5	Oct. 9	4	82	Oct. 13	4	81	Oct. 17	4	80	Oct. 24	7	80	Oct. 25	1	82	20	93	67
2	do	Oct. 10	5	82	Oct. 14	4	81	Oct. 21	7	81	Oct. 30	9	80	Nov. 1	2	80	27	93	67
3	Oct. 6	do	4	82	do	4	80	Oct. 18	4	80	Oct. 26	8	81	Oct. 27	1	79	21	93	67
4	Oct. 7	Oct. 11	4	82	Oct. 15	4	79	Oct. 20	5	81	Oct. 31	11	79	Nov. 1	1	81	25	93	67
5	Oct. 19	Oct. 23	4	80	Oct. 27	4	80	Oct. 31	4	78	Nov. 9	9	76	Nov. 10	1	72	22	91	65
	1920	1920			1920			1920			1920			1920					
6	Mar. 24	Mar. 29	5	74	Apr. 5	7	78	Apr. 15	10	66	Apr. 25	10	76	Apr. 26	1	78	33	87	62
7	Mar. 31	Apr. 8	8	72	Apr. 14	6	68	Apr. 22	8	73	Apr. 29	7	78	Apr. 30	1	69	30	84	61
8	Apr. 1	do	7	72	Apr. 15	7	68	Apr. 21	6	73	Apr. 27	6	79	Apr. 28	1	74	27	84	61
9	Apr. 3	Apr. 10	7	69	Apr. 16	6	66	Apr. 22	6	76	Apr. 28	6	79	Apr. 29	1	67	26	84	61
10	Apr. 15	Apr. 21	6	73	Apr. 27	6	79	May 2	5	73	May 8	6	74	May 9	1	73	24	87	63
11	Apr. 18	Apr. 24	6	79	Apr. 28	4	80	May 3	5	73	May 11	8	74	May 12	1	72	24	87	63
12	Apr. 21	Apr. 26	5	75	Apr. 30	4	78	May 5	5	76	May 12	7	74	May 13	1	75	22	87	63
13	Apr. 25	Apr. 30	5	74	May 5	5	75	May 10	5	74	May 18	8	76	May 19	1	73	24	87	63
14	June 27	July 1	4	78	July 5	4	83	July 9	4	82	July 15	6	84	July 16	1	81	19	93	70
15	June 30	July 4	4	82	July 9	5	83	July 14	5	84	Aug. 2	19	81	Aug. 3	1	82	34	93	70
16	July 7	July 11	4	83	July 15	4	84	July 19	4	81	July 25	6	82	July 26	1	80	19	93	70
17	July 18	July 22	4	82	July 27	5	81	July 31	4	81	Aug. 13	13	81	Aug. 14	1	82	27	93	70
18	July 20	July 24	4	82	July 28	4	81	Aug. 1	4	81	Aug. 8	7	81	Aug. 9	1	80	20	93	70
19	July 24	July 28	4	81	Aug. 1	4	81	Aug. 5	4	81	Aug. 18	13	81	Aug. 19	1	82	26	93	70
20	July 28	Aug. 1	4	81	Aug. 5	4	81	Aug. 10	5	80	Aug. 20	10	81	Aug. 21	1	80	24	93	70
21	Aug. 9	Aug. 13	4	82	Aug. 17	4	81	Aug. 22	5	81	Aug. 31	9	83	Sept. 1	1	82	23	93	70
22	Sept. 5	Sept. 9	4	82	Sept. 15	6	84	Sept. 20	5	80	Sept. 27	7	80	Sept. 28	1	80	23	92	70
23	Sept. 6	Sept. 11	5	82	do	4	85	Sept. 21	6	80	Sept. 29	8	79	Sept. 30	1	75	24	92	70
24	Sept. 8	Sept. 14	6	84	Sept. 19	5	81	Sept. 26	7	80	Oct. 9	13	73	Oct. 10	1	68	32	91	65
25	Oct. 12	Oct. 18	6	74	Oct. 23	5	77	Oct. 28	5	76	Nov. 9	12	69	Nov. 10	1	74	29	86	61
											1921			1921					
26	Nov. 13	Nov. 21	8	64	Nov. 30	9	64	Dec. 12	12	62	Jan. 2	21	61	Jan. 3	1	69	51	77	51
27	do	Nov. 22	9	64	Dec. 2	10	60	do	10	61	Jan. 5	24	63	Jan. 7	2	66	55	77	51
28	Nov. 17	Nov. 25	8	62	Dec. 8	13	63	Dec. 25	17	61	Jan. 14	20	64	Jan. 15	1	62	59	77	49
29	Nov. 20	Nov. 29	9	63	Dec. 9	10	64	Dec. 22	13	60	Jan. 10	19	65	Jan. 12	2	61	53	77	49
					1921			1921											
30	Dec. 19	Nov. 31	12	62	Jan. 9	9	67	Jan. 17	8	61	Jan. 28	11	63	Jan. 29	1	60	41	76	49
		1921																	
31	Dec. 25	Jan. 3	9	61	Jan. 12	9	66	Jan. 23	11	62	Feb. 1	9	63	Feb. 3	2	63	40	77	50
32	Dec. 24	do	10	61	Jan. 16	13	65	Jan. 25	9	63	Feb. 10	16	65	Feb. 12	2	67	50	76	51

	1921																		
33	Jan. 20	Jan. 31	11	63	Feb. 12	12	66	Feb. 22	10	64	Mar. 2	8	59	Mar. 3	1	64	42	78	50
34	Jan. 30	Feb. 11	12	68	Feb. 22	11	64	Mar. 2	8	59	Mar. 12	10	68	Mar. 13	1	75	42	80	51
35	Feb. 1	Feb. 13	12	61	Feb. 23	10	64	Mar. 4	9	60	do	8	70	do	1	75	40	80	51
36	Feb. 12	Feb. 23	11	63	Mar. 9	14	62	Mar. 19	10	76	Mar. 27	8	75	Mar. 28	1	76	44	83	55
37	Feb. 14	Feb. 24	10	64	do	13	62	Mar. 16	7	75	Mar. 24	8	76	Mar. 25	1	76	39	83	55
38	Feb. 15	Feb. 23	8	65	Mar. 3	8	59	Mar. 12	9	71	do	12	76	do	1	76	38	83	55
39	Feb. 23	Mar. 2	7	59	Mar. 10	8	67	Mar. 19	9	76	Apr. 3	15	75	Apr. 4	1	72	40	85	57
																		Mean	
40	July 30	Aug. 4	5	81	Aug. 9	5	81	Aug. 15	6	77	Aug. 27	12	74	Aug. 28	1	73	29	77	
41	Aug. 3	Aug. 7	4	82	Aug. 11	4	78	Aug. 16	5	77	do	11	75	do	1	73	25	77	
42	Aug. 6	Aug. 10	4	80	Aug. 15	5	77	Aug. 19	4	75	Aug. 28	9	75	Aug. 29	1	77	23	77	
43	Aug. 20	Aug. 24	4	77	Aug. 29	5	73	Sept. 4	6	84	Sept. 16	12	80	Sept. 17	1	78	28	78	
44	Oct. 1	Oct. 7	6	68	Oct. 12	5	70	Oct. 19	7	71	Oct. 30	11	71	Oct. 31	1	71	30	69	

LENGTH OF LARVAL STAGE

The length of the larval stage is influenced chiefly by temperature and moisture. With a good food supply of normal moisture content the larval stage during summer months was found to last from 19 to 34 days. Individual larvæ showed considerable difference in the length of the developmental period; thus two larvæ completed their development during summer in 19 and 34 days, respectively, when the mean temperatures ranged from a maximum of 93° F. to a minimum of 70° F. The longest larval development recorded by the writers is 59 days, when the mean temperatures varied from 77° to 49° F. The development of 44 larvæ is recorded in Table 5. In Russia Strachov-Koltchin (*65*) found that the period for larval development varied from 21½ to 84 days, according to the temperature.

NUMBER AND DURATION OF LARVAL INSTARS

FIG. 9.—Chickpeas sectioned to reveal honeycombing of interior of seed by feeding of larvæ and adults of the granary weevil

The larva of the granary weevil molts three times at more or less regular intervals. The first three instars are usually about equal in length; the fourth is somewhat longer. During summer weather the first three instars are of from 4 to 5 days' duration and the fourth lasts from 6 to 19 days. The duration of the larval instars with the mean temperature for the period is given in Table 5.

These data indicate that the first larval instar was from 4 to 12 days in length when the temperature means were from 84° to 61° F.; the second instar from 4 to 14 days in length when the means varied from 84° to 59° F.; the third instar from 4 to 17 days in length when the mean temperatures for the period varied from 84° to 59° F.; the fourth larval stage from 6 to 24 days when the temperature means varied from 84° to 59° F.

THE PUPA

After attaining its growth the larva prepares a pupal cell at the end of its burrow, using a mixture of frass, borings, and larval secretions to wall in the open end of its burrow. If the cell is accidentally broken open before the larva has transformed, the break is repaired. After the cell is completed, the larva assumes a prepupal form that normally lasts for one day in summer or two days in colder weather before it transforms to the pupal stage. Data regarding the length of the pupal stage are given in Table 6.

TABLE 6.—*Duration of the pupal stage of the granary weevil*

No.	Date of—		Length pupal stage	Mean temperatures		No.	Date of—		Length pupal stage	Mean temperatures	
	Pupation	Emergence		Maximum	Minimum		Pupation	Emergence		Maximum	Minimum
	1919		*Days*	*°F.*	*°F.*		1920		*Days*	*°F.*	*°F.*
1	Oct. 25	Oct. 30	5	91	66	24	Oct. 10	Oct. 16	6	88	58
2	Nov. 1	Nov. 6	5	86	66	25	Nov. 10	Nov. 18	8	74	57
3	Oct. 27	Nov. 1	5	91	67						
4	Nov. 1	Nov. 6	5	86	66		1921				
5	Nov. 10	Nov. 17	7	81	59	26	Jan. 3	Jan. 13	10	79	52
						27	Jan. 7	Jan. 16	9	75	48
	1920					28	Jan. 15	Jan. 31	16	75	48
6	Apr. 26	May 3	7	86	64	29	Jan. 12	Jan. 22	10	77	49
7	Apr. 30	May 6	6	88	62	30	Jan. 29	Feb. 12	14	79	53
8	Apr. 28	May 4	6	85	61	31	Feb. 3	Feb. 13	10	79	54
9	Apr. 29	May 5	6	87	61	32	Feb. 12	Feb. 23	11	80	47
10	May 9	May 15	6	89	62	33	Mar. 3	Mar. 18	15	78	59
11	May 12	May 18	6	88	65	34	Mar. 13	Mar. 23	10	90	61
12	May 13	do	5	88	66	35	do	Mar. 21	8	91	62
13	May 19	May 24	5	88	63	36	Mar. 28	Apr. 5	8	85	62
14	July 16	July 22	6	93	71	37	Mar. 25	Apr. 2	8	87	63
15	Aug. 3	Aug. 10	7	91	70	38	do	Apr. 1	7	87	63
16	July 26	Aug. 1	6	92	70	39	Apr. 4	Apr. 10	6	89	60
17	Aug. 14	Aug. 21	7	93	69					Mean	
18	Aug. 9	Aug. 15	6	94	70	40	Aug. 28	Sept. 3	6	82	
19	Aug. 19	Aug. 25	6	95	69	41	do	Sept. 2	5	82	
20	Aug. 21	Aug. 27	6	95	69	42	Aug. 29	Sept. 3	5	84	
21	Sept. 1	Sept. 6	5	93	70	43	Sept. 17	Sept. 22	5	77	
22	Sept. 28	Oct. 3	5	82	60	44	Oct. 31	Nov. 7	7	68	
23	Sept. 30	Oct. 6	6	81	59						

These data indicate that during the warm season of the year, when the mean temperatures vary from a maximum of 85° to 95° F. to a minimum of 61° to 71° F., the pupal stage may require a minimum of 5 days for development. During the hottest summer weather pupal development was completed in from 5 to 7 days. Certain pupæ completed their development in 5, 6, and 7 days when the mean temperature was 77°, 82°, and 68° F., respectively. During the colder season six pupæ completed their development in 16, 10, 14, 10, 11, and 15 days when the mean temperatures were 61.5°, 63°, 66°, 66.5°, 63.5°, and 68.5° F., respectively.

LENGTH OF DEVELOPMENTAL PERIOD

The length of the developmental period of the granary weevil is comparatively short during moderately warm weather. The cycle from egg to adult is recorded in Table 7.

TABLE 7.—*Duration of the developmental period of the granary weevil*

No.	Number of days in—			Number of days from egg to adult	Mean temperature for period	No.	Number of days in—			Number of days from egg to adult	Mean temperature for period
	Egg stage	Larval stage	Pupal stage				Egg stage	Larval stage	Pupal stage		
					° F.						° F.
1	5	20	5	30	80.4	23	4	24	6	34	80.0
2	4	27	5	36	80.4	24	5	32	6	43	77.3
3	4	21	5	30	80.4	25	7	29	8	44	70.4
4	4	25	5	34	80.4	26	7	51	10	68	64.3
5	4	22	7	33	77.0	27	6	55	9	70	64.3
6	6	33	7	46	72.9	28	5	59	16	80	62.9
7	6	30	6	42	73.6	29	5	53	10	68	62.9
8	6	27	6	39	73.6	30	15	41	14	70	62.9
9	6	26	6	38	73.6	31	10	40	10	60	63.3
10	6	24	6	36	74.0	32	8	50	11	69	63.1
11	5	24	6	35	74.7	33	9	42	15	66	65.7
12	5	22	5	32	75.5	34	9	42	10	61	66.0
13	5	24	5	34	75.3	35	9	40	8	57	66.7
14	4	19	6	29	80.5	36	12	44	8	64	67.0
15	4	34	7	45	81.0	37	12	39	8	59	68.6
16	4	19	5	28	81.5	38	12	38	7	57	68.6
17	4	27	7	38	81.5	39	12	40	6	58	69.7
18	5	20	6	31	81.5	40	4	29	6	39	79.0
19	4	26	6	36	81.5	41	4	25	5	34	79.0
20	4	24	6	34	81.5	42	4	23	5	32	79.0
21	4	23	5	32	81.5	43	5	28	5	38	78.1
22	4	23	5	32	79.3	44	5	30	7	42	70.0

Several specimens were reared from egg to adult in 28 days, and this together with a preoviposition period of about 7 days would give a possible complete life cycle from egg to egg of 35 days. This, however, is a much shorter life cycle than normal, for in summer the average length of the period from egg to adult, as shown in Table 7, is between 30 and 40 days, and the preoviposition period may be as short as 6 days in midsummer or, when the adult emerges in the fall or early winter, as long as 123 or 148 days. In the vicinity of Washington, D. C., there are between three and four generations a year.

RESISTANCE TO HIGH TEMPERATURES

As already recorded by the writers (*3*), the granary weevil is not very resistant to high temperatures. Exposure for a very few hours to 115° F., for one hour to 118° to 120° F., or for 30 minutes to 130° F., will kill all stages. Moderately high temperatures also are fatal to the granary weevil if maintained for any length of time. Of adults placed in an incubator maintained at 95° F., four-fifths died on the fifth day of exposure, a few survived for 9 days, and one for 13 days. Little, if any, feeding occurred during this period and no eggs were laid. Eggs incubated at 95° F. failed to hatch, and larvæ exposed to this temperature did not complete their development.

RESISTANCE TO LOW TEMPERATURES

The granary weevil prefers a cool climate in which to breed and is much more resistant to low temperatures than is the rice weevil.

The effect of a moderately low temperature is to prolong the life of the adult weevil. As already recorded by the writers (*3*), a few of the weevils placed in an ordinary refrigerator with a temperature that ranged between 50° and 60° F. lived for a period of 29 months. They were almost inactive at this temperature but fed occasionally. When kept at a temperature of 35° to 40° F. a few adults lived as long as 111 days, whereas at temperatures ranging from 40° to 45° F. adults survived for 105 days. A temperature of 30° to 35° F. proved fatal to adults of the granary weevil after 73 days. A temperature of 25° to 30° F. killed all adults within 46 days. At 20° to 25° F. all adults were dead at the end of 33 days; at 15° to 20° F., at the end of 14 days; at 5° F., at the end of 7½ hours. A constant temperature of zero proved fatal to adults of the granary weevil at the end of an exposure of 5 hours.

Twenty per cent of the eggs of the granary weevil survived an exposure to a constant temperature of 30° F. for 28 days. Larvæ exposed to this temperature survived for 44 days.

PARASITES

The granary weevil is attacked by several parasitic Hymenoptera while in the larval and pupal stages. The two most commonly observed in North America are *Aplastomorpha calandrae* Howard and *Chaetospila elegans* Westw., while *Lariophagus distinguendus* Forst. is apparently the most abundant parasite of the granary weevil in Europe. Goodrich (*34*), in 1921, wrote regarding parasites of beetles infesting grain.

A predacious mite, *Pediculoides ventricosus* Newport, frequently attacks the egg, larva, and pupa of the granary weevil.

