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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 120.

L. O. HOWARD, Entomologist and Chief of Bureau.

REPORT OF A TRIP TO INDIA AND THE ORIENT IN SEARCH OF THE NATURAL ENEMIES OF THE CITRUS WHITE FLY.

BY

RUSSELL S. WOGLUM,
Entomological Assistant.

Issued February 28, 1913.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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BUREAU OF ENTOMOLOGY.

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J. G. Sanders, *collaborator.*

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 11, 1912.

SIR: I have the honor to transmit herewith an account of the trip undertaken by Mr. Russell S. Woglum, a special agent of this bureau, to India and the Orient in search of the natural enemies of the citrus white fly, which for many years has militated against the successful commercial operation of the orange-growing industry in Florida and elsewhere. This paper is especially valuable in view of the fact that Mr. Woglum not only has located many of the natural enemies of the citrus white fly in their native habitat, but has, as well, demonstrated the correct methods of procedure in the transshipping, alive, of predaceous and parasitic material, which has heretofore rendered the importation of natural enemies of our insect pests so precarious. I recommend the publication of this manuscript as Bulletin No. 120 of this bureau.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

REPORT OF A TRIP TO INDIA AND THE ORIENT IN SEARCH OF THE NATURAL ENEMIES OF THE CITRUS WHITE FLY.

INTRODUCTION.

This bulletin has been prepared with the idea of presenting some of the more important phases, from a scientific standpoint, of a journey made in search of parasitic and predatory enemies of the citrus white fly (*Aleyrodes citri* R. and H.). The major portion of the bulletin is devoted to a treatment of material bearing directly on the citrus white fly, its enemies in Asiatic countries, and the efforts toward their collection and introduction into the United States. Supplementary to this is appended a consideration of other topics with which the writer became familiarized during the expedition and which have a more or less direct bearing on the culture of citrus fruits.

The information herein relative to life history, distribution, and injury of the white fly in this country has been taken largely from the results of the work of Drs. Morrill and Back in their investigations of the citrus white fly in Florida.[1]

THE CITRUS WHITE FLY.

General.

The citrus white fly belongs to a group of insects popularly known as the mealy-wings (Aleyrodidæ) and is closely related to the scale insects (Coccidæ), numerous species of which are very injurious to citrus fruit trees in all parts of the world. In fact, entomologists of the earlier days classified the Aleyrodidæ as a division of the Coccidæ. Subsequent investigators, however, have found certain characteristics normal to the group sufficiently distinct to call for its separation into a family of its own.

The first record of the white fly as a serious pest to citrus fruit trees was from the State of Florida, and from the date of that record to the present time its injury has continued as a menace to the most profitable commercial citrus-fruit production. In 1885 the insect was given the scientific name of *Aleyrodes citri* by Mr. Wm. H. Ashmead [2] in a local Florida paper and subsequently was fully described by Riley and Howard, of the Division of Entomology, in Insect Life.[3]

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[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.

[2] Florida Dispatch, n. ser., vol. 11, November, 1885.

[3] Ins. Life, vol. 5, no. 4, pp. 219-226, 1893.

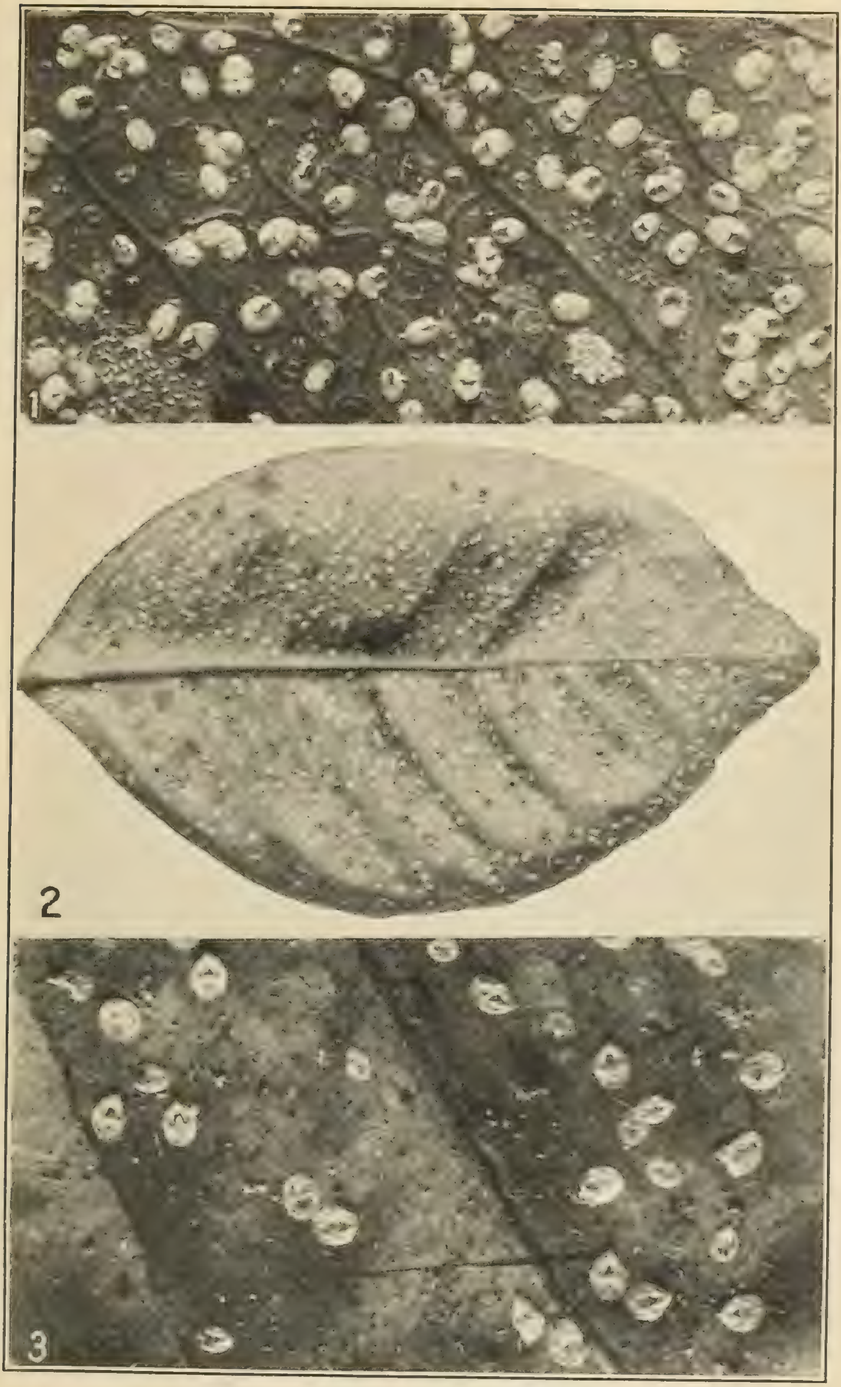
Description.

Although the citrus white fly is known to attack several species of plants, its special importance as a pest is owing to its injury of citrus trees, in which the infestation is confined to the leaves. The insect as commonly seen on trees is of the appearance of a small, thin, transparent or greenish-white scale entirely devoid of wings.

In the earlier stages of development, as hatched from the egg, it possesses three pairs of short, stubby legs and somewhat resembles in general appearance a small louse or mite. So small is the insect at this time and so transparent is it that only the closest observation will reveal its presence to the naked eye. In fact, persons unaccustomed to close observation might easily examine an infested leaf without discovering the presence of these young insects. This is the only time in the life of the immature insect in which it is able to move about the plant. After hatching from the egg the minute larva crawls about the leaves until it finds a situation suitable to its taste. This found, it inserts its elongate threadlike mouthparts into the leaf and then settles down to remain in this position until full grown. The juice of the leaf is extracted through this threadlike mouth. To allow growth, the hard outer skin of the young insect is cast off from time to time. The legs are lost with the first molt, so that in the later stages of development the insect is entirely without the power of locomotion.

With the third molt the insect passes from the so-called larval condition into the pupal stage (Pl. I). This is the last stage of development and the one in which the insect is most commonly noticed. At first thin and so pale green as to be almost transparent, it becomes thickened and opaque on approaching maturity. When almost mature a bright orange spot appears on the back and later two purple spots toward the anterior end. The insect at this time is about one-sixteenth of an inch long or practically the size of the head of a pin. These purple spots are the eyes of the adult and appear from three to eight days before the same is fully mature. When fully developed the pupa case splits down the back, allowing the adult to come out.

The adults are light orange-yellow in color and possess four wings, which enable them to fly about the tree or from one tree to another (Pl. II). This is the only stage in which the white fly possesses much activity, and were it not for the winged adults the mechanical control of this species would be quite easily accomplished. The eggs are deposited on the lower surface of the leaves. An individual female will average about 125 eggs during life. Usually many thousands of eggs are deposited on a single leaf, the leaf presenting an appearance as if sprinkled with grains of dust.



PUPA CASES OF THE CITRUS WHITE FLY.

Fig. 1.—Leaf showing pupa cases of the citrus white fly (*Aleyrodes citri*); also a few pupæ and eggs. Fig. 2.—Underside of orange leaf, showing heavy infestation by citrus white fly. Fig. 3.—Leaf showing pupa cases of the cloudy-winged white fly (*Aleyrodes nubifera*), an insect prevalent on citrus plants in Florida, and very closely related to *Aleyrodes citri*. (From Morrill and Back.)

ADULTS OF THE CITRUS WHITE FLY ON FOLIAGE OF ORANGE.

Fig. 1.—Tender growth of citrus swarming with adults of the citrus white fly. Fig. 2.—Leaf of same, enlarged. (From Morrill and Back.)

Distribution in the United States.

The citrus white fly in the United States has been recorded as existing under natural conditions in Florida, southern Georgia, South Carolina, Alabama, Mississippi, Louisiana, and Texas. In 1907 it was discovered in two localities in California, following which strenuous efforts were made toward its eradication. Recent reports[1] state that the insect has reappeared in one of these districts. In addition to the above citations the pest has long been known from greenhouses in many northern States.

The importance of the white fly as a citrus fruit tree pest is shown almost exclusively in those Gulf Coast States where citrus fruits are produced commercially. Although oranges are being grown quite extensively in Louisiana and Texas, and to some extent in Alabama, it is in Florida that the orange-growing industry stands forth as a great and most important one. The distribution of the white fly in Florida has become so general that it has been reported by Morrill and Back[2] as occurring to a greater or less extent in all but two of the 17 important citrus fruit-growing counties. All important agitation and efforts toward control have originated in this one State. The close association of this insect pest with the orange and grapefruit industry of Florida has led to its frequently being called the "Florida white fly" when referred to in other parts of the United States.

Injury.

The white fly is the most serious enemy of citrus trees in the Gulf Coast States. Considering the extent of its injury, together with the difficulty experienced in its control, it stands as without doubt the most serious pest to citrus-fruit production in the entire United States. Injury from the white fly may be considered from two standpoints—direct injury to the tree by loss of vitality through removal of sap, or injury produced from the presence on the leaves, branches, and fruit of the sooty-mold fungus which flourishes on the honeydew secretions from the white fly. Although the injury due to loss of sap is undoubtedly considerable, it is of small importance compared with the injury directly or indirectly resulting from the fungous growth, and were it not for this secondary consideration the present fear to the citrus-fruit grower of white-fly infestation would be largely eliminated. The sooty mold remains in a more or less nascent period during the winter months and early spring, but later develops rapidly, so that with the approach of summer it has heavily coated those trees severely infested with the white fly.

The fungus naturally follows the distribution of the honeydew, which is prevalent especially on the upper surface of the leaves and

[1] Monthly Bul. Cal. State Comm. Hort., vol. 1, no. 6, pp. 242–243, 1912.
[2] Bul. 92, Bur. Ent., U. S. Dept. Agr., pp. 25–26, 1911.

the upper half of the fruit (Pl. III). It is in these places that the development of the sooty mold is greatest. The mold may also be found to a greater or less extent on the branches and underside of the leaves. The injurious effect resulting from fungous growth on the leaves is due to the check which it places on the assimilative process that takes place within the tissues, retarding the availability of a normal food supply for the tree. The injury to fruit has been carefully worked out by Drs. Morrill and Back,[1] and the following statement is based on their investigations: The greatest injury by the white fly lies in the reduction of the number, size, and quality of fruit produced. Conservative estimates, based on extended observations, have placed the average yield in different white-fly infested groves in Florida as between 20 and 50 per cent below that of normal uninfested groves. In addition to this the packing size of oranges is reduced one or two grades, while the increased number of culls due to retarded ripening and other causes materially lowers the market value of the crop. Moreover, fruit coated with sooty mold must be washed before marketing. It has been shown by Dr. G. Harold Powell,[2] formerly of the Bureau of Plant Industry of this department, that decay in shipment is greatly increased in washed fruit. Hence the cost of washing, augmented by the additional loss from decay in washed fruit over that which is unwashed, is an added loss from white-fly infestation.

Summing up the whole situation after their experience, Drs. Morrill and Back estimate that in the average infested grove the total loss from the white fly may be placed at about 45 to 50 per cent of the value of the orange crop. Considering that fully 45 per cent of the citrus groves in Florida are infested by the white fly it has been estimated that in money value this would amount to more than half a million dollars annually.

Methods of Control and Their Efficiency.

Greater effort has been devoted to the control of the white fly than of any other pest in the Florida citrus belt. Agents of this department commenced studying the white fly as early as the eighties, and since 1906 this bureau has retained a corps of investigators continuously in the field testing the various possible methods toward its successful control. Entomologists from the Florida State Experiment Station have also been working along similar lines for many years. The efforts of these different scientists have resulted in the proposal of three distinct methods for control of the white fly: (1) Fumigation with hydrocyanic-acid gas, (2) spraying with various insecticides, and (3) the utilization of several fungous diseases of

[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.
[2] Bul. 123, Bur. Plant Industry, U. S. Dept. Agr., 1908.

FIG. 1.—ORANGE COVERED WITH SOOTY MOLD (From Morrill and Back.)

FIG. 2.—LEAF OF ORANGE COATED WITH SOOTY MOLD (From Morrill and Back.)

CITRUS AND SOOTY MOLD

this insect already prevalent in certain parts of Florida. As to the comparative efficiency of these three methods authorities are not universally agreed, but from an unbiased point of view it would seem that each has its advantages over the others within certain more or less restricted fields. A discussion of these restrictions is unnecessary in this place. Suffice it to say that by 1909–10 results of investigations had not established universally in the minds of Florida orange orchardists the absolute commercial efficacy of mechanical-control methods.[1]

CONDITIONS LEADING TO THE DEMAND FOR A SEARCH FOR NATURAL ENEMIES OF THE CITRUS WHITE FLY.

The climate of Florida is, in general, very damp, a condition especially suitable to the free development of fungous diseases. Six different fungi have been recorded as attacking the citrus white fly, and their resultant destruction in localities of much humidity appears at times to total a high percentage.

Following a movement toward efficient organization of the citrus industries of Florida, the extent of damage which results from white-fly infestation, as well as its direct bearing on the market quality of the fruit, was brought forward with renewed force. Considering the failure at that time of the mechanical methods to meet adequately the demands of the orchardists, coupled with the apparent partial efficiency of fungous diseases, the time seemed ripe that the popular idea of control by natural enemies should gain a devoted following.

This theory of control by natural enemies, in brief, is that all life in its native home is kept in check by other forms of life which prey upon it; in other words, that all nature is in a state of equilibrium. Chief among these natural factors of control in the case of insect pests are other forms of insect life which are parasitic and predatory on the noxious form. In recent years much attention has been devoted to the discovery and subsequent introduction from one country into another of beneficial insects for utilization in attempted control of certain of our more important insect pests. One of the earliest importations into America was that of a small lady-beetle, *Novius cardinalis* Muls. For several years a large scale insect called the cottony cushion scale (*Icerya purchasi* Mask.) had been producing such extreme injury to the orange and lemon groves of California that the industry was threatened with ruin. Mechanical means of control proved ineffective. In the belief that the insect had been introduced into the United States from Australia, Mr.

[1] Fumigation, though highly efficient in itself as a factor in the control of the citrus white fly, has not met with general adoption, largely because of certain practical considerations which render it unavailable economically under present conditions in Florida. However, recent results with special oil sprays have placed the control of the white fly on a very satisfactory commercial basis.

Albert Koebele was sent by Prof. C. V. Riley, then chief of this office, to that country in search of natural enemies. His discovery of *Novius cardinalis,* its introduction into California in 1889, and its subsequent rapid development and spread soon resulted in such a complete destruction of the cottony cushion scale that the insect has no longer been a factor in citrus production in that State.

This remarkable work of Novius resulted in a great stimulus to the efforts to bring about insect control by means of natural enemies and has become an historical event in applied entomology. It might be added that the universal success against the cottony cushion scale by a single natural enemy has never since been duplicated in the case of any other insect pest. From this most successful introduction to the present day many more or less successful attempts in the utilization of natural enemies have been made. The most extensive work of its kind ever undertaken is that now being carried on under the direction of this bureau in New England against the gipsy and brown-tail moths, which are highly destructive to forest, orchard, and shade trees in that region. These insects were accidental introductions from Europe, and on that continent are preyed upon by numerous natural enemies. Extended efforts in importing all available parasites and predatory insect enemies of these two pests and in establishing them in New England have met with marked success.

Because of these facts and others of a like nature a demand developed in Florida for an exploration of foreign countries to discover if possible the natural enemies of the white fly. Such exploration had been heartily recommended by the various investigators of this bureau who had been working on the white fly problem in Florida, and was also supported by the Florida Experiment Station and by orange growers. The partially effective control by the various fungous enemies of the white fly was an additional argument for the introduction of the natural insect enemies to supplement the work of these beneficial fungi.

As the result of these demands Congress set aside a special appropriation, in 1910, for the purpose of searching the world to discover the native home of the citrus white fly and learning if it was there held in check by natural enemies. If natural enemies could be found these were to be collected, brought to this country, and, if possible, established in Florida.

PREPARATIONS FOR THE SEARCH.

The writer was asked by Dr. Howard, Chief of the Bureau of Entomology, to undertake the mission of searching for the native home of the white fly and of ascertaining if it was anywhere attacked by natural enemies other than those already known in Florida. After bringing to a satisfactory close an investigation of the use of hydrocyanic-acid gas for fumigation purposes in the destruction of scale-insect pests of citrus-fruit trees in southern California—work which had been in progress for three years—the writer proceeded to Washington to make final arrangements for his departure on the mission.

Since the white fly is reported from the United States as being primarily an enemy of citrus it was considered that its distribution would be limited to those regions in which citrus trees occur, and naturally it followed that these were the places to which travels should be directed. It is well known that citrus trees are grown to a greater or less extent in the semitropical and tropical zones throughout the world. The most tenable supposition is that they originated in southeastern Asia, whence their distribution, either directly or indirectly, to those countries in which they are at present to be found.

In the collections of this bureau are specimens of the citrus white fly which have been taken on orange trees in southern China and in Japan. On his way eastward the writer passed through San Francisco on the day that Mr. George Compere, the well-known collector of natural enemies of insects for the State of California, was returning from the Orient with supposedly valuable introductions. An examination of an orange tree which Mr. Compere had secured in Japan revealed the presence of the citrus white fly, thus corroborating previous records from the Orient.

The collection of Aleyrodidæ of the late William Maskell of New Zealand is now in the custody of this bureau. In examining type material from this collection of a species named *Aleyrodes aurantii* Mask., collected on orange in the northwestern Himalayas of India, Prof. A. L. Quaintance, of this bureau, an authority on Aleyrodidæ, decided that this Indian species was none other than the citrus white fly of Florida, *Aleyrodes citri*. Having the above information at hand it was at once evident that special attention should be devoted to a search of that part of the Orient having a tropical or semitropical climate.

The present known distribution of the citrus white fly throughout the world is shown in figure 1.

INVESTIGATIONS IN EUROPE.

On July 31, 1910, passage was taken on a steamer from New York en route to Spain via Gibraltar. This first stop was made in response to a request from the Minister of Agriculture of Spain that the writer demonstrate before the orange growers of that country the procedure of hydrocyanic-acid gas fumigation in the destruction of scale-insect pests of citrus trees. The orange and lemon trees of Spain are seriously affected by several species of scale insects. Satisfactory control of these insects had never yet been accomplished, while many of the orchardists were in despair lest their trees should be ruined.

The month of August was spent in southern Spain, chiefly at Malaga and Valencia in company with Comte de Montornes, Royal Commissioner of Agriculture to the Province of Valencia, and Leopoldo Salas, Agricultural Engineer to the Province of Malaga. During this time the equipment essential in fumigation was acquired until a crew was properly fitted for field work. Demonstration work was then carried on in training the crew until it had become familiar with the general procedure of fumigation. Meanwhile experimental work was being carried on, the results of which furnished a basis for dosage against the insects treated.

Abundant opportunity was found during this demonstration to study the insect pests of citrus trees in different parts of the country.

FIG. 1.—Map showing present known world distribution of the citrus white fly (*Aleyrodes citri*). (Original.)

The citrus white fly, however, could not be found in Spain. From Spain the writer continued to Italy and Sicily and these countries were searched but failed to reveal the presence of *Aleyrodes citri*; nor has this insect ever been found in European orchards. Thus the great citrus belt of Europe, although beset with many injurious insect pests, most of which are mentioned in the appendices of this bulletin, has not yet become infested with this particular menace, the citrus white fly, which has proven so discouraging to the orchardists of Florida.

INVESTIGATIONS IN CEYLON.

Leaving Naples, direct passage was taken to Ceylon, which was reached September 30. Citrus fruits are not grown commercially in Ceylon, their production being confined to scattering trees, in yards and gardens, and are grown for decorative purposes as well as for fruit. Orange trees do not appear to grow with much vigor on this island, and the fruit produced is inferior in size and quality. When picked, the rind is perfectly green, although the flesh may be fully matured. This failure of the fruit to color—a condition noticed in other countries lying near the equator—is doubtless attributable to the excessive dampness of a tropical climate.

The orange trees examined on this island were found entirely free of the citrus white fly. Through the kindness of Dr. E. E. Green, Government Entomologist, his extensive collection of Aleyrodidæ from all parts of Ceylon was examined, but without evidence of the citrus white fly. When we consider the above data it does not seem at all likely that the citrus white fly occurs in Ceylon.

INVESTIGATIONS IN INDIA.

General.

The journey was continued from Ceylon to India, which was entered at Tuticorin, the southernmost seaport of importance. Thence the writer proceeded by rail to Calcutta, his object in visiting this city being to obtain all possible information as to the distribution of citrus trees throughout the Indian Empire. Calcutta is the one city which the naturalist seeking information about this country will first desire to reach. In addition to the natural advantages resulting from the fact that it has been the headquarters of the Government and that it is the largest city with very much the largest white population of any Indian city, it contains the Indian Museum, the largest if not the oldest institution of its kind in the Orient. This building is especially rich in natural history material. Many investigators are employed at this Government institution for research work and to classify and bring to the notice of the public information on the natural history and resources of this great yet little known country.

Through the kindness of Dr. F. Anondale, Director of the Indian Museum, access was had to the entomological collections contained therein. An examination of material of the family Aleyrodidæ brought to light some severely infested orange leaves which were labeled as collected in the northwestern Himalayas about 1893, it being stated on the label that duplicate material had been sent to William Maskell, the late eminent entomologist of the New Zealand Institute. It happened that about 1894–95 Maskell described a new species of Aleyrodes as occurring on orange in the northwestern Himalayas, calling it *Aleyrodes aurantii*. Hence it was at once evident that the material found in the Indian Museum was identical with the *Aleyrodes aurantii* of Maskell. Prof. Quaintance, of the Bureau of Entomology, in examining the Maskell collection, came to the conclusion that the *Aleyrodes aurantii* of Maskell was the same species as *Aleyrodes citri* R. & H., the citrus white fly of Florida. The writer's examination of material in Calcutta corroborated Prof. Quaintance's determination that the citrus white fly occurs in India. Moreover, infested orange leaves from a place in the northwest called Kulu were also found in the museum, and this gave the writer a definite locality for the white fly in India. Kulu is such a difficult place to reach that it was decided to visit first other more available localities in the northern part of the Empire.

During his stay in Calcutta the writer interviewed all available authorities who had acquaintance with agricultural conditions in different parts of that country, but little definite information relative to the distribution of citrus fruit trees was secured. It must be considered that agriculture in India is for the most part in a very primitive condition. Commercial orange growing, as we know it in America, does not exist, but the production of fruit is confined almost exclusively to individual or small patches of trees in yards and native gardens, both on the plains and in the hills or lower elevations of the mountains. (See Pl. IV.) In the latter places they are sometimes grown among the trees of the forest. However, occasionally one sees larger plantings which in extreme instances might reach 5 or even 10 acres in size.

The Botanical Gardens.

The greatest aid to the writer in his searches for citrus fruit trees were the Government botanical gardens which are situated in different parts of the Empire. (See Pl. V.) The more important of these gardens have European directors—men usually familiar with agricultural conditions in their respective provinces. Then, too, most of these gardens contain a large variety of fruit trees. The largest and oldest one is situated near Calcutta. From interviews with the authorities at this garden the writer learned that the oldest garden in Upper India was situated at Saharanpur and also that citrus trees are grown to some extent in this locality.

For this reason, as well as because this would be the most feasible place in which to secure information relative to the distribution of citrus trees in northern India, the writer proceeded to Saharanpur in the latter part of October, 1910. This was a most fortunate move, for in Mr. A. C. Hartless, the superintendent of the Saharanpur Botanical Garden, was found a most capable botanist, whose familiarity with the conditions in India and wide acquaintance with botanists and horticulturists, acquired during 25 years of continuous service in different parts, opened to the writer a source of information pertaining to this problem the equal of which was available in no other one place.

A large number of citrus trees of many varieties are grown in this garden. Orange, lime, and grapefruit are also scattered throughout the immediately surrounding region.

Discovery of the Citrus White Fly at Saharanpur.

An examination of orange trees at Saharanpur soon led to the discovery of the citrus white fly, and subsequent search revealed the fact that it was of general distribution hereabouts. The insect at this time had reached the pupal stage. Specimens of the fly could be found on practically all trees examined, but the infestation was so light that the insect was in no way a serious pest. Of the insects infesting the leaves only a small percentage was living. The trees containing the largest number of living insects were noted to be the ones with the densest foliage and those protected by large overshadowing ornamental trees. In no instance was a tree affected by "sooty mold" (*Meliola* sp.).

Discovery of Cryptognatha flavescens, the Lady-Beetle Enemy of the Citrus White Fly.

Closely following the discovery of the white fly, several minute larvæ of a coccinellid were seen on fly-infested trees, and later it was found that these were feeding on the young pupæ of the white fly. This happy discovery proved conclusively that *Aleyrodes citri* is attacked by a natural enemy in its native home, and thus one part of the mission on which the writer had been sent was successfully fulfilled. Later developments showed that the adults of this species were small reddish-brown beetles, about one-tenth of an inch in length.

Several days were spent in a careful and exhaustive search throughout this region, with the result of finding about 200 specimens of the lady-beetle. These were collected by placing large sheets of cloth underneath the trees early in the morning before the insects had become active and then beating the branches with sticks. In this manner much ground could be covered in a short time.

About 100 specimens of the insect were placed in a small, specially made wooden box containing two chambers connected by an opening about the size of a 50-cent piece. One of these chambers was loosely filled with damp sphagnum moss, the other with dry fiber from a palm tree. Such packing allowed the insects free movement and at the same time reduced possible injury from rough usage to a minimum. The box was so constructed as to allow necessary aeration.

This box was forwarded to the American consul-general at Calcutta, who placed the same in the personal charge of the captain of a cargo steamer sailing direct from Calcutta to the United States. All insects had died before their arrival in Florida.

A second sending made by letter mail also failed to come through in good condition.

This beetle was identified by Mr. E. A. Schwarz, of the Bureau of Entomology, as *Cryptognatha flavescens* Motsch.

Discovery of the Brown Fungus, Ægerita webberi.

During this examination of the Saharanpur region the writer's attention was frequently called to the presence of a brownish fungus attacking the white fly on trees in well-shaded positions. It seemed identical to all appearances with the Florida brown fungus (*Ægerita webberi*), yet in order to be certain in this determination a quantity was sent to Prof. H. S. Fawcett, formerly of the Florida Agricultural Experiment Station, an authority on fungous diseases of the white fly. His identification of it as *Ægerita webberi* was conclusive in showing that this fungus occurs in India as well as in Florida.

The writer failed to find this fungus except in the region about Saharanpur. A great deal of exchanging of plants, especially of citrus trees, between the botanical garden at this place and certain nurserymen in Florida has been going on for many years, and it seems quite likely that the brown fungus was introduced from Florida into India through these exchanges.

Searching at Lahore.

Leaving Saharanpur on November 10 the search was continued northward into the Punjab, and Lahore, the principal city in this Province, was made temporary headquarters. It is located toward the center of a broad plain and is less than 500 feet above sea level, although more than a thousand miles inland from the ocean. The plain is bordered on the north and east by the gigantic Himalayas, while it opens southward in an unbroken stretch to the sea. The climate is generally dry, the temperature of the summer being excessively hot, frequently reaching to between 115° and 120° F., while the winters are comparatively cold, the minimum temperature averaging between 35° and 50° F. It is very seldom that the temperature falls below 35° F.

Orange trees are abundant at Lahore, being found in almost every yard, as well as being the most common plant used for hedges. In the vicinity of this city they are grown to a considerable extent for commercial purposes. This consideration, coupled with the inducement offered by the presence of a large botanical garden, led to the decision that Lahore was the most suitable situation in the north for continuing our efforts, and later developments resulted in demonstrating it to be the most suitable locality in all India. Considering the abundance of orange and lime trees as well as their diverse conditions of cultivation, existing, as they did, from dense growths of seedling trees, entirely uncared for, to well-cultivated orchards of healthy budded stock, it seemed that if the white fly and natural enemies were to be found anywhere in northern India this must be the place.

FIG. 1.—A NATIVE HOUSE IN EASTERN INDIA WITH ORANGE TREES IN THE YARD. (ORIGINAL.)

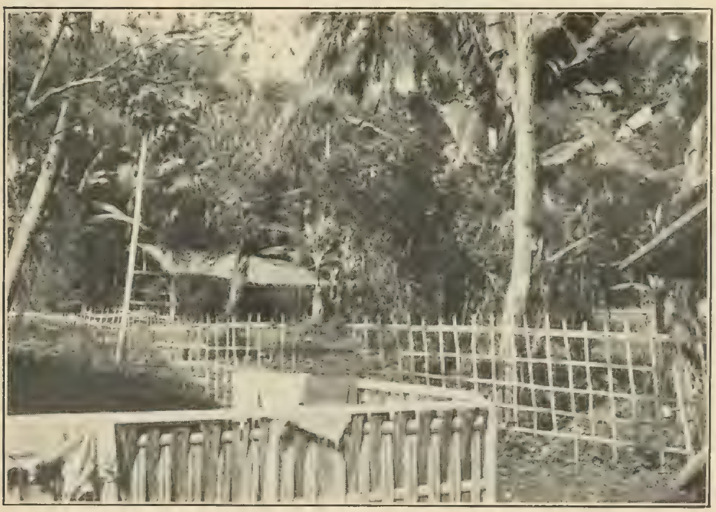


FIG. 2.—HOW ORANGES ARE GROWN IN JAVA. (ORIGINAL.)

[To a large extent the production of oranges depends upon orange trees planted in gardens and about native dwellings. The fruit is largely of the tangerine variety.]

ORANGE PRODUCTION IN INDIA AND JAVA.

FIG. 1.

FIG. 2.

Some of these gardens contain many citrus trees. In the one at Lahore, of which figure 1 is a view, the citrus white fly was found attacked by two natural enemies. The living material transported to the United States was largely collected in this garden. (Original.)

SCENES IN THE BOTANICAL GARDENS OF INDIA.

A careful search, covering several days, resulted in determining that the white fly was of widespread distribution. The infestation was quite similar to that already described as occurring at Saharanpur. Although of general distribution, the fly was in no place so abundant as to be a serious pest. The smut so prevalent in white-fly infestations of Florida was almost entirely absent. While it was not a difficult matter to find large leaves in well-protected, densely foliated trees that contained large numbers of white flies, few were in a living condition. Those alive were in an early stage of pupation.

Discovery of Prospaltella lahorensis, the True Internal Parasite of the Citrus White Fly.

During the investigation at Saharanpur a few pupa cases of the citrus white fly were noticed to differ somewhat in appearance from those of normal shape. Some of these contained very small holes which were of such a character as could easily have been made by a lady-beetle or some other biting insect. However, when large numbers of these abnormally thickened pupa cases were found at Lahore, and always with a small rounded hole in the exposed surface, it was very apparent that this condition was the result of internal parasitism. Considering the type of the host as well as the character of the opening, one was at once led to infer that the parasite was of a hymenopterous species. The cold weather at this time of year had driven almost all insect life into hibernation, so it was impossible to find any living parasites. A large quantity of leaves containing insects which had been parasitized was collected and sent to the Bureau of Entomology in Washington. A careful examination of this material resulted in finding five dead specimens of a very minute insect, which Dr. Howard, Chief of the Bureau of Entomology, determined as belonging to the genus Prospaltella, of the hymenopterous subfamily Aphelininæ.

In stating the results of this examination Dr. Howard wrote:

> The specimens on leaves sent in by Mr. Woglum have been examined with great care. None of the full-grown larvæ or nymphs contained pupal parasites, but five specimens of a very minute aphelinine of the genus Prospaltella were found dead and attached to the orange leaves in the vicinity of perforated Aleyrodes. The size of these specimens is such as to justify the conclusion that they had issued from aleyrodids, and their juxtaposition and the known habits of the genus confirm this conclusion.

As the insect was new to science, it was described as follows by Dr. Howard:[1]

> *Female.*—Length, 0.54 mm.; expanse, 1.42 mm.; greatest width of forewing, 0.25 mm. Antennæ long, not clavate; scape long, slender; pedicel nearly as broad as long; first funicle joint somewhat longer than second; second and third subequal; club equal in length to second and third funicle joints together; terminal segment of

[1] Journal of Economic Entomology, vol. 4, no. 1, p. 132, 1911.

club slightly longer than middle segment, basal segment again slightly shorter. Fore-wings broad, with moderately long bordering cilia; disc uniformly covered with minute cilia; stigmal vein rounded below, its anterior margin for a time parallel with costa; marginal vein faintly indicated, its base joining stigmal in an acute angle. (In this respect this species differs from all other known species of its genus.) General color light yellow; all legs pallid; eyes dark; ocelli coral-red; antennal club dusky; wings hyaline, wing veins dusky.

Male.—Of practically the same size and structure as the female, but differing in color. The coloration closely resembles that of *Aspidiotiphagus citrinus*, to which it bears a superficial resemblance; pronotum brownish; mesonotum orange yellow; metanotum and epimerum brownish; abdomen dark brown except at base and tip where it is lighter; hind femora dusky at tips; wing veins distinctly fuscous, considerably darker than in female.

Conclusions Drawn from Situation at Saharanpur and Lahore.

Our searches at Saharanpur and Lahore had resulted not only in the discovery of the citrus white fly, but, what was especially important, the discovery that it was being attacked by both a predatory enemy and a true internal parasite. It was at once evident that our next duty lay in attempting to collect and transport to Florida living material of these beneficial insects. Unfortunately the season at this time was so well advanced that practically all insect life was in a dormant condition, so that the collecting of living material during the next few months was impossible. Rather than remain inactive in upper India until the following spring, it seemed best to continue the search throughout India and into China with the hope of acquiring a broad grasp of the white-fly situation throughout the Orient. Having the situation thus in hand, we would know whether or not there were other regions equally prolific in natural enemies of the white fly. Such information would be of great value to all future work in this particular field.

Aleyrodes citri in India.

With the exception of the lower part of the peninsula practically all of India suitable to the growing of citrus fruit trees has been searched. The writer has examined orange trees at Peshawur, the frontier city in the northwest near the entrance to the Khyber Pass; along the lower elevations of the Himalayas (Pl. VI, fig. 2) at Dehra-dun; in the United Provinces; in Sikkim below Thibet; and eastward into the Khasia Hills of Assam (Pl. VI, fig. 1). In the west the writer has been among orange trees at Poona, in the Bombay Presidency, and eastward at Nagpur, in the Central Province. Much of the intervening territory between these outposts of travel has been covered.

As a result of these travels it can be stated that in all places visited in India, in which oranges were grown, infestations of the white fly were to be found. This is equivalent to stating that this aleyrodid

FIG. 1.—COUNTRY BOAT, UTILIZED FOR TRAVELING IN ASSAM.

It is so constructed as to afford protection from heat of sun during the day, and one may also sleep within at night with some comfort. (Original.)

FIG. 2.—TRAVELING IN THE OUTER HIMALAYAS.

The traveling in this region was performed for the most part on horseback, with native bearers for carrying provisions. (Original.)

TRAVELING IN INDIA.

is distributed throughout India south of the Himalaya Mountains. (See fig. 2.)

Evidence of parasitism was seen in practically all localities infested with the white fly.

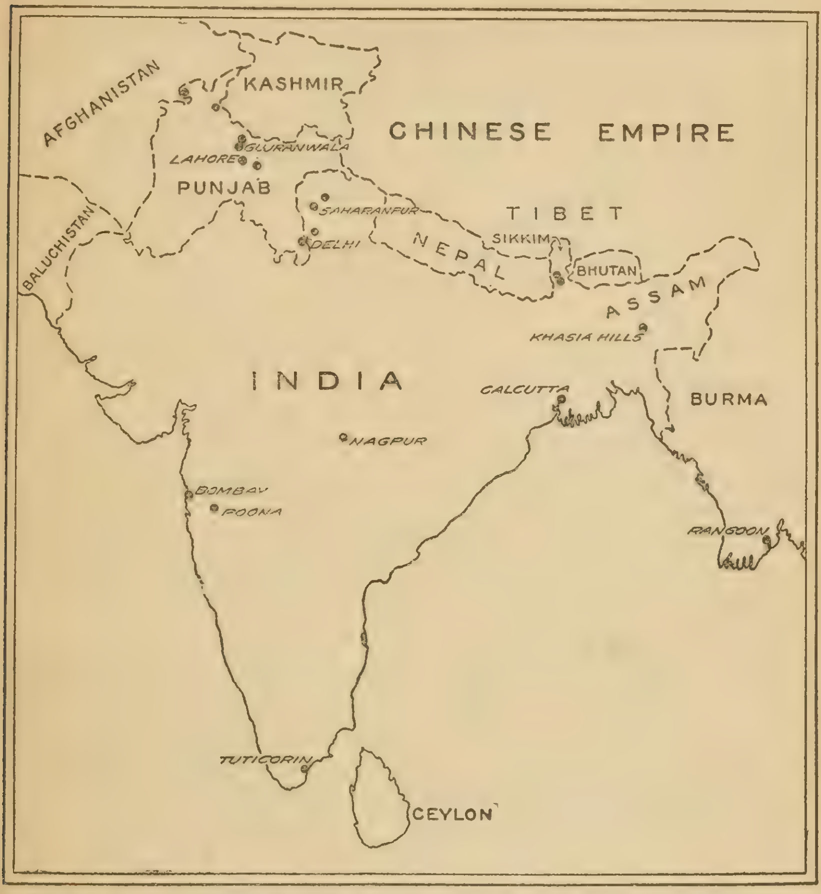


FIG. 2.—Map showing localities in which the citrus white fly (*Alcyrodes citri*) was found in India. (Original.)

INVESTIGATIONS IN BURMA, JAVA, SOUTHERN CHINA, AND THE PHILIPPINE ISLANDS.

Leaving Calcutta December 24, 1910, the writer continued the trip to Burma with the idea of searching a large citrus section reported to be in the vicinity of Moulmein, Lower Burma. A week's search in this region revealed about a half dozen dying orange trees which were free of the white fly. Although reliable information was received from an engineer in the Burmese public works department that orange trees occurred wild some 50 miles to the east in the mountains on the border between Lower Burma and Siam, as well as far to the north in the Upper Shan States on the Chinese border, the limited time at the writer's disposal rendered it inadvisable to explore these distant and very inaccessible regions. Instead return was made to Rangoon, where a steamer was boarded en route to Java via Penang and Singapore.

Batavia was reached on January 16 and a few days were spent hereabouts in making short journeys into the surrounding country. To the biologist visiting Java, the one place to which his attention is particularly directed is Buitenzorg, the seat of the far-famed Botanical Garden, which is situated about 60 miles from Batavia, the capital and principal seaport of the island. After having acquired a knowledge of Batavia and its surroundings, naturally the next move was to proceed to Buitenzorg. Itself most beautiful and surrounded by equally attractive country, this locality is a veritable tropical paradise. The garden is immediately adjacent to the city. Its great variety of plants, beauty of arrangement, and size would place it in the foremost rank of the botanical gardens of the Tropics, while the extensive and well-equipped laboratories for research, as well as a splendid museum, probably afford the investigating biologist a combination of desiderata unsurpassed in the Tropical Zone.

Orange and grapefruit trees occur in the garden and are found scattered throughout the surrounding country. A week was spent in this locality, during which many trees were examined, yet without evidence of the citrus white fly.

Through Mr. Max Wigman, botanist of the Buitenzorg Gardens, detailed information was secured relative to the localities in Java in which citrus trees were most prevalent. Utilizing this information during the following two weeks the journey was continued through the western half of the island. Orange and grapefruit occur throughout this region, the plantings for the most part consisting of scattered trees along the roads and paths or in gardens about the native houses.

At no time during the writer's travels in western Java were there seen as many as a hundred orange or grapefruit trees in a single orchard.

The citrus fruit trees were attacked by a number of insect pests, but no evidence of *Aleyrodes citri* could be found. So many trees were examined in different parts of the island that it would seem a safe conclusion that the citrus white fly does not occur in Java.

Leaving Java early in February (1911) a boat was taken to Singapore, where transfer was made to a steamer sailing direct to Hongkong. On arrival at the latter port a cablegram was received from Dr. Howard advising that a return trip be made to India and that effort be made to secure living material of the two natural enemies of the white fly for transfer to Florida. It was decided to spend a fortnight in southern China before taking return passage, as this would enable the writer to gain some information on conditions in that little-known country.

It was learned from Mr. Tutcher, superintendent of the Hongkong Botanical Garden, that oranges were grown extensively over a broad range of territory inland from Canton, and that a second large citrus-fruit region was westward of the seaport of Swatow. As Mr. Tutcher kindly consented to loan the services of one of his native collectors who was familiar with the Canton region, arrangements were begun for investigating that territory as soon as passports were available.

Application for a passport into the interior was filed at Canton with the American consul general, who stated that it would be about 10 days before the same could be prepared. After returning to Hongkong the writer decided to utilize the delay occasioned by the passport by a trip of inspection to the Philippines, which are about two days by water from this British seaport. While awaiting the sailing of a steamer for Manila a day was spent at Macau, a Portuguese settlement near Hongkong. Some orange trees infested with *Aleyrodes citri* were seen here, thus giving a new and definite record of this insect in southern China.

Manila was reached on February 28. Through the assistance of officials in the bureau of science a number of orange trees were found in this city and carefully examined. No white flies were seen. From information available it would seem that very few oranges are produced in the Philippine Islands. The only localities in which citrus fruits are grown commercially are Santo Tomas and Tanauan, in the Province of Batangas. These localities were examined, but no white flies could be found.

While in the Philippines the writer was taken ill and confined to the hospital throughout the month of March. This illness came at a very critical period and delayed an early return to India. Hastening, as he did, from the hospital before having fully recovered, it was nevertheless impossible to reach India until the last of April, when the spring season was well advanced.

FURTHER INVESTIGATIONS IN INDIA.

Landing in Bombay on April 22, necessary paraphernalia and provisions were at once collected and a native interpreter engaged preparatory to starting inland.

Concentration of Efforts at Lahore.

The writer's objective point was Lahore, in the Punjab, about 1,200 miles inland from Bombay. Previous experience had shown this locality to present the best field of any place in all India for possible successful operations. Not only were there a great number of citrus trees in this region, but the infestation of the white fly as well as the percentage of parasitism exceeded that of any other place visited. This was also one of the few places in India in which young nursery trees were available in large numbers. Being also the seat of a large botanical garden which contained many citrus trees, it afforded excellent facilities for the purpose in hand, and thus was the logical place in which to concentrate efforts.

A stop was made en route at Saharanpur, where success had been achieved the previous year in the collection of *Cryptognatha flavescens*, the predatory enemy of the white fly. Diligent search this time revealed very few living Aleyrodes; so after employing from Mr. Hartless, the superintendent of the garden, a "molle" or gardener who had assisted the writer the previous year, the journey was continued to Lahore.

A careful canvass of the orange and lime trees of the Lahore region was at once started in order to ascertain the prevalent condition of the white-fly infestation. Several days of laborious endeavor covering much of this locality resulted in the finding of a very light or scattering infestation of living Aleyrodes. The number was so small as to be worthless for use in breeding or parasitic work.

Confronted with this discouraging outlook, a trip was made to Gujranwala, about 50 miles north of Lahore and the greatest commercial orange-producing center in northern India. The condition of the white fly on citrus trees here was quite comparable with that at Lahore. Few living insects could be found, although the number of dead specimens on some trees was large. The previous autumn a small garden of an ornamental bush (*Jasminum sambac*), whose flowers are valuable for making perfumed oils, was found surrounded by orange trees. These Jasminum bushes were severely infested with *Aleyrodes citri;* in fact, it was the most severe infestation seen in all India, so much so that the leaves were blackened with a crust of sooty-mold fungus. As he felt confident that this garden would furnish a splendid breeding ground for the white fly, the discouragement of the writer can be well imagined when on examining this garden it was found that the extreme temperature of the previous winter had frozen back most of the bushes and almost eradicated the fly. Returning to Lahore, a most careful search was continued, with the ultimate result of discovering in one part of the botanical garden a well-protected hedge which was well infested with the white fly. This fortunate discovery constituted the basis of future operations.

Discovery of Living Parasites.

Immediate attention was next devoted toward the discovery of the parasite *Prospaltella lahorensis,* which the work of the previous autumn had shown to occur throughout this region. Efforts soon were rewarded with the finding of living parasites in very small numbers on the more protected parts of the infested hedge.

Considerations in Collecting and Transporting Prospaltella lahorensis.

As explained under the discussion of the citrus white fly, this insect very shortly after hatching from the egg settles down on the underside of the leaf to remain in a stationary position throughout its life. If the leaf is removed from the tree, the insect dies when nourishment is no longer available. *Prospaltella lahorensis*, being a true internal parasite of the white fly, is dependent on the living condition of its host in order to attain maturity. From a consideration of this situation it was at once evident that the only practicable way of transporting the parasite to America in a living condition was by means of healthy nursery trees infested with parasitized *Aleyrodes citri*. Moreover, the journey from India to Florida occupies between five and six weeks, while the entire life cycle of the parasite at high temperatures is of about three weeks' duration. This would mean that even if the parasite left India in the egg stage a complete cycle of development would take place and the adults emerge before America was reached. This latter feature necessitated the presence of living Aleyrodes throughout the journey so that the parasites at time of their emergence would have material upon which to work.

As small nursery trees are alone practicable for transportation over great distances, it was at once evident that the success of the mission depended on obtaining young trees well infested with the white fly. Young orange trees were available in sufficient quantities at the Lahore garden, but all were free from living white flies. Young fly-infested trees had not been seen anywhere in that country. The problem thus resolved itself into the artificial infestation of the trees.

Destruction of Young Growth of Citrus Trees by Insect Pests.

A large number of young orange trees from 1 to 4 feet tall were dug and placed in earthenware pots. As these trees contained no young growth, they were placed in a shady place and kept very moist. It is well known that the adult white fly prefers tender growth for oviposition. Young shoots soon developed, but no sooner did the leaves begin to expand than they were immediately attacked so severely by a lepidopterous leaf-miner, *Phyllocnistis citrella* Stainton (Pl. VII, fig. 1) as well as by a bud-worm (*Agonopteryx* sp.), that the young leaves of all the plants curled and shriveled before reaching maturity, thus rendering the plants worthless for the purpose desired.

In order to avoid the destruction of young growth by these two insect pests cloth houses were constructed and into these were placed a second set of potted nursery trees (Pl. VII, fig. 2). The trees were carefully examined before being introduced into the house in order to destroy any of the pests that could be seen. This was not difficult of accomplishment, as the pests pupated in the trees. Inspection was continued every few days so that the plants were soon free of the pests and in due time the development of young growth followed.

Notes on the Life History of Aleyrodes citri in Northern India.

The following notes on the life history of *Aleyrodes citri* on citrus were made at Lahore during 1911 and might be said to be typical of this insect in the great plains of northern India. Observations made at different times of the year in other parts of India would tend toward the probability that the development recorded in the northern part would also be more or less applicable to central India.

On May 1–4, 1911, the earliest dates of observation, the white fly was in the egg and larval stages. Calculating on the basis of the conclusions of Morrill and Back in their white-fly investigations in Florida that during the spring the duration of the egg stage averages somewhat less than two weeks, it would appear from the stages of development existing at Lahore on May 1 that the first brood of adult flies had emerged during the earlier part of April. This conclusion was somewhat corroborated by information from a native entomologist who stated that he had seen adult Aleyrodes in great numbers during the first part of April about the citrus hedge which the writer had found well infested and which he had selected as a basis for operations in collecting. Circumstances prevented a close observation of white-fly development between the middle of May and June 11, but an examination on the latter date showed the insects to be in the pupal stage. By June 24 the pupæ were almost fully matured and in a few individuals the purple eyes of the adults had commenced to be prominent. On June 25 a small number of adults emerged and this emergence continued during the following two or three days. Emergence had stopped and practically all adults disappeared by June 29. From this time throughout July and up to August 20, a period of about eight weeks, the insects appeared to remain perfectly dormant. The last 10 days of August were a period of great activity. Excretions of honeydew appearing on the pupæ between August 20 and 25 marked the first evidence of activity following their dormancy during the hot, dry summer. From August 26 to 30 the pupæ rapidly thickened and the purple eyes and whitish wings of the adults became evident through the thin pupal covering. The first adults commenced to emerge on August 31, and within a week or ten days the flight was as its height. By September 13 ctically the entire brood had emerged. On September 20 very

FIG. 1.—YOUNG CITRUS SHOWING LEAVES OF TOP SHOOTS DEFORMED BY ATTACKS OF A LEAF-MINER (PHYLLOCNISTIS CITRELLA).

At certain times of the year in northern India practically all new growth on young trees is affected by this insect. (Original.)

FIG. 2.—CLOTH CAGES PLACED OVER YOUNG CITRUS TO PROTECT THEM FROM THE RAVAGES OF THIS LEAF-MINER.

The destruction of young foliage on trees as soon as it appeared necessitated artificial manipulation in order to avoid the leaf-miner (*Phyllocnistis citrella*). Two cloth cages were constructed, and in these were placed potted plants. After several hand pickings the plants were freed of the leaf-miners, and the cloth protection permitted the young foliage to develop. (Original.)

THE LEAF-MINER PHYLLOCNISTIS CITRELLA IN INDIA.

few adults remained in flight, while the first eggs deposited were hatching. All eggs were hatched by October 5 and by October 20 many insects had reached the pupal stage.

Investigations at Rajpur and Saharanpur revealed conditions comparable with those at Lahore. Observations throughout northern India in November of the previous year (1910) showed the insect at that time to be in the pupal state. From a consideration of these conditions found in two different years it is evident that the white fly passes the winter in northern India as a pupa.

Number of Broods of the Citrus White Fly.

It has been stated by Morrill and Back that while there may be in Florida from three to six generations, adult flies are found in greatest abundance only during three more or less distinct periods, or generally speaking, there are three broods of white flies each year. Strictly speaking, there is great irregularity of breeding and overlapping of generations so that adult white flies may be found in varying numbers at all times except during the colder periods of winter. In all this irregularity, however, there stand out in prominence three general broods—a spring, a summer, and an autumn one.

Turning to northern India we find a different condition. Here there were two very distinct broods on citrus trees in 1911, adults of the first emerging in early April and those of the second during the first part of September. So far as the writer's observations extended these broods were sharply defined and without overlapping generations. In fact, so sharply defined were these two broods that no adult flies were seen outside of the two normal periods of emergence with the exception of a very few during three to four days in June. The latter emergence was due to a preceding period of high humidity accompanied by slight rains.

The Effects of Temperature on White-fly Development.

The climatic conditions of the plains of northern India are very different from those of Florida, and the resultant effect on the development of the white fly is equally apparent.

Whereas the winters in the Punjab of India average colder than in Florida the summers are very much hotter. During the months of July and August the average daily mean temperature in central Florida is 82° F., while during the same period in 1911 at Lahore it averaged 96° F., or 14° higher. The average daily mean temperature at Lahore for the months of May, June, July, and August was 94° F. and the average maximum temperature for the same period was 107° F. Such high temperatures have naturally a deterrent effect on insect development. Most of these days are bright and sunshiny, and so penetrating is the direct action of the sun that

Europeans require heavy protection in order to withstand it. Then frequently hot blasting winds blow with great violence, stirring up the dust in dense clouds and rendering life doubly uncomfortable.

In the direct rays of the sun the temperature during this time often exceeds 150° F. Failing rains cause vegetation to dry up and insects develop with difficulty. The following instance shows the effect of drought on the white fly:

In the Government Horticultural Garden at Lahore there is a very large nursery containing small orange and lemon trees. These trees were free of living Aleyrodes with the following exceptions: At one side of the nursery there was a large, densely foliated deciduous tree which overshadowed a number of orange trees. Some of these trees which were more densely shaded contained a small number of living white flies. Near the center of the nursery was a densely foliated tree about 10 feet tall, against the base of which were two or three small orange trees which were in shade throughout the day. These trees contained some living white flies, whereas other trees immediately surrounding but exposed to the sunshine contained none. Moreover, it can be stated that at no place in India did the writer find living Aleyrodes on small nursery trees except in situations that were well protected by shade.

The most severe and at the same time extensive infestation of the white fly on citrus in India occurred on a large hedge at Lahore, and this was utilized in the writer's breeding and collecting work. A part of this hedge was protected by a cloth awning and this protected portion was infested on all parts. (See Pl. VIII.) On the part not covered with awning the white fly occurred in abundance only where the hedge was protected by densely foliated overhanging trees which kept the direct rays of sunlight from the hedge plants throughout the heat of the day. The side of the unprotected hedge exposed to the direct rays of the afternoon sun was entirely free of living white flies, whereas on the lower part of the opposite side, which was in shade except for a very short period in early morning, living flies could be found in considerable numbers.

In the case of large citrus trees the greatest number of living insects was invariably found in those having the densest foliage. A tree in which the foliage was light seldom contained living flies except where protected by the shade of a large overhanging species. Although the white flies appeared to prefer trees of the tangerine variety, they were seldom able to multiply to any extent on these because of the small leaves and the less dense foliage than that of other varieties. In any species of citrus in which living specimens of the white fly occurred the infestation was found almost invariably in the shadiest part of the tree or the interior part near the main branches.

If large leaves grew in this part of the tree their examination was usually certain to reveal living insects provided the latter were to be found on the tree. In fact, after extended experience in the examination of citrus trees in India, examination of the larger leaves near the trunk of a tree was found to be such a conclusive key to infestation that the writer was able in most instances to "size up" the infested leaves before starting the inspection.

The statements previously made show the destructive action of very high temperatures on the citrus white fly. The prolonged hot, dry summer weather of the plains of northern India checks the development of almost all terrestrial forms of insect life. During the months of July and August, 1911, not only was the development of the white fly at a standstill, but this condition was also noticeable with other species of Aleyrodidæ as well as with all Coccidæ observed. Insects on the wing were seldom seen. In fact, this extremely hot, dry period appeared equally effective in checking the activity of insect life as does a prolonged cold period, such as occurs during the winter in central Florida or in the orange-growing parts of southern California.

That vast numbers of insects are destroyed in these regions of greatest heat is at once apparent to the entomologist who has spent a summer in India. In summing up the writer's experiences and observations he is led to the belief that this hot, dry climate of the Indian plains exerts a greater influence in holding the white fly in commercial control than all other factors combined.

The Effect of Humidity on White-fly Development.

It has been stated by Morrill and Back[1] that "while a normal amount of humidity is necessary for emergence of the white fly to occur, it is not so controlling a factor as temperature during ordinary Florida weather." We have found that the above statement will have to be modified if applied to the Punjab of India, and this is not surprising when it is considered that the normal humidity and temperature of these two countries are so essentially different.

Under normal conditions at Orlando, Fla., the relative humidity at any season of the year rises to nearly or quite 100 per cent by 6 to 10 p. m., and remains at this degree of humidity until the following morning. Rain falls throughout the year, but is lightest during the winter months.

In the Punjab it was found that the humidity is comparatively low throughout the year. With the exception of a few light falls of rain in the winter the rainfall during a normal year is confined to the so-called "monsoon period," occurring in June, July, and August

[1] Bul. 92, Bur. Ent., U. S. Dept. Agr., 1911.

and averages about 15 inches. Taken as a whole the climate of the Punjab is very comparable with that of portions of the arid southwestern United States.

The writer's observations were confined almost entirely to the year 1911, during which conditions were somewhat abnormal because of the almost total failure of the rains during the monsoon in the plains of northern India. The prevailing extremely high temperature and low humidity throughout the summer (with the exception of two periods of very light rainfall) gave excellent opportunity for observing the effect of high temperature on the development of the white fly, as well as the effect of humidity on its development and emergence. Throughout the period between April and September the humidity continued so low that at no time was foliage noticeably moistened by dew except in a few instances following precipitation. Heavy dews occur during the autumn and winter months, yet they are much less heavy than in Florida.

With these considerations regarding Indian weather in mind, an attempt will be made to specify its effect on the development of the white fly during 1911. It is quite probable that the emergence of the first brood at Lahore took place about the 1st of April. By May 1 it appeared that practically all eggs had hatched, while the insects were in the earlier stages of development. The temperature during the latter half of April averaged about 82° F. Development continued throughout May, and by June 11 the insects were mostly in the thickened pupal condition or approaching maturity. As compared with that of Florida, development thus far had been about normal. The mean temperature from May 1 to June 11 was 93° F. During the period, June 11 to 15, about 2 inches of rain fell, while the humidity, which had averaged about 39 during the preceding six weeks, now rose to an average of 74. This moisture apparently hastened the development of the pupæ. A few of the more advanced individuals changed to adults and emerged about 10 days after the rain. Almost immediately following this period of precipitation the temperature rose, while the humidity returned to normal. This return to previous hot, dry conditions appeared suddenly to check further development, but such pupæ as had already changed to adults began emerging on June 25, 10 days after the last rain. A very light shower of rain fell on June 26 and appeared to bring out all adults ready for emergence. Within four days practically all adult flies had disappeared from the hedge plants.

This hot, dry weather continued throughout July up to August 20. Slight thunderstorms on July 13 and 14 moderated the temperature a few degrees. The very dry, hot atmosphere immediately preceding and following these rains, as well as the sunshine between showers, almost immediately dissipated any marked change of the tempera-

FIG. 1.

FIG. 2.

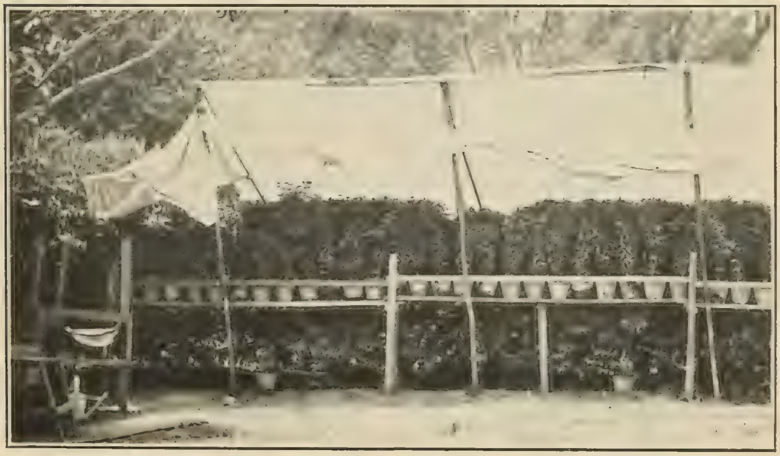


FIG. 3.

These hedges were found well infested with *Aleyrodes citri*, and were protected from the rays of the sun by cloth coverings. In all three figures is seen the method of covering, and in figures 2 and 3 is shown the construction of a wooden platform alongside the hedge for holding the potted orange trees. These potted plants were placed in this position so as to become infested with the citrus white fly when the brood emerged on the hedge plants. (Original.)

AN ORANGE HEDGE IN THE BOTANICAL GARDEN AT LAHORE, INDIA.

ture and relative humidity. The relative humidity as taken at 8 a.m. throughout the period of high temperatures and low humidity between the middle of June and August 20 averaged 52 per cent. The temperature during the same period ranged between an average maximum of 106° F. and an average minimum of 84° F. The average mean temperature was 95° F. So great was the effect of this hot, dry weather on the pupæ of the white fly that they remained in a practically dormant condition throughout this interval, and many were killed by the penetrating rays of the sun.

Lahore is situated in the plains about 50 to 100 miles from the Himalaya Mountains. Heavy rains falling in the outer ranges during the latter part of August affected the humidity of the surrounding plains. By August 20 the effect of these rains began to be felt at Lahore and was marked by a high rise in humidity over that of the preceding weeks, while the dry atmosphere changed to one of muggy oppressiveness. This humidity was accompanied by a slight lowering of the temperature. This condition continued for several days and on August 25 heavy showers fell. A very thorough examination of the infested plants on August 26 showed that a remarkable change had taken place within the past few days. All living Aleyrodes were active, as noticed by exudations of honeydew, a condition not seen during the preceding several weeks of dry weather. The pupæ were also changing to adults. This humid weather, accompanied by occasional showers, continued and by August 31 the first adult white flies emerged. By September 2 they could be seen in great numbers. The issuance of adult white flies was at its greatest height about September 7 or 8, while by September 13 practically all adults had emerged and eggs had been deposited very freely.

The foregoing observations show that when dealing with high temperatures, such as in the Indian plains, humidity is the great factor regulating emergence of adult Aleyrodes. Low humidity coupled with high temperatures between the middle of June and the middle of August kept the pupæ in a dormant condition. The approach of a humid atmosphere on August 20 and continuing into September effected immediate development of the white fly and rapid emergence followed.

The effect of humidity on other insects was equally apparent. Several species of scale insects (Coccidæ) which had been in a dormant condition throughout the summer commenced development with the approach of the humid period during the last of August. The rapidity of this development in the case of some species was most striking. Trees which had contained a moderate infestation of inactive scales during the summer months now became severely infested within a fortnight following the first rain.

Prospaltella lahorensis, the True Internal Parasite.

It has been stated in another part of this bulletin that the first definite discovery of parasitic action on *Aleyrodes citri* was made at Lahore, India. Also it was here that at a later date living material of the parasite was first seen. While no special attempt was made to work out the life history of this insect, numerous observations taken during the summer of 1911 while preparing material for introduction into Florida furnish some definite information on certain points of value.

Adult parasites could be found at any time between May and November. They were most numerous during the months of May and September. Although found in June, July, and August, they were so scarce that it frequently required several minutes before a single specimen could be located. Moreover, during this time of great heat a large percentage of the parasites died within the host before maturity. As no evidence of hyperparasitism was evident and since this mortality occurred at all stages of parasite development, the writer is inclined to attribute this mortality to the effects of the hot dry climate. Observations would lead us to believe that at no time did parasitism of the fly exceed 1 per cent.

The parasite prefers the larval stages of its host, but when necessary will oviposit in the pupæ. Parasitized larvæ and pupæ develop a much greater thickness than healthy ones. They also soon lose their transparency, becoming opaque, and this renders them easy of detection. By the use of a lens the parasitic larvæ, which are of a whitish cast, can be seen within the white-fly host. On reaching the pupal stage the parasite becomes very dark, almost black, so that at this time parasitized white flies containing pupa cases appear very dark. Having attained maturity the parasite eats a small hole in the dorsum of the host and through this opening emerges into the open air.

Parasitized Aleyrodes are largely confined to the shadiest part of the plant. The parasite is apparently distributed throughout the citrus-growing region of the Indian Empire.

Infesting Young Orange Trees with Aleyrodes citri.

It has been stated under another paragraph that young trees infested with living white flies were necessary for the safe transmission of parasites from India to Florida. Since young trees infested with the white fly were not available in that country, infestation was secured in the following way: A large portion of the infested orange hedge at Lahore had been protected by a heavy canvas awning. (See Pl. VIII.) Under this awning immediately adjacent to the orange hedge, and on the side away from the midday and afternoon sun, was constructed a narrow platform for potted citrus trees. This platform was of such height that the top of the young trees placed thereon would approximate or slightly exceed the height of the hedge. (See Pl. VIII, figs. 2, 3.)

Potted plants were arranged on this platform immediately preceding the emergence of the brood of the white fly in September. The awning was then so extended as completely to cover the hedge except at the side on which the plants were placed. This procedure not only protected the foliage from the sun but so shaded the hedge that when the white flies became active in the morning and evening they would come in contact with the potted trees, in their flight toward the light, and thus be more likely to oviposit thereon than upon the hedge itself. All fresh and tender foliage was removed from the hedge before emergence of the white fly took place so as to render its foliage less attractive than that of the potted plants. As a result the flies oviposited freely on the young plants and a gross infestation was thereby secured.

The plants were continued in this position after infestation in order to afford natural conditions for the action of parasites. About the time white-fly eggs commenced to hatch, parasites could be seen running about the young plants, and later it was found that the percentage of parasitism on the young trees was equally as great as had been seen on the infested hedge at any period during the observations.

It was now the middle of October and, believing that all conditions at that time were most opportune for success in carrying through the parasite to America in good condition, the writer commenced boxing the plants on October 18 preparatory to shipment.

Cases Used in Transporting Parasites.

When tender plants are shipped long distances, as from one country to another, a specially made crate called a Wardian case has been used with marked success. These cases much resemble miniature greenhouses, being constructed of heavy wood throughout with the exception of the top, which is made of glass. The cases are perfectly tight except for two small holes at the top, which afford a slight exchange of air with the outside. Plants contained in these cases go great distances without watering. The writer's attention was called to this case by Mr. C. L. Marlatt, assistant chief of this bureau, and by Mr. David Fairchild, in charge of plant introductions in the Bureau of Plant Industry of this department. Request for one of these cases was made to the Government Botanical Garden, Calcutta, and in due time a sample case was constructed and shipped to Lahore. These Wardian cases are used for seedling plants, and consequently are low-topped. It was found that in order to utilize this type of case for our insect-infested plants it would be necessary to make a number of alterations. This was done and the completed case as used for transporting our material to this country is seen in Plate IX. The base measurement of the cases was approximately $2\frac{1}{2}$ by $3\frac{1}{2}$ feet, while the height varied from 4 to 5 feet. Three large holes were made in both ends of the cases toward the top so as to allow a free exchange of air. These holes were covered with fine brass gauze to prevent the escape of insects. Two small doors were made in each case to be used when watering the plants. These doors were kept open in good weather during the voyage and a specially made fine wire-gauze screen placed in the opening. The glass portion of the case was divided into small sections, six on either side. Thick glass was deep set in the heavy frames so as to reduce to a minimum the possibility of breakage en route.

A rack of half-inch boards rested on the bottom of the case, thus keeping the plant jars from coming in direct contact with the bottom. This helped to minimize the effect of sudden jolts as well as to allow seepage of excess water when the plants were watered. Several auger holes were bored in the bottom of each case. The earthenware jars containing trees were tightly packed with a mixture of the fiber from palm trees and sphagnum moss. Strips of boards were tacked over the tops of the jars to keep them in place. The cases were made in sections held together by screws. They could be easily taken apart and reassembled when needed.

CRYPTOGNATHA FLAVESCENS,[1] THE PREDATORY ENEMY OF THE CITRUS WHITE FLY.

During the autumn of 1910 a small reddish-colored lady-beetle was found destroying the white fly at Saharanpur, India, and two shipments of this species were made at that time to America. All insects were dead on their arrival.

When the writer was carrying on an inspection of citrus trees infested by Aleyrodes, immediately following his return to Lahore in May, 1911, his attention was soon directed to a very few larvæ of this coccinellid busily destroying the white fly. By May 9 the larvæ had become fairly numerous on parts of the infested hedge about which work was centered. Very few adults were seen at this time. During the last ten days of May adults had become numerous, while larvæ were seldom seen, which would indicate that the latter had reached maturity. Careful observations were made June 11 to 14 and the discovery was made that not only had all larvæ disappeared, but the adults as well with the possible exception of an occasional straggler and these too disappeared during the latter part of the month. No Coccinellidæ were seen during July, August, and September, but on October 5 one adult and a few young larvæ were found on young

[1] This insect is mentioned in Indian Insects, by H. Maxwell-Lefroy, under the name *Clanis soror*, as attacking *Alcyrodes* sp. on castor (*Ricinus* sp.).

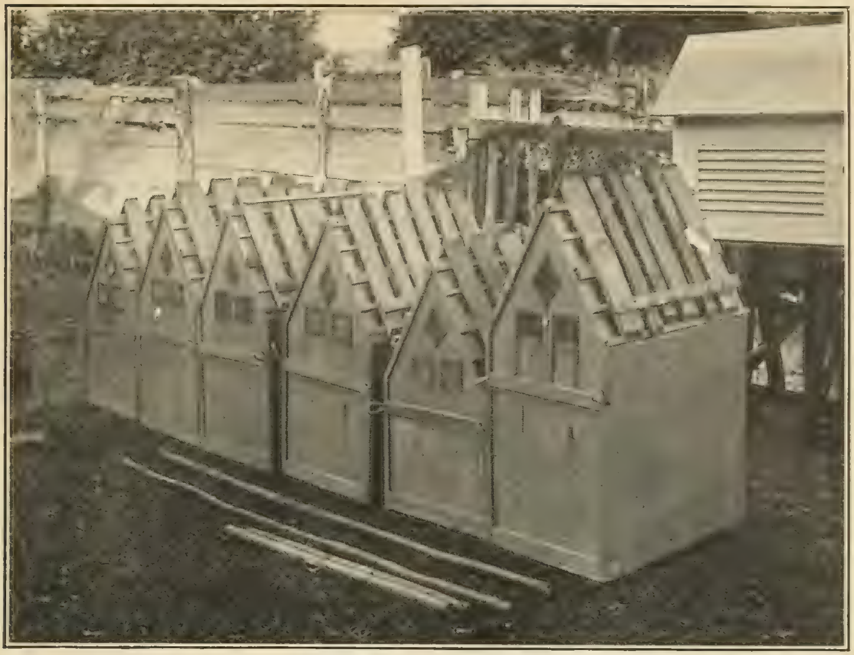


FIG. 1.—THE SIX WARDIAN CASES CONTAINING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY AS THEY ARRIVED AT THE LABORATORY AT ORLANDO, FLA., AFTER THEIR LONG TRIP FROM INDIA. (ORIGINAL.)

FIG. 2.—A WARDIAN CASE WITH THE TOP REMOVED.

This top is tightly fitted on the glass case by means of screws. The elbowed funnel was used in watering the orange trees through the small door at the end. (Original.)

TRANSSHIPPING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY.

FIG. 1.—THE SIX WARDIAN CASES CONTAINING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY LEAVING LAHORE AT THE BEGINNING OF THEIR LONG JOURNEY TO THE UNITED STATES. (ORIGINAL.)

FIG. 2.—NATIVE HINDUSTANI WHO RENDERED ASSISTANCE TO THE WRITER IN COLLECTING THE NATURAL ENEMIES OF THE CITRUS WHITE FLY. (ORIGINAL.)

orange trees infested with larvæ of the white fly. By October 13 the coccinellid larvæ were in large number and a week later adults had become numerous.

This coccinellid feeds upon the eggs and larvæ of the white fly. A few cases have been noted in which pupæ were attacked. They do splendid work when the proper food is in abundance. The most extreme instance of efficient performance by this lady-beetle was observed on some young potted orange trees severely infested with the white fly in the larval condition. About thirty of these trees were grouped closely together in the shade of a large overhanging tree in the Lahore Botanical Garden in order to secure infestation with parasites. Within a period of 10 days these trees had become inhabited by so many lady-beetle larvæ that the white flies were largely destroyed and the trees were rendered useless for the writer's purpose. This insect has been collected by the writer in the Eastern United Provinces and the Punjab.

Preparation of Beneficial Insects for Shipment.

The coming of the rains during the latter part of August, which resulted in the emergence of the fall brood of the citrus white fly and subsequent infestation of the young potted trees, marked the beginning of a period of steady progress toward successful accomplishment of our endeavors in India. Closely following the hatching of the first white-fly eggs numerous specimens of *Prospaltella lahorensis* could be seen walking around on the leaves of the infested young trees. By the middle of October it was evident that many aleyrodid larvæ had been parasitized. Fortunately large numbers of the coccinellid *Cryptognatha flavescens* had appeared simultaneously with the internal parasite.

Believing it to be the ideal time for preparing the shipment, five cases were packed on October 18 with aleyrodid-infested trees. Each of the cases contained between 10 and 20 trees. Three cases were filled with material parasitized by Prospaltella, while each of the other two cases contained about 150 specimens of the lady-beetle Cryptognatha. The lady-beetles were in both the larval and adult stages.

Transporting the Natural Enemies of the Citrus White Fly from India to the United States.

On October 20, 1911, the five cases of natural enemies of the white fly, together with a sixth case, which contained several valuable varieties of citrus fruit trees native to that country, were placed aboard a train at Lahore and started on their long journey to America. (Plate X.) At Bombay the shipment was placed aboard a vessel bound for Europe. As there are no through steamers between Bombay and New York, it was necessary to transship to other vessels at Port Said and Naples. Careful prearrangements enabled good connections to be made at both of these ports, so that little delay was experienced throughout the voyage. New York was reached on November 28, exactly one month out from Bombay.

The writer accompanied the shipment and gave it his personal attention throughout the long voyage. The cases were kept on deck except for the last three days out of New York when cold and stormy weather necessitated their being placed below.

CONDITION OF THE NATURAL ENEMIES ON ARRIVAL AT ORLANDO, FLA.

The cases were shipped from New York to Florida by express, arriving at Orlando on December 2, when they were immediately taken to the Government laboratory. An examination of the contents was at once instituted. The ultimate result was the recovery of 28 active and healthy lady-beetles (*Cryptognatha flavescens*) and 8 adult *Prospaltella lahorensis*. A large number of living Prospaltella in both the adult and pupal states were left in the cases.

This condition of the shipment was all that could be desired. A sufficient number of both the predatory enemy and the true internal parasite had arrived in a living condition for breeding purposes. Thus it seemed to the writer that his mission had been successfully terminated.

CONDITIONS AT ORLANDO, FLA., WHEN THE NATURAL ENEMIES ARRIVED.

The writer's return in December was unfortunate but unavoidable. White flies in Florida at this time are in a practically dormant pupal state and continue in this condition during the winter months. Although the winter weather in central Florida causes such tender insects as the white fly to remain inactive, the more resistant species, such as the Coccinellidæ, are not completely driven into winter quarters, but continue to be more or less active during many of the warmest days.

Mr. R. Wooldridge, an agent of this bureau then stationed at Orlando, had on hand a large number of young orange trees infested with the white fly for use in feeding the natural enemies. All these insects, however, were in the pupal stage and then not suitable as food for either of the two introductions, which attack only the younger stages of the white fly.

LOSS OF THE NATURAL ENEMIES.

Without any experience to act upon, it was not easy to determine the best method of carrying these parasitic and predaceous enemies through the winter. In view of the writer's acquaintance with the conditions in India and from the fact, as he had there determined, that both the parasitic and predaceous enemies of the white fly pass through considerable periods of hibernation, both in the winter season and in the dry season, it seemed to him that the best chance of success was to allow the imported material to go through the winter in a normal condition of hibernation. The alternative was artificially to force, throughout the winter, active breeding of these imported insects and of the white flies as hosts.

With the exception of a small number of the more active specimens of the lady-beetle enemy of the white fly, an attempt was made to carry the imported insects through the winter in a state of hibernation, with the unfortunate result that none of the parasites or of the lady-beetle enemy of the white fly survived.

The small number of more active ladybird beetles referred to were removed from the Wardian cases in which they had been imported and taken into the laboratory and placed on young trees infested with white flies in the dormant, pupal stage. The white fly in this stage was not well suited to them as food, which is by preference the egg and early larval stages, and by the 1st of January all but two of the beetles taken into the laboratory had perished. About the middle of January eggs were obtained from white flies reared in the warm room and the two remaining beetles were removed to a small potted seedling orange tree stocked with such eggs. The feeding of these beetles on the eggs was voracious and they remained alive through the winter but as they were apparently of the same sex they died without reproducing.

The loss of the parasites and the ladybird enemies of the white fly is very regrettable. Possibly such loss can be avoided, if another importation is made at the same period, by adopting the method of keeping the insect enemies and host insects in active breeding throughout the winter in a suitably constructed and well-stocked greenhouse. Possibly an even better chance of success will come from importations so timed as to arrive in early summer.

THE POSSIBLE EFFICIENCY OF THESE NATURAL ENEMIES IF ESTABLISHED IN FLORIDA.

Considering the comparative weather conditions of Florida and the parts of India infested with the white fly, the writer sees no reason why *Prospaltella lahorensis* and *Cryptognatha flavescens* could not be successfully established in this country.

It has already been stated that neither of the two natural enemies of the white fly exerts any great effect in controlling the white fly in India. The great natural enemy of the white fly in that country is the excessive heat, and this very element which limits the injuriousness of the white fly is, in the writer's opinion, largely the one that keeps down the natural enemies of this pest as well. Probably the adults of Prospaltella never emerge from the majority of parasitized larvæ and pupæ of the fly, and this because of their destruction by heat previous to the time for their exit. This same extreme weather which limits the white fly to two distinct broods has both a direct and an indirect effect on the lady-beetle. Since this insect destroys only the younger stages of the white fly, the heat has an indirect effect by limiting the breeding of the pest to two distinct broods, so that there is only a very short time in the spring and in the fall during which food for the coccinellid is available. The direct effect is that the extreme heat produces a deterrent influence on the lady-beetle's activity.

It may be well to state what could be expected of these natural enemies if established in Florida. At the very maximum of possible efficiency the writer believes they would fall far short of commercially controlling the white fly. In fact, it is very doubtful if its commercial control by natural enemies alone is possible. Granting that this high degree of control could not be expected, the writer's observations and experience lead him to believe that the introduction of these natural enemies, especially the lady-beetle, is likely to result in sufficiently beneficial results to be well worth the while. Especially would this be so when these natural enemies were working in connection with the different fungous enemies of the fly now found in Florida.

The elimination in this country of the checks to the development of these natural enemies, which exist in India, would assuredly have a beneficial effect. Whereas in India the white fly can be found on citrus trees only in small quantities and is limited to two distinct broods, the situation is entirely changed in Florida in that there are several broods in a single year. The presence of an adequate food supply throughout a large part of the year, in a climate in which the most extreme day of summer is sufficiently mild to allow their free activity, would seem to present such a favorable situation that these natural enemies of the white fly must needs accomplish excellent results after becoming thoroughly established.

DESIRABILITY OF CONTINUING THE ATTEMPT TO INTRODUCE THESE TWO NATURAL ENEMIES.

It has been pointed out in the preceding discussion that conditions in Florida appear favorable to splendid results from the establishment of these natural enemies, especially the lady-beetle (*Cryptognatha flavescens*). As previous experience has shown how best to cope with the situation in order to carry it through to a successful termination, the present would seem an inopportune time to terminate endeavors in parasite introduction. We have detailed information of localities in which to find the natural enemies, the proper season of the year for their collection, the most successful methods to be employed, manner of shipment, and all other factors regulating the procedure. A greenhouse could be prepared in Florida, so that there would be breeding Aleyrodes on hand at all times of the year.

As an outline of a second attempt at introducing the natural enemies of the white fly, the writer would make the following suggestions on the basis of his past experience: The work should be carried along on a more extensive scale than previously and with the object of continuity should the first attempt fail. Two men should be sent abroad, to arrive in India by March 1. This would give time for adequate preparations before the appearance of the first brood of the white fly in April. Several cases such as were used by the writer in his expedition should be filled with aleyrodid-infested trees and transported to India. This would insure a supply of Aleyrodes as well as citrus trees should any difficulty be experienced in an attempt to secure either on arrival in India. Having collected a supply of natural enemies, one of the two men could return with the same to America while the second man remained in India carrying out preparations for securing material from the second brood of the white fly. Then, if the first shipment should prove a failure, no time would be lost in the second attempt. Should the first shipment come through successfully, as soon as this was definitely known the agent in India could be informed. He could then proceed to the great citrus-fruit-growing regions of southern China and endeavor to find other natural enemies of the white fly in this little-known region, in which it is quite possible the Aleyrodes originated. The writer is very strongly of the opinion that in China there should be other natural enemies not found in India.

FOOD PLANTS OF THE CITRUS WHITE FLY.

The citrus white fly has attained its great economic importance in the United States because of its injurious action to citrus fruit trees. Specific consideration of this matter has been given on pages 11–12 of this bulletin. It has been stated by Drs. Morrill and Back that in the Gulf States oranges of the tangerine group are preferred hosts over other varieties of citrus. This same preference was observed by the writer in India. Similarly, other varieties of oranges are preferred to grapefruit, which was always found highly infested or else free of this insect. Lemons and limes appeared to stand intermediate in point of infestation between oranges and grapefruit. Some varieties of limes were quite as much preferred hosts as oranges. Although living specimens of the white fly were usually found on the larger leaves of infested plants, because of the greater protection from the sun, it is a point of much interest that grapefruit trees were much less severely infested than the orange, although in general their larger leaves produced a more dense shade than those of the former.

The citrus white fly has other host plants than the varieties of citrus, and below is given a list of its definitely known food plants as taken from Bulletin 92 of this bureau, page 29:

Definitely known food plants of the citrus white fly (Aleyrodes citri).

CLASS I. PREFERRED.

Introduced:

1. Citrus (all species cultivated in America).
2. China tree (*Melia azedarach*).
3. Umbrella China tree (*Melia azedarach umbraculifera*).
4. Cape jessamine (*Gardenia jasminoides*).
5. Privets (*Ligustrum* spp.).
6. Japan persimmon (*Diospyros kaki*).
7. Lilac (*Syringa* sp.).
8. Coffee (*Coffea arabica*).

Native:

9. Prickly ash (*Xanthoxylum clava-herculis*).
10. Wild persimmon (*Diospyros virginiana*).

CLASS II. OCCASIONALLY INFESTED.

Introduced:

11. Allamanda (*Allamanda neriifolia*).
12. Cultivated pear (*Pyrus* spp.).
13. Banana shrub (*Magnolia fuscatum*).
14. Pomegranate (*Punica granatum*).

Native:

15. Smilax (*Smilax* sp.).
16. Cherry laurel (*Prunus laurocerasus*).
17. Wild olive or devil wood (*Osmanthus americanus*).
18. Viburnum (*Viburnum nudum*.)
19. Green ash (*Fraxinus lanceolata*).

The bulletin just referred to goes on to say that in addition to those of the foregoing list there are several species reported as food plants of the white fly which, although probably true food plants, can not consistently be included in the recognized list until the observations have been repeated and the infesting species positively identified.

Authorities on the white-fly situation in this country appear agreed that the economic control of this insect necessitates proper attention to different food plants. It can then be seen that in case a citrus orchard was so treated that the fly was eradicated therefrom, the presence of other species of infested food plants in the immediate neighborhood which might escape treatment would furnish a direct source for its reinfestation. Knowledge of the different kinds of food plants would readily enable the horticulturist to determine before treatment whether or not his sole efforts could be devoted to his orchard trees.

As the white fly is an introduced pest it has also been conceded that knowledge of the different preferred food plants might assist materially in the discovery of the original host plant as well as indirectly the original home of the insect. Practically all investigators of the white-fly situation in the Gulf States agree that the China and umbrella trees (*Melia* sp. and var.) are the greatest breeders of the white fly of all known food plants including the citrus. In speaking of the umbrella China tree Morrill and Back state:

> First this insect shows in one respect a greater degree of adaptation to this food plant than to citrus plants, as shown by the very low rate of mortality in immature stages. The second important point is that adult citrus white flies are so strongly attracted by growing leaves of umbrella trees that under certain conditions with umbrella and citrus trees growing side by side more adults collect on three or four umbrella leaves than are present on entire citrus trees of medium size.

From the preference shown in the white-fly region of this country for the different China trees some entomologists have even ventured to state that they believed these trees to be the original host plants. It is known that China trees are native to Asia, and that certain species occur wild in India. The writer found these trees common in northern India, and many were examined. In no instance, however, was the white fly found on China trees in that country, although in some cases the foliage of these trees came in contact with aleyrodid-infested orange plants.

JASMINUM SAMBAC.

Some of the most common bushes throughout India belong to the genus Jasminum, and of these probably *Jasminum sambac* is the most common species. This plant is used for ornamental purposes in yards and gardens, but is of especial importance through cultivation for its very fragrant flowers, which are used in making scented oil as well as in connection with various religious performances of certain native sects. Patches of one-fourth, one-half, or even an acre in size are common throughout northern India, and the writer has seen the plant in every other part of this country in which he has traveled. The special point of interest is that these bushes are invariably infested with the white fly, and usually more or less severely. The writer has seen patches of this plant in which almost every leaf of each plant contained some living white flies. Bushes were sometimes found to be very black with sooty mold, a condition never seen in citrus trees. Not infrequently has the writer examined as many as a score of orange trees with the result of finding living material on only one or two, whereas every Jasminum bush in the immediate vicinity would contain much living material. In the Central Provinces no white flies were seen on citrus trees, yet in numerous instances Jasminum bushes planted between the trees, in some cases even touching their trunks, contained many active insects.

In conclusion, it might be stated that in all localities in which Jasminum bushes were examined, which included northern and central India, these were found infested with *Aleyrodes citri*, and frequently somewhat severely. The white fly was found on citrus trees throughout this region, with the exception of the Central Provinces and the Bombay Presidency; in these places it was seen only on Jasminum. Probably the majority of citrus trees examined were entirely free of the white fly, and where this insect was present it was entirely under control, barring two or three exceptions. On the Jasminum, however, it was seldom that living material was not present, and frequently infestation was more or less severe.

The Jasminum is a low, spreading bush with very dense foliage, which remains on the plant throughout the year. The broods of the white fly on this species are not distinct as on the citrus plants, which was shown by the presence of adult white flies on Jasminum at several different times between the months of May and October.

Enough has already been stated to show the preference, in many instances in India, of the white fly for the Jasminum rather than for citrus plants. The following additional evidence is in itself conclusive: During May, while adult flies were emerging in large numbers on a Jasminum bush, a number of small seedling orange trees of very tender foliage were placed immediately about the plant, so that the leaves of the orange trees were in contact with those of the Jasminum. Very few flies settled on these orange trees, while large numbers would be present on leaves of the Jasminum within a few inches of the former. Even if the bush was so disturbed that the flies in their flight would settle on the orange trees they would ultimately desert these in order to go back to the original food plant.

In addition to citrus plants and Jasminum the only other host of *Aleyrodes citri* seen in India was a large-leaved vine—*Hiptage mandalobata*. The citrus white fly appears to be less parasitized on these two hosts than on citrus trees.

PROBABLE NATIVE HOME OF ALEYRODES CITRI.

Authorities on citrus fruit trees are generally agreed that the native home of this group of plants is southeastern Asia. The writer's observations in the Orient support this conclusion in all respects. By far the most common variety of citrus fruit in the Oriental region is the tangerine (Mandarin) orange, including other forms so closely allied as evidently to belong to the same group. Tangerines are found everywhere that citrus plants can be grown. The writer has seen them throughout the Indian Empire, where they form the bulk of the orange crop, in Ceylon, Java, and the Philippines. In China they are extensively grown and are found also in southern Japan. That oranges are not native to but have been introduced from the mainland into the surrounding islands is very evident from observation of their present condition in the latter places, even if we had no more conclusive evidence. Oranges do very poorly owing to the great humidity of these tropical islands. The trees for the most part are stunted, while the crop of fruit is invariably very light, of small size, and usually ripens without the greenish skin changing to an orange color, as it does in more temperate climates. In short, orange trees in the eastern Tropics appear to be struggling under conditions so ill-suited to their best development, whereas in a semitropical climate they flourish with great prolificness, that it is very evident that they originated in the latter regions.

In India proper oranges do not occur wild. Although grown in all parts of this large country their distribution has resulted after introduction. In the Khasia Hills of Central Assam oranges occur in a half wild state intermingled with the other trees of the forest. They are grown in the extreme northeast of Assam where the Indian Empire is adjacent to southern China. Information was received from an engineer in the Indian service who had traveled extensively along the eastern border of the Empire to the effect that he had seen oranges growing wild in the forests of the North Shan States of Upper Burma. This latter region, which is contiguous with orange districts of China, is only about 300 miles east of that part of Assam in which the writer saw oranges in a half wild state. Oranges are known to occur in southern China, Siam, and Indo-China. From this knowledge, coupled with the writer's own observations, it can be seen that oranges are grown in a more or less scattered condition throughout southern Asia, where climate allows. Eliminating the varieties found in various botanical gardens and on the estates of wealthy natives, and the limited amount of commercial production, the remaining trees in all countries are for the most part seedlings of the tangerine group. In the valleys along the southern slopes of the Himalayas as well as in the Khasia Hills of Assam this is almost exclusively the case. When it is considered that oranges in the eastern part of India are almost exclusively tangerine seedlings, and that these are found growing about most of the native houses as well as being in a half wild state in a part of this region—a condition that does not occur anywhere to the westward—we feel safe in concluding that oranges were first introduced into India through Assam and thence have spread throughout the rest of the Empire. The western region was later affected by varieties introduced from Europe, for it is in this part of India, including the northwest, that budded varieties of citrus trees predominate.

The writer has seen the white fly on citrus trees in the Khasia Hills of Assam, in the lower parts of the Himalayas in Sikkim, and westward throughout northwestern and north-central India. He has also seen this insect at Macau, in southern China, while in the collection of this bureau in Washington is material on orange leaves collected at Canton, southern China. These records are sufficient to lead to the belief that the white fly occurs on citrus plants throughout southern Asia. If citrus is the original food plant of this insect (but we have no conclusive evidence that it is) it would then appear quite probable that its original home was in that part of southeastern Asia in which citrus plants originated and that it followed the distribution of the citrus through other parts of that continent.

In India the white fly prefers Jasminum as a host plant over citrus trees. On this plant the insect was of much greater occurrence and capable of withstanding climatic conditions better than on any other host. Viewing the problem entirely from the standpoint as seen by the writer in India, it would appear that Jasminum was the original host rather than citrus. The most commonly cultivated species of Jasminum, called *sambac*, is considered a native of India, but other allied species are native to China. Various species are cultivated throughout subtropical Asia. Hence it is quite probable that the white fly infests this plant in China as well as in India.

The lightest infestation of the white fly occurs in the eastern part of India while the most severe infestation is in the northwest. Considering climatic conditions one would expect the contrary, as the weather of Assam is of greater humidity and less extreme temperature than the upper country. Trees in the Khasia Hills at between 1,000 and 1,500 feet elevation and surrounded by forest trees so as to be abundantly protected by shade were so lightly infested that only an occasional insect could be found and most of these were parasitized. Although the infestation in the northwest was so light that the insect was in a satisfactory condition of control it could be generally stated to be much more severe than in eastern India. This condition, together with the fact that the only known reports of injury from the white fly received in the Indian Museum came from the northwest during the early nineties, leads the writer to believe that this insect is of recent introduction into that region.

After all has been said and we know that citrus and Jasminum are the present preferred food plants of *Aleyrodes citri* in southern Asia, nobody is able to state definitely that either is the original host, even though indications would tend to point that way. Nevertheless, it is sufficiently certain as to be considered a fact that the citrus white fly is a native of the semitropical part of continental Asia, and the strongest indications point toward the Indo-Chinese region as its original home.

APPENDIX A.

CITRUS FRUITS IN INDIA.

The climate of India is suitable to the production of citrus fruits from the lower altitudes of the outer Himalayas southward throughout the peninsula. Although many places throughout this vast region are splendidly adapted to citrus fruit growing, the acreage at present in commercial production is so limited as to fall far short of meeting even the home demands. Pomelos and limes are of general distribution and lemons are grown to a limited extent, but it is the orange alone that attains commercial prominence.

The locations of supply most widely known and largely depended upon are the Khasia Hills of Assam (Pl. XI, fig. 1), the Nagpur district in the Central Provinces (Pl. XI, fig. 2), Poona in the Bombay Presidency, and Gujranwala in the Punjab. The Khasia Hills supply much of the fruit used in the Calcutta and Assam markets. The chief center of orange cultivation in these hills is a narrow strip of country bordering the south and west sides, which extends from the plains up to an altitude of not more than 1,500 feet. The Khasia orange gardens are seldom composed exclusively of orange trees, but have them scattered through the forests with other trees, especially the areca palm, from which the betel nut is derived. To the American, trees of such a character in a half-wild state would scarcely be looked upon in the light of commercial production, but in India they form the chief source of supply for the entire eastern part of the Empire. These oranges are all seedlings and of the shape and flavor of tangerines. They are inferior to American-grown tangerines in both size and flavor.

The Nagpur orange is the most famous orange in India. The supposed excellence of this fruit is so widespread that it has almost developed into a tradition that in no place else can such excellent oranges be grown as in this limited region. The writer is of the opinion that this popular conception is largely a fallacy. Orange growing at Nagpur has been known for many years, and doubtless at present is carried on there with more care than in almost any other place in India. The fruit almost exclusively produced in this region is a very loose-jacketed tangerine, somewhat above the average size of this orange. It is produced on budded trees, in the selection of which some care was originally used. When it is considered that the bulk of the oranges grown in India are from seedling tangerine trees, many of which develop into unusual monstrosities through lack of selection, it is easily understood that the competition of a large, loose-jacketed fruit, with such an irregular assortment, would quickly place it in a prominent position. The orange production about Nagpur is much less than would be expected, as the total supply is probably taken from far below 1,000 acres.

This so-called Nagpur orange can be grown in other sections with equal success and is the orange largely produced about Poona in the Bombay Presidency. In fact, the writer was informed on good authority that the so-called Nagpur orange purchased in the Bombay markets does not come from the Nagpur region, but rather from Poona.

At Gujranwala, in the Punjab, the Malta orange is the principal kind produced. The trees are budded and in general are in a well-kept and healthy condition.

The normal time for gathering the fruit is November and December. In the more southern and warmer parts of the country the fruit is ready for market in November, but in the Punjab, as well as the outer Himalayan tracts, it is not picked until December. About Nagpur and Poona in the central Provinces two crops of fruit are gathered—one in November, the other in April. The first crop comes at the normal period of fruiting, while the second is produced artificially by the well-known method of removing the dirt from a part of the root system, the result of which is such a shock to the tree than an extra period of blossoming is brought about. The roots are exposed during the dry season in late spring. Irrigation is not practiced throughout this period, which is of about a month's duration. After exposure of the roots for about one month they are heavily irrigated, and in a short time after this treatment the blossoms are said to appear. The maturity of this crop in April, which is an off-season period for oranges, results in the fruit commanding a high price.

In the plains the fruit is carried loose in ox carts to the market place or bazaar, while in the mountainous districts it is first carried in baskets by native bearers (Pl. XII, fig. 1) to the nearest bazaar (Pl. XII, fig. 2), from which it is shipped to the railroad either by country boat or ox cart. The price paid for fruit is variable. One grower at Nagpur stated that he received 1½ to 3 rupees (50 cents to $1) per hundred for fruit at his orchard, while in one of the obscure bazaars in the outer Himalayas, upon which the writer happened, the natives brought oranges in baskets on their backs from points many miles distant to sell at the rate of about 600 for 1 rupee (32 cents).

Citrus trees in India are never pruned. Fertilization is practically unknown except for a few instances in which a little manure is added. The best orange groves are plowed frequently in order to keep down the weeds. Irrigation is almost universally practiced in those places where much fruit is produced. Many horticulturists irrigate every week or 10 days during the warm, dry season. The common system in practice is by means of a single furrow along the base of each row of trees, so that the trees rise directly out of the furrow. Hence the bases of the trees are always standing in water while the irrigation is taking place.

FIG. 1.—ORANGE PRODUCTION IN THE KHASIA HILLS OF ASSAM.

In many of the Khasia gardens the orange trees are intermingled with trees of the forest. Long bamboo ladders are necessary for reaching the fruit. (Original.)

FIG. 2.—A NATIVE ORANGE GROWER, OWNER OF THE LARGEST GROVES IN THE FAMOUS NAGPUR DISTRICT OF CENTRAL INDIA. (ORIGINAL.)

ORANGE PRODUCTION IN INDIA.

FIG. 1.—NATIVES IN THE PROVINCE OF SIKKIM CARRYING ORANGES IN BASKETS TO THE BAZAAR, WHERE THEY ARE PURCHASED BY BUYERS FROM THE LARGE CITIES.

At this bazaar the oranges were brought through the mountains by native carriers from distances as great as 10 to 15 miles and sold at the rate of 600 for 1 rupee (32 cents). (Original.)

FIG. 2.—AN ORANGE BAZAAR IN THE OUTER HIMALAYAS.

Oranges are here purchased from the natives and transported to the railroad in oxcarts. (Original.)

TRANSPORTING ORANGES TO MARKET IN THE OUTER HIMALAYAS.

APPENDIX B.

INSECT PESTS OF CITRUS TREES SEEN BY THE WRITER DURING HIS INVESTIGATIONS IN VARIOUS FOREIGN COUNTRIES.

SPAIN.

Chrysomphalus dictiospermi (Morg.).
Parlatoria zizyphus (Lucas).
Pseudococcus citri (Risso).
Lepidosaphes beckii (Newm.).
Lepidosaphes gloveri (Packard).
Aspidiotus hederæ (Vall.).
Saissetia oleæ (Bern.).
Coccus hesperidum (L.).

ITALY AND SICILY.

Chrysomphalus dictiospermi (Morg.).
Parlatoria zizyphus (Lucas).
Lepidosaphes beckii (Newm.).
Pseudococcus citri (Risso).
Aspidiotus hederæ (Vall.).
Saissetia oleæ (Bern.).
Coccus hesperidum (L.).

INDIA.

Chrysomphalus aurantii (Mask.).
Chrysomphalus aonidum (L.).
Erium sp.
Monophlebus dalbergiæ Green.
Pseudococcus citri (Risso).
Aspidiotus lataniæ Sign.
Lepidosaphes beckii (Newm.).
Lepidosaphes lasianthi (Green).
Coccus hesperidum (L.).
Fiorinia theæ Green.
Vinsonia stellifera (Westw.).
Aleyrodes citri R. & H.
Aleyrodes, 3 species (undetermined).
Papilio demoleus L.
Phyllocnistis citrella Stainton.
Bud moth (*Agonopteryx* sp.).
Borer.

The determination of almost all the Coccidæ included in these lists has been made by Mr. E. R. Sasscer, of this bureau. The scale insects have been arranged in order of economic importance in so far as was possible from the observations of the author and information available. Without doubt the most serious insect pest in India is *Phyllocnistis citrella*, a leaf-mining lepidopteron. It is especially destructive to young nursery stock. While the infestation of individual trees by other of the Indian citrus pests is occasionally somewhat severe, these infestations are not so general as to be of commercial importance.

APPENDIX C.

OBSERVATIONS ON COCCIDÆ AND THEIR NATURAL ENEMIES IN SPAIN, ITALY, SICILY, AND INDIA.

Most species of Coccidæ and Aleyrodidæ seen during the writer's travels in tropical and semitropical regions were parasitized to a greater or less extent. Some species appeared to be attacked by a single natural enemy while other species were affected by several. It might be safely stated that the combination of climatic conditions with natural enemies keeps all scale and aleyrodid enemies of citrus trees in India under commercial control except for occasional sporadic outbreaks. In Spain, Italy, and Sicily also climate and natural enemies have proved of great efficiency against numerous citrus-tree scale pests.

The following specific treatment will be largely confined to pests observed during the writer's travels abroad, which are of economic importance in the United States.

SPAIN, ITALY, AND SICILY.

Chrysomphalus dictiospermi is the most destructive pest of citrus trees in these three countries. According to Prof. Silvestri, the eminent Italian entomologist, this species was first noticed in Italy and Sicily in 1909. Fortunately the infestations of this insect are of a localized nature in these countries. In Spain it is widely distributed and undoubtedly was present here many years before its appearance in Italy. The species is attacked by numerous natural enemies, both parasites and predators, in all three European countries.

Parlatoria zizyphus, the pest which ranks in point of injuriousness next to *Ch. dictiospermi* in these three Mediterranean countries, does not occur in citrus groves in the United States. It can thus be seen that the citrus groves of this country are free of the two pests most injurious to the same plants in southern Europe. *Chrysomphalus dictiospermi* has been reported in greenhouses from most parts of the United States, but no record of the definite establishment of *Parlatoria zizyphus* is at present known.

Lepidosaphes beckii, Saissetia oleæ, and *Pseudococcus citri,* namely, the purple and black scales of California and the citrus mealy bug, which are very serious pests in our own country, produce very little serious injury in the Mediterranean region. It should be of the greatest interest to the citrus fruit growers of California, who spend so many hundreds of thousands of dollars annually in combating these pests, to know that in the chief citrus-fruit producing countries of southern Europe these same pests, though present, are for the most part under natural control so that artificial effort is seldom necessary for their subjugation. To quote from a communication respecting this subject received from Prof. Silvestri:

> The other species of citrus pests (which include the purple and black scales and the mealy bug) produce here and there some injury, but not continually nor so great that the cultivator has any interest in attempting to control them with insecticides. Only occasionally does an outbreak occur of such serious nature as to require artificial means of control.

Lepidosaphes beckii, the purple scale, was observed in Spain but only in such slight infestations, so far as the writer's observations extended, that it may be said to be under commercial control. Mr. L. Salas, the agricultural engineer of the Province of Malaga, informed the writer that the purple scale was once very severe in parts of that Province, but for some unknown reason had suddenly disappeared in recent years. A similar report was heard from another authority in that Province. In Italy and Sicily the purple scale is generally distributed, but is serious only by sporadic outbreaks as stated by Prof. Silvestri. This species is attacked by Coccinellidæ of the genera Chilocorus and Exochomus. Silvestri states that some Acari (mites) eat the eggs.

Saissetia oleæ, the black scale, is another pest generally distributed through Spain, Italy, and Sicily, but is in such perfect control in these countries as to be of no special economic importance. Wherever it was seen the writer always found *Scutellista cyanea* Motsch., the internal parasite, attacking it. Prof. Silvestri states that the black scale is attacked in Italy and Sicily by *Scutellista cyanea*, *Coccophagus flavoscutellum* Ashm., *Erastria scitula* Ramb., and Coccinellidæ of the genera Chilocorus and Exochomus.

Pseudococcus citri is the species of insect which is of the greatest interest to many citrus fruit growers in this country. The purple and black scales can be easily controlled by artificial means, especially fumigation, but these methods have thus far proven unsuccessful against the citrus mealy bug. In certain parts of southern California *Pseudococcus citri* is a very serious pest. However, in Italy and Sicily as well as to a large extent in Spain it is in such perfect control as to be of little commercial importance. Only one grove in Spain was seen by the writer to be at all severely infested by this pest, and in this many larvæ and pupæ of a dipterous parasite were observed among the masses of mealy bugs. A second species of parasitic insect, probably a dipteron, was observed in another part of that country.

The mealy bug was seen in many groves in Sicily, but always to such a limited extent as to do no injury to the trees. Practically every mass of insects examined showed evidence of parasitism. A dipterous species appeared most common. Prof. Silvestri informed the writer that *Pseudococcus citri* is attacked in that country by two species of Chalcididæ, by two to three species of Neuroptera, by a species of Leucopis, and by Coccinellidæ of the genera Chilocorus and Exochomus.

Since the citrus mealy bug is so well under control in Italy and Sicily as well as to a great extent in Spain, it is at once evident that this region should prove a fertile field for study in an endeavor to overcome the mealy-bug pest on citrus trees in America. That natural enemies take a leading part in this natural control of the citrus mealy bug in southern Europe must be admitted by anyone who has carefully examined the prevailing conditions there. The writer is of the opinion that a thorough investigation of the citrus districts of the Mediterranean by a competent entomologist, including extended shipments to this country of the different available natural enemies of such citrus pests as Pseudococcus, Saissetia, and Lepidosaphes, especially the former, would prove a very profitable economic investment for the citrus fruit growers of America.

India.

The main portion of this bulletin is devoted to a treatment of two natural enemies of *Aleyrodes citri*, so no further mention of these species is necessary. *Chrysomphalus aurantii*, the red scale so injurious to citrus fruits in California, occurs throughout India, but in such slight quantities as to produce little injury. Sometimes individual trees in shady situations are severely infested, but such instances are very infrequent. The scale on such trees is invariably found to be heavily parasitized by a species of the hymenopterous genus Aphelinus. *Chilocorus nigritus* Fab., an oriental coccinellid, also attacks this scale. *Pseudococcus citri*, the citrus mealy bug, was very seldom seen in India and in those instances observed was under perfect control. It is quite probable that the species is attacked by natural enemies.

APPENDIX D.

COCCINELLIDÆ INTRODUCED FROM INDIA.

Several species of ladybirds of economic value were included with the shipments of the natural enemies of the white fly. All have failed to develop with the exception of two species, *Chilocorus nigritus* Fab., which preys on various species of Coccidæ, and *Chilomenes sexmaculatus* Fab., which preys upon aphides.

Chilocorus nigritus did admirable work against *Chrysomphalus aurantii* in certain parts of India and was introduced in the hope that it might prove of economic value if established in this country. It is at present being successfully reared in California and Florida.

Chilomenes sexmaculatus feeds on various species of Aphididæ. It is a rapid breeder. One female in captivity has deposited over a thousand eggs. Vast numbers of this species have been reared and liberated in both California and Florida.

APPENDIX E.

FUMIGATION OF CITRUS TREES IN SPAIN.

When the writer stopped in Spain in 1910, while en route to India, no fumigation had ever been practiced. *Chrysomphalus dictiospermi* and *Parlatoria zizyphus* were such serious pests as to have become a menace to profitable orange production in certain parts of the country. The growers affected were eager for some method to control these insects even as were the orchardists of California when the cottony cushion scale was such a pest before *Novius cardinalis* had been introduced.

The writer spent the month of August, 1910, in Spain in an attempt to demonstrate the efficiency of fumigation with hydrocyanic-acid gas against these insects. Compte de Montornes, the Royal Commissioner of Agriculture from Valencia, and Leopoldo Salas, Agricultural Engineer of Malaga, had been appointed by the Minister of Agriculture to supervise such demonstration experiments as were necessary. Through the aid of these gentlemen paraphernalia essential for the equipment of a field fumigation crew such as the writer has used in California [1] were acquired so far as was possible. Intelligent men were selected and drilled in the procedure, so that before leaving Spain a crew competent to carry on field fumigation under the direction of the two eminent Spanish authorities had been established. Dosage tables of the character used by the writer in California were introduced into Spain.

The initial procedure of 1910 has developed very rapidly. In a letter recently received from the Compte de Montornes he stated that now there are 10 complete outfits of 30 tents each, as well as several smaller ones in different parts of Spain. Six of these outfits belong to the Government, the remainder to societies and private individuals. The results everywhere were said to be very satisfactory, and as the success of the process is becoming known to the growers it is producing a great demand for more extended operations.

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[1] Bul. 90, Part I, Bur. Ent., U. S. Dept. Agr., 1911.

INDEX.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 121.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE BEHAVIOR OF THE HONEY BEE IN POLLEN COLLECTING.

BY

D. B. CASTEEL, Ph. D.,
*Collaborator and Adjunct Professor of Zoology,
University of Texas.*

Issued December 31, 1912.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., September 23, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Behavior of the Honey Bee in Pollen Collecting," by Dr. Dana B. Casteel, of this bureau. The value of the honey bee in cross pollinating the flowers of fruit trees makes it desirable that exact information be available concerning the actions of the bee when gathering and manipulating the pollen. The results recorded in this manuscript are also of value as studies in the behavior of the bee and will prove interesting and valuable to the bee keeper. The work here recorded was done by Dr. Casteel during the summers of 1911 and 1912 at the apiary of this bureau.

I recommend that this manuscript be published as Bulletin No. 121 of the Bureau of Entomology.

Respectfully,

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

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

TEXT FIGURES.

THE BEHAVIOR OF THE HONEY BEE IN POLLEN COLLECTING.

INTRODUCTION.

While working upon the problem of wax-scale manipulation during the summer of 1911 the writer became convinced that the so-called wax shears or pinchers of the worker honey bee have nothing whatever to do with the extraction of the wax scales from their pockets, but rather that they are organs used in loading the pollen from the pollen combs of the hind legs into the corbiculæ or pollen baskets (Casteel, 1912). Further observations made at that time disclosed the exact method by which the hind legs are instrumental in the pollen-loading process and also the way in which the middle legs aid the hind legs in patting down the pollen masses. During the summer of 1912 additional information was secured, more particularly that relating to the manner in which pollen is collected upon the body and legs of the bee, how it is transferred to the hind legs, how it is moistened, and finally the method by which it is stored in the hive for future use. In the present paper a complete account will be given of the history of the pollen from the time it leaves the flower until it rests within the cells of the hive. The points of more particular interest in the description of pollen manipulation refer to (1) the movements concerned in gathering the pollen from the flowers upon the body and legs, (2) the method by which the baskets of the hind legs receive the loads which they carry to the hive, and (3) the manner in which the bee moistens pollen and renders it sufficiently cohesive for packing and transportation.

THE STRUCTURES CONCERNED IN THE MANIPULATION OF POLLEN.

The hairs which cover the body and appendages of the bee are of the utmost importance in the process of pollen gathering. For the purposes of this account these hairs may be classified roughly as (1) branched hairs and (2) unbranched hairs, the latter including both long, slender hairs and stiff, spinelike structures.

Of these two classes the branched hairs are the more numerous. They make up the hairy coat of the head, thorax, and abdomen, with the exception of short sensory spines, as those found upon the antennæ and perhaps elsewhere, and the stiff unbranched hairs which cover the surfaces of the compound eyes (Phillips, 1905). Branched hairs are also found upon the legs; more particularly upon the more proximal segments. A typical branched hair is composed of a long slender main axis from which spring numerous short lateral barbs. Grains of pollen are caught and held in the angles between the axis and the barbs and between the barbs of contiguous hairs. The hairy covering of the body and legs thus serves as a collecting surface upon which pollen grains are temporarily retained and from which they are later removed by the combing action of the brushes of the legs.

Although, as above noted, some unbranched hairs are located upon the body of the bee, they occur in greatest numbers upon the more distal segments of the appendages. They are quite diverse in form, some being extremely long and slender, such as those which curve over the pollen baskets, others being stout and stiff, as those which form the collecting brushes and the pecten spines.

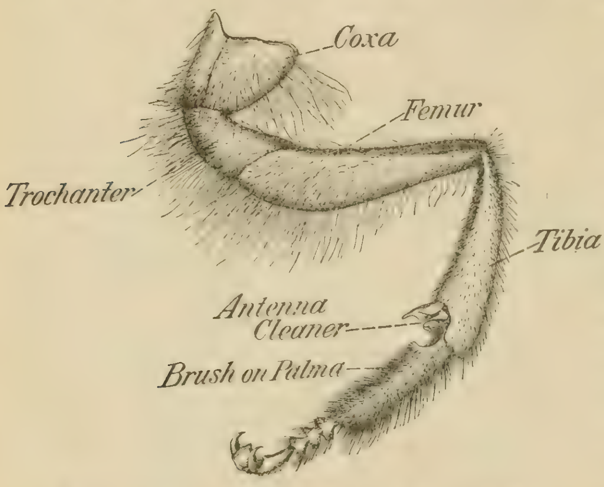

FIG. 1.—Left foreleg of a worker bee. (Original.)

The mouthparts of the bee are also essential to the proper collection of pollen. The mandibles are used to scrape over the anthers of flowers, and considerable pollen adheres to them and is later removed. The same is true of the maxillæ and tongue. From the mouth comes the fluid by which the pollen grains are moistened.

The legs of the worker bee are especially adapted for pollen gathering. Each leg bears a collecting brush, composed of stiff, unbranched hairs set closely together. These brushes are located upon the first or most proximal tarsal segment of the legs, known technically as the palmæ of the forelegs and as the plantæ of the middle and hind pair. The brush of the foreleg is elongated and of slight width (fig. 1), that of the middle leg broad and flat (fig. 2), while the brush upon the planta of the hind leg is the broadest of all, and is also the most highly specialized. In addition to these well-marked brushes, the distal ends of the tibiæ of the fore and middle legs bear many stiff hairs, which function as pollen collectors, and the distal tarsal joints of all legs bear similar structures.

The tibia and the planta of the hind leg of the worker bee are greatly flattened. (See figs. 3, 4.) The outer surface of the tibia is marked by an elongated depression, deepest at its distal end, and bounded laterally by elevated margins. From the lateral boundaries of this depression spring many long hairs, some of which arch over the concave outer surface of the tibia and thus form a kind of receptacle or basket to which the name corbicula or pollen-basket is given. The lower or distal end of the tibia articulates at its anterior edge with the planta. The remaining portion of this end of the tibia is flattened and slightly concave, its surface sloping upward from the inner to the outer surface of the limb. Along the inner edge of this surface runs a row of short, stiff, backwardly directed spines, from 15 to 21 in number, which form the pecten or comb of the tibia. The lateral edge of this area forms the lower boundary of the corbicular depression and is marked by a row of very fine hairs which branch at their free ends. Immediately above these hairs, springing from the floor of the corbicula, are found 7 or 8 minute spines, and above them one long hair which reaches out over the lower edge of the basket.

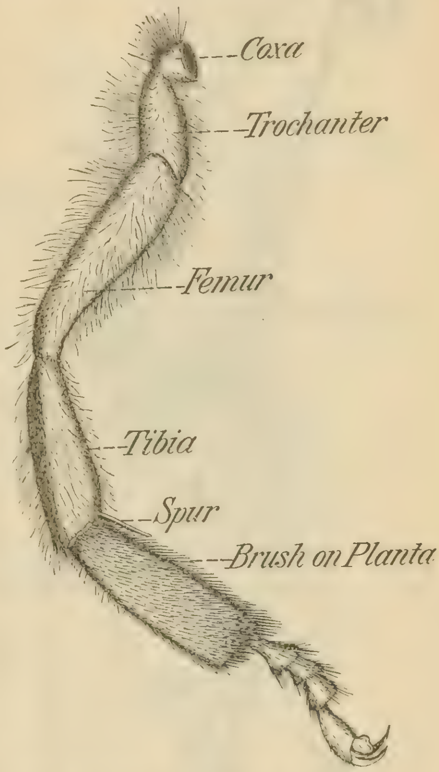

FIG. 2.—Left middle leg of a worker bee. (Original.)

The broad, flat planta (metatarsus or proximal tarsal segment of the hind leg) is marked on its inner surface by several rows of stiff, distally directed spines which form the pollen combs. About 12 of these transverse rows may be distinguished, although some of them are not complete. The most distal row, which projects beyond the edge of the planta, is composed of very strong, stiff spines which function in the removal of the wax scales (Casteel, 1912). The upper or proximal end of the planta is flattened and projects in a posterior direction to form the auricle. The surface of the auricle is marked with short, blunt spines, pyramidal in form, and a fringe of fine hairs with branching ends extends along its lateral edge. This surface slopes upward and outward.

THE POLLEN SUPPLY.

When bees collect pollen from flowers they may be engaged in this occupation alone or may combine it with nectar gathering. From some flowers the bees take only nectar, from others only pollen; a third class of flowers furnishes an available supply of both of these substances. But even where both pollen and nectar are obtainable a bee may gather nectar and disregard the pollen. This is well illustrated by the case of white clover. If bees are watched while working upon clover flowers, the observer will soon perceive some which bear pollen masses upon their hind legs, while others will continue to visit flower after flower, dipping into the blossoms and securing a plentiful supply of nectar, yet entirely neglecting the pollen.

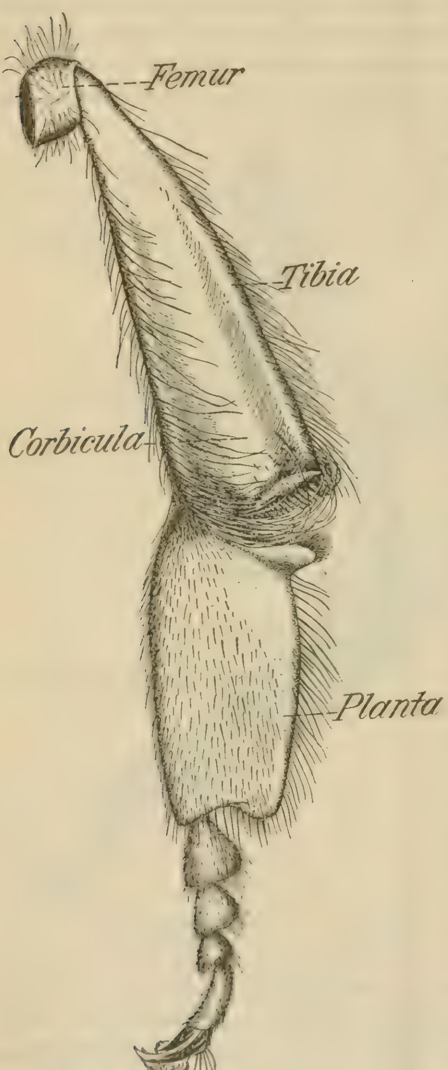

FIG. 3.—Outer surface of the left hind leg of a worker bee. (Original.)

The supply of pollen which is available for the bees varies greatly among different flowers. Some furnish an abundant amount and present it to the bee in such a way that little difficulty is experienced in quickly securing an ample load, while others furnish but little. When flowers are small and when the bee approaches them from above, little, if any, pollen is scattered over the bee's body, all that it acquires being first collected upon the mouth and neighboring parts. Very different conditions are met with when bees visit such plants as corn and ragweed. The flowers of these plants are pendent and possess an abundant supply of pollen, which falls in showers over the bodies of the bees as they crawl beneath the blossoms. The supply of pollen which lodges upon the body of the bee will thus differ considerably in amount, depending upon the type of flower from which the bee is collecting, and the same is true regarding the location upon the body of a bee of pollen grains which are available for storage in the baskets. Moreover, the movements concerned in the collection of the pollen from the various body parts of the bee upon which it lodges will differ somewhat in the two cases, since a widely scattered supply requires for its collection additional movements, somewhat similar in nature to those which the bee employs in cleaning the hairs which cover its body.

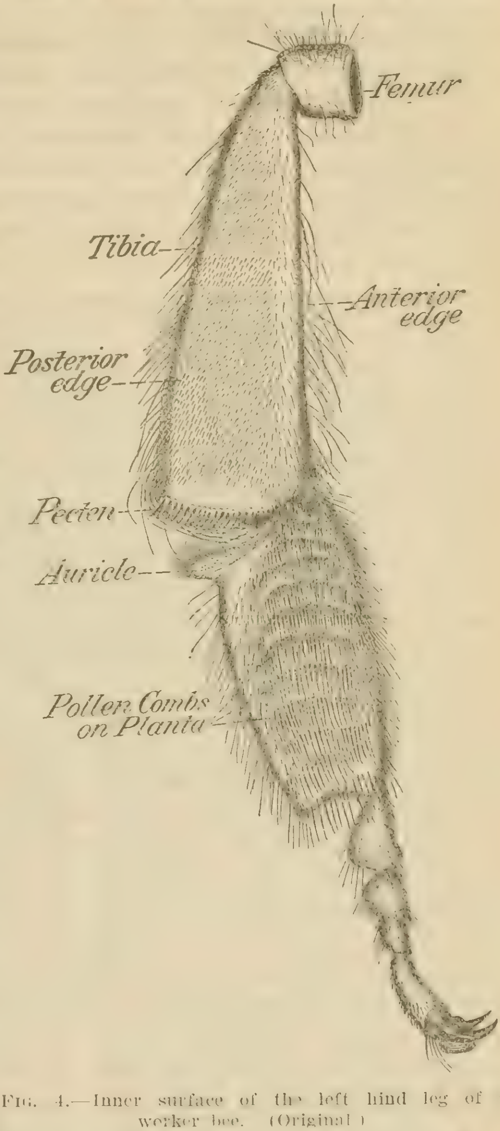

FIG. 4.—Inner surface of the left hind leg of a worker bee. (Original.)

GENERAL STATEMENT OF THE POLLEN-COLLECTING PROCESS.

A very complete knowledge of the pollen-gathering behavior of the worker honey bee may be obtained by a study of the actions of bees which are working upon a plant which yields pollen in abundance. Sweet corn is an ideal plant for this purpose, and it will be used as a basis for the description which follows.

In attempting to outline the method by which pollen is manipulated the writer wishes it to be understood that he is recounting that which he has seen and that the description is not necessarily complete, although he is of the opinion that it is very nearly so. The movements of the legs and of the mouthparts are so rapid and so many members are in action at once that it is impossible for the eye to follow all at the same time. However, long-continued observation, assisted by the study of instantaneous photographs, gives confidence that the statements recorded are accurate, although some movements may have escaped notice.

To obtain pollen from corn the bee must find a tassel in the right stage of ripeness, with flowers open and stamens hanging from them. The bee alights upon a spike and crawls along it, clinging to the pendent anthers. It crawls over the anthers, going from one flower to another along the spike, being all the while busily engaged in the task of obtaining pollen. This reaches its body in several ways.

As the bee moves over the anthers it uses its mandibles and tongue, biting the anthers and licking them and securing a considerable amount of pollen upon these parts. This pollen becomes moist and sticky, since it is mingled with fluid from the mouth. A considerable amount of pollen is dislodged from the anthers as the bee moves over them. All of the legs receive a supply of this free pollen and much adheres to the hairs which cover the body, more particularly to those upon the ventral surface. This free pollen is dry and powdery and is very different in appearance from the moist pollen masses with which the bee returns to the hive. Before the return journey this pollen must be transferred to the baskets and securely packed in them.

After the bee has traversed a few flowers along the spike and has become well supplied with free pollen it begins to collect it from its body, head, and forward appendages and to transfer it to the posterior pair of legs. This may be accomplished while the bee is resting upon the flower or while it is hovering in the air before seeking additional pollen. It is probably more thoroughly and rapidly accomplished while the bee is in the air, since all of the legs are then free to function in the gathering process.

If the collecting bee is seized with forceps and examined after it has crawled over the stamens of a few flowers of the corn, its legs and the ventral surface of its body are found to be thickly powdered over with pollen. If the bee hovers in the air for a few moments and is then examined very little pollen is found upon the body or upon the legs, except the masses within the pollen baskets. While in the air it has accomplished the work of collecting some of the scattered grains and of storing them in the baskets, while others have been brushed from the body.

In attempting to describe the movements by which this result is accomplished it will be best first to sketch briefly the rôles of the three pairs of legs. They are as follows:

(*a*) The first pair of legs remove scattered pollen from the head and the region of the neck, and the pollen that has been moistened by fluid substances from the mouth.

(*b*) The second pair of legs remove scattered pollen from the thorax, more particularly from the ventral region, and they received the pollen that has been collected by the first pair of legs.

(*c*) The third pair of legs collect a little of the scattered pollen from the abdomen and they receive pollen that has been collected by the second pair. Nearly all of this pollen is collected by the pollen combs of the hind legs, and is transferred from the combs to the pollen baskets or corbiculæ in a manner to be described later.

It will thus be seen that the manipulation of pollen is a successive process, and that most of the pollen at least passes backward from the point where it happens to touch the bee until it finally reaches the corbiculæ or is accidentally dislodged and falls from the rapidly moving limbs.

ACTION OF THE FORELEGS AND MOUTHPARTS.

Although the pollen of some plants appears to be somewhat sticky, it may be stated that as a general rule pollen can not be successfully manipulated and packed in the baskets without the addition of some fluid substance, preferably a fluid which will cause the grains to cohere. This fluid, the nature of which will be considered later, comes from the mouth of the bee, and is added to the pollen which is collected by the mouthparts and to that which is brought into contact with the protruding tongue and maxillæ, and, as will appear, this fluid also becomes more generally distributed upon the legs and upon the ventral surface of the collecting bee.

When a bee is collecting from the flowers of corn the mandibles are actively engaged in seizing, biting, and scraping the anthers as the bee crawls over the pendent stamens. Usually, but not always, the tongue is protruded and wipes over the stamens, collecting pollen and moistening the grains thus secured. Some of the pollen may possibly be taken into the mouth. All of the pollen which comes in contact with the mouthparts is thoroughly moistened, receiving more fluid than is necessary for rendering the grains cohesive. This exceedingly wet pollen is removed from the mouthparts by the forelegs (fig. 5), and probably the middle legs also secure a little of it directly, since they sometimes brush over the lower surface of the face and the mouth. In addition to removing the very moist pollen from the mouth the forelegs also execute cleansing movements over the sides of the head and neck and the anterior region of the thorax, thereby collecting upon their brushes a considerable amount of pollen which has fallen directly upon these regions, and this is added to the pollen moistened from the mouth, thereby becoming moist by contact. The brushes of the forelegs also come in contact with the anterior breast region, and the hairs which cover this area become moist with the sticky exudation which the forelegs have acquired in the process of wiping pollen from the tongue, maxillæ, and mandibles.

ACTION OF THE MIDDLE LEGS.

The middle legs are used to collect the pollen gathered by the forelegs and mouthparts, to remove free pollen from the thoracic region, and to transport their load of pollen to the hind legs, placing most of it upon the pollen combs of these legs, although a slight amount is directly added to the pollen masses in the corbiculæ. Most of the pollen of the middle legs is gathered upon the conspicuous brushes of the first tarsal segments or plantæ of these legs.

In taking pollen from a foreleg the middle leg of the same side is extended in a forward direction and is either grasped by the flexed foreleg or rubbed over the foreleg as it is bent downward and backward. In the former movement the foreleg flexes sharply upon itself until

FIG. 5.—A flying bee, showing the manner in which the forelegs and middle legs manipulate pollen. The forelegs are removing wet pollen from the mouthparts and face. The middle leg of the right side is transferring the pollen upon its brush to the pollen combs of the left hind planta. A small amount of pollen has already been placed in the baskets. (Original.)

the tarsal brush and coxa nearly meet. The collecting brush of the middle leg is now thrust in between the tarsus and coxa of the foreleg and wipes off some of the pollen from the foreleg brush. The middle leg brush is then raised and combs down over the flexed foreleg, thus removing additional pollen from the outer surface of this leg. The middle leg also at times reaches far forward, stroking down over the foreleg before it is entirely flexed and apparently combing over with its tarsal brush the face and mouthparts themselves. When the middle leg reaches forward to execute any of the above movements the direction of the stroke is outward, forward, and then back toward the body, the action ending with the brush of the leg in contact with the long hairs of the breast and with those which spring from the proximal segments of the forelegs (coxa, trochanter, femur). As a result of the oft-repeated contact of the brushes of the middle and forelegs with the breast, the long, branched hairs which cover this region become quite moist and sticky, since the brushes of these two pair of legs are wet and the pollen which they bear possesses a superabundance of the moistening fluid. Any dry pollen which passes over this region and touches these hairs receives moisture by contact with them. This is particularly true of the free dry pollen which the middle pair of legs collect by combing over the sides of the thorax.

The pollen upon the middle legs is transferred to the hind legs in at least two ways. By far the larger amount is deposited upon the pollen combs which lie on the inner surfaces of the plantæ of the

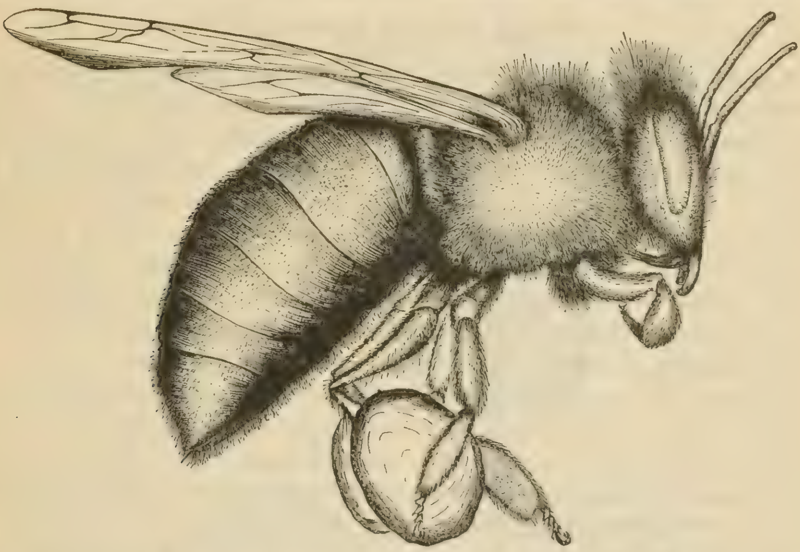

Fig. 6.—A bee upon the wing, showing the position of the middle legs when they touch and pat down the pollen masses. A very slight amount of pollen reaches the corbiculæ through this movement. (Original.)

hind legs. To accomplish this a middle leg is placed between the plantæ of the two hind legs, which are brought together so as to grasp the brush of the middle leg, pressing it closely between them, but allowing it to be drawn toward the body between the pollen combs of the two hind legs. (See fig. 5.) This action results in the transference of the pollen from the middle-leg brush to the pollen combs of the hind leg of the opposite side, since the combs of that leg scrape over the pollen-laden brush of the middle leg. This action may take place while the bee is on the wing or before it leaves the flower.

The middle legs place a relatively small amount of pollen directly upon the pollen masses in the corbiculæ. This is accomplished when the brushes of the middle legs are used to pat down the pollen masses and to render them more compact. (See fig. 6.) The legs are used for this purpose quite often during the process of loading the baskets, and a small amount of pollen is incidentally added to the masses when the brushes come into contact with them. A misinterpretation of this action has led some observers into the erroneous belief that all or nearly all of the corbicular pollen is scraped from the middle-leg brushes by the hairs which fringe the sides of the baskets. The middle legs do not scrape across the baskets, but merely pat downward upon the pollen which is there accumulating.

It is also possible that, in transferring pollen from the middle leg of one side to the planta of the opposite hind leg, the middle-leg brush may touch and rub over the pecten of the hind leg and thus directly place some of its pollen behind the pecten spines. Such a result is, however, very doubtful.

ACTION OF THE HIND LEGS.

The middle legs contribute the major portion of the pollen which reaches the hind legs, and all of it in cases where all of the pollen first reaches the bee in the region of the mouth. However, when much pollen falls upon the body of the bee the hind legs collect a little of it directly, for it falls upon their brushes and is collected upon them when these legs execute cleansing movements to remove it from the ventral surface and sides of the abdomen. All of the pollen which reaches the corbiculæ, with the exception of the small amount placed there by the middle legs when they pat down the pollen masses, passes first to the pollen combs of the plantæ.

When in the act of loading pollen from the plantar brushes to the corbiculæ the two hind legs hang beneath the abdomen with the tibio-femoral joints well drawn up toward the body. (See fig. 7.) The two plantæ lie close together with their inner surfaces nearly parallel to each other, but not quite, since they diverge slightly at their distal ends. The pollen combs of one leg are in contact with the pecten comb of the opposite leg. If pollen is to be transferred from the right planta to the left basket, the right planta is drawn upward in such a manner that the pollen combs of the right leg scrape over the pecten spines of the left. By this action some of the pollen is removed from the right plantar combs and is caught upon the outer surfaces of the pecten spines of the left leg.

This pollen now lies against the pecten and upon the flattened distal end of the left tibia. At this moment the planta of the left leg is flexed slightly, thus elevating the auricle and bringing the auricular surface into contact with the pollen which the pecten has just received. By this action the pollen is squeezed between the end of the tibia and the surface of the auricle and is forced upward against the distal end of the tibia and on outward into contact with the pollen mass accumulating in the corbicula. As this act, by which the left basket receives a small contribution of pollen, is being completed, the right leg is lowered and the pecten of this leg is brought into contact with the pollen combs of the left planta, over which they scrape as the left leg is raised, thus depositing pollen upon the lateral surfaces of the pecten spines of the right leg. (See fig. 7.)

Right and left baskets thus receive alternately successive contributions of pollen from the planta of the opposite leg. These loading movements are executed with great rapidity, the legs rising and falling with a pump-like motion. A very small amount of pollen is loaded at each stroke and many strokes are required to load the baskets completely.

If one attempts to obtain, from the literature of apiculture and zoology, a knowledge of the method by which the pollen baskets

FIG. 7.—A bee upon the wing, showing the manner in which the hind legs are held during the basket-loading process. Pollen is being scraped by the pecten spines of the right leg from the pollen combs of the left hind planta. (Original.)

themselves are loaded, he is immediately confused by the diversity of the accounts available. The average textbook of zoology follows closely Cheshire's (1886) description in which he says that "the legs are crossed, and the metatarsus naturally scrapes its comb face on the upper edge of the opposite tibia in the direction from the base of the combs toward their tips. These upper hairs * * * are nearly straight, and pass between the comb teeth. The pollen, as removed, is caught by the bent-over hairs, and secured. Each scrape adds to the mass, until the face of the joint is more than covered, and the hairs just embrace the pellet." Franz (1906) states that (translated) "the final loading of the baskets is accomplished by the crossing over of the hind-tarsal segments, which rub and press upon each other." Many other observers and textbook writers evidently believed that the hind legs were crossed in the loading process.

On the other hand, it is believed by some that the middle legs are directly instrumental in filling the baskets. This method is indicated in the following quotation from Fleischmann and Zander (1910) (translated):

> The second pair of legs transfer the pollen to the hind legs, where it is heaped up in the pollen masses. The tibia of each hind leg is depressed on its outer side, and upon the edges of this depression stand two rows of stiff hairs which are bent over the groove. The brushes of the middle pair of legs rub over these hairs, liberating the pollen, which drops into the baskets.

A suggestion of the true method is given by Hommell (1906), though his statements are somewhat indefinite. After describing the method by which pollen is collected, moistened, and passed to the middle legs he states that (translated) "the middle legs place their loads upon the pollen combs of the hind legs. There the sticky pollen is kneaded and is pushed across the pincher (*à traverse la pince*), is broken up into little masses and accumulates within the corbicula. In accomplishing this, the legs cross and it is the tarsus of the right leg which pushes the pollen across the pincher of the left, and reciprocally. The middle legs never function directly in loading the baskets, though from time to time their sensitive extremities touch the accumulated mass, for the sake of giving assurance of its position and size."

The recent valuable papers of Sladen (1911, 1912, *a*, *b*, *c*, *d*, and *e*), who was the first to present a true explanation of the function of the abdominal scent gland of the bee, give accounts of the process by which the pollen baskets are charged, which are in close accord with the writer's ideas on this subject. It is a pleasure to be able to confirm most of Sladen's observations and conclusions, and weight is added to the probable correctness of the two descriptions and interpretations of this process by the fact that the writer's studies and the conclusion based upon them were made prior to the appearance of Sladen's papers and quite independent of them. His description of the basket-loading process itself is so similar to the writer's own that a complete quotation from him is unnecessary. A few differences of opinion will, however, be noted while discussing some of the movements which the process involves. As will later be noted, our ideas regarding the question of pollen moistening, collecting, and transference are somewhat different.

ADDITIONAL DETAILS OF THE BASKET-LOADING PROCESS.

The point at which pollen enters the basket can best be determined by examining the corbiculæ of a bee shortly after it has reached a flower and before much pollen has been collected. Within each pollen basket of such a bee is found a small mass of pollen, which lies along the lower or distal margin of the basket. (See fig 8, *a*.) It is in this position because it has been scraped from the planta of the opposite leg by the pecten comb and has been pushed upward past the entrance of the basket by the continued addition of more from below, propelled by the successive strokes of the auricle. Closer

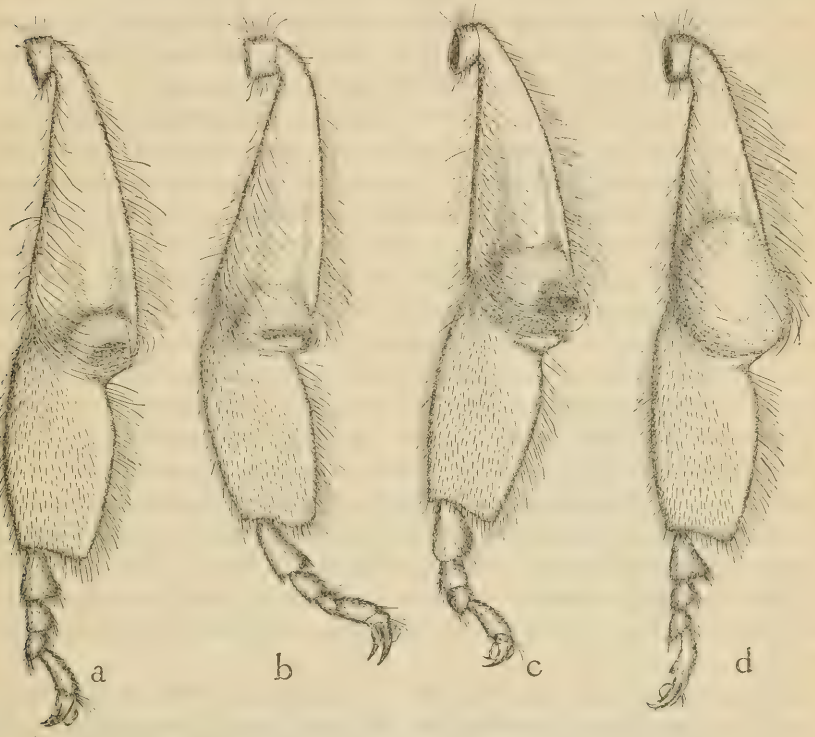

FIG. 8.—Camera drawings of the left hind legs of worker bees to show the manner in which pollen enters the basket. *a*, Shows a leg taken from a bee which is just beginning to collect. It had crawled over a few flowers and had flown in the air about five seconds at the time of capture. The pollen mass lies at the entrance of the basket, covering over the fine hairs which lie along this margin and the seven or eight short stiff spines which spring from the floor of the corbicula immediately above its lower edge. As yet the pollen has not come in contact with the one long hair which rises from the floor and arches over the entrance. The planta is extended, thus lowering the auricle; *b*, represents a slightly later stage, showing the increase of pollen. The planta is flexed, raising the auricle. The hairs which extend outward and upward from the lateral edge of the auricle press upon the lower and outer surface of the small pollen mass, retaining it and guiding it upward into the basket; *c*; *d*, represent slightly later stages in the successive processes by which additional pollen enters the basket. (Original.)

examination of the region between the pecten and the floor of the basket itself shows more pollen, which is on its way to join that already squeezed into the basket.

If the collecting bee is watched for a few moments the increase will readily be noted and the fact will be established that the accumulating mass is gradually working upward or proximally from the lower or distal edge of the corbicula and is slowly covering the floor of this receptacle. (See fig. 8, *b*, *c*, and *d*.) In many instances the successive contributions remain for a time fairly separate, the whole mass being marked by furrows transverse to the long axis of the tibia.

Sladen (1912, *b*) notes the interesting fact that in those rather exceptional cases when a bee gathers pollen from more than one species of flowers the resulting mass within the corbicula will show a stratification parallel to the distal end, a condition which could result only from the method of loading here indicated.

As the pollen within the basket increases in amount it bulges outward, and projects downward below the lower edge of the basket. It is held in position by the long hairs which fringe the lateral sides of the basket, and its shape is largely determined by the form of these hairs and the direction in which they extend. When the basket is fully loaded the mass of pollen extends laterally on both sides of the tibia, but projects much farther on the posterior side, for on this side the bounding row of hairs extends outward, while on the anterior edge the hairs are more curved, folding upward and over the basket. As the mass increases in thickness by additions from below it is held in position by these long hairs which edge the basket. They are pushed outward and many of them become partly embedded in the pollen as it is pushed up from below. When the pollen grains are small and the whole mass is well moistened the marks made by some of the hairs will be seen on the sides of the load. (See fig. 9, *a*.) These scratches are also transverse in direction and they show that the mass has been increased by additions of pollen pushed up from below.

Even a superficial examination of a heavily laden basket shows the fallacy of the supposition that the long lateral fringing hairs are used to comb out the pollen from the brushes of either the hind or middle legs by the crossing of these legs over the lateral edges of the baskets. They are far from sufficiently stiff to serve this purpose, and their position with relation to the completed load shows conclusively that they could not be used in the final stages of the loading process, for the pollen mass has completely covered many of them and its outer surface extends far beyond their ends. They serve merely to hold the pollen in place and to allow the load to project beyond the margins of the tibia.

The auricle plays a very essential part in the process of loading the basket. This structure comprises the whole of the flattened proximal surface of the planta, except the joint of articulation itself, and it extends outward in a posterior direction a little beyond the remaining plantar edge. The surface of the auricle is covered over with many blunt, short spines and its lateral margin is bounded by a row of short, rather pliable hairs, branched at their ends. When the planta is flexed the auricle is raised and its surface approaches the distal end of the tibia, its inner edge slipping up along the pecten spines and its outer hairy edge projecting into the opening which leads to the pollen basket. (See fig. 8, *b*.) With each upward stroke of the auricle small masses of pollen which have been scraped from the plantar combs by the pecten are caught and compressed between the spiny surface of the auricle and the surface of the tibia above it. The pressure thus exerted forces the pasty pollen outward and upward, since it can not escape past the base of the pecten, and directs it into the entrance to the corbicula. The outward and upward slant of the auricular surface and the projecting hairs with which the outer edge of the auricle is supplied also aid in directing the pollen toward the basket. Sladen (1911) states that in this movement the weak wing of the auricle is forced backward, and thus allows the escape of pollen toward the basket entrance, but this appears both doubtful and unnecessary, since the angle of inclination of the auricular surface gives the pollen a natural outlet in the proper direction.

If the corbicula already contains a considerable amount of pollen the contributions which are added to it at each stroke of the auricle come in contact with that already deposited and form a part of this mass, which increases in amount by continued additions from below. If, however, the corbicula is empty and the process of loading is just beginning, the first small bits of pollen which enter the basket must be retained upon the floor of the chamber until a sufficient amount has accumulated to allow the long overcurving hairs to offer it effective support. The sticky consistency of the pollen renders it likely to retain contact with the basket, and certain structures near the entrance give additional support. Several small sharp spines, seven or eight in number, spring from the floor of the basket immediately within the entrance, and the entire lower edge of the corbicula is fringed with very small hairs which are branched at their ends. (See fig. 3.) One large hair also springs from the floor of the basket, somewhat back from the entrance, which may aid in holding the pollen, but it can not function in this manner until a considerable amount has been collected.

As the pollen mass increases in size and hangs downward and backward over the pecten and auricle it shows upon its inner and lower surface a deep groove which runs outward from the entrance to the basket. (See fig. 9, *b*.) This groove results from the continued impact of the outer end of the auricle upon the pollen mass. At each upward stroke of the auricle its outer point comes in contact with the stored pollen as soon as the mass begins to bulge backward from the basket.

Although the process is a rather delicate one, it is entirely possible so to manipulate the hind legs of a recently killed bee that the corbiculæ of the two legs receive loads of pollen in a manner similar to that above described. To accomplish this successfully the operator must keep the combs of the plantæ well supplied with moistened pollen. If the foot of first one leg and then the other is grasped with forceps and so guided that the pollen combs of one leg rasp over the pecten spines of the other, the pollen from the combs will be transferred to the corbiculæ. To continue the loading process in a proper manner, it is also necessary to flex the planta of each leg just after the pollen combs of the opposite leg have deposited pollen behind the pecten. By this action the auricle is raised, compressing the pollen which the pecten has secured, and forcing some upward into the corbicula. Bees' legs which have been loaded in this artificial manner show pollen masses in their corbiculæ which are entirely similar in appearance to those formed by the labors of the living bee. Moreover, by the above method of manipulation the pollen appears first at the bottom of the basket, along its lower margin, gradually extends upward along the floor of the chamber, comes in contact with the overhanging hairs, and is shaped by them in a natural manner. All attempts to load the baskets by other movements, such as crossing the hind legs and scraping the plantar combs over the lateral edges of the baskets, give results which are entirely different from those achieved by the living bee.

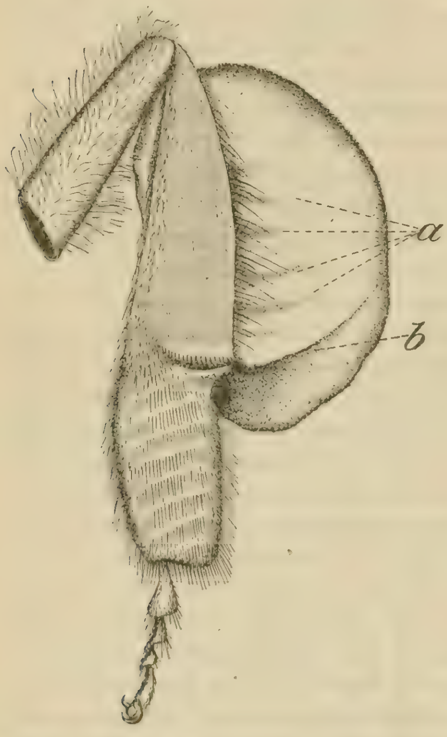

FIG. 9.—Inner surface of the right hind leg of a worker bee which bears a complete load of pollen. *a*, Scratches in the pollen mass caused by the pressure of the long projecting hairs of the basket upon the pollen mass as it has been pushed up from below; *b*, groove in the pollen mass made by the strokes of the auricle as the mass projects outward and backward from the basket. (Original.)

POLLEN MOISTENING.

Many descriptions have been written by others of the method by which pollen is gathered and moistened. Some of these are indefinite, some are incorrect, while others are, in part, at least, similar to my own interpretation of this process. A few citations will here be given:

> The bee first strokes the head and the proboscis with the brushes of the forelegs and moistens these brushes with a little honey from the proboscis, so that with later strokes all of the pollen from the head is collected upon these brushes. Then the middle-leg brushes remove this honey-moistened pollen from the forelegs and they also collect pollen from the breast and the sides of the thorax.—[Translation from Alefeld, 1861.]

In his account of the basket-loading process Alefeld assigns to the middle-leg brushes the function of assembling all of the pollen, even that from the plantar combs, and of placing it on the corbiculæ, this latter act being accomplished by combing over the hairy edge of each basket with the middle-leg brush of the same side.

> It appears probable that the bee removes the pollen from the head, breast, and abdomen by means of the hairy brushes which are located upon the medial sides of the tarsal segments of all of the legs, being most pronounced upon the hind legs. The pollen is thus brought together and is carried forward to the mouth, where it is moistened with saliva and a little honey.—[Translation from Franz, 1906.]

Franz then says that this moistened pollen is passed backward and loaded.

> Since the pollen of many plants is sticky and moist it adheres to the surface of the basket. Dry pollen is moistened by saliva, so that it also sticks.—[Translation from Fleischmann and Zander, 1910.]

> Pollen is taken from flowers principally by means of the tongue, but at times, also, by the mandibles, by the forelegs, and middle legs. The brushes of the hind legs also load themselves, collecting from the hairs of the body. The pollen dust thus gathered is always transmitted to the mouth, where it is mixed with saliva.—[Translation from Hommell, 1906.]

Sladen considers the question of how pollen is moistened by the honey bee, humblebee (bumblebee), and some other bees, but does not appear to reach definite conclusions. In one of his papers (1912, *c*) he states that the pollen of some plants may be found in the mouth cavity and in the region of the mouth, but he reaches the conclusion that this pollen is comparatively "dry," using the word in a "relative sense." He asserts that "nowhere but on the corbicula and hind metatarsal brushes did I find the sticky pollen, except sometimes on the tips of the long, branched hairs on the back (upper) edges of the tibiæ and femora of the middle legs, and then only in heavily laden bees, where it is reasonable to suppose it had collected accidentally as the result of contact with the hind metatarsal brushes."

These and other considerations lead Sladen to think that, in the case of the bumblebee at least, the pollen "may be moistened on the hind metatarsus with the tongue." He states that the tongue of the bumblebee is of sufficient length to reach the hind metatarsus (planta) and that it might rub over the brushes of the metatarsi or be caught between them when they are approximated and thus moisten the two brushes simultaneously. However, he has never seen the tongue of the collecting honey bee brought near to the hind legs, and it appears probable to him that it can not easily reach them. "Possibly the middle or front legs are used as agents for conveying the honey" (in the case of the honey bee). "In the humblebee the tongue is longer, and it could more easily moisten the hind legs in the way suggested."

In an earlier paper Sladen (1912, *a*) gives the following as his opinion of the "way in which pollen dust is moistened with nectar," although he states that this is one of the points "which still remains obscure":

> The only satisfactory manner in which, it seems to me, this can be done is for the tongue to lick the tarsi or metatarsi of the forelegs, which are covered with stiff bristles, well suited for holding the nectar, the nectar being then transferred to the metatarsal brushes on the middle legs, and from these, again, to the metatarsal brushes on the hind legs. The latter being thus rendered sticky, the pollen dust would cling to them. The different pairs of legs were certainly brought together occasionally, but not after every scrape of the hind metatarsi, and their movements were so quick that it was impossible to see what was done. Still, several pollen-collecting bees that I killed had the tarsi and metatarsi of the forelegs and the metatarsal brushes of the middle and hind legs moistened with nectar, and I think it probable that the moistening process, as outlined, is performed, as a rule, during the flight from flower to flower.

Sladen (1912, *c*) also considers the possibility that the fluid which moistens the pollen might be secreted through the comb at the end of the tibia, through the tibio-tarsal joint, or from the surface of the auricle, but finds no evidence of glandular openings in these regions. A suggestion of a similar nature, apparently unknown to Sladen, was made by Wolff (1873), who describes "sweat-glands" which, he claims, are located within the hind tibia and the planta, and which pour a secretion upon the surface of the corbicula and upon the upper end of the planta through many minute openings located at the bases of hairs, particularly those which arise from the lateral margins of the corbicula. Wolff is convinced that the fluid thus secreted is the essential cohesive material by which the grains of pollen are bound together to form the solid mass which fills each fully loaded basket. He noticed that the mouthparts are used to collect pollen, and that some of it is moistened with "honey" or "nectar," but he does not consider that the fluid thus supplied is sufficient to explain adequately the facility with which the collecting bee brings together the scattered grains of pollen and packs them away securely in the baskets. Wolff's description of the basket-loading process itself is strikingly similar to that advocated later by Cheshire.

The writer is not prepared to deny the possibility that the surface of the chitin of the hind legs of worker bees may be moistened by the secretion of glands which lie beneath it, but he is convinced that any fluid thus secreted bears little or no relation to the cohesion of the pollen grains within the baskets. Sections and dissected preparations of the hind legs of worker bees show certain large cells which lie within the cavity of the leg and which may function as secreting gland cells; but similar structures occur in even greater numbers within the hind legs of the drone and they are found within the hind legs of the queen.

As has been noted, the extreme moisture of the plantar combs and of the tibio-tarsal articulation of the hind leg is readily understood when one recalls the manner in which moist pollen is compressed between the auricle and the tibial surface above it.

From the account already given it is evident that, in the opinion of the writer, the mouth is the source from which the pollen-moistening fluid is obtained. It is extremely difficult to determine with absolute accuracy the essential steps involved in the process of adding moisture to the pollen. In an endeavor to solve this problem the observer must of necessity consider a number of factors, among which may be noted (1) the location upon the body of the collecting bee of "moist" and of comparatively "dry" pollen, (2) the movements concerned in the pollen-gathering and pollen-transferring processes, (3) the relative moisture of those parts which handle pollen, (4) the chemical differences between the natural pollen of the flower and that of the corbiculæ and of the cells of the hive, and (5) the observer must endeavor to distinguish between essential phenomena and those which are merely incidental or accidental.

In the first place it should be noted that the relative dampness of pollen within the corbiculæ depends very largely upon the character of the flower from which the pollen grains are gathered. When little pollen is obtained it is much more thoroughly moistened, and this is particularly true in cases when the pollen is all, or nearly all, collected in the region of the mouth, the forelegs, and head. When a bee takes pollen from white or sweet clover practically all of it first touches the bee in these regions. It immediately becomes moist, and in this condition is passed backward until it rests within the baskets. There is here no question of "dry" and "wet" pollen, or of collecting movements to secure dry pollen from other regions of the body, or of the ultimate method by which such free, dry pollen becomes moist.

The sticky fluid which causes pollen grains to cohere is found upon all of the legs, in the region of their brushes, although the pollen combs and auricles of the hind legs are likely to show it in greatest abundance, since nearly all of the pollen within each basket has passed over the auricle, has been pressed upward and squeezed between the auricle and the end of the tibia and the pollen mass above, and by this compression has lost some of its fluid, which runs down over the auricle and onto the combs of the planta. It is not necessary to invoke any special method by which these areas receive their moisture. The compressing action of the auricle squeezing heavily moistened pollen upward into the basket is entirely sufficient to account for the abundance of sticky fluid found in the neighborhood of each hind tibio-tarsal joint. As has been noted, the brushes of the forelegs acquire moisture directly by stroking over the proboscis and by handling extremely moist pollen taken from the mouthparts. The middle-leg brushes become moist by contact with the foreleg and hind-leg brushes, probably also by touching the mouthparts themselves, and by passing moist pollen backward. The hairy surface of the breast is moistened by contact with the fore and mid leg brushes and with the moist pollen which they bear.

The problem of the method of pollen moistening is somewhat more complicated in the case of flowers which furnish an excessive supply. Under such conditions the entire ventral surface of the collecting bee becomes liberally sprinkled with pollen grains which either will be removed and dropped or will be combed from the bristles and branching hairs, kneaded into masses, transferred, and loaded. The question naturally arises whether the movements here are the same as when the plant yields but a small amount of pollen which is collected by the mouthparts and anterior legs. In the opinion of the writer they are essentially the same, except for the addition of cleansing movements, executed chiefly by the middle and hind legs for the collection of pollen which has fallen upon the thorax, upon the abdomen, and upon the legs themselves. Indeed it is questionable as to just how much of this plentiful supply of free pollen is really used in forming the corbicular masses. Without doubt much of it falls from the bee and is lost, and in cases where it is extremely abundant and the grains are very small in size an appreciable amount still remains entangled among the body-hairs when the bee returns to the hive. Yet it is also evident that some of the dry pollen is mingled with the moistened material which the mouthparts and forelegs acquire and together with this is transferred to the baskets.

In all cases the pollen-gathering process starts with moist pollen from the mouth region. This pollen is passed backward, and in its passage it imparts additional moisture to those body regions which it touches, the brushes of the fore and middle legs, the plantæ of the hind legs, and the hairs of the breast which are scraped over by the fore and middle leg brushes. This moist pollen, in its passage backward, may also pick up and add to itself grains of dry pollen with which it accidentally comes in contact. Some of the free, dry pollen which falls upon the moist brushes or upon the wet hairs of the thorax is also dampened. Some of the dry pollen which is cleaned from the body by the action of all of the legs meets with the wet brushes or with the little masses of wet pollen and itself becomes wet by contact. Pollen grains which reach the corbiculæ either dry or but slightly moistened are soon rendered moist by contact with those already deposited. Little pollen gets by the sticky surfaces of the combs of the plantæ or past the auricles without becoming thoroughly moist.