CONTROL MEASURES

Control measures consist chiefly in the use of heat, cold, and fumigants. The use of heat, in the ordinary grain heating and drying equipment on the market, seems not to be popular with grain dealers since grain is purchased by weight and heating results in the loss of moisture. A temperature of 118° F. to 120° F. for one hour or of 130° F. for 30 minutes kills all stages of the weevil actually subjected to it. It should not be forgotten that the grain must be heated sufficiently to allow the proper amount of heat to penetrate to the insects concealed within. In quarantine work the Federal Horticultural Board has found it advisable to require that corn entering this country from Mexico be subjected to a temperature of 200° F. for at least five minutes to insure freedom from insect pests.

Dean (*15*) and Goodwin (*33*) have published on heat control.

Carbon disulphide is the only fumigant at present in general use in the United States for killing weevils in grain in bulk. When carbon disulphide is used at the rate of from 5 to 15 pounds per 1,000 bushels, according to the tightness of the crib, the granary weevil can be killed in all stages. Carbon tetrachloride alone and ethyl acetate-carbon tetrachloride mixture (*47*) vary in effectiveness and must be used from two to four times as strong as carbon disulphide. The ethyl acetate-carbon tetrachloride mixture, however, is not entirely satisfactory to the grain trade on account of an odor which this mixture may leave.

The running of grain from bin to bin during very cold weather has been practiced. The writers observed this method of reducing the temperature of grain during the war period when wheat, in being transferred, was allowed to fall through the air during zero weather from a height of about 25 feet. If grain can be sufficiently chilled by running, it can be protected from weevil attack. Even if its temperature can not be lowered to the point where the cold will prove fatal to the insect's life, much good will result from the suspension of its activity.

Since the control of the granary weevil is not different from that of grain pests in general, no further discussion of control measures is given.

SUMMARY

The granary weevil, *Sitophilus granarius* L., has been known as a grain pest from ancient times. Recognized as a distinct species by Linné in 1758, it has since been discussed as a pest of economic importance by many writers but has not been studied seriously, from a biologic standpoint, until within the last few years. It is often confused with, though easily distinguished from, the closely related and more destructive rice weevil, *Sitophilus oryza* L.

The granary weevil is considered to have originated in either Asia or the Mediterranean region. Unlike other members of the genus Sitophilus, however, which thrive best in tropical and semitropical climates, the granary weevil is now distinctly a temperate-climate species with a world-wide distribution. In the United States it appears to be giving way to *Sitophilus oryza*, and to be the prevailing calandrid species only in the more northern States.

Provided with no effective wings and by nature not very active, the granary weevil is found primarily in the granary or storehouse and depends upon man for dissemination. It does not appear to be well equipped to meet present-day methods of handling and protecting grain, with the result that, in the United States at least, it seems to be losing some of its importance as a pest in grain and certain grain products.

Like calandrid pests in general, the granary weevil causes the destruction of grain and grain products by the direct feeding of the adult beetle and its larva. Adult beetles, being long-lived and voracious, devour much grain throughout their life. They feed not only upon whole grains but upon stock feeds containing cracked grain and even upon finely divided products such as flours. The larvæ feed upon whole grains or upon portions of grains sufficiently large to support the larva throughout its entire development. Although larvæ will not develop in finely divided cereal products such as flours and meals, they can probably develop in these when they become caked from one cause or another. The adult weevils occasionally are destructive by boring holes in the cartons of packaged cereals.

The granary weevil hibernates during the winter months as adult or larva. With the approach of warm spring weather, the adults begin to oviposit and the larvæ to feed and transform. Newly matured adults may remain in the seeds for some time before they emerge. Shortly after emergence copulation takes place and is repeated at frequent intervals throughout life. Parthenogenetic eggs may be laid occasionally, but do not hatch.

It has been found that of adults held at 85° F. under starvation conditions 50 per cent may die by the end of the first week, with a certain few surviving for 19 days. Others, kept at 55° F., were very sluggish; 50 per cent survived for about 3 weeks, and one for 65 days. When given food, adult life is much longer and averaged between 7 and 8 months. Numerous adults lived well over 1 year and of certain adults subjected to a temperature ranging between 50° and 60° F., a few lived for 2 years and 5 months.

Adults begin ovipositing during summer as early as six days after emergence. In early spring the preoviposition period is about three weeks. Adults that emerge late in the fall have the longest preoviposition period, since they hibernate and do not begin ovipositing until the following spring. The extremes found in the preoviposition period were 6 and 148 days.

The granary weevil lays from one to five eggs per day when oviposition occurs, although one or two eggs per day is the more usual number. There is, however, considerable variation, as between different females, in the number of eggs laid per day under identical temperature conditions. This same variation extends to the duration of oviposition and to the total number of eggs laid by females. The longest oviposition period recorded was 287 days, from August 27 to June 10 of the year following. The shortest oviposition period was 67 days, from March 19 to May 25. The average length of the oviposition period for adults emerging during spring and early summer is between three and four months. The total egg-laying capacity of single females varied from 36 to 254.

The incubation period varied in length from 4 days at a mean temperature of 78° to 80° F. to 15 days at a mean of 61° F. No eggs were observed to hatch after the temperature of the grain had reached 95° F. or above, or when it had fallen to 50° to 55° F. Since adults do not oviposit until the temperature is from 61° to 63° F., and do not oviposit with regularity until a temperature of 66° to 68° F. is reached, there seems little reason to believe that eggs are ever laid when they can not hatch within 15 days, unless it be in late fall on approach of cold weather, when they will fail to hatch and will die.

The larva must have for food seeds in size sufficient to supply its growth requirements. In its growth it molts three times at more or less regular intervals. Where development proceeded fairly rapidly the duration of the four larval instars was found to be as follows when the mean temperature varied from 59° to 84° F.: First instar, 4 to 12 days; second instar, 4 to 14 days; third instar, 4 to 17 days; fourth instar, 6 to 24 days. With a good supply of normal moisture content the larvæ completed their development in from 19 to 34 days during summer weather when the mean temperature ranged from a maximum of 93° F. to a minimum of 70° F. The longest larval development recorded by the writers is 59 days when the mean temperatures varied between 77° and 49° F.

After attaining its growth the larva prepares a pupal cell, and after from one to two days in the prepupal form it transforms to the pupa. During the hottest summer weather, when the mean temperatures vary from a maximum of 85° to 95° F. to a minimum of 61° to 71° F., the pupal stage lasts from 5 to 7 days (mean temperatures for the period varying from 68° to 82° F.). During colder weather, with a mean temperature for the period of development varying from 61.5° to 68.5° F., the pupal stage lasted from 10 to 16 days.

The developmental period from egg to adult may be completed in 28 days, which, with a preoviposition period of 7 days, makes possible a life cycle from egg to egg of 35 days. The normal egg-to-adult cycle in summer is between 30 and 40 days, to which should be added, in securing the egg-to-egg cycle, a period varying from 6 days in midsummer to 148 days if the adult happens to emerge during the fall and hibernate as adult. There may be three or four generations a year in the vicinity of Washington, D. C.

The granary weevil is very resistant to low temperatures. Practically all of a large number of adults refrigerated at 30° to 35° F. were found alive after one month, and a few survived for 73 days. Adults exposed to a constant temperature of 15° F. survived only for 9 days, to 5° F. for 7½ hours, and to zero Fahrenheit for 5 hours. Of eggs exposed to 30° F. for 28 days, 20 per cent survived. A few larvæ survived refrigeration at 30° F. for 44 days.

The granary weevil is not very resistant to high temperatures. Exposure for a few hours to 115° F. will kill all stages, and all stages are killed within one hour when exposed to 118° to 120° F. Moderately high temperatures are also fatal if maintained for any length of time. At 95° F. four-fifths of the adults died on the fifth day of exposure, and a few lived 9 days, and one for 13 days; little or no feeding occurred and no eggs were laid. Eggs incubated at 95° F. failed to hatch, and larvæ exposed to this temperature did not complete their development.

The granary weevil in both larval and pupal stages is attacked by several hymenopterous parasites. Although these may become very numerous at times, they can not be depended upon for effective control, which can be secured only by heating the grain to a temperature of 125° F. or above, or by fumigation with standard effective fumigants.

LITERATURE CITED

(1) Back, E. A.
1919. Conserving corn from weevils in the Gulf Coast States. U. S. Dept. Agr., Farmers' Bul. 1029, 36 pp., illus.

(2) ——— and Cotton, R. T.
1922. Stored-grain pests. U. S. Dept. Agr., Farmers' Bul. 1260, 47 pp., illus.

(3) ——— ———
1924. Relative resistance of the rice weevil, Sitophilus oryza L., and the granary weevil, S. granarius L., to high and low temperatures. *In* U. S. Dept. Agr., Jour. Agr. Research, vol. 28, pp. 1043–1044.

(4) Chapman, R. N.
1921. Insects infesting stored food products. Univ. Minn. Agr. Exp. Sta. Bul. 198, 76 pp., illus.

(5) ———
1923. The possibility of transmitting a Calendra infestation from wheat to macaroni thru the processes of milling and manufacturing. *In* Jour. Econ. Ent., vol. 16, pp. 341–348, illus.

(6) Chittenden, F. H.
1895. The more important insects injurious to stored grain. *In* U. S. Dept. Agr. Yearbook 1894, pp. 277–294 illus.

(7) ———
1896. Some insects injurious to stored grain. U. S. Dept. Agr., Farmers' Bul. 45, 24 pp., illus.

(8) ———
1896. Insects affecting cereals and other dry vegetable foods. *In* U. S. Dept. Agr., Div. Ent. Bul. 4, n. s., pp. 112–130, illus.

(9) Cole, F. J.
1906. The bionomics of grain weevils. *In* Jour. Econ. Biol., vol. 1, pp. 63–71.
(10) Commodus, P.
1668. Von Kornwürmen. Plauen. (Not seen.)
(11) Cooley, R. A.
1914. Eleventh Annual Report of the State Entomologist of Montana. Mont. Agr. Coll. Exp. Sta. Bul. 98, pp. 121–136.
(12) Cotes, E. C.
1888. A preliminary account of the wheat and rice weevil in India. Notes on Economic Entomology No. 1, 28 pp., illus. Indian Museum, Calcutta.
(13) Cotton, R. T.
1921. Four Rhynchophora attacking corn in storage. *In* U. S. Dept. Agr., Jour. Agr. Research, vol. 20, pp. 605–614, illus.
(14) Curtis, J.
1860. Farm insects. xiv, 528 pp., illus. Glasgow, Edinburgh, and London.
(15) Dean, G. A.
1913. Mill and stored-grain insects. Kans. State Agr. Coll. Agr. Exp. Sta. Bul. 189, pp. 139–236, illus.
(16) Decaux, F.
1890. Étude sur les insectes nuisibles recuéillis de l'Exposition Universelle; moyens de les détruire. Soc. des Agr. de France, 36 pp.
(17) Defiel, F.
1922. An experimental investigation of the supposed poisonous qualities of the granary weevil, Calendra granaria. *In* Amer. Jour. Trop. Med., vol. 2, pp. 199–211.
(18) Dendy, A.
1918. Observations on the attraction of certain grain beetles, especially weevils, by water. *In* Reports of the Grain Pests (War) Committee, No. 3, pp. 17–18. Royal Society (London).
(19) ——— and Elkington, H. D.
1918. Report on the effect of air-tight storage upon grain insects.—Part II. *In* Reports of the Grain Pests (War) Committee, No. 3, pp. 1–14. Royal Society (London).
(20) ——— ———
1920. Report on the effect of air-tight storage upon grain insects.—Part III. Reports of the Grain Pests (War) Committee, No. 6, 51 pp., illus. Royal Society (London).
(21) ——— ———
1920. Report on the vitality and rate of multiplication of certain insects under various conditions of temperature and moisture. Reports of the Grain Pests (War) Committee, No. 7, 52 pp. Royal Society (London).
(22) Doane, R. W.
1919. Weevils in Australian wheat in California. *In* Jour. Econ. Ent., vol. 12, pp. 308–312.
(23) Domaison, M. L.
1887. [No title.] *In* Bul. Soc. Ent. France (6) vol. 7, p. cciv.
(24) Duhuamel du Monceau, H. L.
1761. Mémoire sur l'insecte qui dévore les grains de l'Angoumois, avec les moyens que l'on peut employer pour le detruire. *In* Mém. Acad. Roy. Sci. [Paris], pp. 289–331, illus.
(25) Durrant, J. H.
1921. Insects associated with grain, etc. *In* Reports of the Grain Pests (War) Committee, No. 9, pp. 33–52. Royal Society (London).
(26) Essig, E. O.
1915. Injurious and beneficial insects of California. Suppl. Mo. Bul. Calif. State Com. Hort., lxxi, 541 pp., illus.
(27) Fletcher, T. B.
1911. Weevil and dry wheat. *In* Agr. Jour. India, vol. 6, pt. 4, pp. 333–343, illus.
(28) ——— and Ghosh, C. C.
1920. Stored grain pests. *In* Rpt. Proc. 3d Ent. Meet. Pusa, 3d to 15th February, 1919, vol. 2, pp. 712–761, illus. Calcutta.
(29) Froggatt, W. W.
1903. Insects that damage wheat and other foodstuffs. *In* Agr. Gaz. N. S. Wales, vol. 14, pp. 481–492, illus.

(30) GAVIT, J. E.
1849. Corn or grain weevil of Europe, (Calandra granaria,) and (Silvanus surinamensis,) the weevil most common in America. *In* Trans. N. Y. State Agr. Soc. 1848, vol. 8, pp. 656–662, illus.

(31) GEER, C. DE.
1775. Mémoire pour servir à l'histoire des insectes, vol. 5. Stockholm.

(32) GIRAULT, A. A.
1912. Insects injurious to stored grains and their ground products. *In* 27th Rpt. State Ent. Nox. & Ben. Ins. Ill., pp. 56–82, illus.

(33) GOODRICH, E. S.
1921. Note on the Hymenoptera parasitic on beetles infesting grain. *In* Reports of the Grain Pests (War) Committee, No. 9, pp. 5–7. Royal Society (London).

(34) GOODWIN, W. H.
1912. Flour mill fumigation. Ohio Agr. Exp. Sta. Bul. 234, pp. 169–184, illus.

(35) GURNEY, W. B.
1918. Insect pests of maize. *In* N. S. Wales Dept. Agr., Farmers' Bul. 116, pp. 37–42, illus.

(36) HASEMAN, L.
1915. Insect pests of field crops. Univ. Mo. Coll. Agr. Exp. Sta. Bul. 134, 39 pp., illus.

(37) HERRICK, G. W.
1914. Insects injurious to the household and annoying to man, xvii, 470 pp., illus. New York.

(38) HINDS, W. E.
1914. Reducing insect injury to stored corn. Ala. Agr. Exp. Sta. Bul. 176, pp. 49–68, illus.

(39) KOMPFE, D.
1879. Die Insekten; naturgeschichtliche Aufsätze über Freunde und Feinde der Landwirthschaft und die freilebenden Thieren, 156 pp., illus. Leipzig. (Not seen.)

(40) LATREILLE, P. A.
1804. Histoire naturelle générale et particulière des crustacés et des insectes, vol. 11. Paris.

(41) ———
1910. Considérations générales sur l'ordre naturel des animaux composant les classes des crustacés, des arachnides et des insectes . . . 444 pp. Paris.

(42) LEEUWENHOEK, A. VAN.
1695. Arcana naturae . . . vi, 568 pp., illus. Delphis Batavorum.

(43) LINNÉ, C. VON.
1746. Fauna Suecica . . . 411 pp., illus. Lugduni.

(44) ———
1758. Systema naturae . . . ed. 10, vol. 1. Holmiae.

(45) LOUNSBURY, C. P.
1903. Weevils in grain. *In* Agr. Jour. Cape of Good Hope, vol. 23, pp. 94–96.

(46) MILLS, W.
1836. Observations upon the corn weevil contained in a letter addressed to the Rev. F. W. Hope. (Calandra granaria in Madeira.) *In* Trans. Ent. Soc. London, vol. 1, pp. 241–242.

(47) NEIFERT, I. E., COOK, F. C., ROARK, R. C., TONKIN, W. H., BACK, E. A., and COTTON, R. T.
1925. Fumigation against grain weevils with various volatile organic compounds. U. S. Dept. Agr., Dept. Bul. 1313, 40 pp., illus.

(48) OLIVIER, A. G.
1790. Encyclopédie méthodique, vol. 5. Paris.

(49) ORMEROD, E. A.
1879. Sitophilus granarius. *In* The Entomologist, vol. 12, pp. 51–54.

(50) ———
1879. Sitophilus oryzae. *In* The Entomologist, vol. 12, pp. 206–207.

(51) PIERCE, W. D.
1919. Contributions to our knowledge of the weevils of the superfamily Curculionoidea. *In* Proc. Ent. Soc. Wash., vol. 21, pp. 21–36.

(52) PLAUTUS, T. M.
196 B. C. Curculio. *In* Plautus, with an English translation by Paul Nixon, vol. 2, pp. 185–269. London and New York, 1917.

(53) QUAINTANCE, A. L.
1896. Insects injurious to stored grain and cereal products. Fla. Agr. Exp. Sta. Bul. 36, pp. 355–385, illus.

(54) RANGO, C. T.
1665. Nützliches Tractätlein von denen Curculionibus oder Kornwürmen und deren Ursprung und Vertreibung, etc., verbessert von Artophago. Berlin. (Not seen.)

(55) RAY, J.
1710. Historia insectorum, xv, 400 pp. London.

(56) REDI, F.
1668. Esperienze intorno alla generazione degl' insetti . . . 228 pp., illus. Firenze. (Not seen.)

(57) RILEY, W. A.
1922. The reputed vesicating properties of the granary weevil, Calandra granaria. *In* New Orleans Med. and Surg. Jour., vol. 74, pp. 678–682.

(58) [RILEY, C. V., and HOWARD, L. O.]
1888. Insects introduced into Chile. *In* U. S. Dept. Agr., Div. Ent., Insect Life, vol. 1, pp. 153–155.

(59) SCHELLENBERG, J. R.
1798. Helvetische entomologie oder Verzeichniss der schweizer Insecten . . . vol. 1. (Incl. French translation by J. de Clairville.) Zurich.

(60) SCHOENHERR, C. J.
1838. Synonymia insectorum. Genera et species curculionidum . . . vol. 4, pt. 2, pp. 601–1121. Paris and Leipzig.

(61) SCHWENCKFELD, C. VON.
1603. Theriotropheum Silesiae . . . 24, 563 pp. Lignicii.

(62) SHERMAN, F., JR.
1903. Injurious insects. *In* Bul. N. C. State Bd. Agr., vol. 24, no. 6, pp. 3–29, illus.

(63) SMITH, R. I.
1909. Corn weevils and other grain insects. N. C. Agr. Exp. Sta. Bul. 203, 27 pp., illus.

(64) STEDMAN, J. M.
1902. The more important insects injurious to wheat in Missouri. *In* 34th Ann. Rpt. State Bd. Agr. Mo. f. 1902, pp. 55–141, illus.

(65) STRACHOV-KOLTCHIN, A. I.
1915. Амбарный долгоносикъ [The black cornworm] (Calandra granaria L.). *In* Contributions of the Voronezh Station for the Control of Pests Injurious to Plants, Bul. 1, 74 pp., illus.

(66) SWENK, M. H.
1910. The principal insects injurious to agriculture during 1908–9. *In* Ann. Rpt. Nebr. State Bd. Agr., 1910, pp. 362–369.

(67) ———
1922. Insect pests of stored grains and their control. Univ. Nebr. Agr. Exp. Sta. Circ. 15, 14 pp., illus.

(68) TASCHENBERG, E. L.
1865. Die der Landwirthschaft schädlichen Insekten und Würmer, xii, 288 pp., illus. Bremen.

(69) TEICHMANN, E., and ANDRES, A.
1919. Calandra granaria L. und Calandra oryza als Getreideschädlinge. *In* Ztschr. Angew. Ent. Berlin, Bd. 6, pp. 1–24, illus.

(70) WALSH, B. D., and RILEY, C. V.
1869. Poisonous flour. *In* Amer. Ent., vol. 1, p. 179.

(71) ZACHER, F.
1920. Mitteilungen über Vorratschädlinge. *In* Mitt. Biol. Reichsanst. Land- u. Forstw. [Berlin], Heft 18, fünfzehnter Jahresbericht, pp. 130–139, illus.

(72) ———
1921. Mitteilungen über Vorratschädlinge. *In* Mitt. Biol. Reichsanst. Land- u. Forstw. Berlin, Heft 21, sechzehnter Jahresbericht, pp. 79–90, illus.

(73) ZVEREZOMB-ZUBOVSKY.
1923. Определитель главнейшихъ насекомыхъ, встречающихся в зерне и зерновых продуктах. [Key to the principal insects found in grain and grain products.] *In* Works Sec. Appl. Ent. Agr. Sci. Com. People's Commissariat Agr., vol. 12, no. 1, 52 p., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

April 24, 1926

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	————
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	THOMAS P. COOPER, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairying	C. W. LARSON, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This bulletin is a contribution from

Bureau of Entomology	L. O. HOWARD, *Chief.*
Stored-Product Insect Investigations	E. A. BACK, *in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
∇

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1395

Washington, D. C. ▼ March, 1926

BATS IN RELATION TO THE PRODUCTION OF GUANO AND THE DESTRUCTION OF INSECTS

By Edward W. Nelson, *Chief, Bureau of Biological Survey*

CONTENTS

ECONOMIC RELATIONS OF BATS

Much has appeared in the public press in recent years about bats, their valuable deposits of guano, their alleged destruction of malarial and other mosquitoes, and the possibilities of increasing their usefulness to man by building artificial roosts for them, and many requests for information on these subjects have come to the department. L. O. Howard, chief of the Bureau of Entomology, in a paper on "Mosquitoes and Bats" read before the meeting of the New Jersey Mosquito Extermination Association in 1916[1] discussed the subject chiefly from the viewpoint of the alleged destruction of *Anopheles* in the vicinity of a bat roost near San Antonio, Tex. Further definite information on the life history and general habits of bats is still in demand from entomologists and officials in charge of health administration and general education.

The available information on the bats of North America would fill a large volume, for scattered from Panama and the Antilles to Alaska and Labrador there are about 260 species and subspecies belonging to 77 genera and 8 different families. Some of the tropical species are blood-sucking vampires and others are fruit-eaters, but nearly all the bats of the United States and farther north are insectivorous. Still the habits of the different species often differ as widely as do their structure, appearance, and range, and the useful

[1] Reprinted also in Public Health Reports, vol. 35, no. 31, pp. 1789–1795, July 30, 1920 (Reprint No. 715).

habits of one species may not apply to others of the same or distant localities. Generalizations from one species can not be safely applied to others without a full knowledge of their habits. Certain bats of highly colonial habits are found in the Tropics and across the southern United States, limited mainly to the southern parts of these States, but these colonial habits do not apply generally to the more northern bats and by no means to all species in the South. This bulletin discusses the relation of colonial bats to the production of guano and the destruction of insects.[2]

THE MEXICAN FREE-TAILED BAT

Most of the sensational reports of discoveries of a great commercial value of bats as well as of sanitary benefits from their presence have been based on one species occurring in southern Texas, the Mexican free-tailed bat, *Tadarida mexicana*, long known in literature as *Nyctinomus mexicanus*, and belonging to the mainly tropical family Molossidae. In tropical and subtropical America, the West Indies, southern Europe, eastern Africa, southern Asia, Australia,

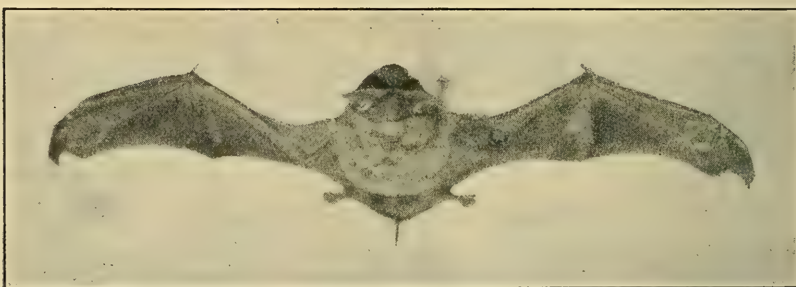


FIG. 1.—Mexican free-tailed bat (*Tadarida mexicana*), a small sooty-brown mammal with a wing spread of about 12 inches; habitant of Mexico and the arid Southwest, and the only species in the United States known to produce guano in commercial quantity

and many islands of the Pacific there are about 40 species of the genus *Tadarida*, but only 4 of these reach northward into southern United States, and only 1 is known from southern Texas.

The range of bats of the species *Tadarida mexicana* is in general restricted to the arid and semiarid sections of the Lower Austral Zone in the United States from Texas to California, and extends also throughout most of the warmer parts of Mexico. The northward limit of their range is apparently fixed by temperature or suitable food supply, and the eastward perhaps by the presence of a related species, *Tadarida cynocephala*, with very similar habits but occupying the humid division of the Lower Austral Zone from southern Louisiana to Florida and South Carolina. Two closely related forms *Tadarida femorosacca* and *Tadarida depressa*, are of rare occurrence in the Southwestern States.

The Mexican free-tailed bats are small, sooty-brown mammals spreading about 12 inches across extended wings, with projecting

[2] While this bulletin was in press a volume just published, by Charles A. R. Campbell, "Bats, Mosquitoes, and Dollars," was received. The book does not in any way alter the conclusions as set forth in these pages.

tails, short, wide ears pointing forward over the eyes like a hat rim, and short velvety fur. (Figs. 1 and 2.) Individually these bats are cleanly animals, but they have the extremely strong musky odor peculiar to the group. This permeates the air of every cave or house which they occupy in any numbers. In some houses where they are present in large numbers it becomes almost unbearably strong, and its offensiveness is increased by the added pungent odor

FIG. 2.—Mexican free-tailed bat (*Tadarida mexicana*), natural size (see also figure 1)

of ammonia from their excrement. In many houses where bats are found among the tiles of the roofs of porches and in crevices over the lintels of doorways and similar places, the odor pervading the premises often advertises their presence to anyone approaching.

In the numerous reports on bat guanos and their chemical components and value as fertilizer, samples have been listed from the caves of Africa, India, China, South America, the West Indies, Texas, and New Mexico. In Porto Rico 110 caves have been listed, containing from 12 to 3,144 tons of guano, and many others examined containing little or no guano.[3] In no case is the species or genus of bat responsible for the guano deposits mentioned, but in every case the records of deposits lie within the range of some species of the genus *Tadarida*. This does not mean that these are the only bats producing guano of high fertilizer value in commercial quantities, but so far as known they are the only bats in America sufficiently gregarious to do so.

BAT CAVES

The most strikingly characteristic habit of Mexican free-tailed bats is that of gathering in large colonies in caves and buildings. This habit renders them valuable through the production of large quantities of guano, and possibly through the consumption of many kinds of injurious insects. They are especially numerous in southern Texas and New Mexico, where for centuries they must have occupied great numbers of the natural caves which afford ideal refuges for them. Many of the larger caves contain hundreds of thousands during the whole or a part of each year.

Some of the caves, such as the great Carlsbad Cavern, N. Mex., are mainly wintering places, where the bats hang in fall, and sleep until the warm days of spring call them out again to seek the most satisfactory feeding grounds, and to feast on their winged prey. Where the caves are in proximity to an abundance of insect life the bats remain throughout the summer, occupying the caves as roosting places during the day, and swarming out over the country in search of food at night. One such cave is about 19 miles north of San Antonio, Tex., on Cibolo Creek; and, although not very extensive, it annually yields a large quantity of guano. This and other caves west of San Antonio are occupied by great numbers of these bats, as are still others in western Texas and across southern New Mexico. Apparently this whole cave region is stocked with bats to its carrying capacity, besides providing wintering shelter for those of outlying areas, where no caves occur.

GENERAL HABITS OF THE SPECIES

Like most other bats, the Mexican free-tailed bats are almost entirely nocturnal in habits and apparently continue active throughout the night. Emerging from their roosting places after sunset, they seek their feeding grounds for pursuit of the flying insects which are their food. They are strong, rapid flyers and will even breast a stiff breeze, but in feeding they keep mainly in the vicinity of trees, buildings, or cliffs, where the air is teeming with insect life. Their progress while feeding is in quick and erratic zigzags as the insects are rapidly snapped up and devoured without a moment's pause.

During summer evenings at San Antonio, Tex., soon after sundown it is common to see great numbers of these bats flying over

---

[3] Gile, P. L., and J. O. Carrero, "The Bat Guanos of Porto Rico and Their Fertilizing Value": Bul. No. 25, Porto Rico Agr. Exp. Sta., pp. 66, 1918.

the town, practically all headed in one direction. They fly several hundred feet above the ground, on their way from their roost to favorite hunting grounds, often in the vicinity of water.

Bats often come into open rooms while seeking their prey and fly about with great skill, avoiding all objects and feasting on such insects as also enter through the open doors or windows, alighting for a moment on the walls or moldings to rest or devour a moth, but always careful to keep out of reach of human occupants. All of our native bats are absolutely harmless. The fear which they sometimes inspire is wholly baseless and has its origin in fictitious stories told to children and passed on from generation to generation.

At early dawn the bats return to their regular sleeping places in caves, dark rooms, under tiles or other openings in roofs, in holes and crevices among rocks, or in hollow walls of buildings. They are usually suspended by their sharp, curved hind claws and sleep until the next evening, where conditions for such a position are favorable. In other places they may be found packed in deep crevices, frequently too narrow even to admit the hand. In the roofs of small caves in the rockhills near the suburbs of Mexico City there are many bats in crevices of this kind. They commonly take possession of deserted attics and similar places in old churches or other buildings and in deserted storerooms.

Mexican free-tailed bats, like many others, have the habit of hanging up part of the night in convenient places near their roosts, as under the roofs of verandas or similar shelter, and the floor beneath is covered each morning with many scattered pellets of excrement.

Exceedingly gregarious, these bats sleep in large numbers closely packed, sometimes hundreds, or even thousands, in a solid mass, clinging to one another in such density that it is difficult to understand how those in the middle of the mass can avoid suffocation. At night, when they leave large caves or buildings where great numbers of them are living, they pour out through their chosen exits in such a swarm that in the dusk of early evening it has almost the appearance of a cloud of smoke.

Observations made in Mexico indicated it to be a common habit for certain bats to fly a number of miles from their roosts to their feeding grounds every evening, but there are no observations as to the distance the Mexican free-tailed bats may go for this purpose. Undoubtedly, however, they comb many square miles of territory about their great roosting places.

To what extent these bats migrate to take advantage of favorite winter and summer climates, or to find favorable wintering caves, is not known, but like many other bats they undoubtedly move about to seek the best seasonal conditions. At times a few wander in summer far from their regular range, as shown by records of scattered occurrences as far north as Colorado and Kansas. Extensive migrations, however, such as occur among some other more northern species of bats, are not known in this group.

HIBERNATION

In winter the Mexican free-tailed bats seek caves or buildings where the temperature is approximately constant and not too cold, and with the first freezing nights outside they hang up for the long winter's sleep. So far as known a temperature of 50 to 55° F. in moderately dry air suits their needs for hibernation, but the limits of variation which they can endure have not been fully ascertained. Before entering hibernation they become very fat, storing up inside of their skins a rich supply of oily food material sufficient to support the greatly reduced vital processes during their torpor of winter.

Before they are fully torpid their stomachs and alimentary canals become entirely empty, their temperature gradually falls to approximately that of the surrounding air, and their circulation and respiration become greatly reduced. When fully in the embrace of the winter sleep their bodies are cold and motionless, and they are apparently dead. Thus they hang often four or five months until the warmer air of spring penetrates to their chambers and stirs their circulation to renewed activity.

In the Tropics all species appear to be active throughout the year.

FOOD HABITS

So far as known the food of the free-tailed bats consists wholly of insects, almost entirely of night-flying species captured on the wing. Moths and beetles seem generally to form the great bulk of the food, but many other insects also are eaten, and in case of an unusual abundance of any nocturnal species, these might be expected to figure largely in the food.

These bats are gluttonous feeders, and in some species 20 minutes after their appearance in the evening the stomachs have been found distended with food, the contents averaging one-quarter the weight of the animal. This would imply a capacity for at least half their weight in insects every night, and even a possibility of their actually eating their weight in them every 24 hours. Such estimates are merely suggestive and must not be used in any conclusive sense until more careful tests can be made of the food actually consumed by each species under varying conditions.

Many other bats not colonial in habits probably have a similar capacity, and over parts of the country where they exist in sufficient numbers may well have an economic value comparable to that of insectivorous birds.

If there were more caves attractive to bats and a greater food supply there would undoubtedly be more bats, whereas any considerable diminution of either factor would tend to reduce their numbers. If, however, the bats should become so numerous as to destroy most of the insect life, there would necessarily result a corresponding decrease in the bat population. The fact that bats of this species each produce only one young a year suggests a long-established and conservative balance between the food supply and the increase of the species.

GUANO DEPOSITS

Bat droppings composed entirely of insect remains and well moistened with bat urine accumulate under the roosting places, often in such large quantity as to be of value as fertilizer. When neither too wet nor too dry it is rich in nitrogen, phosphoric acid, and other important ingredients and has a commerical value in some cases, as shown by chemical analysis, of $30 to $40 a ton.[3]

The rate of accumulation of guano varies greatly in different places, being slight in the caves where the bats merely spend the winters, but much more rapid where they live in great numbers all the year, or through the period of summer activity. In the Cibolo Creek Cave, north of San Antonio, Tex., on March 5, 1924, about an inch of fresh deposit was found on the floor where the guano had been removed during the winter. The bats had been active only a short time, and insect life had but recently become common. From this not very extensive cave there are taken out each year about 60 or 70 tons of guano, said to bring $30 a ton.

The Cibolo Creek Cave consists of a great tunnel sloping gently downward for 200 or 300 yards through the limestone formation toward the creek valley below, and widening out at the lower part in a great room some 75 feet high and 150 feet wide. Here the bats gather in vast numbers, possibly by millions, hanging to the high arched roof, and rain down their little pellets over the entire floor of the cave throughout their season of activity.

The bat roost in this cave has not only been a source of income to the owner since 1896, but also perhaps has been of importance to the community in the destruction of enough insects within the nightly range of the bats to maintain this enormous host. Nevertheless mosquitoes are said to be troublesome at times in the vicinity of the cave, and no scarcity of any kind of insect has been noticed by the residents.