Sladen (1912, *c*) very aptly compares the mixture of dry pollen with wet to the kneading of wet dough with dry flour and suggests that the addition of dry pollen may be of considerable advantage, since otherwise the brushes, particularly those of the hind legs, would become sticky, "just as the board and rolling pin get sticky in working up a ball of dough if one does not add flour." The addition of a considerable amount of dry pollen gives exactly this result, for the corbiculæ then rapidly become loaded with pollen mixed with a minimum supply of moisture and the brushes remain much dryer than would otherwise be the case. However, if too much dry pollen is added the resulting loads which the bees carry back to the hives are likely to be irregular, for the projecting edges of the masses may crumble through lack of a sufficient amount of the cohesive material by which the grains are bound together.

On the other hand, it does not appear at all necessary to mix much dry pollen with the wet, nor do the brushes become sufficiently "sticky" from the presence of an abundance of the moistening fluid to endanger their normal functional activity. I have observed bees bringing in pollen masses which were fairly liquid with moisture, and the pollen combs also were covered with fluid, yet the baskets were fully and symmetrically loaded.

Sladen's different interpretations of the pollen-moistening process are rather confusing, and it is difficult to distinguish between what he states as observed facts and what he puts forward as likely hypotheses. He agrees with me in his observation that all of the legs become moist in the region of their brushes and also in his supposition that this moisture is transferred to them from the mouth. In this moistening process my observations show that the fluid concerned is passed backward by the contact of the middle-leg brushes with the wet foreleg brushes and that the middle-leg brushes in turn convey moisture to the plantæ as they rub upon them. I am also convinced that the wet pollen grains furnish additional moisture to the brushes as they pass backward, and this is particularly true in the case of the extremely moist surfaces of the auricles and the pollen combs of the planta, since here moisture is pressed from the pollen upon these areas. The pollen upon the fore and middle leg brushes is not always "dry" even in "a relative sense."

In describing pollen manipulation several writers state that dry pollen is picked up by the brushes of the legs and is carried forward to the mouth, there moistened (according to some, masticated), and is then carried backward by the middle legs for loading. Obviously such accounts do not apply to cases in which all of the pollen is collected by mouthparts and forelegs. Do they apply in cases where much pollen falls on the body and limbs? Without doubt a certain amount of this free pollen is brought forward when the middle legs, bearing some of it, sweep forward and downward over the forelegs, mouthparts, and breast. However, it does not appear to the writer that this dry pollen is carried to the mouth for the specific purpose of moistening it, or that it is essential to its moistening that it be brought in contact with the mouth. Some of it touches the moist hairs on the forelegs and breast and is moistened by contact. All that remains on the brushes of the middle legs secures moisture from these brushes or from wet pollen which the brushes collect from the mouthparts or forelegs. The supposed necessity of carrying forward pollen to the mouth for moistening is a delusion. Some is accidentally brought forward and into contact with the mouth and gets wet, but the process is not essential.

If the pollen which bees transport to their hives has been moistened with some fluid substance which causes the grains to cohere, this addition should be indicated by differences in the results of an analysis of pollen from a plant as compared with that found in the corbiculæ of a bee which has been working on this plant. For the sake of determining this difference and in an endeavor to ascertain, if possible, the approximate nature of the added fluid, analyses were made of three kinds of pollen, as follows: (1) Pollen collected by hand from the corn plant itself; (2) pollen taken from the corbiculæ of bees which had secured their supply from corn; (3) pollen stored in the cells of the hive. In the first two cases pollen from the same species of plant (corn) was used. The material from the cells of the hive was composed largely of corn pollen, but contained an admixture of some other pollens.

The writer is indebted to Dr. P. B. Dunbar, of the Bureau of Chemistry, for the following analyses:

	Pollen direct from corn.	Corn pollen from corbicula.	Stored pollen from hive.
Total solids	53.47	66.94	79.66
Moisture	46.53	33.06	20.34
Reducing sugar before inversion	2.87	11.07	17.90
Sucrose	2.77	3.06	2.25
Total reducing sugar after inversion	5.79	14.29	20.27
Dry basis:			
Reducing sugar	5.37	16.54	22.47
Sucrose	5.18	4.57	2.82
	10.55	21.11	....

These analyses show conclusively that a very large amount of sugar has been added to the pollen by the time it reaches the corbiculæ. Calculated on a dry basis just about twice as much sugar is present in the basket pollen as in that from the corn plant. Not only is this so, but the additional fact is disclosed that over three times as much reducing sugar is present in the corbicular pollen as sucrose. This latter result indicates that honey (largely a reducing sugar) rather than nectar (containing more sucrose) is the chief sugar ingredient of the corbicular pollen. The additional amount of sugar (here again a reducing sugar) in the stored pollen of the hive is what might be expected, since it is supposed that the workers add honey and possibly other ingredients to the pollen within the storage cells.

The total solid percentages, corn 53.47, corbicula 66.94, stored pollen 79.66, also show that the fluid substance which is added is one highly charged with solids, a condition which honey amply fulfills.

In the descriptions which have been cited of the pollen-gathering process in which the mouth is supposed to supply the requisite fluid three substances are mentioned: Nectar, honey, and saliva. The analyses herein given indicate that reducing sugar is mingled with the pollen, and in the case of corn it is indicated that honey is used in greater abundance. Without doubt a certain amount of saliva also finds its way to the pollen, but the proportion of this substance has not been determined. This salivary fluid may have adhesive qualities, but this is scarcely necessary, since honey alone is amply sufficient for this purpose.

It appears probable that the fluid which a bee adds to the pollen which it is collecting varies somewhat in amount, since the pollen of different plants differs considerably in moisture content and that of the same plant will differ in this respect at different times. Pollen collected in the early morning before the dew has left the plant is much more moist than that found upon the same plant later in the day, and the grains, if taken when moist, have a natural tendency to become aggregated and form small masses. Moreover, this may explain the fact that bees make their pollen-collecting trips during the morning hours, rather than in the afternoon, although some may be seen upon the flowers throughout the whole day.

STORING POLLEN IN THE HIVE.

When the bee has fully loaded its baskets and before it returns to the hive it often spends a little time upon the plant from which it has been collecting, occupied with the task of cleaning scattered grains of pollen from its body and of patting down securely the loads which it has obtained. Upon its return to the hive it hurries within and seeks for a suitable place in which to deposit the pollen. Some returning bees walk leisurely over the combs and loiter among their sister workers, while others appear to be greatly agitated, shaking their bodies and moving their wings as though highly excited. Many pollen-bearing bees appear eager to receive food upon their return to the hive, and they will solicit it from other workers or take it from the honey-storage cells. The workers of the hive at times take a little of the fresh pollen from the baskets of the laden bee, nibbling it off with their mandibles or rasping off grains with their tongues.

If the combs of a colony are examined, stored pollen will be found in various parts of the hive. In the brood frames the greatest amount is located above and at the sides of the brood and between this and the stored honey. Cells scattered through the brood from which young bees have lately emerged may also contain pollen. In the outer frames of the hive, where brood is less likely to be found, nearly all of the cells may be packed with pollen, or honey-storage cells may be found interspersed with those filled with pollen. As a rule pollen is not stored in drone comb, although this occasionally happens.

As the pollen-bearing bee crawls over the combs it appears to be searching for a suitable cell in which to leave its load. It sticks the head into cell after cell until finally one is located which meets its requirements, although it is an open question as to why any one of a group should be chosen rather than another. This selected cell may already contain some pollen or it may be empty. If partly filled, the pollen which it contains is likely to be from the same species of plant as that which the bee carries, although different kinds of pollen are often stored in the same cell.

In preparation for the act of unloading the bee grasps one edge of the cell with its forelegs and arches its abdomen so that the posterior end of the abdomen rests upon the opposite side of the cell. The body is thus held firmly and is braced by these two supports with the head and anterior thoracic region projecting over one of the neighboring cells. The hind legs are thrust down into the cell and hang freely within it, the pollen masses being held on a level with the outer edge of the cell, or slightly above it. The middle leg of each side is raised and its planta is brought into contact with the upper (proximal) end of the tibia of the same side and with the pollen mass. The middle leg now presses downward upon the pollen mass, working in between it and the corbicular surface, so that the mass is shoved outward and downward and falls into the cell. As the pollen masses drop, the middle legs are raised and their claws find support upon the edge of the cell. The hind legs now execute cleansing movements to remove small bits of pollen which still cling to the corbicular surfaces and hairs. After this is accomplished the bee usually leaves the cell without paying further attention to the two pellets of pollen although some collecting bees will stick the head into the cell, possibly to assure themselves that the pollen is properly deposited. It has been stated by some (Cheshire, for example) that the spur upon the middle leg is used to help pry the pollen mass from the corbicula. This structure is in close proximity with the mass while the middle leg is pushing downward upon it, but its small size renders difficult an exact estimate of its value in this connection. It is certainly true that the entire planta of the middle leg is thrust beneath the upper end of the pollen mass, but the spur may be used as an entering wedge.

Pollen masses which have been dropped by the collecting bee may remain for some time within the cell without further treatment, but usually another worker attends to the packing of the pollen shortly after it has been deposited. To accomplish this the worker enters the cell head first, seizes the pollen pellets with its mandibles, breaks them up somewhat or flattens them out, probably mingles additional fluid with the pollen, and tamps down the mass securely in the bottom of the cell. As is shown by the analyses of corbicular pollen and of stored pollen, certain substances are added to the pollen after the collecting bee leaves it in the cell. Sugar is certainly added, and it is generally supposed that secretions from some of the salivary glands are mixed with the pollen after deposition. It appears probable that the stored pollen or "beebread" is changed somewhat in chemical composition through the action of the fluids which have been added to it, either during the process of collection, at the time of packing, or later.

SUMMARY.

Pollen may be collected by the worker bee upon its mouthparts, upon the brushes of its legs, and upon the hairy surface of its body. When the bee collects from small flowers, or when the supply is not abundant, the mouthparts are chiefly instrumental in obtaining the pollen.

The specialized leg brushes of the worker are used to assemble the pollen, collecting it from the body parts to which it first adheres and transporting it to the pollen baskets or corbiculæ of the hind legs. In this manipulation the forelegs gather pollen from the mouthparts and head; the middle legs, from the forelegs and from the thorax; the hind legs, from the middle legs and from the abdomen.

The pollen baskets are not loaded by the crossing over of one hind leg upon the other or to any great extent by the crossing of the middle legs over the corbiculæ. The middle legs deposit their loads upon the pollen combs of the hind plantæ, and the plantæ, in turn, transfer the pollen of one leg to the pecten comb of the other, the pecten of one leg scraping downward over the pollen comb of the opposite leg. (See fig. 7.) A little pollen is loaded directly from the middle legs into the baskets when these legs are used to pat down the pollen masses. (See fig. 6.)

Aside from the foregoing exception, all of the pollen which reaches the baskets enters them from below, since it is first secured by the pecten combs, and is then pushed upward by the impact of the rising auricles, which squeeze it against the distal ends of the tibiæ and force it on into the baskets to meet that which has gone before.

The long hairs which form the lateral boundaries of the baskets are not used to comb out pollen from the brushes of any of the legs. They serve to retain the accumulating masses within the baskets and to support the weight of the pollen, as it projects far beyond the surfaces of the tibiæ.

Pollen grains are moistened and rendered cohesive by the addition to them of fluid substances which come from the mouth. Analyses show that honey forms a large part of this moistening fluid, although nectar and secretions from the salivary glands are probably present also.

In the process of pollen manipulation this fluid substance becomes well distributed over the brushes of all of the legs. The forelegs acquire moisture by brushing over the mouthparts, and they transfer this to the hairs of the breast and to the middle-leg brushes when they come in contact with them. The middle-leg brushes transmit their moisture to the pollen combs of the hind legs when they rub upon them. All of these brushes also transport wet pollen which has come from the mouthparts and thereby acquire additional moisture. The auricles and the plantæ of the hind legs become particularly wet from this source, since fluid is squeezed from the wet pollen when it is compressed between the auricles and the distal ends of the tibiæ. Dry pollen which falls upon the body hairs becomes moist when brought into contact with the wet brushes or with wet pollen.

During the process of manipulation pollen passes backward from its point of contact with the bee toward its resting place within the baskets.

Pollen which the collecting bee carries to the hive is deposited by this bee within one of the cells of the comb. As a rule, this pollen is securely packed in the cell by some other worker, which flattens out the rounded masses and adds more fluid to them.

BIBLIOGRAPHY.

ALEFELD, Dr.—Vol. 5, Nos. 15 and 16, Eichstädt Bienen Zeitung. Summarized in "Die Bienenzeitung in neuer, geschichteter und systematische geordneter Ausgabe." Herausgegeben vom Schmid und Kleine: Erste Band, Theoretischer Theile. 1861.

CASTEEL, D. B., 1912.—The manipulation of the wax scales of the honey bee, Circular 161, Bureau of Entomology, U. S. Dept. Agriculture, pp. 15.

CHESHIRE, F. R., 1886.—Bees and bee-keeping; scientific and practical. Vol. I, scientific; II, practical. London.

FLEISCHMANN und ZANDER, 1910.—Beiträge zur Naturgeschichte der Honigbiene.

FRANZ, A., 1906.—In "Unsere Bienen," herausgegeben von Ludwig, A., Berlin. pp. [viii]+831.

HOMMELL, R., 1906.—Apiculture, Encyclopédie Agricola, Paris.

PHILLIPS, E. F., 1905.—Structure and development of the compound eye of the bee. Proc. Acad. Nat. Sci. Philadelphia, vol. 57, pp. 123–157.

SLADEN, F. W. L., 1911.—How pollen is collected by the social bees, and the part played in the process by the auricle. British Bee Journal, vol. 39, pp. 491–493, Dec. 14.

SLADEN, F. W. L., 1912.—(*a*) How pollen is collected by the honey bee. Nature, vol. 88, pp. 586, 587, Feb. 29.

1912.—(*b*) Further notes on how the corbicula is loaded with pollen. British Bee Journal, vol. 40, pp. 144, 145, Apr. 11.

1912.—(*c*) Pollen collecting. British Bee Journal, vol. 40, pp. 164–166, Apr. 25.

1912.—(*d*) How propolis is collected. Some further notes on pollen-collecting. Gleanings in Bee Culture, vol. 40, pp. 335, 336, June 1.

1912.—(*e*) Hind legs of the worker honey bee. Canadian Bee Journal, vol. 20, p. 203. July.

WOLFF, O. J. B., 1873.—Das Pollen-Einsammeln der Biene. Eichstädt Bienen-Zeitung. 29 Jahrg. Nrs. 22 u. 23, pp. 258–270.

INDEX.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 122.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE ARGENTINE ANT.

BY

WILMON NEWELL, M. S.,

AND

T. C. BARBER, B. S. A.

ISSUED JUNE 26, 1913.

WASHINGTON:
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1913.

ARGENTINE ANTS UPON A TEA TABLE. (ORIGINAL.)

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J. L. Webb, *engaged in rice insect investigations.*

R. A. Cooley, D. L. Van Dine, A. F. Conradi, C. C. Krumbhaar, *collaborators.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., January 2, 1913.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 122, of the Bureau of Entomology, a manuscript entitled "The Argentine Ant," by Mr. Wilmon Newell, formerly a collaborator, and Mr. T. C. Barber, formerly an agent of this bureau.

The Argentine ant is an imported pest of great importance. It is unique among injurious insects of this country in the diversity of the damage that it causes. It is not only a household pest of the first rank, but it affects materially the interests of sugar planters, orange growers, and others. The territory infested by this ant is being rapidly extended. For all of these reasons it is important that there be placed on record a full account of the studies that have been conducted regarding it.

The work upon which this manuscript is based was begun by Mr. Newell as secretary of the Louisiana State Crop Pest Commission. Later Mr. Newell continued the work as a collaborator in this bureau, and Mr. Barber, an agent of the bureau, but working under Mr. Newell's direction, added to the results obtained.

Respectfully,

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

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE ARGENTINE ANT.

INTRODUCTION.

The Argentine ant (*Iridomyrmex humilis* Mayr), which is made the subject of the present paper, is the first among the Formicidæ to attain the front rank among injurious insects in the United States. In its field the Argentine ant is not excelled in destructiveness by even the gipsy moth, the boll weevil, or the San Jose scale. Though this ant is limited as yet to comparatively small areas, the observations and experience of the authors fully convince them that future years will see this insect steadily invading new territory and forcing its depredations upon the inhabitants of all southern California and most of the Gulf States.

The present paper aims to present, in as concise a manner as possible, the principal results of five years of almost constant observation and experiment by the senior author at Baton Rouge, La., and in the orange-growing section of the same State, together with observations made by the junior author at New Orleans in connection with his investigations of sugar-cane insects.

The junior author has prepared in their entirety the portions dealing with the "Area of ultimate infestation," and the "Relation of the ant to Coccidæ and Aphididæ," and to him is also to be credited the important discovery that mating of the queens may occur within the formicary or nest of the colony. The remainder of the paper, except where otherwise noted, is compiled from the notes and records of the senior author.

In the tedious work which accompanied the determination of the ant's life history, from 1907 to 1910, much assistance was rendered by the young men associated with the senior author in the work of the Louisiana State Crop Pest Commission, particularly Messrs. Harper Dean, A. H. Rosenfeld, G. A. Runner, M. S. Dougherty, G. D. Smith, and R. C. Treherne.

The writers are under obligations to Dr. W. M. Wheeler, of the Bussey Institution, Harvard University, for permission to use his redescription of *Iridomyrmex humilis* and for his kindness in reviewing the paragraphs upon "Systematic position" and "Resemblance to other ants."

Our thanks are also due to Messrs. R. S. Moore and John Meyer, extensive orange growers of Louisiana, for their liberal cooperation

and assistance in experiments carried out in the infested orange districts.

GENERAL CONSIDERATIONS.

Twenty years ago the Argentine ant was first noticed in New Orleans, La., by Mr. Edward Foster, reference to whose interesting account of the "Introduction of *Iridomyrmex humilis* Mayr into New Orleans" will be found on a subsequent page. The species had doubtless been introduced years before that time, but was gathering strength and establishing itself for a considerable period before its numbers became sufficient to attract attention. Mr. Foster mentions it as occurring in 1891 in "fair numbers." Since then it has increased from a few scattered and apparently insignificant specimens to armies and hordes numbering myriads of individuals. It has spread from a few blocks on the water front of the Mississippi River over practically the entire city, and has sent out vast numbers of colonists for hundreds of miles along the railways and waterways radiating from New Orleans. These pioneers have succeeded in founding scores of communities of more or less importance in the smaller cities and towns. Each of these communities is in turn furnishing its quota of migrants, and these are extending the affected territory in all directions from the original source of infestation. Thus, instead of the dispersion being from one source only, it is now taking place from hundreds of different points. From an unknown and little noticed insect this ant has developed into one of the foremost household pests in the world, and its ravages affect, directly or indirectly, the majority of the crops grown in the South. Former indifference to its movements has given way to concern at its approach, which, in the orange belt at least, means heavy depreciation in the value of property.

Continuous study for several years has served to enlighten us on most of the salient features in the life history and economy of the species. A considerable number of poisons and repellents have been tested and have given good results. Methods of isolating, ditching, and winter-trapping have been devised, and have proved their practical value in large experiments under field conditions.

Just how much territory this ant will ultimately infest we can not foretell with accuracy from the data at present available. It is quite safe, however, to venture the opinion that the species will eventually spread over a considerable portion of the Southern States—certainly over all of the orange and sugar-cane belts, and perhaps over all of the cotton belt. In California it is likely to cover the territory corresponding in temperature to the belts mentioned for the South, which will include the belts occupied by oranges and other tender fruits.

HISTORY AND DISTRIBUTION.

As stated on another page, this species was first described by Dr. Gustav Mayr from specimens collected near Buenos Aires, in Argentina. It is also included in the list of Argentine ants by Dr. Carlos Berg.[1] Its occurrence in the Argentine Republic is therefore unquestioned, and that Argentina is its native home is also borne out by the fact that it does not appear to be generally a pest of importance in that country. Dr. F. Lahille, of the Argentine department of agriculture, in a letter to the senior author, states that it "is uncommon in Buenos Aires and in Argentina generally, where it does not cause annoyance or trouble of value." Mr. Arthur H. Rosenfeld, formerly associated with the writers in entomological work in Louisiana and now located at Tucuman, Argentina, writes that he has been unable to find the species there. Rev. E. Wasmann, S. J., states that this ant "is a native of Brazil and Argentina," and Rev. Albert Biever, S. J., of Loyola College, New Orleans, whose careful studies of this species are mentioned on other pages, has corresponded with various priests in Brazil and Argentina, with the result that he finds that this species is a serious pest in parts of Brazil and evidently in Argentina also. For example, in a letter to Father Biever, Rev. J. Ferol, S. J., of the Colegio del Salvador, Buenos Aires, writes:

The ants (*Iridomyrmex humilis*) of which your reverence makes mention are of no utility whatsoever, but on the contrary are voracious and destructive. Of means employed to destroy them the most effective, according to information given me, is the use of an instrument and ingredient of which inclosed herein I send a prospectus and instructions concerning its use and functions.

Forel[2] mentions its occurrence in collections from the States of São Paulo and Rio Grande do Sul, in Brazil. Wheeler[3] also mentions its occurrence in that country. Dr. Lahille also states that the Argentine ant occurs in Uruguay and is "especially common in Mercedes and Montevideo," cities not far removed from Buenos Aires.

According to Stoll[4] and Wheeler[5] the Argentine ant, after its accidental introduction into the island of Madeira, entirely exterminated another ant, *Pheidole megacephala* Fab., which was itself an introduced species that had exterminated the native ants before it.

In 1907 M. N. Martins[6] recorded the occurrence of this ant in Lisbon and Oporto, Portugal, and gave a vivid account of its ravages in those cities and their environs.

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[1] Enumeración sistematica y sinonémica de los Formicidos Argentinos, Chilenos y Uruguayos. 1890.

[2] Ameisen aus São Paulo (Brasilien), Paraguay, etc. Verhandlungen der k. k. zool.-bot. Ges. in Wien, 1908.

[3] Entomological News, January, 1906, p. 24.

[4] Zur Kenntnis der geographischen Verbreitung der Ameisen, Mitth. Schweiz. Ent. Ges., vol. 10, pp. 120–126, 1898.

[5] Ants: Their structure, development, and behavior, p. 154, 1910.

[6] Une fourmi terrible envahissant l'Europe (*Iridomyrmex humilis* Mayr). Broteria Revista de Sciencias Naturaes, vol. 6, pt. 1, pp. 101–102, 1907.

In 1908 Prof. C. P. Lounsbury recognized this ant in Cape Town, South Africa, where it had already become a household nuisance and had displayed its usual rôle of attending mealy-bugs and other insects. The general belief in Cape Town, according to Prof. Lounsbury, was that the pest had been introduced through the medium of forage, large quantities of which were imported from Argentina during the Boer War (1900–1902) and stored in Cape Town.

In July, 1910, the late Edwyn C. Reed, of Concepcion, Chile, in a letter to the senior author, reported the occurrence of the species in that country in large numbers.

In 1908 ants collected by Mr. J. Chester Bradley, of the University of California, were identified as *I. humilis* by Dr. W. M. Wheeler. Immediately following this discovery Prof. C. W. Woodworth, of the California Agricultural Experiment Station, visited the authors' laboratory at Baton Rouge, La., for the purpose of becoming familiar with the methods used in studying the insect and with the information which had been gathered concerning it up to that time. On his return to California he published a brief circular [1] concerning its occurrence in that State.

From the foregoing it is readily seen that during the past few years this ant has thoroughly established itself, as a nuisance of the first order, on four continents, and, owing to the readiness with which it is disseminated through the ordinary channels of commerce, there seems little reason for supposing that it will not eventually invade all of the semitropical countries of the globe.

INTRODUCTION INTO LOUISIANA.

As with most imported species, the original time and place at which a foothold was obtained by the Argentine ant in Louisiana must be largely conjectural. However, we are able to conjecture with rather strong circumstantial evidence to guide us. Not only does the testimony of inhabitants indicate New Orleans to be the original starting point of this species in the South, but its enormous numbers and the extent to which it has exterminated other species of Formicidæ confirm the opinion that it has been in New Orleans longer than elsewhere.

Mr. Edward Foster,[2] of the editorial staff of the New Orleans Daily Picayune, has given us the earliest record of its occurrence in New Orleans. He noted it in 1891 in St. Charles Avenue, 9 squares from the river and 12 from Canal Street. It was then

[1] The Argentine ant in California. Cal. Agr. Exp. Sta., Cir. 38, August, 1908.

[2] The introduction of *Iridomyrmex humilis* into New Orleans. Journ. Econ. Ent., vol. 1, No. 5. pp. 289–293, October, 1908.

present in "fair numbers." At that date it was very scarce in Audubon Park and below Canal Street, but was present in considerable numbers between Magazine Street and the river.

"Five or six years later" he found it in St. Peters Avenue, near St. Charles, but it was not abundant. This is about 40 squares north and west from the point on St. Charles Avenue first referred to by Mr. Foster.

In a personal letter to the senior author, Mr Foster writes as follows:

I have known the species since 1891. At that time it was a rarity in Audubon Park, but was very common in the section immediately above Canal Street. Below Canal Street it was not at all plentiful. The boundary of the nuisance then was virtually from Magazine Street to the river. The coffee ships from Brazil, I understand, have always landed about where the wharves are now situated (on the river front, adjoining the area above mentioned), but from what we know of the spread of insect nuisances the first batch of immigrants must have come in years before I came across their descendants.

Mr. E. S. G. Titus,[1] quoting Mr. E. Baker, former superintendent of Audubon Park, states that in 1896 "they extended over but a small area, reaching approximately from Southport docks to Carrollton Avenue and from the river bank to Poplar Street," and that "in 1899 they were first noticed in Audubon Park." This area, from Southport to Carrollton Avenue, is located about 5 or 6 miles northwest of the area between Magazine Street and the river, noted by Foster to be well infested as early as 1891. Mr. Baker, therefore, had not been familiar with the original area of heavy infestation, but merely noted the species after it had invaded the part of the town where he resided. Mr. Titus's information that the species was first noted in Audubon Park in 1899 was of course secured from citizens, who failed to note the ant until it had reached prodigious numbers in the same place that Foster had found it a "rarity" in 1891. The dissemination to Audubon Park was undoubtedly from the heavily infested area between Magazine Street and the wharves already referred to.

The distribution of the species in 1904, as given by Mr. Titus,[2] was as follows:

Across the river in Algiers and adjoining small settlements; at West End, Spanish Fort, and Milneburg, summer resorts on Lake Ponchartrain; Bay St. Louis, Miss., a summer resort between New Orleans and Mobile; along the Texas & Pacific Railroad at Donaldsonville, Cheneyville, and Alexandria; along the Southern Pacific at Thibodeaux, Schriever, Houma, Berwick, Morgan City, Franklin, New Iberia, and La Fayette, and at Opelousas.

There is every reason for supposing that this ant was introduced into New Orleans by means of the coffee ships which have for years

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[1] Bul. 52, Bur. Ent., U. S. Dept. Agr., p. 79, 1905. [2] Ibid., p. 82.

passed back and forth between that city and Brazilian ports. This view is supported by the fact that large numbers of the ants were first noticed in the vicinity of the wharves where these ships unloaded their cargoes and also by the fact that these ships have been the only means of regular communication between New Orleans and the countries in which the ant is indigenous. That this and other species of ants are actually transported on ocean-going vessels has been frequently observed. Thus in July, 1911, the senior author, while a passenger on one of the largest coastwise vessels between New Orleans and New York, found colonies of this same ant occupying protected situations in the woodwork of the steamer. Dr. W. M. Wheeler also writes us that while returning from Guatemala aboard a fruit

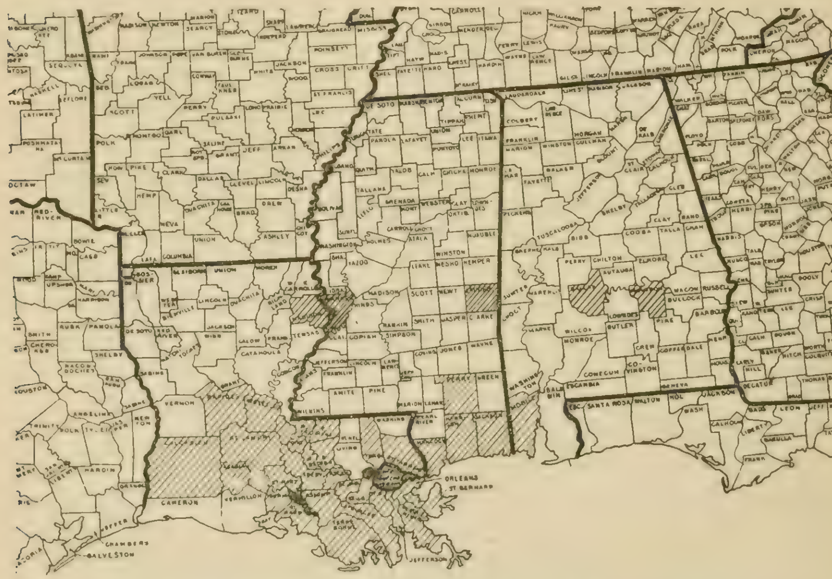

FIG. 1.—Map of Alabama, Mississippi, and Louisiana, showing counties in the Southern States which are infested by the Argentine ant, according to the authors' records. (Original.)

steamer in January, 1912, he found it infested with another common ant, *Prenolepis longicornis* Fab.

PRESENT DISTRIBUTION IN THE SOUTHERN STATES.

The area in the Southern States within which the Argentine ant is known to occur at present extends from Montgomery, Ala., to Lake Charles, La., a distance of about 380 miles east and west; and from Delta, La., to the mouth of the Mississippi River, a distance of about 250 miles north and south. (See fig. 1.) This section is not uniformly infested, but contains a great number of infested areas of more or less importance, ranging in size from many square miles of occupied territory, as illustrated by the infestation at New Orleans, to areas where the ants are so scarce that one not accustomed to their habits would fail to discover them. The latter condition prevails at present in Mobile, Ala. The only places remote from railroads where they have been discovered are upon the banks of the Mississippi River below infested localities. Their presence in such locations is easily accounted for by supposing that they have been carried thither on driftwood, which, carrying numbers of ants from infested places farther up the stream, has become stranded on the river banks, thus establishing new foci. In all other cases the infested territory is on a railroad, and usually on a main line running out from New Orleans. For example, nearly every town along the Southern Pacific Railway between New Orleans and Lake Charles is infested, and the same statement applies to points on the Louisville & Nashville Railroad between New Orleans and Mobile.

OCCURRENCE AND DISTRIBUTION IN CALIFORNIA.

The first specimens of the Argentine ant observed in California were collected in 1907 by Mr. J. Chester Bradley, at that time an assistant in the entomological department of the University of California. The identity of the specimens was not established until 1908, when Dr. W. M. Wheeler found them to be *Iridomyrmex humilis* Mayr.

As soon as the dangerous nature of the pest was known, Prof. C. W. Woodworth took steps to make a study of the species along the same lines as was being conducted in Louisiana at that time, and as a result of his preliminary work he issued a warning circular [1] to the public in August, 1908. In this circular he gave a brief outline of the habits of the ant and reported the following localities as infested: In the central portion of the State, East Oakland, Alameda, San Francisco, San Jose, Cupertino, and a point near Campbell; in the southern part of the State, Los Angeles, Azusa, and Upland.

In 1910 Prof. Woodworth published another small bulletin [2] giving the results of his two years' study of the insect. In this paper the infested territory was more clearly defined, and was estimated as consisting of a total area of 5,000 acres. About twice the area was reported infested in 1910 as in 1908, owing to the discovery of a few new colonies and the natural spread of the ones first discovered.

Our information as to the extent of the infested area in California (see fig. 2) has been obtained principally through the kind offices of Mr. Ralph Benton, of the California Agricultural Experiment Station, and Mr. P. E. Smith of Santa Paula, Cal., as well as from the publi-

[1] The Argentine ant in California. Cal. Exp. Sta. Cir. 38, Berkeley, Cal., August, 1908.

[2] The control of the Argentine ant. Cal. Exp. Sta. Bul. 207, Berkeley, Cal., October, 1910.

cations by Prof. C. W. Woodworth, already referred to. All of these persons agree that the following California points are infested: Alameda, Azusa, Berkeley, Byron Hot Springs, Campbell, College Park, Cupertino, Fruitvale, Los Angeles, Melrose, Oakland, Riverside, San Francisco, San Jose, Stockton, and Upland.

FIG. 2.—Distribution of the Argentine ant in California. From data furnished by Messrs. Ralph Benton and P. E. Smith. (Original.)

AREA OF ULTIMATE INFESTATION.

Up to the present we have no exact data to indicate the final limits of the area which may become infested by these ants. They apparently thrive as well at Delta, La., at an elevation of 87 feet, as they do near the mouth of the Mississippi River, 300 miles to the south and almost at sea level. They seem to be little or not at all affected by the variation in the amount of precipitation annually as between different localities, for they seem to flourish as well at San Jose and Los Angeles, Cal., with average annual rainfalls of 14.8 and 15.6 inches, respectively, as they do at New Orleans, La., where the average annual rainfall is 57.6 inches. The range of temperature to which they have adapted themselves at different points does not vary so greatly, but is nevertheless considerable. They have succeeded in establishing themselves at San Francisco, Cal., where the mean annual surface temperature is 56° F., or 13° cooler than the mean annual surface temperature at New Orleans, La.

If we assume that the Argentine ant is unable to persist in localities where the mean annual temperature is below 55°, we will find that the isotherm of this temperature extends almost up to Columbus, Ohio, and past St. Louis, Mo., and will include over one-third of the United States, or more than 1,000,000 square miles. It is very unlikely, however, that this neotropical species will be able to endure the cold winters in the northern parts of this area. It will probably be more nearly correct to assume that its advance will be checked when it reaches the minimum isotherm of zero, or, in other words, where the thermometer drops to zero or below during the average winter. On constructing this isotherm we find that we have the following area within the United States liable in the course of time to infestation by the Argentine ant:

Starting at the Atlantic coast line; one-half of North Carolina, one-half of South Carolina, one-half of Georgia, Florida, a portion of Alabama, one-third of Mississippi, most of Louisiana, all of lower Texas, a corner of New Mexico, one-half of Arizona, a little of Nevada, practically all of California, and a coastal strip through Oregon and Washington. This would extend the infestation into fourteen States, more or less, and is undoubtedly a very conservative prediction, as already the ant is established at one point, Delta, La., which is above this line.

In spite of these considerations we are still in the dark as to the altitudes at which this insect will thrive, and it may be found later that altitude will severely limit the distribution of this species, as it does that of many other insects. Table I gives the elevation and climatological data for a number of infested points in the United States, and from this table it will be noted that the elevation of points now infested varies from sea level to 338 feet.

The climatological data given in Table I are taken from Bulletin Q, Weather Bureau of the United States Department of Agriculture, 1906, entitled "Climatology of the United States," by Alfred Judson Henry.

TABLE I.—*Data concerning various towns infested with the Argentine ant.*

Name of town.	Elevation.	Mean annual temperature.	Absolute maximum temperature.	Summer maximum, mean.	Absolute minimum temperature.	Winter minimum, mean.	Mean annual precipitation.
	Feet.	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*
Montgomery, Ala	196	66	107	90	− 5	40	50.8
Mobile, Ala	11	67	102	89	− 1	45	62.1
Vicksburg, Miss	229	65	101	90	− 1	42	53.8
Meridian, Miss	338	64	104	89	− 6	38	53.4
Hattiesburg, Miss	154	67	103	92	− 1	40	48.1
Biloxi, Miss	24	67	100	88	1	43	61.3
Alexandria, La	77	66	109	92	2	39	54.9
Baton Rouge, La	62	67	103	90	2	42	54.6
Delta, La	87	(1)	(1)	(1)	(1)	(1)	(1)
Lake Charles, La	22	67	103	91	3	41	53.3
New Iberia, La	15	68	101	89	6	45	53.7
New Orleans, La	8	69	102	88	7	48	57.6
Sacramento, Cal	29	60	108	87	19	40	19.9
San Francisco, Cal	28	56	100	65	29	46	22.5
San Jose, Cal	95	58	104		18		14.8
Los Angeles, Cal	287	62	109	82	28	45	15.6

[1] Records not available.

NOTE.—"Summer maximum, mean"=the average of the total maximums for June, July, and August. "Winter minimum, mean"=the average of the total minimums for December, January, and February.

COMMON NAME.

The name "Argentine ant" was first used by the senior author for this species in 1908, when the public was on the point of accepting the name "New Orleans ant." The permanent use of the latter name would manifestly have been unjust to the Crescent City, for that city was in no way responsible for the introduction of the pest. As stated on preceding pages, this ant was originally described from specimens collected in Argentina, South America, and up to the present time we have no reasons for not believing that this is one, at least, of the countries in which this ant is native. The naming of this ant after the country from which it was first described is by no means without precedent. Many other common insects, such as the San Jose scale, American cockroach, Colorado potato beetle, Mexican cotton-boll weevil, etc., have received their popular names in the same manner.

Various common names have been suggested from time to time, among them "crazy ant," "tropical ant," "pernicious ant," etc., but all have the disadvantage of being as applicable to other species as to *Iridomyrmex humilis* and none of them is distinctive.

The term "Argentine ant" has been readily accepted, alike by entomologists and the press, is concise, and not likely to be confused with similar names; hence we believe it to be as good a name as can be adopted.

MEANS OF DISPERSION.

NATURAL SPREAD.

Under strictly natural conditions, the rate of dispersion of Argentine ants is very slow. Owing to their intensely social habits they spread but slowly from a locality until the number present becomes excessive for the food supply or unless adverse conditions, such as flooding, occur which compel them to seek fresh locations. They will then spread in all directions, but will go little farther than is necessary to give them sufficient foraging area to insure the food required. However, if a large food supply is discovered at a considerable distance from the colony, a heavy trail of workers will soon be formed between the food and the nest, composed of many thousands of tiny insects, each busy carrying a load of the coveted material back to the nest or going out for another load. Sometimes they will construct a new nest in the neighborhood of the food supply, and to this they will transport a number of pupæ, larvæ, and eggs from the parent nest. In the course of a day or so this new colony will be thoroughly established, with a full supply of queens, workers, and immature stages, and will then be capable of supporting itself and increasing in numbers without assistance from the parent nest.

Under normal conditions it is likely that the rate of spread does not amount to more than a few hundred yards each year. When food is plentiful, a well-traveled road or a paved street may restrict the spread for a considerable period, but when any much-desired food supply, such as the excretions of aphides or scale insects, is to be reached, nothing short of running water proves an effective barrier.

FLIGHT.

It is possible, but scarcely probable, that the queens may aid the natural dispersion by means of flight, but there are several reasons why this is doubtful. One of them is that the flight itself is a very uncertain event, as during the five years that these ants have been studied in Louisiana only one general flight has been observed. It has been established that the young queens can mate in the nest without taking a marriage flight at all, and apparently this is what usually takes place. Even should a fertilized winged queen fly or be transported by the wind to any considerable distance from the ant-infested territory, it is very doubtful whether any eggs she might lay would ever hatch. The queen has never been observed assisting in the slightest degree with the rearing of the young in the nest, nor have we succeeded in getting eggs to hatch when they were not cared for by the workers. As the workers are never winged, the queen would necessarily be alone, and it would be very unlikely that the queen would develop the instinct of attending to and caring for the eggs, larvæ, and pupæ in succession for several months. Also, the queens are quite helpless and appear to be entirely incapable of defending themselves against other insects. The writer has observed a queen ant being captured and bound by a minute spider, considerably smaller in size than her own head, without making the least attempt to struggle. It therefore seems improbable that a defenceless queen could maintain herself in a hostile country for several months without the assistance of workers.

Furthermore, we have several times kept Argentine ant queens isolated in small nests, sometimes singly and sometimes in groups, but have never yet succeeded in hatching eggs in these nests, or in rearing larvæ to the adult stage.

The fact that ditches of running water have proven sufficient barriers to prevent the spread of the species in orange groves appears to disprove the theory that queens returning from the nuptial flight can, without the assistance of workers, establish new colonies.

DISPERSION BY STREAMS.

As previously mentioned, driftwood is probably the most important agency in the natural dispersion of the Argentine ant. Along the Mississippi River, below the infested territory, we find a considerable number of larger or smaller colonies of the ants, and in places the batture[1] will be infested for miles, with practically no ants inside the levee. This can only be accounted for by ants floating down the river upon driftwood from infested localities. The river banks are covered with logs, more or less rotten, which have stranded during high water. In the infested territory these logs are found full of ants in all stages in enormous numbers. During high water some of these logs drift and lodge alternately, gradually working down the river, and distributing colonies in their wake.

The writer has several times seen complete colonies of ants on a floating log, unable to escape. All that was required was a little further rise of the water to start them down the river, with their cargoes of ants.

ARTIFICIAL DISSEMINATION.

Unquestionably the main distributing agent of the Argentine ant is man himself, by means of railway trains, boats, and other vehicles which he controls and utilizes in the transportation of freight and commodities of all kinds. The ants must necessarily have been introduced to this country by means of ships, and railways have been the

[1] The "batture" is that land lying between the true bank of the river and the levee. The batture is subject to overflow during high water, is ordinarily not cultivated, and is frequently overgrown with willows. The batture is said to be "outside" the levee, while land protected by the levee from high water is said to be "inside" the levee.

principal means of dissemination since they succeeded in establishing themselves. This is evident, as all the centers of infestation so far discovered, with the exception of those down the Mississippi River, the presence of which has just been explained are located upon railway lines; in the Southern States, upon main lines running out of New Orleans.

The ants are easily transported in packing and freight of various kinds. Large numbers of potted plants are shipped out of New Orleans to the surrounding country, and in many cases complete colonies of ants are sent with them in the soil surrounding the roots. Boxes and barrels of groceries, packing placed around fragile material to prevent breakage, and shipments of household goods may all contain queens and workers when shipped from infested points. The writer has observed a queen and many workers inside an empty passenger coach, which had been standing on the track for several hours during a rainstorm.

The danger of promiscuous infestation is somewhat lessened by the fact that it is necessary for a queen ant to be transported with the workers in order that a new colony may be founded. In a large series of experiments conducted to determine this point we have never yet found any indication that the workers were able to produce eggs, or to reproduce their kind in any manner. Consequently large numbers of workers may be scattered broadcast over uninfested territory and, though they may live for a considerable time, they will ultimately die out if a queen is not present. It is probably due to this fact that these ants have not infested a great deal more territory than they have during the past 10 years, as it is a certainty that thousands of workers are being continually shipped from infested territory into uninfested localities. At the same time the danger that fertile queens will be transported is considerable, for we have frequently found deälated queens foraging with the workers. The fertile queens will "take up" with any workers of the species, and it is only necessary for a queen *and* workers to be present in a new locality in order to start a self-perpetuating infestation.

Steamboats plying up and down rivers, carrying freight from infested points, are responsible for spreading great numbers of ants. For example, between New Orleans and Baton Rouge, La., there are over a hundred steamboat landings. These are nearly all infested by the Argentine ant, and probably the insects were first introduced in the freight shipped direct to these points from New Orleans or Baton Rouge. Many of the river steamboats are so heavily infested by permanent colonies of this ant that the workers are almost as much of a nuisance in the cook's galley as they are in culinary establishments on shore.

ECONOMIC IMPORTANCE.

Up to the present time the Argentine ant has attracted most attention as a household pest. Particularly during rainy weather, when honeydew is scarce, the ants invade houses in myriads and drive the housekeepers almost to distraction. Nearly everything which is edible for human beings is attractive to them, and ceaseless attention and strenuous effort are necessary to keep them out of pantry and kitchen. The use of poisons and repellents must be continuous; if there has been a little carelessness in this regard the foodstuffs become filled with countless numbers of ants in a very short time.

Among the foodstuffs most eagerly sought may be mentioned honey, sirups, sugar, candy, cakes, cookies, jams, marmalades, preserves, fruit juices, cream, olive oil, lard, egg (either raw or cooked), fish (either fresh or canned), and various raw meats, such as chicken, veal, mutton, pork, beef, etc. Corn meal is sometimes the object of attack and wheat flour to a slight extent.

Aside from their invasions of food the ants are household nuisances generally. No corner or nook is safe from their explorations and the discovery of something edible is quickly heralded in the nest, whence come thousands of workers to carry away the plunder. In heavily infested sections it is often necessary to place bedposts upon panes of glass coated with vaseline or other repellent in order that the occupant may sleep in peace. To have ants running all over one's person is disagreeable enough, but what is more serious, they will not hesitate to attack any part of the body where skin or membranes are tender enough to be pierced by their mandibles.

Authentic cases are on record where it has been necessary to take babes from their cradles and repeatedly immerse them in water to rid them of the ants which crawled by hundreds over their bodies and into their mouths and nostrils. We have even received reports of infants being killed by the ants, but such reports we have not verified. Such a thing is not, however, outside the realm of possibility.

In groceries and stores they are kept out of sirups, sugar, molasses, and like products only with great difficulty. In restaurants and confectionery shops the closest vigilance is required to keep the ants out of the cakes, candies, ice cream, fruits, etc., as well as out of ice boxes, refrigerators,[1] show cases, and windows. Meat in butchers' shops is also a great attraction, and if left unprotected for even a short time thousands of ants will be swarming over it.

In nurseries and among ornamental plants the ants foster and protect countless thousands of scale insects and plant lice, the excretions of which furnish the choicest delicacy with which the ants

[1] The temperature of the ordinary refrigerator is not low enough to deter the ants in their foraging.

regale themselves. This protective care results in rapid increase of these insects, with resultant damage to the plants infested. In florists' establishments the ants sometimes sever the petals of cut flowers in their search for nectar.

Visits to flowers of various kinds seem a natural habit, and when the ants do not find the nectar readily available they quickly cut their way to it in all cases where the plant tissue is tender enough to permit of it. In their attacks upon orange blossoms they are particularly severe, as they sometimes eat their way into the fruit buds even before the latter are fully open. The workers have also been noticed regularly visiting the extra-floral nectaries of cotton and other plants.

To truck growers the ants are very troublesome, owing to the manner in which they remove certain garden seeds before they have sprouted. Lettuce seed is especially subject to this attack, and in infested districts the rows of lettuce seed are covered with corn meal, which is also attractive to the ants. By the time the ants have removed the meal the lettuce seeds will have sprouted. The ants also assiduously attend plant lice on a number of vegetables, making the latter unpleasant to handle. Cabbage heads are often found through which plant lice and ants are completely distributed, the cabbage leaves merely serving as divisions between layers of the insects.

In the sugar-cane fields the ant again comes to the front, owing to its fondness for the excretions of the sugar-cane mealy-bug, *Pseudococcus calceolariæ*. (See figs. 3, 4.) In order to protect these insects from storms and enemies, the ants build protective coverings and shelters over them and attend them constantly. (See fig. 5.) As the result of these attentions the mealy-bugs thrive in numbers and destructiveness to an extent which is impossible where the ants are not present. Luckily the territory infested by the mealy-bug is as yet very restricted, but this insect threatens to become a serious problem in the future, owing to the manner in which it destroys the eyes of "seed cane" after it is planted, preventing sprouting and thus injuring the stand. The vacant rows in a field of cane, due to this injury, are shown in figure 3. The control of this mealy-bug therefore resolves itself into the problem of controlling the ant.

In cornfields it can be easily noticed that aphides are several times as numerous, and are also more generally distributed, in districts infested by the Argentine ant than in the noninfested districts. The ants are also found in great numbers attending plant lice upon cotton plants, and in a cotton field at Baton Rouge, where these ants were very numerous, it was noticed that the cotton aphides remained abundant throughout the entire summer and autumn, whereas during these portions of the year they are normally almost absent.

It is in the orange groves of southern Louisiana, however, that this ant has probably inflicted the most serious injury. This injury is discussed at length on a subsequent page. Suffice it to say that at present the Argentine ant is there regarded as the most serious insect problem, owing to the marked increase of scale insects which follows its introduction and spread. The value of land in that section depends to a considerable extent upon the presence or absence of the Argentine ant. The ant also does considerable damage to the fig crop by boring through the ripened fruit or entering the calyx end of the ripening fig and tunneling the interior. It also assists in the

FIG. 3.—Injury to the stand of sugar cane by the sugar-cane mealy-bug (*Pseudococcus calceolariæ*), which is attended by the Argentine ant. (Original.)

increase of the destructive mealy-bug, *Pseudococcus citri*, which injures figs to a considerable extent.

The ant is a veritable plague among honey bees, and beekeeping on any considerable scale is invariably abandoned after the ants become numerous.

In the poultry yard this ant is a pest that must be reckoned with. The ants find the nests of sitting hens particularly attractive, and if perchance an egg be broken the ants will come in such numbers that the fowl will abandon her nest. The blood and fluids from partially incubated embryos are particularly liked by the ants, and when the eggs are hatching the workers swarm over the young chicks in such numbers as to cause their death. Repellents which can be adapted to such a case are rare, even pyrethrum powder being practically ineffective. The only substance we have found which would at all protect the sitting hens is zenoleum powder, liberally sprinkled in the nest and among the hen's feathers from time to time during the brooding period. The nests of many birds are frequented by the ants in the same way, and the number of young birds destroyed in this manner must be considerable. The ubiquitous English sparrow, however, seems to flourish, as ever, in spite of the ants.

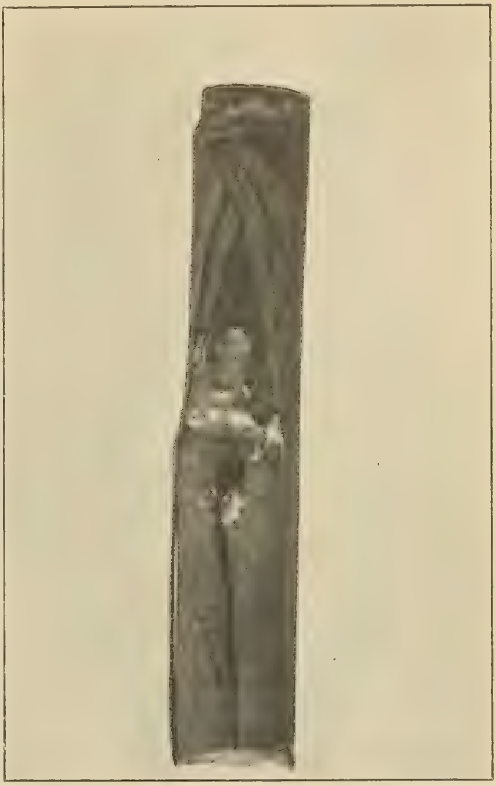

FIG. 4.—Sugar-cane mealy-bugs on sugar cane. (Original.)

Another form of injury, though indirect, is due to the antagonism which exists between the Argentine ant and other species of ants, and which terminates only with annihilation of the native species. As the result of this, beneficial species of ants (such as the "fire ant," *Solenopsis geminata*, which destroys a considerable number of boll weevils in their immature stages) are exterminated, and their place is taken by the infinitely more troublesome Argentine ant.

It may presently be found that the Argentine ant is an important agent in the spread of disease. The workers congregate in great numbers around garbage pails, privies, etc., and are frequently very hard to keep out of sick rooms, the odors seeming to attract them. They have been watched busily carrying away the sputum of a negro who was suffering from tuberculosis. There are many ways in which it is possible for these ants to assist in the distribution of various disease-producing organisms.

Rarely the activities of this ant take on a beneficial aspect. Father Biever states that they have in many cases completely exterminated the bedbugs in the hovels and tenements occupied by poor people in the city of New Orleans. The same authority several years ago called attention to the scarcity of the common "chiggers" or so-called "red bugs" in parks and yards heavily infested by the ant, and this latter observation has been verified by the junior author in the case of Audubon Park, New Orleans. At Baton Rouge, however, the senior author found the "chiggers" very abundant in premises heavily infested by the ants. The manner in which these ants destroy the sorghum midge is described on following pages.

SYSTEMATIC POSITION.

According to the classification adopted by Dr. W. M. Wheeler,[1] the Argentine ant is placed in the subfamily Dolichoderinæ, which

FIG. 5.—Covering constructed by the Argentine ant to protect the mealy-bugs. (Original.)

is one of the five main subdivisions of the family Formicidæ. The Dolichoderinæ are characterized by the cloacal orifice being slit-shaped and ventrally located instead of being circular and terminally located, as in the camponotine ants, by vestigial sting, by single-segmented abdominal pedicel, by a much shortened or bell-shaped gizzard (proventriculus), by the pupæ being always naked (not inclosed in cocoons), and usually by anal glands which produce a secretion having a very offensive odor. In the case of the Argentine ant, however, this odor is entirely lacking.

[1] "Ants, their structure, development, and behavior," 1910.

The subfamily Dolichoderinæ contains six North American genera: Dolichoderus (Hypoclinea), Forelius, Tapinoma, Dorymyrmex, Liometopum, and Iridomyrmex. Iridomyrmex is essentially tropical in its distribution and only two species are known to occur in the United States,[1] the native *Iridomyrmex analis* Ern. André, common in cotton fields of the South, and the introduced species, *Iridomyrmex humilis* Mayr, or Argentine ant.

DESCRIPTION OF THE SPECIES.

Three forms only of the adults are found in the colonies of the Argentine ant, the females or queens, the workers, and the males. (See fig. 6.) Major and minor workers do not occur, and no workers seem to act in the capacity of soldiers or scouts more than others. As previously noted, the species was first described as *Hypoclinea humilis* by Dr. G. Mayr, in 1868, from workers collected in 1866 near Buenos Aires in Argentina, the original description appearing in the Annuario della Societa dei Naturalisti di Modena, volume 3, page 164. Following is Mayr's description of the species kindly furnished by Dr. W. M. Wheeler, of the Bussey Institution, Harvard University, from the original edition:

Operia: Long. 2.6 mm. Sordide ferruginea, micans, mandibularum parte apicali flavescenti, abdomine nigrofusco, tarsis et nonnunquam tibiis testaceis; microscopice adpresse pubescens; absque pilis abstantibus; subtilissime coriaceo-rugulosa, mandibulis nitidis sublaevigatis punctis nonnullis; clypeus margine antico late haud profunde emarginatus; thorax inter mesonotom et metanotum paulo et distincte constrictus, pronoto fornicato, mesonoto longitrorsum recto, transversim convexo, metanoto inermi longitrorsum fornicato, pronoto paulo altiori; petioli squama compressa rotundata.

At the request of the senior author, Dr. Wheeler prepared the following redescription of the worker, and descriptions of the queen and male, thus making a complete and comprehensive description of the species:

Iridomyrmex humilis Mayr.

Worker: Length 2.2–2.6 mm.

Head oval, broader behind than in front, with its posterior margin slightly concave in the middle. Eyes flattened, in front of the middle of the head. Mandibles with two larger apical and several minute basal teeth. Clypeus short, convex in the middle, with broadly excised anterior margin. Frontal area and groove present but rather indistinct. Antennal scapes extending about one-fourth their length beyond the posterior corners of the head. Joints 1–5 and the terminal joint of the funiculus distinctly longer than broad; remaining joints nearly as broad as long. Thorax slender, narrower than the head; broadest through the pronotum which is convex, rounded and nearly as long as broad. Mesonotum nearly as long as the pronotum, sloping, laterally compressed, in profile evenly continuing the contour of the pronotum. Me-

[1] An undetermined species of Iridomyrmex, apparently introduced, has been found by Dr. W. M. Wheeler in a greenhouse at Boston, Mass.

soëpinotal constriction rather deep, extending obliquely downward and backward on each side. Epinotum short, nearly twice as high as long, convex on the sides, with a short convex base, and a longer, flatter and more sloping declivity. Petiole small, less than half as broad as the epinotum; its scale in profile, compressed, cuneate, inclined forward, with flattened anterior and posterior surfaces and rather acute apex; seen from behind its border is entire and evenly rounded or even slightly produced upward in the middle. Gaster small. Legs rather slender.

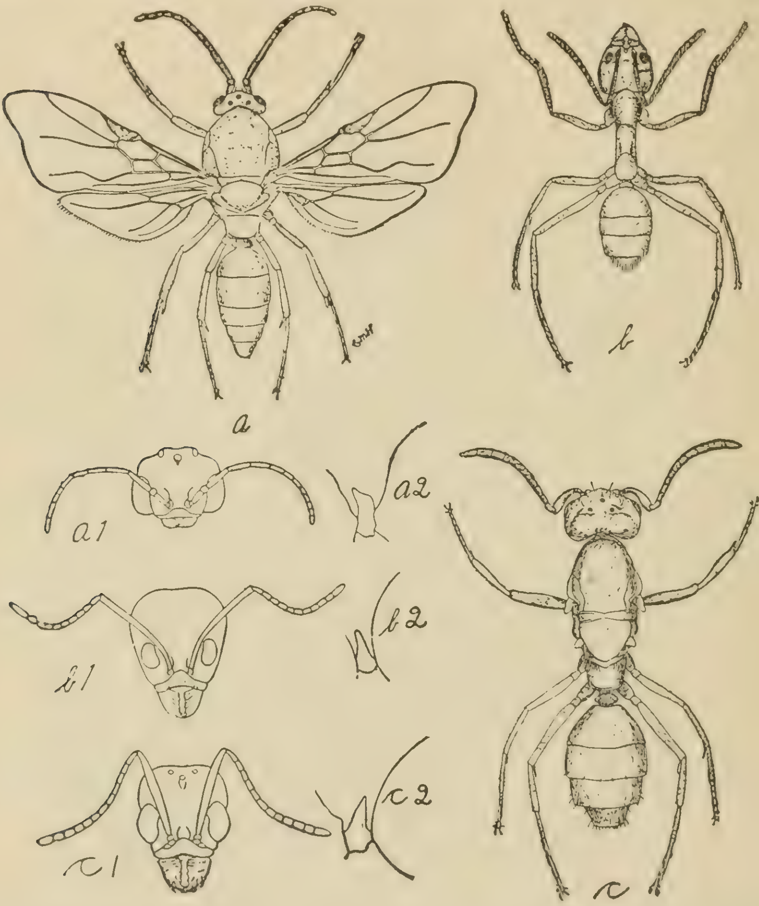

FIG. 6.—The Argentine ant, adult forms: *a*, Adult male; *a1*, head of male; *a2*, petiole of male; *b*, worker; *b1*, head of worker; *b2*, petiole of worker; *c*, fertile queen; *c1*, head of queen: *c2*, petiole of queen. All greatly enlarged. (Senior author's illustration.)

Body minutely shagreened or coriaceous, subopaque and glossy; mandibles, clypeus and anterior border of the head more shining. Mandibles minutely and rather obscurely punctate.

Hairs few, suberect, yellowish, confined to the mandibles, clypeus, tip and lower surface of the gaster. Pubescence short and uniform, grayish, so that the body has a slightly pruinose appearance.

Brown; thorax, scapes and legs somewhat paler; mandibles yellowish; apices of the individual funicular joints blackish.

Female (deälated): Length 4.5–5 mm.

Head, without the mandibles, but little longer than broad, with rather angular posterior corners, straight, subparallel sides and straight posterior border. Eyes large and rather convex. Mandibles and clypeus like that of the worker, scapes proportionally shorter and stouter. Thorax large, as broad as the head, elongate elliptical, nearly three times as long as broad. In profile the scutellum is very convex, projecting above the meso- and epinotum. Epinotum with very short base and long abrupt declivity. Petiolar node erect, more than half as broad as the epinotum. Gaster elliptical, somewhat shorter and a little broader than the thorax. Legs slender.

Sculpture like that of the worker but more opaque; mandibles and clypeus also less shining.

Scattered hairs more numerous than in the worker and also present in small numbers on the vertex, gula, mesonotum, prosternum, and fore coxae. There is also a row of short hairs along the posterior margin of each gastric segment. Pubescence distinctly longer, more silky, and denser than in the worker.

Dark brown; antennae, legs and posterior margins of the gastric segments reddish; mandibles, sutures of thorax and articulations of legs yellow.

Male: Length 2.8–3 mm.

Head much flattened; including the flattened eyes, as broad as long. Vertex and ocelli prominent. Cheeks short. Mandibles small, overlapping, with a single, acuminate apical tooth. Anterior clypeal border straight. Antennae slender; scape only between three and four times as long as broad; first funicular joint globose, broader than any of the other joints; second joint much longer than the scape; joints 3–5 growing successively shorter; joints 6–12 considerably shorter and more slender. Thorax very robust, elliptical, broader than the head, which is over-arched by the protruding, rounded mesonotum. Scutellum even more prominent than in the female. Epinotum with subequal base and declivity, the former slightly convex, the latter feebly concave, forming an angle with each other. Petiole small, its node with rather blunt margin, slightly inclined forward. Gaster very small, elongate elliptical, with small rounded external genital valves. Legs slender. Wings with a four-sided discal cell and two well developed cubital cells. The costal margin is depressed or folded in just proximally to the stigma.

Sculpture, pilosity and pubescence as in the worker; color more like that of the female, except that the antennae, legs, mandibles and internal genitalia are pale, sordid yellow. Wings smoky hyaline, with brown veins and stigma.

I. humilis belongs to a small group of neotropical species embracing also *I. iniquus* Mayr, *dispertitus* Forel, *keiteli* Forel and *melleus* Wheeler. The workers of *keiteli* and *melleus* may be at once distinguished by their color, the former having a yellowish brown head and thorax and the remaining parts brownish yellow; the latter being pale yellow with a blackish gaster and funiculus. In these and in *I. iniquus* and *dispertitus* the mesoëpinotal constriction is much deeper than in *humilis* and the meso- and epinotum are of a different shape. The mesonotum in profile does not form a continuous, even line with the pronotum and the epinotum is very protuberant and almost conical. *I. humilis* represents a transition from the above group of species to that of *I. analis* Ern. André, which is very common in the Southern States. This species has a shorter, more robust thorax, more like that of Tapinoma, and much less constricted in the mesoëpinotal region.

The above description was drawn from a number of workers, males and females taken from the same nest in Baton Rouge, La., by Mr. Wilmon Newell. The types described by Mayr were captured by Prof. P. de Strobel in the environs of Buenos Aires.

RESEMBLANCE TO OTHER ANTS.

There is little difficulty in distinguishing *Iridomyrmex humilis* Mayr from its nearest American relative, *Iridomyrmex analis* Ern. André. The latter species is quite common in cotton fields and other situations in the South, is much lighter in color than *humilis,* and possesses a very disagreeable odor which is entirely lacking in the case of *humilis.* The clearly marked trails of the Argentine workers, when on their foraging expeditions or when moving from place to place, have no counterpart in the case of *analis,* the workers of which in large measure forage independently of each other. *I. analis* constructs inverted cone-shaped mounds or craters on the surface above the underground nests, while what little dirt is excavated by *humilis* is scattered about the entrance to the nest in promiscuous fashion, the ants evidently desiring to rid themselves of the excavated pellets as expeditiously and conveniently as possible. The "wet-weather sheds" of the Argentine ant, constructed only during or just after prolonged rainy spells, bear no resemblance whatever to the craters of *analis;* but on the contrary are more or less flat, composed of fine particles of earth, unstable in structure and supported by grass or leaves.

However, the superficial resemblance of *I. humilis* to several species of other genera is even closer than to *I. analis* and is sufficient to make positive identification of *humilis* well-nigh impossible except by one skilled in detecting the characters used by myrmecologists for classification. Among the southern forms most likely to be mistaken for *I. humilis,* and vice versa, may be mentioned the "crazy ant" (*Prenolepis longicornis* Fab.) and *Dorymyrmex pyramicus* Roger. The workers of both these species are of practically the same size and color as those of *humilis* and the workers of all three travel and forage in much the same way. Prenolepis is distinguished from *I. humilis* by its camponotine characters, particularly the shape of the gizzard, by the cloacal orifice being round rather than slit-shaped, and by the presence of stiff, erect hairs upon the body. Dorymyrmex is easily distinguished by the conical or pointed elevation upon the epinotum (last dorsal segment of the thorax), a structure that is entirely lacking in Iridomyrmex, the epinotum of which is evenly convex.

The resemblance of *I. humilis* to still other species is sufficient to be confusing at times, but one can, by a process of eliminating certain easily observed characteristics, determine with reasonable probability whether a colony of living ants belongs to this species or not. First to be noticed is the size of the ants under suspicion. The workers of the Argentine ant are from 2.2 to 2.6 mm. in length, the largest individual we have ever seen measuring 2.75 mm. If workers are more than 3 mm. or less than 2 mm. in length, it may be safely concluded that the ant under observation is of some other species. The Argentine queen, however, is from 4.5 to 5 mm. in length. The color of the Argentine ants—all adult forms—is a very deep brown, almost approaching black, and the color is uniform over the entire body. The possession of head and thorax of one color with abdomen of a different color immediately eliminates a specimen from this species. A colony containing workers of more than one size is also eliminated, since all Argentine workers are of one size or caste. The fact that the petiole or pedicel (connecting joint between the thorax and abdomen) of *I. humilis* consists of only one segment readily distinguishes it from the species of Solenopsis and other myrmicine ants. The pupæ of our species is never inclosed in cocoons, but always naked, with legs, eyes, segments, etc., plainly visible. Argentine workers, when crushed between the fingers, give no perceptible odor, and this readily distinguishes them from their closest relative, *I. analis*, as well as from their more remote relatives, the species of Tapinoma. The Argentine worker does not possess a functional sting and does not even attempt to sting. This again separates the workers from those of a great many species, including Solenopsis, most of which sting viciously upon the slightest provocation. Upon being disturbed, particularly in the nest, some of the Argentine workers will attempt to bite, but by far the great majority devote their energies to escaping rapidly or to removing the larvæ and pupæ to a place of safety. What few do attempt to bite are not successful in piercing the skin of one's hands owing to their weak jaws. It is only when reaching tender places, such as the skin between the bases of the fingers for example, that they are able to make their bites effective.

If, therefore, ants suspected of being *Iridomyrmex humilis* meet the following qualifications, and in addition exhibit the habits already described, there is a reasonable probability that they belong to this species, and examples should be submitted to a specialist for examination:

Workers not over 3 mm. nor less than 2 mm. in length
Workers uniformly colored; deep brown, nearly black.
Workers of uniform size; no distinction as to caste.
Workers traveling in well-defined trails or lines to and from the nest.
Workers emitting no offensive odor when crushed.
Workers unable to sting and unable to bite effectively.
Pupæ not inclosed in cocoons.
Petiole or pedicel consisting of only one segment.
Petiole prolonged dorsally into a wedge-shaped scale, inclined slightly forward.
Epinotum devoid of a pointed or conical elevation.
Ocelli absent in workers, present in queens and males.

METHODS OF STUDY.

When the study of this ant was undertaken, two requisites presented themselves—a type of artificial formicary in which continuous observations could be made and individuals kept track of from the time of egg deposition until the adult stage was reached, and some method by which all individuals of a colony could be confined to their own formicary.

Space need not be taken to describe the types of artificial formicaries which were not successful.

The Janet cages proved successful only in the case of very large colonies, but in these the multiplicity of individuals made accurate observations impossible. It may be remarked that this type of cage is excellent for studying the community life as a whole and for making experiments with poisons or with parasitic fungi or bacteria.

Cages totally inclosed were not successful, for the reason that the ants, when deprived of the privilege of leaving their nest, failed to act in a normal manner.

The cage finally adopted was, with modifications, the one described by Sir John Lubbock on pages 2 and 3 of his classic work.[1] This consists essentially of two glass plates containing between them a layer of pulverized earth in which the ants may burrow at their pleasure. Considerable difficulty was experienced in getting the glass plates the proper distance apart; if too far apart the ants could make burrows which were not open to observation, and if too close together insufficient room was afforded the queen in which to stand and walk upright. As the queen is about twice as tall as the worker, it seemed for a time that a suitable cage could not be constructed. After repeated trials, however, it was found that if the space between the glass plates were made exactly 1.75 mm. the queen would have sufficient room and the workers could not construct invisible galleries.

This type of cage and its supporting stand are well illustrated by figures 7 and 8. Figure 7 shows the several parts of the cage; *3* is the cage proper, consisting of two plates of glass held uniformly 1.75 millimeters apart by strips of leather at all four edges, a door or opening being left at one corner. (See fig. 9.) Old negatives, the films removed with caustic soda, have been found the most desirable for making these cages, both because such glass is remarkably clear and free from imperfections and because it is of uniform thickness. The size of the cage may vary from $3\frac{1}{4}$ by $4\frac{1}{4}$ up to 8 by 10 inches or even larger. Leather was found more satisfactory for making the edges of the cage than either glass or wood. The strip of leather between the glass margins is about $\frac{1}{2}$ inch in width. It is extremely difficult to find a strip of glass uniformly 1.75 millimeters thick and it is also

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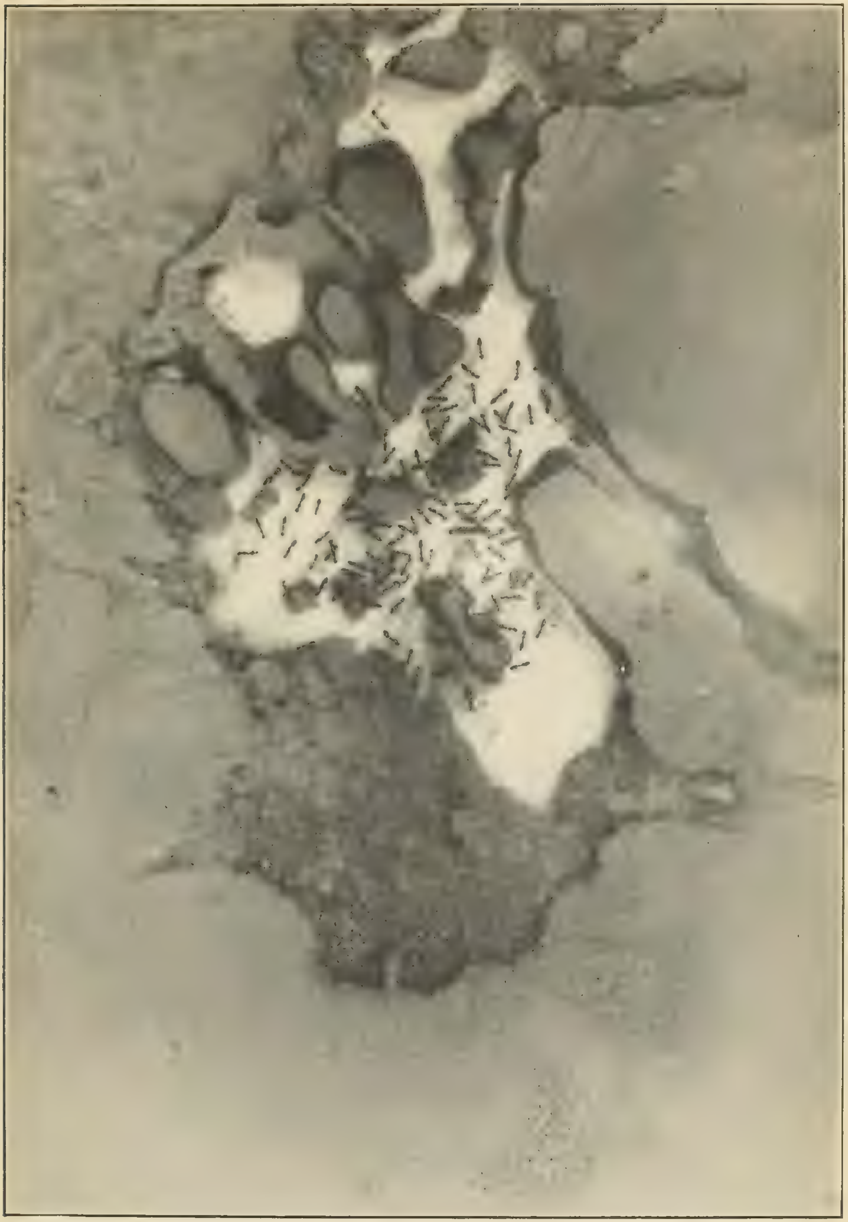
[1] Avebury. Ants, bees, and wasps, 1881.



A SMALL COLONY OF ARGENTINE ANTS AS SEEN IN ONE OF THE ARTIFICIAL FORMICARIES. (ORIGINAL.)

difficult to attach one piece of glass to another firmly. Wooden strips present the disadvantage of quickly decaying and of warping, no matter what glue or cement is used to hold them in position. Since it is sometimes desirable to place moist earth in the cages, or to add moisture from time to time, a waterproof cement is most desirable for attaching the glass plates to the leather strip. The space between the glass plates is filled with finely pulverized earth after completion and drying of the cage, and in this the ants are permitted to burrow and construct galleries as they please. (See Pl. II.)

The cage proper is supported on a platform (*1*) which in turn rests firmly upon a standard (*2*) having a base (*4*). The platform must have its upper surface perfectly level and it must remain so for an

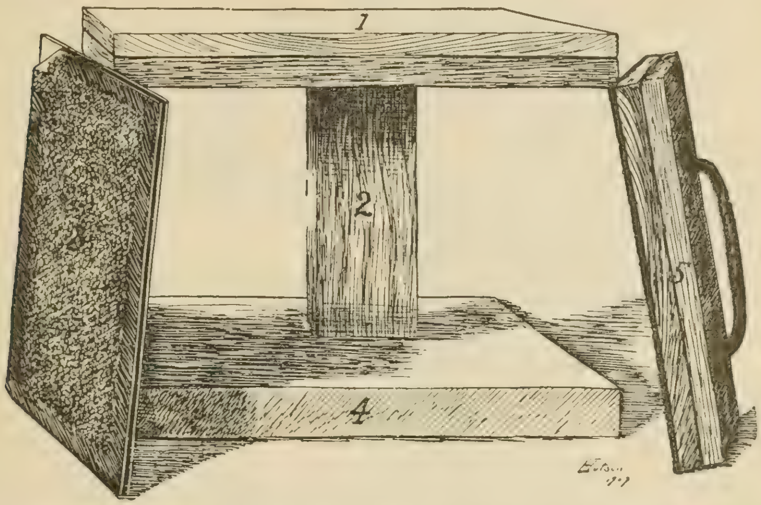


FIG. 7. Artificial formicary or cage used in studying the Argentine ant: *1*, Supporting platform; *2*, standard; *3*, cage proper, made of glass and leather, containing earth; *4*, base; *5*, cover. (Senior author's illustration.)

indefinite time, otherwise the ants will take up their abode between the cage and platform rather than in the cage itself. The platform is therefore made of two pieces of even, seasoned cypress $\frac{7}{8}$ inch thick, screwed together with numerous screws and with the grain of the two pieces at right angles to each other. On this platform the cage rests without fastenings of any kind. The cover (*5*) is constructed of two pieces of cypress in the same manner as the platform, but in addition has an iron handle attached to its upper surface and has a piece of felt glued to its under surface, so that, when it is placed upon the cage proper, all light is excluded except at the entrance. The cover is of the same outside dimensions as the cage itself. To insure the platform remaining level it is often necessary to make the base of two pieces in the same manner as the platform, or to nail strips across it at right angles to the grain. Both platform and base are attached to the standard by long screws with heads countersunk. Food is furnished by placing it on a piece of cardboard at any point on the cover or platform. The base stands in running water, as explained below. This type of cage permits the ants to leave their nest within the cage and to forage over the platform, cover, and stand in natural fashion, but their escape from the stand is prevented by the very natural barrier of water, which they find when they approach the bottom of the standard. It is not possible for them to conceal larvæ or eggs where the observer can not find them and they can not bring

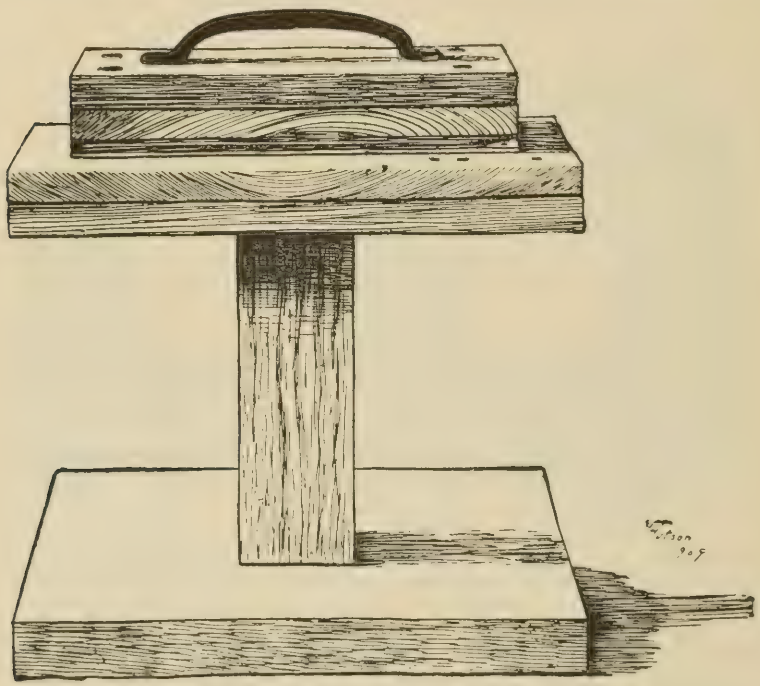


FIG. 8.—Artificial formicary with parts assembled ready for use. (Senior author's illustration.)

in larvæ or pupæ from outside sources to the annoyance and vexation of the student.

While the ants are very fond of sweets, we have found that sweets alone will not suffice for food indefinitely. Animal food is also required, and we find that by supplying the colonies with a "balanced ration" of honey and fresh beef or veal they will work in a perfectly natural manner for many months without other food.

The problem of confining the ants to the cage and its stand was not so easily solved. We first tried Sir John Lubbock's method of placing a moat of glycerine or water about the stand, but both liquids dried too quickly and were effective for only a few hours. Recourse was had to the proverbial chalk line without success. Bands or ditches of kerosene, crude oil, tar, oils of sassafras and citronella, tree tanglefoot, zenoleum, naphthaline, coal-tar disinfectants, whale-oil soap, sharp-edged tin, and fur were all failures. Certain powerful odors, such as those of zenoleum, sassafras, and citronella, act as repellents temporarily, but after a few hours of evaporation are no longer effective. Ordinarily these ants will not cross bands of cotton tape which have been impregnated with a saturated solution of corrosive sublimate and dried, but when attempting to leave an area to which they have been confined by this means they are much more persistent in crossing it.

Water with a film of whale-oil soap on it acted as a repellent for a few hours only, while a film of kerosene upon water merely afforded

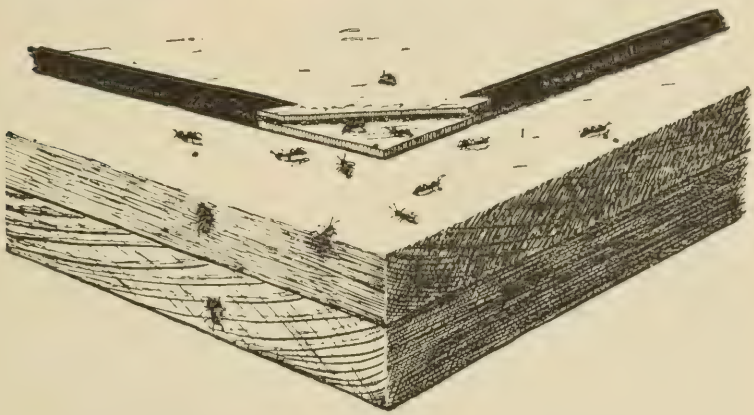


FIG. 9.—Entrance of artificial formicary shown in figures 7 and 8. (Senior author's illustration.)

a convenient floor upon which the ants could travel. The difficulty in confining the workers with any liquid or mucilaginous substance lies in the fact that they are exceedingly light,[1] and sticky substances shortly harden on the surface, so that the workers are supported. The surface film of clear water is in fact almost strong enough to support a worker not loaded. It is not unusual to see an ant alternately walking and swimming in crossing a narrow ditch of water which has been standing for a few hours. Minute dust particles collecting upon standing water shortly form a film upon which the workers pass with ease. Perfectly fresh water therefore served to confine the colonies to their cages, and at first our observations were made upon colonies in cages which were standing in dishes of water. This, however, necessitated frequent changing of the water, and observations were often brought to an abrupt finish by other duties which prevented the change of water in the vessels at the right time.

[1] The average weight of one worker is 0.0002077 gram.

In February, 1908, the senior author constructed, on the grounds of the Louisiana Experiment Station at Baton Rouge, a small building for the purpose of studying this ant more in detail. The building was 10 by 30 feet and equipped with benches having upon them galvanized iron trays $2\frac{1}{2}$ by 12 feet, 4 inches deep. In these trays the cages were placed and by means of suitable connections running water 2 inches in depth was kept passing through the trays day and night. As the ants would not voluntarily enter running water this arrangement worked admirably. The interior arrangement of this building is shown in Plate III. The iron trays and ant cages are shown upon the right, with work tables, chemicals, etc., on the left. The building was equipped with electric and extension lights for night examinations, and a combined thermograph and hygrograph recorded the temperature and humidity of the room at all times. For convenience this building was referred to as the "formicarium." Plenty of windows insured full ventilation at all seasons, and to avoid abnormally high temperature in summer a second or accessory roof was placed two feet above the main roof. This laboratory also proved a convenient insectary for the rearing of other insects.

The Argentine ant possesses a marked proclivity for attacking all insects which one has *under observation*, and all rearing experiments in cages, no matter what the insect, must be protected from the ants. The trays of running water therefore served to keep the ants away from general cage experiments as well as to confine them to the cages in which they themselves were being studied.

ESTABLISHING COLONIES FOR STUDY.

To establish a colony in one of the artificial formicaries or cages is comparatively easy. It is only necessary to secure a fertile queen from some thriving outdoor colony and place her on the stand, first placed in water, together with any desired number of workers which have been captured by attracting them to a sweetened sponge or piece of fresh meat. Any lot of workers will accept any queen and vice versa. When queen and workers are thus placed upon the cage and its stand, they usually, after a few hours, take up their abode in the nest proper. At first we experienced some difficulty in preventing them from collecting beneath the stand, but it was presently found that if a little dirt were removed from another colony and placed in the entrance of the new formicary the ants would enter at once and adopt it as a suitable home. After the establishment of such colonies the queen usually commences egg deposition in from 6 to 48 hours.

By establishing colonies in this manner, without immature stages present, it is easy to observe the daily rate of egg deposition, the incubation period of the eggs, and the duration of the larval and pupal

"FORMICARIUM," OR SPECIAL INSECTARY, CONSTRUCTED AND EQUIPPED FOR THE STUDY OF THE ARGENTINE ANT. (ORIGINAL.)

stages. In some of the records given below single individuals have been kept under observation from deposition of the egg, through larval and pupal stages, to the adult. In other cases the time from deposition of the first egg until hatching of the first larva was assumed to be the period of incubation, date of hatching of first larva to formation of first pupa the duration of the larval period, etc.

While these cages were invaluable in studying the life history of the ants, the small amount of space available for them between the glass plates made the number of ants they would contain very limited. For the purpose of studying the general habits of large colonies of ants a modification of the Janet cage was used. As its name implies, this cage was invented by Mr. Charles Janet,[1] and is described by him as follows:

> The apparatus (an artificial horizontal nest of porous mineral substance) described in this treatise gives, in reference to the raising of ants, remarkable results. Ants die in a short time when placed where they can not receive sufficient moisture; but (and this is the delicate point) this moisture must be maintained within certain limits. The apparatus invented up to the present do not solve this difficulty. Furthermore, they do not lend themselves easily to observation, nor do they permit one to withdraw with ease specimens when needed. The artificial nest is formed of a block of plaster, or any other porous substance, which has hollowed out of it a certain number of small cells, placed one after the other and communicating. These cells are covered with an opaque slab designed to keep the cells dark between the periods of observation. A cup of water placed at the end of the block allows it to absorb moisture. The cell nearest this cup is the dampest, and the one farthest away the driest. I leave this last always light so that it resembles, for the breeding under observation, a space outside of the nest. If the water-cell has been kept too moist, the ants go into the cell farthest away, that is to say the driest. When, on the contrary, the apparatus becomes too dry the ants return to the walls of the cell containing the water, which is always damper than the other parts of the nest. They can thus choose for themselves the part of the nest presenting the degree of moisture which suits them best.

The chief modification adopted was the use of a five-celled cage instead of one of four cells, as described by Janet. Also, the ants were not inclosed within the cage, but were allowed to enter or leave at will. To permit of this the Janet cages were placed upon platforms, which stood in running water. These platforms were considerably larger than the cages, and this gave the workers quite an area to forage over, simulating natural conditions quite closely. The food was placed upon the platform, outside the nest, and the workers thus had to carry it in and feed the larvæ in the same manner in which it was done outdoors. These cages had sufficient capacity for many thousands of ants. They were used for observing the behavior of large colonies and for the purpose of noting the effects of poisons and various control measures.

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[1] Studies on ants. Note 2. Apparatus for the raising and observation of ants and other small animals which require a moist atmosphere. Extract Ann. Ent. Soc. France, Mar. 10, 1893; vol. 62, pp. 467–482, figs. 11–12. (Translated by Miss A. O'Conor.)

LIFE HISTORY.

THE EGG.

(Pl. IV, *A*.)

The egg is elliptical, pearly white, lustrous, without markings, and the membrane is extremely thin and delicate. The surface is somewhat mucilaginous, so that when eggs come in contact they adhere to each other. This enables the workers to handle them en masse and also permits of their being deposited upon the walls or ceilings of the ants' habitations.

The average size is 0.3 mm. long by 0.2 mm. wide. The largest egg encountered while measuring a series was 0.34 mm. long by 0.24 mm. wide, and the smallest 0.27 mm. by 0.187 mm.

As time for hatching approaches the luster fades and the surface takes on a dull appearance. This is not sufficiently pronounced and uniform, however, to be taken as a safe guide to immediate hatching. When the embryo takes on the larval shape the membrane not infrequently adapts itself in a way to the general contour of the inclosed embryo, thus making it very difficult to distinguish between the eggs and the newly-hatched larvæ.

In the large Janet style cages the workers seem to take elaborate care of the eggs in order to secure for them just the requisite amount of humidity. Frequently they will be shifted several times in the course of the day, first being stored in one corner, then moved to the center of the compartment, afterwards carried to another compartment, and perhaps finally stuck to the glass ceiling. Sometimes the eggs are separated from the larvæ and pupæ; at other times they will be stored together in apparently hopeless confusion.

The care of the eggs by the workers seems essential to complete embryonic development. Eggs deposited in test tubes by isolated queens have gone through a portion of the embryonic development, but we have not been successful in getting them to hatch. This may be due in part to the ease with which the delicate embryos are injured in handling and to the fact that when placed on glass the condensing moisture may retard or stop development.

The queen appears to act merely as an egg-producing machine, and once the egg has been deposited she pays no further attention to it. The act of oviposition has been observed several times and does not occupy more than a few seconds of time. An attendant ant appears to be anxiously watching for the appearance of the egg, and it is immediately picked up and rushed off to the nearest "egg pile," sometimes before it has time to touch the floor of the nest.

Attempts to get fertilized queens, unattended by workers, to deposit eggs and rear the resulting larvæ to maturity have been unsuccessful. Such queens stop laying a few days after their isolation and seemingly pay no attention to what few eggs they do deposit.

Eggs are deposited at all seasons of the year. The large majority of them are produced during the summer, but a few are laid in warm spells during the winter months. The rate of deposition has not been determined, but one queen under observation in a cage deposited at the rate of 30 eggs per day, now and then suspending oviposition for several days at a time.

In outdoor colonies oviposition ceases when the daily mean temperature drops below 65° F., but is usually begun again when the mean temperature rises above this point, regardless of the time of the year.

No indication has been found of workers depositing eggs, even in colonies that were queenless for long periods; neither did queenless colonies ever rear queens from the eggs and larvæ present in the nest at the time queenlessness occurred.

PERIOD OF INCUBATION.

The period of incubation varies with the season of the year, and in proportion as the temperature remains high or low. The shortest incubation period observed has been 12 days, the longest 55 days, and the average is about 28 days. The longer periods are doubtless accounted for by the entire suspension of embryonic development during cool weather, and it is not impossible that the viability of eggs may be entirely destroyed by a temperature as low as 25° or 30° F., but on this point more data are needed.

The period of incubation has been determined, ordinarily, by placing a queen and workers, but no immature stages, in an artificial formicary and then noting the time from deposition of the first egg to appearance of the first larva. This period was assumed to be the real period required for incubation. In other cases single groups of eggs have been kept under constant observation throughout the entire period of incubation. The following table shows the variation in development at different seasons, together with the average daily mean temperatures prevailing:

TABLE II.—*Duration of the egg stage of the Argentine ant at different seasons—worker.*

Record No.	From—	To—	Days.[1]	Average daily mean temperature during period.	Average daily mean humidity.
				°F.	*Per cent.*
1	Oct. 1, 1907	Nov. 15, 1907	45½	(2)	....
3	Dec. 22, 1907	Feb. 14, 1908	55	(2)	....
4	Mar. 14, 1908	Apr. 9, 1908	27	70.3	70.2
6	May 1, 1908	May 23, 1908	23	74	68.9
7	July 20, 1908	Aug. 10, 1908	22	81	82.9
8	July 25, 1908	Aug. 12, 1908	19	81	81.5
12	June 30, 1908	July 18, 1908	19	81.1	74.9
14	July 24, 1909	Aug. 5, 1909	12	82.5	78.8

[1] Average days, 27.8.

[2] Cages kept in office; record of exact temperatures not available. The balance of the records were made in the "formicarium" and the recording instruments kept in the same room with the cages; hence the temperature and humidity records are correct for the exact location of the eggs under observation.

THE LARVA.

(Pl. IV, *B*, *C*.)

The larva when first hatched is not distinguishable from the egg without the assistance of a magnifying glass. For a time after hatching the body is considerably curved, the cephalic end being almost in touch with the caudal end, but as development progresses the larva assumes more and more of a straight form. The curvature is not entirely lost, however.

A recently hatched larva, measured with the compound microscope and eyepiece micrometer, was 0.49 mm. long by 0.32 wide. The fully grown larvæ (workers) average 1.7 mm. long by 0.66 mm. wide. The largest one under our observation measured 1.87 mm. by 0.765 mm.

With the exception of slight constrictions of the body, the larvæ are incapable of motion, thus being entirely helpless and relying altogether upon the ministrations of the attendant workers. The latter, however, perform their duties faithfully, and care for their charges with the greatest solicitude. They feed and groom the young larvæ continually and transport them from place to place whenever necessary. In case of danger their first instinct appears to be to remove the young to a place of safety, and they readily sacrifice their own lives in order to accomplish this.

The larvæ are fed often by the attending workers upon regurgitated and presumably predigested food. There is nothing in the appearance or actions of the workers which do the feeding to indicate that they are different from those which perform other duties, or that they are assigned to the particular and exclusive duty of being nurses. The feeding of the larvæ has several times been observed under a magnifying glass, and is as follows: The larva ordinarily lies upon its side or back. The attending worker approaches from any convenient direction, usually from one side or from the direction in which the head of the larva lies, and, spreading her mandibles, places them over the mouth parts of the larva, which are slightly extruded. The tongue of the worker is also in contact with the larval mouth. While the worker holds the body and mandibles stationary a drop of light-colored, almost transparent fluid appears upon her tongue. This fluid disappears within the mouth of the larva, but it can not be ascertained to what extent the larval mouth parts are moved during the operation, as they are obscured from view by the mandibles and head of the attending worker. Slight constrictions of the larval abdomen during feeding are sometimes noticeable, at other times not. The time required for feeding a single larva varies from 3 to 30 seconds, depending doubtless on the hunger of the "baby." The workers

IMMATURE STAGES OF THE ARGENTINE ANT. (ORIGINAL.)

A, eggs; B, larvæ and worker pupæ; C, larvæ, more enlarged; D, pupæ of workers; at center, male pupa. All enlarged. (Senior author's illustration.)

proffer food to, or at least inspect, each larva, for the worker doing the feeding will place her mandibles to the mouth of one larva after another, feeding those which seem to require it.

Both larvæ and pupæ are groomed or licked with the tongues of the workers; thus they are ever kept in a state of absolute cleanliness.

The most pronounced increase in size of the larvæ occurs during the first five days after hatching. As is the case with other ants, nothing is voided from the alimentary canal during the larval period, the undigested portions of the food being retained in the stomach, the latter having no open connection with the intestine. As the larva reaches its full growth this meconium, or mass of undigested material, becomes quite large and is distinctly visible as a dark object in the posterior portion of the body. At about this time communication is established between stomach and intestine and the meconium is voided. The larva then enters the prepupal or semipupal stage. While the insect in this stage is not very different in appearance from a full-grown larva, close examination shows a number of slight differences. Aside from the absence of the meconium, the cephalic and thoracic regions become markedly smooth and shining, with segmentation very indistinct, while the segmentation in the abdominal region is, if anything, more pronounced than before. The line of demarkation between abdomen and thorax is now in evidence, but without any very noticeable constriction. The mouth parts are protruded more than in the larva. The difference in appearance between larval and prepupal stages is not great but is sufficient to enable one to predict, with reasonable accuracy, the approaching transformation to the pupal stage proper.

In the later portion of the larval stage we have first been able to distinguish between the males and workers. The male larvæ grow to a somewhat larger size than do the worker larvæ, and it is thus possible to predict with some degree of certainty which of grown larvæ will transform to males and which to workers. In all other respects, however, they are apparently alike. The larval stage of the queen is unknown to us.

DURATION OF THE LARVAL STAGE.

The duration of the larval period has been determined by observation in the artificial nests in the same manner as the incubation period already described.

The following table shows the duration of the larval period at different seasons.

TABLE III.—*Duration of larval stage of the Argentine ant at different seasons—worker.*

Record No.	From—	To—	Days.[1]	Average daily mean temperature during period.	Average daily mean humidity.
				° *F.*	*Per cent.*
1	Nov. 16, 1907	Jan. 15, 1908	61	52.2	....
6	Feb. 5, 1908	Apr. 1, 1908	57	62.2	71.9
8	.....do.......	.....do.......	57	62.2	71.9
10	Feb. 15, 1908	Mar. 28, 1908	43	62	72
3	Feb. 29, 1908	Mar. 26, 1908	27	67	73
9	Apr. 10, 1908	Apr. 24, 1908	15	76.6	75.3
7	Apr. 12, 1908	Apr. 25, 1908	14	76.1	75.2
2	July 19, 1908	Aug. 1, 1908	14	80.5	82
11	Aug. 13, 1908	Aug. 27, 1908	15	81.7	71.7
4	Sept. 4, 1908	Sept. 14, 1908	11	81.1	73.6

[1] Average days, 31.4.

THE PUPA.

When the pupal stage is reached by the young ant all doubt is removed as to the sex of the individual, for one can tell at a glance which pupæ will transform into adult workers, which to males, and which to queens. The pupæ of these three forms are easily distinguishable and will be discussed in the order named.

THE WORKER PUPA.

(Pl. IV, *B*, *D*.)

The worker pupa immediately after transformation from the larval stage is pure white, without markings, except that the compound eyes are prominent as jet-black spots upon the head. The pupa is slightly larger than the grown larva, the average length being about 2 mm. The head is by far the most prominent portion. A pupa measuring 2.04 mm. in length was found to have a head 1.19 mm. in length (dorso-ventral diameter), while the thorax and abdomen measured 0.51 and 0.561 mm., respectively.

As time for transformation to adult approaches the pupa changes to a creamy color, then through a light brown to a dark brown, the latter shade being almost as dark as the body color of mature workers. The time of these changes varies with the duration of the pupal stage, but the following record of changes in color of a pupa which occupied a full 20 days from larva to adult (callow), is near the average:

First to seventeenth day—Pupa pure white, except compound eyes.
Eighteenth day—Turned to a light creamy yellow.
Nineteenth day—Became a light brown.
Twentieth day—The brown color deepened.
Twenty-first day—Reached teneral stage.

In some colonies there is more or less of an indistinct sorting of the immature stages, pupæ being placed in one portion of the nest and larvæ in another. This tendency is not perceptible in many colonies and is usually most noticeable in very large colonies.

The duration of the pupal stage has been determined in the manner already described for the incubation and larval periods. The range of pupal development is shown in the following table:

TABLE IV.—*Duration of pupal stage of the Argentine ant, individual workers, 1908-9.*

Record No.	From—	To—	Days.[1]	Average daily mean temperature during period.	Average daily mean humidity.
				° *F.*	*Per cent.*
1	Jan. 21, 1908	Feb. 14, 1908	25	56.5	68.3
2	Mar. 14, 1908	Mar. 27, 1908	14	67.5	71.8
5	Mar. 26, 1908	Apr. 11, 1908	17	73.8	68.9
6	Mar. 30, 1908	Apr. 14, 1908	16	73.8	70.2
3	Apr. 5, 1908	Apr. 15, 1908	11	76	73.5
10	do	Apr. 18, 1908	14	76.3	74
7	do	Apr. 20, 1908	16	76.7	74
8	Apr. 8, 1908	Apr. 23, 1908	16	76.6	74.5
9	Apr. 25, 1908	May 13, 1908	19	71	63.5
11	do	May 14, 1908	20	71.2	61.4
4	Aug. 1, 1908	Aug. 11, 1908	11	82.2	80
12	Aug. 6, 1908	Aug. 16, 1908	11	83	74.8
13	Aug. 10, 1908	Aug. 20, 1908	11	82.8	70.7
14	Aug. 28, 1908	Sept. 7, 1908	11	81.4	71
19	Apr. 5, 1909	Apr. 28, 1909	24	70.1	68.4
21	June 13, 1909	June 22, 1909	10	82.75	68.75
22	June 24, 1909	July 6, 1909	12½	84.08	76.08

[1] Average days, 15.

THE MALE PUPA.

(Pl. IV, at center.)

The male pupa is fully 50 per cent larger than the worker pupa and has, by comparison, an enormous thorax. The male pupæ vary in length from 2.78 to 3.23 mm., with an average length of 3.04 mm.[1] As the average length of the thorax alone is 1.19 mm., it is at once seen what a relatively large part of the body it constitutes. The male pupa is shown in the center of Plate IV.

When first transformed from the larval stage the male pupa is pure white, with exception of the compound eyes, which are faintly tinged with brown. Gradually the color of the compound eyes deepens and the ocelli become visible as minute dark spots upon the head. The male pupa, like the worker pupa, passes through gradations of creamy yellow, light brown, and dark brown to almost black before transforming to the adult stage. The color reached by the male pupa just prior to transformation is much deeper than that attained by worker pupæ. The males are assisted in their transformation to the adult stage by

[1] From measurements of 10 specimens by Mr. Arthur H. Rosenfeld.

the workers, and the pupal skin, or at least a portion of it, is worked backward to the tip of the abdomen and there shed entirely. Within a few hours after transformation the wings of the male become fully expanded. The following table shows the duration of the male pupal stage at different seasons.

TABLE V.—*Duration of pupal stage of the Argentine ant, individual males, 1908.*

Record No.	From—	To—	Days.[1]	Average daily mean temperature during period.	Average daily mean humidity.
				° *F.*	*Per cent.*
1	Apr. 11	May 1	19½	73.6	69.8
2	Apr. 14	May 4	20½	73.6	68.6
3	...do....	...do....	20½	73.6	68.6
4	Apr. 17	May 10	24	72.3	67.3
7	...do....	...do....	24	72.3	67.3
8	Apr. 18	May 11	24	72.2	66.7
9	...do....	May 13	26	72.8	66.5
5	Apr. 20	...do....	24	71.8	65.8
6	Sept. 24	Oct. 21	28	70.5	67.8

[1] Average days, 23½.

The normal time of appearance of the male pupæ is in the spring, but the appearance of a relatively small number in autumn is not uncommon. During April and May they are usually abundant, gradually disappearing in the latter part of May and early June. Only in one case have they been observed in midsummer, when three or four male pupæ were found at Baton Rouge, July 24, 1909, in a huge nest which contained thousands of immature stages.

THE QUEEN PUPA.

The pupa which is to become a queen is readily distinguished from the male or worker pupa by its size, as it is considerably larger than the male and more than twice as large as the worker pupa. The whole body is more uniformly developed than in the case of the male pupa. The head and thorax are not nearly so large in proportion to the rest of the body, the abdomen is much larger, and the dividing line between head and thorax is much more distinct. Apart from its size the queen pupa is readily recognized by the presence of the prominent wing pads.

Queen pupæ have been found only during April and May. The duration of this stage has not been worked out, as we have not been fortunate enough to secure larvæ which would transform into queen pupæ in our cages. Considerable numbers of these pupæ have, however, been collected in the field by the junior author and have been reared to the adult stage in the artificial formicaries, observations on them extending over a period of two weeks. The queen pupal stage seems to occupy relatively more time than is required for the worker pupal stage, but the gradual change in color from pure white to brown is about the same. It seems probable that the queen pupal stage extends over three or four weeks, depending upon the prevailing temperature. As many as 35 queen pupæ were collected from one colony in Audubon Park, New Orleans, La., on April 29, 1910; hence there is every reason for believing that the virgin queens are reared in large numbers.

Reasoning from what is known concerning the development of queens in the case of such insects as the honey bee, one would expect to find the queen ant developed from the same kind of an egg that produces the worker and that the queen would be developed as a result of special food given to the female larva. It is possible that the diet furnished to our colonies in confinement did not contain the requisite materials out of which the workers could elaborate a food suitable for rearing queens, and this may account for their failure ever to appear in the artificial formicaries, no matter how populous the latter were.

THE CALLOW OR TENERAL STAGE.

During the last few hours of the pupal stage, in all forms, the legs, mouth parts, and antennæ become more prominent and the pupa is assisted in its transformation by the workers, who attempt to straighten out the legs and antennæ. We are convinced that there is a very thin transparent membrane or skin surrounding the pupa, which is shed at time of transformation, but its existence is difficult to establish satisfactorily.

Immediately after transformation the young ant is colorless, almost transparent, but is otherwise identical in appearance with fully mature specimens. To this stage, following the custom of some authors, we apply the term "callow." The callow is at first very clumsy and walks with uncertain steps and staggering gait, reminding one much of a worker bee just emerged from the brood comb. During this stage the workers seem still to feel a responsibility for the callow's welfare, for when the colony is disturbed the callows, like larvæ and pupæ, are unceremoniously grabbed up by the workers and hustled to a place of safety.

The body of the callow deepens in color quite rapidly and in from 48 to 72 hours after transformation from the pupa becomes indistinguishable from that of other adults.

TIME REQUIRED FOR COMPLETE DEVELOPMENT.

By adding together the minimum periods required for the development of worker eggs, larvæ, and pupæ, as given in Tables II, III, and IV, we find that at least 33 days are required for development from egg to adult, and in a similar manner addition of the maximum periods gives 141 days as the maximum time required.

From the tables also it is seen that the average period of incubation of the eggs is 28 days, for development of the larvæ 31 days, and for maturing and transformation of pupa to adult 15 days. By adding together these averages we arrive at 74 days as the average period of development. This, of course, can not be termed the time required for the development of a generation, since workers do not reproduce, and the term "generation" can be used only in referring to the succession of queens.

The time required for complete development of males is, of course, still unknown, for male larvæ could not, in their earlier stages of growth, be distinguished from the worker larvæ; while the larval form of the queen is still unknown.

THE ADULTS.

There are only three adult forms in the case of this ant, namely, the queen, male, and worker. Of the immature forms there are three, egg, larva, and pupa, of each the queen, male, and worker. There is hardly sufficient difference between the virgin queen and the deälated queen after fertilization to justify considering them as distinct forms. A complete colony may therefore consist of a queen and workers only, of queens and workers, or of a queen (or queens), males, and workers. With each of these combinations may be associated any one or more of the three immature stages, corresponding to each of the three adult forms, or nine immature stages in all. Plate II shows a colony consisting of 1 queen, about 100 workers, and about 20 eggs, with no larvæ, pupæ, or males present. For a technical description of these adult forms the reader is referred to other pages. The following descriptions are general in their nature:

The Worker.

The worker measures from 2.25 to 2.75 mm. in length and is well illustrated at *b*, figure 6. As with the queen, the abdomen extends to about the tarsi of the hind legs when the worker is active or engaged in feeding. The abdomen is capable of considerable distension, and when the worker is fully engorged with sirup or other liquid its chitinous plates are forced apart, rendering the connecting membranes distinctly visible. The writer has often noticed workers returning from their attendance upon plant lice with abdomens so distended that they looked like little drops of silvery liquid. Particularly is this appearance presented when the returning workers are viewed with a strong light beyond them.

As would naturally be expected in the case of so small a creature, the weight of a single worker is very small. To determine it, 1,000 workers, freshly captured and killed with cyanid fumes, were carefully counted and weighed on an analytical balance. The thousand insects weighed 0.2077 gram, which gave the average weight of each worker as 0.0002077 gram, or two-tenths of a milligram.

As already stated, there is only one caste among the workers. In a large colony there seems to be something of a division of labor, certain ones engaging in foraging, others in nursing, and still others in excavating or sanitary work. However, any individual worker can assume the duties of any other, and does do so when exigencies demand. Worker callows, barely hardened into mature adults, go forth in search of food and the hardened veterans of many months' service seem to make as efficient nurses as even the youngest.

LENGTH OF LIFE.

The workers are particularly long lived. A colony of about 70 workers was made queenless and broodless on July 8, 1908. By October 10 the number of workers had become reduced to about 40, and some of the original ones survived until February 25, 1909, a period of 6½ months. As this colony was queenless, the workers in it were not under normal conditions. With a queen present it is ordinarily impossible to ascertain the length of life of individual workers, owing to the constant maturing of young. However, in one case we had opportunity to observe the survival of workers with queen present and with immature stages absent. A colony started on October 10, 1908, proved to have an infertile, deälated queen and was kept under observation to see how long the workers would survive. The last of these died on July 22, 1909, having lived for 9 months and 12 days after their capture. Their age at the time they were confined in the cage on October 10 was, of course, unknown; but it appears safe to conclude that under normal conditions the workers not infrequently live to an age of at least 10 or 12 months.

Mr. G. D. Smith was successful in keeping a queen and several workers for more than two months, during which time they had no food other than that which may have been contained in the drinking water furnished them. During this period of prolonged fasting the queen even deposited eggs, some of which hatched into larvæ.

The Male.

The appearance of the adult male is illustrated at *a*, figure 6. The males average about 2.8 to 3 mm. in length. The most noticeable feature about them is the manner in which the thorax is enormously developed. The abdomen is relatively small and the head short and blunt. The shape of the head alone permits distinction between the male and virgin (winged) queen without the aid of a glass.

The normal time of appearance of the males, of course, follows the appearance of the male pupæ, usually in the spring, but a few appear in the fall. They are plentiful in the colonies during the latter part of April and May, and numbers are still to be found in June. After the beginning of July, however, they vanish, and are very seldom seen during the hot months of the summer. A few are occasionally found during October, November, and December, and in one case a few males were found in a colony as late as January.

The males are essentially drones, and never exhibit any indications of industry or usefulness beyond their special function.

The Queen.

Adult queens are found in two forms, the winged and the wingless or deälated. The former is the virgin queen and the latter the fertile or egg-laying queen.

THE VIRGIN QUEEN.

When the queen reaches maturity she possesses long narrow wings which are rather opaque, gray in color, with the veins and stigma pale brown. In other respects she does not differ in appearance from the deälated queen, described on page 49. The wings are retained until after the queen has mated. Mating may take place during the nuptial flight in spring, but under some circumstances occurs within the nest without any flight being made. In the latter case the queen loses her wings shortly after fertilization and assumes her egg-laying duties in the home nest along with the older queens already there.

The earliest date at which we were able to find virgin queens in the outdoor colonies was April 1. Normally the first spring appearance of males precedes the first appearance of virgin queens by about three weeks.

Probably owing to the extreme shortness of the winged stage, winged queens are very hard to find in the outdoor nests. Although they must exist in large numbers every spring, they have been collected only occasionally. Most of our observations have been made upon specimens reared from pupæ in artificial nests.

An enormous and general flight of males and virgin queens was observed at Baton Rouge, La., in the spring of 1908, when large numbers of both sexes were captured in butterfly nets. On the other hand, during the spring of 1910 and that of 1911 no general flight was observed at New Orleans, La., although close watch was kept for one. Considerable numbers of males were seen flying around the city electric lights, and individual males were found flying aimlessly in various localities, but no queens were found with them, and no flight took place that could compare with the one noted at Baton Rouge in 1908.

At the same time a large number of queen pupæ transformed into winged queens in a large Janet style nest in the laboratory at Audubon Park, New Orleans, La. About an equal number of males were also present in the same nest, which the junior author watched closely for a flight. Nothing of the kind took place. On two occasions all ants were driven out of the nest—workers, males, and queens—to see if they could be induced to fly, but after wandering around for a time they all returned to the nest. The males could be seen actively pursuing the young queens inside of the nest, and although copulation was never actually observed, it must have taken place. In the course of time all the queens lost their wings and commenced to lay an enormous number of eggs. These eggs hatched, and finally developed into workers, proving that they were fertile. The males all died one by one, the last one disappearing when about two months old. It is therefore evident that the nuptial flight is not a necessity.

Under natural conditions the tendency toward a general flight may be partially controlled by the comparative numbers of males and young queens in the nests and colonies. The weather conditions about flying time may also exercise a very important influence upon the flying impulse; cool, cloudy, and rainy weather tending to restrain the inclination to flight, and warm, clear weather encouraging it. The severity of infestation may also be an important factor, as the ants would be more likely to fly in crowded communities than in localities where they are comparatively scarce.

The males are much more given to flight than the virgin queens. In the formicarium at Baton Rouge males were often found flying during their season, and seemed to have no preference as to time of flight. They were found flying on cloudy days as well as on clear ones and as frequently at night as in the day.

THE DEÄLATED, OR FERTILE, QUEEN.

The deälated queen is illustrated at *c*, figure 6. The deälated queen measures from 4.5 to 5 mm. in length, and queens measuring 6 mm. in length are not uncommon. It should be remarked here that during egg-laying periods the abdomen is much larger and longer than shown in the drawing. Normally the abdomen extends well beyond the tarsi of the hind legs. Unfortunately, a drawing can not show the delicate silky pubescence of the queen's body, and in life she is a far more beautiful creature than one would imagine from the drawing, correct though the latter is in anatomical detail.

The credit for first discovering and recognizing the queens of this species seems to belong to Mr. E. Baker, formerly superintendent of Audubon Park, New Orleans, and Prof. R. E. Blouin, formerly in charge of the Audubon Park Experiment Station.

The rate at which the queen deposits eggs varies with the prevailing temperature, and egg deposition is suspended entirely at low temperatures. In the artificial formicaries, already described, the number of eggs laid each day varied from 1 or 2 to as many as 50 or 60. Thirty per day is not far from the normal number in warm weather, when the food supply is abundant. It appears probable, however, that the queens deposit much more rapidly in large colonies, although from the nature of the case this can not be verified by direct observation. Egg deposition becomes very slow, or ceases entirely, in the artificial formicaries when the daily mean temperature falls below 68° F.

Practically all queens under observation have shown a disposition to suspend egg deposition entirely for longer or shorter periods, even when the occurrence of such periods can not be accounted for by low temperatures.

Fertile queens confined in test tubes without accompanying workers will often deposit a few eggs upon the walls of the tubes, but we have been totally unable to get colonies established by confining queens in artificial formicaries without workers accompanying them. This failure has not been due to any need of workers to feed or care for the queen, since she can feed herself from a supply of honey or sugar as readily as can a worker. Ordinarily she attends to her own toilet, and it is doubtful whether she is in reality "attended" by the workers in the sense that queen bees are attended.

Fertile queens do not confine themselves to the formicaries, either natural or artificial. Isolated deälated queens are not infrequently found wandering about buildings by themselves, and while the queens in artificial formicaries ordinarily stay within the nest proper, they have at times been seen outside of it. The finding of deälated queens wandering about, coupled with the fact that workers readily accept a queen from any source, seems to indicate that new colonies may sometimes be established in nature by workers associating with such wandering queens.

The length of life of the queen has never been determined, but there is no doubt that it extends over several years. Observations have been carried on with the same queen for considerably over a year.

The number of queens that may be found in a colony varies from one to several in the summer nests, and may reach into the hundreds in the large winter colonies. Queens never show the least hostility to each other or to the workers.

In the laboratory at Baton Rouge it was our custom to put all surplus queens into one colony, kept for the purpose, and leave them there until wanted. As many as several dozen queens were sometimes in this colony at once, all living peaceably together, and with the number of queens sometimes exceeding the number of workers.

Queens will frequently leave the nests with the workers, and will be observed in the foraging trails. Ten queens were collected in 30 minutes from a large trail of workers at New Orleans, La., during January, 1911. These were quite remote from the nearest nest. Any colony will immediately accept a strange queen without hesitation, and it is probable that a constant interchange of queens takes place between different colonies.

THE COLONY AS A WHOLE.

In size the colonies may vary from a dozen to many thousands of individuals and the number of queens present in a colony may vary from one to many hundreds. Although the Argentine ant is particularly aggressive and a hard fighter when coming in contact with most other species of ants, there is no apparent antagonism between separate colonies of its own kind. In fact, in heavily infested areas the workers and queens are so intermingled that the individuality of colonies is entirely lost sight of and all colonies appear to become part and parcel of one enormous community. In this respect the species may be said to have a more perfect social organization than even the honey bees, colonies of which are very distinct and the individuals of which usually repel with alacrity any visitor from another colony.

SEASONAL HISTORY.

In order to connect the scattered and individual life histories already given into one united whole it may be well to take a glance at the changes which occur in the ant colonies with the different seasons.

WINTER COLONIES.

The tendency of the Argentine ants to segregate into large winter colonies is very pronounced, and during the winter small colonies are very scarce, while nearly every protected situation will reveal the presence of enormous colonies. The stages which are represented in the nest are queens, workers, eggs, larvæ, and worker pupæ. During cold weather very few changes occur. The egg and larval periods are very much lengthened compared to the summer rate of development. The workers themselves move very little, and a large colony will subsist upon a small supply of food for long periods. During warm days heavy trails of workers emerge from the nests and carry back anything available for food. Except for this the ants may be considered as almost in hibernation during the winter months.

When the temperature falls as low as 60° F. the ants become sluggish, and foraging is largely suspended. At from 50° to 55° F. there is practically no foraging, and when this temperature is reached within the nest all adult ants become inactive, moving only occasionally, and even then with apparent difficulty. Activity is not strictly limited by these temperatures, however. On one occasion we found workers foraging in a building the interior of which was at 43° F., but the colony itself was outside the building and at a higher temperature. Very few refrigerators are cold enough to keep out these invaders when the outside temperature is warm enough for them to forage normally. On the very hottest days of summer they will enter refrigerators and even crawl into the ice chamber itself in order to reach some much-desired delicacy.

The most ideal location for the large winter colonies is in piles of decomposing vegetable matter. This material gives off a large quantity of heat during the process of rotting and consequently furnishes the ants with automatically heated apartments. In the same manner in which the ants seek optimum humidity conditions during the summer months, so they will regulate their location to preserve an even temperature in their nests in the winter. In cold weather they will carry the young stages toward the center of the piles, while in warmer weather they will be found near the surface.

Of course all the ants are not able to find ideal locations for the winter months, and great numbers have to locate themselves as well as they can. In open fields great numbers will be found under large ridges, or along ditch banks, particularly those which have a southern exposure. Many will burrow into the ground at the bases of large trees, where their tunnels and galleries will sometimes attain a depth of 12 to 14 inches.

Under Louisiana conditions the winter colonies are in evidence during the months of December, January, and February. The segregating tendency becomes marked during November, and the "divisional migration" normally occurs in February, but may not take place until March if the spring is cold and wet.

SUMMER COLONIES.

As soon as the weather gets warmer in the spring and food becomes abundant the large winter colonies break up into a great number of smaller colonies. These usually consist of one or more queens and a considerable number of workers, and they establish themselves in any good location where a supply of food is available. In places where food is exceptionally abundant these summer colonies will still remain very strong in numbers. Under large magnolia or oak trees, for example, colonies with 10 or 20 queens and many thousand workers are nearly always present.

A short time after the "divisional migration" has taken place in the early part of March, the large amount of food brought in by the workers, acting in conjunction with the warmer temperature, appears to stimulate the queens to lay great numbers of eggs. Most of the young stages carried through the winter or which have slowly matured during winter have by this time transformed into workers, so that the colonies consist of many workers, with comparatively few immature stages other than the eggs. Hatching takes place during the latter half of March, and the larvæ resulting from these eggs, after developing, transform into three classes of pupæ, viz, queen, male, and worker. Of these the male pupæ preponderate, with the workers a close second and queen pupæ a very poor third. The male pupæ appear in great numbers several days before the queen pupæ appear, which may possibly indicate a slightly longer larval period for the queens than for the males.

The adult winged males appear during the latter part of April and in May, and are in evidence in the nests until the beginning of June, when they begin to disappear. The winged queens appear a few days later. For some reason the winged queens are extraordinarily difficult to find in the nests, although their large size and long narrow wings should make them very conspicuous. However, only three winged queens have as yet been located in the nests under natural conditions in Louisiana. Fortunately the queen pupæ are not so difficult to discover, and a considerable number have been reared to the adult stage in Janet style nests in the laboratory, where most of our observations upon this stage have been made.

The appearance of the winged queens and males may or may not be followed by a nuptial flight. In either case, after the queens have become fertile they lose their wings and immediately start laying great numbers of eggs. These eggs develop into workers, with the exception of a few eggs which are laid in the late autumn and develop into males. It thus follows that the most rapid and conspicuous increase in numbers occurs during July, August, and September, when the eggs laid by the army of young queens complete their life history and transform into adult workers.

From then on to late in the fall the history of the colonies is very similar and devoid of incident. The numerical strength of the ants is constantly on the increase, and it is probable that the greatest natural dispersion occurs during the fall months, after the nests have been excessively crowded by the activity and increase of the summer.

During the latter part of October and in November the nights begin to get cool and we find the first inclination toward the formation of the winter colonies. The nests in exposed open situations are gradually deserted, and strong colonies accumulate in well-protected situations. This becomes more pronounced during the latter part of November, and in the beginning of December we find that the winter colonies with which we began are once more restored and that large united colonies are the rule, with small colonies the exception.

COMPOUND COLONIES OR COMMUNITIES.

Mention should not be omitted of the pronounced manner in which the social habit is extended beyond the limits of the individual nest or formicary. During the summer season of activity, and in heavily infested areas, communication between adjacent colonies is commonly observed. Not only the workers, but even fertile queens, travel from one colony to another. So closely are adjacent colonies associated in their activities that one can not do otherwise than consider a heavily infested area as one enormous "compound colony" or community.

MIGRATIONS.

Four distinct types of migration are exhibited by these ants, without including the long trips which they take in columns to and from the nests in search of food.

GENERAL MIGRATION OR DISPERSION.

By general migration is meant the slow but steady spread of the ants from infested points into adjacent uninfested territory. This is practically continuous, and while under natural conditions it may amount to only a few hundred feet per year it is greatly accelerated by artificial dissemination of the ants by man and his agencies.

MIGRATION TO FOOD SUPPLY.

When the supply of food becomes scarce in the immediate vicinity of a colony and a plentiful supply is discovered at a distance by the foraging workers, movement of the colony in toto to the neighborhood of the latter is not infrequent. Trees or plants harboring large numbers of scale insects are invariably surrounded by many populous colonies and the housewife who grows careless, permitting the ants to get food in plenty within her domicile, is soon repaid by having the premises overrun with the pests. One can easily note this form of migration by keeping a constant supply of honey or sirup in one place for several days and providing a suitable nesting place—such as a decaying log—near it. The latter is shortly occupied by one or more colonies.

CONCENTRATING MIGRATION.

Concentrating migration takes place within the infested territory and consists of the coming together of a large number of smaller colonies to form a single large colony. This migration occurs under various adverse conditions. During floods the ants will concentrate in great numbers upon elevated ground, or many colonies will carry their young stages up the same tree in order to get protection from the rising water. The most pronounced concentration, however, occurs at the approach of cold weather in the fall, when large numbers of colonies concentrate at one point to form the large winter colonies, often consisting of hundreds of queens and many thousands of workers. These colonies are fully described elsewhere.

DIVISIONAL MIGRATION.

Divisional migration is the opposite of concentrating migration, and is always in evidence after a large number of ants have concentrated at one place. It is most conspicuous in the spring, when the large winter colonies break up into a great number of smaller ones. These small colonies usually consist of one or more queens and a supply of workers. They distribute themselves in all directions from the large colony, and locate in any place which affords suitable protection and an available food supply.

NESTS OR NATURAL FORMICARIES.

Almost any place seems to be suitable for the location of nests of the Argentine ant, provided that light and water may be sufficiently excluded. Some of the situations in which they have been found are within hollow trees, beneath the rough bark of growing trees, in forks of trees, in rubbish and compost heaps, in decaying logs and timbers, beneath boxes and boards, under and in brick foundations, in stored household goods, beneath shingles on roofs, in rolls of wrapping paper, between walls of dwellings, in flowerpots, in piles of brick and stove wood, in garbage cans, in bags of sugar, in birds' nests, in discarded tin cans, in moss packing about the roots of nursery stock, and in straw packing containing glassware or china, in beehives with colonies of bees, under discarded tin roofing, around the roots of cotton, corn, sugar cane, and other growing crops, in railway cars, in various places on river steamboats and ocean-going vessels, in old clothes, under street-car tracks, under brick and concrete pavements, in greenhouse benches, inside the husks of roasting ears, inside of cotton bolls, in hollow iron electric-light posts, in the cracks and crevices in telephone and telegraph poles, and in the cinder ballast of railroad tracks.

Most of the situations named are used as permanent nesting places so long as weather conditions do not force the ants to find more suitable quarters. With the advent of unfavorable conditions the ants move their colonies with alacrity.

Many permanent nests are located in the tops of trees, in rotten branches, or in places where borers or termites have been working.

In rotten logs the ants will nearly always utilize old borer or termite tunnels for their nests, but do not appear to do any boring for themselves.

The facility with which entire colonies move is sometimes amazing. If a nest is disturbed the workers will frequently move all stages and establish another nest in a fresh location in the course of a very few minutes.

UNDERGROUND NESTS.

The ants seldom burrow to any great depth in the ground. The exceptions to this occur during hot, dry weather in the summer or during particularly cold spells in the winter. In the dry spells they evidently work downward in an endeavor to secure sufficient humidity for the young, while in the wintertime they sometimes go deep into the soil for the sake of protection from the cold. The deepest burrows which we have measured have been 14 inches in depth, but they usually average from 4 to 10 inches under normal conditions. These deep burrows are usually located at the foot of tree trunks, or under the ridges in cane, cotton, or corn fields.

Under more favorable circumstances, however, the underground galleries average from 1 to 4 inches in depth. In summer time the ants appear to do as little excavating as possible and seem to limit their efforts to excluding light and water. When the nests are located above ground, under boxes, boards, stones, etc., very little soil is used, and this is utilized in closing holes, etc., to keep out light and drafts.

WET-WEATHER NESTS OR SHEDS.

In wet situations or after heavy rains, when the ground has become soaked with water, the ants construct curious honeycombed structures around the bases of tree trunks. These are made of a great number of fine, loose particles of soil, usually supported by grass stems or loose leaves. They vary from one-half inch to as much as 5 inches in height, and sometimes cover an area of several square feet. They are built with great rapidity by the workers, and are extremely frail, falling in at the lightest touch. As a result of this weakness these nests disappear after a few days of dry weather, or are washed away by showers. They consist of a maze of covered galleries, in which large numbers of the larvæ and pupæ are placed. Their purpose appears to be to afford protection to the young stages until the ground gets dry enough for the underground galleries to be reoccupied, or they may be used to dry and "air" stages which have become wet, the loose construction permitting a liberal circulation of the air through the walls and ceilings. (See Pl. V.)

WET-WEATHER NEST OR SHED, ERECTED BY ARGENTINE ANTS DURING RAINY WEATHER. (ORIGINAL.)

GENERAL OBSERVATIONS.

AVERSION TO LIGHT.

The ants demonstrate in many ways their dislike of light, or at least their aversion to it. Their nests are always located in dark places, the ants are active all night, and their immature stages are never exposed to light except for brief periods in emergencies. If the opaque cover is removed from the top of an artificial ant nest for a considerable time, all the ants will come out and will refuse to return until the cover is replaced. Several experiments were made at Baton Rouge, La., in 1909, using different colored glasses for cage covers, but the ants were not satisfied unless the cover was absolutely opaque. While they will go anywhere into daylight in search of food, they will cover over as thoroughly as possible, with their protective "sheds," the colonies of scale insects, mealy-bugs, and aphides which they habitually frequent.

SENSE OF SMELL.

The workers exhibit a very keen sense of smell by the manner in which they locate certain foods. Meat which is wrapped in heavy wrapping paper will attract thousands of the insects, and they will work their way through the various folds and crevices of the paper in a surprising manner until they reach the meat itself. The workers readily secure entrance into the ordinary Mason or glass fruit jar, if one omits placing beneath the cover the rubber ring or gasket. No matter how tightly the cover is screwed on, the workers follow the spiral threading between cover and glass until the interior is reached.

Another illustration of the sense of smell is seen in the readiness with which trails are restored when broken or disturbed. If a line of ants be moving across a floor in a circuitous line, for example, and all ants be swept from the floor with a broom, the next on-coming workers will follow exactly the original course. This may be repeated indefinitely and the trail will always be established in the original location. If, however, some strong-smelling substance, like oil of citronella or kerosene, be placed upon the trail the ants become confused at once and by their aimless wandering about show plainly that they can not locate the original pathway.

SIGHT.

While the Argentine ants are extremely sensitive to light, it is doubtful if they possess the sense of sight. The action of light can generally be described as exerting a repelling influence upon them and they avoid it as much as they can. That they do not use eyesight in locating food substances has long been recognized. Their trails will frequently encircle the spot which they ultimately hope to attain. They will never attempt to avoid a hand threatening from any direction as a spider will do, but will continue going ahead until their antennæ touch the obstacle. The manner in which they religiously follow their trails and the confusion which results when these trails are destroyed proves that they do not trust to a sense of sight in traveling. This is illustrated again by the fact that they are active all night in the darkest situations.

HEARING.

The sense of hearing in these insects is not acute, even if indeed it be developed at all. The ants are not disturbed by ordinary noises, such as talking or working about the nests. If, however, one emits a loud shout within a few inches of the formicary, or fires a pistol near it, the ants are thrown into the confusion and excitement characteristic of them when disturbed. It seems not impossible that in such cases they have detected actual vibrations of the surface on which they are located, due to the action of the sound waves. Strangely enough, in situations where loud noises and vibrations are of constant occurrence, the ants become accustomed to them. Thus at New Iberia, La., we found ant colonies between and under the ties of a railroad track over which many trains passed daily.

CANNIBALISM.

Cannibalism in any form is extremely rare in the case of this species, and true cannibalism has not yet been observed. The only thing at all approaching it was observed in the case of a colony kept in our formicarium, the workers of which developed a habit of eating the eggs as fast as they were deposited by the queen. This colony was established in an artificial formicary on November 27, 1907, and from that time until the early part of July, 1908, larvæ were reared more or less continuously and in the usual numbers. In July it was noticed that the number of immature stages became steadily smaller, and on July 28 a quick removal of the cover from the cage disclosed several workers in the act of eating eggs. Thinking that this might be due to lack of sufficient food of an animal nature fresh meat was at once furnished the colony and was thereafter kept continually accessible. In spite of this the egg-eating habit continued until November 5, 1908, all eggs being eaten within a few hours after their deposition by the queen. By this time the number of workers in the colony had been reduced to six, and by November 11 the queen and remaining workers were dead, the colony having apparently been exterminated through lack of any maturing workers to replace those dying from old age and accident.

SANITATION.

All adult members of the colony keep themselves scrupulously clean, after the manner of most hymenopterous insects. Workers divest their bodies and legs of foreign matter by persistent rubbing of the body and antennæ with their legs, while the tarsi are cleaned by pulling them between the mandibles. At times we have seen the workers assisting each other in these operations, particularly when some gummy or adhesive substance became attached to the head and mandibles. On one occasion the senior author observed one worker industriously cleaning the mandibles of a companion. During this operation, which lasted for several minutes, the worker receiving the kindly ministrations stood with her head well raised, mandibles extended, and feet firmly braced, while the teeth of her mandibles were thoroughly cleaned by those of her sister.

The queen is occasionally cleaned and groomed by the workers, but for the most part she attends to her own toilet, being nearly as skillful and dextrous at the task as are the workers themselves. Larvæ and pupæ are groomed from time to time, this grooming being done with the tongues of the workers.

Dead adults or larvæ are not tolerated within the colony and are removed immediately. Dead adults are also invariably removed from the vicinity of any food supply which the ants are visiting.

Decaying animal matter is not tolerated in near proximity to the nests. If the ants are unable to remove it bodily they will carry particles of earth with which to bury it, much after the manner adopted by honey bees in covering with propolis any dead animal which they can not remove from their hives. The following example will serve to illustrate this habit: A small minnow, recently dead, was placed near the entrance of one of the artificial formicaries. It was immediately covered with workers, and in the course of a few hours all the soft portions had been torn apart and carried into the formicary, little remaining except the bones and skin. On the following day another fresh minnow was given the same colony. While this was torn apart the same as the first one, it did not receive nearly as much attention. When a third minnow was given the colony the workers paid no attention to it, having evidently had fish "a plenty." As soon as it commenced to decay the workers brought particles of trash and dirt from their nest and piled these up around the minnow. This work they continued for three days, by the end of which time the remains of the minnow were completely buried. Decaying fruit left near the artificial nests was treated in the same manner.

RATE OF TRAVEL.

One of our associates, Mr. G. D. Smith, made some interesting experiments to determine how rapidly the workers travel both in going to food and in returning from it with their loads. Sirup was placed on the comparatively smooth floor of an infested building, and when the ants were visiting it in large numbers a distance of 6 inches was measured off on one of the principal "trails." The rate of travel of individuals over this 6 inches was then noted. Mr. Smith found that the average time required to travel the 6 inches when going to the food supply was 12½ seconds, or at the rate of 29 inches per minute. When returning from the food, presumably with their stomachs filled with sirup, the average time required to travel the 6 inches was 21 seconds, or at the rate of 17 inches per minute. The rapidity with which the foraging ants can travel (29 inches a minute, or 145 feet per hour) explains their ability to keep thoroughly patroled all of the walls, furniture, and other contents of a building within their reach. It explains at the same time the reason for their so quickly locating food supplies left accessible to them.

The rate of travel over horizontal polished surfaces is, however, much greater than that cited above. On a tiled floor or on the top of a glass showcase their speed is two or three times as great as that just given. In fact, it is almost impossible to capture the workers on a tiled floor, so rapidly do they move. This same degree of speed is not attained on vertical polished surfaces, such as window panes.

STORAGE OF FOOD.

Only to a very small extent do the workers of this species provision their nests for future emergencies. They are given to carrying lettuce seed, and perhaps other seeds, into their colonies at times, but the bulk of these seed are used up in a short time, and in a few days all have disappeared. Apparently the desire to carry in a full supply of any desirable food is the cause for this storage, rather than any fixed instinct toward providing the colony with permanent stores. In like manner, when the ants have access to large amounts of granulated sugar, the granules are carried into the nest and deposited in various parts of the galleries, there being no place set aside, apparently, as a granary or storehouse. Like the seeds above mentioned, the supply of sugar is consumed within a few hours or a few days after its acquisition. Particles of meat are deposited in the galleries in similar manner, often to be neglected until they are too dry to be of much service. Even when dried, however, they seem to furnish a relish or variation in the diet, as workers may be seen, from time to time, rasping off small shreds with their mandibles and then masticating these with apparent enjoyment.

Liquid food, such as honeydew, sirup, etc., is not deposited anywhere in the nest, and if any liquid food is kept in reserve at all it is merely that which is retained in the stomachs of the workers. Apparently liquid food is consumed soon after being brought into the formicary, as evidenced by the following observation:

Some fresh honey was placed upon the food table of an artificial formicary, and when the first worker was observed to leave the honey the top of the formicary was removed and her actions observed. Upon entering the colony she was met by three other workers, all of which placed their mandibles to hers. As she regurgitated the liquid they sipped it up. When one of these workers had received a sufficient quantity she retired and another took her place, as many as four or five workers sometimes feeding at once. The foraging worker in this manner supplied about 15 others with food, after which, her supply being apparently exhausted, she left the group of assembled feeders and went her way, leaving some of them hungry and still unsatisfied.

RELATIONS WITH OTHER ARTHROPODA.

FORMICIDÆ.

It may be said in general that the Argentine ant will not tolerate the presence of other species of ants within its domains. There are a few exceptions to this rule. In 1908 Mr. G. A. Runner and the junior author found a small colony of *Monomorium minimum* Buckley living in the same tree stump with a colony of Argentine ants at Baton Rouge. The Monomorium colony possessed a number of young stages and appeared to be unmolested by the Argentine ants. The following season, however, the Argentine ants were in full possession of the stump, and no trace of Monomorium could be found. During the same summer another small colony of *M. minimum* was noticed living in a fig tree in territory heavily infested with the Argentine ant. This was also at Baton Rouge. This colony was observed for several weeks, but finally died out, though it could not be determined whether the Argentine ants were responsible for its annihilation.

In another case a log was split open, disclosing vigorous colonies of both *Iridomyrmex humilis* and *M. minimum*. Whether the ants were occupying the same chambers or whether the nests were in close but disconnected chambers could not be ascertained, but the Monomorium workers were seen to pick up and carry away the larvæ of *humilis* with as much solicitude as they did their own. Just what relationship obtains between these two species we have not been able to determine, but certain it is that *humilis* tolerates this small species to a much greater extent than it does any other ant. At Baton Rouge *Monomorium minimum* still seems to maintain its normal abundance, and this certainly can not be said of any other species of ant.

An account of the methods used by the Argentine ants in overcoming other species of ants was published by the senior author[1] in the Journal of Economic Entomology.

Prof. W. M. Wheeler, in Entomological News for January, 1906, gives an interesting account of the way in which this species obtained a foothold in Madeira and supplanted another introduced species, *Pheidole megacephala* Fabr.

COCCIDÆ AND APHIDIDÆ.

The liquid excretions of the various species of scale insects and aphides form one of the chief sources of food for the Argentine ant. The large variety of trees and plants in the South gives support to a great number of coccids and plant lice, and these insects in turn yield sustenance to myriads of ants. In return for this food supply the ants shelter and protect these insects, with the result that the latter increase beyond all customary proportions. As the result of this symbiotic manner of living we find that a comparatively small area of land frequently supports enormous numbers of ants, scale insects, and aphides, while the plants themselves become so severely infested that some of them are killed and many more seriously injured.

All through the summer months, and also during warm days in winter, heavy streams of ants can be seen ascending and descending the trees and plants; the ascending ants empty, the descending ones heavily laden with the liquid excretion which they have obtained from the various scale insects and plant lice. During the summer this activity is well-nigh endless, and the ant trails can be observed at all hours of the day and night. All scales and aphides are closely attended, but some species appear to attract more of the ants than do others. The large unarmored scales and the plant lice appear to be the chief favorites, the mealy-bugs, however, following them very closely in this regard.

Aside from protecting the aphides and scale insects from ladybird beetles and constructing earthen shelters over them, the ants only rarely foster them directly. In one case only have insects of this character been actually found in the ants' nests. In January, 1909, Mr. G. D. Smith, in excavating an underground colony at Baton Rouge, found a number of barnacle scales, *Ceroplastes cirripediformis* Comst., on tree roots which passed through the formicary. These scale insects were full grown and vigorous. At this season of the year no live scales of this species could be found above ground. It may be remarked in passing that this is one of the species to which the ants are very attentive during the summer and autumn months.

[1] Notes on the Habits of the Argentine or "New Orleans" Ant, *Iridomyrmex humilis* Mayr. Wilmon Newell, Journ. Econ. Ent., vol. 1, no. 1, pp. 21–34, 1908.

Workers are often seen carrying plant lice and scale insects, and this fact, coupled with the observed phenomenal spread of scales in ant-infested territory, brings one inevitably to the conclusion that the workers carry and establish these pests upon new growth and upon new host plants.

During March, 1910, a considerable number of adult female scale insects were found embedded in a band of "tree sticky" placed around a magnolia tree to repel the ants. This band was located 4 feet from the ground. The scale insects were a species of Odonaspis [1] which is found upon Bermuda grass close to the surface of the ground. There was apparently no other way for these insects to get up the tree except through the transporting agencies of the ants.

On sugar cane the ants have frequently been seen carrying around small sugar-cane mealy-bugs. They do not appear to pick them up unless they are rudely disturbed or frightened, but the fact remains that they have been seen transporting them. Experiments made by the junior author showed that the ants would pay no attention to the larval mealy-bugs until after the latter had commenced to feed on the canes and produce exudations. The following three paragraphs are quoted from our notes:

> Placed a piece of paper on which were about 2,000 "seed mealy-bugs" across a strong ant trail, and weighted it down flat, so that the ants could not get underneath it. At first the ants were bewildered at losing their trail, and ran over the paper in all directions. They absolutely refused to notice the young mealy-bugs, and after a while reestablished their trail *across* the paper, and commenced traveling the same as before. The mealy-bugs were swarming directly across the trail, but the ants paid no attention to them.
>
> This seems to indicate that the ants have no dealings with the mealy-bugs until they begin to secrete the juices from the cane stalks. These young mealy-bugs had never fed, being taken directly from the tube in which they were hatched. Thus they would probably not have excreted any liquid. At the same time the ants did not show any hostility toward them.
>
> The eggs are out of reach of the ants when they are enveloped in the egg mass, as the waxy covering appears to entangle the feet of the ants, being slightly sticky and adhesive. The egg stage and young larval stages are therefore removed from the sphere of the ants' influence.

Even though the actual transportation of plant lice, aphides, and mealy-bugs by the ants may not assume much economic importance, there is, nevertheless, no doubt that the ants assist these insects greatly in other ways. They build shelters over them, these consisting of fine particles of earth, protecting them from storms and hindering the attacks of parasites. These shelters have been noticed in many different localities. In Bulletin 52, Bureau of Entomology, Mr. E. S. G. Titus gives an illustration of a large shed built by the ants over the surface of a persimmon, protecting a number of Florida wax scales (*Ceroplastes floridensis* Comst.). These sheds are also present

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[1] Determined by Mr. E. R. Sasscer.

in great numbers on sugar cane, Johnson grass, willows, and oaks, and, in fact, in all places where a number of coccids or plant lice are exposed to the weather.

The stimulation resulting from the attentions of the ants while collecting the sweet liquids appears to have the effect of greatly encouraging the numerical increase of the aphidids and coccids. During the summer of 1910 the junior author reared several generations of sugar-cane mealy-bugs on sugar cane planted in large pots. One-half of these pots were isolated from the Argentine ants, while to the others they were allowed free access. The mealy-bugs grew and multiplied in both lots of cane, but there was great difference between the thriftiness of the isolated and nonisolated insects. In the pots to which the ants had access the mealy-bugs multiplied so freely that finally they almost smothered out the sugar cane with their cottony egg masses. In the isolated pots, while the mealy-bugs increased in numbers, they were not nearly so numerous or healthy looking as in the ant-infested pots. At the end of two months the number of mealy-bugs in the ant-infested pots probably exceeded the number of mealy-bugs in the isolated pots to the extent of at least five to one.

That the same conditions exist in the cane fields is shown by the number of mealy-bugs which can be found in the fields infested by the Argentine ant as compared to their scarcity in fields not infested by the ant. Only one field under the latter conditions has been discovered as yet, but it has been watched closely for two years. The mealy-bugs have never become sufficiently numerous to attract the attention of the working hands, and they can be found only with considerable difficulty. On the other hand, in the fields where the mealy-bugs and ants are associated the former have become so numerous that the white cottony egg masses can be easily observed from the road while driving through the fields.

The same thing holds true with scale insects generally. In the orange groves invasion by the ants is followed by a rapid increase of scale insects, particularly the chaff scale (*Parlatoria pergandii* Comst.) and various species of Lecanium. So rapidly do these scales increase that, unless prompt measures are taken against the ants, the second year of infestation shows a severe curtailment of the crop, and the fourth or fifth year witnesses the death of many of the trees. The rapid decline of orange trees under conditions of heavy ant infestation is well illustrated by Plate VI, which shows a tree after exposure to attacks of the ants and chaff scales for three seasons.

The ants constantly attend the citrus white fly (*Aleyrodes citri* R. & H.), and a marked increase in this injurious pest always accompanies ant infestation.

ORANGE TREE AFTER EXPOSURE TO ARGENTINE ANTS FOR THREE SEASONS. (ORIGINAL.)

During a period of 18 months 48 species of scale insects have been collected in Audubon Park, New Orleans, all of which are attended by the Argentine ant. Many of these species, however, are visited sparingly, and are evidently regarded as sources of food when the more popular species fail to furnish a sufficient amount for the needs of the ants. A few species are particularly favored by the ants, and the trees and plants upon which they occur are always crowded with large numbers of the workers.

Among these favored species may be mentioned the Magnolia scale (*Neolecanium cornuparvum* Thro), which is found upon the various magnolia trees. This scale is very large and unarmored, and the young scales appear in great numbers during February and March. As this is the period during which the ants have the greatest difficulty in securing sufficient food it naturally follows that they concentrate upon the magnolia trees in immense numbers, and the soil at the bases of the trees is turned into gigantic ant nests. During June and July this scale is brought under control by the larva of a small black ladybeetle, and the number of ants in the magnolia trees falls off greatly. By this time, however, an abundance of scale insects and plant lice of many different species can be found everywhere, and the ants do not have to place such dependence upon the magnolia scale.

Another species which attracts great numbers of workers is the soft scale (*Coccus hesperidum* L.). This species has been collected upon a variety of plants in Audubon Park, among which may be mentioned the orange, banana, *Camellia japonica*, coral tree, cocoa tree, rubber trees, myrtle, and maidenhair ferns. This scale can be found in all stages at almost any time of the year, and is always heavily attended by ants.

Other important scale insects from the Argentine ant's point of view are the sugar-cane mealy-bug (*Pseudococcus calceolariæ* Mask.), the two barnacle scales (*Ceroplastes cirripediformis* Comst. and *C. floridensis* Comst.), and the black scale (*Saissetia oleæ* Bern.). The last three species are found upon a variety of plants.

A complete list of the scale insects and aphides which this ant attends would comprise a check list of these species for the entire ant-infested territory. The following list, however, includes the more important species upon various plants and crops which are the most eagerly sought after by the ants. Most of the determinations have been made at Washington, D. C., through the courtesy of Messrs. E. R. Sasscer, J. G. Sanders, and Theo. Pergande. So far as possible the species most attractive to the ants have been placed nearest the host plants, and they follow in order of preference within certain limits.

LIST OF COCCIDÆ AND APHIDIDÆ ATTENDED BY THE ARGENTINE ANT.

Upon bamboos: *Asterolecanium bambusæ* Bdv., *Odonaspis secreta* Ckll., *Odonaspis inusitata* Green.

Upon banana: *Coccus hesperidum* L., *Chrysomphalus aonidum* L.

Upon cotton: *Aphis gossypii* Glov.

Upon corn: Undetermined aphis (probably *Aphis maidis* Fitch).

Upon figs: *Pseudococcus citri* Risso, *Lecaniodiaspis* sp., *Aspidiotus camelliæ* Sign.

Upon hickory, elm, hackberry, and various shade trees: *Pseudococcus* sp., *Ceroplastes cirripediformis* Comst., *Ceroplastes floridensis* Comst., *Chionaspis longiloba* Cooley, *Chionaspis americana* Johnson.

Upon magnolias: *Neolecanium cornuparvum* Thro, *Aspidiotus camelliæ* Sign., *Toumeyella turgida* Ckll.

Upon mulberries: *Chrysomphalus tenebricosus* Comst.

Upon oaks: *Kermes galliformis* Riley, *Eulecanium caryæ* Fitch, *Eulecanium quercifex* Fitch, various aphidids.

Upon orange: *Coccus hesperidum* L., *Parlatoria pergandii* Comst., *Lepidosaphes beckii* Newm., *Lepidosaphes gloverii* Pack., *Chrysomphalus aonidum* L., *Aphis gossypii* Glov.; also the white fly, *Aleyrodes citri* R. & H.

Upon palms and other ornamentals: *Coccus hesperidum* L., *Eucalymnatus tessellatus* Sign., *Aspidiotus lataniæ* Sign., *Aspidiotus hederæ* Vall., *Chrysomphalus dictyospermi* Morg.

Upon peach, pear, and other fruits: *Aspidiotus perniciosus* Comst., *Aulacaspis pentagona* Targ., various aphidids.

Upon persimmons: *Ceroplastes cirripediformis* Comst., *Eulecanium corni* Bouché, *Pulvinaria vitis* L.

Upon strawberry: *Aphis forbesi* Weed.

Upon sugar cane: *Pseudococcus calceolariæ* Mask., *Aphis gossypii* Glov.

Upon sweet gum: *Cryptophyllaspis liquidambaris* Kotinsky.

Upon various shrubs: *Coccus hesperidum* L., *Saissetia oleæ* Bern., *Pulvinaria cupaniæ* Ckll., *Aspidiotus lataniæ* Sign., *Chrysomphalus aonidum* L.

Upon willows: *Eulecanium nigrofasciatum* Perg., *Pseudococcus* sp. (near *citri*), *Chionaspis salicis-nigræ* Walsh, *Aspidiotus perniciosus* Comst., various undetermined aphidids.

In considering the remarkable increase in scale insects and aphidids which invariably accompanies heavy infestation by this ant one can not avoid taking into account the persistence with which the ants drive away ladybird beetles which attempt to prey upon the insects fostered by the ants. So thoroughly are the Coccidæ and Aphididæ protected in this manner that it is rare that a ladybird can be found at all on the infested trees. The only exceptions to this rule thus far noted are a species of Pentilia, a few specimens of which the senior author found in an infested orange grove below New Orleans, and the coccinellid mentioned before as preying upon the magnolia scale.

ANTAGONISM TOWARD OTHER INSECTS.

The Argentine ant is strongly antagonistic to nearly all forms of insect life, with the exception of the Coccidæ and Aphididæ. The amount of damage it is able to inflict upon other insects, however, is governed by the strength, fleetness, structure, or habits of the insect attacked. Thus it is able to destroy house flies, butterflies, mosquitoes, etc., only when the latter are hurt or disabled, as under ordinary conditions they are much too swift for the ants to catch. In the same manner nearly all forms of beetles are strong enough to escape from the ants when caught, and their external covering is so hard that the ants can make no impression upon it; but an injured beetle of any kind is very quickly overcome by the numbers of the ants, and his body is finally cleaned out of the shell piecemeal. Newly emerged adult beetles of many species are often captured by the ants before their chitinous integument has hardened, and they are then an easy prey.

Cutworms and hairless caterpillars found upon the surface of the ground are destroyed in great numbers; but the ants will not burrow into the ground after hidden cutworms, and most hairy caterpillars appear to be invulnerable to them. Web-spinning caterpillars are also safe from their attacks, and the spiny, mealy projections surrounding coccinellid or ladybeetle larvæ appear to protect these latter very effectively. Insects and other small related animals which the ants can meet upon even terms are, however, almost always overcome; not so much on account of the individual valor of the Argentine ants as by reason of their overpowering numbers.

Nests of the social wasps, *Polistes* sp., which were brought into our laboratory as food supplies for cultures of Pediculoides, were quickly found by foraging workers, and the latter soon killed and removed all of the wasp larvæ and pupæ that could be reached. Many of the cells in the comb of Polistes were entirely or partially open so that the ants had ready access to the insects inside. As the prey in this case was too large to be handled by individual ants, as many as two or three dozen would unite in removing a single wasp pupa or larva. Even the adult wasps, just emerging from the cells, were set upon by the ants before they had attained sufficient strength to escape by flight. More and more of the ants would get on these adult wasps until the latter were helpless and were dragged away, still alive, by scores of the worker ants. So anxious were the ants to get at these wasps that when the latter were placed on top of a fruit jar standing in a tray of water the ants swam the 3 inches of fresh water, climbed the glass sides of the jar, and continued their attacks as before; nor could they be made to desist until oil of sassafras was placed upon the water.

The nests of mud-dauber wasps, *Pelopæus* sp., were also brought into the laboratory for the same use as the Polistes. The mud-dauber larvæ were of course inaccessible to the ants, but parasitic flies [1] which emerged from these were seized by the ants as fast as

[1] Identified by Mr. C. H. Tyler Townsend as a species of Pachyophthalmus.

they emerged and were summarily disposed of in the same manner as were the Polistes. Invariably the flies were seized before enough time had elapsed for their wings to expand and dry, and only a very small percentage of them escaped the ants.

Cockroaches are esteemed a great delicacy by these ants, and while the workers are not able to capture uninjured roaches, they attack in great numbers any roach so unlucky as to be injured. Dead cockroaches are also eagerly visited by the ants and all soft parts removed. It seems almost retribution that one of the few natural enemies of the Argentine ant should itself be a larval cockroach (*Thyrsocera cincta* Burm.), mention of which is made on a following page.

THE ARGENTINE ANT AND THE BOLL WEEVIL.

Prior to the advent of the boll weevil in the territory infested by the Argentine ant there was considerable speculation as to whether so combative an ant might not prove to be an insect of some value in protecting the cotton crop against weevil ravages. Any hopes of this kind which were entertained have not thus far been realized. In one rather unimportant respect the ants seem to annoy the boll weevils. At Baton Rouge the Louisiana Experiment Station had a few small plats of cotton, aggregating less than an acre, within the city limits and in a section where the Argentine ants were exceedingly abundant. The plats were bordered on one side by the Louisiana State University campus, with its large oak trees sheltering hundreds of ant colonies, and on the other side by the batture of the Mississippi River, which was likewise a seething mass of ant colonies. The ground in the cotton plats was therefore heavily infested by the ants, and when this field also became infested by the boll weevil the outcome was watched with considerable interest. During September, 1909, it was found that the ants, in their steady patrol of the plants while attending cotton lice, worried the adult boll weevils considerably. Whenever an ant encountered a boll weevil it would nip the legs of the latter, usually causing the weevil to fly to another plant or drop to the ground. In no case were the ants found killing fully matured weevils, though in a few instances they did attack and kill unhardened weevils which had just issued from infested squares. The great abundance of ants in these plats evidently resulted in many of the weevils being driven off, for something of a top crop was produced in the fall of 1909. It is worthy of note in this connection that the heavy ant infestation obtaining in these plats will not be duplicated in large cotton fields for many years to come, if, indeed, such will ever be the case. Conditions in large cotton areas are not such as to attract the Argentine ant in numbers. It was also of interest to note that the presence of the ants in these particular plats resulted in an abnormally heavy infestation of the plants by the "cotton louse," *Aphis gossypii* Glov., throughout the entire growing season.

Were the jaws of the Argentine ant powerful enough to pierce the cotton squares so that they could remove the boll-weevil larvæ, and were they so inclined, they might be of substantial service in destroying this pest. However, repeated experiments made by the senior author proved conclusively that the ants would not do this. The following experiment will serve as an illustration of those carried out:

On July 10, 1908, three weevil-infested squares were placed on the food table of an Argentine-ant colony in the insectary at Baton Rouge. The workers crawled over them constantly for three hours, but made no attempt to bite into them and evidently did not suspect the presence of food inside of them. Afterwards the weevil larvæ were removed from the squares and placed, alive and uninjured, on the food table. The ants attacked them, hesitatingly at first and then with avidity, and in the course of a minute one large weevil larva was dragged an inch across the food table, vertically another inch, and into the vestibule of the nest. Another lot of weevil-infested squares was placed on a board inside the insectary where the ants had been securing other food for several days. The squares were left here for five hours, during which time the ants crawled over them constantly, but made no effort to open them. The ends of the squares were then broken off so that the ants could enter them if they chose. None entered. Presently some of the weevil larvæ wriggled themselves completely out of the squares and they were then attacked by the ants and dragged away.

These and similar experiments lead one to the conclusion that the Argentine ant will never be of material value as an enemy of the boll weevil. In fact, in this respect it can not hope to approach in efficiency the common native fire ant, *Solenopsis geminata* Fab.

BENEFICIAL ASPECTS OF THE ANT'S ACTIVITIES.

In some few cases the predatory habits of the ant take on a beneficial aspect. In the summer of 1908 Mr. R. C. Treherne was associated with us in the investigation of the sorghum midge (*Diplosis*) *Contarinia sorghicola* Coq. In the course of his work Mr. Treherne placed heads of sorghum, milo maize, etc., in cages for the purpose of rearing the adult midges. In a very short time he found that the Argentine ants were invading the cages and were carrying away the adult midges almost as fast as they emerged. (See fig. 10, from drawing by Mr. Treherne.) To continue the observations it was necessary to isolate the cages over trays of water or oil. For the purpose of more closely observing the capture of the midges by the ants, about 200 of the former were placed inside a large glass bell jar. The jar was raised a trifle at its lower edge by the insertion of a match. In the course of three minutes two Argentine workers had found their way into the jar and each had captured an adult midge. Other workers soon followed. In about 15 minutes fully three-fourths of the flies had been captured and at the end of 30 minutes all had been either captured and carried away or were in possession of workers. The first midges captured were quickly carried to the ants' nest, but presently the workers seemed less appreciative of their prizes and spent much more time in playing with them, although in but few cases were the midges relinquished. Occasionally a midge would succeed in taking flight after a worker had taken hold of it; in such cases worker and midge tumbled to the floor, but without the midge being released. That the workers were unable to see the midges was made evident many times over in this experiment, for workers repeatedly passed within one-sixteenth of an inch of their prey without even changing the direction of travel. Only when the worker touched the midge with her antennæ could she locate the latter.

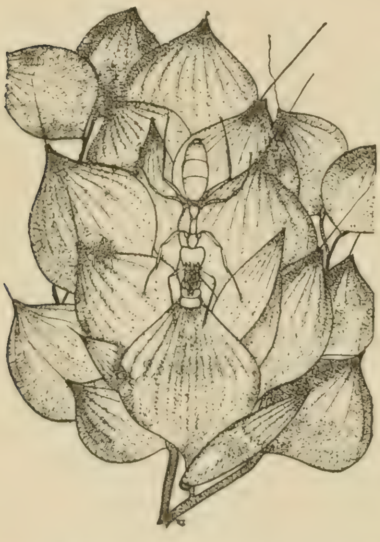

FIG. 10.—Argentine ant removing the pupa of a sorghum midge from between the glumes of a sorghum head. (Original.)

Later on it was found that the ants thoroughly patrolled the sorghum heads in the field and not only captured the midges as they were emerging from their pupal cases between the glumes but also removed the pupæ themselves. That this ant is by far the most important natural enemy of the sorghum midge in southern Louisiana there can be no doubt,[1] but its services in this regard do not begin to expiate its many other crimes.

The Argentine ant is a persistent enemy of the white ants, or termites, and will capture and kill them at every opportunity. Especially during the mating season of the termites every male and queen that falls to earth is quickly set upon by the ants. The latter cut off their wings, and frequently also legs and antennæ, and then bear them away, still alive, to their nests. Wherever colonies of termites are accidentally exposed the ants soon destroy them, carrying away all stages. Not infrequently one finds the Argentine ant colonies domiciled in the old termite galleries in logs and timbers, the assumption being that the ants had first destroyed the termite colonies and then taken possession of their domiciles. When winged termites were

[1] Dean, Harper, Bul. 85, Part IV, rev., Bur. Ent., U. S. Dept. Agr., p. 57, 1911.

furnished to the ants in our artificial formicaries the wings were quickly amputated, although the termite itself was not always carried into the formicary, possibly because, in such cases, the ants were already bountifully supplied with animal food.

The Rev. Albert Biever, of New Orleans, whose observations on the Argentine ant are elsewhere mentioned, is authority for the statement that these ants have in many cases entirely exterminated the bedbugs in the houses of many of the poorer people in New Orleans.