In another cave on the Frio River, not far from Uvalde, Tex., about the same quantity of guano had been taken out for many years, until a fire in the guano drove out the bats and for the time ended the deposition. Other caves in the region west of San Antonio yield a somewhat smaller output of guano, and many in western Texas and southern New Mexico and Arizona have yielded it in commercial quantities.

In the great Carlsbad Cavern of southeastern New Mexico the quantity of guano removed during the 20 years from 1901 to 1921 is estimated roughly at 100,000 tons. This was the accumulation of hundreds or perhaps thousands of years, but as vast numbers of bats congregate here in fall to use the cave largely as a wintering place and as many leave again in spring for lower country and a better food supply, the guano accumulation is relatively slow, apparently not more than 1 inch a year. Many years must elapse before the deposit can again become of commercial value.

ARTIFICIAL ROOSTS FOR BATS

Interesting experiments in building roosts for the purpose of colonizing guano-producing bats (*Tadarida mexicana*) have been carried on for many years by C. A. R. Campbell, of San Antonio, Tex. An excellent description of one of these buildings (fig. 3) at Lake Mitchell is given by Doctor Howard,[4] from careful notes

[3] Gile and Carrero, op. cit.
[4] Howard, L. O., op. cit., pp. 1792–1793.

by F. C. Bishopp, in charge of the field station of the Bureau of Entomology, at Dallas, Tex., as follows:

The Campbell bat roost consists of a sort of tower set on four posts about 10 feet above the ground. According to Doctor Campbell, the size of the roost may be varied considerably. As I recall them, the dimensions of the roost at Mitchell Lake are about as follows: Twelve feet square at the bottom, the walls slanting inward toward the top, which is about 6 feet square. Height, about 20 feet. On the outside, the building is covered with drop siding with tar paper beneath. The roof is shingled and projects over the edges. It is slightly elevated so as to permit of the entrance and exit of the bats. Additional entry space is allowed entirely down one side of the building. This opening, which is about 2½ feet wide, is provided with boards slanting upward so as to exclude light to some extent but allows the bats to enter between them. The central portion of the house from the side provided with the entrance to the opposite side is unobstructed from top to bottom, thus leaving an air space about 2½ feet wide. On each side of the shaft, and running to the two other sides of the building, is a series of shelves made of matched flooring. These shelves slant upward and outward at an angle of about 30°. In the first house constructed these shelves were about 5 inches apart, but I believe in the later model they are closer together. Wire netting is tacked on top of each of the shelves so as to provide places for the bats to hang. The slant is given so as to allow the guano to roll down and drop into the center of the bottom structure, which is provided with trapdoors opening downward. This is to permit of the emptying of the manure into a wagon which is placed under the roost.

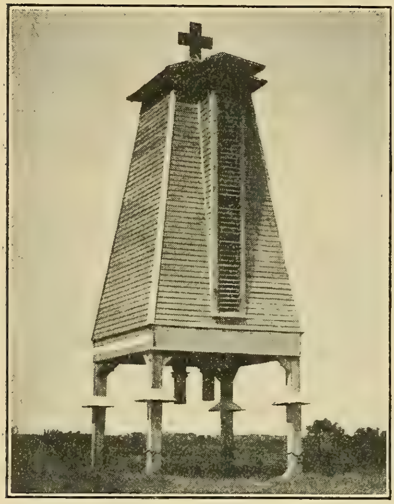


Fig. 3.—Bat roost at Mitchell Lake, Tex., occupied by a colony of Mexican free-tailed bats, estimated on March 4, 1924, to number 10,000, and yielding about 2 tons of guano a year. (Photograph by Charles H. Gable)

This roost when visited by Vernon Bailey, of the Biological Survey, in company with F. C. Bishopp and Charles H. Gable, of the Bureau of Entomology, on March 4, 1924, was occupied by a large number of bats, all of the species *Tadarida mexicana*. During the evening it was estimated that about 10,000 bats flew from the roost in the half hour between 6.45 and 7.15 o'clock. They left so rapidly from both sides of the tower that they could not be counted after the first five minutes. It seemed probable that fully 10,000 were using the roost at that time. Mr. Gable says that they were much more numerous in midsummer, but none were seen there in winter, as, according to Doctor Campbell, most of the bats disappear then and return early in spring, the first sometimes appearing about the middle of February.

About two tons of guano are taken from this roost every winter, part of which is packed in 10-pound sacks and sold at $1 a sack to local florists and individuals for use on house plants, and part of it in larger lots to local gardeners at lower prices. This roost apparently pays good dividends on the original cost and is considered a valuable investment. It is the only one of five, however, constructed in and about San Antonio that has ever been extensively occupied by bats, and others built in Florida and Georgia had failed to attract bats up to March, 1924. So far as can be learned, the bat roost at Mitchell Lake, near San Antonio, is the only one of the eight built that has been occupied by bats, but this does not mean that others in favorable situations may not attract them.

There would be many advantages in being able to colonize bats successfully in certain localities either in artificial roosts or artificial caves and tunnels, but so far none of the experiments can be considered entirely successful. Doctor Campbell's experiment is interesting as far as it reaches, but so far it has succeeded in only one case and with only one species of bat.

The choice of roosting places by bats is evidently dependent upon factors not always readily understood. In many cave regions where bats are abundant, only certain of the numerous caves available and apparently suitable are actually occupied. Although bats may in some instances be attracted to artificially prepared roosts, prospective builders should be informed, before deciding to risk what may be a needless expenditure of funds, that there is no assurance that such structures will be used (fig. 4).

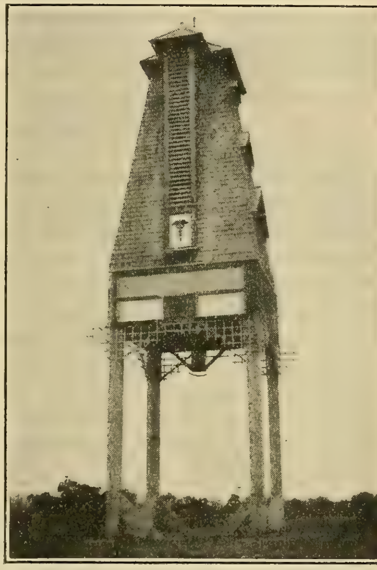


FIG. 4.—Bat roost near Military Academy, San Antonio, Tex., built by popular subscription in 1920 at a cost of $2,000, for mosquito control, but never occupied. In only one of eight such structures, from Florida to Texas, have bats taken up their abode

BUILDINGS OCCUPIED

The walls or attics of many old buildings in San Antonio, Austin, Del Rio, and other communities in western Texas are occupied by these bats. In 1923 two wagonloads of bat guano were taken out of the attic of the courthouse at Austin, and the openings carefully closed to prevent the return of the bats. The strong odor of the bats and guano rendered the building unendurable for human beings, as it has in the case of many private dwellings where the bats have taken up their abode in hollow walls or attics. To prevent their return, however, it is only necessary to close all openings in the buildings at night when the bats are out.

In the vicinity of Patzcuaro, Michoacan, at an altitude of 7,500 feet, the writer found *Tadarida mexicana* the most common species of bat, although the summer climate here was much cooler than in the localities most frequented by them. Here they were sometimes found in caves, but were more numerous among the tiles and other crevices in the roofs of the houses, and in openings in larger buildings as well. In an old building in the middle of Patzcuaro, where these bats were clinging in great numbers to the ceilings of two rooms, the owner made a regular business of gathering the guano and selling it at the rate of 3 cents a pound, Mexican money. At the time of the writer's visit in July thousands of bats were hanging from the roof and several inches of excrement covered the floor, giving off an excessively strong odor of ammonia. The owner stated that the bats migrate when the weather becomes cold in fall and return in spring. Soon after they return they have their young.

At another place in the same town a man built a small detached room in the yard back of his house for the purpose of smoking bacon and other meat, but before he began to use it bats of this species took possession in such numbers and produced so much guano that he abandoned his original purpose and was making a good return on his investment through the sale of guano. The writer heard also of bat guano being taken from a cave on the southern slope of Mount Popocatepetl.

THE FLORIDA FREE-TAILED BAT

The following extract from a letter from Hiram Byrd, State Health Officer of Florida, to L. O. Howard, Chief of the Bureau of Entomology, under date of June 26, 1912, relative to bats taking up their abode in an uncompleted opera house begun in 1895, at Tavares, Fla., undoubtedly refers to the Florida free-tailed bat, *Tadarida cynocephala*, and if so shows that this species has the same colonial habits as the one found in Texas:

> The doors and windows of the lower floor of this opera house were securely fastened up to keep intruders out, but the upper windows were only closed by loose boards, which soon dropped out, making it easily accessible to bats. They took advantage of it, and in the course of a few years were there in countless thousands. I know of no way of estimating the number. . . . The only time I was ever there at the right hour was on a trip to Eustis. The train stopped at Tavares one-half hour before sunset and remained there something like 45 minutes. I took advantage of the occasion to see the bats emerge from the building. I had only been watching a few minutes when they began, first a single one, then two or three together, and as if the rustle started them, then they began seriously flying out of the window with incredible swiftness. There must have been at least half a hundred a second. I watched this stream of bats pouring out for half an hour or so, and was told by some of the residents of Tavares that it would continue until something like half an hour after dark, making probably two hours altogether.

About two years after the opera house had been cleaned out and converted into a packing house, Doctor Byrd made inquiries of citizens in the vicinity of Tavares and Eustis, Fla., as to whether they had experienced any appreciable difference in the number of mosquitoes since the time the bat roost in the building was at its height, and as a result of these inquiries stated that he was convinced that if there was any difference it was not noticeable.

MALARIAL CONTROL BY BATS

During many years of study of the mammals of Mexico, the writer lived a large part of the time in places where Mexican free-tailed bats were extremely abundant. Their presence in no case appeared to have the slightest influence on the prevalence of malaria. In many Mexican villages and ranches, where nearly every inhabitant was infected with malaria and where malarial mosquitoes were swarming about the houses, these bats were living in the roofs in great numbers, apparently without having the slightest influence on the numbers of the mosquitoes. At one large cave, water in the entrance afforded a breeding place for mosquitoes, which were present in such numbers as to cause great annoyance in efforts to collect some of the bats for scientific specimens.

The assertions of Doctor Campbell that bats feed very extensively on mosquitoes, practically eliminating them in the vicinity of bat roosts and thus effectively preventing malaria, have been followed with interest by entomologists of the Department of Agriculture, and all evidence carefully weighed by Doctor Howard [5] in his paper on the subject. He has written the following two paragraphs for insertion in this bulletin:

"After a prolonged effort I have been unable to substantiate the claims made by Doctor Campbell as to the value of bat roosts in the great reduction of the mosquito population of a given locality, even in Texas. Bats obviously prefer other and larger insects. They undoubtedly swallow mosquitoes when they encounter them in flight, but only incidentally. Observations by trained men on the ground in Texas deny his claims both as to marked relief from mosquitoes or relief from malaria. One of the experts of the Bureau of Entomology stationed at San Antonio informs me (May, 1925) that of the four bat roosts at San Antonio only one is inhabited by bats, and that in endeavoring to watch the flight of the bats from this roost in the evening he was so annoyed by mosquitoes that he was obliged to abandon his observations. He further tells me that a Mexican, resident 300 yards from the roost, states that the mosquitoes are very bad at his house.

"As to other parts of the world, I am told by no less authority than Professor Grassi that in Italy the most malarious regions are precisely those where bats are most abundant."

SUMMARY

Nearly all the bats of North America north of the Tropics consume vast quantities of insects, but apparently do not exterminate any. In evaluating their services as insect destroyers it is to be borne in mind that they feed almost entirely on night-flying species.

The Mexican free-tailed bat, ranging in the United States in southern Texas, New Mexico, Arizona, and California, is extremely colonial in habits, occupying numerous caves and some buildings, and producing in places sufficient quantities of guano to be used commercially as fertilizer.

The possibility of colonizing these bats by building suitable roosts has been demonstrated in the United States, but in only one instance. Many difficulties are likely to be encountered in establishing colonies. Elaborate and expensive structures built outside the range of a colonial species or in places where the bats of the locality find other quarters preferable may not be occupied. Unless the bats can be attracted in large numbers, there is little hope of establishing a

[5] Op. cit.

worth-while colony, because of the slow rate of reproduction, there being only one at a birth.

In the single colony of bats successfully established there seems to be a profitable yield of guano. Other attempts have failed, and anyone contemplating the construction of bat roosts for commercial gain should be advised that the returns may be disappointing and wholly out of proportion to funds expended.

Mosquitoes have been found abundant in and about bat caves, and in the single case known where colonial bats have been artificially established there has been no appreciable diminution in the insect life or in the local abundance of mosquitoes. The assertions that bats will eradicate or even noticeably reduce the numbers of mosquitoes, and with them malaria, are shown by studies of their food and general life habits to be misleading and without foundation.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1397

Washington, D. C. ▼ June, 1926

THE PINK BOLLWORM,[1] WITH SPECIAL REFERENCE TO STEPS TAKEN BY THE DEPARTMENT OF AGRICULTURE TO PREVENT ITS ESTABLISHMENT IN THE UNITED STATES.[2]

By W. D. Hunter,[3] *Senior Entomologist, in Charge of Southern Field-Crop Insect Investigations, Bureau of Entomology, and Member of the Federal Horticultural Board.*

CONTENTS

HISTORICAL

In 1842 the superintendent of the Government cotton plantations at Broach, India, sent specimens of a very destructive cotton insect to the distinguished English entomologist, W. W. Saunders. The specimens were described as a new species, *Depressaria* (now *Pectinophora*) *gossypiella*, by Saunders in a paper presented to the Entomological Society of London on June 6, 1842 (*18*).[4] This is the first published record concerning the insect which is now attracting so much attention in the principal cotton-producing countries of the world.

For 61 years after the publication of Saunders' description no published statement regarding the pink bollworm was issued. In 1904, however, an article was issued by J. Vosseler (*20*) regarding the great injury caused by the insect in German East Africa. With-

[1] *Pectinophora gossypiella* Saunders; order Lepidoptera, family Gelechiidae.
[2] This bulletin supersedes Department Bulletin 723, issued under the same title in 1918.
[3] Died October 13, 1925. The manuscript of this bulletin had its final revision by the author June 22, 1925.
[4] Numbers (italic) in parentheses refer to "Literature cited," p. 29.

in the next few years several additional articles dealing with the problem caused by the pest in German East Africa appeared. In 1909 D. T. Fullaway (*8*) published an account of the pink bollworm and its relation to cotton culture in the Hawaiian Islands, stating that it appeared to have been introduced from India within "comparatively recent" years.

Only a few more or less technical papers were published from 1909 to 1913. Since the latter date a considerable literature has been built up, consisting largely of papers emanating from Egypt, where the pest has attracted increasing attention.

ORIGINAL HOME

The original home of the pink bollworm is probably India and possibly southern Asia generally, and its original host plants were the wild and cultivated cottons of that region. This conclusion, published by the writer (*13*) in an earlier bulletin on this subject, was also announced by Marlatt (*15*) at about the same time, after a more exhaustive discussion of the evidence available. If this natural range of the insect extended to Africa it must have been limited to central Africa and at least it did not extend to the Nile Valley region, where cotton has been an important cultivated crop for a century or more. The occurrence of the insect in Egypt is apparently traced definitely to large shipments of seed cotton or imperfectly ginned cotton from India in 1906–7, and the spread of the insect from the points in the lower Delta, near Alexandria, where this cotton was sent for reginning, throughout the Delta, and ultimately throughout Egypt, is so well confirmed by circumstantial evidence as to leave no doubt as to the entry of the insect at that time into Egypt. With the first occurrence of the insect in Egypt it was confused more or less with other insects commonly found in cotton bolls in that country, and this confusion led to a statement by Dudgeon (*6*) that this insect had probably been in Egypt for many years. The careful investigation of the situation and determination of original points of infestation and spread by expert entomologists in the employ of the British and Egyptian Governments have fully disproved this early surmise and pointed out the real manner of introduction of the insect into Egypt.

As already noted, the pink bollworm has been recorded as a cotton pest in India since 1842, and the original report made by the superintendent of the Government cotton plantation at Broach, India, is of sufficient importance to be given in full, as follows:

> The inclosed is an insect which was very destructive to the American cotton which was sown here (Broach) on light alluvial soil. The egg is deposited in the germen at the time of flowering, and the larva feeds upon the cotton seed until the pod is about to burst, a little previous to which time it has opened a round hole in the side of the pod for air, and at which to make an exit at its own convenience, dropping on the ground, which it penetrates about an inch, and winds a thin web in which it remains during the aurelia state. Curious enough, the cotton on the black soil was not touched by it. The native cotton is sometimes affected by it.

The significant thing in the paragraph is the statement that the insect was very destructive to the American cotton and that "*native cotton is sometimes affected by it.*" The fact that the American cotton was much more affected than the native varieties is in accord with the general experience with imported plants in relation to native plant pests, and with introduced pests in respect to native plants. The American variety was apparently unresistant in comparison with the native cottons of India, which, with little doubt, had been long associated with this pest and had developed a certain degree of resistance.