Father Biever also states that in some sections of the city the "red bug," or chigger, has entirely disappeared with the advent of the ants. The junior author's observations in Audubon Park, New Orleans, are of similar nature, the chiggers being entirely absent where once they were a plague. At the same time the senior author still retains some very unpleasant memories of daily attacks by chiggers on premises in Baton Rouge which were heavily infested by the ants. We are thus unable, as yet, to state with certainty that the ants always destroy these annoying pests.

The attitude of the Argentine ant toward other species of ants has already been discussed and its action in destroying other ants takes on either a beneficial or injurious aspect according to whether the annihilated ant is itself one of beneficial or injurious nature.

SYMBIOTIC RELATIONS.

The relationships which exist between the Argentine ant and those insects or other creatures which it tolerates in its nests or in the near vicinity can not be considered as symbiosis, yet mention of these may be permissible at this point. Despite the hostility which these ants exhibit toward most insects which are not directly of service to them, a few instances have been noted in which other insects and crustaceans were permitted to live in close proximity to their nests, or even within the nests themselves.

Certain staphylinid beetles have frequently been found in decayed logs which were full of Argentine ants. Efforts have been made to keep some of these beetles in the artificial formicaries along with colonies of the ant under observation, but the results have been variable. In experiments of this kind made by the junior author the beetles were invariably set upon by the ants in the formicary and either killed or driven out. In similar experiments by the senior author no apparent attention was paid to the beetles, so far as could be observed, and they were tolerated in the formicary for a week or longer, after which they evidently left of their own accord.

On August 17, 1909, a large ant nest was discovered in Baton Rouge under a large dry-goods box. About 20 specimens of "spittle insects" (family Cercopidæ) were also present in the same nest, attached to straws of grass. These were apparently protected from the ants by the wet, sticky secretion which surrounded them. This is the only instance, however, in which the presence of these insects has been recorded in the colonies.

Sowbugs (Oniscidæ) apparently go among the Argentine ants with impunity. These little crustaceans are often found in the ant nest, especially if they are located under boards or boxes in moist places. There does not appear to be any relationship existing, and the ants are apparently indifferent to their presence.

With the exception of two species of mites, which are true inquilines in the ant colonies, the Argentine ant does not pay much attention to the majority of mites and spiders. Mention is made on a later page of certain spiders which prey upon the ants to a limited extent. The cattle tick (*Margaropus annulatus* Say) flourishes with undiminished vigor in the ant-infested region, and the same may be said of the "red mite" of the orange and the red spider of ornamental plants (*Tetranychus bimaculatus* Harv.).

INQUILINES.

Only two true inquilines, both mites, have thus far been found in the colonies of the Argentine ant. These were first discovered at Baton Rouge by the senior author in 1908, and were subsequently found in various localities and in nests of various kinds, usually in those located in masses of decaying vegetation or litter. Soon after they were first found specimens were sent to Dr. L. O. Howard, who submitted them to Mr. Nathan Banks, of the Bureau of Entomology. Mr. Banks found them to be new, and his descriptions of them were published in the Journal of Economic Entomology, volume 1, pages 263 and 264 (1908), together with notes on their habits, by the senior author.

NATURAL CONTROL.

As compared with most injurious insects which reach great abundance the Argentine ant is remarkably free from natural enemies, and very few of these have been noted during the course of our investigations, while even these few are of little importance. No true parasites of this ant have been observed and apparently the only enemies are predatory ones.

NATURAL ENEMIES.

INSECTS AND SPIDERS.

In 1909 Mr. Harper Dean observed a small cockroach capturing Argentine ant workers in a room in Baton Rouge, La. This insect from time to time caught up and ate workers which were traveling about the floor. The cockroach was captured and sent to the Bureau of Entomology, where it was identified by Mr. A. N. Caudell as a nymph of *Thyrsocera cincta* Burm., a species occurring in the southern United States, Mexico, and Central America. A similar habit by individuals of this species was subsequently observed by the senior author on one or two occasions, but the number of ants destroyed by this insect is certainly inappreciable.

A jumping spider of the family Attidæ was seen to capture a few workers, and various species of the cobweb weavers (Theridiidæ) had the habit of reposing beneath the stands supporting our artificial formicaries and there depleting the colonies under observation. In fact, so persistent were they that it was necessary to examine the stands daily and destroy these spiders. Among the most abundant of these was one which was identified by the late Prof. B. H. Guilbeau, of the Louisiana State University, as *Theridium tepidariorum*. Spiders of this family were not observed destroying ants in outdoor colonies, but it is possible that they do so.

BIRDS.

On one occasion Mr. G. A. Runner observed an English sparrow industriously picking up the Argentine workers from a trail which crossed a wide roadway at Baton Rouge. This habit is not, however, a common one with this bird.

The flicker or yellowhammer, *Colaptes auratus*, has often been seen industriously digging up shallow ant nests in lawns and grass plats, evidently for the purpose of obtaining the pupæ and larvæ, and should doubtless be credited with being the most important natural enemy which this ant has in the South. Our knowledge of the extent to which native birds subsist upon these ants is very limited as yet, and the subject is one well worth more complete investigation than we have been able to give it.

EXPERIMENTS WITH PEDICULOIDES.

The idea of finding some parasite which would destroy the ants naturally suggested itself early in our investigations. Owing to the readiness with which the small parasitic mite, *Pediculoides ventricosus* Newp., parasitizes the larvæ of wasps and beetles whenever it can obtain access to them it was thought worth while to see if this parasite could be successfully used against the ant. For our experiments we first reared enormous colonies of these mites on living wasp larvæ and thereafter placed these infested larvæ in the formicaries, where they could be closely observed. The following experiment will illustrate the results obtained:

For the experiment we selected a large populous ant colony which was domiciled in a plaster of Paris Janet cage of several chambers.

All immature stages of the ant were present in abundance. On March 14 the cover to one of the living chambers was raised and one of the mite-infested larvæ was dropped in among the workers and larvæ in the formicary. The workers set to work immediately to kill the hundreds of mites. The larval mites were picked up in the workers' mandibles, chewed a bit and then thrown aside. Adult mites were seized by the legs and vigorously pulled until they released their hold on the wasp larvæ, after which the workers would crush them in their mandibles. However, the subsequent developments were entirely unexpected. A worker was seen to mount the wasp larva, eagerly destroying mites and becoming at the same time covered with a dozen or more of the mite larvæ. Within a minute the worker desisted from destruction of the mites about her and turned her attention to the ones on her body, trying to dislodge them by rubbing head and abdomen with her legs. Failing thus to get rid of them, she resorted to various gymnastic performances, such as jumping and rolling over. Soon afterwards her movements became slow and feeble and finally ceased entirely, it being evident that she had either been killed or paralyzed by the bites of the larval mites. Observations were suspended until March 18, when it was found that the adults and larvæ of Pediculoides were greatly reduced in numbers. No mites could be seen on any of the ant larvæ or pupæ, and all of the latter had been removed from the chamber where the mites were introduced.

The workers in leaving the cage to forage were compelled to pass through the infested chamber, but in doing so they made the widest possible detour about the mite-infested material. This status of affairs continued for some time, the mites gradually decreasing in numbers until by April 28 they had all disappeared. On this date cultures of the mite were again introduced into the colony, but in much greater quantities than before. A spoonful of mite-infested wasp larvæ was placed in each chamber of the formicary. The ants did not this time attempt to kill the mites, but inside of two minutes after the introduction of the latter the colony had completely deserted the formicary, taking with it all eggs, larvæ, and pupæ. Not being able to find other suitable quarters on account of the water surrounding the formicary, the ants on the following day decided to return to the nest. They attempted to remove the Pediculoides, but the mortality among the workers was heavy, many being carried out at the entrance. On the following day the number of dead workers was too great for removal, and many of them remained in the cage. The continual warfare against the mites continued for several days, the ant colony becoming by May 6 severely depleted in workers as well as in larvæ, some of which were killed by the mites. At the same time it was evident that the Pediculoides were being destroyed much more rapidly than they could increase. After May 6 the ant colony appeared to recover slowly. By July 22 the colony had completely resumed its normal condition and the mites had been exterminated.

That the Pediculoides could live and breed upon the ant larvæ was established by placing the latter in a glass dish which was isolated from all workers and permitting them to become infested. On them the Pediculoides grew and increased as well, apparently, as on wasp and other larvæ. Such enormous cultures of the mite as were introduced into the ant colonies in these experiments could not possibly occur in nature, and it seems a safe conclusion that this parasite can make no headway against the ant under normal conditions.

EXPERIMENTS WITH FUNGOUS DISEASES.

During 1909, at Baton Rouge, several experiments were made in the attempt to inoculate the ants and their larvæ with the chinch-bug fungus, *Sporotrichum globuliferum*. Cultures were prepared from beef extract and corn meal, sterilized at a pressure of 18 pounds per square inch for 30 minutes at a temperature of 256° F., and these were then inoculated with the fungus from a dead beetle. After these cultures had been stored for about a week in a dark, damp place, they all showed a heavy white layer of fungous growth over the surface, and this layer was used in the experiments.

Large quantities of this fungus were placed in Janet cages which contained strong and healthy colonies of ants with many immature stages. For a short time the workers would busy themselves carrying out the fungus and dropping it over the side of the cage support, but after a time they apparently became accustomed to its presence. It grew and increased inside the apartments in which the ants and their young stages were domiciled until it formed a heavy white mass over nearly everything, but in not a single instance was an ant or a young stage observed which appeared to be in the least inconvenienced by it.

As a number of dead ants were found covered with fungi the various organisms on them were isolated and cultures made. The principal fungi obtained were Aspergillus and Penicillium. Cultures of these were also introduced into the ant colonies, but without effect. It was therefore concluded that they were purely saprophytic on the dead ants on which they were found.

Attempts were also made to infect colonies with *Bacillus larvæ*, the germ causing the disease among honey bees known as American foul brood. Owing to the fact that this bacillus attacks the larval stages of the honey bee, and considering the similarity of ant and bee larvæ, it was thought that this disease might attack the larval stages of the ant. The experiments were made in a locality where the ant infestation was very heavy but where honey bees were not kept. Honey was thoroughly mixed with broken and mashed brood combs containing bee larvæ badly infected with foul brood, and this honey was then fed in abundance to foraging workers. Subsequent examination of the colonies receiving this infected material failed to show any indication of the disease.

No attempt was made to experiment with this disease under laboratory conditions, on account of the danger of accidentally infecting honey bees in the neighborhood.

LOW TEMPERATURES.

The winter temperatures experienced at Baton Rouge, La., seemed not to produce any appreciable mortality among the ants. During the winter of 1909–10 a colony at Baton Rouge was kept out of doors all winter with no other protection than the plaster of Paris walls of the cage in which it was confined. This colony successfully withstood a temperature of 22° F., the lowest temperature recorded during the winter. It is safe to assume that in their underground nests and in well-protected situations they can withstand a much lower degree of cold than this.

FLOODS.

Heavy rains appear to be the only meteorological phenomena which produce any appreciable effect upon the Argentine ants, but even in this connection it is worthy of note that the most heavily infested sections at present are within regions of exceedingly heavy annual rainfall.

After sudden severe rainstorms it was noticed that the ditches and drains at Baton Rouge and New Orleans contained thousands of the dead ants, evidently washed from trees and ground before they could reach a place of safety. The sudden rising of flood waters over lowlands would appear to destroy many colonies and the larvæ in them, yet, strange to say, the batture along the Mississippi River, which is annually covered for several weeks with several feet of water, continues to be an area of approximately maximum infestation. So facile are the ants in migrating to higher grounds or in ascending trees, taking with them all larvæ and pupæ, that it is likely that the mortality from this source is much less than would be expected. The mere destruction of foraging workers by rains does not effect any appreciable diminution in the rate of increase since, if the colonies themselves remain unharmed, the deposition of eggs and the rearing of more workers continues unabated.

METHODS OF REPRESSION.

It is as a household pest that the Argentine ant has forced itself most into prominence, particularly in the infested cities and towns, although it is doubtful if the financial loss due to its inroads in this respect even begins to compare with the losses suffered by the florists, bee keepers, and orange growers. Early in the course of our studies we undertook experiments looking to the development of measures by which householders could obtain some relief from this pest.

A successful campaign against the Argentine ant is by no means devoid of work, but the control measures thus far devised are no more cumbersome or expensive than those employed in the warfare against many other insects, and their intelligent employment is found well worth the while in reduced annoyance from this pest.

Studies of the ant's life history early developed the fact that permanent relief can be obtained only by actual destruction of the ants themselves. The use of repellents only serves to permit the continued increase of the pests and to postpone the time when more laborious methods of warfare must be adopted. Not only is it necessary to kill the ants outright, but it is also necessary to adopt means which will kill the queens. It is hardly necessary to call attention to the difference between killing ants and the usual insects with which we have to contend. If one kills a female gipsy moth or boll weevil, for example, possible future progeny of that particular individual is made impossible. Such is not the case when one destroys a worker ant, for the rate of increase and the development of future generations are in no way interfered with. This is true for the reason that the workers take no part in reproduction, all eggs being deposited by the queens. That the destruction of foraging workers does not materially affect the domestic economy of the colony or retard the rate of increase by reducing the available food supply is shown by repeated observations upon the number of foragers required to keep the colony supplied with food. In the artificial formicaries counts were made of the number of workers going out for food during periods varying from five hours to several days, and in no case did the number of foraging workers out at one time exceed more than 1 per cent of the number of individuals in the colony. From this we naturally conclude that less than 1 per cent of the workers can keep the remainder, including the queens and immature stages, supplied with food. These observations were made in cases where the food supply was only a few inches from the nest and was always in abundance. In times of food scarcity, and when it is necessary for the workers to travel considerable distances in order to reach a food supply, a larger percentage would have to engage in foraging. Observations by the junior author upon a large number of field colonies leads him to the conclusion that even under the most adverse conditions not more than 10 per cent of the workers are required for foraging. Under normal outdoor conditions the food supply is abundant and at such times it is very doubtful whether more than 2 per cent of the workers are ever engaged in foraging at any one time. The futility of destroying the foraging workers is therefore self-evident, for the number of workers leaving a colony during any given period is little if any greater than the number reaching maturity within the colony during the same period.

In spite of these facts repellents are very desirable and their use is, under most conditions, absolutely imperative in the protection of foodstuffs, such as sugars, candies, cakes, molasses, honey, vegetable oils, fresh meats, etc.

EXPERIMENTS WITH REPELLENTS.

Our first experiments consisted in testing the various substances which had been used in successfully repelling other species of ants.

Experience with artificial formicaries and with the hives of honey bees very quickly showed that water would deter the workers for only a short time. In our first experiments with colonies kept under observation the nests were placed on platforms supported above trays of water. As soon as the water had stood for a few hours minute dust particles, settling from the air, formed a very thin, almost imperceptible scum on it, and this the workers traversed with ease. A scum which, when viewed by reflected light, is barely perceptible to the eye will support the workers. When such standing water was removed and fresh substituted for it the ants would plunge into it as before, evidently expecting the scum to be there still. Instead of drowning, as might be expected, the workers merely swam, or crawled upon the bottom of the tray until they reached the edge or the wooden support of the nest, when they proceeded to crawl out. Workers thrown into water can readily crawl up one's finger or up a stick if it is brought near them. The senior author has observed workers which had accidentally fallen into a glass decanter three-fourths full of water gain a foothold on the smooth glass sides and crawl out successfully, feet up and body down, on the wet glass. The workers will apparently not enter fresh water voluntarily, but evidence indicates that they will sometimes do so in the attempt to reach their nests or to reach some much-desired food supply. When running over a film of oil or dust upon the water the feet and legs do not get wet, but when the film breaks through, as sometimes happens, the worker swims with her legs and a portion of the body submerged. Running water, such as a stream in a ditch or trough, seems to be a successful repellent, but the practical uses of such a stream are very limited. The use of running water as barriers to prevent the spread of infestation in orange groves is more fully described upon a subsequent page.

Sir John Lubbock in his book, "Ants, Bees and Wasps," describes bands of fur which kept the ants within his artificial formicaries. The kind of fur used by Sir John Lubbock is not specified, but the finest we were able to secure was that from an ordinary "cottontail" rabbit. With this the following experiment was made:

Two devices were prepared, each consisting of a small wooden box nailed to the top of a rounded 2-inch stake about 2 feet in length. Around the support (stake) of one box a roll of the fur was tightly placed, arranged so that the hairs projected downward and so that the ants would have to crawl "against" them in going up the stake. Fur was not placed upon the other device. The latter was stuck in the ground and a supply of honey placed in the box. The ants visited the honey at once and as fast as they removed it the supply was renewed. This continued for several days, when this device was removed and the one with the fur was put in its place, also with honey in the box. The interruption of the "trail" confused the ants for a little, but within a minute's time they were going up the new device and working their way persistently among the hairs of the fur. In a short time they were able to get through it, when they continued to the food supply at the top and removed it as before. The workers were forced to make their way slowly through the fur, wrestling in turn with the hairs in their way, but at most the fur did no more than delay them a little; it did not repel them in the least.

Various experiments were made with certain proprietary and coal-tar disinfectants for protecting food supplies from the ants. Woodwork rubbed or painted with these substances was not crossed by the workers during periods of from 2 to 48 hours after the applications, but none of these substances was effective for more than two days. Oil of citronella seemed more distasteful to the ants and they would not cross woodwork treated with it as long as the odor remained. Evaporation of this oil is, however, quite rapid.

The use of zenoleum powder was found quite effective. Sprinkled heavily on the floors of infested houses it killed many of the workers with which it came in contact and answered fairly well for breaking up trails and causing the workers to seek food elsewhere. It was also found of some service in keeping ants out of the nests of sitting hens.

Pine tar was not effective. In an attempt to feed honey to bees in the open air the feeder was supported on a stick around which were placed two separate bands of fresh pine tar. The feeder was placed out in the afternoon and by 6 o'clock the next morning the ants had crossed both bands of tar and the honey was black with them. To stop them, two fresh bands of tar were applied. Within 30 minutes the ants which were trying to get out of the feeder had forced their way into the tar in sufficient numbers to form a bridge and over this the ants were soon passing freely to and fro, despite the strong odor of the tar itself.

The following experiment proved the inefficiency of tobacco dust: In the middle of a large iron pan with flat bottom was placed a dish of honey. This dish was surrounded by a layer of tobacco dust from

1 to 2 inches wide and thick enough to obscure entirely the bottom of the pan. This arrangement was made at 2 p. m., and by 5 p. m. the ants were crossing the tobacco dust and getting the honey with as much facility as they would have crossed an equal amount of soft dirt. The experiment was repeated, finely powdered sulphur being substituted for the tobacco. The sulphur was not crossed so quickly as the tobacco dust, but within 24 hours the ants were crossing it freely. On one occasion the senior author planted a small lettuce bed, and thinking to protect the seeds until they germinated, he spread over the surface of the bed a layer of tobacco dust covered in turn by a layer of powdered sulphur. The ants got the seeds.

Tree tanglefoot, when placed about the trunks of trees up which the ants were traveling, checked them for periods varying from a few hours to three or four days. However, a more dilute form of this material, used with much success in the gipsy moth work in Massachusetts by Mr. D. M. Rogers, has recently been tested by the junior author with the result that in one case it kept the ants off the trees for as much as two weeks without being renewed. There is therefore a possibility that this special form of tanglefoot may have a use in the protection of trees.

Kerosene acts as a repellent until the odor has largely disappeared, but a film of kerosene on water only affords a good floor for the ants to travel on.

Various devices in the form of inverted troughs of tin or other smooth surfaces have been tried without success.

Crude petroleum, of all the liquids tested, has proved to be the most effective repellent. When placed in dishes supporting the legs of tables, benches, etc., it will continue to repel the ants even after a great amount of dust and trash has accumulated in it. Its use indoors, owing to its oily nature and disagreeable odor, is of course impracticable. Out of doors it is useful for giving temporary protection to such food materials as sugars, molasses, honey, etc.

CORROSIVE SUBLIMATE AND "ANT TAPES."

The only repellent found to possess any merit (aside from sweetened arsenical solutions, described below) was dry corrosive sublimate. Woodwork or cloth which has been treated with a saturated water solution of corrosive sublimate and allowed to dry will not be crossed by the ants while any of the sublimate remains. This fact is utilized in a practical way by soaking ordinary cotton tape about 1 inch wide in the corrosive sublimate solution, wringing it out, and then drying it. When this "ant tape" is fastened around the legs of tables, edges of shelves, etc., the ants will not cross it for many months, provided only that it is not allowed to get wet. The explanation of this remarkable action of the sublimate may be found in the extremely irritating effect which it has on tender membranes and surfaces. The finely powdered sublimate and the minute crystals when inhaled cause a severe irritation of the throat and nostrils, giving rise to sneezing and nasal discharges. The continued or careless handling of freshly made ant tape will often have the same effect. It seems not improbable that the sublimate particles may have something of an irritating effect upon the sensory organs of the ants. The ants are quick to detect and avoid corrosive sublimate even when it is in solution and mixed with other substances. All attempts to poison them with this substance have been ineffectual, for they can not be induced to partake of their most favorite foods when the latter contain the poison in as weak a proportion as 1 to 500.

In some of the tests made by the senior author the corrosive sublimate tape has been found to retain its efficiency for over 11 months in rooms where, except when the temperature was too low for insect activity, workers could be seen at all hours of the day and night.

Our method of preparing the tape is first to heat corrosive sublimate and water in a *porcelain* or *granite-ware* vessel until the maximum amount is dissolved. This solution is allowed to cool to ordinary temperatures, filtered, and ordinary cotton or binding tape is soaked in it for several hours. The tape is then removed and pinned upon a wall to dry, after which it is ready for use. It is very important that no iron, tin, or steel come in contact with the solution, or with the tape itself after being prepared. The tape is effective for only a short time when used on metal surfaces. The extremely poisonous nature of corrosive sublimate must be continually kept in mind, both in the preparation of the solutions and tape and in the use of the tape itself. With this tape it is a comparatively easy matter so to isolate dining tables, kitchen cabinets, refrigerators, etc., as to protect all food supplies in the ordinary residence. The same method is constantly used by confectioners in infested sections for the protection of their candy cases and supplies.

EXPERIMENTS WITH FUMIGANTS AND CONTACT INSECTICIDES.

Following the announcement by Mr. R. S. Woglum,[1] of the Bureau of Entomology, in September, 1908, that he had succeeded in destroying colonies of other ants with a solution of potassium cyanid, considerable interest was aroused in the question as to whether the same method could be used with success against the Argentine ant. The senior author conducted a number of experiments at Baton Rouge to determine this point, among which the following illustrates the results obtained:

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[1] Los Angeles Times, Los Angeles, Cal., Sept. 20, 1908.

A solution of potassium cyanid was made at the strength of 1 ounce of 98 per cent cyanid to 1 gallon of water. The site selected for the experiment was the area surrounding a few small cotton plants which were heavily infested with the cotton louse, *Aphis gossypii* Glov. Around the plants the earth was literally honeycombed by numerous small colonies of the Argentine ant, the workers of which were in constant attendance upon the aphides. The experiment was made at 11 a. m. on a bright day, with the temperature at about 77° F., when the workers were busily visiting the lice and foraging elsewhere for food and when the activities of the colonies were at about a maximum. The solution was sprayed onto the trails of traveling ants and the ground itself was sprayed until thoroughly wet with the solution. By the time the spraying was completed the odor of the cyanid was so strong as to affect the operator. In spite of this the solution did not immediately kill the workers with which it came in contact, but they appeared to succumb within about five minutes after the spraying. Five hours after the spraying the odor of cyanid was still very strong and the number of dead workers on the surface of the ground fully equaled, or exceeded, the number of living ones in sight at the time of spraying. Many live workers were busily engaged in carrying away the dead. The ground was examined and thousands of living ants in all stages—workers, pupæ, larvæ, and eggs—were found less than half an inch below the surface. Two days later the area was again examined and the ant colonies were apparently as populous as ever. This and other experiments seemed to demonstrate the impracticability of using this solution for destruction of the colonies, particularly as the earth would have to be treated with a sufficient amount of the solution to saturate it thoroughly to a depth of several inches. This would probably destroy all vegetation, would be expensive, and would involve the risk of injury to or loss of life by the operator and others. For species constructing compact nests having single or few openings the solution is doubtless effective but, owing to the multitudinous openings and galleries of the Argentine ant nest, destruction could be accomplished only by the use of enormous quantities of the solution.

The resistance of this species to hydrocyanic-acid gas was well illustrated in experiments made in attempting to fumigate the winter trap-boxes in orange groves. These trap-boxes are described more in detail on pages 95–96. They were about 2 feet wide, 2 feet high, and 3 feet long, made of rough lumber and filled with decaying cottonseed and hay. During the winter months these boxes contained enormous colonies. For fumigating them to destroy these colonies galvanized-iron covers were made (see Plate XII) which would fit over them easily. A 6-inch hole was made in the top of each cover-box for the introduction of the chemicals used in fumigating. Just beneath this opening, which could be closed practically air-tight, was placed the usual earthenware crock for holding sulphuric acid and water. Experimental fumigation of these boxes was commenced with a charge of $\frac{1}{4}$ ounce of 98 per cent potassium cyanid and the requisite amounts of water and sulphuric acid. This strength was found not to kill any ants in the box except those which were actually outside the packing at the time of fumigation. Gradually this charge was increased until as much as 4 ounces of cyanid were used at a time in the inclosed space of 22 cubic feet. Even at this strength, which corresponded to 18 ounces of cyanid per 100 cubic feet, ants more than 8 inches from the outside of the box were not affected by a confinement of four hours. In later experiments an iron rod was used to make holes all through the contents of the box and the same charge used as before, 18 ounces of cyanid per 100 cubic feet. After the gas had been confined for five hours the boxes were examined and it was found that only those within a couple of inches of the perforations were killed. Larger charges could not be used, simply because the cover-box would not contain a generator of sufficient capacity. Even had a charge heavy enough for effective results been found its cost would have been prohibitive in practical field work.

Experiments were accordingly undertaken with bisulphid of carbon for destruction of the ants in the boxes. Holes were made to the very bottom of the contents, bisulphid poured into these, and the metal cover placed over the box, its lower edges afterwards being mounded up with dirt. One-half pound of bisulphid, used in this manner and confined by the metal cover-box for five hours, destroyed all ants, and all stages, in the boxes. Mention is made of the use of this fumigant on page 96.

Other experiments made with the bisulphid of carbon showed it to be the most available fumigant for the destruction of colonies in accessible situations.

When colonies are so situated that they can be fumigated with bisulphid nothing is more effective for their destruction, but the difficulty of applying this measure lies in the situation of colonies in all sorts of inaccessible places (see list of nesting places, p. 55) and to the fact that in heavily infested areas the galleries of one nest are practically continuous with those of others, affording many ants the opportunity of escaping from the fumes.

Such substances as hot water, kerosene, crude oil, etc., will, of course, destroy the ants sprayed with them and often it is quite practicable to use these substances for the destruction of colonies that are discovered by turning over boards, pieces of wood, piles of trash, etc.

Many preparations have been sold throughout the infested sections for the purpose of destroying the ants. In nearly all cases these have been merely fluids which would kill the ants when coming in contact with them and the directions have stipulated that the ants should be sprayed with the solutions when on their foraging trails. In view of the foregoing statements relative to the small proportion of workers foraging at any one time it is not at all remarkable that such preparations have always yielded nothing but disappointment, even though enormous numbers of foraging workers were destroyed by their use.

EXPERIMENTS WITH POISONS.

The use of poisons is generally the first measure suggested for the destruction of an injurious insect, and experiments along this line were begun by the senior author early in the course of his investigations. An appreciation of the salient features in the life history of the pest soon emphasized the futility of using a poison which would destroy the workers only. Any poison, to affect the rate of production or to exterminate the species, must be one which will destroy the fertile queens and the immature stages, all of which are located within the nest and are supplied with food by the workers.

No way could be devised by which poison could be administered to the queens and larvæ except by having the workers carry it to them from sources of supply outside the nest itself. The problem therefore resolved itself into the search for some poison which would be fatal, but which at the same time would act so slowly within the workers' stomachs that they could transport it to the colony and there feed it to the inmates before perishing themselves.

Some small measure of success attended our experiments in this line but, incidentally, another and much more valuable use for poisonous mixtures was discovered.

Arsenate of lead, containing but little arsenic in soluble form, naturally suggested itself as the most promising substance for the purpose. Accordingly it was tried in various experiments, of which the following will serve to illustrate the results obtained:

A mixture was made of 1 part pulverized sugar, 1 part paste arsenate of lead, and 2 parts of honey. The ants carried this away rapidly and on August 11 exhausted the entire amount that had been put out. The supply was renewed, but on August 12 it remained untouched. An examination of the nest was then made and it was found to be entirely deserted; the colony had moved away, taking with it all immature stages. That this action had been taken to get outside the sphere of danger from the poison there can be little doubt, for this colony had occupied the same spot for many weeks, despite the fact that it had been frequently dug open for examination and had been entirely submerged at times during hard rains. No dead ants were found in the empty nest; any such, if present, were taken away at or before the time of vacating the formicary. The ants will not tolerate dead within their living chambers, the cadavers always being removed expeditiously and often to a considerable distance. This makes it extremely difficult to tell, by examination of a colony in nature, how many of the individuals have been killed by any poison fed to the workers. The action of the colony in moving outside the zone of danger was observed in many subsequent experiments in which poisoned food was used, and this gave us the clue to the use of sweetened arsenical mixtures as *repellents* for driving the colonies away from infested situations. The same phenomenon, improperly understood, has been responsible for the conclusion, arrived at by several experimenters, that the use of such mixtures was actually exterminating the ants, their absence after use of the poison being ascribed to their death and not to their migration to a safer place.

That the mixtures containing lead arsenate, such as those just described, do destroy the individuals within the nest and that their continued consumption by the ants would result in extermination if the colony did not move away from them, were established by experiments made with colonies kept in artificial formicaries where migration from the poison was made impossible. In one such experiment a small amount of the mixture last described (1 part lead arsenate paste, 1 part pulverized sugar, and 2 parts honey) was kept constantly on the food table of a colony in the formicarium. On the same table, but a short distance from it, food not poisoned was also kept at all times. The workers from this colony therefore had their choice between poisoned and nonpoisoned food. A few workers died each day, the larvæ all succumbing a few days after inauguration of the experiment. At the end of about 20 days the colony seemed demoralized and discouraged, the queen ceased to lay, and the workers did not work with their accustomed activity. At the end of 44 days all individuals were dead, the queen having lived until near the end of the period.

Many solutions and mixtures containing white arsenic (arsenic trioxid) were tested in various ways and the one which gave by far the best results was made by combining one-fourth gram of arsenic trioxid with 20 grams of granulated sugar in 100 cc. of water.[1] When placed in a small dish anywhere within the foraging range of a colony this preparation would be greedily taken for a few hours, after which the ants would not touch it as long as it remained in the same position. When the dish was moved a few feet away or placed in another part

[1] To give warning of its dangerous nature it is well to add to this mixture sufficient confectioner's color paste to dye it a brilliant red or green. Fruit juices, as of raspberry or similar fruits, may be added to accomplish the same end.

of the same room and "rediscovered" by the workers they seemed not to recognize its dangerous nature and would take it as before. After a few experiences of this kind the colony would move away from the vicinity. Only in rare instances were these migrations actually witnessed, as they seemed usually to take place during the night. A solution containing more than one-fourth of 1 per cent of arsenic did not give as good results for, in such cases, many of the workers died while sipping up the poison or on their way to the colony. Thus the poisonous nature of the substance was more quickly detected by the ants and work on it was stopped proportionately sooner. In all cases the ants removed the dead and dying from along their trails and from the vicinity of the poisoned mixture.

A number of experiments were made to determine whether or not the ants could distinguish between poisoned and nonpoisoned foods, with the result that they evidently could not do so; this perhaps being the reason that they moved their colonies away from the vicinity. One of these experiments was as follows:

On July 9 a fruit jar containing honey was placed on the floor of a small shed, where the ants had been very abundant for weeks. By the following day all honey had been removed by the workers and more was placed in the jar. Between the 9th and the 12th the jar was replenished several times, the ants during this time carrying away more than a half pint of honey. At noon on July 12 a small glass vessel containing a mixture composed of one-half of 1 per cent of arsenic and 20 per cent of sugar was placed about 3 inches from the honey jar. The ants commenced taking this solution at once, and in the course of five minutes the vessel was black with them. At 4 p. m. on the same day they were still working with undiminished vigor on both the honey and the poisoned solution. At 8 a. m. on July 13 there were only about one-fourth as many ants visiting the jars as on the previous day. They were still working on both the honey and the solution and many dead ants lay about. At noon of the same day very few were visiting the vessels, but many were engaged in carrying away the dead bodies of their erstwhile sisters. A few were still taking the arsenic solution, but it was evident that the ants did not know which of the food supplies was destroying them. At 2 p. m. on July 14 only two workers were in the vicinity of the vessels and neither of these was feeding. On July 15 all ants, both alive and dead, were gone, and not a single worker could be found in the building. Plenty of the nonpoisoned honey still remained in the jar. On July 16 and 17, also, no ants were to be found in the shed, even though heavy rainstorms in the meantime drove them indoors in many other buildings and decreased their available outdoor food supply. This experiment and many others demonstrated not only the effect of the poison in driving the ants from the vicinity, but also that food supplies could be protected merely by having the poison near them. In practical work it was found that the placing of two or three saucers containing a little of the arsenical solution about a room or under tables bearing honey, meats, etc., would effectually rid the vicinity of ants in from one to three days' time, and, what was more to the point, the ants would not return in numbers so long as the dishes of poison were kept there.

CONTROL OF THE ANT IN RESIDENCES.

No one measure will afford satisfactory relief from this pest and the householder who would find permanent immunity from attack must plan a warfare based upon an intelligent appreciation of the facts above set forth. Of utmost and primary importance is cleanliness. By this is meant not merely absence of dirt in the usual sense, but that precautions must be taken not to leave particles of food where the ants can have access to them. Even crumbs of bread or cake left on a kitchen floor will attract the pests. Above all else fruits, sweets, oils, and meats must be kept where the ants can not reach them. The more abundant the food supply the more abundant will the ants become, and it has been repeatedly observed that there are many more colonies in residences occupied by shiftless owners than in those occupied by careful housekeepers.

Foodstuffs can not be isolated from the ants except by the use of repellents such as have been described, particularly ant tape. This last should be placed around the legs of all tables, benches, etc., on which food supplies are kept, and the tables must not be allowed to touch the wall or other objects by means of which the ants can find access to them.

The corrosive sublimate tape is, of course, poisonous, and when there are children in the house precautions must be taken that they do not get hold of it. At the same time we have never known of a case of poisoning resulting from its use. It is wise, also, to wash the hands well with soap and warm water after handling the tape.

To assist in repelling the ants the sweetened arsenical mixture, described on page 85, containing one-fourth of 1 per cent of arsenic, should be placed in small dishes or saucers in pantries and beneath tables, refrigerators, etc.

Along with these repelling measures colonies of the ants should be destroyed at every opportunity. Hot water, kerosene, or crude oil can be used for destroying every colony that is accidentally exposed to view by the overturning of leaves, boxes, pieces of wood, etc. For this purpose we have found a small compressed-air sprayer, filled with kerosene or crude oil and kept in a handy place, very useful. Colonies nesting in the ground can be quickly destroyed by thrusting a sharp stick into the nest and pouring in a sufficient amount of carbon bisulphid or gasoline, afterwards closing the hole with damp earth.

On most city premises the ants can be further reduced by making use of winter trap nests or trap boxes, such as are described on pages 95–96 under the caption "Experiments with winter trap boxes."

Mention should not be omitted at this point of the steps advocated by the Rev. Albert Biever, of Loyola College, New Orleans, who, by his constant advocacy of warfare against this pest, did much to enlighten the people of New Orleans concerning it. Father Biever's plan was to place sponges moistened with sweetened water in locations visited by the ants, and when these were covered with the pests to dip them into boiling water. The sponges were then recharged and the process repeated as long as the ants would visit them. By this persistent destruction of the workers Father Biever expected so to deplete the colony that not enough workers would remain to care for the queens and larvæ and the latter would perish from starvation.

A most novel way of destroying these ants was described by Mr. Edwyn C. Reed, of the Museo de Concepcion, Concepcion, Chile, in a letter to the senior author. Mr. Reed says:

> The only sure cure would be to take Biblical measures and root up the city infested, stone by stone, and strew it with salt. As such a radical cure is not practical, we must be content with palliatives, and I find the following very effective: This ant is very fond of olive oil, and so, in sardine tins, saucers, etc., I put a little olive oil in its runs. The ants flock to the oil and in eating it get clogged up, so that for a spoonful of oil I get about that quantity of ants, dead and harmless. In practice this so weakens the nests that I get rid of them. Last November I moved into a house sadly infested by them and at once applied the oil. They came to it by thousands and stayed there. In a month's time I could appreciate the result, and by the end of our southern summer very few were to be seen.

CONTROL OF THE ANT IN APIARIES.

The keeping of bees is made well-nigh impossible in sections heavily infested by the Argentine ant. Single colonies of the ants often contain more individuals than a colony of bees, and in addition the colonies of ants are by far the most numerous. The Argentine ants are not only exceedingly fond of honey but they attack the bee larvæ in the cells with a ferocity that is amazing. Thousands upon thousands of the ants will enter the hive, carrying away honey and attacking the larvæ. The bees themselves are unable to cope with such small enemies. The ants are too small for them to sting and were they even to attempt picking up the ants in their mandibles and carrying them out of the hive they could make no appreciable headway against the thousands of intruders. The bees adopt what is perhaps the best method of defense under the circumstances, that

BEEHIVE ON ANT-PROOF HIVE STAND, THE LATTER RESTING UPON A CONCRETE BLOCK. (ORIGINAL.)

of trying literally to kick out the invaders. A worker bee will run in among the ants and, whirling about, will give repeated vigorous kicks with her hind legs, throwing the ants in every direction, even to a distance of 10 or 12 inches. The ants are not, however, killed by this rough treatment, and they shortly return to the attack. In a few hours after the attack has commenced the bees become thoroughly disorganized and give up further defense, sometimes swarming out as a last resort. At such times the normal hum of the hive gives place to an entirely different note, which the experienced bee keeper at once recognizes as that of distress.

The difficulties of extracting and handling honey in the presence of these pests can be readily imagined. In order to extract we first scrubbed the floor of the building, using copious amounts of carbolic acid in the water. The foundations of the building and a space about a foot wide all around the building were then sprayed with crude oil. The extractor, as well as the uncapping can, was placed in a large iron tray containing several inches of water. When all these preparations were complete, the supers were taken from the hives, and as fast as brought in were stacked on tables the legs of which were wound with the corrosive sublimate ant tape. Extracting was done as expeditiously as possible, but with all our pains the ants were all over everything before we could extract and bottle three or four hundred pounds of honey. Even our clothing was teeming with the workers and all human effort was helpless to keep them out of the honey.

The number of apiaries destroyed by the ant in southern Louisiana has been considerable, and one of our first lines of experimental work was to devise some means of protecting the beehives from the foraging ants. Among the various schemes that were tried the following were found most efficient:

Placing the hive upon a stand having four legs and placing each of these legs in a tin cup containing crude petroleum served to deter the ants for a time, but rain water soon displaced the oil in the cups, and then with the first accumulation of dust on the water the ants found their way across it. This device also had the disadvantage of killing all bees which attempted to crawl up the legs of the stand.

Another device, somewhat more successful than the open cups, consisted of a stand the legs of which had at their tops inverted troughs of galvanized iron so arranged that rain water could not enter them, and so fixed that the ants would have to cross the troughs containing oil in order to reach the hive. Stands protected with this appliance successfully repelled all ants for about two months but, like the open cups of oil, resulted in the death of some bees.

As our previous experiments had shown the repellent power of ant tape, already described, it occurred to us that this might be used in the construction of an "ant-proof" hive stand. Accordingly a four-legged hive stand was made with top and sides extending some distance beyond the legs and downward, so as to prevent rain water from reaching the upper end of each leg. The top and sides were made thoroughly water-tight and the ant tape wound several times about the upper end of each leg. Below the tape, fitting snugly around the leg, was a piece of zinc about 6 inches square to prevent water from splashing upward from the ground during storms. One of these hive stands, turned on end to show the method of construction, is illustrated in figure 11, and the details of construction are further shown in figures 12 and 13. These figures are from drawings by Miss Ethel Hutson. The two front legs of the stand were made an inch shorter than the rear two to give proper drainage to the hive. In putting on the tape we wrapped about a yard of tape about each leg, placing corrosive sublimate between the layers. Made in this manner these stands by actual test repelled all ants for 11 months without any attention being required except to prevent grass and weeds from growing up and touching the hive and upper part of the stand. With corrosive sublimate between the layers of tape the latter is effective until it disintegrates or until it gets wet, and bees crawling up the legs pass the barrier of tape without injury or inconvenience. Our stands were made of tongue-and-groove lumber, which made them rather cumbersome, but there is no reason why such stands should not be made with top and sides of galvanized iron. This would make them light, durable, and cheap.

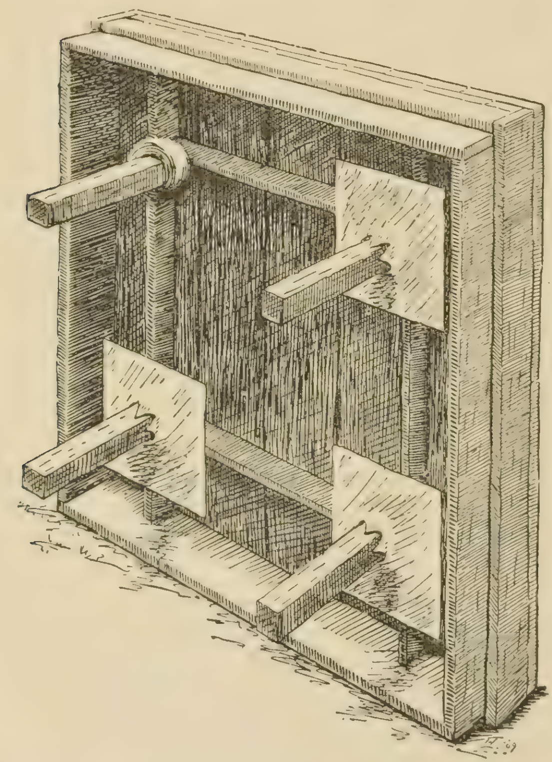


FIG. 11.—Ant-proof hive stand, upturned, showing method of construction. (Senior author's illustration.)

In spite of the fact that the hive stand was absolutely ant proof we experienced much difficulty in preventing grass from growing up under the hives and affording a passageway for the ants. To eliminate this difficulty we covered the entire apiary with about 5 inches of cinders and placed each hive stand upon a concrete block. (See Plate VII.)

Rev. Albert Biever, S. J., devised a unique method of protecting his bees from the ants. This method he describes as follows:

> Blocks of wood are obtained, upon which the legs of the bee stand rest. Then the cover of a lard can or large tin box sufficiently wide when placed in an inverted position on top of the blocks will overlap the block of wood on all sides. A paste consisting of vaseline mixed with kerosene and red pepper is then spread thinly over the inside of the can or cover, and the ants will never be able to reach the legs of the stand and gain access to the hives. An advantage of this method is that the paste need not be renewed more than once every year or two, and, being protected from the weather, it can not be washed off.

One can successfully keep a few colonies of bees in any portion of the ant-infested area by making use of the special stands described above, but eternal vigilance is the price of success, for when the ants do gain access to the bees the latter are likely to be disorganized within a few hours and the swarms will abscond. Along with the use of the ant-proof stands one should also use every means for reducing the ant colonies in the vicinity of the apiary.

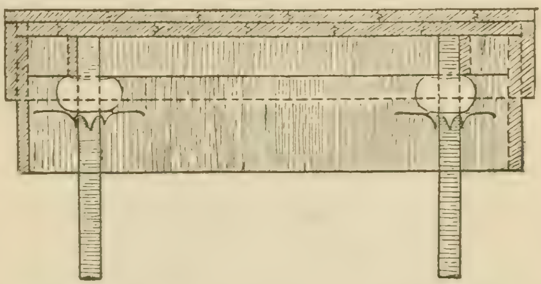


FIG. 12.—Sectional view of ant-proof hive stand, showing method of making top and sides water-tight by "breaking" the joints. (Senior author's illustration.)

The commercial apiarist can hardly continue keeping bees with profit after his apiary is invaded by this pest, the amount of labor in constructing hive stands and keeping down vegetation being almost prohibitive. In such cases the wisest course would be to remove the entire apiary to some locality where these ants do not occur. As already noted, the infestation is not infrequently confined to cities and towns, and small rural sections still free from this pest can usually be found within driving distance.

CONTROL OF THE ANT IN ORANGE GROVES.

The main orange-growing section of Louisiana lies along the banks of the Mississippi River below New Orleans and extends for a distance of about 50 miles. This section has the reputation of producing oranges of exceptionally high quality, and the industry has proven a paying one for many years past. A considerable number of localities have during the past 15 or 20 years become infested by the Argentine ant, due, no doubt, to drifting logs containing ant colonies that lodged along the banks of the river. The warm winters, coupled with the presence of considerable moisture at all times, have made possible very rapid increase of the ants, and the first result of their activities has been a greatly accelerated rate of increase by all scale insects, and particularly by the chaff scale (*Parlatoria pergandii* Comst.). Not only do the ants protect this scale from its natural enemies, but they colonize the larvæ upon the young growth of the orange trees and upon trees not previously infested.

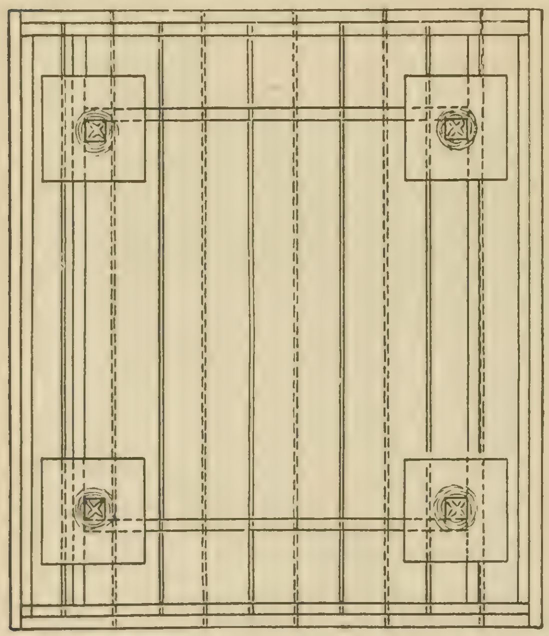
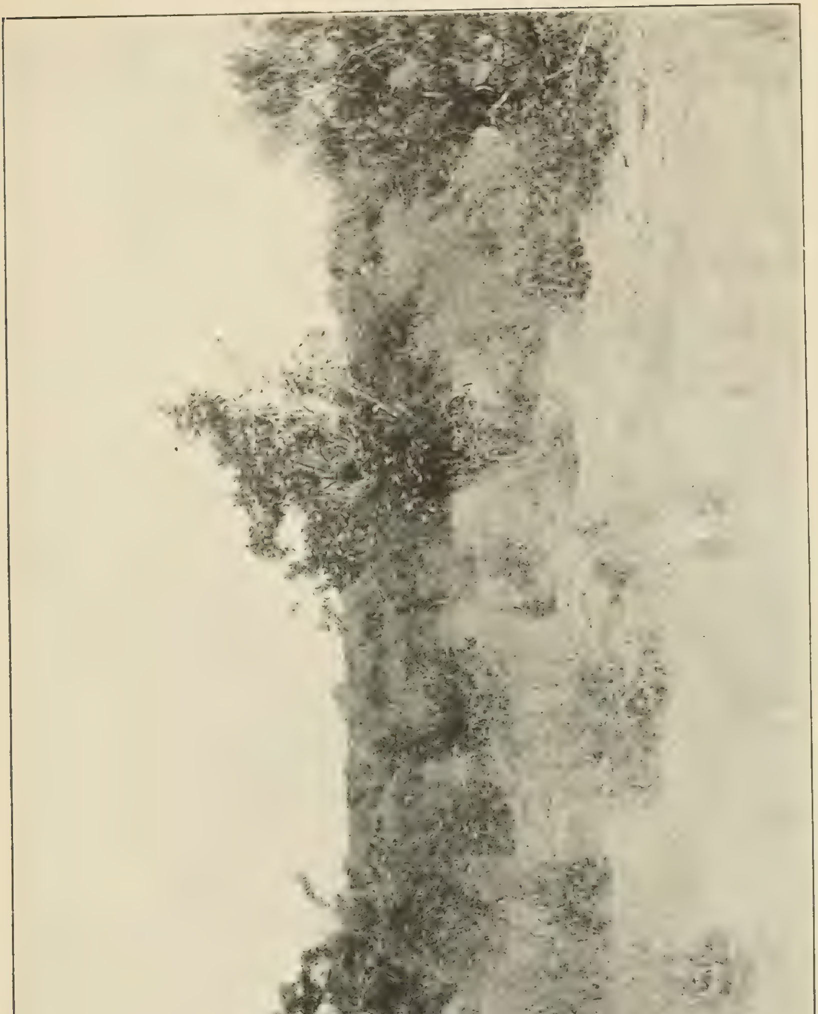


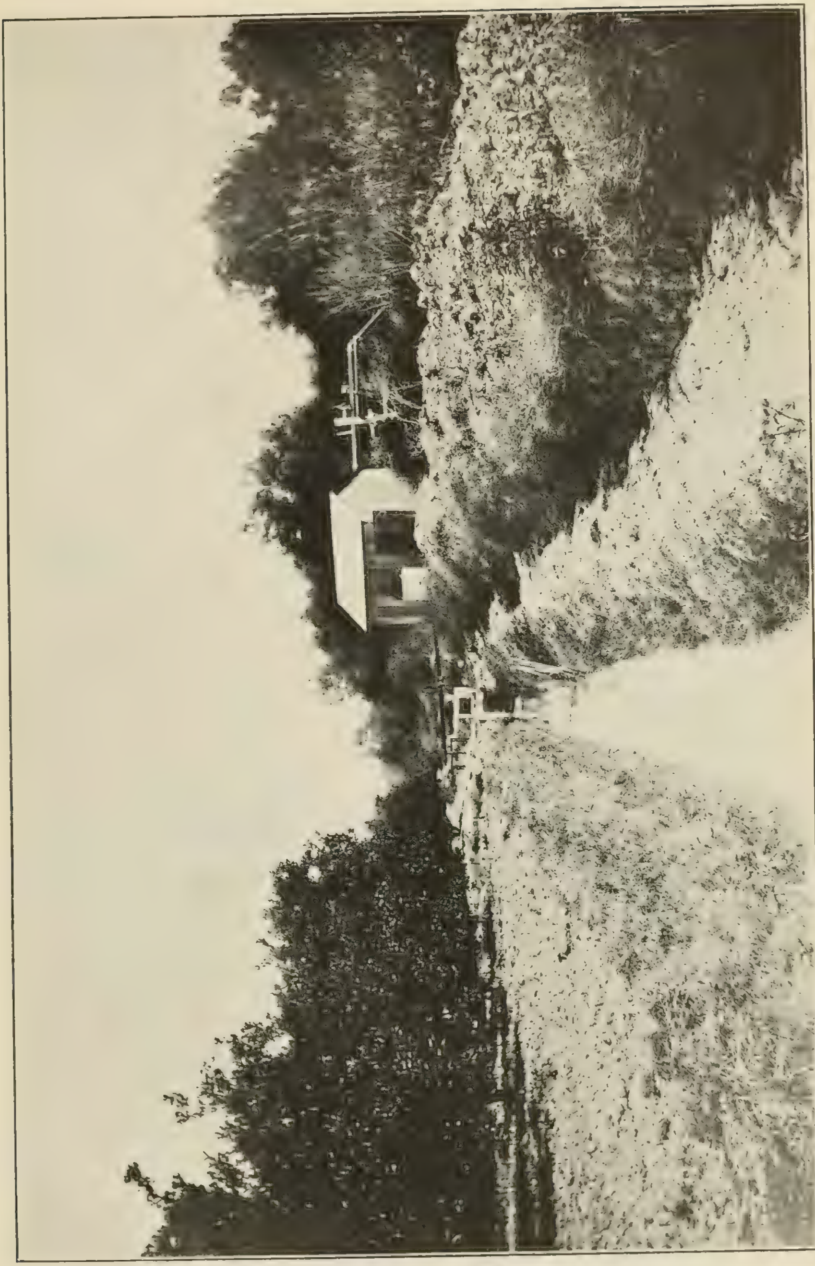
FIG. 13.—Sectional view of ant-proof hive stand from above, showing construction. (Senior author's illustration.)

At times the ants eat into the orange buds, evidently in quest of nectar, and buds thus injured do not set fruit. This habit is not always exhibited by the ants, and it may be that it is more or less dependent upon the prevalence of scale insects on the trees. The secretions of aphides and scale insects are preferred to other food, and it seems not unlikely that when honeydew is abundant the buds are not molested by the ants. Whether or not the ants do any other direct damage to the trees is still an unsettled question, but certain it is that the bearing qualities of an orchard are seriously impaired by the second season of infestation, the crop is almost entirely lost by the third season, and the trees are dying rapidly by the fourth year of infestation. (See Pl. VIII.) One orchard which well illustrates the rate of destruction consisted of a 20-acre tract of young grapefruit trees, visited by the authors in March, 1910. The trees at this time were about 4 to 5 feet in height and appeared very vigorous and healthy. The ants were, however, rapidly infesting the field from adjoining orchards. During the summer of 1910 the ants increased

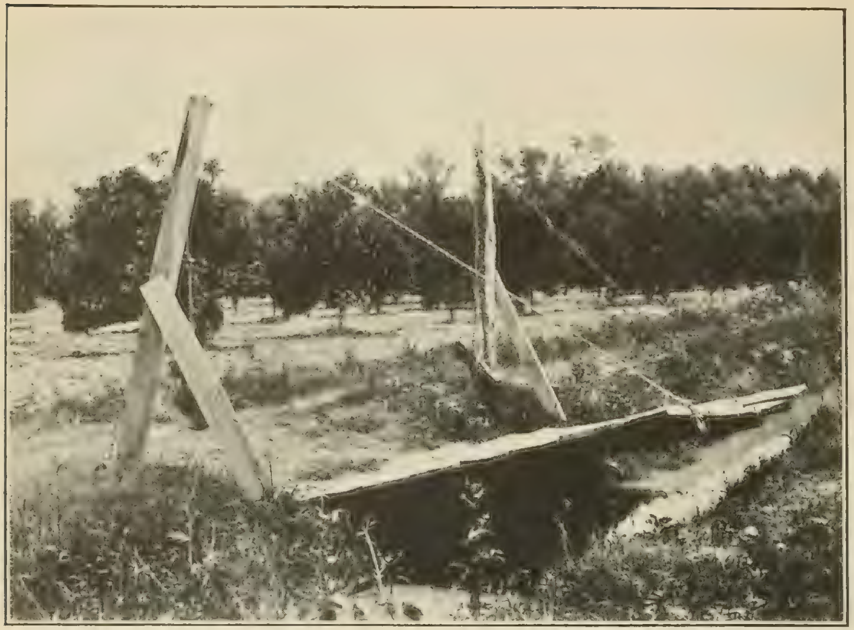


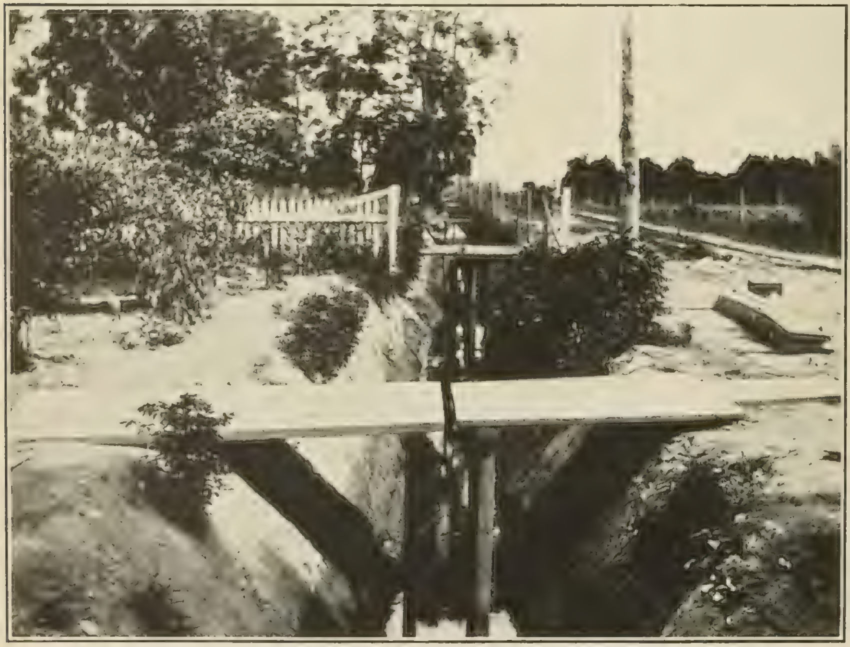
ORANGE ORCHARD DYING AS A RESULT OF INFESTATION BY THE ARGENTINE ANT. (ORIGINAL.)

Batture of the Mississippi River, 50 Miles below New Orleans, Overgrown with Willows and Heavily Infested by the Argentine Ant. (Original.)



SIPHON, PUMPING PLANT, AND BARRIER DITCH USED IN LIMITING THE SPREAD OF THE ARGENTINE ANT. (ORIGINAL.)





BRIDGES WHICH THE ARGENTINE ANT CAN NOT CROSS. (ORIGINAL.)

rapidly, as did the Lecaniums, which were constantly attended by the ants. The owner sprayed industriously with whale-oil soap, but without apparent effect. During 1911 many of the trees died, and at the present time (March, 1912) the orchard is practically ruined and the owner has abandoned hope of saving enough trees to make the orchard profitable. The condition of dying trees is well illustrated by Plate VI, which shows a Louisiana Sweet orange tree that has been exposed to ant infestation for three seasons. This tree stood near the levee, outside the barrier ditches described below, and was exposed to the work of the ants.

Another orange orchard which we have had under close observation has been infested for 7 years, and during this time no measures have been taken to control the ants. In this orchard fully 60 per cent of the trees are dead and the remaining trees are heavily incrusted with both the chaff scale and the purple scale (*Lepidosaphes beckii* Newm.). So abundant are the ants here that a bit of earth disturbed by one's foot at any point in the orchard will reveal a seething mass of ants. A recent crop from this orchard consisted of but 250 boxes of inferior quality. Other orchards, of approximately the same size but not yet infested by the ant, produced in the neighborhood of 3,000 boxes. At Soccola Canal there is a small tract of land on which four orange orchards have been planted in succession, all of which have died before reaching bearing age. The entire neighborhood is heavily infested, and Mr. S. M. O'Brien, of Nairn, La., states that to his knowledge the ants have been abundant at Soccola for at least 17 years. The plat has now been entirely abandoned as an orange grove, the last of the dead orchards having been removed during 1911 and the land devoted to the growing of truck crops.

METHOD OF DISSEMINATION IN THE ORANGE SECTION.

As already indicated, the most probable sources of original infestations in the orange section were drifting logs in the river, these logs carrying living colonies of the Argentine ant. In times of flood these logs are thrown up on the batture (the space between the river bank and the levee) and remain there in large numbers. It is the history of practically all infestations in this section that the ants first appeared on the batture, then along the levee, and from the latter worked their way back from the river. At all the infested points the levee is found to be teeming with the ants and the batture itself is a constant breeding place. A portion of the infested batture, covered with a thick growth of willows, is shown in Plate IX. Here the ant colonies are found under every particle of driftwood and trash, and during almost the entire year they are in attendance upon Coccidæ and Aphididæ on the willows. For a number of weeks each year this batture is covered with several feet of water from the river, but the infestation seems not to be lessened thereby. During flood time many of the ant colonies migrate to the levee adjoining, while still others ascend the trees out of the water's way. Curious nests or sheds, constructed by the ants from particles of earth and trash, are of common occurrence in the tops of the willow trees.

In some few places it is evident that the railroad has been the means of introduction, the infestation having started at points on the railroad where considerable merchandise from New Orleans was constantly being unloaded.

EXPERIMENTS IN THE ORANGE GROVES.

The writers' first experiments with the pest in orange groves were commenced in the spring of 1910. At that time only one grower in the Louisiana orange section was attempting anything like a systematic campaign against the ants. This grower had adopted a novel and rather effective method of destroying them. The infested portion of his orchard immediately adjoined the levee and, as is usual with land along the river, was lower by several feet than the water in the river during flood stages. The water could therefore be siphoned over the levee to the orchard as rapidly as needed. (See Pl. X.) To prevent the spread of the ants to additional territory the infested block had been surrounded by a ditch, a section of which may also be seen in Plate X, in which water was kept at all times. During flood stages of the river the water was siphoned over for the ditches at small expense and through the ditch system drained away to the swamp in the rear of the plantation. At other times the water was kept in the "ant ditches" by use of a gasoline engine and pump installed on the levee, as shown in Plate X. It was, of course, necessary to take precautions that the ants should not find accidental and artificial means of crossing the ditches. Permanent bridges for the passage of teams could not be left, so a swinging bridge which could be lifted when not in use was devised. The ditching system for preventing spread of the ants was shortly adopted by many other growers, some of whom used an ingenious divided bridge (Pl. XI) which could be crossed readily by teams, but which had a 2-inch crack through the middle that effectually prevented the passage of the ants.

The grower referred to had put in practice the following method of destroying the ants: A small levee or ridge was made around the infested block of trees. Water was then admitted through the siphon from the river until the ground in the block was entirely covered. As the water slowly rose the colonies of ants moved up into the orange trees. Then the water was drawn off and the ants, descending, found the ground still too wet to live in, whereupon they migrated en masse to the surrounding small levee. The water was then turned on for the second time to keep the ants on this ridge, and here they were destroyed by exposing the colonies with a shovel and scalding them with hot water or spraying them with kerosene. At the senior author's suggestion a number of small boxes filled with hay and trash were placed at various points in the orchard. When the water was admitted it was found that the colonies moved into these boxes in preference to going up the trees. They could thus be destroyed with one flooding instead of two, as formerly.

It may be remarked in passing that the ditches, when pains have been taken to prevent the ants crossing them, have effectively limited the spread of the ants through the groves. This fact amply substantiates our observations, mentioned on pages 19–20, to the effect that colonies are never established by individual queens returning from a marriage flight. Were colonies established in this manner, the areas of infestation would not be sharply defined, nor would ditches retard the dispersion of the ants from heavily infested centers.

EXPERIMENTS WITH WINTER TRAP BOXES.

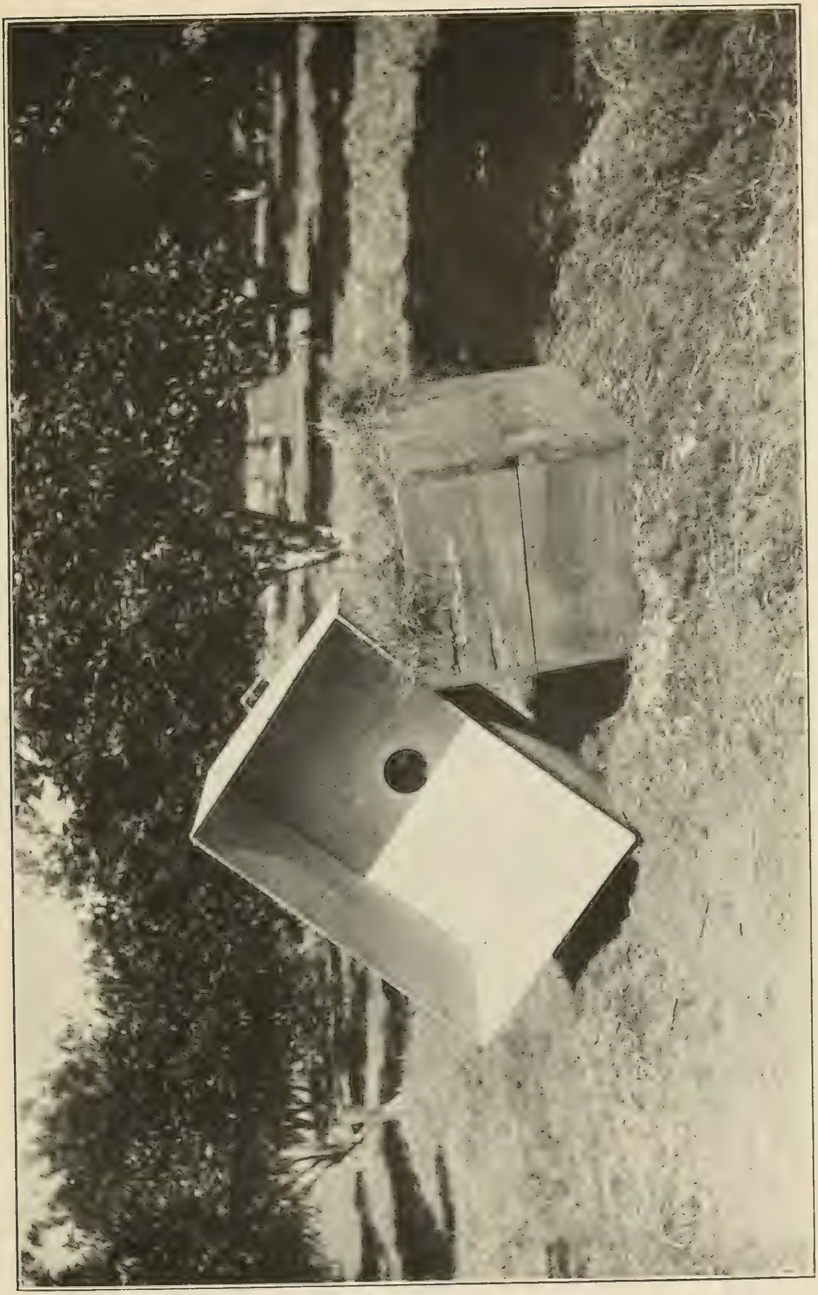
The success which had followed experiments at Baton Rouge in getting the ant colonies to concentrate during the winter in boxes of decaying vegetable matter induced us to try the same plan in an infested orange grove. Accordingly in November, 1910, a large number of boxes, each 2 by 2 by 3 feet, of rough lumber, were made and distributed throughout the infested block. Each was filled, during the latter part of October, with a mixture of cotton seed and dead grass. The top of each box was left exposed to the weather, so that rain would enter to moisten the contents and start decay. An examination of the boxes on November 16 showed that many colonies had entered them, but that many still remained in the ground. To afford the ants less natural protection the orchard was cultivated to remove the standing grass and weeds. In January, 1911, the authors again visited this orchard and found all boxes filled almost to overflowing with enormous ant colonies. Each box contained workers by the hundreds of thousands and queens by the hundreds. A close examination in various parts of the orchard showed, however, that not all colonies had entered the boxes. Some few colonies had remained in their underground nests, particularly where grass or weeds had been overlooked in the November cultivation and where, therefore, these colonies were afforded more protection than in the plowed portions. Whether the already crowded condition of the boxes had prevented other colonies from entering them we could not determine.

Experiments were now undertaken in destruction of the colonies in the boxes. Metal covers had already been constructed for confining gases in the trap boxes. (See Pl. XII.) Experiments were first made in fumigating the boxes with hydrocyanic-acid gas (see pp. 82–83), but these were not successful. Carbon bisulphid was next tried, with perfect success. Delay in obtaining a sufficient supply of bisulphid resulted in delayed treatment of many of the boxes, and doubtless some of the colonies escaped as the weather became warmer in the early part of February. Nevertheless, the number of queens and workers destroyed ranged into the millions. The owner wished to deal the ants the hardest blow possible, so early in the spring he flooded the orchard, drove the remaining ant colonies to the boxes, and fumigated these the second time.

The results of this work were eminently satisfactory. The orchard was first infested by the ants in 1909. In 1910 they reached enormous numbers; chaff and purple scales increased until the trees were almost encrusted, and many of the trees showed signs of failing. The foliage began to turn yellow, and the crop of 1910 fell off severely, in spite of the flooding that was done by the owner in the spring of 1910. During the summer of 1911, following the use of the trap boxes, the orchard improved remarkably, and the crop was up to the original production. It was found that when the boxes were left in the orchard ant colonies took up their abode therein during the summer months; for this reason these boxes were fumigated with bisulphid from time to time. An examination of the orchard in January, 1912, showed that the infestation by the chaff scale had been greatly reduced by diminution of the ants, even though the owner had done no spraying for destruction of the scale insects. The ant infestation showed some increase in the autumn of 1911, but the orchard had returned to its normal healthy condition, and it was evident that a continuation of these methods would insure good crops indefinitely. A view of this orchard, taken in January, 1912, is shown in Plate XIII.

One important point came to light in these experiments, and that was the necessity of placing the trap boxes in position early in the autumn so that the vegetation in them would be decaying well at the approach of cool weather in November. With considerable decomposition going on at the time the ants are seeking winter quarters, the warmth of the box becomes very attractive to them.

The use of arsenicals and other poisons in the infested orange groves was found impossible, for the reason that the secretions of scale insects and aphides are preferred by the ants to all other foods.



TRAP BOX AND FUMIGATING COVER FOR DESTRUCTION OF ARGENTINE ANT WHILE IN WINTER QUARTERS. (ORIGINAL.)

ORANGE GROVE IN WHICH CAMPAIGN WAS WAGED AGAINST THE ARGENTINE ANT—APPEARANCE OF THE GROVE AFTER RECOVERY. (ORIGINAL.)

BIBLIOGRAPHY.

1868. Mayr, G.—Formicidæ novæ Americana.<Annuario della Soc. Naturalista Modena, vol. 3, No. 4, p. 164.

1870. Mayr, G.—Neue Formiciden. Key to Genus *Hypoclinea*, p. 959.

1870. Mayr, G.—*Hypoclinea* (*Iridomyrmex*) *humilis*.<Verh. zool.-bot. Ges. Wien, vol. 20, pp. 954, 958.

1888. Emery, C.—Ueber den sogenannten Kaumagen einiger Ameisen.<Zeitschr. f. wiss. Zool. vol. 46, p. 386, Taf. 28, figs. 17–19 (gizzard).

1890. Berg, Carlos.—Enumeración sistematica y sinonemica de los Formicidos Argentinos, Chilenos y Uruguayos.<An. Soc. Cient. Argentina, vol. 29, pp. 5–43.

1893. Dalla Torre, K. W. von.—Catalogus Hymenopterorum hucusque descriptorum systematicus et synonymicus, vol. 7 (Formicidæ).

1898. Stoll, O.—Zur Kenntnis der geographischen Verbreitung der Ameisen. <Mitth. Schweiz. Ent. Ges., vol. 10, pp. 120–126.

1905. Titus, E. S. G.—Report on the "New Orleans" ant.<Bul. 52, Bur. Ent., U. S. Dept. Agr., pp. 79–84, fig. 7.

1905. Stoll, O.—The ants of the Bahamas.<Bul. Amer. Mus. Nat. Hist., vol. 21, p. 89.

1906. Sanderson, E. Dwight.—National control of introduced insect pests.<Bul. 60, Bur. Ent., U. S. Dept. Agr., p. 99.

1906. Wheeler, Wm. M.—On certain tropical ants introduced into the United States.<Ent. News, vol. 17, p. 23.

1907. Newell, Wilmon.—The "New Orleans" ant.<Cir. 13, La. State Crop Pest Comm., p. 9, April.

1907. Martins, M. N.—Une fourmi terrible envahissant l'Europe (*Iridomyrmex humilis* Mayr).<Broteria Revista de Sciencias Naturaes, vol. 6, part 1, pp. 101–102.

1908. Forel, A.—Ameisen aus São Paulo (Brasilien), Paraguay, etc.<Verhandlungen der k. k. zool.-bot. Ges. in Wien, pp. 394, 395, 396.

1908. Newell, Wilmon.—The Argentine or "New Orleans" ant.<2d Bien. Rept. La. State Crop Pest Comm., 1906–07, pp. 7–9, fig. 1.

1908. Newell, Wilmon, and Rosenfeld, Arthur H.—A brief summary of the more important injurious insects of Louisiana.<Journ. Econ. Ent., vol. 1, no. 2, p. 152, April.

1908. Newell, Wilmon.—Notes on the habits of the Argentine or "New Orleans" ant.<Journ. Econ. Ent., vol. 1, pp. 21–34, February.

1908. Newell, Wilmon.—Two interesting inquilines occurring in the nests of the Argentine ant.<Journ. Econ. Ent., vol. 1, no. 4, pp. 262–265, August.

1908. Woodworth, C. W.—The Argentine ant in California.<Cir. 38, Cal. Agr. Exp. Sta., p. 11, figs. 2, August.

1908. ———.—A new pest. (Reported occurrence of the Argentine ant in East Oakland, Cal.)<Country Gentleman, p. 749, August 6.

1908. Foster, E.—The introduction of *Iridomyrmex humilis* into New Orleans. <Journ. Econ. Ent., vol. 1, no. 5, pp. 289–293, October.

1909. Froggatt, W. W.—Report on parasitic and injurious insects, 1907–1908. <Dept. Agr. N. S. Wales, p. 19.

1909. Newell, Wilmon.—The life history of the Argentine ant.<Journ. Econ. Ent., vol. 2, no. 2, pp. 174–192, figs. 1–4, plates 5–7, April.

1909. Newell, Wilmon, and Rosenfeld, Arthur H.—Some insects injurious to truck crops.<Cir. 27, La. State Crop Pest Comm., pp. 112–116, 126, July.

1909. Newell, Wilmon.—Measures suggested against the Argentine ant as a household pest.<Journ. Econ. Ent., vol. 2, no. 5, pp. 324–332, fig. 1, pl. 1, October.

1909. LOUNSBURY, CHAS. P.—Destruction of Houtkapper white ants.<Agr. Journ., Cape Town, July. (Mention of ineffective measure against *Iridomyrmex humilis.*)

1909. LOUNSBURY, CHAS. P.—Report of the Government Entomologist for 1908. Cape Town, S. Afr., pp. 66–68.

1909. NEWELL, WILMON.—3d Bien Rept. La. State Crop Pest Comm. for 1908–1909, pp. 4–5, December.

1910. LOUNSBURY, CHAS. P.—Report of the Government Entomologist for 1909. Cape Town, S. Afr., pp. 90–91.

1910. SMITH, JOHN B.—Insects and entomologists: Their relation to the community at large.<Pop. Sci. Monthl., vol. 76, no. 3, p. 221, March.

1910. DEAN, W. HARPER.—Some notes upon the life history and habits of the sorghum midge, *Contarinia* (*Diplosis*) *sorghicola* Coq.<Journ. Econ. Ent., vol. 3, no. 3, pp. 205–207, April.

1910. ROSENFELD, ARTHUR H.—Insects notably injurious in Louisiana during 1908 and 1909.<Journ. Econ. Ent., vol. 3, no. 2, p. 213.

1910. WHEELER, WM. M.—Ants, their structure, development and behavior. New York, pp. 663, figs. 286, and plates. *Iridomyrmex humilis*, pp. 153, 154, 155, 233, 542.

1910. GARRETT, J. B.—A preliminary report on the sugar-cane mealy-bug.<Bul. 121, La. Agr. Exp. Sta., p. 10, July.

1910. SAJO, KARL.—Die argentinische ameise, eine neue sechsfussize Grossmacht. <Prometheus, Jahrg. 21, pp. 634–638, 1 fig.

1910. SAJO, KARL.—Une invasion de fourmis.<Prometheus, p. 634. Reviewed in Revue Scientifique, Paris, p. 309, September 3.

1910. BARBER, T. C.—The Coccidæ of Audubon Park, New Orleans, La.<Journ. Econ. Ent., vol. 3, no. 5, p. 423, October.

1910. WOODWORTH, C. W.—The control of the Argentine ant.<Bul. 207, Cal. Agr. Exp. Sta., Berkeley, Cal., pp. 20, figs. 28, October.

1911. DEAN, W. HARPER.—The sorghum midge.<Bul. 85, part 4 (revised), Bur. Ent., U. S. Dept. Agr., p. 57.

1911. NICKELS, L. J.—Field work in the control of the Argentine ant.<Journ. Econ. Ent., vol. 4, no. 4, pp. 353–358.

1911. NEWELL, WILMON.—Practical information for beginners in beekeeping.<Bul. 142, Tex. Agr. Exp. Sta., p. 37, December.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 123.

L. O. HOWARD, Entomologist and Chief of Bureau.

A PRELIMINARY REPORT ON THE SUGAR-BEET WIREWORM.

BY

JOHN E. GRAF,

Entomological Assistant,

Truck Crop and Stored Product Insect Investigations.

Issued February 28, 1914.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., February 24, 1913.

Sir: I have the honor to transmit herewith the manuscript of a paper entitled "The Sugar-Beet Wireworm (*Limonius californicus* Mannh.)," by John E. Graf, an entomological assistant of this bureau.

This very active enemy to the sugar beet in the Pacific region has been the subject of study in the Bureau of Entomology since 1909. The present paper is somewhat preliminary in character, but so many facts have been learned that it is believed advisable to submit them for publication at the present time. While this wireworm has been known in America for many years, no good report of its injuries was available until very recently. The paper sets forth the manner of injury, the history of the species, the insects associated with it in the destruction of the beet roots in different stages of growth, the number of its food plants, its life history and habits, suggestions as to the methods for its control, and other useful data, and is well illustrated.

I recommend the publication of this manuscript as Bulletin No. 123 of this bureau and would urge that it be issued at an early date, as there is great demand for information on the part of the sugar-beet growers of the country, all of whom are more or less troubled by the ravages of wireworms.