The later records of this insect show that it was reported from India on several occasions prior to 1900, or about that period, and those records confirmed also its occurrence eastward through Burma, Siam, and the Philippines, long previous to what was undoubtedly its original entry into Egypt in 1906–7.

The insect was first observed in Egypt in 1911, and the first severely infested field, one near Alexandria, was noted in 1912. The increase of the damage from this insect in Egypt has been steady since 1912, in spite of very laborious and expensive control operations enforced by the Egyptian Government.

The present distribution of the pink bollworm is therefore reasonably traceable to its spread from southern Asia in comparatively recent years. The possible exception may be found in German East Africa, and even there the natural explanation of its occurrence is its recent introduction with cotton imported from India. It is, however, possible that the natural range of the insect may have included central Africa and that the African infestation may therefore have come from native stock.

PRESENT RANGE

With the exception of certain infestations in Texas and New Mexico, the known range of the pink bollworm is as follows:

East Africa, west Africa, Egypt, Angola, Italian Somaliland, Nigeria, Sierra Leone, Sudan, Zanzibar, India (very generally), Bengal, Ceylon, Burma, Siam, Straits Settlements, China, Korea, Philippines (Luzon), Hawaii, Brazil, West Indies (St. Croix, St. Kitts, Anguilla, Monserrat, Porto Rico, Santo Domingo, Haiti, St. Vincent), Mexico, and Australia. There is also a record from Japan, although it may be erroneous. At any rate, according to a statement published by Fullaway (*8*), it is not confirmed by Professor Kuwana, Government entomologist. Another doubtful record is from Mesopotamia.[5]

The introduction of the pink bollworm into Brazil and Mexico is recent, and available records show very clearly how it was accomplished. The information from Brazil comes through Edward C. Green, formerly superintendent of the cotton department of the Brazilian Ministry of Agriculture, who has published a very full statement on the subject (*11*). In 1913 Green made a trip of inspection through the greater portion of the cotton-producing area in Brazil. Special attention was paid to the seed, not only in the fields but in the ginneries, and no infestation was found. In 1916, however, another trip showed that the pink bollworm was present over wide areas in the States of Parahyba, Rio Grande del Norte, and Ceara. It seems that in the years 1911, 1912, and 1913, the

---

[5] For a complete statement concerning the distribution of the pink bollworm, with citations, see the Second Annual Report of the Egyptian Cotton Research Board, 1921, pp. 136–137.

Government of Brazil imported 9 tons of Egyptian cottonseed. This seed was not fumigated, as it was not suspected that any injurious insect was likely to be carried by it. A test for germination showed 89 per cent viable. It is altogether probable that a large percentage of the unviable seeds were those attacked by the pink bollworm. All of this seed was sent to agricultural inspectors in various States and by them was distributed further throughout the cotton-growing districts. There can be no doubt that the general establishment of the pink bollworm in Brazil was due to the importation of the Egyptian seed, and that incalculable losses to the country could have been avoided if proper quarantine precautions had been taken.

In 1911 two importations of Egyptian seed were brought into Mexico; one, of 25 sacks, was planted near Monterey, and the other, of 6 tons, in the vicinity of San Pedro, in the Laguna district. From what is known of the prevalence of the pink bollworm in Egypt in 1911 it is probable that both shipments of seed were infested and that both of them contributed to the present infestation in Mexico. It is true that cotton culture has not been continued in the vicinity of Monterey, but the crop of Egyptian cotton produced there in 1911 attracted considerable attention and much of the seed was shipped to the Laguna district.

In 1917, specimens of the pink bollworm, collected by H. H. Jobson, were received from China. Following is a quotation from Jobson's notes:

> The collection which I have was secured from the seed room of one of the ginneries in Shanghai and from the fields at Tungchow, about 12 hours' ride by boat up the river from Shanghai. The infestation is more or less general throughout China; however, there may be some small areas where it is not present. A majority of the cotton grown within a radius of 100 miles of Shanghai is shipped into that port before being ginned, and from evidences found at the ginning establishments there is no doubt but what all those regions are infested. In fact, the larvæ are so numerous that by going into the seed room of the gins a person may secure any number of them within a very short time, as they may be seen crawling around over the seed and on the walls.

The infestation in Australia was first reported in 1923, from Queensland, and appears to have resulted from the carriage of cottonseed by soldiers returning from Europe to Australia, who stopped at Alexandria, Egypt.

The infestation in the West Indies was apparently caused by a small shipment of cottonseed imported from Hawaii in 1911 to be used on the island of St. Croix for experimental purposes.

PRESENT DISTRIBUTION IN MEXICO

As far as is shown by absolutely definite evidence, the pink bollworm in Mexico is confined to localities in the northern part of that country, one of them being the Laguna district, a valley isolated by mountain ranges about 200 miles from the Texas border. The Laguna, in which the greater part of the Mexican cotton crop is produced, consists of about 1,200 square miles of tillable land. Other localities known to be infested in Mexico (fig. 11, p. 26) are Allende (about 40 miles south of Eagle Pass), the Trevino Ranch (immediately opposite Del Rio), Santa Rosalia (in Chihuahua), Monclova, the Juarez Valley, and the area in Chihuahua opposite

Presidio and Brewster Counties, Tex. In all these cases the infestations were caused by seed from the Laguna. The insect has frequently been found alive in freight cars coming from the interior of Mexico to Texas border ports.

DESCRIPTION AND LIFE HISTORY

The pink bollworm has four stages; namely, egg, larva, pupa, and adult, or moth. The moth (fig. 1) resembles somewhat the common clothes moth of this country. From tip to tip of the extended wings it measures from three-fifths to four-fifths of an inch. It is of a dark-brown color, the forewings ending in a rather sharp point. The hindwings are somewhat broader than the forewings and end in an even sharper point. The eggs are very small objects, somewhat oval, about one-twenty-fifth of an inch long and one-fiftieth of an inch broad. The surface is white and finely wrinkled. The larva (fig. 2) when first hatched is glassy white with light-brown anterior markings. It grows rapidly, and when mature measures nearly a half inch in length. It is cylindrical, white, with the dorsal side of a strong pink color.

FIG. 1.—The pink bollworm (*Pectinophora gossypiella*): Adult. Much enlarged. (Busck.)

The pupa (fig. 3) is about two-fifths of an inch in length, reddish brown, the posterior end pointed and ending in a hooklike process.

Several insects are found in bolls of cotton in the United States which may be mistaken for the pink bollworm. One of these is the so-called pink cornworm or scavenger bollworm (*Pyroderces rileyi* Walsingham), which frequently is found in decaying bolls, especially those which have been injured by disease. It has not been known to attack healthy bolls. It does not normally make its way into the seed, and this fact will help in distinguishing it from the pink bollworm. Another insect which may be mistaken for the pink bollworm is the common bollworm of cotton (*Heliothis obsoleta* Fab.). This is the same insect that feeds on corn and is known in some parts of the country as the corn earworm. It bores holes through the carpels of the boll, feeds for a short time, and then proceeds to another boll. In the early stages it sometimes assumes

FIG. 2.—The pink bollworm: Outline drawing of larva, showing structure. Much enlarged. (Busck.)

a somewhat pinkish color. It may be distinguished from the pink bollworm by its habits, especially by the fact that it does not feed altogether in the interior of the bolls and that it is not found within the seeds. When full grown it is much larger than the pink bollworm, measuring about 2 inches in length.

There is also an insect which feeds in plants known as "nigger heads" (*Rudbeckia* spp.), and another feeding in cat-tails (*Typha* spp.), both of which are sometimes mistaken for the pink bollworm (*12*, *pp. 813*, *831*). The latter is especially confusing, as it is often found in cotton bolls late in the season.

The insect most likely to be mistaken for the pink bollworm is the boll weevil. Although the boll weevil is sometimes found in seeds, it generally is found feeding within the interior of the boll. It discolors the fiber considerably, and this causes the interior of the boll to assume a more or less decayed appearance, quite unlike the appearance of bolls infested by the pink bollworm, in which decay generally does not occur. *This so-called cleanliness of the work of the pink bollworm is one of the most useful characteristics in differentiation.*

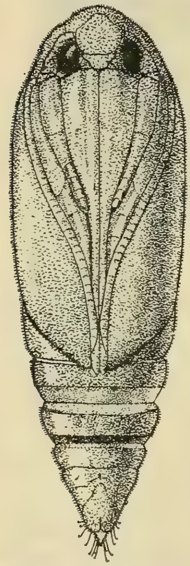


FIG. 3.—The pink bollworm: Pupa. Much enlarged. (Busck.)

The accompanying illustrations will assist the reader in deciding whether the work in question is that of the pink bollworm or some other insect found in cotton bolls.

Figure 4 shows on the left the appearance of the interior of an injured boll, and on the right the characteristic small circular opening made by the larva in leaving the boll or for the purpose of allowing the adult to emerge.

Figure 5 shows on the left the characteristic opening made by the ordinary bollworm (*Chloridea obsoleta*). It is of large size and surrounded by a raised margin. The exit holes of the pink bollworm, shown on the right, are much smaller, more regular, and without raised margins.

Figure 6 shows the appearance of locks of cotton bearing the typical injury caused by the pink bollworm.

Figure 7 shows individual seeds infested by the pink bollworm. In the lower line are the "double seeds." These are frequently found as the result of the webbing together of two seeds by larvæ of the later stages in order to obtain more room for pupation.

Figures 8 and 9 illustrate the pink bollworm in a burr and the typical opening made by this insect when it makes its way from one lock to another.

Although these descriptions may help in enabling anyone to determine whether the pink bollworm is present in a cotton field, it will always be best to send any specimens to an entomologist for authoritative determination. It is extremely important that any possible infestation by this insect be brought to attention at the earliest possible date, that prompt eradicative measures may be taken.

Under the authority of the Federal Horticultural Board, August Busck spent a number of months in the Hawaiian Islands in 1915

FIG. 4.—Exit holes of pink bollworm in cotton bolls

FIG. 5.—Two bolls showing distinction between exit holes of the ordinary bollworm or corn earworm (*Chloridea obsoleta*) and those of the pink bollworm (*Pectinophora gossypiella*). The large hole in the boll to the left was made by the ordinary bollworm; the two small ones in the boll to the right are typical of the pink bollworm

studying the life history and habits of the pink bollworm. The following statements regarding the life history and habits of the

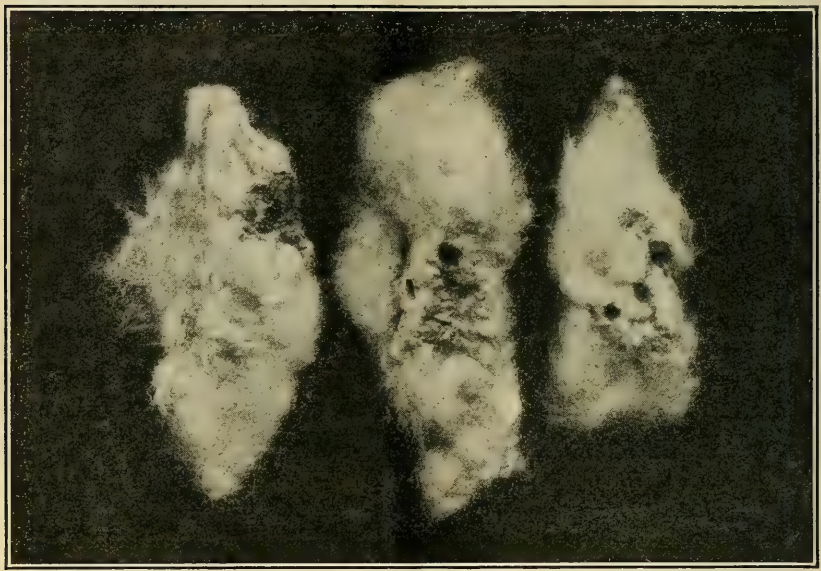


FIG. 6.—Cotton locks showing typical injury by the pink bollworm (*Pectinophora gossypiella*)

pest are based upon Busck's paper (*3*), and subsequent observations by a number of entomologists in Mexico.

The eggs of the pink bollworm are laid singly or in groups on all parts of the plant above ground, about 50 per cent of them being laid on the green bolls. In Mexico the favored position is at the

FIG. 7.—Cotton seed containing pink bollworms, opened to show the cells. Both the single and double seeded cells are shown, the double seeded ones being broken apart

base of the boll, between the boll wall and calyx. Often more than 50 eggs and shells have been found on a single boll. It is estimated that a female will deposit in the neighborhood of 100 eggs. These hatch in from 4 to 12 days.

The larva, on hatching, proceeds to bore its way into either a square or a boll. Squares are preferred early in the season, before the green bolls have become three-fourths grown. The square, even though it contains a larva, usually develops into a bloom. If the larva has attained nearly full development before the bloom opens it webs the ends of the petals together, and on opening they do not flare out normally; the bloom presents a rosetted appearance and is easily distinguished as infested. The infested bolls sometimes become recognizable by a reddish or blackened discoloration which follows attack. Close examination will also reveal the small entrance holes of the larvæ. But the only conclusive evidence of infestation is the larva within the boll, as disclosed by dissection.

FIG. 8.—Pink bollworm on carpel of cotton boll, which shows also typical hole made by worm while traveling from one lock to the next

The food of the larva is the seed within the boll. It devours one seed and generally proceeds to the next one above. Ordinarily a single larva does not make its way outside of the lock which it first invades, but occasionally the adjoining lock may be entered. It is to be noted that the larva restricts itself to the interior of the boll and never makes its way to the outside for the purpose of reaching another boll.

During the summer the full-grown larva either cuts a hole in the outer boll wall for the emergence of the moth and pupates immediately under it, or drops to the soil and pupates within the surface layer of soil or under trash on the surface. In the fall the majority of the larvæ remain in the bolls for hibernation. Often the larva protects itself by webbing two seeds together, the attachment being made to the openings brought into contact by the insect. These "double seeds" are characteristic of the work of the insect. Since usually they are not destroyed in the process of ginning, they furnish the best means of determining quickly whether any lot of seeds is infested.

During the summer the larval stage occupies from 20 to 30 days. Late in the season this stage may be more or less indefinitely prolonged, and pupation correspondingly delayed (*9, p. 9*). It is this feature in the life history of the pest which has facilitated its carriage to many remote quarters of the earth. As this longevity is one of the most important points in the life history of the insect a summary of the existing records concerning it is given in Table 1.

TABLE 1.—*Longevity of resting larvæ of the pink bollworm*

Country	Authority	Conditions under which kept	Longevity
			Months
Egypt	Gough [1]	Stored seed	27
Do	do.[1]	do	16
Do	Ballou [2]	do	24
Do	do.[3]	do	30
Do	do.[4]	do	31
Do	Willcocks [5]	Natural conditions	22
Hawaii	Busck [6]	Stored seed	18
Mexico	Loftin, McKinney, and Hanson [7]	do	12
Do	Ohlendorf [8]	Stored bolls [10]	Over 16
Do	Unpublished [9]	Stored bolls	16¾

[1] (*9, p. 9.*)
[2] (*1, p. 11.*(
[3] (*1, p. 16.*)
[4] (*2, p. 264.*)
[5] (*21, p. 154.*)
[6] (*3, p. 356.*)
[7] (*14, p. 16.*)
[8] (*17, p. 10.*)
[9] Unpublished manuscripts, U. S. Department of Agriculture.
[10] Resting larvæ in stored seed lived 15 months.

After a variable time, as has been indicated, the larva transforms into a pupa or chrysalis. The pupal stage lasts from 6 to 20 days, at the end of which the moth emerges. The life of the moth is rather

FIG. 9.—Typical holes made by pink bollworms through cotton-boll carpels

short. Under favorable conditions Busck succeeded in keeping some specimens alive for 32 days, but under the same conditions the great majority of the insects died in from 14 to 20 days.

The moth is seldom seen in nature. It habitually hides during the day under stones or brush. The normal time of flight is from 6.30 to 8 p. m. Although apparently capable of prolonged flight, the moths prefer to go no farther than the first cotton field. They are so quiet in their habits and so easily overlooked that many may occur unnoticed in the field.

The question of the extent to which the pink bollworm moth is attracted to lights is one which has been discussed extensively in the literature. In Hawaii, Busck (*3*) found that there is no attraction to lights under the conditions prevailing where he worked. Loftin, McKinney, and Hanson (*14*) made extensive tests in the Laguna region of Mexico, but failed to find any definite indications of such attraction. Fletcher (*7*), working in India, and Matsumoto (*16*), working in Korea, also failed to find much attraction to lights. However, several Egyptian investigators, including Gough and Willcocks, have found moths coming to lights under certain conditions (*1, p. 238.*) Gough captured a large number of specimens in light traps in the warehouse in which cottonseed was stored, and Willcocks with 18 traps captured about 19,000 moths in three months, but did not consider that this was enough to warrant the use of light traps as a control measure.

It is very probable that the differences in the observations are due to the varying conditions under which they were made. It is well known that insects are much more strongly attracted to lights under certain climatic conditions than under others.

The explanation of the Egyptian observations may perhaps be found in the climate of the locality in which they were made. It is also possible that the quality of the lights used by the various experimenters may help to explain the discrepancies. At any rate, it seems to be clearly indicated that under no known conditions is there attraction sufficient to be of any importance in control work.

Considerable attention has been paid in various countries to the food plants of the pink bollworm. In Egypt the insect has been found breeding in okra, hemp, and hollyhock. There are similar records from India. In the Hawaiian Islands it has been found in various species of cotton and in *Hibiscus youngianus*. From Brazil there are records of its occurrence in *Cochlospermum insigne* and *Bombax monguba* (*4*).

The most extensive studies of the alternative plants of the pink bollworm have been conducted in Mexico (*14*). Okra and hollyhock were frequently found infested, as was a native desert plant, *Hibiscus cardiophyllus* Gray. A large series of malvaceous plants from the United States were planted for the purpose of observation. The following eventually became infested in greater or lesser degree: *Hibiscus coccineus* Walt., *H. militaris* Cav., *Kosteletzkya virginica* L., *Hibiscus syriacus*, and *Malvastrum americanum* (L).

Several experiments were performed to determine whether the pink bollworm could live over from year to year when supplied with any of these alternative food plants. Special attention was paid to okra. In no case did the insect live under such conditions. This result appears to have been due primarily to the fact that the seed pods of okra and related plants crack open on drying, so that the larvæ webbed up in them drop to the ground and become subject to the influence of moisture and the attacks of enemies. It is more than likely, however, that under some conditions the insect may be able to perpetuate itself on these plants.

In Texas and Louisiana, where noncotton zones have been maintained for the purpose of stamping out the pink bollworm, the alternative plants have been disregarded, for the reason that most extensive searches have failed to disclose any of the insects in any of the malvaceous plants growing in such zones. Certainly the apparent success of the noncotton zones (and clean-up measures) in eliminating the infestation minimizes the importance of the existence of the pink bollworm on plants other than cotton under such conditions as have prevailed in the United States. It must be remembered that there has never been any heavy infestation of cotton by the pink bollworm. The number of moths produced has in every case been exceedingly small. With a very heavy infestation the results might have been very different, since out of a larger population of moths there might be a sufficient number of aberrant individuals to continue the species on other plants.

NATURAL ENEMIES

The pink bollworm has a number of insect enemies wherever it occurs. In the Hawaiian Islands Busck (*3*) found at least five species attacking it. Other species have been recorded from Egypt, Brazil, and India. In Mexico, early in July, 1921, as high as 33 per cent of the pink bollworm larvæ in blooms were killed by parasites. Two species of Hymenoptera, *Microbracon mellitor* Say and *Habrobracon gelechiae* Ashm., were responsible for this unusual destruction.

By far the most important enemy of the pink bollworm is a small mite known as *Pediculoides ventricosus* Newport. Its attack is confined almost entirely to pink bollworm larvæ in stored seed. It is a common enemy of insects and occurs throughout the world. It has apparently increased to a very considerable extent in Egypt, but does not seem likely to be sufficiently abundant at any time to serve as an important agent in controlling the pink bollworm. Neither do the available records indicate that any insect or mite enemies of the pest are likely to be of any practical importance in controlling it.

It is interesting to note that the mite to which reference has been made also attacks human beings. In 1914 large quantities of Egyption cottonseed were shipped to London. The laborers employed in handling this seed became affected with a rash of the skin caused by the punctures of the mite. The irritation was severe and resulted in a strike for higher wages. The writer has learned from E. C. Green that in Brazil, since the establishment of the pink bollworm there, children who play about seed houses soon become affected by a dermatitis which probably is the same as that which has been found to follow the attack of the mite in other parts of the world.

NATURE AND EXTENT OF DAMAGE

The pink bollworm affects cotton production in several ways. In the first place it destroys a certain number of bolls or portions of bolls, causing the lint from them to be short and kinky. (Fig. 10.) The injury, however, is not limited to the yield and quality of lint. The crop of seed is correspondingly reduced, and what seed is obtained is of light weight and poor grade. In the crushing of Egyptian seed in England it was found that the oil content was lower than normal by about 20 per cent, and that the oil actually obtained was dark in color and of comparatively low value. The work of the insect is also of importance in connection with seed for planting. The percentage of germination is naturally low and much larger quantities must be planted to obtain a stand.

From what has been said it is evident that the pink bollworm must be of interest to all classes of persons concerned in the cotton trade as well as to those engaged more especially in the cultivation of the crop and the utilization of the seed.

Accurate information concerning the damage by the pink bollworm in Egypt is contained in a paper by L. H. Gough (*10*). This investigator conducted studies in lower and middle Egypt to determine the relative number of bolls attacked by the pink bollworm. Samples, each of 100 green bolls taken at random in fields in various localities, were sent to Cairo, where they were given

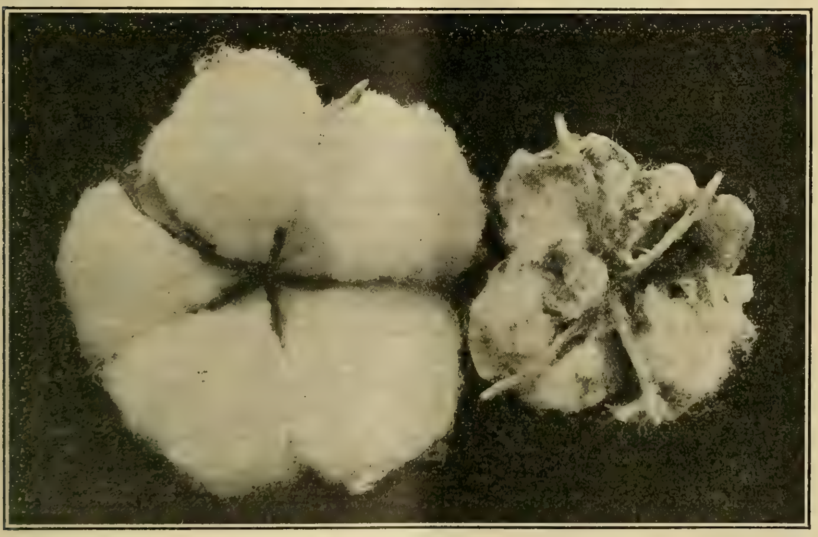


FIG. 10.—At left, normal cotton boll; at right, boll injured by the pink bollworm

very careful examination. The total number of bolls examined was more than 106,400, and the examinations were continued from July to November, 1916. The following are among the results of this investigation:

Percentage infested during July, less than 10.
Percentage infested during August, from 5 to 25.
Percentage infested during September, from 25 to 75.
Percentage infested during October, from 75 to 85.

These figures show in a very striking manner the great damage of which the pink bollworm is capable, and may be taken as a fair indication of the injury which would be done in the United States if it were allowed to spread here, as the seasonal conditions here are similar to those in Egypt. In short, they show that approximately 20 per cent of the August bolls and 50 per cent of the September bolls would be destroyed or rendered practically valueless by the insect. They further illustrate the rapid increase of infestation of green bolls with the advance of the season, and indicate the possibility of a severe reduction of yield, particularly in all late-maturing cottons where the second and third pickings are important. Fortunately for Egypt, one of the principal varieties of cotton grown there, the Sakellarides, matures its crop early and yields most of its cotton with the first picking. In spite of this favorable circumstance, however, and of expensive control operations enforced by the Government, a very conservative estimate by experts indicates that this insect causes a loss of at least 17 per cent to the Egyptian crop. In the Hawaiian Islands the pink bollworm has prevented the development of the cotton industry, which at one time showed considerable promise.

In Brazil, through correspondence with the governors of the principal cotton-producing States of the Republic, the minister of agriculture collected data for an estimate of the damage to the cotton crop caused by the pink bollworm in 1917. The loss reported ranged from 30 per cent of the crop in the State of Alagoas to two-thirds of the crop, or 30,000 metric tons, in the State of Ceará.

DAMAGE IN MEXICO

Special effort has been made to ascertain the degree of damage which the pink bollworm causes the cotton crop in the Laguna district of Mexico. In making the estimates two plans have been followed, one being to send experienced crop reporters to the Laguna, who collected data according to the plans followed in estimating injury to the crops from various causes in this country. Planters were interviewed and the consensus of their opinion as to the actual loss was determined. The other method consisted in estimating the quantity of cotton left unpicked in the fields on account of the injured bolls passed over by the pickers. In Mexico there are no important causes other than the pink bollworm which render bolls unpickable. The relation between the number of unpicked bolls and the number picked, as shown by the burrs remaining on the plants, has been taken in a general way to indicate the loss. This method is only a rough approximation; its accuracy will vary from year to year because, regardless of the degree of actual damage, the fields will be picked more thoroughly in years when the price is high than when it is low.

The actual injury caused by the pink bollworm in 1917 was investigated by a joint body representing the Mexican and American commissions, which visited many plantations in the Laguna. It reported that the loss to the crop of 1917 chargeable to the pink bollworm was not less than 30 per cent.

In 1919 a very special study of the various forms of injury was made (*14*). It was determined that the injury could be classified approximately in the following manner:

(1) Loss in squares and blooms; of 343 normal blooms observed, 40.8 per cent dropped off without setting bolls; of an equal number of infested bolls 67.6 per cent dropped off. An undetermined loss was also due to early shedding of infested squares.

(2) Loss in pickable cotton; the lint suffered deterioration in quality, the seed was reduced 6.9 per cent in weight, and the oil was unfavorably affected in both quantity and quality.

(3) Loss in nonpickable cotton; 19.98 per cent of the entire crop was rendered unpickable.

On the basis of the foregoing data the loss for the crop of 1919 was calculated at 20.89 per cent. In 1920 a similar estimate showed a total loss of approximately 38 per cent of the crop.

In 1921 the quantity of nonpickable cotton was calculated at 12.8 per cent, and in 1922 at 7.97 per cent. The losses through shedding and other causes were not estimated for these years. On account of the high price of cotton in both years, the fields were undoubtedly picked cleaner than usual. It is therefore probable that the actual losses were not materially lower than in other seasons.

In 1923 the loss was calculated at 16 per cent. Because of peculiar conditions, including a lack of rains during the growing season, it was evident that the damage was less than normal.

A study of the damage in the Laguna by expert statisticians was conducted by H. H. Schutz and E. S. Haskell, of the Bureau of Agricultural Economics. The following is quoted from their report:

Estimated losses to cotton crops caused by cotton pink bollworm, Laguna district, Mexico, 1915–1921

Year	Number of records or estimates	Average loss	Range of losses	Year	Number of records or estimates	Average loss	Range of losses
		Per cent	*Per cent*			*Per cent*	*Per cent*
1915	6	25.0	5 to 50	1919	27	19.0	2 to 50
1916	6	25.0	5 to 40	1920	36	30.4	4 to 70
1917	9	22.1	5 to 60	1921	39	22.4	3 to 70
1918	20	20.2	0 to 40				
				Average		23.4	

It was stated by the Laguna planters that formerly practically all cotton made before the first killing frost in the fall was No. 1 (good, middling, or better), and that picked later was No. 2 or No. 3, with but a small difference in the prices of the first two grades; however, the difference in price now runs at times as high as 11 cents per pound, depending upon the percentage of pink bollworm infestation.

On account of the number of breaks and loss of time in retying the ends, some of the spinners dislike to use late-picked Laguna cotton. Mauro de la Peña, manager of the Fabric La Fé Torreon, made tests with normal lint, and lint injured by the pink bollworm. Using a standard English dynamometer, the lint having been spun into 120-yards lengths of No. 18 thread, the normal cotton showed a resistance of 92 pounds, whereas the damaged, in three tests, offered resistance of 68, 75 and 72 pounds.

It is thought that from September, 1918, to August, 1919, the seed produced in the Laguna suffered no appreciable loss in weight, but in the following season 15 to 50 per cent of the seed was practically barren; this was particularly true of all but the early seed. The quantity and quality of oil produced is naturally proportional to the quantity and quality of seed produced. The percentage of undeveloped and worm-eaten seed in the late picking causes a reduction in the quality as well as the quantity of oil. The resulting oil is darker, and more residue remains in the process of refining; the cake is dark and carries an odor offensive enough to affect the animals to which it is fed.

One oil-mill operator estimates that the percentage of oil normally averages 17, that of cake 44, and that of hulls 35; and that the loss in oil from seed of the 1919-20 season was 0.5 point, and that for the following season 1 point. Another oil mill reports that the percentage of oil was formerly 16, but that now, because of injury caused by the pink bollworm, it is but 13½. He also states that even the first or early picking yields but 15 per cent of oil, and that this is appreciably infested; further, that 25 to 30 per cent of the seed produced late in the season is almost worthless, and yields only 10 to 11 per cent of oil. The 1920 seed handled by this mill averaged 13¼ per cent of oil; the 1921 seed, 14 per cent. Good seed formerly weighed, on an average, 25 tons per carload; now a carload is found to weigh but 21 to 22 tons.

PRECAUTIONS TAKEN TO PREVENT THE INTRODUCTION OF THE PINK BOLLWORM INTO THE UNITED STATES

With the approval of the plant quarantine act on August 20, 1912, the Department of Agriculture for the first time obtained authority to regulate the importations of plants and plant products from foreign countries and to take the steps necessary to prevent the introduction of injurious insects and plant diseases by such importations. The pink bollworm was one of the first insects to be considered after the plant quarantine act went into operation. Its foreign status and its menace to American cotton were first brought to the attention of the Federal Horticultural Board in April, 1913, and on May 20 of that year a formal hearing was called at Washington to consider the advisability of prohibiting the importation of cottonseed from all foreign countries. A quarantine was promulgated on May 28, 1913, to take effect on July 1 of that year. This quarantine forbade the importation into the United States of cottonseed of every species and variety, and cottonseed hulls from any foreign locality and country excepting the Imperial Valley in the State of Lower California in Mexico. The importation from this region in Mexico was covered by regulations. The importance of this action was shown in May, 1913, by the receipt in Arizona of a shipment of 500 pounds of Egyptian seed which was found to have an infestation by the pink bollworm of about 20 per cent. Thanks to the quarantine law of Arizona and the activity of A. W. Morrill, the State entomologist, the whole shipment was destroyed by fire.

A little later (August 18, 1913), on the recommendation of experts of the Bureaus of Entomology and Plant Industry of this department, this quarantine was amended to provide, under regulation, for the entry, for milling only, of cottonseed from the States of Nuevo Leon and Tamaulipas, Mexico. A still later amendment permitted the introduction of seed from other of the northern States of Mexico.

The reasons advanced for allowing the regulated entry of Mexican cottonseed were that no insects which were not found in the United States were known to occur in Mexico, and that the culture of cotton there is more or less continuous with that in the United States. The absence of any cotton pests in the Republic of Mexico which did not occur in the United States at that time had been established by field inspections by several of the entomologists of the department.

To protect the United States from the possible entry of the pink bollworm from the Territory of Hawaii, a domestic quarantine was promulgated June 24, 1913, prohibiting the importation of cottonseed and cottonseed hulls from this territory.

It was thought that the United States was sufficiently safeguarded against the pink bollworm by the quarantines against cottonseed as such, but it soon came to notice that considerable quantities of seed were coming to the United States in bales of lint. A careful examination of picker waste from a large number of bales of Egyptian cotton was made. It was found that considerable numbers of seeds passed around the rollers in the gins and some between the roller and the knife through small openings caused by wear. The waste from 37 bales which was examined showed sound seeds, some of them infested, varying from 27 to 600 per bale. The average per bale was 215. The variation in the different bales depended upon the grade of the cotton, the lower grades having many more seeds than the better ones. It was estimated on the basis of the examination of waste from the 37 bales that over 16,000 live larvæ of the pink bollworm were being brought to the United States each year, of which several hundred went to the mills in the Cotton Belt.

It thus became evident that a quarantine which did not take into consideration the seeds in bales of lint was inadequate. Consequently in May, 1914, a public hearing was held to discuss various means of protection. The different proposals made were that foreign cotton be excluded altogether from the United States; that it be admitted only under a guaranty that all seeds had been eliminated, or that the cotton had been disinfected; that it be allowed to proceed only to mills outside of the Cotton Belt; and that it be sent to southern cotton mills only after a period of storage of 18 months or more in northern localities. At the public hearing, and subsequently through conferences with members of the cotton trade and representatives of manufacturing associations whose assistance was very valuable to the department, it became evident that there were insuperable obstacles in the way of any of the plans mentioned. It therefore became necessary to make an exhaustive study of the possibility of destroying any infestation which might be found in the bales of lint. The use of cold was found to be impracticable. The use of heat was also impracticable on account of the time necessary to penetrate the highly compressed bales of Egyptian cotton and on account of the increased danger from fires when bales which had been heated were opened in the mills.

About this time E. R. Sasscer, of the Federal Horticultural Board, and Lon A. Hawkins, of the Bureau of Plant Industry, had been conducting some experiments in the destruction of insects in various plant products by fumigation in a vacuum. It was found that the killing power of hydrocyanic-acid gas was increased enormously in vacuum and it thus became possible to reach certain classes of insects which heretofore had been uncontrollable. It therefore seemed possible that the vacuum process might be utilized in the fumigation of bales of cotton without necessitating their opening. A small experimental plant was established by the board at Washington and a long and what turned out to be a most interesting series of experiments was begun by Sasscer.