Respectfully,
C. L. Marlatt,
Entomologist and Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The present bulletin is intended as a preliminary report of the investigations which have been carried on with the sugar-beet wireworm (*Limonius californicus* Mannh.) since 1909. The life-history work has not been completed; in fact it was not until the spring of 1912 that it could be started on a scale which gave any promise of ultimate success. As tests of many of the control measures were finished during the latter part of 1912, and as it will be several years before a complete study can be finished, it has been decided to publish a report at this time giving all the observations and experiments which have been carried on thus far.

During the coming years, in addition to the completion of the life-history studies, work will be carried on with other control measures. The relation of the birds of the sugar-beet fields to the wireworms will also be investigated, as will the bacterial and fungous diseases which have been observed to affect this species.

The author wishes to acknowledge his indebtedness to Dr. F. H. Chittenden and Mr. H. M. Russell for assistance and suggestions throughout the work. Mr. Russell began the study of *Limonius californicus* in 1909. The cooperative work of Mr. R. S. Vaile, of the Ventura County horticultural commission, and Prof. H. S. Fawcett, of the University of California, is also deserving of grateful acknowledgment.

J. E. G.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE SUGAR-BEET WIREWORM.

(*Limonius californicus* Mannh.)

HISTORICAL.

The sugar-beet wireworm (*Limonius californicus* Mannh.) has been known in the coast lowlands of southern California for many years, having been more or less destructive to sugar beets during the time they have been grown here, and prior to that time was known as an alfalfa and corn pest. In many localities the alfalfa had to be plowed up and replanted every few years, as the ravages of this larva so thinned it out that only a partial crop could be harvested unless replanting was resorted to at intervals. Owing to the fact that the ground in the alfalfa fields is nearly always damp to the surface, the wireworms seldom worked deep, and while they tunnelled through the crown of the plant, it was only a chance injury or a heavy infestation that could make itself felt, so that its destructive powers in the alfalfa fields is proof enough of its abundance.

The wireworm has also been noted as a corn pest for years, many growers reporting that on occasions it has been impossible to secure an average crop even with several plantings. Mr. Nelson Ward, of Compton, reports that on pulling up cornstalks he has discovered from 17 to 30 wireworms burrowing through the roots and into the crown of a single plant.

LOSSES DUE TO THE SUGAR-BEET WIREWORM.

There is great variation in the estimates of losses ascribed to this insect, and very probably the correct estimate would run far above the others. The reason for this is that unless the injury is exceptional it is likely to go entirely unnoticed. When the wireworms work scatteringly, their injury is apparent only to the observer who is looking especially for it, and at the right time. The writer bases this assertion on observations made during the early spring of 1912. At this time the adults were being collected, and as several hundred acres of beet fields were carefully gone over several times, it was possible, by close observation, to get a good estimate of the progress of the injury and the total damage done.

The sugar beets were quite small, having just been thinned, and were consequently at just the right age to receive the greatest injury. The roots were simple, not having swelled, and wherever a beet plant was attacked it was generally killed, as the roots were almost invariably severed by the feeding of the wireworms. All the plants which were noted wilting down were examined, and always with the same result, viz, the tender taproot was cut and blackened and a search generally revealed the offender, a wireworm, in the soil near by. A great amount of just such work was noted, but it differed from that of 1911 in that it was more scattered.

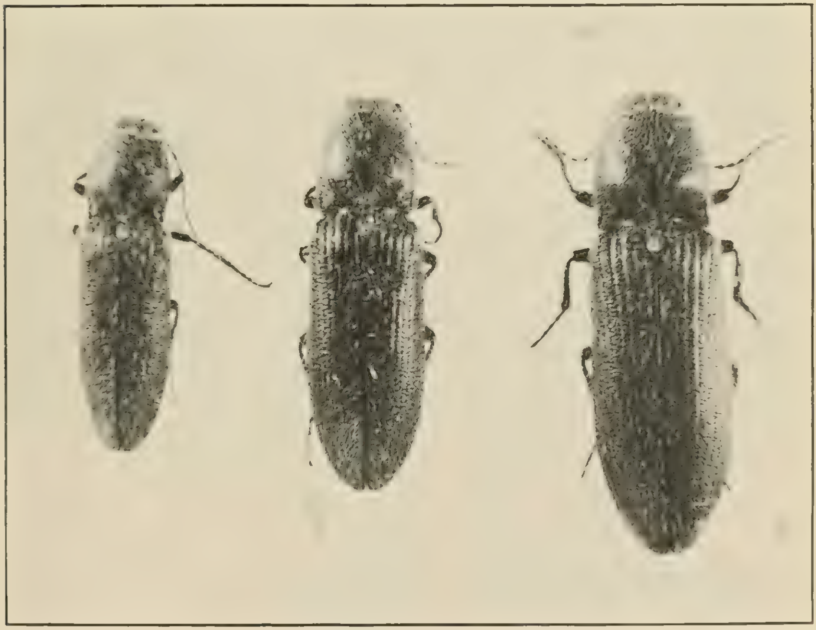
In 1911 the wireworms seemed to be working in groups, and many spots of varying size were completely cleared of beets. In 1912, however, the fields were almost entirely free from this type of work. Places were observed where from three to six beet plants had been killed in one group, but by the time the beets are mature their foliage so covers the ground that all trace of the injury is lost to the casual observer. One incident will illustrate this point. A small beet field of 10 acres located near the laboratory was carefully watched that some idea might be gained of the progress and time of injury. Every day many of the plants were found dead, but seldom were more than three or four plants killed in a place. While this injury was considerable it was kept well scattered. At the time of the last examination the beets, then nearly ripe, so covered the ground with their foliage that even where several adjoining plants had been killed it was difficult to find any signs of the injury. This shows that it is an easy matter to overlook the destructive power of this wireworm.

The sugar-beet wireworm may be considered the worst insect enemy of the sugar beet in southern California at the present time. It has this distinction for two reasons: First, it is constant, appearing every year to a greater or less extent; and, second, its injury occurs in such a manner that replanting is generally impracticable, or at least of little value. While beets and alfalfa appear to be the favorite food plants, the sugar-beet wireworm is also very injurious to corn (fig. 3, p. 18) and beans (Pls. VI, VII).

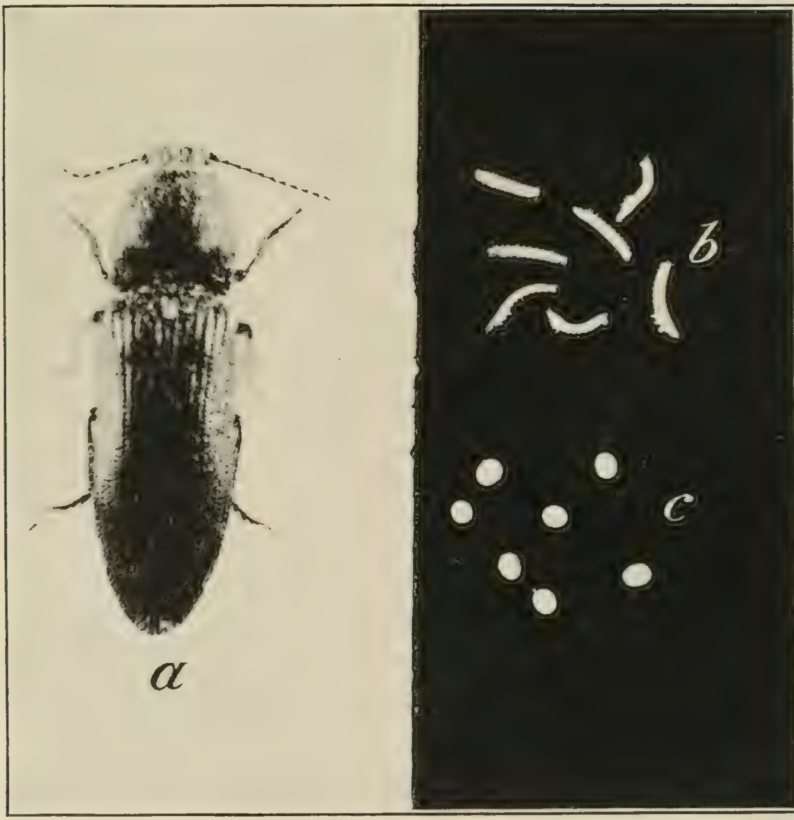
It would be a difficult matter to figure the loss due to the wireworm, either in percentage of the crop, tons, or dollars, but an approximation will show its importance economically. Mr. R. S. Vaile, horticultural commissioner of Ventura County, in his annual report for 1912, places the loss to lima beans alone in his county at $10,000. For 1913 he estimates the loss at $25,000 or more. If the other counties where this wireworm is destructive are taken into consideration it will be seen that probably the lima-bean growers alone lose at least $50,000 a year by this insect. Add to this the loss to sugar beets, which is probably even greater, and it is readily seen that this wireworm presents no small problem in southern California.

INSECTS FOUND WITH THE SUGAR-BEET WIREWORM.

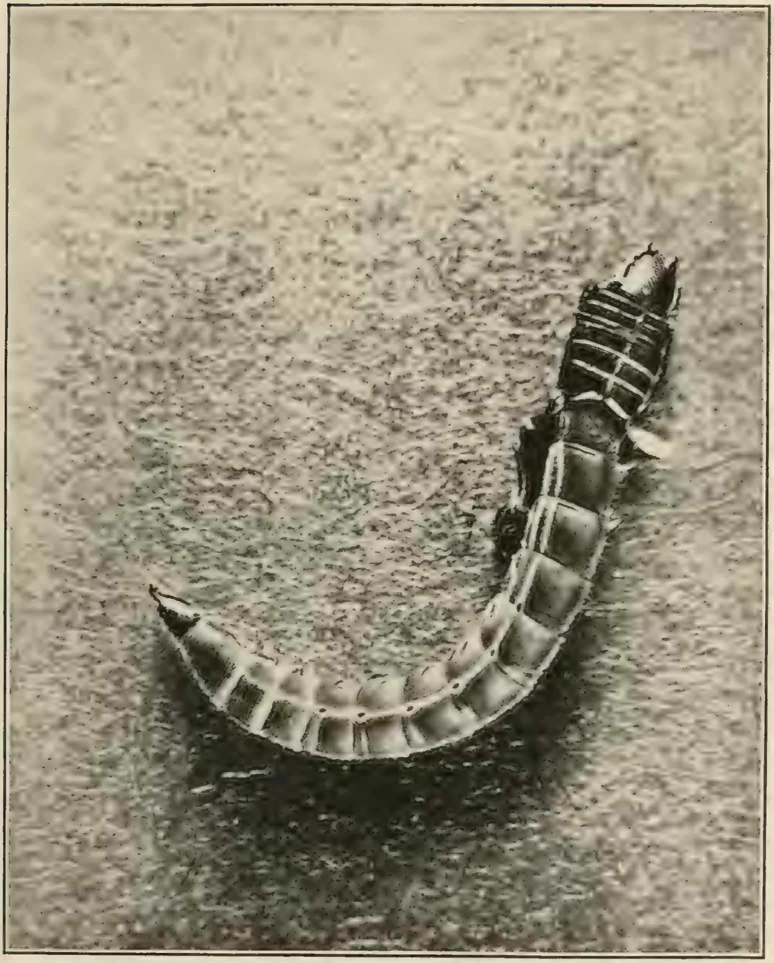
Collections of wireworms in the beet fields of southern California show at a glance that they are made up of several species. These differ widely in appearance, hence there is little chance of their being mistaken for one another. Two of them, *Limonius californicus* Mannh. and *Drasterius livens* Lec., are of the waxy color usually found in



ADULTS OF THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS), SHOWING VARIATION IN SIZE. (ORIGINAL.)



STAGES OF THE SUGAR-BEET WIREWORM. FIG. *a*.—ADULT. FIG. *b*.—NEWLY HATCHED LARVÆ. FIG. *c*.—EGGS. (ORIGINAL.)



A SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS) MOLTING; THE CAST-OFF SKIN SHOWING NEAR THE ANAL PLATE. (ORIGINAL.)

WIREWORMS AND WIREWORM-LIKE LARVÆ; THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS) BEING THE THIRD LARVA FROM THE LEFT, AND THE LARGE ONE AT THE RIGHT BEING A FALSE WIREWORM. ABOVE IS A DIPTEROUS PARASITE. MAGNIFIED. (ORIGINAL.)

wireworms. The latter is considerably the smaller of the two, and only an occasional individual has come under observation. The other wireworms are white, with a slight yellow tinge. Two of them belong to the genus Cardiophorus, one having been identified by Mr. E. A. Schwarz, of this bureau, as *Cardiophorus æneus* Horn. The other has not yet been reared, but as several adult specimens of *C. crinitus* Blanch. have been taken in the fields, it is probable that it belongs to this species. The other wireworm found in the fields is a large, robust, whitish one, considerably larger than *Limonius californicus*. This has not been reared and remains undetermined.

In the spring, when the adults are found in the beet fields, four other elaterids are found with them, though in lesser numbers. The most common one resembles in general characteristics *Limonius californicus*. It is of about the same size and outline, but differs from *L. californicus* in the color of its elytra, which are a decided buff instead of a deep brown. Dr. Chittenden has stated that this may prove to be a new variety of *californicus*, since, while it resembles that species quite closely, it seems to disagree in several small particulars. From the numbers of these which were found with *L. californicus* it is possible that they may be of economic importance. This species may be called the lesser sugar-beet wireworm to distinguish it from *L. californicus*.

The other elaterids which were found occurred in very small numbers, so that they may be disregarded from an economic standpoint. These have been determined as *Drasterius livens*, *Cardiophorus æneus*, and *C. crinitus* (?). These three are considerably smaller than *L. californicus* and there is therefore little chance of their being mistaken for the latter.

Another beetle commonly noted in the fields is a carabid, *Platynus* sp., slightly larger than *L. californicus*, robust, black in color, with a slight metallic tinge.

Two species of tenebrionids are also commonly found with *Limonius californicus*. Both are short, very robust, and dull black in color. One is *Blapstinus* sp., the other a species of Coniontis.

CLASSIFICATION, SYNONYMY, AND COMMON NAMES.

Limonius californicus (Pl. I; Pl. II, *fig. a*) belongs to the common genus Limonius of the family Elateridæ. It further belongs to the tribe Elaterini and group Athoi.

It was described from America in 1843 by Mannerheim as *Cardiophorus californicus* and has since been referred to the genus Limonius. *Cardiophorus californicus* is its only known synonym.

The larvæ of this entire family of insects are commonly known as wireworms. The adults, due to their habit of throwing themselves into the air when placed on their backs, have received the names "skipjacks," "click-beetles," "spring-beetles," and "blacksmiths."

DESCRIPTIONS.

The Adult.

Following is the original description by Mannerheim[1] in Latin, followed by a translation into English.

136. *Cardiophorus californicus:* elongatus niger, punctatissimus, tenue pubescens, thorace convexo, subquadrato, elytris dorso depressis, leviter punctato-striatis, sterno profunde punctato, convexo, tarsis articulis omnibus et unguiculis simplicibus.

Longit. $5\frac{1}{3}$, $4\frac{1}{3}$ lin. latit. $1\frac{2}{3}$, $1\frac{3}{4}$ lin.

Habitat in California, D. D. Blaschke et Tschernikh.

[Translation.]

Cardiophorus californicus: Elongate black, closely punctate, finely pubescent; thorax convex, subquadrate; dorsal surface of elytra depressed, feebly striate-punctate; thorax beneath deeply punctate, convex; all joints of the tarsi and claws simple.

Length $10\frac{2}{3}$–$9\frac{1}{2}$ mm., width $3\frac{1}{3}$–$3\frac{1}{2}$ mm.

Habitat, California (Blaschke and Tschernikh).

The Egg.

The egg of *Limonius californicus* (Pl. II, *fig. c*) is for the most part opaque white, though it shows small, irregular, semihyaline areas when placed on a white surface in dim light. The surface appears smooth under the low power of the microscope, but under the high power it appears to be slightly scaly. It reflects light weakly from the lighted side. That the shell is quite tough is proven by the fact that even when the eggs are rolled about in the soil they are seldom distorted.

The egg is ellipto-cylindrical in shape. Both ends are broadly rounded and resemble each other. Measurements of 30 eggs gave an average length of 0.69 mm. and an average width of 0.5 mm. The length varied between 0.63 and 0.735 mm. and the width between 0.473 and 0.53 mm.

The Larva.

The nearly mature larva of *Limonius californicus* (fig. 1; Pl. II, *fig. b;* Pls. III, IV) is subcylindrical in shape and shiny, waxy yellowish-brown in color. The segments are very minutely and sparsely punctate. The head and venter are flattened dorsally and darker in color. There is a light dorsal stripe on the posterior end of each segment with the exception of the venter.

The head is depressed and considerably narrower in front. The mandibles are strong, notched, deep brown in color, changing to black at the tip.

[1] Bul. Soc. Imp. Nat. Moscou, vol. 16, p. 238, 1843.

The first thoracic segment is broad and long, being about equal in length to the venter. The other thoracic segments are short, being about equal in length to the first two abdominal segments. The remaining abdominal segments are a little longer and quite similar. The legs are short and armed with heavy, short brown spines.

The abdominal segments are slightly constricted where they join one another. There are from two to four hairs on the lateral side of each segment. The spiracles are brown, conspicuous, and are situated in a poorly defined, light lateral stripe. They are slightly nearer the anterior end of the segment.

The venter is depressed dorsally, with raised edges. It is sparsely hairy around the edge. The caudal notch has a small tooth on each side pointing slightly upward and backward. The margin of the notch varies from deep brown to black.

The average length of the mature larva is from 18 to 21 mm., and the width is from 2.5 to 3 mm.

THE PUPA.

When first formed the pupa is opaque white, but after a time the eyes show through as pale, dusky, blue spots. About this time the thoracic segments become a pale waxy yellow, but no other changes take place until shortly before emergence.

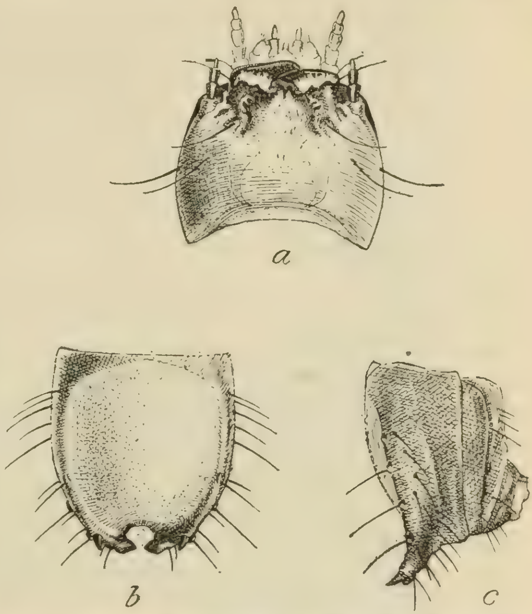


FIG. 1.—The sugar-beet wireworm (*Limonius californicus*): *a*, Head; *b*, anal segment from above; *c*, same, lateral view. Highly magnified. (Original.)

The pupa (Pl. V.) very much resembles the adult beetle in shape, except that the abdomen is slightly longer in the pupal stage. The head is bent forward slightly, and each anterior angle is armed with a long, heavy spine, which tapers regularly to a point. The mouth parts are conspicuous. The antennæ are laid along the margin of the head on the ventral side, and their tips are behind the tibiæ of the second pair of legs. On the underside of the head and near the prothorax are two short, heavy spines. There are also two short, stout spines on the dorsal side of the head near the posterior angles.

The case covering the springing apparatus is plainly visible between the anterior coxæ. The leg cases are folded similarly to those of other Elateridæ. All of the posterior pair, excepting the tarsi, are covered by the wing cases, which are curved around and almost meet on the ventral side, at the distal end of the third abdominal segment.

The abdomen is contracted sharply at the seventh segment, so that the eighth segment is only a little more than half as wide as the anterior end of the seventh.

The anal segment bears two long, heavy spines on its posterior angles. These spines are slightly divergent, are pitted, and the distal half of each is brown, changing to black at the tip.

The pupæ vary greatly in size. Measurements taken from several individuals give an average length of 11.5 mm. and a width of 3.6 mm.

DISTRIBUTION.

This wireworm is found quite generally throughout the western half of California. It is abundant in the lower sugar-beet lands of southern California. The main districts affected by it are those of Ventura, Orange, and Los Angeles Counties. These three districts comprise probably the choicest sugar-beet land in southern California. The station for the study of this insect was located in Compton, in Los Angeles County, about 10 miles from the coast, and surrounded by about 12,000 acres of sugar beets.

Limonius californicus has been reported from the following places, all in California: Riverside, San Bernardino, Los Angeles, Lake, Monterey, and El Dorado Counties, by Prof. H. C. Fall; near Owens Lake, collected by Dr. A. Fenyes; Marin County, specimens in the collection of the University of California; Orange, Ventura, and San Diego Counties. (See fig. 2.)

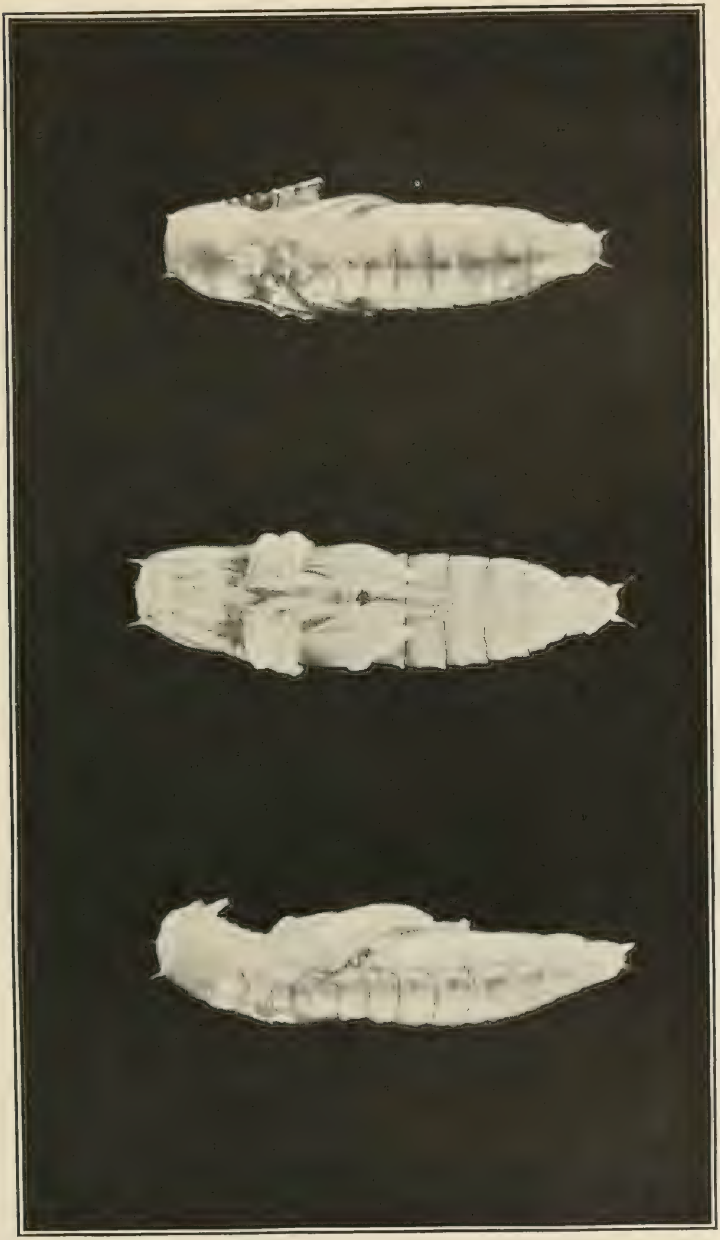
Prof. A. L. Melander, entomologist of the Washington Agricultural Experiment Station, Pullman, Wash., reports that in the collection there they have a single specimen which was collected in eastern Washington.

It is thus seen that this species is fairly well scattered along the western half of California. It is probably not of economic importance outside this State.

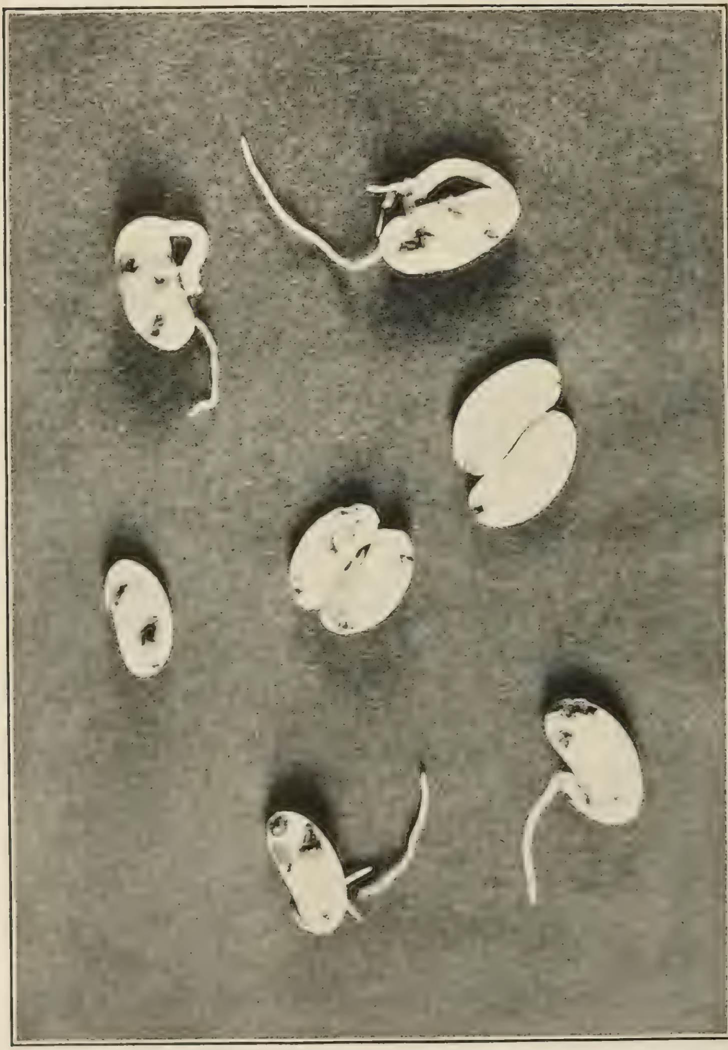
FOOD PLANTS.

The larvæ of *Limonius californicus* have been noted to feed on the following plants:

Sugar beet.
Wild beet (*Beta* sp.).
Potato (*Solanum tuberosum*).
Lima bean (all varieties).
Corn (all varieties).
Johnson grass (*Sorghum halepense*).
Dock (*Rumex hymenosepalus*).
Alfalfa (*Medicago* spp.).
Pigweed (*Amaranthus retroflexus*).
Chrysanthemum.
Nettle (reported by H. M. Russell).
Wild aster (reported by H. M. Russell).
Mustard (*Brassica niger*).



PUPA OF THE SUGAR-BEET WIREWORM. LATERAL VIEW AT LEFT; VENTRAL VIEW IN MIDDLE; DORSAL VIEW AT RIGHT. ENLARGED.
(ORIGINAL.)



Injury by the Sugar-Beet Wireworm to Germinating Beans. About Natural Size. (Original.)

INJURY BY THE SUGAR-BEET WIREWORM TO GERMINATING BEAN. ENLARGED. (ORIGINAL.)

It is difficult to note a preference of this wireworm for any particular food plant, as sugar beets, lima beans (Pls. VI, VII), corn (fig. 3), potatoes, and alfalfa all seem to be favored. After these

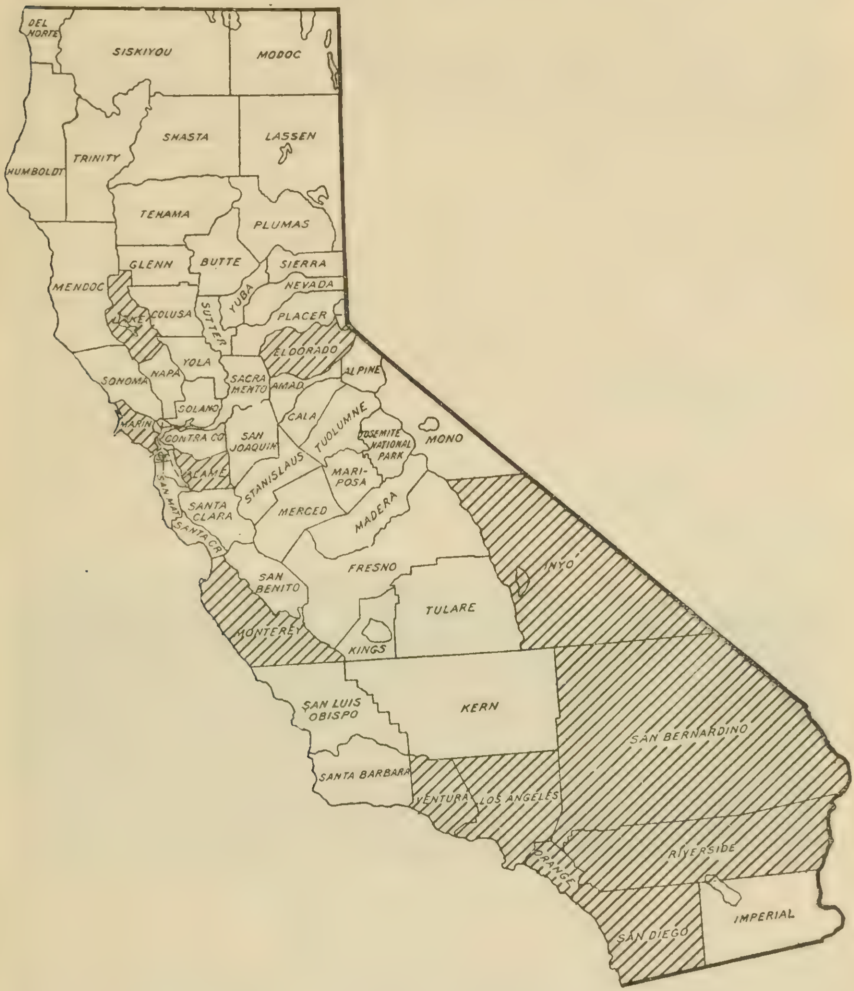


FIG. 2.—Map of California showing counties from which the sugar-beet wireworm has been reported. (Original.)

in order come Johnson grass and wild beets. The remaining food plants seem to be taken more from necessity than choice, and it is only occasionally that larvæ are discovered feeding on them.

LIFE HISTORY AND HABITS.

The Egg.

TIME AND PLACE OF DEPOSITION.

The eggs (Pl. II, *fig. c*) are all deposited during the spring and in the greatest numbers about the middle or latter part of April. (See diagram, fig. 4.) During the latter part of March immature eggs to the number of from 25 to 40 could be dissected from the swollen abdomens of the females.

On April 9 the first eggs were laid. These were placed in the loose damp soil of the rearing cages, about 1½ inches below the

Fig. 3.—Injury by sugar-beet wireworm (*Limonius californicus*) to field of sweet corn, Dominguez, Cal. (Original.)

surface. It seems that it is intended that the eggs shall always be placed singly, as out of about 8,000 eggs taken from the soil only a very few cases were noticed where several eggs were together. Never were more than three eggs in a group, and these were not held together in any way.

Food plants seem to have no effect on the place of deposition, as there were always as many eggs found at the edges of the cage as there were surrounding the young beet plant at the center. At first this was supposed to be due to the fact that the tender root hairs are scattered rather generally through the soil, but later tests seemed to indicate that the place of deposition is affected more by the condition of the soil, a loose damp soil being selected by the adults in preference to other kinds.

Nearly all the eggs were placed in the first inch and a half of damp soil, and the greater part of these about 1 inch below the line of dampness.

A small mite, which has been identified by Mr. Nathan Banks as (*Gamasus*) *Parasitus coleoptratorum* L. (?), was commonly noted in the soil with the eggs but was never seen destroying them.

NUMBER AND HATCHING OF EGGS.

Complete records for the eggs could not be obtained, so the number of eggs laid by a female of this species is still a question. One female which had been isolated after fertilization laid 71 eggs before death, and 11 were added by dissection, bringing the total to 82 eggs. Another female gave a total of 63 eggs by oviposition and dissection. Two others gave 61 and 52 eggs. Twenty-five dissections gave the number of eggs as between 28 and 40, or an average of about

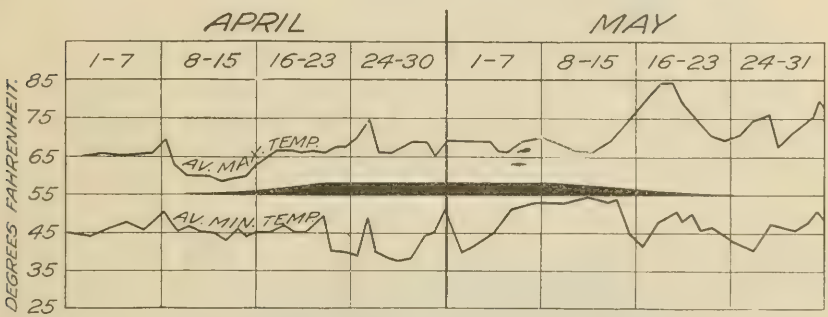


FIG. 4.—Diagram showing the period eggs of the sugar-beet wireworm were in the soil, with temperature; season of 1912, Compton, Cal. (Original.)

34 eggs per individual. It is quite probable that 100 eggs or even more may be deposited by a single female.

Practically all the eggs hatch. In the laboratory over 94 per cent of 5,000 eggs hatched successfully, even after they had been handled and kept under artificial conditions. Those which did not hatch were for the most part either allowed to dry out or were killed by a fungus. Eliminating two cages—the one which dried out and the one in which the fungus appeared—it would be safe to say that over 98 per cent of about 4,200 eggs which were kept under laboratory conditions hatched safely.

There is an optimum zone, in so far as the degree of dampness is concerned, for the hatching of the eggs. Some eggs kept in a dry vial indoors, where it was not too warm, failed entirely to hatch and after a time shriveled up. On the other hand, the eggs which were kept too damp were subject to a fungous attack. Water itself seems to have little effect on the hatching of the eggs, as some which were kept partially submerged part of the time hatched in good shape.

As hatching time approached, large, irregular, hyaline areas appeared in the eggs in various places. At first nothing could be seen of the embryo, but about a week before hatching its outlines could be made out with difficulty. The embryo became little plainer, even at the time of hatching.

LENGTH OF EGG STAGE.

The length of the egg stage varied under laboratory conditions from 23 to 33 days, most of the eggs hatching in from 27 to 30 days, so that the length of the egg stage may be roughly considered as a month. It seems probable that the period might be shortened materially under favorable conditions, out of doors, and eggs laid in the warm damp soil might possibly hatch in from 15 to 25 days.

The Larva.

EMERGENCE FROM THE EGG.

The larvæ (Pl. II, *fig. b*) emerge from the eggs by eating a small hole in the shell and crawling out. In all the cases noted the hole was very little larger than the body of the wireworm, so that it is a matter of a few moments for the young wireworm to leave the shell entirely. In the case of several which were timed, between two and seven minutes elapsed from the appearance of their heads through the shell until they were entirely free. During the earlier part of the hatching season no eggshells could be found, and it was thought probable that the larva on emerging used the shell for food. Such did not prove to be the case, however, as later, when more eggs were hatching, it was observed that the larva on hatching leaves the old shell almost at once. In a few cases the larvæ crawled around the shells for a short time but did not attempt to eat them and always left them intact. Where the eggs are hatching in the soil, the young larva remains for a short time in the cavity occupied by the egg. That the eggshells are quite tough was proven by the fact that the empty shells were able to retain their shape for some time.

THE NEWLY HATCHED LARVA.

When first hatched the larva (Pl. II, *fig. b*) is semiopaque white. The extreme tips of the mandibles are the only parts which show any color, and these are light yellow. The general proportions of the newly hatched larva are very much like those of the older ones. They vary little in size. Their average length is 2 mm. and the width is 0.27 mm.

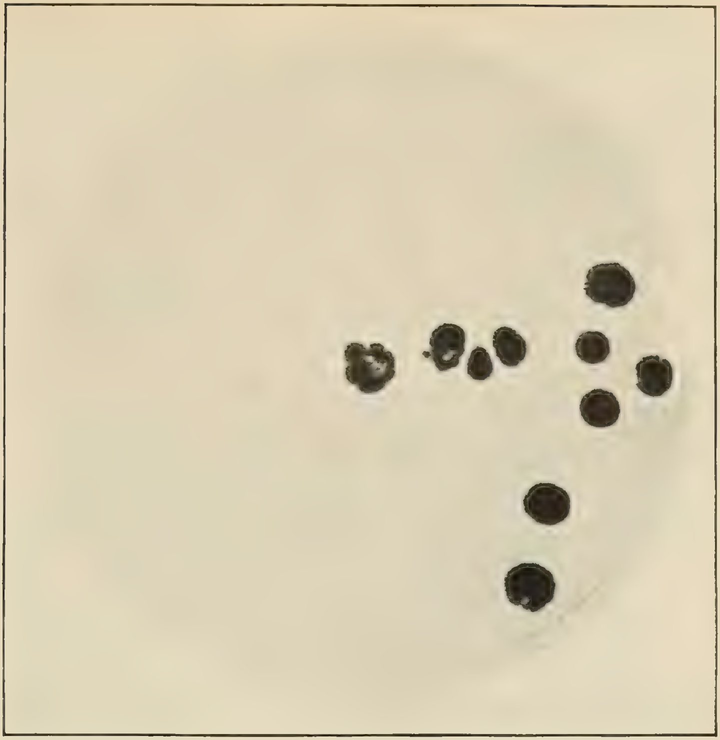


FIG. 1.—SUGAR-BEET WIREWORMS IN PETRI DISH, KILLED BY BACTERIA IN CULTURES OF AGAR. (ORIGINAL.)

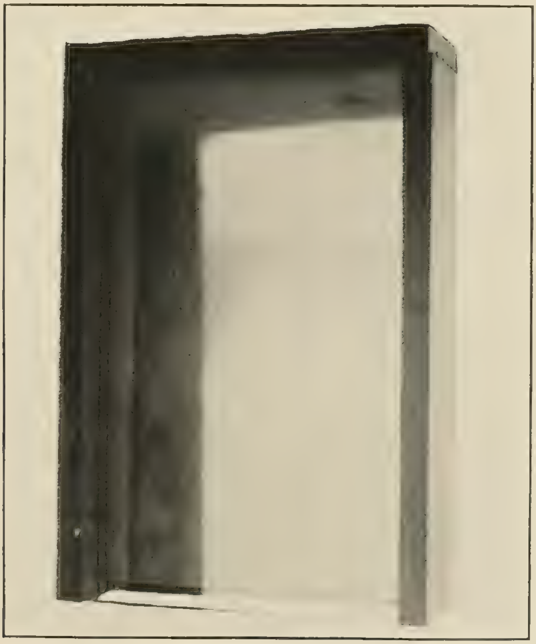


FIG. 2.—A ROOT CAGE USED IN REARING YOUNG WIREWORMS. (ORIGINAL.)

When these larvæ are exposed to a moderately subdued light they color quite rapidly and become noticeably yellow all over their bodies in a day's time. When the newly hatched larvæ are kept in darkness they color more slowly, and two or three days elapse before their bodies become yellowish. Their skin is quite tender, but in spite of this they can survive rather rough handling.

REARING CAGES USED.

Several styles of cages were used in an endeavor to find one in which the wireworms could be successfully reared and at the same time watched. Only three types gave any promise of success, and these will be reviewed briefly.

The first type used was simply a petri dish with damp filter paper in it. Several sheets of filter paper were used so that when the larvæ crawled between the sheets it was almost the same as if they were in damp soil. Slices of beets were placed in the cage and renewed daily. These were of use not only as food for the wireworms, but they also assisted in keeping the atmosphere of the dish damp and cool. These dishes were then kept in insect boxes to insure perfect darkness and to assist in keeping the temperature even. This style of rearing cage was very successful for the first two weeks, and much was expected of it, but from that time on one bad point after another presented itself, and within a month the cage was given up as impractical. The two worst points in connection with this cage are that the amount of moisture can not be regulated and, secondly, that there is no drainage and the cage tends to foul easily. The cages were cleaned every day and fresh filter paper added, but in spite of all these precautions a red bacterium (Pl. VIII, fig. 1) made its appearance in several of the cages at about the same time, and as there seemed to be no way to check it this style of cage was given up.

Another rearing cage (fig. 5) which was used was made of plaster of Paris, and was patterned after the Janet ants' nest, except that it was more simple. It is a plaster-of-Paris block with two depressions in it. Water is kept in one and the wireworms in the other. The water readily soaks through the block, and if the dish is covered with a tight-fitting piece of glass the depression containing the wireworms is kept damp and cool. The cage is further improved by painting the glass plate black to exclude light. Dr. Chittenden suggested a coating of paraffin for the outside of the dish to cut down the excessive evaporation. This scheme worked well where only part of the dish was coated. Whenever the entire outside of the cage was coated, however, the drainage was cut off, the cage became foul, and the wireworms died. The great advantage of this cage, as pointed out by Messrs. Knab and Dimmock, is that it can be sterilized simply by heating. Most of the first trials of this cage were failures, but it soon gave promise of being a simple and safe receptacle in which to rear wireworms.

The other style of cage was the common root cage (Pl. VIII, fig. 2), so often used for the study of underground insects. The cages used in these experiments had the glass walls very close together (one-eighth to one-fourth inch) so that there would not be much soil in which the larvæ could hide. The root cages were not so successful as it was hoped they would be, for the larvæ were usually able to conceal themselves and it seemed almost impossible to wet the cages properly. Used in conjunction with the other cages, however, they gave fair success.

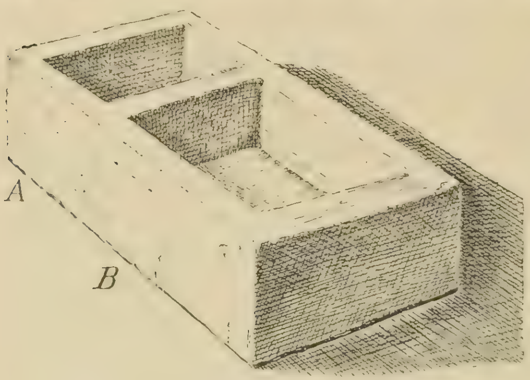


FIG. 5.—Janet ants'-nest plaster-of-Paris cage, used in rearing sugar-beet wireworms. *A*, compartment for larvæ; *B*, compartment for water. (Original.)

The majority of the young wireworms were kept in large flowerpots, so that in case of accidents to the rearing cages not all the larvæ would be lost. These pots had an added advantage in that they provided soil conditions quite similar to those out of doors. The flowerpots were emptied and examined from time to time so that the larvæ could be watched.

HABITS OF THE YOUNG WIREWORMS.

The young wireworms are quite active, moving over smooth surfaces or burying themselves in the loose soil with ease. Some placed in a root cage buried themselves almost at once, but were temporarily checked by a layer of compact earth about an inch below the surface. On the following day several had entered the compact layer and the next day one was noted at a depth of 4 inches.

When very young they are unable to survive in dry earth even for a relatively short time. Some which were placed in a petri dish with dry soil were dead at the end of five hours, a few dying after the first hour and a half.

These larvæ shun the light and when exposed to it hide under any object which they can find. When placed in the petri-dish cages they soon crawl between the layers of filter paper at the bottom. Experiments were made to test their ability to locate food, by placing a slice of sugar beet in the cages and noting the time it took them to collect under it. The beet slice was not larger than a dollar and was placed in the center of a large petri dish. Within 10 minutes all the wireworms were under it. This experiment was repeated by using a piece of damp cardboard the size of the beet slice and again timing the wireworms. In this test all the larvæ finally gathered under the cardboard to escape the light, but a longer time was required before this took place. These tests were repeated several times as checks and always gave the same results, so it is evident that the larvæ are able, to a small extent, to locate food.

The larvæ begin feeding noticeably, though lightly, very soon after hatching. A fresh slice of sugar beet was placed in the cage every day, and when each slice was removed the minute black feeding marks could be noticed. The depressions made by the feeding could be made out only with a hand lens, but the black stain, so characteristic of wireworm injury, had spread out and was quite conspicuous.

The wireworms grow quite rapidly during the first two or three weeks, and it might be added that this is the only time in their long larval life when their growth is apparent. They approximately double in size in this time and then remain about the same size until they molt. At the time of their first molt they take a sudden jump in size and from this time on their growth is very slow.

An attempt was made to trace the molts with these wireworms, but unfortunately it had to be abandoned. The death rate in the exposed cages was so high that it soon became apparent that none could be brought entirely through in this manner. Added to the difficulty was the fact that since their time of molting was so irregular only a few could be kept in a single cage. After about a thousand larvæ had died in these cages it was concluded that it was impossible to carry the observations to completion with the forms of rearing apparatus at hand. The cast skins of the larvæ could not be found, owing to their small size and transparency, and the only molts that could be traced were in the case of certain larvæ which increased in size quite noticeably overnight. The increase in the width of the head was found to be the best test.

From time to time the soil in the flowerpots containing the bulk of the wireworms was carefully examined to see whether anything could be learned concerning the feeding habits of the larvæ under natural conditions. In every case the larvæ were found scattered rather generally through the soil, and as many of them were found around the edges of the pot as directly around the beet root. Since the root hairs were scattered pretty generally through the soil it seemed probable that the larvæ fed on them. This was further indicated by the fact that no feeding marks could be found on the main beet root. At any rate it is safe to say that, from the standpoint of injury due to their feeding, the wireworms during the first year of their larval life may be disregarded. Larvæ were generally found from 1 to 3 inches below the surface, but as the soil in the rearing cages was kept damp to the surface they would evidently be found deeper under field conditions.

Examination from time to time during the summer revealed no startling changes. Growth was very slow, but the wireworms became more active, and their skins a deeper yellow and noticeably harder.

APPROXIMATE LENGTH OF LARVAL STAGE.

As the first larvæ of this species were hatched from the eggs in the spring of 1912 there are no data concerning the complete life history or even of the way the larvæ pass their first winter. At the date of this writing (Oct. 15, 1912), however, it seems quite evident that this year's wireworms will turn out next spring to be the "small ones" which are always noted coming up to feed during February and March.

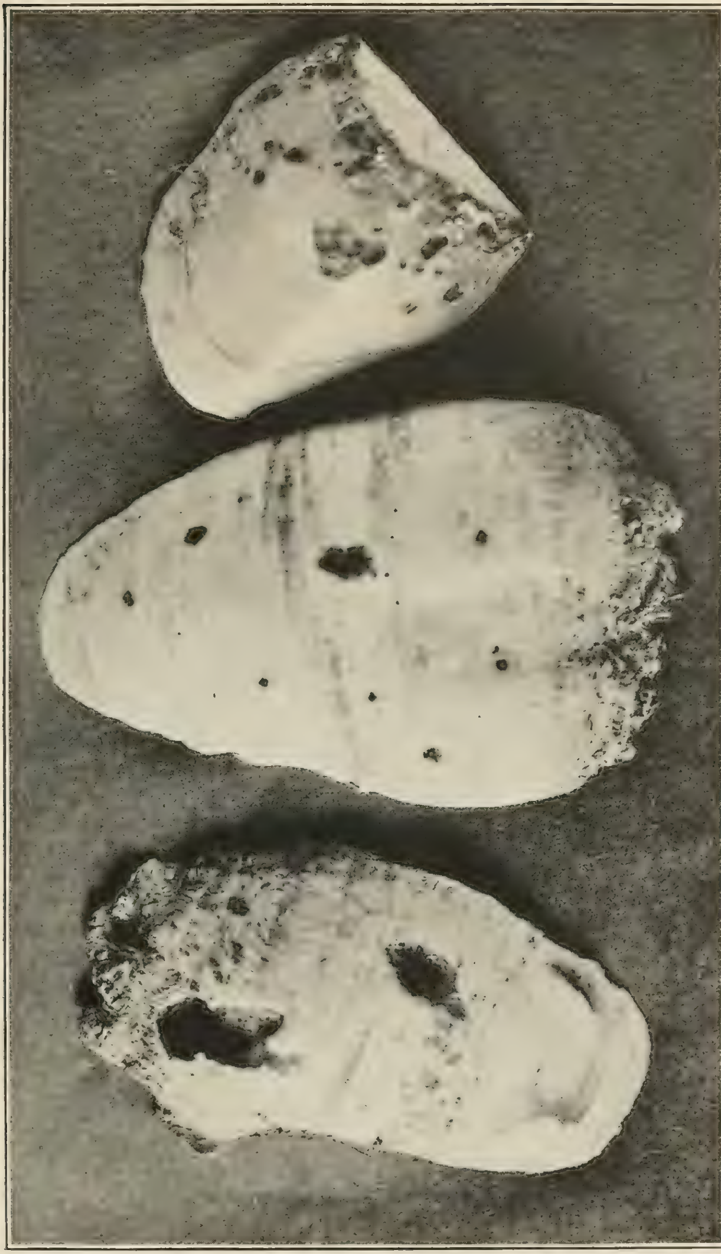
At the time the beetles were being collected, in March, 1912, there was no vegetation of any kind in some of the fields, and the wireworms, coming out from hibernation, were attracted to the old beet roots which are found in greater or less numbers in all of the fields. Nearly all larvæ collected at this time, to the number of over 3,000, were readily separable into two sizes. This has been reported before by other investigators.[1] The smaller ones appeared to be about one-third grown, and very probably were the ones which had hatched the preceding spring, and were consequently about a year old. The larger ones showed more variation in size, occurring from three-fourths grown to practically mature. These larvæ were probably 1 and 2 years older than those of the smaller size. That there is a difference in age in the wireworms of this latter group is proved by the fact that of 100 isolated during March only 17 pupated in the period from July to September, and the remainder, some of which at the time of writing (December, 1912), had recently molted, had gone deep into the soil in the cages and seemed prepared to spend the winter. Now, from the fact that none of these large larvæ could have come from eggs the preceding spring it seems very probable that this species will uphold the contentions of most of the American writers on this subject and spend three years in the larval state. To be exact, it would be a trifle over three years, as Prof. F. M. Webster[2] has pointed out, "the larvæ hatching in the spring and pupating in the late summer." Larvæ have also been carried in the laboratory from June, 1910, to April, 1912, without pupating, so it seems evident that the larval stage could not be less than three years.

[1] Eleventh Report on the Noxious, Beneficial and other Insects of New York. By Asa Fitch, M. D., 1866.

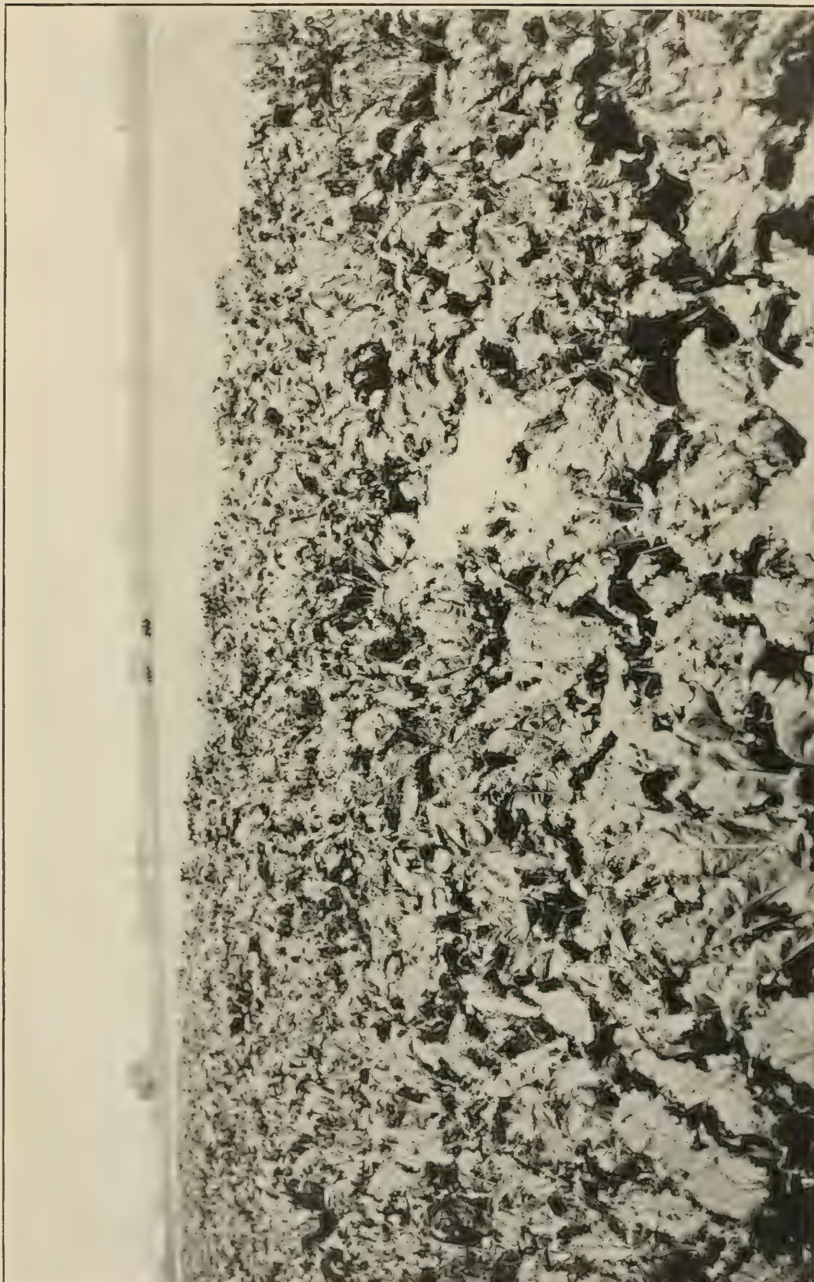
[2] Underground Insect Destroyers of the Wheat Plant. By F. M. Webster. Bul. 46, Ohio Agr. Exp. Sta., 1892.

WORK OF SUGAR-BEET WIREWORMS. YOUNG SUGAR-BEETS, SHOWING INJURY BY WIREWORMS TO TAPROOTS; BLACKENED FEEDING MARKS VISIBLE ON END OF ROOTS. (ORIGINAL.)

WORK OF THE SUGAR-BEET WIREWORM. NEARLY MATURE BEETS KILLED BY WIREWORMS; BLACKENED FEEDING MARKS NOTICEABLE ON TAPROOTS. (ORIGINAL.)

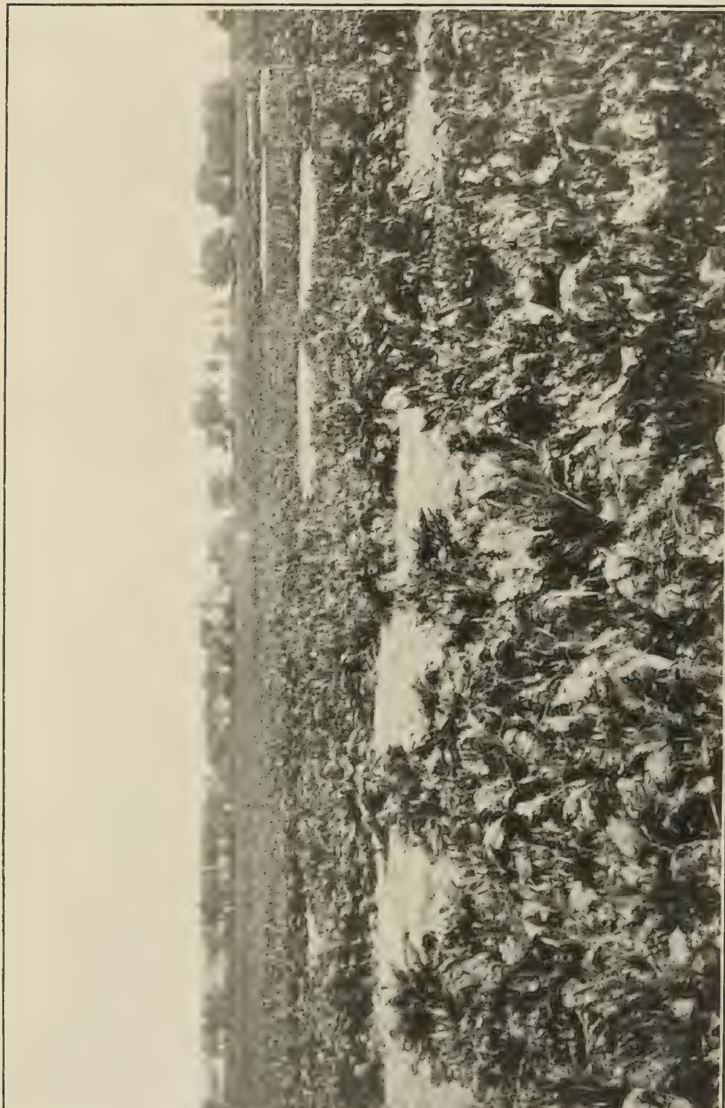


WORK OF THE SUGAR-BEET WIREWORM. MATURE BEETS SHOWING OLD SCARS RESULTING FROM WIREWORM INJURY. (ORIGINAL.)

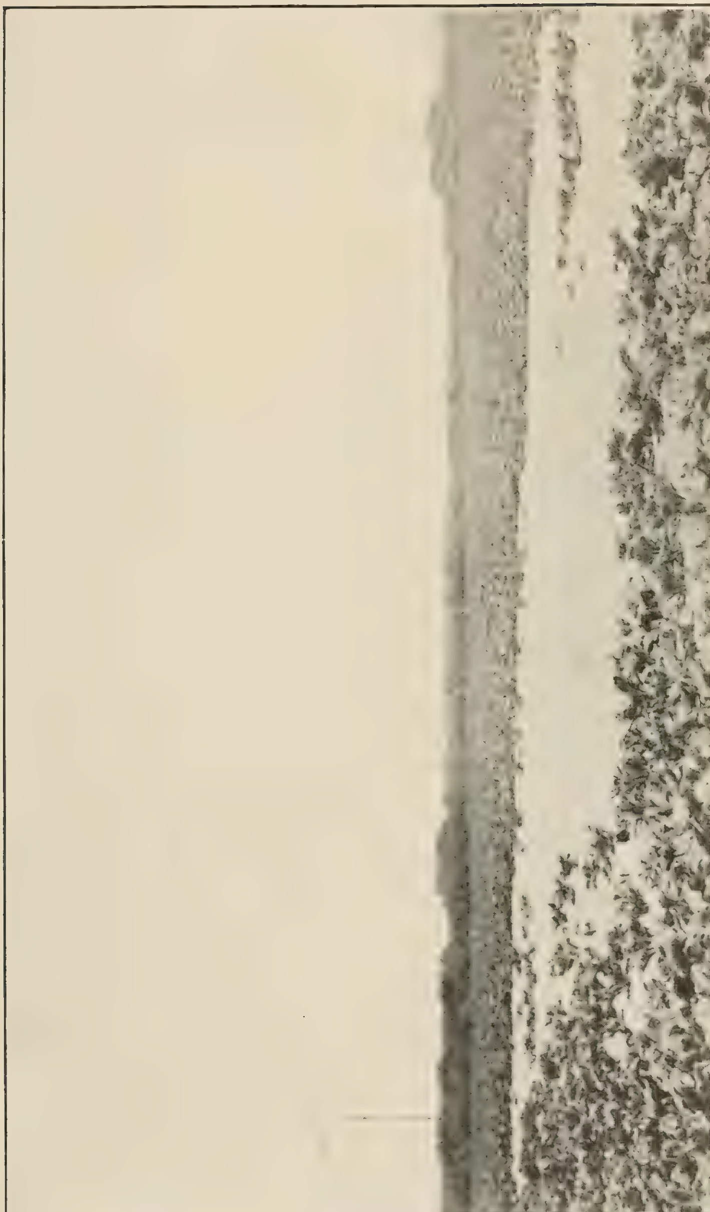


RAVAGES OF THE SUGAR-BEET WIREWORM. BEET FIELD, SHOWING SMALL CLEARED SPACE RESULTING FROM THE WORK OF WIREWORMS.
(ORIGINAL.)

RAVAGES OF THE SUGAR-BEET WIREWORM. BEET FIELD, SHOWING CLEARED SPACES RESULTING FROM THE WORK OF WIREWORMS. (ORIGINAL.)



RAVAGES OF THE SUGAR-BEET WIREWORM. BEET FIELD, SHOWING CLEARED SPACES, MORE EXTENSIVE THAN IN PLATE XIII, RESULTING FROM THE WORK OF WIREWORMS. (ORIGINAL.)



RAVAGES OF THE SUGAR-BEET WIREWORM. BEET FIELD, SHOWING VERY LARGE CLEARED SPACE RESULTING FROM THE WORK OF WIREWORMS. (ORIGINAL.)

HABITS OF THE OLDER WIREWORMS.

While these wireworms were being collected in the fields there was a good opportunity to observe their feeding habits and their actions after emerging from hibernation. As the soil was wet to the surface by the intermittent rains, it was easy for the wireworms to reach the old beets which were scattered around on top of the ground. As the larvæ had just emerged from hibernation they fed extensively, with the result that whenever several wireworms attacked a beet root it was soon honeycombed with their channels. Many of the wireworms noted were buried far more than their own length in the half-rotted beets.

FIG. 6.—A sugar-beet wireworm devouring one of its own kind; to illustrate cannibalistic habit. (Original.)

These larvæ are carnivorous on occasions (see fig. 6), even under field conditions; especially is this so during the early period when they are feeding most busily, and when at the same time they tend to be crowded. Under average field conditions, however, cannibalism is unimportant from an economic standpoint, as these larvæ are vegetable feeders by choice.

LOCATION OF FOOD BY THE WIREWORMS.

Whether or not the wireworms, under field conditions, can locate food at a distance, and, if so, at what distance, is more or less problematical. When wireworms were injuring beets in the fields it was found by careful digging that all which were near the beets were actually feeding on them. Wireworms noticed in fields containing young beets were almost always found in the beet rows, in spite of the fact that the ground there is compact and unfavorable for them. These facts seem to carry out the idea gained from the experiments with the young larvæ, that they can locate food at a short distance, though this is not proven conclusively.

ACTIVITY OF THE WIREWORMS.

During the spring, when the soil is kept wet by the rains and loose by cultivation, it is probable that the wireworms are able to travel from one beet plant to another. Under laboratory conditions they have been noted to travel several inches daily, in the root cages, and the soil then is very apt to be compacted by wetting. This point was tested by placing several wireworms in a root cage without food in order to compel them to move. The soil, which was quite damp at first, was allowed to become pretty thoroughly dry, and then the cage was watered. The water followed the channels of the wireworms, and in this way the wireworms could be easily traced by the wet streaks through the soil. These cages were 18 by 24 inches, yet in the week or 10 days the soil was drying out the wireworms had been able to channel all through the soil. Late in the summer, when the soil is more dry and compact, they move about much more slowly and are less anxious to feed, but as they do all their damage in the spring their actions at the latter time are of the utmost importance. From all the observations on their activity it seems not only possible but even probable that one wireworm can destroy several young beet plants in a season. The sugar-beet plants are from 6 to 8 inches apart in the rows.

WIREWORM INJURY TO BEETS.

During the latter part of February and in March and April the ravages of the wireworms in the beet fields are very noticeable, especially so when the insects are present in numbers. In a year such as 1912, when their work was well scattered, injury can be noted, but it is possible to overlook it.

When the young beet plants are attacked they wilt, and upon examination the root is found to be either badly scarred or entirely severed. (Pl. IX.) This injury generally takes place between 1 and 4 inches below the surface. There are two general types of injury; in one the taproot is cut off clean, and the beet wilts and dies (see Pl. X); in the other the wireworm, after eating into the root, turns and descends, eating off a side of the root as it goes down (see Pl. IX). This, of course, scars the root badly, and if the beet is quite young and tender it is apt to die. If, however, the beet is quite strong and the root is swollen a little, so that the injury does not cut off the sap supply, it will recover, though always remaining distorted and undersized. (See Pl. XI.)

In years when the wireworms appear in numbers they are likely to be concentrated in certain spots. When this occurs they kill off all the beet plants in these areas, causing the characteristic "bald spots." (Pls. XII–XV.) When once they have collected in this manner and have cleared off the beets it is almost impossible to raise beets there during that year, even if replanting is resorted to several times, as the wireworms kill them as soon as they germinate.

The injury caused by the wireworms is characteristic and should never be mistaken. In the first place, if the injury is recent, an examination will reveal the wireworm near by in the soil. If no wireworm is present an examination of the wound will readily show whether or not it is wireworm injury. The wound itself is stained black, as if rubbed with ink. Sometimes the black stain has penetrated for a short distance into the sound beet tissue, but where it has not, it is considerably darker than the dry tissue surrounding an ordinary old wound.

Effect of overflowing on the wireworm.—From the fact that wireworm injury is often noticed in fields which have been overflowed in the latter part of the winter, it has naturally been supposed that overflowing of the land is favorable to wireworms. This has not been proven to be entirely true. A careful watch was kept on the fields which are subject to overflow, and from these observations it seems that overflowing the land is of account only as it affects the character of the soil and is therefore secondary. In overflowed land which tends to be sandy the wireworms are likely to be destructive year after year. On the other hand, flooded land which is a heavy silt and rich in humus is seldom so badly injured as is sandy unflooded land. One thing has been noticed, however, and that is that flooding the land does not seem to injure the insect in the least and therefore gives little promise as a control measure. Some of the beet fields which have suffered the most during the last few years are those which almost every year are quite thoroughly flooded for two or three days.

TIME THE WIREWORMS CAN LIVE WITHOUT FOOD.

Whether or not these larvæ are able to find food in the soil is hard to determine, but judging from the length of time they are able to live without food it seems possible that they do receive some sustenance from the soil, probably in the form of decaying vegetation. This is further borne out by the fact that where larvæ are kept for a time in a cage without food all the lumps of leaf mold disappear and the soil in the cage becomes homogeneous.

Several observers have reported that these larvæ can survive long periods without food, and one example which was noted in the laboratory will furnish added proof. During June, 1910, Mr. H. M. Russell commenced a starvation experiment by placing several wireworms in a root cage, with ordinary soil, without food. In July, 1911, seven larvæ were still alive and healthy. This cage was watered regularly, except on two occasions, during the late summer of 1911 and was then allowed to become quite dry. As the larvæ were killed by the drying soil they were removed so that they would not furnish food for the survivors. On September 12, 1911, the cage was again examined and only one larva was found alive. Two dead ones were found near the surface in the dry earth, and they had probably been killed by the drying out of the soil. This cage was then watered regularly and examined at intervals. The larva was still alive and active on April 15, 1912. During the latter part of April the cage, which was kept in the outdoor insectary, was blown over by the wind and broken. Before it was noticed the soil had dried out to such an extent that the larva was dead. An

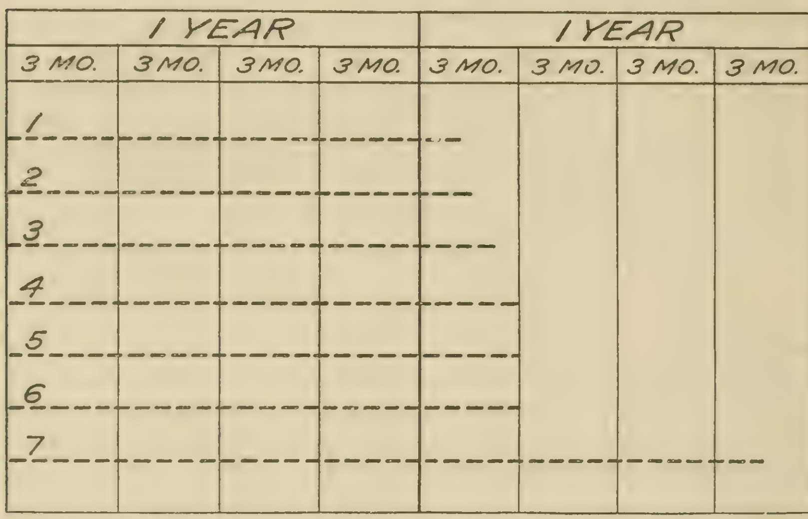


FIG. 7.—Diagram showing length of life of sugar-beet wireworm without food. (Original.)

examination of the channels through the cage showed that the wireworm had been quite active up to the time of its death. While these larvæ might have secured a little food during the earlier part of the experiment they could not have done so later, as they were checked up and removed when they died. In this experiment seven wireworms lived over a year without food, and one almost two years, as shown in the following diagram (fig. 7).

These wireworms did not grow normally, for when the last one died after being in the cage two years it was less than half size. This larva should have pupated that fall, as it was at least a year old when the experiment began, and therefore should have been mature.

RELATION BETWEEN INJURY IN THE BEET FIELDS AND THE SIZE AND ABUNDANCE OF WIREWORMS.

As is the case with practically every destructive insect, the greatest harm is done by the maturing larvæ. It is therefore only a matter of watching the progress of injury in the beet fields to tell whether or not there are many mature wireworms, and whether, therefore, there will be an abundance of beetles the following year. In every year during which observations have been made thus far it has been a simple matter to foretell this point. In 1911 injury to the beets was quite heavy and general. From this it was reasonable to suppose that there were many mature wireworms in the soil and that the next year would see an abundance of beetles. Such proved to be exactly the case and beetles were quite common in the fields; so much so, in fact, that it was no extraordinary feat to collect over 25,000 of them for the rearing work. In 1912, in the vicinity of Compton, the wireworm injury, while quite general, was light, and using the same reasoning it was probable that there would be few beetles in the spring of 1913. This has been partially proven by the fact that very few of the larvæ taken in the fields during 1912 pupated the same fall. The 300 wireworms collected in the summer of 1911 produced almost as many pupæ in the fall of that year as the 12,000 wireworms collected in the summer of 1912 produced during the succeeding fall.

MOLTING OF THE WIREWORMS.

The wireworms molt in their channels, and wriggling from their old skin (Pl. III) they lie still for some time until their new skin has hardened. If the channel is larger in cross section at the place where the wireworms molt, it is so little larger as to be almost unnoticed. When ready to molt the larvæ lie still for some time, in certain cases for several days, before the skin splits and they are able to free themselves. In a majority of the cast skins noted the skin had split down the dorsum of the thorax. Where this occurs the process of molting is simple and seldom takes more than two or three hours. The cast skin is also in one piece. Now and then the skin splits irregularly, and in these cases the molting process requires more time, sometimes several days. In one case noted the wireworm shed the skin from its head a full week after it had molted on its thorax and abdomen. In such cases the skin is quite apt to be torn into several pieces and is almost useless for study.

Directly after molting the wireworm, with the exception of its mandibles, is a rather shiny opaque white. The mandibles are yellowish, shading to brown at the tips. The wireworms color quite well in from one to three days, but they often remain quiescent for weeks after molting. This is especially apt to be the case in the fall, when they are sluggish.

Most of the larvæ observed during 1912 molted twice. A few were seen to molt once, although it is possible that a molt might have been overlooked in a few instances. In the case of a few others it was thought that a third molt was seen, but this is doubtful. From this it is impossible to give even the approximate number of molts with any degree of accuracy, but present indications are that they molt at least five or six times.

The Pupa.

PUPATION.

In about July or August the mature larvæ become shorter, and while they are not more constricted between the segments, they have the appearance of being so, as the segments swell slightly in the middle. At the same time there is a slight change in color, the entire larva appearing sickly and of a dirty yellow color. During this period the wireworms lose most of their activity, and whatever movements they make are slow and weak. When pupation is only a short time off they are quite helpless, and if their pupal cells are broken open they are unable to make new ones. Several which were taken in this condition were able to pupate safely, the operation taking place in a Janet ants'-nest cage.

THE PUPAL CELL.

The pupal cell is simply an enlargement at the end of the larval channel, and is slightly elliptical in shape. It is unlined but is quite smooth and the soil is well compacted. The depth of the pupal cell below the surface varies between 4½ and 9 inches, but most of those observed were at a depth of about 6 inches. It is apparent that the wireworms move very little preparatory to pupating, as pupæ are often dug up with the wireworms close to the old beet roots.

SOIL CONDITIONS AFFECTING PUPATION.

The pupæ (Pl. V) are unaffected by a little dryness, but if the soil becomes quite dry for a long period they do not emerge. Many healthy pupæ were dug up in the field in soil which contained only a little moisture. Those which came through best under laboratory conditions were from cages where the soil was kept only moderately damp. Where the soil was too wet a large percentage of the pupæ sickened and died. Those found dead under these conditions were attacked either by a fungus or a bacterium, or sometimes by both. It was not determined whether these organisms were parasitic or saprophytic. An attempt was made to rear some of the pupæ in the plaster-of-Paris cages, but the cages seemed to be too damp, and all the pupæ died. These appeared like those killed in the flooded cages, and the same bacterium and fungus infested them.

VITALITY OF THE PUPA.

The pupal stage is the most unprotected state in the life cycle of this insect, and is the one wherein the insect is most liable to mechanical injury. A small percentage of the pupæ dug up out of doors were injured when their pupal cells were broken open, and consequently died. On the whole, however, the pupa is not nearly so susceptible to injury as is the popular belief. Such pupæ as were unearthed in the field were kept under artificial conditions and handled quite roughly and often, yet most of them produced adults. The two pupæ which were photographed for this bulletin (see Pl. V) were handled several times with forceps, were exposed on a glass plate to light and temperature for hours, and on one occasion were dropped from the table to a chair, a distance of about 10 inches. In spite of this treatment both produced normal adults, and when last observed, October 14, 1912, were alive. There were several similar cases in which the results were the same as in the example cited. The pupæ are quite helpless and are unable to make new pupal cells in case the old ones are destroyed. For this reason, probably, a large percentage of those disturbed in the field die from exposure. The pupæ are sensitive to light, heat, and contact, and when disturbed move their abdomens in such a way that the tip describes a circle. As the pupa becomes older it becomes more deeply colored and more sensitive and active.

CHANGES IN COLOR OF THE PUPA.

The first signs of coloration of the pupa are the eyes, and these appear as dusky bluish spots. The abdomen and thorax then become slightly yellow and the mouthparts and wing covers very faintly dusky. The tip of the abdomen remains whitish. About a week before emergence the entire pupa becomes darker, and just a few days before emergence the wing covers and mouthparts are quite dusky and the eyes assume a dusky color, the mouthparts, eyes, and wing covers remaining a little the darkest and being quite conspicuous.

LENGTH OF THE PUPAL STAGE.

The length of the pupal stage under laboratory conditions varied from 25 to 36 days, with most of the adults emerging in about 26 to 32 days. These were kept as nearly as possible under conditions which would compare favorably with field conditions. This gives, roughly, a period of a month for the pupal state.

The Adult.

EMERGENCE OF THE ADULT.

During the last few days before emergence the pupa becomes very sensitive to light or contact, and when disturbed turns around in its pupal cell by moving its abdomen. An attempt was made to photograph one during this state, but in the hour and a half it was exposed it did not remain quiet long enough for an exposure to be made. The abdomen is drawn in and out as if the beetle were trying to break the pupal skin. This goes on for some time, often for more than a day, and finally the pupal skin splits down the dorsum of the thorax and is worked off. The beetle (Pl. XVI), which has been quite active in shedding its skin, now becomes quiescent, and folding its legs and antennæ as they were in the pupa, remains in the pupal cell. The cast pupal skin lies in the posterior end of the pupal cell along with the last larval skin, and helps form an obstruction between the pupal cell and the old larval channel. The cast pupal skin is semitranslucent white and thin, but at the same time quite tough.

In two cases the legs of the beetle broke through the leg cases before the pupal integument split down the dorsum. Neither of these adults completely emerged, and after moving their legs feebly for a few days they died.

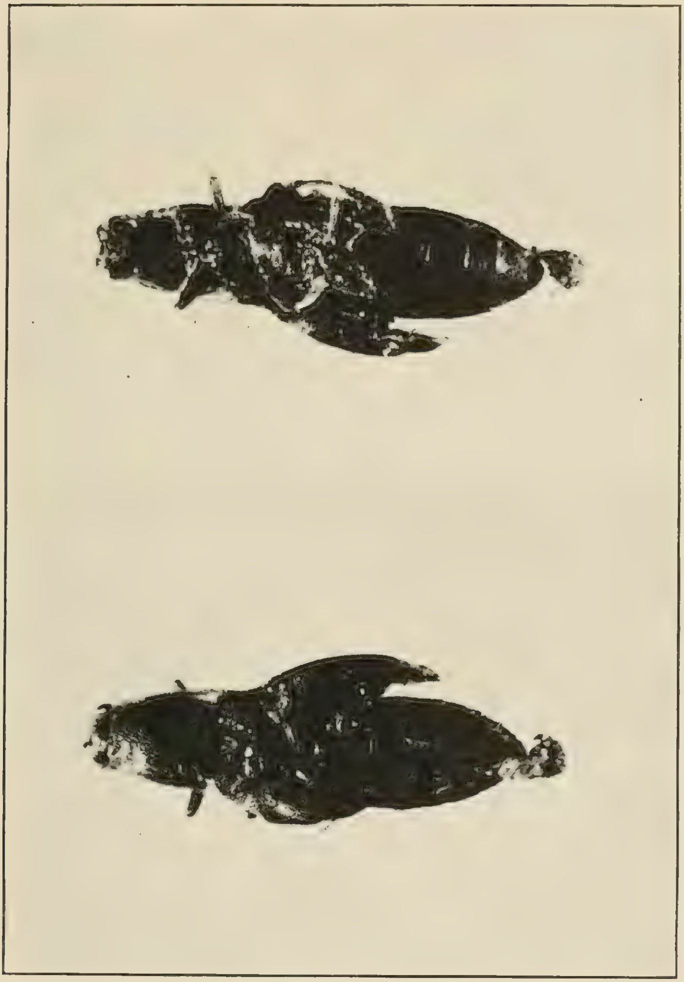
PERIOD OF EMERGENCE.

The period of emergence of the beetle from the pupa varies widely. This was true both of those which were reared in the laboratory and of those pupæ which were collected outdoors. Adults emerged between early August and October in the laboratory, and pupæ from the fields have given adults between the same dates. One pupa from the field transformed to adult October 6. Mr. Russell observed one adult emerge in the laboratory as late as October 17.

Beetles disturbed during the fall are able to bury themselves and live if they are not injured. Several which emerged in the laboratory were constantly disturbed so they could be watched, but it seemed to have no ill effects on them.

ACTIONS DIRECTLY AFTER EMERGENCE.

As soon as the pupal skin is shed the adult, retaining the position it had held as a pupa, lies in the pupal cell. At first the beetle is a little softer and lighter in color, but soon becomes hard and fully colored. Since none of the pubescence on its thorax or elytra has been rubbed off, it appears grayish in color. At this time these beetles are totally different in their actions than they are in the spring, when they appear on the surface, being negatively heliotropic and hiding under anything they can find or burrowing into the soil when exposed to light. They also seek damp, cool quarters in



ADULT OF THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS) ISSUING FROM THE PUPAL SKIN. DORSAL VIEW AT LEFT; VENTRAL VIEW AT RIGHT. ENLARGED. (ORIGINAL.)

FIG. 1.—BEETLES OF THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS) IN SECONDARY HIBERNATION UNDER SLICE OF SUGAR BEET. (ORIGINAL.)

FIG. 2.—BEETLES OF THE SUGAR-BEET WIREWORM PHOTOGRAPHED WHILE FEEDING ON SLICES OF SUGAR BEET. (ORIGINAL.)

HABITS OF THE BEETLES OF THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS) preference to the dry, warmer ones. The habit of feigning death, so marked in the spring when they appear, is totally lacking at this time, and about the only way to make them move is to touch them.

When they are dug up from their pupal cells, or from the ground in which they have been hiding, they become active in a short time, look for another hiding place, and as soon as they find it draw in their legs and antennæ and resume hibernation. They are very sluggish, move slowly, and do not attempt flight.

APPEARANCE OF BEETLES IN THE SPRING.

In the early spring, during a period which covers two months, the beetles dig out of their cells, appear at the surface of the ground, and become partially active. That the time of this "emergence" is governed by several factors is strongly suggested by the diversity in the time of appearance. The average mean temperature is probably the main factor, but such causes as the kind and porosity of the soil in which they have pupated, and the rains, certainly help in determining the time of their appearance. This latter point was suggested by the fact that beetles were always more abundant in the fields following a rain than they were directly preceding it. This might be explained by the fact that their cells became too wet and they had to dig out for safety.

Just after their appearance in the spring the beetles are very sluggish and collect under rubbish of all kinds in the field. They still appear to be in a state of semihibernation and none are ever noted sunning themselves, feeding, or moving about. When their shelters are removed they are found in the same position they maintain during hibernation, with their legs and antennæ folded closely against their bodies. When the sunlight strikes them they slowly become active and search for another hiding place. In every respect their condition at this time resembles hibernation, except that they more quickly become active. To distinguish between this condition and their true hibernation in the soil, the former for want of a better word was called "secondary hibernation." This period lasted from about the middle of February, or a little earlier, till the middle of March. It is little more than a transition period between their hibernation and their period of activity. During this time the weather was quite cold, with cloudiness and showers at intervals.

BEGINNING OF THE PERIOD OF ACTIVITY.

The beetles are so slow to show signs of activity and so sluggish during the earlier part of their active period that no hard and fast line can be drawn between the latter and their so-called secondary hibernation. Furthermore, under every beet active and inactive beetles may be found side by side. Now and then, about the middle or latter part of April, a beetle is seen sunning itself at the edge of a beet under which it had been hiding. At about this time, also, it was noted that the underside of many of the beets which sheltered beetles was roughened and had the appearance of being shredded. At first no attention was paid to this until by chance a beetle was noted feeding on an old beet, and then it was seen that the roughened places on the beet were the feeding marks of the adults. Whenever a beet was turned over the beetles were for the most part active (Pl. XVII, fig. 2), but a few were still in their secondary hibernation (Pl. XVII, fig. 1). The feeding marks on the beets become more and more noticeable but are never especially extensive, as the adults at the period of their greatest activity are light feeders.

Even at this time the beetles are not entirely normal in their actions. This is most noticeable in regard to the habit of feigning death, so characteristic of most of the elaterids. When a group is exposed by removing the beet under which they have been hiding, at least half of them move about searching for shelter. This is probably due to the fact that their senses are not very acute at this time, and they consider only shelter. About a month later, however, when a group of beetles is exposed by removing the beet shelter, most of them remain quiet for some time, even though they may happen to be in an unusual position.

VARIATION IN THE SIZE OF BEETLES.

Among the beetles taken in the field there was a very noticeable variation in size. (See Pl. I.) The length was often found to vary between 9 and 12.2 mm., and the width between 2.5 and 3.5 mm. The larger ones outnumbered the smaller ones almost 2 to 1, since about 15,000 of those collected could be referred to the larger size to about 9,000 of the smaller, while about 2,000 or 3,000 were so nearly on the dividing line between the other two sizes that they were unclassified. At first the large ones were thought to be females and the small ones males, so it was concluded that the females outnumbered the males about 2 to 1. Such did not prove to be entirely the case, for when copulation became general some of the small ones proved to be females, and not a few of the larger ones were seen to be males. Everything considered, it seems that sex is quite independent of size, for the males and females were seen to occur in about equal numbers.

VARIATION IN THE COLOR OF BEETLES.

From the outset it was noted that there was great variation in the color of the beetles. This difference was most noticeable on the elytra, which varied from light buff to deep brown or dusky black.

There seemed to be a rather plain dividing line between those with the buff wing covers and those with the brown ones, so they were separated. About 1,500 or 2,000 could be referred to the former class. Some of these were sent to Dr. Chittenden for determination, and concerning them he wrote as follows:

> No. 495 (?) is *Limonius* sp. near *californicus*. It does not appear to agree perfectly with the *californicus* with which I have compared it, and is not represented in our duplicate collection.

The relationship of these beetles will be worked out in the future.

The true adults of *Limonius californicus* also varied considerably in color, as some were found which were a relatively light brown. These color variations occurred in all sizes and both sexes, so color seems to have no bearing on the sex of the adult.

FEEDING OF THE ADULTS, AND FOOD PLANTS.

When the beetles were first collected the character of their food was unknown, and in an endeavor to find their natural food all the different kinds of foliage found in the beet fields were tried, but without success. Adults by the hundreds were placed in cages containing tender young beet plants, and while they climbed all over the plants they were never seen to feed on them, nor could any feeding marks be found on the plants. A close watch was kept on the adults collected in the field, and at last, as has been stated before, they were noted feeding on the old left-over beet roots, now half dried and partially rotten. When these were substituted for the beet foliage in cages, feeding was begun at once. A few instances were noted where the adults had eaten into the roots to such an extent that the head and thorax were hidden. Such cases, however, were rather exceptional, and the beetles may be considered as light feeders. In addition to this, their feeding, from an economic point of view, may be disregarded.

The adult has been noted feeding on the following substances:

Old beet roots.
Alfalfa roots (*Medicago* sp.).
Johnson-grass roots (*Sorghum halepense*).
Wild beet roots (*Beta* sp.).
Young beet roots.

The old beet roots are the favorite food, and it is only occasionally that beetles are noted feeding on the other substances listed.

The beetles seem to be able to locate food readily and at quite a distance. In the laboratory whenever a slice of beet was placed in the cages the adults would be clustered about it in a very short time.

In the field the beetles were always found at the old beets and always occurred in the greatest numbers where the beets were most plentiful.

In one field, which had a great many old beets on the surface, the beetles were taken from under almost every one, and sometimes in large numbers. It was a common matter to find from 30 to 70 adults under single beets, and as many as 243 have been found hiding under one beet. Another favorite shelter was afforded by the old beet tops (Pl. XVIII) left in the field from the previous year's harvest.

In the field which adjoined this one there were few or no old beet tops and beets for shelter, and here beetles were rarities. This field, just the year before, suffered more than any of the surrounding fields from wireworm injury, so there must have been beetles which developed from the mature wireworms that had caused the damage. In other fields, however, which had suffered similar injury but in which the old beets had been allowed to remain, beetles were present in large numbers. There seems to be only one explanation for this fact, and that is that the adults had emerged from the cleaned fields and, not finding any shelter, had been obliged to move to other fields or be destroyed by the birds. This was further indicated by the fact that all the beetles found in the clean fields were moving about. The state of affairs was found to be the same in other fields aggregating over 600 acres, where the conditions were similar.

FIG. 8.—Screen cage used in observing oviposition of adults of the sugar-beet wireworm under field conditions. (Original.)

STYLES OF REARING CAGES USED.

Several styles of rearing cages were used, but only a few will be considered. The ones used indoors consisted of battery jars, flowerpots, and flowerpots with lantern globes. The highest death rate was found in the first, because there was no drainage and the contents

SECONDARY HIBERNATION OF THE SUGAR-BEET WIREWORM (LIMONIUS CALIFORNICUS). BEET TOPS USED BY BEETLES AS QUARTERS FOR SECONDARY HIBERNATION. (ORIGINAL.)

tended to become foul. The two types last mentioned were about equal in efficiency, but the main difficulty lay in the fact that they were small and it was easy to overcrowd them.

The cage used most successfully was a large screen cage of the common type, kept outdoors. (See fig. 8.) Within the cage were several flowerpots, buried to the level of the ground, each containing young beet plants. The soil in the pots was kept loose and damp, and the soil around the flowerpots was tamped hard. This cage was large, well ventilated, and gave the beetles plenty of room in which to fly about. Its best feature lay in the fact that the beetles all deposited their eggs in the flowerpots, since this was the only place where they could bury themselves easily. It this way the eggs were concentrated much more than they would have been under natural circumstances. As soon as one flowerpot contained a great many eggs it could be removed and another substituted. This cage also gave natural conditions, as the soil it contained was just as damp as that in the field, and since the cage was placed in the sun and was so airy the beetles were always kept at the field temperature. The death rate was very much lower in this cage than in any of the others and there were live adults in it for some time after all had disappeared in the other cages.

DURATION OF LIFE UNDER VARYING CONDITIONS.

To test the duration of life under varying conditions some adults were placed in various styles of cages and others were kept under various conditions as concerned the food and water supply. Some were kept without either food or water, some with food but without water, and some with water but without food. In every instance the beetles lived much longer than was expected of them and proved that they are not only quite hardy but can get along on little food.

One hundred and forty adults were placed in dry battery jars without food or water, and the jars were closed with gauze. The results were as follows:

Eighty-two adults died in from 9 to 12 days.
Forty adults died in from 12 to 14 days.
Eleven adults died in from 14 to 16 days.
Five adults died in from 16 to 18 days.
One adult lived 20 days.
One adult lived 22 days.

None of the beetles was very active after the twelfth day. These conditions were much more severe than any that they might encounter under field conditions.

The adults kept with water but without food were also kept in battery jars. These jars contained about 3 inches of soil, and this soil was kept quite damp by additions of water from time to time. This cage presented very much the condition which would hold in the field if all the food could be eliminated. Five hundred and sixty beetles were used in this experiment, with the following results:

About 60 died before 10 days.
About 100 died before 10–15 days.
About 200 died before 15–18 days.
About 100 died before 18–22 days.
About 60 died before 22–25 days.
About 30 died before 25–28 days.
About 6 died before 28–30 days.
About 2 died before 30–31 days.
About 1 lived for 34 days.
One lived for 40 days.

The last 10 to die were females. Their abdomens were quite swollen, but they did not lay any eggs—at least none could be found—and when they were dissected after death the ovaries, while containing some eggs almost mature, were quite shrunken and dry. None of the beetles was very active after 15 days, and after 25 days they were very feeble, the last few to die being unable to walk during the last days they lived.

Many adults were separated and kept in vials and given food but no water. Care was exercised to have this food as dry as possible. Out of 78 used in this experiment only 12 died during the first 15 days, and the remainder were quite active. It was so difficult to obtain the food dry enough to affect them that the experiment was discontinued.

LENGTH OF TIME ADULTS CAN BE SUBMERGED.

Several adults were submerged in water in a tube and kept below the surface by a smaller tube placed within the first one. The water was perfectly clear and care was taken to remove all the air. At the end of 15 minutes the beetles had ceased to move and at the end of 20 minutes they were removed. They seemed dead, but within a few minutes were moving about actively and seemed none the worse for their treatment.

Another lot was submerged for 40 minutes and within a half hour after being taken out were as active as ever. The tests were not carried further, as these were considered as severe as any they would be subjected to under field conditions. Twenty adults were floated on water for 15 hours and at the end of that time only three were dead. From these results it was concluded that a majority of the beetles could survive a severe storm.

EFFECT OF TEMPERATURE ON THE ADULTS.

The adults of many of the eastern species have been reported by some observers as being primarily nocturnal in habits.[1] Other observers record them as flying readily both by day and night. The adults of *Limonius californicus* seem without exception to be warm-weather insects. They not only attain their greatest activity during the middle of the day when the heat and light are at the maximum, but during the morning and evening hours they are sluggish and quiet. Some specimens were kept in the writer's room during their entire life and none was ever observed feeding or copulating at night. On the warmest nights a very few were observed moving about sluggishly, but their activity at this time can not be compared to that which occurred during the daytime and especially when the temperature was over 75° F.

Several experiments were conducted for determining the direct relation between temperature and activity. The apparatus used was very similar to that used in the boll weevil investigations,[2] except that instead of the outer tube a flask was used, as it was believed that this would afford more even heating.

The results agreed quite closely with those recorded in Bulletin No. 51 (pp. 101–102) and an approximation is given below:

48° F. Beetles quiescent.
54° F. Few crawling about sluggishly.
60° F. Beetles all moving about.
70° F. Beetles becoming active.
75° F. More active, few flying.
80° F. Many flying.
85°–90° F. All flying, very active, seem greatly excited.
93°–94° F. Period of greatest activity.
97° F. Few becoming quieter. Seem to be suffering.
99° F. Many becoming quieter.

This experiment was varied slightly by placing damp filter paper in the inner tube so that the heat would not be so dry. The new results did not differ very startlingly from the preceding, except that the beetles did not seem to suffer so much at the higher temperature and seemed less excited.

Under field conditions 75° to 80° F. seems to be the optimum temperature for their various activities. At 70° F. they are quite active, but few are noted in flight, especially if there is a moderate wind blowing. At 60° F. very few are noted moving in the fields, and these are generally close around the beets under which they have been hiding. The beetles are always more active on bright days than on darker days, even if the temperature is the same. This

[1] Comstock and Slingerland, Bul. 33, Cornell Agr. Exp. Sta., 1891.
[2] Bul. 51, Bur. Ent., U. S. Dept. Agr., Pl. XVI, fig. 72, 1905.

difference in their actions caused by light was very noticeable when cages were removed from the insectary and placed in the sunlight. The beetles would fly about at once and before long many pairs could be taken in copulation. When the cages were replaced in the insectary activity would cease as suddenly as it had begun.

ABILITY OF THE ADULTS TO WITHSTAND UNFAVORABLE CONDITIONS.

The adults showed remarkable ability to withstand shocks of various kinds, whether occasioned by physical injury or by sudden and unfavorable climatic conditions.

A few cases noted in the field will show their ability to withstand physical injury. When beetles were collected in the fields individuals were noted on several occasions to have been injured by their predaceous enemies, *Calosoma cancellatum* Esch. and *C. semilaeve* Lec., and these were separated from the others so they could be watched. Those which had merely lost some of their legs did not seem to be in the least inconvenienced. Others which were quite severely injured managed to survive as long as most of the other beetles. One, which had its abdomen so nearly severed near the anterior end that it had lost one of its elytra, lived for several days.

As to their ability to withstand unfavorable weather conditions, it may be stated that while over 25,000 beetles were collected from the field in a period which exceeded a month, very few were found dead. During this period there were sudden and great changes in temperature and several severe rainstorms.

In view of the fact that the beetles seem to be so hardy in the field, it is difficult to explain the heavy death rate which was noted in all the cages about the time of oviposition. It seems that they must lose much of their vitality during their later life, so that by the time oviposition is about to take place they are comparatively weak.

METHOD AND TIME OF MATING.

When once the adults have attained their normal activity they mate readily during the warmer hours of mild days. Beetles were taken mating as early as March 17, 1912, and as late as April 23, 1912. Every pair taken in copulation in the field was taken between 9.30 a. m. and 3 p. m. No pairs were ever found in copulation if there was a strong wind blowing or if the sky was cloudy or the weather cold and rough. The mated pairs were generally found near or beneath the beets under which they had been hiding and feeding, though one pair was found in a crack in the soil, about 2 inches below the surface.

Temperature has a very direct effect on copulation, as was proved by the laboratory experiments. Battery-jar cages, when taken from the cold rooms, contained only semidormant beetles, but after being placed in the sun for a time the beetles very soon became active and copulation took place. When the cages were returned to the cold rooms it was only a few moments until copulation ceased and the beetles became sluggish again.

The method of mating of these beetles seems to be more or less unique. The male shows no signs of excitement until he comes in contact with the female, and then he rapidly attempts copulation. After the male has assumed his position he throws himself over backward so that he is on his back with his body in the same line with that of the female, but pointing in the opposite direction. The male then folds his legs and antennæ close against his body and remains quiescent during the operation. If disturbed the female seeks shelter, walking slowly and dragging the male after her. The duration of the process varied greatly in the cases noted, covering from 7 to 19 minutes. After the operation the male was generally noted to be much more active than the female, but was not seen to attempt copulation a second time, even where the pair were confined in a small vial for some hours.

Much of the copulation attempted in the cages was unsuccessful, about nine attempts out of every ten coming under this head. Whenever several males were attempting copulation with the same female at the same time they were noted to fight one another.

About April 1, 1912, the abdomens of the females began to swell noticeably and a close watch was kept for the eggs. Every day about six females were dissected so that the development of the eggs could be watched. The immature eggs were small and disk-shaped, being little more than half as large as the mature eggs. They appeared as opaque spots in the translucent jellylike ovaries, which filled quite completely the ventral portion of the abdomen. The development of the eggs was relatively slow, the greatest change appearing in the ovaries, which increased rapidly in size until at the time of oviposition they practically filled the abdomen.

ACTIONS OF THE ADULTS AFTER MATING.

During the last week before oviposition the females spent all their time burrowing under the soil, and were never noted feeding or on the surface. Whenever they were dug up they immediately buried themselves again. If the ground was not allowed to dry out too much the females remained active and healthy, but in several cells in which the soil completely dried out the females died.

The males did nothing but feed and crawl about on the surface. They lived, on the average, from two to four weeks after mating, so it seems possible that one male might fertilize more than one female.

In one instance, when the female in a cell had been dug up she came in contact with the male. The latter attempted copulation, but unsuccessfully.

OVIPOSITION.

On April 9, 1912, the first eggs were deposited. These were laid in a vial which contained several females in which the development of the eggs was more advanced. These eggs were scattered throughout the soil.

In only one instance was a female noted in oviposition, and that was under unnatural circumstances. Several gravid females had been placed in a glass, on the bottom of which was about half an inch of very compact soil. This glass was placed in the dark room for several hours, and when observed again one female was attempting oviposition between the soil and the glass. The beetle thrust her ovipositor down several times, and finally the egg was placed in the bottom of the hole made by the ovipositor. The ovipositor was then withdrawn slowly and then thrust back part way several times as if the beetle were trying to cover the egg. The entire operation took but a very short time.

When the soil in the cages was broken up and examined for eggs it was seen that oviposition under natural conditions must be quite similar to that observed, as eggs were found at intervals under the channel made by the digging female.

By the latter part of May the females became very scarce, as they live but a short time after laying their eggs. The males for the greater part died during about the middle of the period of oviposition.

Approximate Length of the Life Cycle.

Considering the length of the egg stage as one month and the length of the pupal stage as the same, these, added to the length of the life of the adult, will give from five to eight months. If, as has been stated before, the larval stage lasts for over three years, it is seen that the length of the life cycle from egg to egg would be four years.

SEASONAL HISTORY.

Beetles from Emergence to Hibernation.

The life of the adult, from emergence, through hibernation, until their appearance after hibernation, is governed to a great extent by conditions over which the beetles themselves have no control. The greater part of the beetles emerge from the pupæ about the middle of September. The beets are plowed up for the most part during September and October, so the insect is in danger of being disturbed either during the pupal stage or soon after it has changed to the adult. The plowing which the land receives at this time can hardly be called a plowing, but the ground is torn up to a depth of from 6 to 12 inches. As the soil is dry, that disturbed is for the most part in large clods, so there is little chance that many pupæ or adults will be disturbed.

Those which by chance are disturbed are either killed outright or have to live under changed conditions until spring. If they happen to be pupæ the chances must be very much against them, and they will probably either be injured by the sharp particles of dirt or will dry out. If the insects are in the adult stage they will have a better chance of survival, but here also they may be compacted into the soil and killed, or be eaten by birds, since, living under unnatural conditions, they are obliged to appear earlier in the spring than they would otherwise. Even when kept under laboratory conditions many of those disturbed in the fall can not live till the normal time of their appearance.

Hibernation.

The adults pass the severest part of the winter in the soil. If disturbed they winter in their pupal cells, where they are well protected, as these are on the average about 6 inches below the surface. This tempers the winter for them very well, and moisture can reach them only after heavy rains, and these seldom if ever occur except at the latter part of the hibernating period. When the beetles are disturbed in the fall they dig down into the soil for shelter. The depth to which they go varies. In some cases, where the soil is powdery, they go down only about from 1½ to 3 inches, but when the soil is partially made up of clods and full of cracks they are sometimes found from 4 to 6 inches below the surface.

Mortality During Hibernation.

Under ordinary circumstances and where the pupal cells are undisturbed, a large percentage of the beetles emerge safely—at least this is so under laboratory conditions. One cage was watered and kept outdoors so that the beetles were subjected to conditions as severe as the ordinary field conditions, yet all came through safely. Of those disturbed in the fall, not enough have been tested to give representative figures, but thus far almost a third of those treated in this way have died during hibernation.

Gradual Emergence from Hibernation.

The time of the appearance of the beetles in the spring is influenced to a large extent by artificial agencies, the most important of which is spring plowing. This plowing, which takes place as soon as possible after the first rains, is quite thorough, averaging from 10 to 14 inches deep, and as the soil is damp and mellow at this time very few clods are left. This treatment disturbs most of the beetles, and these, unless the weather is too severe, may come to the surface and finish their hibernation in any sheltered place they can find. If the weather is severe and cold many of the beetles prefer to remain in the soil. It is due to these conditions that there is a variation in the time of appearance of the adults, as has been proven by systematic collection in the fields.

Collections were made in some of the fields day after day and tabulated. The beets which sheltered adults every day were marked, and the beetles which were collected from them every day were noted. The following table gives the number of beetles which were taken from under the same beet on the dates given:

Table I.—*Emergence of adults of the sugar-beet wireworm from hibernation in the field.*

Date.	Number of beetles.	Date.	Number of beetles.
Feb. 29	2	Mar. 12	4
Mar. 1	1	Mar. 13	7
Mar. 2	7	Mar. 14	1
Mar. 3	3	Mar. 15	3
Mar. 4	17	Mar. 16	86
Mar. 5	2	Mar. 17	11
Mar. 6	1	Mar. 18	0
Mar. 7	1	Mar. 19	2
Mar. 8	0	Mar. 23	1
Mar. 9	29	Mar. 24	36
Mar. 10	47	Mar. 26	9
Mar. 11	13		

As these notes were taken before the beetles were moving through the field very generally, it appears that the latter must have come from the soil near the beets which were used for hibernating quarters.

Secondary Hibernation.

The beetles which are driven to the surface prematurely seek what may be termed "secondary hibernation" under almost any shelter which can be found. The substances in the following list, under which beetles were found, are named in about the order of preference:

(1) Left-over beets.
(2) Old beet tops.
(3) Wild beet roots.
(4) Alfalfa roots.
(5) Johnson grass roots (*Sorghum halepense*).
(6) Lambsquarters (*Chenopodium* sp.).
(7) Pigweed stalks (*Amaranthus retroflexus*).
(8) Wood.
(9) Clods.
(10) Cracks in soil.
(11) Old sacks.
(12) Manure.
(13) Miscellaneous rubbish.

Items 8 and 9 (wood and clods) sheltered practically all the beetles. The last-named item included paraffin roofing, old bottles, pottery, etc. The wide diversity of this list shows that the beetles are not very particular about the character of their shelter.

It is interesting at this time to note that no beetles were taken from under charred beets or wood ashes. This point was well illustrated in the corner of one of the fields which proved to be the choicest collecting ground. It happened that in this place a large amount of rubbish had been burned the previous year, and about half the old beets lying about on the ground were charred. Adults were taken in numbers from this corner daily, but not one was ever found under the beets which were charred. The same thing was true of the wood ashes.

The numbers of beetles taken from single beets were much larger than might have been expected. As has been stated before, as many as 243 have been taken from under a single beet, and on one occasion 187 were taken from under a single beet top which was less than 3 inches in diameter. The concave top was entirely filled with the beetles, which in some places were piled from 2 to 4 deep.

Occurrence of Beetles in the Field.

Up to the middle of March the adults are found close to their hibernating quarters, either feeding or sunning themselves. At about this time, however, there is a general dispersal of beetles, and their collection becomes a difficult matter. Flight is of common occurrence, as is copulation. The writer watched many beetles which were moving about the fields, to see what they were doing, but to all appearances they did nothing except wander about. Some were watched to see if they would oviposit, but nothing of this kind was noted.[1] To judge from their actions in the laboratory cages, these adults were moving about preparatory to burrowing into the soil for oviposition.

Effect of Food in the Field on Dissemination.

In the latter part of their secondary hibernation, and before they scatter through the fields, their presence depends very much on two factors, namely, food and hibernating quarters. Once they begin moving they feed very little, and food seems to have no effect on the direction or amount of their movement.

As this is, economically, the critical point in the life of the adults—since where they collect, the eggs will be laid—they were watched carefully to see if there were any factors which governed their dispersal through the fields. The amount of food and the size of the

[1] Subsequent rearing work in the laboratory proved that this was quite too early for oviposition.

young growing beets were carefully taken into consideration, but the significance of these points, if there is any, is too slight to be noticeable. While the beetles have quite a strong flight, it was observed that they stay relatively near their hibernating places, so the most important factors at this period are the food and hibernating quarters which determined their presence earlier. These conclusions were arrived at from observations in fields aggregating several hundred acres. These factors, however, govern dissemination under normal conditions only.

Other Factors Governing Dissemination.

One factor which governs the direction of flight of the adults to some extent is the wind. This factor, however, has its limitations, as the beetles can fly with ease against a very light breeze, and if the wind is blowing too strongly they do not fly at all.

The floods which are apt to occur during the time the beetles are in secondary hibernation, or a little later, are probably of some importance—at least they must be so locally, where the San Gabriel River spreads over many acres of the beet fields almost every year. This river flows slowly and carries much rubbish, so that a large percentage of the beetles carried along would probably survive.

NATURAL CONTROL.

Enemies and Checks to the Beetles.

The adults of *Limonius californicus*, being slow in their movements and conspicuous, are quite subject to the attacks of predaceous enemies. The good work of these enemies is further helped by the fact that the fields are quite bare at the time they are present in the largest numbers, while the beetles are concentrated for a part of the time.

Unfortunately no figures can be given regarding the relations between the birds of the beet fields and the beetles, but a few observed facts may be given at this time. The only notes which bear on the insectivorous habits of the birds locally were taken on examination of the excrement of the California shrike (*Lanius ludovicianus gambeli*) during the month of April. This excrement was made up almost entirely of coleopterous wing covers, and of these *Limonius californicus* and *Blapstinus* sp. formed about 90 to 95 per cent. A very reasonable estimate would be that at least 70 to 80 per cent of the excrement examined was composed of fragments of *Limonius californicus*.

Many observers have determined the fact that nearly all insectivorous birds eat different species of Elateridæ readily, as the latter do not seem to be in the least distasteful to them. Following is a partial list of the birds occurring in the beet fields, which have been proven to be insectivorous.[1] Those marked (*) were especially abundant:

Killdeer (*Oxyechus vociferus*).
* Valley quail (*Lophortyx californicus vallicola*).
Western nighthawk (*Chordeiles virginianus henryi*).
Ash-throated flycatcher (*Myiarchus cinerascens cinerascens*).
* Western meadowlark (*Sturnella neglecta*).[2]
* Brewer's blackbird (*Euphagus cyanocephalus*).
* Native sparrow.
* California shrike (*Lanius ludovicianus gambeli*).

Next to the birds as insect destroyers can be ranked the predaceous beetles belonging to the family Carabidæ, or ground beetles. Only two were noted, *Calosoma cancellatum* Esch. and *C. semilæve* Lec., but these proved to be important factors in the control of the beetles. Both of these occurred commonly throughout southern California. Sometimes as many as 15 to 20 would be noted in a single collecting trip. *Calosoma cancellatum* occurred in the greater numbers.

These predatory enemies are able to dispose of a large number of adults daily, as many outdoor observations proved. In one instance the examination of a large beet gave 31 live elaterids, 1 *C. cancellatum*, and the remains of 117 elaterids. This beet had been examined just two days previously, so this represented not more than two days' work. The rapidity of the work may be judged from the fact that the remains of a dozen of the elaterids were still moving their legs feebly when discovered.

The carabids in feeding never touch the head or thorax, but bite off all or a part of the abdomen. As the abdomen, except when filled with eggs, contains little food it is readily understood how these ground beetles are able to destroy so many elaterids a day. The carabids did most of their feeding while the elaterids were in their secondary hibernation or early feeding period. They were especially valuable at this time, as they could dig under the beets and destroy the beetles collected there.

These predaceous enemies—carabid beetles and birds—make a very good combination, as the beetles are an effective check early in the season, and later, when the elaterids are moving through the fields, the birds are at their best.

Sudden and very severe storms probably act as further checks, but in a mild year, such as 1912, very few beetles were found to have been killed in the field. The adults are also attacked by a fungous disease. This disease works well under laboratory conditions, but less

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[1] See Senate Document No. 305, 62d Congress, 2d Session, p. 14, 1912.

[2] Mr. Bryant, in the Pomona Journal of Entomology, vol. 4, No. 3, speaking of the western meadowlark, says, "Ground beetles are taken each month of the year." He then names *Limonius californicus* among those taken.

than 0.1 per cent were affected by it in the field. These two checks are of very little importance.

Enemies and Checks to the Larvæ.

Two characteristics of the wireworms, their thick skins and their underground life, cause them to be almost free from enemies. Of the 10,000 larvæ collected not one was noticed which was attacked by an internal parasite, although such parasites have been reported attacking Elateridæ. Curtis [1] reports an ichneumon parasite on wireworms in Great Britain, and says that Bierkander (of Sweden) also found them. Dr. S. A. Forbes [2] reports a single instance where a parasitic fly was reared from a wireworm. Very probably there are no efficient parasites in this group.

The sugar-beet wireworm is, however, eaten readily by several kinds of birds whenever exposed. During the spring, when several of the fields at Dominguez, Cal. (6 miles from the ocean), were being plowed, it was noted that sea gulls (*Larus* sp.) were very abundant in the fields and followed the plow much as chickens do. They occurred by the hundreds and, as they are known to be omnivorous, they must have eaten numbers of wireworms. At this time and earlier crows were also very abundant in the beet fields. During this period the wireworms were feeding at the surface on the left-over beets, and it was easy for the crows to reach them. As crows are famed as wireworm destroyers it is only reasonable to suppose that they killed large numbers of the larvæ. This point will be investigated thoroughly in the future work on this insect.

Larvæ of a large carabid, probably *Calosoma cancellatum* Esch., have been found in the ground together with injured wireworms.

In addition to bird and insect enemies one fungous and two bacterial diseases have been noted on this wireworm. The fungus is only observed occasionally in the field, hence it is probably of little importance economically. The bacterial disease of the mature larva was especially disappointing, as it seemed to work only in certain cages. This naturally led to the belief that its presence was probably more the result of unfavorable conditions than the cause of them. The bacterial disease of the young larva did not promise much, as it did not seem to attack mature larvæ under any conditions.

As has been mentioned under the heading "Rearing cages used" (p. 21), many of the young wireworms which were kept in petri dishes died of a bacterial disease. This disease spread very rapidly, and there seemed no way to check it. Wherever it appeared, all the healthy wireworms were removed to a sterile cage and the infected cage sterilized. The cages were examined several times a day and all

[1] Farm Insects. By John Curtis, 1860, pp. 181. [2] 18th Rept. State Ent. Ill., pp. 47, 1891-92.

wireworms were removed just as soon as they showed traces of the disease. In spite of all these precautions the disease spread unchecked until, within 10 days of its appearance, it had killed every wireworm in the petri dishes, to the number of about 1,000.

The disease spread in the same way every time, and the wireworms killed by it were so characteristically colored that they could never be mistaken. When a larva became diseased, there was a very faint reddish coloration in the anterior portion of its body. When placed under the microscope, it looked as if the head and thoracic segment contained little, brilliant red, oil globules. The following day the specimen would be a deep blood-red all over its body and so putrid that when picked up on a pin point it would fall to pieces. The larvæ immediately surrounding it would show the faint red coloration and the following day they would be red and putrid, while the larvæ nearest them would be showing signs of infection. When the dishes were not sterilized, all the larvæ in a dish would be killed in from three to four days.

That the red bacterium was the cause of the trouble was very strongly suggested by the fact that whenever one infected wireworm was placed in a sterile cage the disease immediately made its appearance. This was further borne out by the fact that where a whole infected wireworm was used to make a culture on agar, a pure culture of the red bacterium almost invariably resulted. When the cultures were made on agar, the colonies showed in their true color—a beautiful rich blood-red. (See Pl. VIII, fig. 1, p. 20.)

It is interesting to note at this time that the mature wireworms which were exposed to infection by this bacterium were never affected by it.

Everything considered, the larvæ of *Limonius californicus* seem to be affected very little by their animal enemies and by their fungous and bacterial diseases, even when these latter are working under favorable conditions.

Fungi Affecting the Pupæ and Eggs.

A few pupæ in the laboratory were attacked by a fungus and presumably killed by it, as they died a short time afterward. As this occurred only in two cages and as no fungus-killed pupæ were found out of doors, it is probable that this infection only occurs under artificial conditions. Even if it did occur in the fields it would spread slowly, for during the time the insect is in the pupal stage the humidity is low and the soil in the fields is rather dry.

A fungus which attacked and killed some of the eggs of *Limonius californicus* in the rearing cages in the laboratory would probably seldom or never occur out of doors. Even if it did it would not be of great economic importance, for when sound eggs were isolated in the cage in which the fungus was working they were seldom attacked, showing that the fungus must spread slowly. Its appearance was probably the result of unfavorable artificial conditions.

REMEDIAL MEASURES.

Historical.

Most of the literature thus far devoted to the study of wireworms from an economic standpoint has been a consideration of remedies. Probably no other insects have had more remedies tried for their control and with less success. Some of the remedies have been partially successful, but generally their cost has been such that their use for average crops is entirely impractical. One which would come under this head was a method tried on a small scale in Europe some time ago and consists in baiting the wireworms and collecting them.

Eleanor A. Ormerod,[1] studying several species, gave as remedies (1) compacting the ground, (2) clearing off vegetation, and (3) making applications of gas lime. She stated that crop rotation was of little value. John Curtis [2] suggested as remedies frequent plowing to turn up the larvæ, and applications of soot and lime. Mary Treat,[3] writing on these insects, suggested spring and fall plowing and the trapping of larvæ. Fall plowing as a remedy was recommended by C. M. Weed.[4]

The two most important sets of recommendations based on actual exhaustive experiments and careful study were those of Comstock and Slingerland [5] at Cornell and S. A. Forbes [6] in Illinois. Their recommendations are quite different, Forbes suggesting a careful rotation of crops, while Comstock and Slingerland advise fall plowing for the destruction of the pupæ and trapping the adults with poisoned bait.

Tests of Suggested Remedies Against the Sugar-Beet Wireworm.

ATTEMPTS TO DESTROY THE ADULTS WITH POISONED BAITS.

In testing remedies for the sugar-beet wireworm only those were tried which heretofore had promised at least partial success and which were at the same time thoroughly practical.

Experiments with poisoned bait were carried on against the adults, using the bait much after the method suggested by Comstock and

[1] Manual of Injurious Insects and Methods of Prevention. By E. A. Ormerod, 1890, pp. 109.
[2] Farm Insects. By John Curtis, 1860.
[3] Injurious Insects of Farm and Garden. By Mary Treat, 1882.
[4] Insects and Insecticides. By C. M. Weed, 1891.
[5] Bull. 33, Cornell Agr. Exp. Sta., 1891.
[6] 18th Rept. State Ent. Ill., 1891.

Slingerland.[1] These experiments from the first gave entirely negative results, as the beetles could not be induced to feed on any kind of foliage, either in the poison or check cages. Further experiments were carried on, using such substances as bran, shorts, alfalfa meal, and ground beet roots. The last bait was the only one which gave any promise, and this proved successful only under laboratory conditions. Where the poisoned bait was applied in the cages a few beetles were killed by it, but where it was tested in the field it gave negative results. This was probably on account of the light feeding habits of the adults and the abundance of food in the fields. The poisons used in the bait were Paris green, arsenite of zinc, arsenate of lead, and strychnine.

FALL PLOWING FOR DESTRUCTION OF THE PUPÆ.

The destruction of the pupæ by cultivation, while probably it has never been tested under field conditions, has been recommended by many students of this group because it is directed against the most helpless stage of the insect. From observations made of the results obtained by disturbing pupæ in the laboratory cages, there can be no doubt that this remedy would prove beneficial, since not only would it break open many cells and kill the pupæ mechanically, but it would also disturb the rest so that they would come out earlier in the spring and be subject to the attacks of their bird enemies. This fall plowing would have to be quite deep (9 to 10 inches), and very thorough, to be effective.

The main objection to this remedy is that three or four years must elapse before the benefits derived from it become apparent. One point will serve to illustrate this. It was reported through Mr. R. S. Vaile, the horticultural commissioner of Ventura County, Cal., that in one instance, in a field which had been fall-plowed, the wireworms were worse than in any of the surrounding fields. This was doubtless true, and would have been possible had the plowing killed every pupa. The wireworms which do the main damage for at least the next two years are already in the soil at the time of the plowing and are unaffected by it. This is true because the wireworms are not of sufficient size to be very injurious until the third year. Mr. Vaile states that it is a rule with many of the bean growers in his county to fall-plow their fields; and that any benefits which might have resulted from such a treatment have never been noticeable. He adds, however, that the thoroughness of this plowing might be improved upon in many cases.

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[1] Bul. 33, Cornell Agr. Exp. Sta., 1891.

EXPERIMENTS WITH DETERRENTS AGAINST THE WIREWORMS.

A fairly exhaustive series of experiments was carried on, using repellent substances against the larvæ. While some of these experiments are a repetition of the work done by Comstock and Slingerland, the greater number are rather an addition to their work. From the start this work promised little, but was undertaken because, if successful, it would afford a remedy which would give immediate results, and this is most important with this insect.

A system was adopted regarding both the nature of the experiments and the times of application. Three tests were given each experiment in the spring, when the larvæ were most active, and a test was given in the fall just before their hibernation period. The last one was on a small scale and was carried on merely for the sake of added evidence.

Flowerpots were the cages used in the spring experiments. It was found that if the hole in the bottom was stoppered with cork, none would escape in the time of the experiment. It was also noted that where about half an inch of dry soil was placed on top of the damp soil of the cages the wireworms would never come entirely to the surface. This treatment, then, allowed the flowerpots to be buried to the surface of the soil out of doors, and with the exception that the larvæ were a little crowded it gave outdoor conditions.

In the first test of each experiment 50 larvæ were used and the test covered 20 days. In the two remaining tests in the spring 25 larvæ were used each time and the experiment was allowed to run for 30 days. In the experiments with deterrents the following substances were tested:

(1) Carbolic acid.
(2) Carbolic emulsion.
(3) Turpentine.
(4) Kerosene.
(5) Kerosene emulsion.
(6) Whale-oil soap.
(7) Potassium cyanid solution.
(8) Potassium cyanid solid.
(9) Copperas solution.
(10) Copper sulphate.
(11) Potassium sulphid solution.
(12) Tar water.
(13) Ash water.
(14) Nicotine sulphate.
(15) Free nicotine solution.
(16) Cresol (so-called coal-tar creosote).
(17) Salt solution.
(18) Lead chromate.
(19) Dry sulphur.

These deterrents were used on beet and lima-bean seeds, both of which are attacked by this species. It was hoped that in these experiments a deterrent could be discovered for protecting the tender roots until the plant had secured a fair start. If this could be accomplished the injury due to wireworms would be materially lessened.

CARBOLIC ACID.

Some seeds were soaked in a 10 per cent solution of carbolic acid overnight, were allowed to dry for some time, and were then planted in the pots. Fifteen were planted in the cage which contained the 50 larvæ. This cage was broken up in 20 days and examined, with the following results: Two seeds were destroyed before germination; seven after germination, and six were untouched; three larvæ were dead. In the check cage three seeds were untouched; most having been destroyed just after germination, and one larva was dead. The check cages gave even less favorable results, so it seems clear that the carbolic acid has little effect as a deterrent.

CARBOLIC EMULSION.

Carbolic emulsion was made by using the following ingredients in the proportions named:[1]

Crude carbolic acid	gallons	5
Whale-oil soap	pounds	40
Water (hot)	gallons	40

The seeds treated were soaked in this emulsion overnight. After drying [2] in the sun for two hours they were planted. The results of the experiments are summarized in the following table:

Table II.—*Experiments with carbolic emulsion as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked.		Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
			Before germination.	After germination.				
								Days.
Experiment	50	15	2	7	6	3	0	20
Check	50	15	10	3	2	1	1	20
Experiment	25	10	1	7	2	3	0	30
Check	25	10	4	6	0	2	0	30
Experiment	25	10	3	5	2	1	2	30
Check	25	10	4	2	4	5	0	30

A glance at the foregoing summary shows that while carbolic acid might possibly be of value, it can not at this time be considered a practical remedy for wireworms.

TURPENTINE.

Seeds were soaked overnight in turpentine and after being allowed to dry were planted in the cages containing the wireworms. The turpentine had affected the seeds considerably and all of them were more or less "blistered."

[1] Essig, Pomona Journ. Ent., vol. 2, no. 3, p. 252, 1910.

[2] The seeds were dried in these experiments because, if used under field conditions, they would have to be treated in this manner before they could be used in a beet planter. This would be the only practical way the emulsion could be applied.

TABLE III.—*Experiments with turpentine as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked.		Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
			Before germination.	After germination.				
								Days.
Experiment	50	15	3	5	7	0	0	20
Check	50	15	3	4	8	0	0	20
Experiment	25	10	4	3	3	7	0	30
Check	25	10	5	2	3	1	1	30
Experiment	25	10	8	0	2	3	2	30
Check	25	10	7	3	0	4	1	30

A glance at columns 6 and 7 of Table III shows that there is little difference between the treated and untreated seeds—too little to promise much for this method.

KEROSENE.

Kerosene was given a trial as a deterrent in spite of the fact that it gave negative results in the experiments of Comstock and Slingerland. The seeds were treated by soaking in kerosene overnight. The kerosene in some instances removed part or all of the skin from the seeds. The results are summarized below.

TABLE IV.—*Experiments with kerosene as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked.		Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
			Before germination.	After germination.				
								Days.
Experiment	50	15	8	3	4	2	2	20
Check	50	15	12	1	2	0	6	20
Experiment	25	10	8	1	1	1	0	30
Check	25	10	10	0	0	4	1	30
Experiment	25	10	7	1	2	0	0	30
Check	25	10	8	2	0	0	0	30

This table shows that while treated seeds are a little less liable to attack before germination yet in the long run there is little difference between treated and untreated seeds. Germination tests carried on at the same time show that kerosene kills some of the seeds, so this would at least offset any benefits which might possibly be derived by protection.

KEROSENE EMULSION.

As the pure kerosene showed a weak tendency to keep the wireworms away temporarily it was thought that if some distasteful substance were mixed with it the combination of the two might be more successful. To this end kerosene emulsion was prepared by using whale-oil soap. The seeds were soaked in this overnight and then dried in the sun. The seeds did not dry thoroughly and tended to adhere to one another. This would be a great disadvantage, as it would be hard to run these treated seeds through a planter. The following summary further shows its impracticability:

TABLE V.—*Experiments with kerosene emulsion as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked. Before germination.	Seeds attacked. After germination.	Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
								Days.
Experiment	50	15	6	2	7	0	2	20
Check	50	15	10	3	2	1	1	20
Experiment	25	10	0	3	7	0	0	30
Check	25	10	4	6	0	2	0	30
Experiment	25	10	6	3	1	2	0	30
Check	25	10	4	2	4	5	0	30

WHALE-OIL SOAP.

The seeds used in the whale-oil-soap experiment were treated in two different ways. At first they were coated with the soap, but this method proved impractical (1) because the seeds could not be used in a planter and (2) because they tended to rot. The seeds were then treated by soaking in a concentrated water solution of the whale-oil soap. This second method overcame the objections to the first method. The results are summarized below.

TABLE VI.—*Experiments with whale-oil soap as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked. Before germination.	Seeds attacked. After germination.	Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
								Days.
Experiment	50	15	10	2	3	0	0	20
Check	50	15	12	1	2	0	6	20
Experiment	25	10	4	3	3	0	3	30
Check	25	10	10	0	0	4	1	30
Experiment	25	10	6	4	0	1	0	30
Check	25	10	8	2	0	0	0	30

This table shows that the treatment of the seeds with whale-oil soap holds little promise of success.

TAR WATER.

Since satisfactory results in seed protection by coating the seeds with tar have been reported, it was thought possible that similar results might be obtained by soaking the seeds in tar water. In this way it should give the benefits of coating the seeds with tar, and at the same time not have the disadvantage of causing the seeds to rot. This water is procured by allowing a mass of coal tar or pine tar to stand in water for some time. The water becomes slightly colored and smells very strongly of tar. A very little tar will suffice for treating a large amount of water.

The seeds were treated by allowing them to soak in this water overnight, and they were then planted. They smelled quite strongly of tar even after they were allowed to dry partially. The results obtained are shown in the following summary:

TABLE VII.—*Experiments with tar water as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked.		Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
			Before germination.	After germination.				
								Days.
Experiment	50	15	7	2	6	0	1	20
Check	50	15	3	4	8	0	0	20
Experiment	25	10	4	3	3	1	2	30
Check	25	10	5	2	3	1	1	30
Experiment	25	10	6	2	2	0	2	30
Check	25	10	7	3	0	4	1	30

In spite of the fact that the table seems to indicate that tar water is ineffectual, this method is to be given a more extensive trial next spring.

ASH WATER.

Ashes have long been used and recommended as a deterrent against various insects, and especially wireworms. It has been mentioned previously that the beetles appear to be driven out by ashes. About the only way that ashes could be used on a large scale would be to soak the seeds in water which had been used to leach out ashes. This method was used, the seeds being partially dried before planting. The following summary shows that any benefits which might have been derived from the use of this method are too small to be of much importance.

TABLE VIII.—*Experiments with ash water as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked.		Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
			Before germination.	After germination.				
								Days.
Experiment	50	15	5	5	5	0	2	20
Check	50	15	10	2	3	1	0	20
Experiment	25	10	6	2	2	7	0	30
Check	25	10	4	6	0	2	0	30
Experiment	25	10	7	1	2	2	1	30
Check	25	10	4	2	4	5	0	30

NICOTINE SULPHATE.

Some seeds were soaked overnight in nicotine sulphate and dried before planting. This sulphate, which is advertised to contain 40 per cent nicotine, is a dark, viscous liquid and smells very strongly of nicotine. When used pure it tended to rot many of the seeds. The best germination results were obtained when it was diluted about one-half with water. The summary shows that it could not be recommended as a deterrent.

TABLE IX.—*Experiments with nicotine sulphate as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked— Before germination.	Seeds attacked— After germination.	Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
								Days.
Experiment	50	15	8	7	0	0	2	20
Check	50	15	10	3	2	1	1	20
Experiment	25	10	6	2	2	7	1	30
Check	25	10	10	0	0	4	1	30
Experiment	25	10	8	2	0	0	6	30
Check	25	10	7	2	1	0	0	30

FREE NICOTINE.

Seeds were soaked in nicotine solution overnight. This fluid, which contains free nicotine in water, has a very sharp nicotine odor and is also 40 per cent nicotine. As the results obtained in two out of the three tests were negative, its value as a deterrent must be slight. Some of the bean seeds were riddled by the wireworms. The results are shown below:

TABLE X.—*Experiments with free nicotine as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked— Before germination.	Seeds attacked— After germination.	Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
								Days.
Experiment	50	15	4	7	4	0	3	20
Check	50	15	3	4	8	0	0	20
Experiment	25	10	3	3	4	3	0	30
Check	25	10	5	2	3	1	1	30
Experiment	25	10	7	2	1	0	2	30
Check	25	10	4	2	4	5	0	30

CRESOL.

Cresol, so-called coal-tar creosote, was tried in these experiments because it is used quite successfully in keeping dermestid larvæ out of collections. It is a thin liquid, rather dark in color, and with a strong tarry odor. The seeds were soaked in it overnight. The results, which are summarized in the following table, do not promise much for the use of this substance in protecting seeds.

TABLE XI.—*Experiments with cresol as a deterrent against the sugar-beet wireworm.*

	Larvæ used.	Seeds used.	Seeds attacked— Before germination.	Seeds attacked— After germination.	Seeds untouched.	Larvæ missing.	Larvæ killed by fungus.	Duration of test.
								Days.
Experiment	50	15	8	3	4	7	1	20
Check	50	15	10	2	3	1	0	20
Experiment	25	10	6	2	2	0	0	30
Check	25	10	4	6	0	2	0	30
Experiment	25	10	5	4	1	0	2	30
Check	25	10	7	3	0	4	1	30

OTHER SUBSTANCES TESTED AS DETERRENTS.

The other deterrents will be considered very briefly, since, with the possible exception of two, none gave much promise of ultimate success.

Copperas solution.—Seeds soaked overnight in a copperas solution, dried, and planted in the pots were almost as readily eaten as those in the check cages.

Copper sulphate.—Copper sulphate did not give much promise as a deterrent, as the seeds soaked in a solution of it overnight were eaten readily by the wireworms, and with apparently no ill effects.

Potassium sulphid.—Seeds treated with a concentrated solution of potassium sulphid appeared neither distasteful nor injurious to the wireworms.

Salt.—The seeds treated by soaking in a salt solution seemed for a time to be partially immune to the attack of wireworms. By the time several tests were completed, however, it was seen that while they were more immune from attack just before germination, enough were killed just after germination to make this procedure useless from a practical standpoint.

Sulphur.—Some seeds were coated with a paste made of equal parts of sulphur and flour, and after being allowed to dry were planted. When examined later many had rotted and the rest had been riddled by the wireworms. Some of the larvæ were partially covered with sulphur, but did not seem in the least inconvenienced. It was considered that this experiment would give negative results, since the sulphur, kept under the damp cool soil, would not give off fumes to any extent, and hence its best effect would be lost.

Lead chromate.—Seeds treated as in the foregoing experiment, but using lead chromate in place of sulphur, were not protected in the least, nearly every seed being drilled through in several places.

THE USE OF POTASSIUM CYANID AGAINST THE WIREWORMS.

Potassium cyanid was one of the first remedies tested for the wireworms, because it has the properties both of an excellent deterrent and a deadly poison. Used as a deterrent, the seeds were treated in two different ways. In the first the cyanid was used as a solid and drilled in with the seed. This method affords excellent protection to the seed, but the drawbacks connected with it have thus far made it impracticable. The cyanid burns the seed wherever it comes in contact with it, and when germination begins, it burns the tender roots. Another argument against its use for this crop is its cost. In the second method of seed protection the seeds were soaked overnight in a solution of cyanid in water, dried, and planted. In this method it was also quite effective as a deterrent, but unfortunately its effects on the roots were such that it could not be used. At the present time it seems very doubtful if the cyanid can be used in such a strength that it will keep away the wireworms and at the same time not harm the plants. This point is going to be tested further.

While these experiments were being carried on it was noted that in some of the cages most or all of the wireworms had been killed. These larvæ had the appearance of having been killed by a fungus, but as their bodies were not filled with the fungus it was apparent that they had been killed in some other way. It was thought that perhaps they had been killed by the fumes of the cyanid, and later experiments seemed to bear out this point. With this in view, many experiments were carried on in an attempt to discover some good method for the application of the cyanid. From these, two plans were selected for final trials, one in which the cyanid was used as a solid, and the other in which it was used as a liquid. The results are given below.

According to the first plan the cyanid was drilled into the ground much after the method used for fertilizers. This plan was finally given up, as the cyanid was not distributed evenly through the soil, and therefore had to be applied more heavily than was necessary in order to be effective. As the cyanid is very destructive to plant growth it is readily seen that it would have to be used as sparingly as possible.

The method of using the liquid consisted in making a solution of the cyanid in water and applying it evenly over the land. This could then be made to permeate the soil to any depth by irrigation. By this method the cyanid is used sparingly, as it is evenly applied. Unfortunately it has been impossible to try this remedy thoroughly, up to the present time. In all the experiments where this method was employed its killing power was very good. To test it further, it was applied in a cage containing beets, with the result that both beets and wireworms were killed. It was used several times more, and in weakened solutions, but invariably the results were the same. By this time the season was so far advanced that experiments along this line had to be given up for the year. The conclusions that seem justified from this experiment at the present time appear to be that the wireworms may be killed by applications of a solution of potassium cyanid to the soil, but that the beets are also killed by the same treatment. It is a question whether a certain strength of cyanid can be found which will kill the wireworms and spare the beets. Possibly, however, the wireworms can stand a stronger application of the cyanid than the beets can. As this is the only insecticide which has given promise of good results against the wireworms, it will receive further careful tests. The possible effect of this cyanid on the soil and future crops is also an interesting question, and one which will have to be investigated. There is a possibility that this cyanid might be applied directly after the crop is removed and before the wireworms have become dormant for the winter.

EXPERIMENTS WITH POISONED BAIT AGAINST THE WIREWORMS.

In the experiments in the use of poisoned bait against the wireworms the points which were chosen for solution were, (1) to find a substance for the bait which would be very attractive to the wireworms, and (2) to find a poison to go with it which would certainly kill the larvæ. Thus far success has not been attained in the solution of either. The following materials have been experimented with as bait:

Beans.	Bran.
Corn.	Alfalfa meal.
Cornmeal.	Shredded beets.

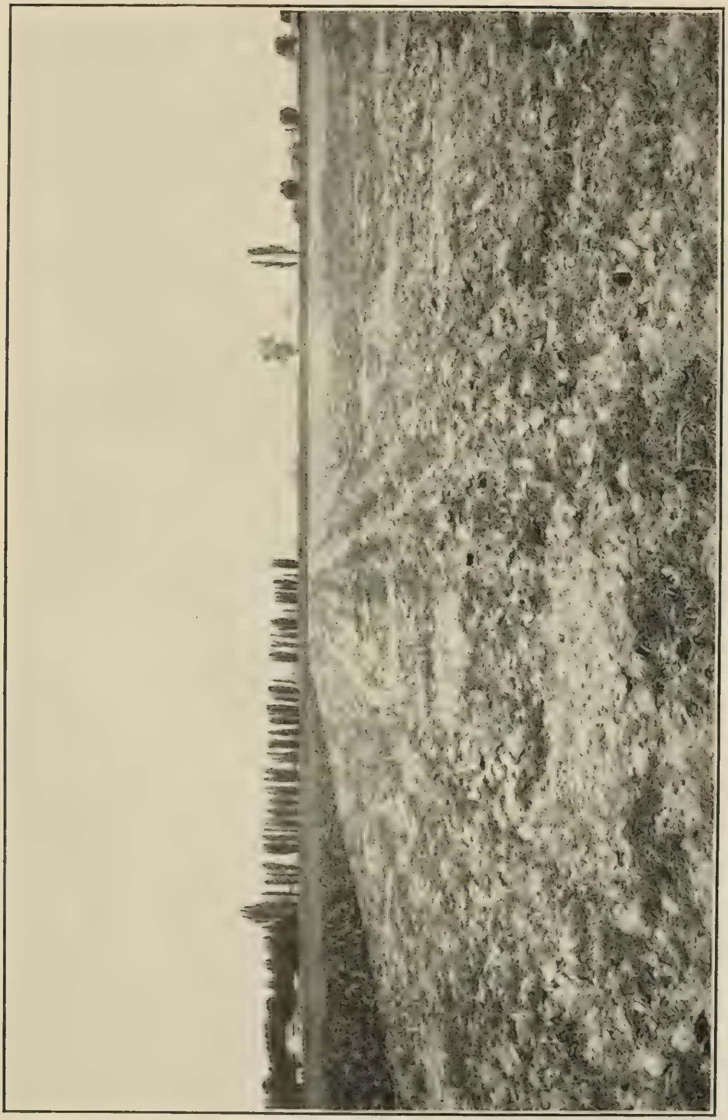
Of these the only ones which have proved attractive enough to be used with the poisons were beans, corn, and shredded beets. Series of experiments were conducted using each bait with every poison, and checks were employed in each. The following poisons were used:

(1) Lead chromate.	(4) Paris green.
(2) Potassium cyanid.	(5) Lead arsenate.
(3) Strychnine.	(6) Zinc arsenite.

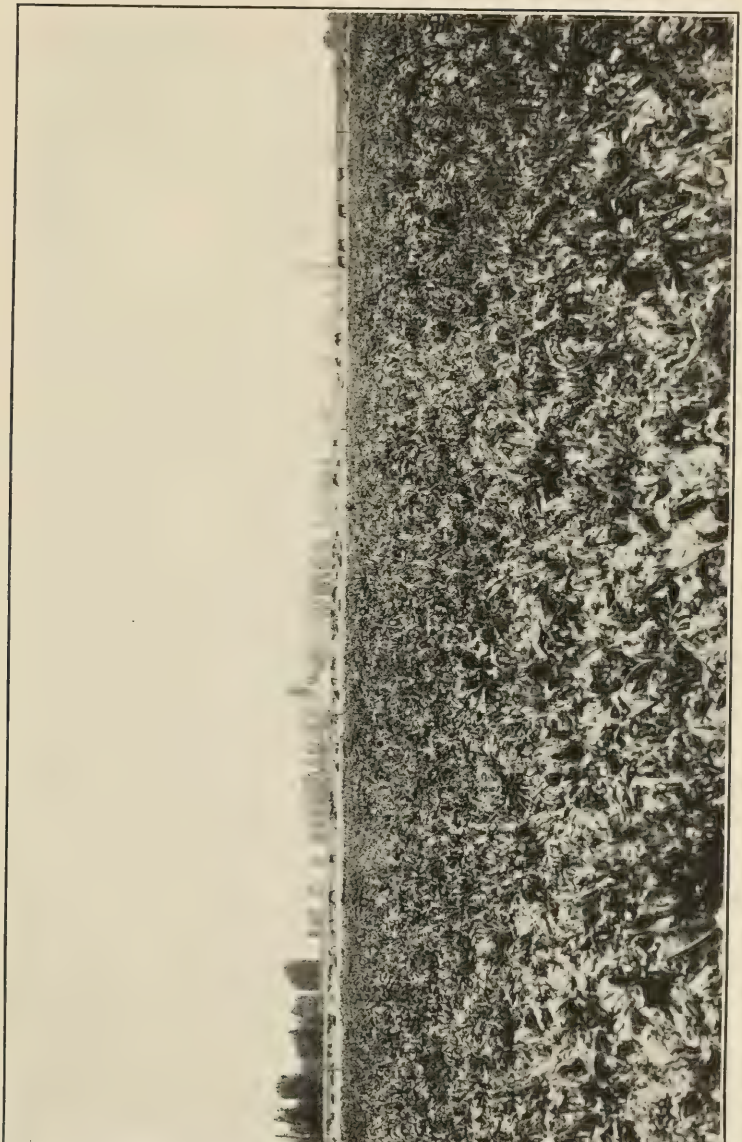
The first four named, being insoluble, were applied to the bait in paste form with flour. In the case of every poison except the cyanid the wireworms were observed eating the bait, and if they suffered any ill effects from it they failed to show it to a noticeable degree. The bait containing the cyanid was eaten sparingly on account of its deterrent qualities. Wireworms were found dead in some of the cages in which potassium cyanid was used, but whether their death

FIG. 1.—FIELD OF YOUNG BEETS AT AGE WHEN THEY BEGIN TO BE PARTIALLY SAFE FROM SEVEREST INJURY BY THE SUGAR-BEET WIREWORM. (ORIGINAL.)

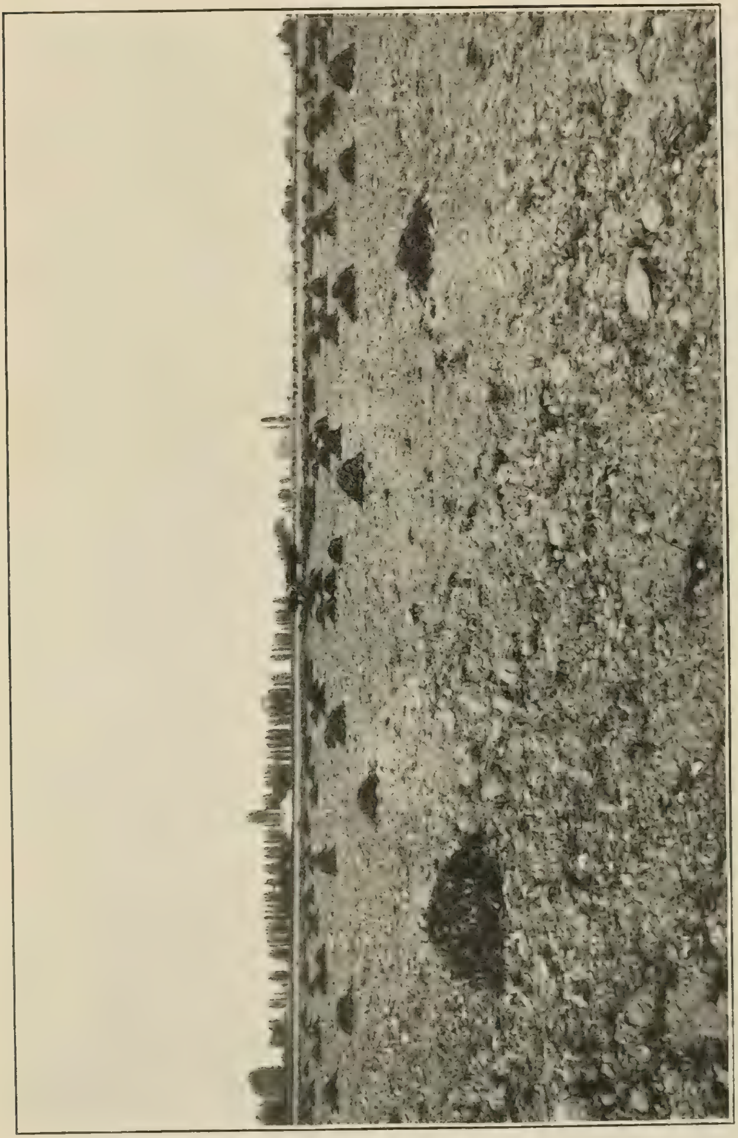
FIG. 2.—BEET FIELD, SHOWING CONDITIONS FAVORABLE FOR INCREASE OF WIREWORMS. WEED HEDGES WHICH SHELTER ADULTS IN SECONDARY HIBERNATION. (ORIGINAL.)



CONDITIONS FAVORING THE SUGAR-BEET WIREWORM. BEET FIELD IMMEDIATELY AFTER HARVEST, SHOWING BEET TOPS CARELESSLY SCATTERED OVER GROUND. (ORIGINAL.)



CLEAN CULTURE AGAINST THE SUGAR-BEET WIREWORM. NATURAL METHOD OF CLEARING OFF BEET TOPS BY PASTURING CATTLE IN THE FIELD WHICH HAS BEEN INCLOSED BY A TEMPORARY FENCE. (ORIGINAL.)



CLEAN CULTURE AGAINST THE SUGAR-BEET WIREWORM. COLLECTING THE BEET TOPS IN PILES AND HAULING THEM FROM THE FIELD AS FOOD FOR STOCK. (ORIGINAL.)

FIG. 1.—BEET FIELDS SEPARATED BY STRIP OF ALFALFA. (ORIGINAL.)

FIG. 2.—FIELD OF ALFALFA ADJOINING FIELD OF SUGAR BEETS. (ORIGINAL.)

CONDITIONS FAVORING THE SUGAR-BEET WIREWORM.

was due to eating the poison or to the effect of fumes has not been determined.

The results in the use of strychnine and potassium cyanid have been quite well verified in an entirely independent series of experiments carried on by Mr. R. S. Vaile.

From the foregoing it can be seen that the experiments thus far tried in the use of poisoned bait against the sugar-beet wireworm have been far from satisfactory. They are to be continued in future work.

EXPERIMENTS WITH GUANO FERTILIZER.

The only fertilizer tested on the wireworms was a mixture of bird and bat guano, a South American product, which is chiefly nitrogenous and is characterized by a strong and lasting odor of ammonia. It was hoped that the strong ammonia odor would drive the wireworms deeper into the soil. The results from its use thus far—it has been tried only on a small scale in the laboratory—seem to indicate that it would have to be used at the rate of from 8 to 10 tons per acre to be partially effective. As this is many times heavier than an average dressing for the soil it would probably be impractical to use it.

PROTECTION OF BEETS BY EARLY PLANTING.

The protection of beets by early planting is a remedy which was early suggested by Mr. H. M. Russell and has since been given a practical test on a large scale. The advantage of this method is very plain. When the beets are planted early the plants are quite hardy and the roots are swollen by the time the wireworms are doing their worst injury. (See Pl. XIX, fig. 1.) These swollen roots can stand a severe attack without having their sap supply cut off, and in consequence a much smaller number of them are killed.

Mr. H. J. Mayo, one who grows sugar beets on a large scale in both Los Angeles and Orange Counties, writes as follows concerning early planting:

> * * * In the season of 1911 I planted early and the results were very good, especially on the heavy land, as the beets seemed to get a start, and the worms did not seem to affect them so much, although they were in the ground and from examinations that I made they worked on the beets; but where the beets got the start the worms did not bother them so much.
>
> In my opinion early planting will relieve a great deal of the danger of the wireworm.

Clean Culture against the Adults.

The following in regard to remedial measures is the result neither of theory nor of experiment. It was suggested to the writer by observations taken in the field at the time the hibernating beetles were being collected. It was suggested also by the different states of affairs noted in different fields where various systems of culture had been practiced. These observations were carefully made in fields aggregating over 600 acres, and daily during a period covering about two months.

Two different methods are practiced by the growers in disposing of the beet tops which remain in the field (see Pl. XX) after the crop has been harvested. Some growers leave them in the field to be plowed under and act as a fertilizer, while others use them for stock feed. In the latter method, which may be spoken of as clean culture, the beet tops are either disposed of by pasture (Pl. XXI) or they are hauled from the field (Pl. XXII). The tops are removed best by pasturing either with cattle or sheep.

The tops which are left for fertilizer are supposed to be plowed under, but by the time the land has been harrowed several times, and planted, not a few have reappeared on the surface. Then as the beetles appear in the spring and enter their secondary hibernation they find excellent shelter and feeding places (see Pl. XIX, fig. 2), and most of them remain in the field near the place where they emerged and are able to pass this critical period of their lives safely. On the other hand, where the tops and old beets have been cleared off, the beetles find no place to hide, and consequently move to other fields in search of shelter. Very few can hide under clods or in the soil on account of intermittent rains.

One illustration of the effects resulting when beets are left in the fields will be sufficient, for this same state of affairs was found to exist in all the fields examined.

The beet fields *A*, *B*, and *C* adjoined one another as shown in the diagram (fig. 9). At the right of *C* was a field of alfalfa. In *A* the beet tops had been left in the field to act as a fertilizer; in *B* and *C* they had been cleared off. During the preceding year the field *C* had suffered from wireworm injury as much, if not more, than any field in the Compton district. On this account there must have been many mature wireworms there, and consequently many beetles emerging, yet when the beetles were collected in these fields hardly any were found in *B* and *C*, and they were taken in *A* literally by thousands. As an experiment, about 50 old beets were scattered in the field *C*, along the line *c c*. These beets were inspected daily from this time on, and found to shelter large numbers of adults, even though none had been taken previously in *C*. Conditions in the other two fields remained as before, no beetles, or very few, being found in *B* while *A* yielded its usual number.

A simple conclusion can be drawn from these observations. The beetles collected only where they could find shelter, and those which emerged from perfectly clean fields had either to move to other fields where they could find shelter or to remain where they were, exposed to the attacks of their predaceous enemies, the birds. In the instance cited probably many were eaten by birds, as these were quite abundant at the time, and the fields were bare.

In the observations dealing with the dispersal of the beetles throughout the fields it was determined that for the greater part the beetles remain and lay eggs near the place where they have been feeding. From this it is easy to see that in the fields which contain the greatest number of old beets and beet tops the largest number of beetles will deposit their eggs. As the wireworms can not travel very far from where the eggs are laid it is readily seen that large numbers of beetles in a field are the forerunners of large numbers of wireworms in that field later, with their resulting injuries to the crop.

A condition leading to the successful hibernation and dispersal of wireworms is illustrated in Plate XXIII, figures 1 and 2. In these instances the immediate proximity of alfalfa fields to those containing beets affords effective shelter for the hibernating beetles, and, as alfalfa is only second as a host to beets, provides abundant food for a continual supply of larvæ and adults. Reinfestation under such conditions is naturally very likely to occur through the migration of the beetles from the alfalfa to the beets, and both crops may thus be injured.

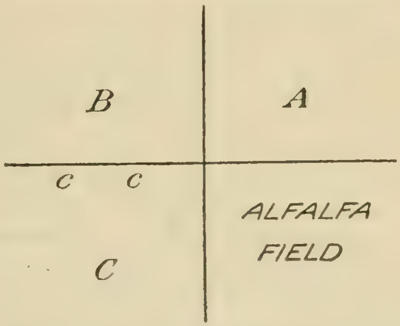


FIG. 9.—Diagram of beet fields, to illustrate the effect of clean culture in reducing injury by the sugar-beet wireworm. (Original.)

The main drawback to clean culture is that even where it is practiced faithfully several years must pass before positive results will be apparent. As has been stated, the same thing is true with regard to fall plowing for the destruction of the pupæ. This would be advantageous in one way, however, in that the benefits would be felt for two years after the treatment had been discontinued. The main difficulty is that a grower, after practicing this remedy for two years, might suffer heavily from wireworm injury, become discouraged, and stop the treatment. The only way to give this remedy a fair trial would be to practice it faithfully and wait until the third or, better, the fourth year before drawing conclusions.

The greatest advantage of this remedy is that it is entirely feasible and, being cultural in character, is also entirely practical, regardless of the crop grown. For the best results it should be practiced in conjunction with fall plowing, and to reduce the injury from the wireworms already in the soil early planting should be employed.

Considering that all the growers have idle horses during the late fall, the plowing would not appear to be a large item of expense, especially when its value to the soil is taken into consideration.

In conclusion it may be safely stated that the clean-culture remedy, especially when reenforced by fall plowing and early planting, is easily the most promising remedy which has thus far come under observation during the sugar-beet wireworm investigations.

SUMMARY.

(1) The sugar-beet wireworm kills the beet plant by injuring the root. It is most injurious while the beets are young and is destructive only in the wireworm or larval stage.

(2) The life cycle probably covers four years. About one month each is required for the egg and pupal stages; seven to nine months for the adult stage, during the greater part of which the beetle is in hibernation; and about three years, or the rest of the time, for the larval stage.

(3) Thus far it seems to be impractical to employ remedies against the larvæ. As these live underground and are protected by a thick integument it is difficult to injure them. They also seem able to eat a certain quantity of many poisons and deterrent substances with safety.

(4) Plowing in the fall is a fair remedy against the pupæ, but at that time of the year the soil is dry in southern California and is turned up in large clods; consequently many pupæ escape destruction.

(5) Much of the injury to the beets may be avoided by early planting, thus giving the roots a good start before the wireworms are doing their most extensive feeding.

(6) Clean culture against the adults, by compelling them to seek shelter elsewhere and exposing them to the attacks of their bird enemies, seems to be the most practical remedy found thus far for this insect. The efficiency of this remedy would be increased if fall plowing and early planting were used with it.

BIBLIOGRAPHY.

1843. MANNERHEIM, G. G. VON.—Bull. Soc. Imp. Nat. Moscou, vol. 16, p. 283, 1843.
Original description of *Limonius californicus* under the name *Cardiophorus californicus*.

1912. VAILE, R. S.—Ann. Rept. Hort. Comm. Ventura County, 1912.
Brief account of damages, and remedies proposed for experiment.

INDEX.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 124.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE ROSE SLUG-CATERPILLAR.

BY

F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop and Stored Product Insect Investigations.

Issued October 31, 1913.

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CONTENTS

ILLUSTRATION.

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THE ROSE SLUG-CATERPILLAR.

(*Euclea indetermina* Boisd.)

INTRODUCTION.

It is only within comparatively recent years that the slug-like caterpillar, *Euclea indetermina* Boisd., has been known to injure the rose. In August, 1905, the Bureau of Entomology received two reports of attack to the foliage of rosebushes by this species. The insect has, however, been previously observed to have this food habit.

August 15, 1905, Dr. A. D. Hopkins furnished specimens of the larva from Kanawha Station, W. Va., stating that a dozen or more individuals could be found feeding on the leaves of a single rosebush. By August 20 the specimens received had transformed to pupæ. During the last week of August the same species, accompanied by specimens of both the penultimate and last stages, was received from Mr. S. D. Nixon, with report that it was injuring roses at Baltimore, Md.

The rose slug-caterpillar has been figured and described in its various stages, but is not a common species and, therefore, not well known. It is, however, strongly and attractively marked and very interesting in its transformations, resembling in some particulars the more common and related saddle-back caterpillar ([*Empretia*] *Sibine stimulea* Clem.). The accompanying illustration (fig. 1), notes, and brief descriptions have been brought together as of interest to rose growers and also to nurserymen, for the caterpillars also attack young trees and shrubs. It is in the last two stages of its larval existence that this species attracts most attention. The moth which it produces is less often seen.

THE MOTH.

In its adult stage this insect is nearly as attractive as the larva. Its coloration is unusual in the boreal American fauna. The general color is pale cinnamon brown; the forewings are darker and crossed diagonally by a green band, which occupies more than half the wing, leaving a wide border of darker brown and an inner or basal area of the same color and of the form shown in figure 1, *a*. The hind wings and the underside of the wings are nearly uniform pale brown, as is also the body, except on the edges of the wings and the tip of the abdomen. The thorax is like green plush. The wing expanse of the male is generally a little less than an inch; of the female, a little more.

The moth closely resembles (*Parasa*) *Euclea chloris* H.-S., for which it has often been mistaken.[1]

THE EGG.

The egg is described by Dr. H. G. Dyar as follows:

Singly, or in small groups, slightly imbricated. Elliptical, flattened, translucent pale ochre-yellow on glass, 1.5 by 9 mm.; reticulations obscure, possibly only in a strong light, rounded hexagonally, nearly linear, somewhat irregular. No special characters. They hatch in nine days.

THE LARVA.

The following is descriptive of the larval forms received from West Virginia and Maryland, but according to other describers the general color varies from red to sulphur-yellow.

The penultimate stage.—In the penultimate stage the larva closely resembles the mature form, but the prominent spine-bearing processes are paler and less reddish, being chiefly of a dull lemon-yellow color, with the exception of the small lateral spiny tufts, which are orange at the base. Between the third and fourth processes the dorso-lateral stripes are distinctly carmine. The length of the slug-caterpillar at this stage is about half an inch or a little more.

The full-grown larva.—The full-grown larva looks very unlike any common species with which it could be compared, but in the general arrangement of its spines it resembles *Sibine stimulea*. Its form is similar, but the general impression as to color is orange, which is the color of the principal spine-bearing processes, of which there are seven pairs, as follows: Two in front, two behind, one pair in the middle, a shorter pair proceeding from the first thoracic segment just above the head, and the seventh pair proceeding from the second thoracic segment on each side. There is a dorso-lateral vermilion-scarlet stripe bearing six pairs of moderately long spinous processes and four rosette-like spinous tufts. There is also a lateral red stripe and a sublateral red stripe bearing nine rosette-like spinous tufts. The thin violet or mauve lines, in the middle of the back, as shown in figure 1, *c*, alternate with white. The length is about three-fourths of an inch.

THE PUPA AND COCOON.

The pupa (fig. 1, *f*) is so similar to that of *Sibine stimulea* that a detailed description is not necessary for present purposes. It is a trifle smaller than the latter, and in its early stage pale yellow with

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[1] Both species belong to the family Cochlidiidæ.

pale brown eyes and palpi. It measures about three-eighths of an inch in length. The hornlike process extending above and between the eyes is prominent.

The pupal stage is passed in a cocoon (fig. 1, *g*) of rounded oval form, looking not unlike a very small puffball. It is chocolate colored, of firm, nearly parchment-like consistency, and roughened opaque on the outer surface. It measures about four-tenths of an inch in its longer diameter and three-eighths inch in the shorter.

HISTORICAL.

Among the notes of the Bureau of Entomology is one copied from Riley's notebook recording the occurrence of the larvæ on chestnut at South Pass, Ill., in August, 1869. It contains a good description of the larva, and states that it feeds on the edges of the leaves, devouring every particle as smoothly as if cut with a pair of scissors. Pupation takes place about September 20. It is worthy of note that Riley was of the opinion that the end of the lid of the cocoon was

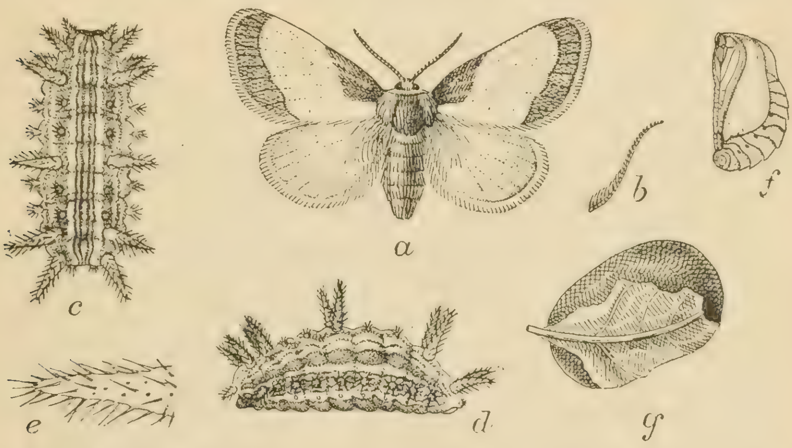

FIG. 1.—The rose slug-caterpillar (*Euclea indetermina*): *a*, Female moth; *b*, male antenna; *c*, larva, dorsal view; *d*, larva, lateral view; *e*, spine of larva, much enlarged; *f*, pupa; *g*, cocoon. All enlarged; *e*, greatly enlarged. (Original.)

cut by the larva before transformation to pupa, while it is quite obvious that the cephalic armament of the pupa is designed for that purpose, the pupa constantly wriggling around and around, thus making the perfectly circular flap.

October 7, 1883, larvæ were found feeding on oak in Virginia, and at another time feeding on paw paw when in bloom at Point of Rocks, Md.

August 3, 1889, this species was received from Vineland, N. J., where it was taken on Kansas plum.

September 3, 1896, the insect was reported feeding on the leaves of Japan plum at Barnesville, Schuylkill County, Pa.

In 1897 Dr. H. G. Dyar published a very full account of the life stages of this species and gave reference to its literature.[1] The larva appears to have been known as long ago as 1797, when Smith and Abbot figured it in connection with another species of moth to which it did not belong, namely, "*Limacodes cippus*." Under this name the species is mentioned by Harris.[2] The moth was not described until 1832.[3]

The recognized synonyms of *Euclea indetermina* are as follows: *Callochroa viridis* Reak., *C. vernata* Pack., and *Parasa chloris* Grote *et auct.* (*non* H.-S.).

As remarked by Dr. Dyar, the larvæ feed on various kinds of low-growing bushes. The list of food plants observed includes rose (*Rosa* spp.), wild cherry (*Prunus* spp.), oak (*Quercus* spp.), chestnut (*Castanea dentata*), hickory (*Carya* spp.), paw paw (*Asimina triloba*), bayberry or wax myrtle (*Myrica cerifera*), flowering dogwood (*Cornus florida*), plum, apple, and pear.

LIFE HISTORY.

The various descriptions which have been furnished of this species agree in many easily observable particulars, but differ somewhat in detail. All writers seem to agree in stating that the larvæ mature during September, but it will be noted that the specimens which were received from West Virginia had matured August 20.

Eggs are deposited during July, in small groups slightly imbricating or overlapping, and hatch in about nine days. The larvæ generally mature toward the middle of September, remaining on the underside of the leaves—something unusual considering their conspicuous coloration. The larvæ or caterpillars undergo eight distinct stages, and occasionally nine, before transforming to pupæ, and it has been observed that in stage I, which is passed rapidly, they take no nourishment. The species hibernates in its cocoon, and the moth has generally been observed to issue in July.

As to the manner of forming the cocoon in confinement, all of the cocoons reared by the writer were attached to some object. Mr. M. V. Andrews,[4] who reared hundreds of this species in confinement, states that in all cases it either forms its cocoon adherent to the stem of the food plant or, occasionally, draws two leaves together for a shelter. There appears to be a somewhat general agreement, however, that in nature the cocoons are formed on the ground among loose rubbish.

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[1] Journal N. Y. Ent. Soc., vol. 5, pp. 10–14, pl. 2, 1897.
[2] Harris, T. W., Insects Injurious to Vegetation, Flint ed., 1862, p. 421.
[3] Boisduval, Cuvier's Animal Kingdom, pl. 103, fig. 8, 1832.
[4] Psyche, vol. 2, p. 271, 1879.

This species is of equal interest with the saddle-back caterpillar, with which it has been compared in previous pages, not alone on account of its beauty in all stages and its habits, but because of the urticating or stinging spines borne by the caterpillars. At the bases of these spines are glands which secrete an irritating fluid similar in its effect to that of nettles. It follows that rough handling of the caterpillars results in the breaking off of the tips of these spines, which enter the skin and release a small drop of the irritating liquid, producing a burning sensation which varies in intensity according to the person exposed.

REMEDIES.

In case only a few rosebushes or young trees are attacked, handpicking is ample for controlling this insect, the precaution being taken to use a glove, thus avoiding being "stung." Should the caterpillars occur on several plants, and if a spraying outfit is available which may be used without danger of poisoning to human beings, a spray of Paris green or arsenate of lead may be applied.

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L. O. HOWARD, Entomologist and Chief of Bureau.

THE FLORIDA FERN CATERPILLAR.

BY

F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop and Stored Product Insect Investigations.

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CONTENTS.

ILLUSTRATIONS.

THE FLORIDA FERN CATERPILLAR.

(*Eriopus floridensis* Guen.)

RECENT INJURIES.

During recent years a species of caterpillar, *Eriopus floridensis* Guen., native to Florida and tropical America has made its appearance in injurious numbers in northern greenhouses, notably in the District of Columbia, in Illinois, and in Ohio. It is apparently restricted to ferns, on which it feeds naturally in its occurrence in the open in the warm South, and it has undoubtedly been introduced into northern greenhouses in ferns from Florida. It is a comparatively large and conspicuous species of caterpillar and, though not closely related to the true cutworms, has the same habit as cutworms of cutting or severing portions of the fern plants, apparently destroying more than it requires for food. The fern growers of the District of Columbia have experienced much trouble in the treatment of this species. Some have had good results, but others were not able to cope with it with the remedies tried, and even found it difficult to control by the laborious method of hand picking. Finally, however, the insect has yielded to this method, and at the time this was written (February, 1913) it was not to be found except in one greenhouse out of upward of a dozen inspected.

DESCRIPTIVE.

THE MOTH.

The moth (fig. 1) belongs to a group of noctuids in which the forewings bear at the sides, above the middle, a projecting area or tooth, forming an outline as shown in the figure. The hind-wings are rather broad and well rounded at the sides. The thorax and abdomen are wide, the latter especially so in the female. The color of the forewings is pale brown, marked with white scales, forming the peculiar and attractive pattern shown in the illustration. The hind-legs are dull buff, edged with dusky brown; the lower surface is paler.

The wing expanse is about $1\frac{1}{8}$ inch and the length of the body about half an inch.

The following description is copied from Sir George F. Hampson's Catalogue of the Noctuidæ:[1]

♀. Head and thorax greyish tinged with rufous and mixed with a few black scales; palpi thickly irrorated with black; frons whitish with black bar above; antennæ with the extremity of basal joint, the basal part of shaft above and below, and the shaft above beyond the sinus black; tegulæ mostly black, edged with grey, with angled grey line near base and grey line at middle; fore and mid tarsi black at extremities; abdomen ochreous tinged with fuscous, the basal crests rufous, the crest on 3rd segment black. Forewing ochreous greyish tinged with rufous, the veins defined by slight blackish streaks; subbasal line represented by double black striæ filled in with whitish from costa and

FIG. 1.—Florida fern caterpillar (*Eriopus floridensis*): Moth above; striped larva at left; dark larva at right. Enlarged. (Original.)

cell and with double black striæ before it from cell; antemedial line double, filled in with whitish, angled outwards below costa, acutely angled outwards on base of vein 2, then excurved, a whitish striga before it from submedian fold to vein 1; orbicular with brown centre and whitish annulus, very narrow and slightly angled outwards at median nervure; reniform whitish with white bar on inner edge followed by a brown line, oblique, its lower extremity produced to a hook, a triangular brown patch before it extending to costa; an oblique brown line from beyond lower edge of cell to vein 1, then bent outwards to inner margin; postmedial line double, brown, angled inwards below costa,

[1] Cat. Noct. Brit. Mus., vol. 7, pp. 548–549, London, 1908.

then bent outwards, slightly incurved at discal fold, oblique below vein 4 and incurved at submedian fold; subterminal line whitish, defined on inner side by a triangular brown patch from costa to vein 6, angled inwards above vein 5, then outwards to termen at vein 4 and defined by an oblique blackish mark on inner side, then indistinct, oblique, waved, with a sinuous whitish line before it; the termen red-brown with white line before it slightly defined by black on inner side, incurved from vein 7 to 4 where it angles outwards, then waved; cilia red-brown with yellowish line at base. Hind wing ochreous whitish tinged with red-brown especially on terminal area; a slight brown discoidal bar; cilia whitish; the underside whitish, the costal area tinged with ochreous and slightly irrorated with brown, a brown discoidal bar, postmedian line bent outwards below costa, then crenulate, traces of a diffused subterminal line, three small black spots on termen below apex defined by whitish on inner side.

♀. Ground-color much darker red-brown.

The synonymy is as follows:

Eriopus floridensis Guenée, Noct., vol. 2, p. 292 (1852); Smith, Cat. Noct. N. Amer., p. 309.

Eriopus elegantulus Herrich-Schaeffer, Corresp.-Blatt. zool. min. Ver. Regens, 1868, p. 117.

Callopistria floridensis Guenée (*auct.*).

THE LARVA.

The larva (see fig. 1) is slender, with forelegs and prolegs normal and well developed. The head is small, wider than long, greenish in life, or pale yellow in inflated specimens, with the V-mark strongly marked. While this species is very variable in general color, there is one characteristic mark which extends transversely across the anterior border of the thorax in a blackish line and abruptly backward under the spiracles to the second thoracic segment, and sometimes nearly to the anal segment. The thoracic plate is about twice as wide as long, and not very strongly marked.

The general color varies from yellow to bright green to dark, nearly black. In the palest form the thoracic border may extend nearly to the third joint of the thorax and then cease, or reappear in short, longitudinal dashes just below each spiracle. In the forms which are a little darker these lines are more pronounced, and similar transverse dashes mark the dorsal surface of the last three abdominal segments. In the more strongly marked form, shown in the figure at the left, these transverse bands are of a maroon color and very conspicuous. In most forms, and especially in the dark ones, one of which is shown at the right in the figure, there is a conspicuous longitudinal white line just above the stigmata or spiracles. This is almost lacking in the entirely grown forms. These two extreme color variants are so different that if observed separately they would not naturally be associated with the same insect, the last form presenting a decidedly velvety appearance.

The length is 1⅜ inch (33 mm.) and the width 0.2 inch (4 mm.).

THE PUPA.

The pupa is robust, of the usual shining mahogany-brown color, the posterior apex ending in two minute outcurved spines. The wing-pads are prominent.

The length is five-eighths inch, and the width about half that.

The eggs and immature stages of the larva have not come under observation.

DISTRIBUTION.

The type locality is Florida. Hampson records also Mexico, Guatemala, Costa Rica, Bahamas, Jamaica, Cuba, Haiti, Santa Lucia, St. Vincent, Venezuela, British Guiana, Brazil, and Trinidad. The species is also recorded from Santo Domingo. It is obviously a neotropical form and the only species of its genus occurring in the United States.

INJURIES AND HABITS.

July 10, 1907, this species was reported as a pest by Mr. H. M. Russell (at that time working under the writer's direction), who observed it at Orlando, Fla., attacking the fronds of potted maidenhair fern in that vicinity. It was noticed that the larvæ usually fed at night, although sometimes found feeding during the day. They concealed themselves in the daytime at the base of the ferns or were found resting low down on the stems, and they appeared to have a habit of crawling up the stems and eating off several leaflets on one side, thus spoiling the beauty of the plants. The larvæ observed began to transform to pupæ August 1.

During September of the same year Mr. Bartos, Mr. J. E. Watson, and Mr. F. H. Kramer, of Anacostia, D. C., made complaint that this caterpillar was injurious to several species of ferns in greenhouses. On September 24 Mr. C. H. Popenoe, an entomological assistant in this bureau, was detailed to obtain additional specimens and make observations on the habits of the insect and the conditions of the greenhouses. Larvæ were obtained in different stages, chiefly between half-grown and nearly grown specimens. They were feeding in the afternoon on the upper surface of the leaves. The usual method of attack, as observed, consisted in biting off the midrib leaf one-half to one-third the way up. Maidenhair or Adiantum ferns were attacked either by biting off the leaflets at the tips of the fronds or by biting off the entire frond about 1 inch above the ground. The majority of the larvæ observed were resting either near the tip of the frond of the midrib or else concealed in the stems at the base of the plant. An entire house of Adiantum had been completely stripped of the leaves by the larvæ, and one grower stated that his fern crop had been damaged to the extent of $1,000. It was stated that the larva would cut the plants entirely bare, and each new leaf would be attacked by two or three larvæ as soon as it appeared. The same grower stated that these cutworms troubled his ferns the previous year and that larvæ, pupæ, and imagos were seen throughout that winter and preyed on the ferns the whole year.

July 3, 1908, Mr. J. E. Watson called at the office, requesting methods for the control of this caterpillar, which was doing great injury to some fern plants (*Nephrolepis whitmani*) in the greenhouse. He estimated that damage to the extent of $4,000 had been caused by the caterpillars during the previous year. During September Mr. Watson and Mr. Bartos made another complaint of this species. Mr. Duder, another florist, also complained of the species. A visit was made on September 28, 1908, and a number of larvæ, mostly full grown, some about to pupate, were secured.

The larva spins a loose cocoon by drawing together dead leaves and particles of earth next to the ground. It sometimes draws together green leaves to spin the cocoon. Though not strictly a nocturnal feeder it shuns bright light and is most often found feeding exposed in the early morning.

The moth is seldom seen by day and when aroused it usually flies down under the benches to seclude itself. Thus many moths are caught in spider webs that abound in dark corners in the greenhouses.

Since the ravages by this species were repeated in 1908 with even greater loss than in 1907, two growers stated that unless some immediate steps could be taken to check the pest the raising of ferns in local greenhouses would be abandoned.

The caterpillars seem to do the greatest damage early in the year, especially during May, but owing to the uniformly warm temperature of the greenhouses, winter as well as summer, there is no time when they are scarce enough to allow the ferns to put out a full head of fronds. They attack the tender leaves, especially the growing tips of young fronds, thus checking any attempt on the part of a plant to replenish the dying fronds with a new growth, and so far stunting it as to render it of no commercial value.

From larvæ obtained in September the moths began to issue October 26, continuing to emerge until November 19. The pupal stage was ascertained to be in three cases 23, 25, and 27 days, respectively, in cool October weather.

October 13, 1909, Mr. H. Walter McWilliams, Griffin, Ga., furnished specimens of this caterpillar, found on ferns, and stated that it cuts the fronds and injured the sale of the plants.

January 18, 1910, Mr. John J. Davis[1] reported this species to be a serious pest on greenhouse ferns in Illinois. It was first reported

[1] Journ. Econ. Ent., vol. 3, p. 183, 1910.

from Onarga, Ill., in 1907, and later from Chicago. Incidentally he mentioned that Mr. A. H. Rosenfeld believed that the same species occurred on ferns in Louisiana. In the twenty-seventh report of the State entomologist of Illinois, dated 1912 and received by the writer March 10, 1913, after the present bulletin had left his hands, an article appears on this subject by Mr. Davis, who is now in the employ of this bureau. He mentions injury to ferns near Chicago, Ill., gives notes on life history, and adds descriptions of all forms, with illustrations of larva, pupa, moth, and sexes. In remarks on remedies he states what we have already learned, that arsenicals can not be applied to ferns in sufficient strength to kill this so-called cutworm, because they are apt to adhere to the surface in such a way as to make it difficult to handle the plants. Poisoned baits are also mentioned, together with pyrethrum and nicotine preparations.

July 21, 1911, Dr. Thaddeus McLaughlin, Springfield, Ohio, furnished specimens of this species, stating that it had destroyed some fine ferns.

What appears to be the first record of the food habit of this species was made in the Yearbook of the Department of Agriculture for 1908 (p. 578) and reads as follows:

> The Florida fern caterpillar (*Callopistria floridensis* Guen.) has been injurious in local greenhouses, one florist reporting damage to his ferns to the extent of $4,000.

NATURAL ENEMIES.

Ichneumon extrematis Cress.—This ichneumon fly, which is of moderate size, black, lightly marked with white, was reared from a pupa of the Florida fern caterpillar from Anacostia, D. C., September 26, 1907. It was seen in the act of issuing from a number of pupal cases, showing a characteristic exit hole. This parasite and two other species were seen flying about the infested greenhouses.

Sargaritis sp.—This small ichneumonid parasite (Chttn. No. 2117[oo]) was reared from *Eriopus floridensis* from Anacostia, D. C., September 30, 1907.

A tachinid fly attacks this species, a single specimen, unidentified, having issued from the cocoon of its host August 22, 1907, at Orlando, Fla.

METHODS OF CONTROL.

Many remedies were tried by the growers at Anacostia, some of which were suggested by the writer and others by different persons in the city of Washington. Naturally some of these, which were not advised by entomologists, did not produce the desired effect.

Hellebore.—September 20, 1907, one grower sprayed his entire crop with a strong decoction of hellebore. This was successful in driving away the larvae but it scalded the foliage of the ferns so badly that many of the plants died. He was advised to use arsenate of lead.

Poisoned bait.—This same grower employed a bait of poisoned bran and molasses, about as advised for cutworms, but without material effect, the caterpillars preferring the ferns.

Carbon bisulphid.—Fumigation with carbon bisulphid was tried by Mr. Watson in June, 1908, but he stated that it had been of no avail in the destruction of this pest. In the same greenhouse, in charge of Mr. Watson, strips of cloth were saturated with carbon bisulphid and placed on the ground about the plants, but although this remedy was sometimes successful it was not entirely reliable since the caterpillars had necessarily to be where they would receive the fumes if they were to succumb.

Hand picking.—The time-worn, laborious, but, if properly pursued, effective remedy of combating the insect by hand measures was employed by numerous growers. One of these reported that the numbers of the caterpillar had been materially reduced by hand picking and poisoning. Another grower made a practice of going over the ferns every day and picking off all the caterpillars that could be seen, thus reducing the numbers of the pest in his greenhouse. It seemed to be the consensus of opinion that the average grower would obtain the best success by hand methods, one of the best methods consisting in shaking each individual plant over the ground and trampling upon the caterpillars as they fall.

Arsenate of lead.—Arsenate of lead was advised, and an assistant was detailed to an infested greenhouse where this remedy was employed, to determine the extent of injury and to advise measures for the possible extermination of the cutworms. On his arrival he was informed that several thousand had been hand picked from the ferns a day or two before and that over 200 had been picked from a space only 5 feet square. The plants had also been sprayed with arsenate of lead at the rate of $2\frac{1}{2}$ pounds to 50 gallons of water, applied twice, but the final result was not reported. Some of the growers complained that lead arsenate, when used in a solution strong enough to kill the caterpillars, would at the same time leave a white deposit on the plants which destroyed their commercial value. Owing to the delicacy of ferns a spray of Paris green strong enough to kill the caterpillars would also burn the foliage. Paris green, properly combined with Bordeaux mixture, should not produce this effect.

Hydrocyanic-acid gas fumigation.—Some of the local growers were advised by the writer to fumigate with hydrocyanic-acid gas, but it was not tried, so far as can be learned. If fumigation by this method were employed several times at about the time when the insects are hatching from the egg, or undergoing their molts, it should assist very materially in reducing the numbers of the pest.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 126.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE ABUTILON MOTH.

BY

F. H. CHITTENDEN, Sc. D.,

In Charge of Truck Crop and Stored Product Insect Investigations.

Issued December 6, 1913.

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CONTENTS.

ILLUSTRATIONS.

THE ABUTILON MOTH.

(*Cosmophila erosa* Hübn.)

HABITS AND RECENT INJURY.

During September, 1909, while stationed at Diamond Springs, Va., Mr. C. H. Popenoe noticed that the leaves of okra, hollyhock, and Abutilon on the farm of the Virginia Truck Experiment Station were being badly injured by the Abutilon moth (*Cosmophila erosa* Hübn.). Many larvæ and pupæ were present, defoliating the plants mentioned. The insect occurred in large numbers and in all stages, so that it actually was a serious pest. From this lot moths were reared November 13, 1909. In October of the same year Mr. E. G. Smyth, who relieved Mr. Popenoe at Diamond Springs, noticed the attacks of this species on hollyhocks and Abutilon throughout that month.

During early August, 1912, the writer noticed this species at work on the grounds of the Department of Agriculture, causing very serious injury to Abutilon. The previous year the species was quite abundant on hollyhocks, as mentioned, and "peppered" them with holes. The larval work on Abutilon was quite different. The larvæ were mostly small when observed, and their place of concealment was not at first found, but larvæ were obtained by inserting an umbrella under the leaves and shaking them down. The heat at the time the observations were made was most intense, and the insects were undoubtedly concealed.

Later, August 30, 1912, the writer observed the work of this insect on Abutilon, and in a short time the larvæ could be obtained from the leaves in great numbers, as they were rapidly defoliating the plants. After enough larvæ were taken away for rearing purposes the plants were sprayed under the writer's direction by Mr. A. B. Duckett, September 10. After the spraying, which appeared to be quite successful, it was found that a few larvæ were still present on the plants October 3. They ranged in size from quite small to half grown, and a few pupæ were still on the plants.

Mr. J. F. Strauss collected this species August 20, 1912, on *Hibiscus esculentus* at Washington, D. C. In all cases observed the 12-spotted cucumber beetle (*Diabrotica duodecimpunctata* Oliv.) caused some of the injury, while ants also invaded the open bolls, which they were devouring. He noted that one larva pupated August 21 and emerged as adult August 29, or in 8 days. Another pupated August 21 and emerged August 30, or in 9 days. That was during a hot period, and a shorter time was taken to transform than would be necessary at a cooler time.

The opinion expressed by Riley that this is exclusively a southern species was modified somewhat by the same author when he found the eggs and larvæ quite abundantly in September, 1882, on *Abutilon avicennæ* at several localities in the District of Columbia.

On September 21 the largest larva was nearly an inch long, and on October 3 it spun up and transformed to pupa. The first moth issued October 15, and on October 16 several moths were captured at sugar. On October 22 quite a large number of larvæ of all sizes, from those just hatched to the nearly full-grown individuals, were found feeding on the same plant at Ivy City, D. C., and October 25 eggs and young larvæ were found on the leaves of *Malva rotundifolia* at Giesboro Point, D. C. The moths from these larvæ began issuing December 1, and more than a dozen had made their appearance by December 4.

In the writer's experience this species appears to prefer Abutilon to hollyhock. It does not spread to any great extent, and hibiscus may not prove to be its natural food plant.

This species was last seen on October 12, 1912, when Mr. M. M. High sent one larva found on cowpea leaves at Gulfport, Miss., and on October 31, 1912, when a moth issued from our own material at Washington, D. C.

A portion of a badly infested Abutilon plant is shown in Plate I and a skeletonized leaf in Plate II.

SYNONYMY.

This species has been described under several different names, as shown in the following synonymy, adapted from Hampson (8):

Cosmophila erosa Hübn., Zutr. Samml. exot. Schmett., vol. 2, p. 19, figs. 287, 288.
- *Cosmophila xanthindyma* Boisd., Faun. Ent. Mad., p. 94, pl. 13, fig. 7; Moore, Lep. Ceyl., vol. 3, p. 155, figs. 1, 1 *a*, *b* (larva); C. & S. No. 2234.
- *Cosmophila indica* Guen., Spec. Gen. Lep., Noct., vol. 2, p. 396.
- *Cosmophila auragoides* Guen., Spec. Gen. Lep., Noct., vol. 2, p. 397.
- *Cirrœdia veriolosa* Walk., List Lep. Ins. Brit. Mus., pt. 11, p. 750.
- *Cirrœdia edentata* Walk., List Lep. Ins. Brit. Mus., pt. 11, p. 750.

It has, however, been generally mentioned in literature as *Anomis erosa* Hübn.

DESCRIPTION.

The moth so closely resembles the cotton moth (*Alabama argillacea* Hübn.) of the Southern States as to be readily mistaken for it by anyone familiar with the latter. The egg closely resembles that of the cotton moth. The larva bears some resemblance to that of the cotton moth, but more to that of the cabbage looper (*Autographa brassicæ* Riley), especially on account of the structure of the legs, as

ABUTILON PLANT, SHOWING ALMOST COMPLETE DEFOLIATION BY LARVÆ OF THE ABUTILON MOTH (COSMOPHILA EROSA) AT WASHINGTON, D. C. (ORIGINAL.)

LEAF OF ABUTILON, SHOWING SKELETONIZING OF LEAVES DUE TO LARVÆ OF THE ABUTILON MOTH, LEAVING ONLY THE MAIN RIBS. WASHINGTON, D. C. (ORIGINAL.)

ABUTILON PLANT, SHOWING INCREASED GROWTH AFTER DESTRUCTION OF LARVÆ OF THE ABUTILON MOTH BY SPRAYING WITH NICOTINE SOLUTION. (ORIGINAL.)

shown in Plate IV, figure *b*. It will be noticed that there are only three pairs of prolegs, or prop legs, in addition to the anal pair. This larva when quite young is pale greenish-yellow, showing very little characteristic marking. This is not shown in the figure, because the basis was a photograph, and it could not be filled out on account of the growth of the material after the first photograph.

It will be noticed at first that the larva when extended at full length is decidedly slender, more so than any species of Autographa. The striping is similar to that of *A. brassicæ,* and the larva is inclined to be translucent throughout the stages. When at rest, the body may be held perfectly straight, as in the case of geometrids or inch-worms. This habit, together with the coloration, which is very similar to that of its food plant, renders the larva decidedly inconspicuous; indeed, it furnishes a most excellent example of protectional coloration.

Technical descriptions of the different stages follow. That of the adult is from Hampson (8) and those of the immature stages are from Riley (5, 6).

THE ADULT.

♂. Head and thorax orange yellow, irrorated with brown; abdomen brown above. Forewing fuscous, suffused with purple gray; a large yellow patch irrorated with red occupying the whole basal half of wing except the inner margin; irregular ante and post medial red lines meeting at inner margin, the latter produced to an irregular angle beyond the lower angle of cell, then excurved to its lower angle; a white speck in cell; a dentate submarginal line, the area beyond it brown; the cilia white at tips. Hind wing dark fuscous; the cilia white at tips. Underside of forewing with the costal and outer area pale, speckled with red; hind wing pale, the costal area speckled with red.

♀. Bright orange yellow; forewing slightly red speckled and with slight purplish suffusion below the postmedial line; the cilia white at tips.

(Larva. With three pairs of abdominal prolegs. Grass green, with dorsal and lateral series of minute white specks; the prolegs reddish. Food-plant *Hibiscus*.)

THE EGG.

Diameter 0.8 mm., circular, flat below; the upper surface varies somewhat in convexity, in some being almost hemispherical, whilst with others it is quite flat, in general shape and size reminding one of the egg of *Aletia xylina* [*Alabama argillacea*]. Color, pale yellowish green, almost of the same shade as the lower side of the leaves. The number of ribs which run from the base toward the summit varies in different eggs from 31 to 38. Of these ribs from 11 to 13 reach to about one-fourth the distance above the base, 5 to 7 halfway toward the summit, and 16 to 18 to near the summit. The space between these ribs is divided quite constantly by 12 low transverse ribs, which at the intersection with the radiating ribs form a small though quite sharp triangular point, which is especially conspicuous in the empty egg. The spaces between these ribs form shallow, squarish depressions, which are finely granulate. The summit is almost smooth, surrounded with three series of small, roundish cells, which become larger away from the center, and beyond these another series of three rows of larger cells of different shapes, though more or less squarish.

THE LARVA.

First stage.—Length of the newly hatched larva, 2 mm. Color very pale greenish yellow along the dorsum, white and transparent toward the sides; head pale yellowish, without any markings; eyes black, tips of mandibles brown. Antennæ short, 3-jointed; first joint stout, very short and somewhat conical; second joint longest, clavate, its tip obliquely truncate externally, bearing at inner and outer angles a stout spine, which is a little longer than the third joint; third joint shorter than second, cylindrical, with a small tubercle at tip, resembling a fourth joint, and provided at its tip with a fine hair; at the inner side of the third joint, at base of the apical tubercles, arises a stout spine which is almost as long as the joint itself. Piliferous warts, pale brownish, each bearing a long and slender pale hair. Legs rather long, white; only two pairs of prolegs, situated on abdominal joints 8 and 9.

Second stage.—The first molt takes place seven or eight days after hatching; at this time the larvæ differ from the newly hatched specimens only in the somewhat larger size and slightly darker color.

Third stage.—In from six to seven days the second skin is cast, and with this molt appears the third pair of abdominal legs on joint 7. They are, however, extremely small and scarcely noticeable; they are not used in walking. The color now is a darker green, lighter toward the sides, and with a pair of rather indistinct whitish dorsal stripes. Head highly polished, pale, faintly greenish, with two pale, dusky oblique stripes. Cervical shield slightly dusky, with a darker posterior margin. Piliferous warts black, the hairs colorless. The abdominal legs are marked externally with a broad dusky stripe.

Fourth stage.—The third skin is cast six or seven days after the second molt. The larva is now almost of the color of the leaves, and measures about 14 mm. in length. The median and somewhat wavy lateral lines are darker than the rest of the body; the subdorsal stripes and sutures between the joints are white. The prolegs on abdominal joint 7 are now quite distinct, though rather small, and are used in walking.

Fifth stage.—The fourth skin is cast three to five days later, the larva having changed very little in appearance, except that the dorsal and lateral lines and the piliferous warts are distinctly dusky.

Sixth stage.—Five or six days later the fifth skin is shed, and the larva does not change in appeareance.

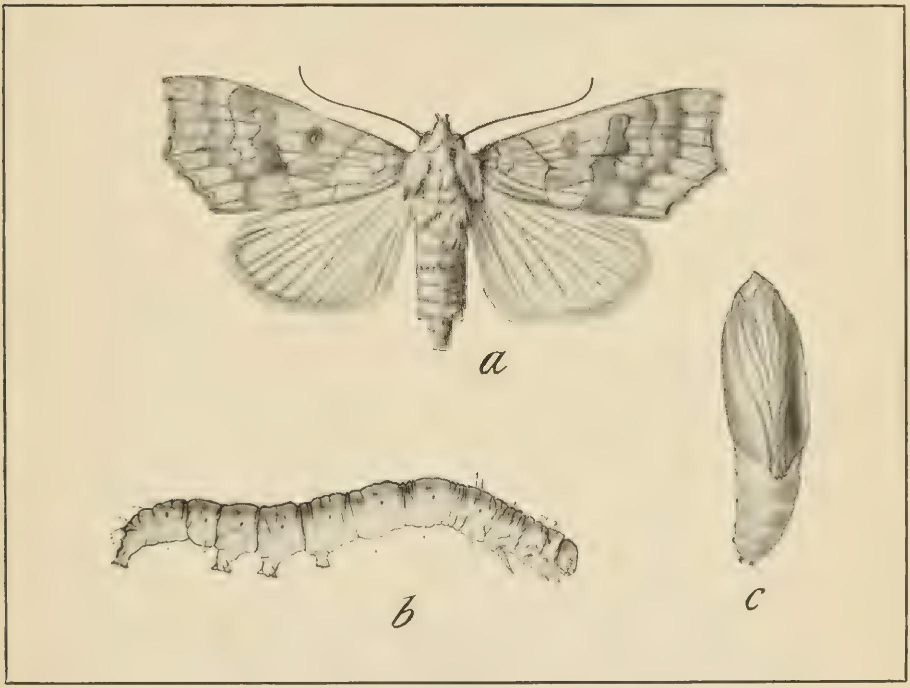
Seventh stage.—The sixth molt takes place about five days after the fifth, and the whole appearance of the insect is considerably changed. The color is pale, translucent, pea-green. The head is not polished, of the color of the body; the two oblique dusky stripes are composed of several irregular spots; the labrum is white, antennæ pale greenish, and the eyes black. The median and the two subdorsal lines are composed of numerous irregular spots of a lemon-yellow color, of which those on median and the lower dorsal lines have a more or less distinctly dusky shade on either side; the lateral line is quite broad and almost white. Piliferous warts pale yellow, surrounded by transversely oval, indistinct, dusky rings. The whole body is speckled with numerous, usually transversely oval, small, lemon-yellow spots, which inclose from two to three almost colorless, glistening, round dots. Stigmata orange. Legs pale green; claws and hooklets pale brown; venter bluish-green.

Length of full-grown larva about 35 mm. (1⅜ inches).

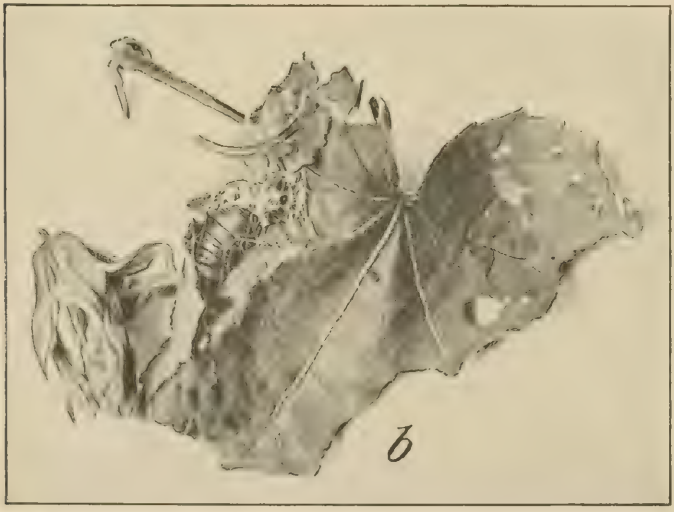
Larvæ at work on an Abutilon leaf are illustrated in Plate V, above.

THE PUPA.

Length, 15 mm. Color, blackish-brown; wing-sheaths opaque, the remaining portion faintly polished. Front of head prolonged into a short, stout, conical projection; near its base ventrally are two fine and quite long hairs and two similar pairs



THE ABUTILON MOTH (COSMOPHILA EROSA): *a*, ADULT; *b*, LARVA, SHOWING ARRANGEMENT OF LEGS; *c*, PUPA. ENLARGED. (ORIGINAL.)



a, ABUTILON LEAF, SHOWING PENULTIMATE STAGE OF LARVA OF THE ABUTILON MOTH NEAR MIDDLE; *b*, PORTION OF PUPA OF THE ABUTILON MOTH AT LEFT ON LEAF, SHOWING PARTIAL CONCEALMENT. (ORIGINAL.)

dorsally near insertion of antennæ. Eyes prominent and considerably polished. Legs reaching to tip of wing-cases; antennæ shorter. Median line of prothorax quite sharp and carinate, median line of mesothorax faintly elevated, somewhat polished. The whole anterior portion of body finely and closely granulated. Metathorax and the three following abdominal segments, with numerous shallow, circular depressions, each having a central granule. The circular depressions on abdominal joints 4–8 are somewhat larger and their margin is slightly elevated; the posterior third of joints 4–6 is of a lighter color than the rest of the body and very closely and quite coarsely granulated, while the posterior third of abdominal joints 7 and 8 is polished and not granulated. The last joint is very peculiarly formed; its tip is broad and prolonged each side into a short, stout, and sharp tooth directed forward, and between these two is a pair of slender and also bristle-like spines, directed forward and with their tips curved in the shape of a loop; another pair of similar bristle-like spines, which are directed forward and inward, are situated, one at each side, on a small projection at the base ventrally of the stout lateral teeth, and between these is a large projection which is armed at its edge with two large, stout, claw-like teeth, which stand at right angles to the body of the pupa. The anal swelling is smooth, circular, and quite prominent; the remaining portions of the tip are marked with coarse, elevated ridges, both dorsally and ventrally.

The pupa is shown in Plate V, below.

EXPERIMENTS IN CONTROL.

The following formula was used for spraying the infested Abutilon:

Nicotine sulphate, 40 per cent	ounce..	½
Whale-oil soap	pound..	½
Lukewarm water	gallons..	5

The whale-oil soap was thoroughly dissolved in 5 gallons of water and the solution, after the addition of the nicotine sulphate, was thoroughly agitated. The plants were sprayed in the morning while some dew remained on them, and in the form of a fine spray or mist from all sides as well as from above and below, the idea being, if possible, to reach every insect on the plants. The weather was calm and clear.

Two days after this treatment about 95 per cent of the larvæ were found dead. Only four or five larvæ were observed to be living, and these, it is believed, came from adjoining unsprayed plants. In a few days the plants began to take on a new appearance, putting out a second growth of leaves. Unfortunately, however, three weeks afterward another lot of larvæ attacked the same plants, although their numbers were much less than on the occasion of the first attack. They were, at the time of discovery, full grown and starting in to do considerable injury.

To complete the experiment, destroy the insects, and save the plants, the same solution was applied again with the result that it entirely eradicated all of the insects, and the Abutilon plants thrived thereafter free from insect attack of any kind up to the end of the season. (See Pl. III.) It is believed that some of the insects were in the egg stage when the spraying was made on the first occasion and that they are not reached when in this condition.

An extremely interesting matter in connection with this injurious occurrence and the application of remedies is that throughout the season of 1913 to October 13 none of the insects made their appearance on the Department grounds where the spraying work was done, showing either the absolute thoroughness of the application or, possibly, that the insect never returned to this particular locality.

BIBLIOGRAPHY.

The following bibliography is by no means complete, but includes references to the principal literature:

1. Hübner, Jacob. Verzeichniss bekannter Schmetterlinge, p. 249, 1816.
   Original description.
2. Hübner, Jacob. Zutrage zur Sammlung exotischer Schmetterlinge, zweytes hundert, p. 19, figs. 287, 288, 1823.
3. Guenée, Achille. Histoire naturelle des insectes. Species général des Lepidoptères. Noctuélites, t. 2, p. 395, 1852.
4. Grote, A. R. North American Noctuidæ in the Zutrage, second and third hundreds. Can. Ent., vol. 12, p. 116, 1880.
   Savannah, Ga., and Alabama recorded as localities.
5. Riley, C. V. Report of the Entomologist. (In Report of the [U. S.] Commissioner of Agriculture, 1881 and 1882, pp. 167–170, pl. 8, fig. 1, 1882.)
6. Riley, C. V. Fourth Report of the U. S. Entomological Commission, p. 345, pl. 2, figs. 1–3, 1885.
7. Smith, J. B. Catalogue . . . of . . . Noctuidæ . . . in Boreal America, p. 241, 1893. (Bul. 44, U. S. Nat. Mus.)
   Bibliography, description of moth, distribution.
8. Hampson, G. F. The fauna of British India, vol. 2, pp. 408, 411, 1894.
9. Staudinger, Otto, and Rebel, Hans. Catalog der Lepidopteren des palæarctischen Faunen-Gebietes, 3. Aufl., p. 234, 1901.
10. Dyar, H. G. Notes on cotton moths. Insecutor inscitiæ menstruus, vol. 1, p. 4, January, 1913.
    References under *Cosmophila erosa* Hübn., food plants, and distribution in brief.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON INSECTS AFFECTING VEGETABLE AND TRUCK CROPS.

CONTENTS AND INDEX.

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I. THE SPOTTED BEET WEBWORM

By F. H. CHITTENDEN, *In Charge of Truck Crop and Stored Product Insect Investigations.*

II. THE STRIPED BEET CATERPILLAR

By H. O. MARSH, *Entomological Assistant.*

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Truck Crop and Stored Product Insect Investigations.

F. H. Chittenden, *in charge.*

C. H. Popenoe, H. O. Marsh, M. M. High, Fred A. Johnston, John E. Graf, C. F. Stahl, D. E. Fink, A. B. Duckett, F. B. Milliken, Thomas H. Jones, *entomological assistants.*
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Marion T. Van Horn, Pauline M. Johnson, Anita M. Ballinger, Cecilia Sisco, *preparators.*

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

ERRATA.

Page 1, line 6 from bottom, for *Walw.* read *Walk.*

Page 1, line 6 from bottom, for *pharsiusalis* read *phrasiusalis.*

Page 7, line 2 from bottom, for *xanthamelæna* read *xanthomelæna.*

U. S. DEPARTMENT OF AGRICULTURE,

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L. O. HOWARD, Entomologist and Chief of Bureau.

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THE SPOTTED BEET WEBWORM.

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Marion T. Van Horn, Pauline M. Johnson, Anita M. Ballinger, Cecilia Sisco, *preparators.*

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

U. S. D. A., B. E. Bul. 127, Part I. T. C. & S. P. I. I., May 31, 1913.

PAPERS ON INSECTS AFFECTING VEGETABLE AND TRUCK CROPS.

THE SPOTTED BEET WEBWORM.

(*Hymenia perspectalis* Hübn.)

By F. H. Chittenden, Sc. D.,
In Charge of Truck Crop and Stored Product Insect Investigations.

INTRODUCTORY.

The spotted beet webworm (*Hymenia perspectalis* Hübn.) has attracted the writer's attention on two occasions from its occurrence on beets in the District of Columbia. It is a singular fact that it was first observed in 1905 and that its presence did not again become noticeable until after a lapse of seven years, or until 1912, when it became a veritable pest. It may be classified both as an enemy to sugar beet, because of its occurrence on that plant normally, and as an insect injurious to ornamental plants in both the garden and greenhouse. The larva is at first sight rather plain, but on closer examination it is seen to be distinctly and beautifully marked. The moth is also a most beautiful creature and has often been found flying about the District of Columbia. The food plants which will be mentioned in the present paper probably do not by any means exhaust the list.

DESCRIPTIVE.

THE MOTH.

Hymenia perspectalis is a member of the family Pyralidæ and subfamily Pyraustinæ, according to Dr. Dyar's classification. It has been described under various synonyms as follows: *Spoladia animalis* Guen., *S. exportalis* Guen., *Zinckenia primordialis* Zell., *Desmia rhinthonalis* Walw., and *Hymenia pharsiusalis* Walk.

The genus (under the name Zinckenia) is characterized by Sir George Hampson as follows:

Palpi upturned, the 2nd joint broadly scaled in front and not reaching vertex of head, the 3rd well developed and acuminate; maxillary palpi long and filiform; frons rounded; antennæ of male nearly simple, the base of shaft excised, and a tuft of hair [rising] from basal joint; tibiæ with the spurs long and nearly equal. Fore wing with veins 3, 4, 5 from angle of cell; 7 well separated from 8, 9, to which 10 is approximated. Hind wing with vein 3 from angle of cell; 4, 5 approximated for a short distance; 6, 7 from upper angle, 7 anastomosing with 8.

THE EGG.

The egg was not seen by the writer owing to the lateness of the season when continuous work was begun. We therefore have to depend upon the description furnished by Mr. Davis. He writes, in substance, that the female deposits her eggs flat and singly on the stem of the plant near the base. The egg is oval, 0.57 mm. by 0.82 mm., and being transparent pale green is quite conspicuous on the plant. Its surface is slightly convex and covered with microscopical, irregular polygonal areas appearing as a netlike sculpture on the surface.

Walker's description of the species under the name *phrasiusalis* follows:

Female. Brown, rather slender, whitish beneath. Palpi vertical, slightly curved, rising higher than the head; second joint slightly fringed; third lanceolate, about half the length of the second. Pectus pure white in front. Abdomen extending a little beyond the hind wings; hind borders of the segments white. Fore legs with brown bands. Wings moderately broad, with a cupreous tinge; markings white; fringe here and there white. Fore wings with the interior line slender, nearly straight; exterior line much interrupted, broad and regular in front; reniform mark represented by a transverse subquadrate spot. Hind wings with the exterior line broad, complete, attenuated hindward. Length of the body 4 lines; of the wings 9 lines.

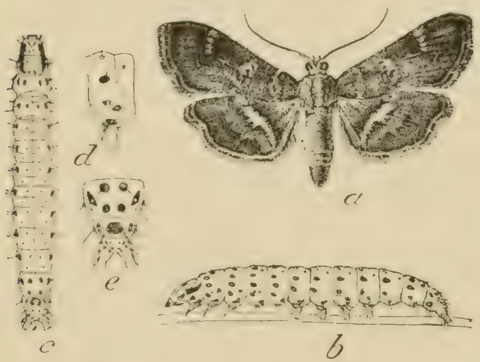

FIG. 1.—The spotted beet webworm (*Hymenia perspectalis*): *a*, Moth; *b*, larva, lateral view; *c*, larva, dorsal view, showing characteristic markings on head and joints; *d*, abdominal joint; *e*, anal joint. *a–c*, Enlarged; *d*, *e*, more enlarged. (Original.)

Less technically, this moth may be described, in comparison with the related *Hymenia fascialis* Cram.,[1] as of very similar form and having a similar pattern. The color is paler brown, inclining to cinnamon. The white fasciæ or bands are much less conspicuous, especially the second band on the fore wing two-thirds from the apex. The fascia on the hind wings is of different shape, not more than half as wide as in the other species, and more irregular. The

[1] See Bul. 109, Pt. I, Bur. Ent., U. S. Dept. Agr., November 6, 1912.

pattern is about as illustrated in figure 1, *a*. The average wing expanse is 20 mm., while the body is 8 mm. long. The venation is as shown in figure 2, and the external male characters are illustrated in figure 3.

THE LARVA.

The larva of this species is, when nearly mature, subcylindrical and somewhat depressed. When contracted it is about ten times as long as it is wide, and when extended still longer. The general color is green, brighter in the younger individuals and paler just before transformation. The head is prettily marked with purplish dots, leaving a white, longitudinal center through each half. The head is well divided, the two lobes meeting somewhat narrowly. The thoracic plate is of about the same width as the head, having a black border with conspicuous tubercles clothed with rather long hairs. Of these tubercles there are two conspicuous pairs on the first thoracic segment, with two others on each side. The second thoracic segment is very similarly marked. The abdominal segments are marked with four tubercles on the dorsum and larger ones each side. The arrangement of the spots on the anal segment is well shown in figure 1 at *e*. The location of all these tubercles is well illustrated in figure 1, the arrangement from above being shown at *c* and the lateral arrangement at *b*. The length of this larva when extended is about 20 mm. When at rest, or retracted, it is considerably less. The width at the widest portion is about 2.5 mm.

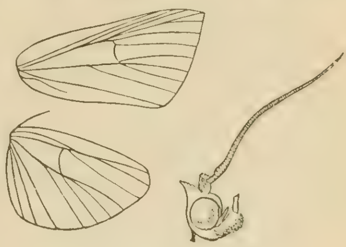

FIG. 2.—Venation of *Hymenia fascialis*, showing characters of the genus; head and antenna, lateral view, at right. (After Hampson.)

The pupa, unfortunately, was not preserved.

FIG. 3.—External male characters of moth of *Hymenia perspectalis*. Greatly enlarged. (Original.)

DISTRIBUTION.

The distribution accorded this species by Hampson is " Nearctic, Neotropical, Ethiopian, and Australian regions." Nothing is known of the origin of the species, and it is uncertain whether it comes from the Old or the New World, but it is obviously exotic and introduced into the United States. As the known species are from Africa, this may indicate the original habitat. The species is not known in Europe, but it will probably in time become cosmopolitan.

The record of injurious occurrences includes only Brooklyn, N. Y., and Washington, D. C. Undoubtedly the species occurs in troublesome numbers in many localities, but no records are available.

Through the kindness of Dr. H. G. Dyar and from other sources I am enabled to furnish the following distribution:

Washington, D. C., October 1, 1879.
Kansas, September, 1872.
Ohio.
Georgia, April, 1879.
Hurricane Mills, Tenn. (G. G. Ainslie).
Brownsville, Tex. (McMillan).
Tryon, N. C., July 3, 1904 (W. F. Fiske).
Dallas, Tex. (Boll).
Texas (Belfrage).
Miami, Fla. (Schaus).
Pernambuco, Brazil (Koebele).
Oaxaca, Mexico.
Grenada, British West Indies.
St. Lucia, British West Indies
Guatemala (Cockerell).
Costa Rica (Schaus).
Panama (Busck).
Venezuela.
French Guiana.
Peru.
Rio de Janeiro, Brazil.
Newark, N. J.
Cuba.
Sarawak, Borneo.
Central America.

NOTES ON OCCURRENCE.

ATTACK ON BEETS AND CHARD.

October 1, 1905, the writer first observed this species in a small colony on sugar beets growing in the insectary garden connected with the Bureau of Entomology. The insect was studied at that time with sufficient care to enable a drawing of the larva to be made, which is presented herewith. The moth, however, was not reared because of an accident which occurred to the rearing jar in the writer's absence.

September 30, 1912, after a lapse of seven years, this same species was again detected by the writer and readily recognized from the drawing previously made. It was first noticed and caused considerable injury on Swiss chard growing in the grounds of the Bureau of Entomology. The infestation covered one-half of a row of chard, where the damage was practically complete. Injury, however, was complicated by another insect with which it was associated, the spinach or beet flea-beetle (*Disonycha xanthomelana* Dalm.), which had been injurious to the same plants in an earlier and a later generation and was still at work throughout the time that the lepidopterous larva was observed, and even later. The work of both species is illustrated in Plates I and II, while Plate III shows, for comparison, a chard plant which has been slightly infested but not injured. The large holes were made chiefly by the beetles earlier in the season, and the blacker portions show where the larvæ or caterpillars did their greatest damage.

From the outset of attack it was noticed that larvæ were rarely seen during the daytime and evidently were nocturnal or practically

SWISS CHARD INJURED BY THE SPOTTED BEET WEBWORM (HYMENIA PERSPECTALIS).

[Note complete breaking down of plant, as compared with ordinary injury by the spinach flea beetle (*Disonycha xanthomelana*), shown in Plate II.] (Original.)

SUGAR BEETS SHOWING INJURY FROM COMBINED ATTACK OF SPOTTED BEET WEBWORM AND SPINACH FLEA-BEETLE. (ORIGINAL.)

SWISS CHARD IN SAME ROW AS SHOWN IN PLATE I, NOT ATTACKED BY THE SPOTTED BEET WEBWORM BUT SHOWING MILD ATTACK BY THE SPINACH FLEA-BEETLE. (ORIGINAL.)

so, and that they concealed themselves about the bases of the plants near the roots and under portions of leaves or petioles which rested on the ground. This was especially noticeable at the time when the larvæ were attaining their full growth.

Subsequently, October 3, the writer, with Mr. A. B. Duckett, found larvæ of this species at work on table and sugar beets. On the sugar beets similar injury to that on Swiss chard had been done, but for some reason the larvæ were scarce. The work was quite apparent, however. On the table beets the larvæ looked considerably darker, due to the darker food plant on which they fed. They were observed at this time in all stages of growth from the first stages of the larva to the last stage. The location of the chard and table and sugar beets had much to do with the growth of the larvæ, the sun playing an important part.

On a single leaf of sugar beet taken October 4 the larvæ remained in the same position for about 24 hours. The leaf was small, and after this period, after capture, only slight growth of the larvæ could be observed, especially in the case of the younger stages.

These latter were probably in the second stage. They were very nearly white, showing very feeble markings. They measure about 3.5 mm. in length. In what appears to be the third stage the larvæ assume decided markings, but are not nearly so dark as in the next stage. They are decidedly green in color, and measure about 10 mm. in length.

In the last stage the larvæ, just before pupating, turn pale and somewhat yellowish.

The cocoon is formed in different ways—on the plant and on the ground—and is covered with more or less webbing, and sometimes with an abundance of black excrement which naturally soon grows dry.

INJURY TO ORNAMENTAL PLANTS.

On October 6, 1912, the writer observed at Iowa Circle, Washington, D. C., severe injury to foliage plants of the order Amaranthaceæ. The most seriously injured area was a large circle in one of the beds at the west end of the park. The plants were practically ruined, merely hanging together in shreds. Opportunity did not offer to obtain the larvæ because of the crowd of pedestrians and others seated in the immediate vicinity. On another plat where the plants did not receive nearly so full sunlight the larvæ were found in more abundance, but only half as much injury had been accomplished. It is plain that the first lot had mostly matured and the second lot were near maturity. The plant in question, on which the insects were most abundant, was *Telanthera versicolor*, or the Alternanthera of florists.

There were also beds of the *Achyranthes acuminata* of florists, known botanically as *Iresine lindeni*, which were slightly injured by this pest. It was noticed that the larvæ, as in the case of attack to other low-growing plants, rest chiefly during the daytime on the lower leaves and near the roots.

October 7 the writer observed much injury to several plats of Alternanthera on the grounds of the Department of Agriculture, but larvæ were difficult to obtain until the much injured lower leaves were noticed; then no trouble was experienced, Mr. Duckett easily taking about a dozen. In this case, as in others, with the exception of that at Iowa Circle, colonies of the spinach flea-beetle (*Disonycha xanthomelæna* Dalm.) were present and had been responsible for the early injury. When first collected the two species were in the proportion of five of the flea-beetle to two of the webworm, but later the lepidopterous larvæ were found to be doing the greatest damage. A few young larvæ were observed at this time.

Cut leaves of beets and refuse stems were placed near the affected Swiss chard as decoys, with the result that many larvæ were found, some within the stems and some of them on the side nearest the ground. Many were also found on and under leaves[1] which had withered.

Larvæ which transformed to pupæ October 4 emerged as moths October 25, or in 21 days. Larvæ which transformed to pupæ October 12 emerged on October 30, or in 18 days. One which pupated October 16 emerged October 31, or in 15 days, showing the length of the last generation of the season to vary between 15 and 21 days, according to temperature. None of the moths which were kept for the purpose deposited eggs, nor did any remain over as larvæ, as in the case of many related species in hibernation. Hence it is doubtful if this species really hibernates in the District of Columbia, and it may be that the region is reached by moths which fly from more southern places in warm days in spring or early summer. At any rate injury has never been noticed until the autumn. One moth was captured by the writer as late as December 10 in the insectary. It might have emerged from the plants there or obtained access to the building from the outside.

OTHER RECORDS AND NOTES.

The foregoing records have been made from the writer's personal observations. In looking over the notes of the Bureau of Entomology a much earlier record was found, dated April 1, 1896, when Mr. Theodore Pergande noticed large numbers of the moth flitting about in the propagating house of the Department of Agriculture

[1] This habit of concealment on the dried leaves is a very common one among both beetles and caterpillars. *Disonycha xanthomelæna* was observed in similar locations, even on dried leaves growing high on the plants.

and was told by the gardener that this moth evidently belonged to a small larva which was doing great damage to the leaves of several varieties of Alternanthera grown in boxes and pots in the greenhouse. It was also observed that the larvæ worked mainly at night and that they concealed themselves during the daytime between the roots of these plants at the bottom of the pot.

November 27, 1909, Dr. H. T. Fernald sent specimens of this species for identification that had been received from Cuba.

November 15, 1910, Mr. D. K. McMillan, while working under the writer's direction at Brownsville, Tex., collected the larvæ of this species on Amaranthus and beets in that vicinity. The larvæ were attacking the leaves and flowers of both plants and webbing the leaves and stems. Moths were very numerous on December 6 of the same year, a few larvæ still being found on the food plants mentioned. Parasites were reared from larvæ taken November 15.

April 11, 1912, Prof. Glenn W. Herrick, of Cornell University, Ithaca, N. Y., sent specimens of the moth with report that they were reared from larvæ found very abundantly in a greenhouse in Brooklyn, N. Y., and that they were especially bad on Alternanthera.

Mr. John June Davis has forestalled the writer in publishing an article on this same species, which he terms the Alternanthera worm. He records that in 1910 this species was found eating the foliage of the variegated border plant Alternanthera, and states, what the writer has also noted, that if the larvæ are numerous enough to attract attention they usually defoliate the plant repeatedly as new shoots and leaves put forth, thus ruining it for ornamental purposes and sometimes killing it. The article includes descriptive matter, notes on habits, and suggestions as to remedial measures, among which arsenicals, hand picking, and light traps are especially mentioned.

ASSOCIATED INSECTS.

THE YELLOW-NECKED FLEA-BEETLE.[1]

(*Disonycha mellicollis* Say.)

October 8, 1912, the writer observed, in a badly infested plat not previously examined in Iowa Circle, Washington City, about 20 individuals of the yellow-necked flea-beetle (*Disonycha mellicollis* Say) congregated in a space of less than a square foot. They were in a warm place, the sunlight was strong, and hence they could all have escaped, though they could have been captured that evening. The writer captured enough specimens to be sure of the species, although this insect can be readily separated from *xanthomelana* in life some-

[1] See also Bul. 82, Pt. II, Bur. Ent., U. S. Dept. Agr., pp. 29–32, 1909.

what better than in dried specimens. It is singular that this park should have been so badly infested by this species, while only one individual could be found in a long search on the grounds of the Department of Agriculture. The difference in distance is not more than 1½ miles.

THE SPINACH FLEA-BEETLE.

(*Disonycha xanthomelæna* Dalm.)

During the year 1912 beets as well as spinach grew very rapidly in the District of Columbia during rainy days, succeeded by warmer ones, but owing to press of other work the writer was unable to give them and their insect enemies as much personal attention as they deserved, and another reason was that the species involved, *Disonycha xanthomelæna* Dalm., has already been written up with considerable care.

Nevertheless there is always something new to learn, as there will be of all species, as long as we continue to observe them under different environments and atmospheric conditions. The table beets grew so rapidly that in spite of the larvæ and adults of the spinach flea-beetle, which "peppered them full of holes," they made considerable progress.

The spinach began to die rapidly about the beginning of the third week of June, and in four days nearly every plant appeared as if dying. In addition to the spinach flea-beetle, the spinach aphis (*Rhopalosiphum dianthi* or *Myzus persicæ* auct.) was also present, but, as affirmed by Dr. Erwin F. Smith, who, with the writer, examined the plants June 25, there was no evidence of disease or of malnutrition. If the plat of spinach had been a field, the plants would undoubtedly have perished, owing to the combined attack of the flea-beetles and the aphides, and this in spite of the fact that the aphides were being rapidly destroyed by ladybirds.

To determine the extent or degree of injury, comparison was made of a beet root taken from our experimental plat, which had been very little affected by this flea-beetle, with another lot which had been badly affected, with the result that it required nine of the affected roots to equal the weight of one that was practically unaffected. The small roots were picked out at random by the writer from the place most badly affected, which was at the sunny end of the plat.

It should be mentioned in this connection that plants growing where they were shaded by hedge plants were comparatively little affected by insects. This same observation has been made in connection with the imported cabbage caterpillar (*Pontia rapæ* L.), which is not disturbed by wasps when feeding in shady places.

Fig. 1.—Moths of the Spotted Beet Webworm (Hymenia perspectalis), Male above and Female below. Much Enlarged. (Original.)

Fig. 2.—Moth of the Hawaiian Beet Webworm (Hymenia fascialis). Much Enlarged. (After Marsh.)

Evidently this and other species of flea-beetles, or at least many of them, are in the habit of feeding to some extent in sunshine as well as in shade.

In regard to remedies for the spinach flea-beetle, while conducting some experiments in July, 1912, F. H. O'Neill, student assistant, spraying for cabbage butterflies and honey bees,[1] to see if sweetened and poisoned substances would kill any of them, observed that a mixture of arsenate of lead used at the rate of 6, 12, and 25 pounds, and similar amounts of molasses, to 100 gallons of water, did not destroy the butterflies or bees, but about 60 dead individuals of this flea-beetle were counted beneath the radishes July 16. The flea-beetles were not in particular evidence during these days; but they had "peppered" the beets with the usual small holes and must, therefore, have been abundant about the roots of the plants and come up to feed on the leaves, to their very swift undoing. It was not expected that the poison would kill either the butterflies or the honey bees which were present, and these were practically all unharmed.

THE HAWAIIAN BEET WEBWORM.

(*Hymenia fascialis* Cram.)

In a single instance the Hawaiian beet webworm (*Hymenia fascialis* Cram.) was reared from Swiss chard with the spotted webworm at Washington, D. C. Moths issued on October 7. The chard is a new food plant. The species is recorded by Marsh as attacking table and sugar beets, stock beets or mangel-wurzels, and several species of Amaranthus, Euxolus, purslane (*Portulaca oleracea*), cucumbers, and chenopodiaceous weeds. The moths of the two species are shown, for comparison, in Plate IV.

NATURAL ENEMIES.

On several occasions during October the last two stages of the nymph of the spined soldier-bug (*Podisus maculiventris* Say) were observed attacking the larvæ of the spotted beet webworm. This was the only predaceous insect observed, although there are probably several others.

The same is true of the parasitic enemies, a single one being noticed, a small braconid, *Hemiteles* sp. (Chttn. No. 2194°). This latter was reared October 7.

The very closely-related *Hymenia fascialis* has several parasites, and the probabilities are that if the present species were studied more carefully in other regions a number of other natural enemies would

[1] These experiments were made at the request of correspondents.

be discovered. Undoubtedly also wasps of the genus Polistes, besides *Limnerium hawaiiense* Cram., *Chelonus blackburni* Cram., and *Cremastus hymeniae* Vier., enemies of *H. fascialis* in Hawaii, will attack this species in its larval condition.

CONTROL.

It is obvious from the notes on the occurrence of this insect that injury was discovered too late for the application of insecticides. In practically every case the larvæ were in the last stage, the few younger larvæ merely indicating the exception to the rule. Such being the case it was not possible to test any remedies whatever. It is interesting to relate, however, in the case of Swiss chard, that many of the plants, being able to withstand a considerable degree of cold, recovered and put forth new leaves, practically a second crop of leaves developing, and that the moths hatched from all larvæ and did not deposit eggs, at least not in confinement. What they would do under natural conditions is not quite certain for this latitude.

In the case of the related Hawaiian beet webworm, Mr. H. O. Marsh has demonstrated that Paris green applied at the rate of 2 pounds in 100 gallons of water did not burn beet foliage, and the same would be true of chard and the ornamental plants which this species attacks. Whale-oil soap at the rate of 8 pounds to 100 gallons of water is added, and serves as an effective adhesive agent or "sticker," thus enabling a more even distribution of the poison over the leaf surfaces.

In addition to Paris green, Mr. Marsh demonstrated that nicotine sulphate, used at the rate of 1 fluid ounce to 4 ounces of whale-oil soap and 4 gallons of water, sprayed upon cabbage, resulted in the destruction of other small and larger larvæ. He expresses the belief also, reasoning from analogy, that this formula, although not actually tested on Hymenia larvæ, would probably prove entirely effective.

Arsenate of lead and arsenite of zinc should both be tested for this insect should it occur in numbers and an opportunity be afforded for an early application of these poisons as sprays. The most important item in the control of this insect is the detection of injury early in the season, before actual damage is accomplished. Among other remedies fall plowing should be practiced. It is unwise to grow susceptible plants in the same locality in which this insect has been abundant the previous season.

There is no proof as yet that as far north as the District of Columbia this species will in the near future renew attack or become as bad a pest as in 1912. The possibility exists, however, and a close lookout will be kept for its reappearance.

BIBLIOGRAPHY.

1. Hübner, Jacob.—Schmett. Eur., Pyr., fig. 101, 1796. (Not seen.)

2. Zeller, P. C.—Lep. Microptera in Caffrorum<K. Vet. Akad. Handl., Stockholm, 1854, pp. 55–57, 1852.

   Characterization of genus Zinckenia and description of *primordialis* n. sp.

3. Guenée, M. A.—Hist. Nat. insectes, Deltoides et Pyralites, Paris, p. 226, 1854.

   Described as *Spoladea perspectalis* from South America and North America. Occurrence on *Lilium canadense.* Larva briefly described.

4. Guenée, M. A.—Idem.

   Described from Pernambuco, Brazil, as *Spoladea animalis* n. sp. Description as *Spoladea exportalis* n. sp., from New Holland (Australia).

5. Walker, Francis.—Cat. Brit. Lep. Het., vol. 19, p. 932, 1859.

   Description as *Desmia rhinanthalis* n. sp., from Sarawak, Borneo.

6. Walker, Francis.—Cat. Brit. Lep. Het., vol. 19, p. 944, 1859.

   Description as *Hymenia phrasiusalis* n. sp., from Rio de Janeiro, Brazil.

7. Hampson, Sir G. F.—Proc. Zool. Soc. Lond., p. 623, fig. 21 (*fascialis*), 1898.

   Description of genus; synonymy and references to species.

8. Davis, John June.—In 27th Rept. State Ent. Ill., pp. 103–106, figs. 16–21, 1912.

   General account, with notes on habits and remedies.

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L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON INSECTS AFFECTING VEGETABLE AND TRUCK CROPS.

THE STRIPED BEET CATERPILLAR.

BY

H. O. MARSH,
Entomological Assistant.

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CONTENTS.

ILLUSTRATIONS.

PLATE.

TEXT FIGURES.

U. S. D. A., B. E. Bul. 127, Part II. T. C. & S. P. I. I., May 19, 1913.

PAPERS ON INSECTS AFFECTING VEGETABLE AND TRUCK CROPS.

THE STRIPED BEET CATERPILLAR.

(*Mamestra trifolii* Rott.)

By H. O. Marsh,
Entomological Assistant.

INTRODUCTION.

Among the caterpillars or "worms" which infest sugar beets in the Arkansas Valley in Colorado and Kansas is the so-called garden Mamestra or clover cutworm (*Mamestra trifolii* Rott.). This insect is ordinarily one of the minor beet pests, although during some years it develops in sufficient numbers to cause noticeable damage. The writer had this insect under observation in the Arkansas Valley during portions of four years (1909–1912), and this article is based on notes made during those years.

In the Arkansas Valley the larvæ were found on two plants only—sugar beet and lamb's-quarters (*Chenopodium album*). Sugar beet appeared to be the favorite.

EXTENT OF INJURY.

Except in the year 1911 the larvæ were rare and caused practically no damage throughout the years the species was under observation. During 1911 hundreds of beet fields were examined in the territory between Pueblo, Colo., and Garden City, Kans., and almost without exception the larvæ were found on beets in all of these fields. The larvæ were most abundant and generally distributed during the middle and latter half of June. During this month about 75 acres of small beets in various portions of the valley were observed to be stripped of foliage. About 5 acres were destroyed. As a rule the defoliated beets promptly recovered and put out new leaves, but occasionally the larvæ destroyed the crowns of the plants, and when this damage occurred the plants died.

During July, August, and early September the larvæ were moderately common on beets, but the infested areas were scattered and practically no damage resulted. Late in the fall they developed in considerable numbers on beets in some fields. At this season, however, the infested beets were mature, and no noticeable damage resulted. The majority of these larvæ reached maturity during October, and many pupæ were observed during the latter part of the month and in early November. The winter of 1911–12 was exceptionally severe, and the extreme cold apparently killed the pupae. No live individuals were found during the following spring, and the larvæ were very rare throughout the summer of 1912.

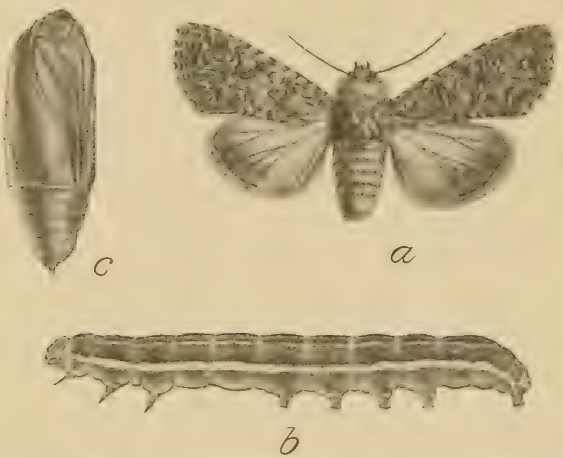


FIG. 4.—The striped beet caterpillar (*Mamestra trifolii*): *a*, Moth; *b*, caterpillar; *c*, pupa. Enlarged. (Original.)

GENERAL APPEARANCE AND HABITS.

The adult of the striped beet caterpillar is a stockily built moth belonging to the lepidopterous family Noctuidæ. (See fig. 4, *a*.) The forewings are dull grayish brown and have an expanse of about $1\frac{5}{16}$ inches. The hind wings are grayish, with brown markings. The moths are attracted to lights but are sluggish and, except for occasional individuals which may be found resting on boards, telegraph poles, and in similar locations, are seldom seen by the casual observer.

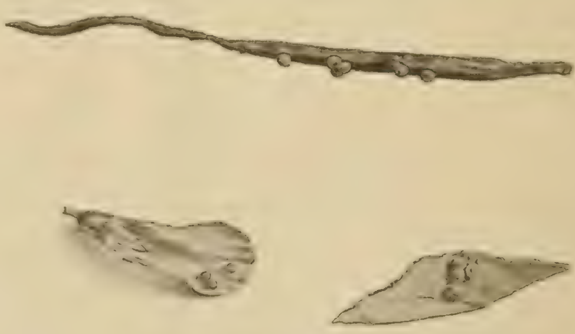


FIG. 5.—The striped beet caterpillar: Eggs. (Original.)

The eggs (fig. 5) are rather large, pearly white or pale yellow, ribbed, and hemispherical. They are deposited singly on the underside of the leaves.

The mature larvæ (fig. 4, *b*) are about 1¼ inches in length and are dull green, with a more or less distinct pinkish stripe along each side. The larvæ are voracious feeders. When infesting sugar beets they prefer the older leaves, and the infested foliage may be entirely consumed, with the exception of the petioles. The full-grown larvæ burrow into the soil to the depth of about an inch and form pupation cells in the earth by wriggling about.

The pupæ (fig. 4, *c*) are "chunky," reddish brown, and about nine-sixteenths of an inch in length.

LIFE HISTORY.

There are three generations of this insect in the Arkansas Valley each year. The first moths are to be found during the latter half of May. These deposit eggs, from which a generation develops during the first part of July. Eggs deposited by the July generation produce moths during the latter part of August and in early September. The larvæ of the third generation mature late in the fall, and the pupæ which develop live through the winter in cells in the soil. Adults develop from these pupæ during the latter half of May of the following year.

REARING RECORDS.

During 1911 and 1912 the following rearing records were obtained in the laboratory at Rocky Ford, Colo.

On June 1, 1911, a few eggs were collected in the field from sugar beets. They were deposited singly on the underside of the leaves. The record is as follows:

June 1	Eggs collected.
June 5	Eggs hatched.
June 19	Larvæ reached maturity.
June 21	First pupæ formed.
July 2	First adults issued.

From the foregoing records the stages are as follows:

	Days.
Egg stage	4
Larval stage	16
Pupal stage	11
Total	31

On June 7, 1911, two apparently mature larvæ were collected in the field from sugar beets. They burrowed into the soil and formed their pupation cells June 9 and pupated June 11. The adults issued June 29. In this case the pupal period was 18 days.

September 17, 1911, a female moth captured at Rocky Ford was placed in a cage containing sugar-beet foliage, alfalfa blossoms, and dilute honey. She fed eagerly on the honey sirup, and on September 19, 123 eggs were deposited. The record is as follows:

September 19	First eggs deposited.
September 24	Eggs hatched.
November 4	First larvæ reached maturity.
November 10	First pupæ formed.
May 16, 1912	First adults issued.

From the foregoing records the stages are as follows:

	Days.
Egg stage	5
Larval stage	47
Pupal stage	187
Total	239

The moths which issued May 16 were placed in a cage and fed with dilute honey. The first eggs were deposited May 20. The record is as follows:

First generation.

May 16	Moths issued.
May 20	First eggs deposited.
May 25	Eggs hatched.
June 12	First larvæ reached maturity.
June 16	First pupæ formed.
July 5	First adults issued.

From the foregoing records the stages are as follows:

	Days.
Egg stage	5
Larval stage	22
Pupal stage	19
Total	46

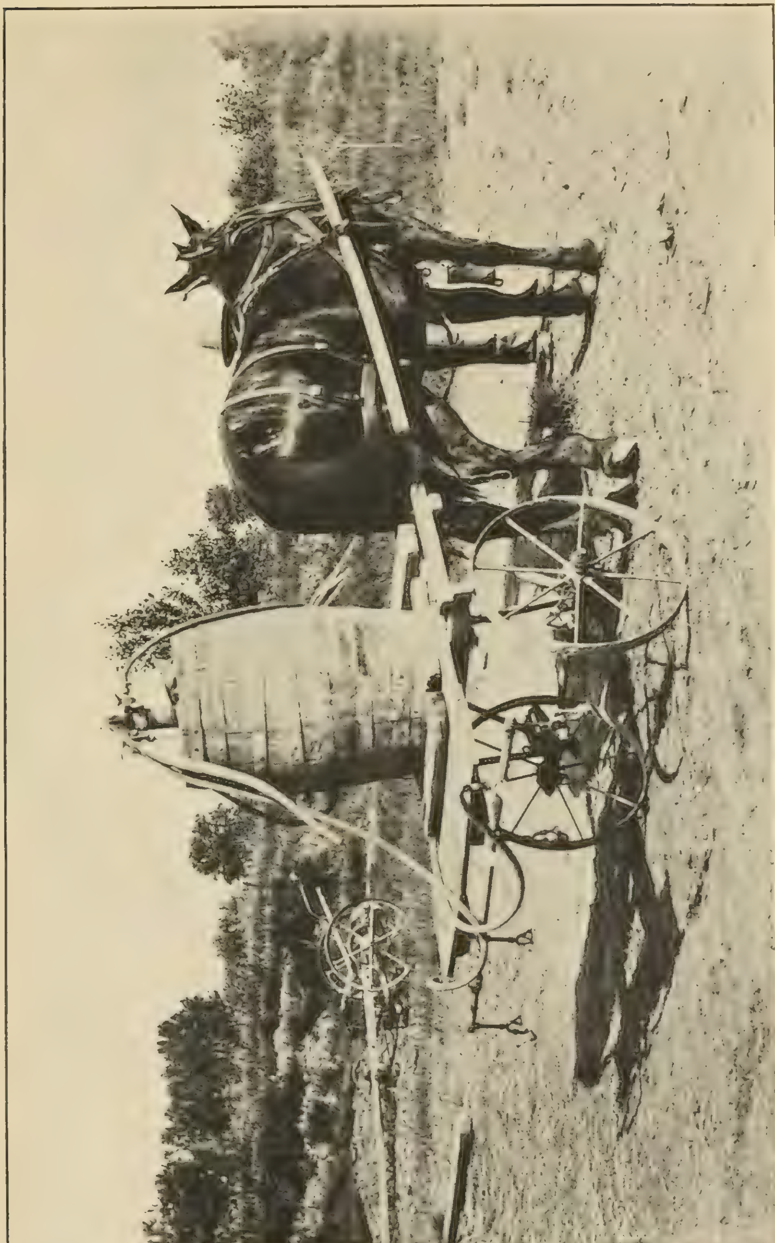
The moths which issued July 5 were placed in a separate cage and the first eggs were deposited July 11. The record follows:

Second generation.

July 5	Moths issued.
July 11	First eggs deposited.
July 17	Eggs hatched.
August 2	Larvæ reached maturity.
August 5	First pupæ formed.
August 20	First adults issued.

From the foregoing records the stages are as follows:

	Days.
Egg stage	6
Larval stage	19
Pupal stage	15
Total	40



FIELD SPRAYER SUITABLE FOR SPRAYING SUGAR BEETS. (ORIGINAL.)

Only nine moths of the second generation developed in the cages and, unfortunately, all were females. They deposited hundreds of eggs which were infertile, failing to hatch. Judging from the records which were obtained the previous fall it may be concluded that there are three full generations each year.

EGG-LAYING RECORD.

On September 17, 1911, a female moth was captured and placed in a cage. Eggs were deposited as follows:

	Eggs deposited.
September 19	123
September 20	114
September 21	82
September 22	78
September 23	82
September 24	25
Total	504

The moth died September 25.

NATURAL ENEMIES AND OTHER CHECKS.

As previously noted, the pupæ are formed in earthen cells, near the surface of the soil, in the beet fields. When the beets are cultivated or plowed out at harvest time, many of the cells are broken open and the pupæ crushed or exposed to the weather. This is an efficient check.

During the winter of 1911–12 the minimum temperatures at Rocky Ford ranged from —15° to —26° F. This exceptionally cold weather apparently killed many pupæ.

In addition to these factors in control, there are several species of parasitic and predaceous insects which serve to check the increase of the Mamestra larvæ. The following records were obtained at Rocky Ford:

Microdus inedius Cress., a braconid, was reared July 9, 1912. It is a medium-sized red and black insect with dusky wings.

Meteorus sp. (Chttn. No. 597), a smaller braconid, honey yellow in color, was reared July 11.

A still smaller species, a braconid (Chttn. No. 598), was reared August 1, but not positively identified. The body is black, the antennæ and legs are yellow, and the abdomen is marked with yellow. The larvæ of this parasite feed externally, in a cluster, on the dorsal surface of the Mamestra larvæ.

Phorocera claripennis Macq., a tachinid, was reared August 4. This fly is a common cutworm parasite.

Perilloides bioculata Fab., a pentatomid, was frequently found stabbing the partly grown Mamestra larvæ.

Phidippus coloradensis Thorell, a spider, was found rarely, feeding on the smaller larvæ.

RECOMMENDATIONS FOR CONTROL.

During 1911 the writer conducted several spraying experiments against the larvæ with Paris green, arsenate of lead, and arsenite of zinc. It was found that the larvæ of all sizes were readily killed with arsenicals. In fact this is one of the most easily controlled pests which occur on sugar beets in the Arkansas Valley.

Paris green proved more quickly effective than other poisons tested, and the following formula is recommended:

Paris green	pounds	3
Whale-oil soap	do	6
Water	gallons	100

This mixture should be applied to sugar beets with a field sprayer (Plate V) at the rate of from 75 to 100 gallons to the acre. It is necessary to wet only the surface of the leaves with spray.

CONCLUSION.

In the Arkansas Valley the striped beet caterpillar is a minor enemy of sugar beets. Ordinarily it is held in check by cultural methods and natural enemies. Occasionally, however, it develops in injurious numbers, and when this occurs the larvæ can be easily controlled by spraying with Paris green.

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INDEX.

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