While this investigation was in progress an order regulating the entry of all imported lint cotton was promulgated by the Secretary of Agriculture April 27, 1915, effective July 1, 1915, and a domestic quarantine regulating the movement of cotton lint from the Territory of Hawaii to the mainland was promulgated June 11, 1915, effective on and after July 1, 1915. Under this order and quarantine, tentative regulations were issued governing and restricting the entry of foreign cotton and also providing for the screening of all rooms or buildings in which foreign cotton was kept and the daily burning of all grades of mill waste in which seeds of such cotton might be found. A corps of inspectors was employed and, to insure the faithful following of regulations, frequent examinations were made at the mills where foreign cotton was used. In general, sympathetic cooperation was obtained. This was especially noticeable in the case of southern mills, the owners and managers of which seemed to realize the danger of introducing the pink bollworm and complied with the orders and regulations of the Federal Horticultural Board in the most hearty and public-spirited manner.

In the experiments with vacuum fumigation of lint cotton conducted by Sasscer, under the direction and with the advice of the Federal Horticultural Board, tests were made with variations in the dosage of cyanid, the degree of vacuum, the length of exposure, the temperature, and the depth of penetration. Steel tubes pointed at one end were provided. These had perforations near the point and were sealed in such a manner as to be perfectly airtight at the other end. Insects were placed within them, and the tubes were then driven into the bales. After the experiment was performed the insects were removed for examination. In this way the exact effect of the fumigation under all varying conditions at different depths within the bales could be determined. At the same time chemical tests were made by the Bureau of Chemistry of this department to run parallel with the tests with insects. These chemical tests confirmed the rapid penetration of the gas.

As a result of a suggestion made following a conference of a committee of cotton manufacturers with the Federal Horticultural Board, the then Office of Markets and Rural Organization of this department conducted a series of manufacturing tests with cotton which had been fumigated with hydrocyanic-acid gas to determine whether the fumigation by this agent would cause any injury to cotton fibers. The results of these tests indicate that such fumigation of cotton did not cause any deterioration of the cotton, either as to percentage of waste, spinning qualities, tensile strength, or the bleaching, dyeing, or mercerizing properties of the cotton (*5*).

In the first series of experiments various insects more or less related to the pink bollworm, but which are native to the United States, were used. After the preliminary work was done and the probable requirements for destroying any insect in the bales of lint were determined, it was decided to add a series of experiments with the pink bollworm itself. For this purpose, under extreme caution to avoid escape, a number of insects were brought from the Hawaiian Islands. The results in all essential respects were similar to those that followed in the case of the insects treated previously.

As the result of all of this work, which taxed the ingenuity of the investigators engaged in it, it was found feasible on a commercial scale to fumigate densely compressed bales of cotton and kill any insect which might be inside.

On March 10, 1916, the fumigation of all bales of foreign cotton arriving at the United States was required as a condition of entry. Advance notice had been given to the importers and others concerned. In spite of considerable difficulties in obtaining materials and in working out mechanical problems, large plants were erected in a remarkably short time and became available for use on the date mentioned. Two of these plants were erected in Boston and one in Oakland, Calif. A little later two additional plants were erected at New York City and one at Newark, N. J. Plants are now available at Seattle, Wash., Oakland and San Francisco, Calif., and Astoria and Portland, Oreg. These establishments have a capacity sufficient to handle all of the imported cotton without any special delay. The larger plants have a capacity of upward of 1,000 bales per day.

The procedure to be followed in the fumigation of foreign cotton is given in an order of the Federal Horticultural Board (*19*)[6].

Later investigations led to the placing of restrictions on certain kinds of cotton waste, cotton wrapping material and cottonseed products. On April 11, 1916, the collector of customs at Norfolk, Va., telegraphed the board that some 189 tons of cottonseed from Lagos, West Africa, constituted a portion of the cargo of the British steamship *Appam*, brought to Newport News as a German prize of war. In coöperation with the Office of Markets the board took immediate steps to dispose of this seed, which was found to be infested by the pink bollworm. A provisional sale had been made by the admiralty board to the proprietor of an oil mill in South Carolina. This was set aside as soon as the danger of introducing the pink bollworm was explained. After considering a number of methods of disposing of this seed, it was finally decided to have it treated with sulphuric acid and thus made available as a fertilizer. Through the coöperation of one of the largest manufacturers of fertilizers this was done with the utmost dispatch. The entire lot of 4,000 bags of seed was placed in sulphuric-acid vats within four days from the time the presence of the seed at Newport News became known to the department. As an additional precaution the two holds of the *Appam* which contained the seed were fumigated with a heavy dose of hydrocyanic acid gas, and the docks, lighters, and trucks, as well as floors and platforms, were thoroughly cleaned of any scattered seeds.

To guard against the possibility that the pink bollworm had escaped prior to the treatment which has been described, repeated inspections were made later of the cotton fields near Newport News, which are at a distance of about 10 miles. No traces of infestation have been found, and it now seems certain that the establishment of the insect from this seed was prevented.

DISCOVERY IN MEXICO

Earlier in this bulletin attention has been directed to the fact that when the quarantine against foreign cottonseed was placed in operation the State of Lower California, Mexico, was not included, and that subsequently cottonseed was permitted entry, for milling purposes only, from certain northern States of Mexico. The reason for this was that several of the entomologists of the department had been in northern Mexico and had found no traces of infestation by any insects other than those which are known to occur in the United States. These explorations were made some years previously, however, and it was thought desirable to make new examinations on ac-

[6] Detailed information as to the activities of the Federal Horticultural Board and its quarantine and other restrictive orders and regulations relating to cotton and cotton products, may be found in its service and regulatory announcements.

count of the suspicion that the pink bollworm or some other destructive pest might have been introduced in the meantime. Accordingly arrangements were made in 1916 to dispatch an agent to Mexico. Shortly before the time fixed for his departure the activities of the bandits became so great that the trip had to be postponed indefinitely. If it had not been for these circumstances the presence of the pink bollworm in Mexico would have been known some months before it actually came to the attention of the department.

On November 1, 1916, the department received from a planter in the Laguna district, who was then residing in Mexico City, a number of specimens of cotton bolls which had been attacked by insects. The sender was under the impression that the insect was the boll weevil, which, though introduced in the Laguna on numerous occasions, had, on account of climatic conditions, never been able to maintain itself. Several of the bolls were found to be infested by the boll weevil, but others showed the presence of the pink bollworm. The determination was first made by W. D. Pierce and confirmed by August Busck and other specialists of the Bureau of Entomology.

On November 3, 1916, the situation was considered by the Federal Horticultural Board, and on November 4 an amendment to the regulations, extending the quarantine to cottonseed and cotton from Mexico, was issued by the department. An investigation was immediately started to determine the extent of the infestation in Mexico and the number of shipments of cottonseed from that country to the United States. It was soon found that a large quantity of Mexican cottonseed had been shipped to mills in Texas during the season of 1916. In previous years no Mexican cottonseed had been shipped to the United States, and it was only the disturbed conditions in Mexico and the unprecedentedly high price of seed in the United States that caused the seed mentioned to be forwarded to this country.

In 1916 a total of 446 carloads of Mexican seed had been brought into Texas prior to November 4, all of which went to the mills at Beaumont, Pearsall, Kaufman, Hearne, San Antonio, Houston, Dallas, Wolfe City, New Braunfels, Grand View, and Alice. The quantities varied from 1 carload, which went to Wolfe City, to 114 carloads, which went to Beaumont. Ninety-three carloads were shipped to Hearne and 69 to Kaufman, both located in regions where cotton is cultivated on every plantation. The State authorities in Texas were notified and the Federal Horticultural Board began a campaign to expedite the crushing of the seed and the destruction of any scattered seeds about the premises. The cooperation with the State was brought about by Fred Davis, commissioner of agriculture, the entomologist of his department, E. E. Scholl, and the chief nursery inspector, E. L. Ayers.

DISCOVERY IN TEXAS

As the result of field examinations, the first specimen of the pink bollworm in Texas was discovered in Hearne on September 10, 1917, by Ivan Schiller, an inspector of the board. This was found in a small field adjoining the oil mill which had received Mexican cottonseed. Later four additional specimens were found, none of them more than one-fourth of a mile from the mill. On October 5 a specimen was found in a field near the oil mill at Beaumont by inspector H. C. Millender, and on October 25 specimens were taken at Anahuac, in Chambers County, by H. S. Hensley. The first two of these infestations were undoubtedly due to the Mexican seed which had been shipped to the United States in 1916. The infestation in Chambers County, however, can not be attributed to such shipments. It was found to extend around Galveston Bay from Smiths Point to the vicinity of Texas City. It was heavier near the bay and diminished regularly toward the interior. After considerable investigation, in which all possible theories were weighed, the conclusion was reached that this infestation was probably due to Mexican bales of cotton which were shipped to Galveston in 1915. During this year several thousand bales of cotton from the Laguna in Mexico reached Galveston by way of El Paso. This cotton was on the docks at Galveston at the time of the hurricane of August, 1915. With several thousand bales of Texas cotton it was washed from the docks and distributed around the shore line, in some cases 75 miles away. Many of the bales were broken open by the force of the water. It is well known that Mexican bales contain large numbers of seeds, and cotton plants were found growing along the high-water line during the fall of 1915 and the spring of 1916. This theory, while not altogether satisfactory, is considered by August Busck, who has paid more attention to the study of the pink bollworm than any other entomologist, to be an adequate explanation of the present situation around Galveston Bay.

As soon as the presence of the pink bollworm in Texas was discovered, the Federal Horticultural Board, in cooperation with the Department of Agriculture of the State of Texas, undertook active measures to eradicate it. The work consisted at first of scouting to determine the limits of infestation, the destruction of any possible infestation remaining in the fields, and the safeguarding by various means of the cotton produced in the infested fields and in neighboring ones during the season of 1917.

The work of removing any possible infestation from the fields consisted in uprooting or chopping down the plants, the collection by hand of all locks or portions of locks which were found on the ground, and the burning of all the accumulated trash. In this work 1,624 acres of land in the vicinity of Hearne was cleaned, and 7,170 acres in southeastern Texas. The work was not confined to fields in which infestation was actually discovered, but included fields at a considerable distance beyond the outermost points found infested. It involved the employment of an average of about 500 laborers for the months of November, December, January, and February, and a portion of March. In many cases the laborers were assembled in camps and housed and provisioned by the department. In other cases, where the work was in the vicinity of towns, it was possible to employ local labor. The safeguarding of cotton products from the infested areas in 1917 consisted in the milling of the seed under supervision at certain mills selected because their construction would enable the work to be done with practically no danger of disseminating the pest. The baled cotton, as far as possible, was caused to be exported or shipped directly to northern mills.

COTTON-FREE ZONES

In 1917 the legislature of Texas passed an act intended to give authority to prevent the establishment of the pink bollworm in the State. By this act authority was granted to quarantine the districts in which the insect might be found, and to establish zones in which the planting of cotton might be prohibited. Under this authority, on January 21, 1918, the Governor of Texas quarantined the Hearne district as well as the territory found infested in southeastern Texas. In the case of Hearne the quarantined area included a territory within a radius of 3 miles from the mill. In the case of southeastern Texas the quarantined area included a safety zone, approximately 10 miles in width, covering the outermost points infested.

On February 25, 1918, following the recommendation of the commissioner of agriculture, the Governor of Texas issued a proclamation prohibiting the planting of cotton in the quarantined areas.

The finding of infestation by the pink bollworm in Mexico not far from Del Rio in the spring of 1918 made it necessary to place in operation another section of the Texas pink bollworm act. As a consequence a third noncotton zone was provided to include McKinney, Maverick, and Valverde Counties.

SPECIAL REGULATIONS AT MEXICAN BORDER

The risk of direct entry of the pink bollworm from Mexico by flight or by accidental carriage necessitated the provision in the regulations governing the entry from Mexico of cottonseed cake, meal, or other cottonseed products, including oil, that permits for such entry should be issued only for the products named coming from mills located in the Laguna district of Mexico. The object of this proviso with relation to Mexico is to deter the erection of mills near the border of the United States, with the consequent risk of escape of insects from seed brought for crushing to such mills near the border.

ORGANIZATION OF THE PREVENTIVE WORK OF THE DEPARTMENT OF AGRICULTURE

In general, the basis of the work in Texas and other States has been scouting to determine the location and extent of infestations. When this has been done noncotton zones are provided, with surrounding zones in which all cotton products are safeguarded as to distribution and use. Two years has been found a sufficient time for maintaining the noncotton zones, but the regulated zones are continued longer. As soon as infestation is found the fields are thoroughly cleaned by removing and burning all bolls, burs, and other material which might harbor the insect. This work extends far beyond the fields actually found infested and is carried on each year in the regulated zone surrounding any noncotton zone. Of course all noncotton zones are carefully scouted and all volunteer cotton destroyed.

It is probable that this clean-up work has been the most important factor in what seems now to have been a successful effort at eradication in large areas. No attempt has been made to reach such larvæ as might be in the soil. Certainly the vast majority of the insects in the field in the fall and winter are in the bolls on the plants and in the bolls and trash on the ground, and these are effectively disposed of. The remaining insects are in a very unfavorable situation on account of the normally heavy winter rains, as experiments performed in Mexico show clearly that in moist soil the insect rarely if ever passes the winter alive.

The following is a general outline of the lines of preventive work begun in 1917 and continued up to the present time:

The exclusion from the United States of cottonseed from all foreign countries except the Imperial Valley of Lower California, Mexico. Cottonseed from Hawaii and Porto Rico has also been excluded.

The regulation and safeguarding of the entry of cottonseed products from all foreign countries and from Hawaii and Porto Rico.

Regulation of entry and disinfection of all imported cotton and cotton waste, and of burlaps which have been used as wrappings of foreign cotton, including such material from Hawaii and Porto Rico.

Survey, eradication, and control work in Texas and elsewhere, in cooperation with State authorities.

Regulation of rail and other traffic with Mexico.

Determination of distribution in Mexico and cooperation in control measures with the Mexican Government or local Mexican authorities.

Investigation in Mexico of the life history and habits of the pink bollworm, as a basis for control measures.

The work at the Texas border ports consists in the regulation of traffic from Mexico to prevent the importation, through accident or otherwise, of any Mexican cottonseed. It includes the inspection and disinfection of baggage, the cleaning or disinfection of all freight, express, and other shipments, except those which could not possibly carry infestation, restriction on the entry of railway cars from Mexico, regulation of the transfer of freight, express, and other shipments, certification of all cars or other carriers of merchandise as a condition of entry into the United States (excepting merchandise or other materials of strictly local origin), and the cleaning of domestic cars as a condition of receiving freight originating in Mexico for movement into the interior of the United States.

The work in Mexico consists in research and in cooperation with the Mexican Government and planters for eradicating the pink bollworm from that country. The loss which the pink bollworm has already shown itself capable of causing, and the fact that the cotton lands are owned by comparatively few persons, are grounds for hope that the main infestation in the Laguna district may be destroyed. Various conditions, however, have prevented any very definite progress along this line.

CHRONOLOGICAL SUMMARY OF INFESTATIONS

The origin of the Hearne infestation of 1917 has already been narrated. The area cleaned up comprised 1,624 acres. A noncotton zone was maintained for three years. No reinfestation has been found up to the present time.

The Trinity Bay infestation comprised 156 fields of the crop of 1917. A noncotton zone was provided in 1918, but, on account of a defective State law, it was discontinued during 1919. In the latter year 51 infested fields were found. In 1920, 1921, and 1922, noncotton zones of limited size were established where infestation has been observed. In the scouting in the vicinity of these zones 28 fields were found infested in 1920, 1 in 1921, and none in 1922 or 1923. The clean-up operations were conducted in each of the years except 1918, at a total cost of $219,266.68.

In the Big Bend district the first infestation was found in the crop of 1918, and was evidently caused by the bringing in of cottonseed from the interior of Mexico. Twenty-one fields, including some in Mexico, were found infested, all of which were cleaned up. A noncotton zone was maintained there in 1919 and 1920. The infestation has continued, evidently owing to reintroduction of the insect from Mexico. The infested fields numbered 12 in 1921, 24 in 1922, and 33 in 1923. In 1921 and 1923 a part of the infested fields enumerated were in Chihuahua, Mexico. The Pecos Valley also was first found infested in 1918, to the extent of nine fields, as a result of the carriage of seed cotton from Big Bend. The area was cleaned up in 1918 and 1919, but no noncotton zone was established. Infestation has recurred in 1919, 1920, 1921, 1923, and 1924. Much labor has been expended in scout work.

TABLE 2.—*Number of man-days scouting and number of infested fields in each infested district for each crop to June 30, 1925*

District	1917		1918		1919		1920		1921		1922		1923		1924	
	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields	Man-days	Infested fields
Texas:																
Hearne	164	5	471	0	650	0	505	0	369	0	172	0	255	0	0	0
Trinity Bay	645	156	829	0	1,796	51	2,006	28	1,518	1	891	0	1,225	0	1,030	0
Big Bend	0	0	4	[1] 21	(1)	1	0	0	22	[1] 12	27	24	66	[1] 36	167	62
Pecos Valley	0	0	555	9	1,123	1	850	15	299	21	386	0	421	5	631	15
El Paso Valley	0	0	103	0	158	0	339	14	78	9	261	4	406	1	397	1
Ennis	0	0	0	0	0	0	0	0	798	5	671	0	740	0	835	0
Marilee	0	0	0	0	0	0	0	0	340	2	461	0	611	0	612	0
Louisiana:																
Cameron	0	0	5	0	104	22	213	0	319	0	632	0	718	0	655	0
Shreveport	0	0	0	0	46	0	486	10	320	0	332	0	648	0	744	0
New Mexico:																
Mesilla Valley	0	0	0	0	0	0	240	[2] 5	27	[2] 6	77	[2] 1	231	0	260	0
Carlsbad	0	0	111	0	57	0	310	2	63	4	282	0	1,212	0	695	0
Totals:																
Texas	809	161	1,962	30	3,727	53	3,729	58	3,430	53	2,881	29	3,724	42	3,672	78
Louisiana	0	0	5	0	150	22	699	10	639	0	964	0	1,366	0	1,399	0
New Mexico	0	0	111	0	57	0	521	6	84	7	347	0	1,443	0	955	0
Total	809	161	2,078	30	3,934	75	4,949	74	4,153	60	4,192	29	6,533	42	6,026	78

[1] In 1918, 1921, and 1923, some of the fields enumerated under the Big Bend district were in Chihuahua, Mexico, but are here counted as being in Texas. In 1919 only a fraction of a man-day was devoted to scouting, and is not enumerated.

[2] In 1920, 1921, and 1922, a part of the fields here ascribed to the Mesilla Valley district were in El Paso County, Tex., and the totals by States are adjusted accordingly.

The infestation in the Cameron Parish district was discovered in 1919. There has never been any very satisfactory determination of its origin, but it is probably connected with the infestation in the Trinity Bay area. Twenty-two fields were found infested. A noncotton zone was maintained effectively during the two following years and there has been no recurrence of the infestation. The area was cleaned up in 1919.

In the Shreveport district 10 fields were found infested in the crop of 1920, a result of seed shipped from the Cameron district prior to the discovery of infestation there. A noncotton zone was proclaimed in 1921 and continued through 1922, and there has been no recurrence of infestation. The area was cleaned up in 1920 and again during 1922 and 1923.

In the Mesilla Valley in New Mexico 5 fields were found infested in 1920. A clean-up campaign was begun, but it was discontinued when the extent of the infested territory in this district and in the adjoining El Paso district was determined. The infestation has continued.

In the El Paso Valley 14 fields were found infested in 1920. A clean-up campaign was begun, but it was discontinued on account of the general infestation in this and the adjoining Mesilla Valley and the proximity to Mexico. The infestation has continued.

The Carlsbad infestation was found in 2 fields in 1920. No clean-up was undertaken, and the infestation reappeared in 1921. There was no recurrence, however, in 1922 or 1923.

The Ennis, Tex., infestation, consisting of 5 fields, was found in 1921. It originated with the shipment of 14 carloads of cottonseed from New Mexico before infestation had been found there. The infested area was cleaned up in 1921, 1922, and 1923, and intensive scouting has not disclosed any reinfestation. A noncotton zone was maintained during 1922, the clean-up work for that year being conducted in the fields immediately outside of the small zone necessary under State law.

The Marilee infestation, consisting of two fields of the crop of 1921, originated in the reshipment from Ennis to Marilee of some of the New Mexican cottonseed which caused the infestation at Ennis. The area was cleaned up in 1921 and a noncotton zone was maintained during the following year. The area was cleaned again in 1922 and 1923. No reinfestation has occured.

The detailed records of the amount of scouting performed in each of these districts are given in Table 2 and the locations of the several districts are shown in Figure 11.

SCOUTING OUTSIDE OF KNOWN INFESTED DISTRICTS

The most important consideration connected with the attempt to control the pink bollworm in the United States has been whether all infestations have been discovered. A very large amount of scouting has been done in regions outside of the various areas in which the insect has been found, including numerous points to which possibly infested material has been shipped. Whenever an infestation has been found the shipments for the three preceding years which could possibly have introduced the insect have been traced to their destinations and careful scouting conducted. Of course, much attention has been given to scouting immediately outside of the various noncotton zones and regulated zones. Attention has been given to numerous reports of the occurrence of the insect which have been due to misidentifications. The routes of traffic from the Mexican border and the entire Mexican frontier have been thoroughly inspected. Table 3 shows the amount of this scouting in the various States where it has been done.

TABLE 3.—*Total number of man-days scouting and number of localities receiving attention in each State for each crop to January 31, 1924*

State	1917		1918		1919		1920		1921		1922		1923	
	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities	Man-days	Localities
Central:														
Arkansas	0	0	19	9	0	0	0	0	37	2	0	0	0	0
Louisiana	0	0	17	10	539	49	1,717	76	1,328	36	1,212	31	977	10
New Mexico	0	0	111	2	57	3	528	12	84	18	347	10	1,058	31
Oklahoma	0	0	0	0	0	0	0	0	99	3	132	4	0	0
Texas	1,184	73	2,942	101	4,436	139	5,078	149	6,743	222	5,482	155	4,676	132
Mexico	0	0	(1)	1	48	21	0	0	208	21	57	4	63	16
Western:														
Arizona	0	0	43	14	60	23	0	0	316	7	215	9	0	0
California	0	0	0	0	0	0	14	3	204	13	61	6	0	0
Eastern:														
Alabama	0	0	25	2	67	6	0	0	16	9	0	0	0	0
Florida	0	0	0	0	0	0	0	0	10	6	0	0	0	0
Georgia	0	0	176	6	97	13	0	0	33	18	0	0	0	0
Mississippi	0	0	19	7	7	2	[2] 677	?	[2] 259	?	[2] 254	?	0	0
North Carolina	0	0	13	3	155	14	0	0	56	11	0	0	0	0
South Carolina	0	0	114	9	151	14	0	0	60	17	0	0	0	0
Tennessee	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Total	1,184	73	3,479	164	5,617	284	8,014	240	9,453	384	7,760	219	6,774	189

[1] Half a man-day or less [2] Scouting by State inspectors

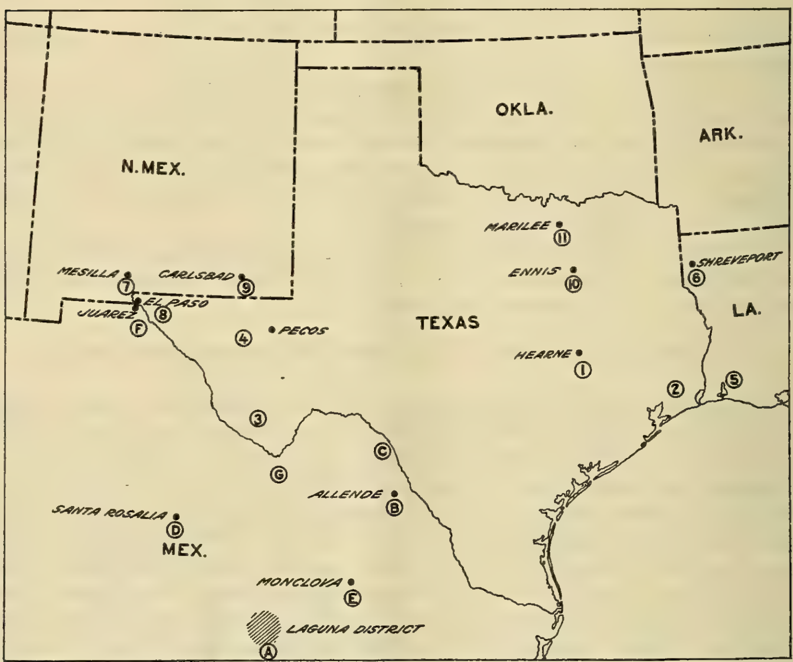


FIG. 11.—Map showing approximate location of infestations by the pink bollworm in Mexico and the United States: *A*, the Laguna district; *B*, Allende; *C*, the Trevino ranch; *D*, Santa Rosalia; *E*, Monclova; *F*, the Juarez Valley; *G*, the area in Chihuahua opposite Presidio and Brewster Counties, Tex.; *1*, Hearne; *2*, the Trinity Bay (Galveston Bay) area; *3*, the Big Bend area; *4*, the Pecos Valley; *5*, the Cameron Parish district; *6*, Shreveport; *7*, the Mesilla Valley; *8*, the El Paso Valley; *9*, Carlsbad; *10*, Ennis; *11*, Marilee. The Texas infestations at Hearne, the Trinity Bay area, Ennis, and Marilee, and the Louisiana infestations (the Cameron Parish district and Shreveport) seem to have been eradicated

PRESENT STATUS

The most noteworthy feature of the present status of the infestations which have been discovered in the United States is that they fall into two groups. One of these includes the infested districts found in western Texas and New Mexico; the Big Bend, Pecos, Carlsbad, El Paso Valley, and Mesilla Valley. All these show infestations continuing from year to year, with breaks of no great significance in some instances.

The other group includes all districts in which infestations have appeared in the United States, except those just named. They are six in number, four of which are in eastern Texas and two in western Louisiana. Following are the latest years in which infestation has been known to exist in the several districts: Hearne, 1917; Cameron, 1919; Shreveport, 1920; and Trinity Bay, Ennis, and Marilee, 1921.

In the eastern areas the success of the efforts at eradication appears to be strongly indicated. It is by no means certain that eradication has actually been accomplished in all these six districts, one of which included all or parts of seven counties. The extremely slight infestation, involving enormous difficulties in finding it, the longevity of the insect, and the insidious nature of its work, all suggest the possibility of a new infestation, to be eventually discovered in one or more of these districts. This possibility, however, is decidedly remote, so thoroughly has the scouting been done. In the more heavily infested places in the Trinity Bay area, the scouting included the examination of every boll and bur left on the plants after picking the cotton in fields planted after the termination of the noncotton zones. Such a possible infestation, however, would not be a serious matter, as the methods of eradication already worked out have been highly effective and are available at any time.

A great danger lies in the possibility that there may be infestations in unsuspected localities in the United States. The systematic search through practically the entire Cotton Belt by the Department of Agriculture and by the various State agencies has reduced this possibility to perhaps a negligible item. If any infestations are discovered, the perfection of the known methods of eradication will greatly facilitate, if not insure, their elimination.

Although the situation as regards the eastern infestations, many of which are in solid cotton territory, may be said to be satisfactory, the situation in the western areas is not so favorable. In these, on account of their proximity to Mexico, it has been impossible to take steps toward eradication, such as the establishment of temporary noncotton zones. Permanent noncotton zones would be required, and these have been impracticable on account of economic and other conditions. The danger of the spread of the insect from the western areas is by no means as great as might appear. In the first place, there is a barrier of 200 miles or more where no cotton is planted. The areas are also under quarantine, and all materials which could possibly carry the infestation from them are safeguarded. The volume of the infestation is greatly lessened by the requirement that all seed produced be disinfected by heat as a part of the process of ginning. Climatic conditions are also holding the insect to small numbers. The districts are of considerable elevation, ranging from

2,500 feet to about 4,000 feet above sea level. A careful study made in the El Paso Valley shows that there has been no noticeable increase in the amount of infestation during the last four years. These conditions greatly minimize the danger from the western infestation. The experience of several years shows that it is perfectly feasible to eliminate practically all danger of spread to other regions. There is a chance, however, that this spread may occur despite all precautions, and it is undoubtedly wise to maintain the restrictions with the utmost vigor.

On the whole, the conclusion seems to be warranted that the work done has resulted more succesfully than in the beginning was thought possible, and fully justifies the efforts and expenditures which have been made. This work must be continued, however, by preventing any possible recurrence in the districts where infestation has been found, by being ready to handle any undiscovered infestations in the Cotton Belt proper, by minimizing as far as possible the danger of the spread of infestation from the western areas, and by taking every precaution against new infestations from Mexico.

LITERATURE CITED

(1) BALLOU, H. A.

1918. The pink bollworm (Gelechia gossypiella) in Egypt. *In* Jour. Econ. Ent. vol. 11, No. 2, pp. 236–245.

(2) ———

1919. Cotton and the pink bollworm in Egypt. *In* West India Bulletin, vol. 17, No. 4, pp. 237–292, 9 figs.

(3) BUSCK, AUGUST.

1917. The pink bollworm, Pectinophora gossypiella. *In* Jour. Agr. Research, vol. 9, No. 10, pp. 343–370, 7 figs., pls. 7–12.

(4) CAYLA, V.

1921. A propos du "ver rose" du cottonier au Brésil Agron. Colon., 6e Ann., No. 41, pp. 195–197.

(5) DEAN, WILLIAM S.

1916. Manufacturing tests of cotton fumigated with hydrocyanic-acid gas. U. S. Dept. Agr. Bul. 366. 12 pp.

(6) DUDGEON, G. C.

1913. The pink bollworm. *In* Agr. Jour. Egypt, vol. 2, pt. 2, 1912, pp. 45–48, 1 pl.

(7) FLETCHER, T. B. and MISRA, C. S.

1920. Cotton bollworms in India. *In* proc. 3d Ent. Meeting (1919), at Pusa, vol. 2, pp. 443–472, 1 pl., Calcutta, 1920.

(8) FULLAWAY, D. T.

1909. Insects of cotton in Hawaii. Hawaii Agr. Exp. Sta. Bul. 18. 27 pp., 18 figs.

(9) GOUGH, L. H.

1916. The life history of Gelechia gossypiella from the time of the cotton harvest to the time of cotton sowing. Min. Agr. Egypt. Tech. and Sci. Serv. Bul. 4 (Ent. Sect.). 16 pp.

(10) ———

1917. The rate of increase of the pink bollworm in green bolls in the period July to November, 1916. Min. Agr. Egypt Tech. and Sci. Serv. Bul. 13 (Ent. Sect.). 20 pp. incl. tables, 1 diagram.

(11) GREEN, EDW. C.

1917. A lagarta rosada dos capulhos no Brazil. Seu historico, disseminacão, prejuizos, parasitas e modo de combatel-a. Sociedade Nacional de Agricultura, Rio de Janeiro. 21 pp.

(12) HEINRICH, CARL.

1921. Some Lepidoptera likely to be confused with the pink bollworm. *In* Jour. Agr. Research, vol. 20, No. 11, pp. 807–836, pls. 93–109.

(13) HUNTER, W. D.

1918. The pink bollworm, with special reference to steps taken by the Department of Agriculture to prevent its establishment in the United States. U. S. Dept. Agr. Bul. 723, 27 pp.

(14) LOFTIN, U. C., MCKINNEY, K. B., and HANSON, W. K.

1921. Report on investigations of the pink bollworm of cotton in Mexico. U. S. Dept. Agr. Bul. 918. 64 pp., 11 figs., 5 pls.

Detailed report dealing with distribution, life history, seasonal history, food plants, dispersal, natural control, repression; list of literature cited.

(15) MARLATT, C. L.

1918. The origin of the pink bollworm. *In* Science, n. s., vol. 48, pp. 309–312.

(16) MATSUMOTO, S.

1920. Watano gaochu akamimushi oyobi akadani [The red worm and red mite infesting cotton]. Kwangyo mohanjo kenkyuhokoku [Science report of the Industry Model Station], Cotton Plantation Branch Station, Moppa, Korea, 25 pp., 4 pls.

Review of Applied Entomology, VIII A, p. 319.

(17) OHLENDORF, W.
1926. Studies of the Pink Bollworm in Mexico. U. S. Dept. Agr. Bul. 1374, 66 pp., 15 figs.

(18) SAUNDERS, W. W.
1843. Description of a species of moth destructive to the cotton crops in India. *In* Trans. Ent. Soc. London, vol. 3, pp. 284–285. (Presented to the society in June, 1842.)

(19) U. S. DEPARTMENT OF AGRICULTURE, FEDERAL HORTICULTURAL BOARD.
1916–17. Service and Regulatory Announcements, No. 26, March, 1916, pp. 38–40; No. 45, October, 1917, pp. 119–120.

(20) VOSSELER, J.
1904. Einige Feinde der Baumwollkulturen in Deutsch-Ostafrika. *In* Mitt. Biol. Landw. Inst. Amani, No. 18, 4 pp.

(21) WILLCOCKS, F. C.
1916. The insect and related pests of Egypt. Vol. 1, The insect and related pests injurious to the cotton plant. Part 1, The pink bollworm. 339 pp., 17 figs., 10 pls.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

May 14, 1926

Secretary of Agriculture	W. M. Jardine.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	————
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Information	Nelson Antrim Crawford.
Director of Personnel and Business Administration	W. W. Stockberger.
Solicitor	R. W. Williams.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Agricultural Economics	Thomas P. Cooper, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	W. B. Greeley, *Chief.*
Bureau of Chemistry	C. A. Browne, *Chief.*
Bureau of Soils	Milton Whitney, *Chief.*
Bureau of Entomology	L. O. Howard, *Chief.*
Bureau of Biological Survey	E. W. Nelson, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Bureau of Dairying	C. W. Larson, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. Cottrell, *Director.*
Office of Experiment Stations	E. W. Allen, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*
Insecticide and Fungicide Board	J. K. Haywood, *Chairman.*
Packers and Stockyards Administration	John T. Caine, *in Charge.*
Grain Futures Administration	J. W. T. Duvel, *in Charge.*

This bulletin is a joint contribution from

Bureau of Entomology	L. O. Howard, *Chief.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY