UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 427

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

Washington, D. C. PROFESSIONAL PAPER February 6, 1917

THE POTATO TUBER MOTH.

By J. E. GRAF,[1] *Entomological Assistant, Truck Crop and Stored Product Insect Investigations.*

CONTENTS.

The account of the potato tuber moth (*Phthorimaea operculella* Zell.) given in the following pages is the result of an investigation of this insect carried on in southern California from 1912 to 1916.[2]

During the latter part of 1911 the late H. M. Russell conducted a few life-history experiments at Compton, Cal., but the work was not taken up as a special project until the following year. The laboratory work was conducted almost entirely at Whittier and Pasadena, Cal. The material for rearing and collection of parasites, however, was collected from the following counties: Los Angeles, Orange, Riverside, San Bernardino, and Ventura.

HISTORICAL.

The tuber moth was first mentioned in literature by Capt. H. Berthon (1)[3] who described it, under the name of the "potato grub," as being very damaging to potatoes in Tasmania in 1854, and con-

[1] Resigned Jan. 16, 1916.

[2] The writer wishes to express his indebtedness to Dr. F. H. Chittenden for suggestions throughout the work, and for the use of notes from his files; practically all the data on the occurrence of the tuber moth within the United States outside of California being taken directly from his notes.

Acknowledgment is due Mr. S. S. Rogers, Assistant Plant Pathologist of the University of California Experiment Station, for allowing the writer to collect data relative to the tuber moth in the experiment field at Van Nuys; to Mr. B. L. Boyden of the Bureau of Entomology, who conducted all the rearing experiments from December, 1913, to April, 1914, and to Mr. F. R. Cole for illustrations of the moth in its different stages and parasites, and for assistance in rearing.

[3] Figures in parentheses refer to similar numbers in the "Bibliography," p. 52.

NOTE.—This bulletin is of interest to entomologists and to potato growers especially in the warmer sections of the country.

55889°—Bull. 427—17——1

cluded that it was probably the same insect which had in previous years caused so much trouble in New Zealand.

The tuber moth has been known in California (San Francisco) since 1856,[1] and in southern California at least since 1874.

Mr. William Wood, commissioner of Los Angeles County, reports that in 1874 when planting potatoes in the vicinity of Whittier, Cal., the seed potatoes were badly attacked by the larva of this insect, and in most of the eyes the sprouts had been killed. He states that the Chinese who planted a majority of the fields were in no way worried by the presence of the insect, so he did not consider it a new arrival. The description of the injury given, and the fact that Mr. Wood is quite familiar with this insect, would indicate that the tuber moth was well distributed in southern California before 1874.

The first recognized technical description of the species was made by Zeller (5) in 1873 from specimens collected in Texas. In 1874 the insect was redescribed from specimens collected in Algeria.

An article published by David Gunn (66) mentions the tuber moth as occurring in Canada in 1878. Staudinger and Rebel (39), in their catalogue of Lepidoptera published in 1901, also list this locality. As yet, however, these statements remain unverified, and the tuber moth is not at present known to exist in Canada.

In California the potato tuber moth has been reported as established and working on potatoes in the following counties:

Alameda, Contra Costa, El Dorado, Kern, Los Angeles, Modoc, Monterey, Napa, Orange, Riverside, Sacramento, San Benito, San Bernardino, Santa Clara, Santa Cruz, San Diego, San Joaquin, San Luis Obispo, Shasta, Sonoma,[2] Stanislaus, Ventura, and Yolo.

DISTRIBUTION.

In literature the tuber moth has been given the following distribution, the date appended being either that of the publication, or the time its occurrence was reported.

New Zealand, "Some years before 1854." (1)[3]
Tasmania, 1854 (Capt. H. Berthon). (1)
California (San Francisco), 1856.
Texas, 1872. (4)
Algeria, 1874. (5)
California, 1874.
Australia, 1878 ("Some years back"). (7)
California, 1881. (13)
    (Los Gatos, Santa Clara County, 1888). (21)
    (Alameda County, 1891). (24)
    (Bakersfield, Kern County, 1891). (23)
Florida, 1897. (35)
North Carolina, 1897. (33)
Virginia, 1897. (36)
South Carolina, 1897. (36)
South Africa, 1898. (37)
Hawaii, 1905. (50)
India, 1906. (59)
Southern Europe. (59)
Italy, 1906. (Some years before.) (73)
Cuba, 1907. (54)
France. (88)
Spain. (88)
Canary Islands. (88)
Azores. (88)

[1] California Orchard and Farm, September 15, 1893.
[2] Localities furnished by Mr. E. O. Essig, of the University of California.
[3] Numbers in parentheses refer to similar numbers in the "Bibliography," p. 52.

POSSIBLE ORIGIN.

A study of the literature shows that the tuber moth was known to be present almost simultaneously in Australasia, the United States, and Algeria. It is indeed strange that, considering this fact and, in addition, the fact that this country is the home of a wild potato and tobacco, of all the entomologists who have studied the tuber moth, only one, Gerald McCarthy (31), who found the tuber moth mining tobacco in North Carolina in 1897, should claim that this country is its native home. McCarthy also found the moth in *Solanum carolinense*, a native weed common in the southeastern part of the United States. Speaking of the tuber moth, he says, "This insect probably inhabited its present range prior to the coming of the white man."

Dr. Picard (83, 84), a prominent authority on this insect, says that a Mediterranean origin for this species must be excluded. Considering the fact that he has not found a specific natural enemy, in the shape of a parasite, on the insect, his opinion must be given considerable weight. He mentions either Australia or the United States as a possible origin for the tuber moth.

Analyzing the facts as presented by these two countries, it is seen that it was reported from both places at practically the same time. Edw. Meyrick, one of the earlier authorities on the Microlepidoptera, states that it is not an Australian form. In addition, there is no mention of any natural enemies of the species, which is quite significant, considering that many competent entomologists have worked on it in Australia.

On the other hand, in the United States there are several parasites on the tuber moth, and, as previously stated, this country is the home of a wild potato and tobacco, its two favorite food plants. When it is considered that it was not until the sixteenth century that the potato was introduced into Europe, and that it was not until many years later that the use of the potato became at all general, it seems only reasonable to suppose that the rapid dissemination of the tuber moth came about by following the potato "around the world."

Furthermore, the tuber moth is an insect which could be introduced easily from one locality to another, as once it infests potatoes it is assured of food enough to carry it through several generations; and as the insect can stand lower temperatures than the tubers, it would never be in danger of being killed by freezing.

The entire economic history of the tuber moth is another indication that it originated in America. Losses reported to potato crops in Algeria, India, Tasmania, South Africa, Australia, and New Zealand are far heavier than any ever reported from California or Texas. Climatic conditions being equal, it is generally true that a pest is more injurious in an adopted home, for a time at least, than in its natural one, since the change always favors its being freed from some of its natural enemies and checks. This is especially true of the tuber moth, since most of its parasitic enemies aid in reducing it only when it appears as a leaf miner, and if it were introduced into a new locality in the tubers, these would be left behind.

When all these facts are considered, there is some argument in favor of considering America as its native home.[1]

NATURE OF INJURY.

Injury by the tuber moth is accomplished through two widely differentiated methods of attack: (1) To the growing plant, and (2) to the tuber (fig. 1). The injury to the plant is incident to the mines in the leaf and petiole and to the tunnels in the stem. As a rule the egg is deposited on the leaf, and the larva as soon as hatched starts to mine in the leaf. As the larva grows the leaf becomes too thin for mining, and if there is not another leaf near by to tie up, the larva either rolls the leaf or enters the petiole. If the larva confines its work to the leaves it injures one-third to one-half a leaf during its larval life, but where necessity drives it to mining the petiole it kills the entire leaf. Once started in the petiole the larva rapidly works its way to the main stem, which it begins to tunnel. (Fig. 2.)

The larva generally works downward in the stem, although in a very few cases where the stem is thick and succulent it may turn and work upward. Wherever a larva works within the stem for several days before becoming mature the terminal section of the stem usually dies. It is easy to see that wherever this occurs generally over a field while the potato plants are young considerable injury might result through the reduction of leaf surface and a weakening of the plants.

A factor which would make this possible would be the stacking of a large amount of infested potatoes from the first crop near fields where the second crop of potatoes was just beginning to come up. Only one instance of this type of injury has been noted, although in 1912 conditions were as bad as they would ever be allowed to become.

In one small field (about 7 acres) at least half of the plants were materially injured and the yield was probably reduced one-fourth to one-third. The moths were very abundant in this field at the time the potato plants were coming up, and several could be found on each plant. The reason that more injury was not caused was probably due to the fact that vigorous young potato plants are quick to grow away from any injury.

---

[1] Notwithstanding the opinions above expressed there are, perhaps, equally good reasons for supposing that this species is of exotic origin, and since it was first reported in New Zealand it would be natural to look to that vicinity for its natural habitat. It has been somewhat generally credited with being native to North Africa, and with reason, since the flora of that continent is particularly rich in solanaceous plants. In fact, the tropical regions of Africa and South and Central America include among their native plants nearly nine hundred species of Solanaceae.—F. H. Chittenden.

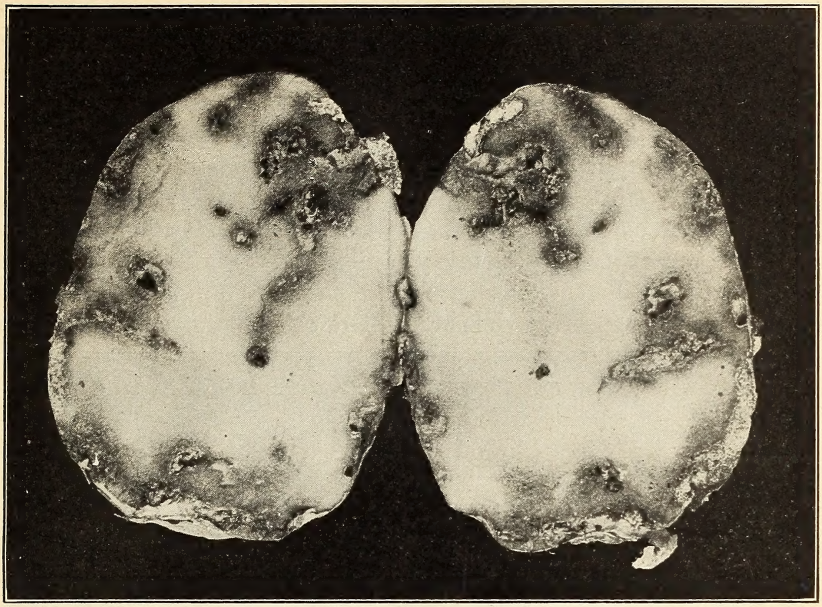


Fig. 1.—Potato section showing injury by larvæ of tuber moth (*Phthorimaea operculella*). (Original.)

Fig. 2.—Injury by tuber moth to potato plants, showing mines in leaves, petioles, and stem. (Original.)

In large fields near the one mentioned above larvæ could be found in most of the plants, but apparently the vigor of the plants was not noticeably affected and the amount of damage done, if any, was certainly small. Taking all things into consideration, the damage done by the tuber moth to the growing plant in southern California is slight in comparison to that caused to tubers.

The tuber-feeding larva injures the potatoes themselves by tunneling through them, so filling these tunnels with excrement and fungus that the potatoes, even if not severely injured, are very unsightly and of small market value. The character of the injury (figs. 3-5) does not seem to be influenced by the condition of the tuber or climatic condi-

FIG. 3.—Potato sliced to show advanced injury by potato tuber-moth larvæ. (Original.)

tion, some larvæ digging subepidermal channels while others tunnel directly through the substance of the tuber. The loss consists not only of the actual substance of the tuber which is channeled and ruined, but is also due to the fact that badly injured tubers are unsightly and undesirable for food.

ECONOMIC IMPORTANCE.

Since the first report of the tuber moth, large losses have been reported from various sections of the world. Analysis of these reports shows beyond a doubt that in mild, dry climates the tuber moth works very serious injury to stored potatoes. In similar climates,

FIG. 4.—Potato in more advanced state of infestation by tuber moth. Larvæ of second generation reared from this tuber pupating. (Original.)

FIG. 5.—Potato showing rot (at left) following attack by potato tuber moth. (Original.)

but where potatoes are not habitually stored, the tuber moth is more in the nature of an annoying pest, causing minor losses practically every year, but becoming of primary importance only where conditions favor its increase. Careless planting, late and slow harvesting, and poor markets with the consequent holding back of the crop, would bring about such conditions.

The tuber moth is reported to have done much injury to potatoes in Tasmania in 1855, and it was then stated that it "has of late years been making ravages amongst tubers in New Zealand" (1).

In 1875 it was reported to have been injurious for the preceding years in Algeria. Specific instances give the losses at El-Bear as three-fourths of the entire crop (6). Meyrick (9) mentions large losses caused by it in Australia in 1878–79, and gives an authenticated case where four-fifths of the crop in one field was destroyed. The tuber moth was reported as destructive to potatoes in California in 1881 and 1882 (13), and in 1901 (37).

In 1897 the tuber moth was noted mining in tobacco in North Carolina (31) and in 1899 was mentioned as being destructive to tobacco and eggplant in Florida (33). In 1898 it was reported from South Africa as being common in potatoes, but, due to the fact that the potatoes were marketed very quickly, seldom causing much damage. Literature further records damage by the tuber moth in India in 1906 (62).

In Australia, India, Tasmania and New Zealand the damaging outbreaks have been of periodic occurrence from the time the tuber moth has been reported. Usually some explanation is given for this condition, and it is noticeable that the outbreaks generally occur during dry years. Authorities seem to agree that the tuber moth is a dangerous pest only to stored potatoes.

This probably explains why the tuber moth attracts so little attention in the United States, where it has long been present. In the warm, dry sections potatoes are never habitually stored, and as these districts supply early potatoes for the neighboring States, under normal conditions the entire crop is harvested as early as possible.

Records of the Los Angeles County Horticultural Commission show that the importation of potatoes is twice as great in the fall as is the exportation in the early summer. This alone shows that normally potatoes once harvested are not held sufficiently long to permit infestation by the moth, or once infested they are used up before their food value is materially impaired thereby. The tuber moth can become of importance only during times of poor market conditions, when the potatoes are held for a rise in price.

CLASSIFICATION AND SYNONYMY.

The tuber moth belongs to that very large and cosmopolitan family of Microlepidoptera, the Gelechiidae. The genus Phthorimaea was founded by Meyrick in 1902 (43), the tuber moth being made the type.

There seems to be not a little difference in the synonymy given this insect by various authors, so the following list has been selected from the literature cited in the bibliography:

Phthorimaea operculella (Zell.) Meyr., 1902	(43)
Gelechia terrella Walk., 1864 [1]	(2)
Gelechia operculella Zell., 1873	(5)
Bryotropha solanella Bdv., 1874	(6)
Lita solanella Meyr., 1879	(9), (11)
Gelechia tabacella Rag., 1879	(10)
Lita tabacella Rag., 1885	(15)
Gelechia solanella Meyr., 1886	(16)

The foregoing synonymy does not take into consideration the *Gelechia similiella* (3) and the *G. solaniella* (4) of V. T. Chambers, which were described in 1872 and 1873, respectively. *G. similiella* was described first and the name subsequently changed to *solaniella* when the larva of this form was found mining in *Solanum carolinense.* Later, in 1878 (8), Chambers adds to his description of *G. solaniella.* Specimens were collected in Kentucky and Texas. It appears from the life notes he adds that the insect in question might be *Phthorimaea operculella*, but there seem to be no types in existence to substantiate this.

DESCRIPTION.

THE EGG.

The egg when freshly laid is opaque, pearly white in color, and with a faint iridescence. As the egg becomes older it becomes yellowish and the iridescence becomes more pronounced, so that at the time of hatching it is nearly lemon-yellow with the iridescence strongly marked. As hatching time approaches the thin shell sometimes becomes more or less distorted, and the outlines of the embryo within can be distinguished. Due to the habit of the moth of ovipositing on rough surfaces, the eggs are often distorted and the shape varies greatly. Two masses of eggs on the surface of a potato are shown in figure 6.

The egg is ellipto-cylindrical in shape, the bluntly rounded ends closely resembling each other. An average of several measurements gave a length of 0.48 mm. and a width of 0.36 mm.

---

[1] Oldest name, but a homonym.

THE FULL-GROWN LARVA.

The full-grown larvæ (fig. 7, left and right) are slightly fusiform in shape, and plainly constricted at the segments.

The head is dark brown, with the exception of the frons, which is lighter in color. The cervical plate is black, with a pale narrow median line, and the thoracic legs are black. The venter and sides of the abdominal segments are a waxy white and the dorsum is generally a light pink, though in some larvæ there is enough green present to give the dorsum a very light greenish tinge. The spiracles are small, dark, and inconspicuous. There are about 10 to 14 small light hairs on each segment, at the base of each of which there is a small black spot. There are five pairs of prolegs, and near the base of each, on the outside, is a small black projection armed with three stout, short, black hairs. The anal plate varies from a yellow to dusky yellow in color. The full-grown larva is from 9.5 to 11.5 mm. in length, and when fully extended is even slightly longer. At the widest point the average is about 1.5 mm. in width.

FIG. 6.—Egg masses of the tuber moth on the surface of a potato. Enlarged. (Original.)

As pupation approaches the entire larva becomes greenish in color, and much shorter.

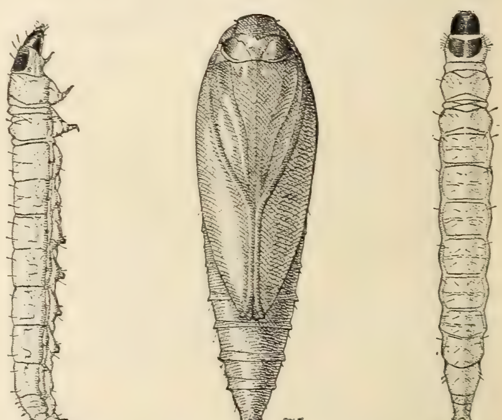


FIG. 7.—The potato tuber moth: Ventral view of larva at left; dorsal view at right; pupa in middle. Larva much enlarged; pupa still more enlarged. (Original.)

THE PUPA.

When first formed the pupa (fig. 7, center; fig. 8) is white, with green markings, but soon changes to deep uniform brown. In general form it is spindle-shaped, being broadly rounded at the head, widest at the thorax, and tapering evenly to the last abdominal segment. The cases for antennæ and legs fold closely on the venter and are rather inconspicuous. The wing cases are also closely folded and generally reach the distal end of the fourth abdominal segment. The tips of the wing cases and the eyes are darker in color. All the segments of the abdomen are armed with a few weak hairs, and the anal segment, aside from its short, stout dorsal hook, bears many light hooked spines arranged in a circle.

THE COCOON.

The cocoon (fig. 9) is white, rather loosely woven, and very thin. The exposed portion is more tightly woven and much thicker, and is

FIG. 8.—Mass of potato tuber-moth pupæ. (Original.)

covered with excrement or débris to such an extent that the white silk of the cocoon is seldom visible. The cocoon is therefore more nearly tectiform than complete and is generally torn in two when the upper part is lifted. As the larva generally seeks some depression in which to pupate, this heavier part is seldom more than half of the entire cocoon and more often less.

The covering of the cocoon is generally composed of particles of the material surrounding it.

THE MOTH.

The moth (figs. 10, 11, 12) is small, having a wing expanse of a little more than a half inch (12 to 16 millimeters). The general color is gray. The forewings bear on the outer half a fringe of light gray as wide at the base as the width of the wing. The surface is more or less spotted and mottled with black and ocher. The hind-wings are much shorter and narrower and have a still stronger fringe of buff.

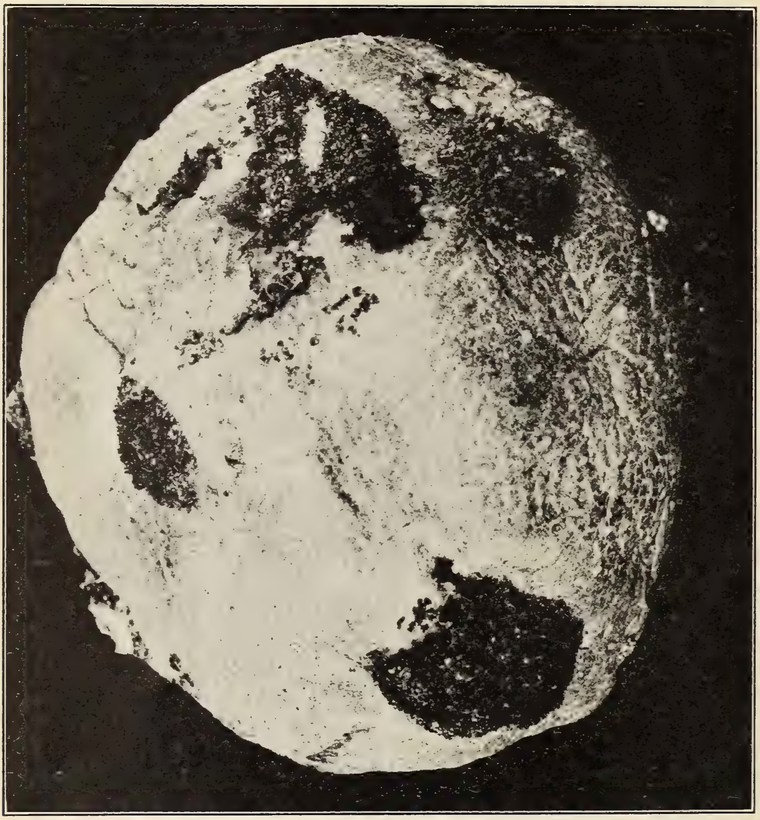


FIG. 9.—Cocoons of tuber moth on exterior of potato, showing method of grouping many cocoons closely under black excrementitious webbing. (Original.)

The antennæ are long and slender and the palpi are comparatively long and conspicuous. The abdomen is also slender.

The following description is a translation of Zeller (5):

> The male bears on the upper side of the anal segment a large oval disk, from each side of which protrudes a readily perceptible tuft of crumpled hair. The somewhat lighter female—if it is the female—has somewhat wider fore-wings, and the dot on the cross-vein and the one before it darker in color, the one toward the inner margin distinctly lighter.

Of the size of the smallest [species] *terella* or of the largest [species] *senectella*. Head whitish, mixed with a little ocherous, brighter on the dorsum. Ocelli I can not perceive. Antennæ gray, lighter on the undersides, with well-defined joints. Palpi whitish, second joint flattened, with noticeably channeled bristles, and having a gray efflorescence on the outer sides near the end. Third joint more than half as long as the second, awl-shaped, finely pointed, with a brown spot between the base and middle. The four front legs light gray, the outsides dusted with brown, tarsi brown, the joints

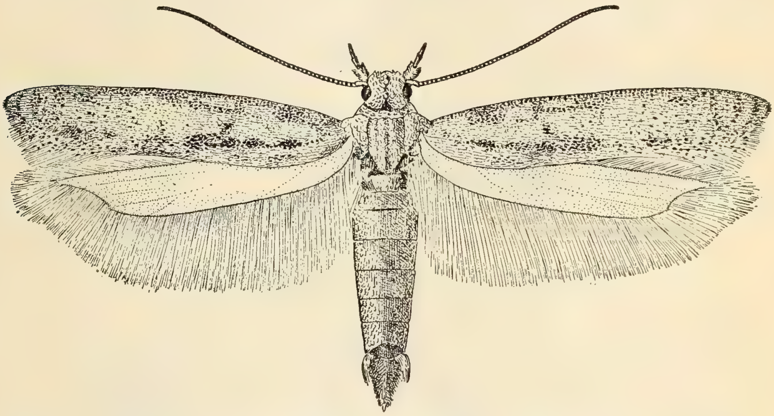


FIG. 10.—The potato tuber moth (*Phthorimaea operculella*). Greatly enlarged. (Original.)

with whitish ends. The hind legs pale yellow, the tibiæ with small light-colored hairs, and the tarsi brownish at the joints. Abdomen yellowish dust-gray, grayish-white beneath, the last joint, in the male, as long as one-third of the abdomen, bright ocher yellow. Two elliptical, somewhat hollowed disks lying with their hollows upon one another. The lower projects somewhat from beneath the upper and is clothed on the upper side with a rich covering of somewhat loose-lying hairs, appressed above and projecting over the margin. On both sides of the base of the upper disk stands an outwardly crumpled brush of hair reaching nearly or quite to the end. In the female the anal joint is of the usual length, and is of the form of a truncated cone, the ovipositor slightly projecting.

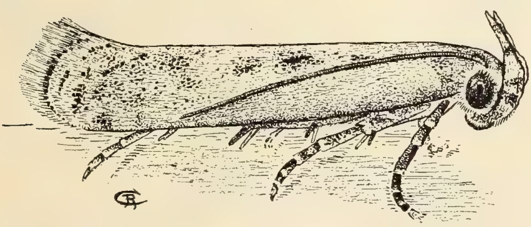


FIG. 11.—The potato tuber moth: Natural position at rest. Much enlarged. (Original.)

Fore-wings $2\frac{1}{4}$ to $2\frac{1}{2}$ ‴ in length, smaller in the male than in the female, light gray, dusted yellowish gray, particularly toward the base, in the middle pure ocherous. Along the middle fold lies a longitudinal blackish streak, inclosed at both ends with whitish dashes. Above this lie two small blackish dots, the lower nearer the base than the upper. On the cross-vein is a larger dot, nearly ringed about with light gray. At the rear margin is an indistinct row of blackish, somewhat larger dots. Fringes light gray, inwardly dusted with darker, and especially near the tip.

Hind wings hardly as broad as the fore-wings and with underturned hind fringe, bright gray. Fringe longer than the width of the wing, with a yellowish sheen toward the base. The entire underside uniform gray.

In a doubtful female the whole dorsum is of the same color as the head, the abdomen as before stated. The broader fore-wings are lighter at the front margin, plentifully sprinkled with uniform gray without the usual ocherous color in the middle, and the general ocherous tone of the whole. At the fold lies a black dot with a whitish border. Obliquely behind and over this dot there is no double spot, but a separate stronger deep-black ringlike dot, bright and strikingly inclosed. The cross-vein dot is smaller, but also black and similarly ringed with light color. Since the hind fringes are almost entirely broken off, I can not say further about the markings. The hind wings are sensibly broader than the fore-wings, and less finely pointed.

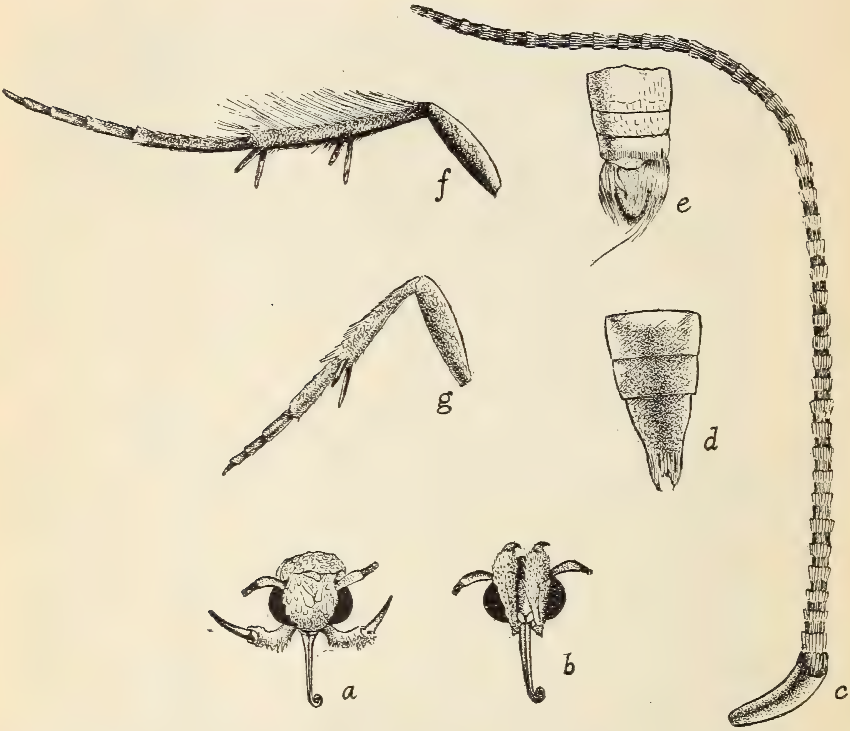


FIG. 12.—Potato tuber moth details: *a*, *b*, Views of the face; *c*, antenna; *d*, tip of abdomen of female; *e*, tip of male abdomen; *f*, hind leg; *g*, foreleg. All much enlarged. (Original.)

FOOD PLANTS.

Prof. F. Picard (83) gives the following food plants for the tuber moth:

Potato (*Solanum tuberosum*), *S. commersoni*.
Darwin potato (*Solanum maglia*), Bittersweet (*S. dulcamara*), *S. miniatum*.
Eggplant (*S. melongena*).
Tomato (*S. lycopersicum*).
Red pepper (*Capsicum annuum*).
Tobacco (*Nicotiana tabacum*), *N. sylvestris*.
Henbane (*Hyoscyamus albus*), Matrimony vine (*Lycium europaeum*), *Fabiana imbricata*.

To this list may be added nightshade (*Solanum nigrum*), which has been noted as an occasional food plant for tuber-moth larvæ in Southern California.

In the files of the Bureau of Entomology there are also records of this species boring into the stems of poka or Cape gooseberry (*Physalis peruviana*), made by Mr. Jacob Kotinsky in Hawaii. The species has also been found mining the leaves of *Physalis mollis* and *Solanum elaeagnifolium*, at Brownsville, Tex., by Messrs. McMillan and Marsh, of this bureau.

The tuber moth is unable to increase rapidly on plants which confine its activities to mining the leaves, owing to the abundance of its parasitic and predacious enemies. In California, therefore, only the potato, tomato (figs. 13, 14), and eggplant (fig. 15) may be considered as affording suitable protection to the larvæ, and of these, the potato only is of primary importance. While adults have been reared from tomato and eggplant fruit, no important infestations have been noted under field conditions, even where moths were abundant and close at hand.

LIFE HISTORY AND HABITS.

THE EGG.

The egg, under outdoor conditions, is deposited early in the spring on the underside of the foliage of young potato plants. Sometimes the eggs are placed on the stems or petioles of the leaves, but more often the body of the leaf is selected. In such cases the eggs are placed singly, though two or more may be quite close together. Three is the largest number that has been noted on a single leaf in the field.

In bins, or in stacks of potatoes, oviposition takes place throughout the winter, but is most general during the warmer months. The eggs are usually deposited in the eye or a rough scar on the potato, and when placed in this way are generally grouped, as many as 30 having been found in one eye. In sprouting potatoes the eggs are often placed in circles around the base of the sprout. In this way they are protected on all but one side.

Another favorite place for oviposition is at the point of scab injury, and the narrow deep cracks caused in this way are very often filled with the eggs of the tuber moth. Here also they are protected. Where the eggs occur in more or less of a mass, scales from the wings and body of the moth are thinly scattered over them. This probably is not due to an effort of the moth to hide the eggs, but is the result of her moving about during the deposition of the egg mass.

In potato bins eggs are often found on the sacks, in depressions on the sprouts, and on débris occurring on or between the potatoes. However, very small numbers of eggs are found deposited in such places, and they generally occur singly.

The eggs are usually deposited during the evening, night, or early morning, although in cool weather and in darkened bins oviposition takes place at all hours of the day. Daylight oviposition out of doors occurs only on cold and dark days. A single moth under laboratory conditions will deposit 150 to 250 eggs with the extremes of 38

FIG. 13.—The potato tuber moth as a leaf-miner on tomato. An uncommon form of injury. (Original.)

for the minimum and 290 for the maximum; oviposition is completed in from 6 to 17 days, and by far the greater number of eggs is usually deposited in about 4 days.

The largest number obtained in one day from a single female was 68, and this female on two consecutive days deposited 112 eggs.

FIG. 14.—Tender stems of tomato killed by potato tuber-moth larvæ. Uncommon form of injury. (Original.)

The length of the egg stage varies with the temperature. Eggs deposited in midwinter may require 34 days to hatch, while those deposited during July and August may hatch in 5 days. There are, naturally, all degrees between these extremes. There seems to be no true hibernation of the egg, those which develop slowly passing through about the same color changes and requiring about the same time in proportion as those which develop very quickly.

There is more or less regularity in hatching of the eggs deposited, even where the period of incubation is the longest. In the case of those which took 34 days, all which were deposited during one night hatched during 36 hours. Practically all the uninjured eggs hatch successfully. From a count kept of those deposited under laboratory conditions only 5 out of 730 eggs failed to hatch; of these 4 were sterile, and the other, after partial development, collapsed.

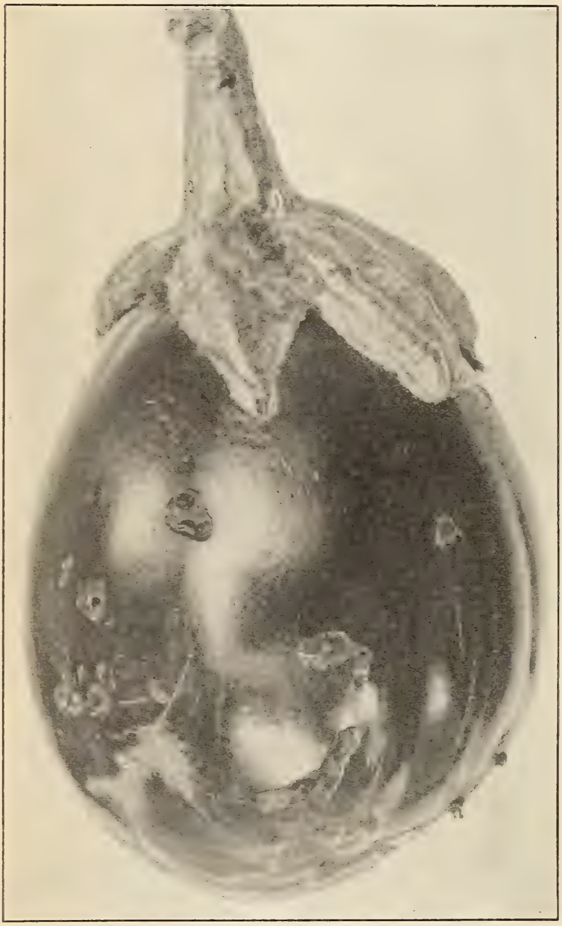


FIG. 15.—Potato tuber-moth injury to exterior of fruit of eggplant. (Original.)

The shells of the eggs, as indicated by the color changes before hatching, are very thin and collapse shortly after the larvæ leave them.

THE LARVA.

EMERGENCE AND FEEDING HABITS.

The larva emerges by eating a hole through the eggshell. The newly hatched larva is about 1 millimeter in length and is quite light in color with the exception of the head, which is dark brown; it is inconspicuous and very difficult to detect when on the surface of a potato.

The larvæ are quite active and begin feeding almost at once. They seldom move far from where they hatch before they begin to burrow. When the egg is laid on a leaf there is slight chance that the larva will migrate to another leaf or to the petiole before starting a mine. In the case of a tuber the larva generally begins where the egg was located, since the irregularity chosen by the moth for oviposition affords a favorable location for starting a tunnel. For this reason the damage to potatoes first becomes evident in the eyes. The fact that the entrance hole is very small and webbed over makes it difficult to detect infestation in potatoes shortly after the eggs have hatched.

After a few days a pink coloration may be detected around the injured eye, and closer examination evidences the presence of excrement held in the web at the entrance to the burrow. The larvæ first burrow straight through the skin and into the substance of the tuber. Some then turn their mines so that they follow close under the skin of the potato. A fungus grows in the burrow and discolors it so that the course of the work may be easily followed. Later the skin of the potato partially dries and sinks so that the scar becomes very prominent; this is commonly called subepidermal injury. This type is the most noticeable, but is not so injurious to the tuber as the deeper channel; and as it dries out more easily, it is not so apt to be the cause of rot.

The channel of the tuber-moth larva is as a general rule deeper and may even go through the center of a large potato. This form of injury is more difficult to detect from the outside than the subepidermal form, but from its greater injury to the potato is the more important. The surface injury may be cut out without much loss to the tuber, but to remove the burrow through the center, the tuber must be cut to pieces and much of it lost.

There seems to be no definite course followed by the larva which might determine the character of injury or the direction taken in the tuber. Some channels are partly subepidermal and partly deep, while other larvæ construct subepidermal channels and still others deep ones.

The channels or galleries generally measure 1 to 3 inches in length and are quite tortuous. The portion occupied by the larva is fresh and white, but the older parts are covered with a matlike brown fungus and often partially filled with excrement. In older injury the mycelium of the fungus may entirely fill the channel. The growth is very compact, and if the tuber is cut in such a way that the injury is exposed the fungus may be lifted out in one piece.

It should be added at this point that, in its occurrence in California, the larva does not prefer to feed upon the tubers in the ground as long as the potato tops are green and succulent. However, as soon as the tops become dry and hard the larvæ do not hesitate to attack the exposed part of a potato, and will even dig through a thin layer of soil in order to reach the buried tubers.

EFFECTS ON THE TUBER.

The immediate effect of the potato-tuber moth on the potato is in the reduction of its market value. This takes place in two ways: (1) By ruining the substance of the part of the potato actually attacked, (2) by causing the entire tuber to be unsightly and, therefore, undesirable. Losses through the tuber moth may practically all be classed under these two heads. It is true that the larvæ cause decay in the tubers, but when this takes place the infestation is generally so heavy and the injury so far advanced that the tubers have ceased to have value, either for food or for seed.

The growing sprouts of seed potatoes also form a favorite point af attack. When thus attacked they are badly injured or killed, and potatoes which have too long been exposed to the attacks of the moth are likely to have their value as seed materially reduced.

NUMBER OF LARVÆ DEVELOPING IN TUBERS.

Since several generations of the insect may develop in a single tuber, it is difficult to determine the maximum that a tuber of average size will support. Mature larvæ have been noted, apparently of normal development, in tubers which contained no appreciable moisture and which were simply a network of pith holding together the dried burrows of previous generations of tuber worms. In one generation 121 pupæ and 3 mature larvæ were taken from a tuber 4 cm. by 6 cm. by 9 cm. The substance of the tuber had been so completely destroyed that on removal from the breeding jar it collapsed.

DEATH OF LARVÆ IN TUBERS.

The normal rate of mortality among the larvæ while tunneling in tubers is very low. Whenever too many develop in a tuber and a putrid condition ensues, very few of the partially developed larvæ escape. Some may leave the tuber and go in search of other food, but most of them remain in the decaying tuber and die.

Larvæ mining in potato tops are very susceptible to change of weather, and in short cold and rainy periods most of the larvæ in the leaves are killed. Those in the stems, being better protected, are safer from weather changes.

LENGTH OF FEEDING PERIOD OF LARVÆ.

The length of the feeding period varies with the temperature. During July and August the active larval life requires as few as 14 days, while during December and January the same period sometimes lasts 69 days. This much greater length of the larval stage in winter is a result simply of retarded development and can not be considered hibernation, as the larva is active and feeding at all times.

METAMORPHOSES.

The instars of the insect show the greatest irregularity, even where conditions as regards food and temperature are kept as nearly uniform as possible. In determining the molting periods, a large number of larvæ, hatched on the same day, were placed on tubers and on each succeeding day the larvæ were dissected from a tuber and preserved in formalin. For the first two days the larvæ were of approximately the same size, but from the time of the first molt the greatest variation was noticeable; when some had reached the last instar others hatched on the same day and feeding on the same tuber were only half grown.

This variation was also very noticeable in the life-history work. Where the first mature larvæ appeared in 18 days, there were mature larvæ leaving the tuber for the succeeding 6 days. Table 1 shows the variation in the length of the larval period with larvæ from the same egg masses.

TABLE 1.—*Length of larval stage of the potato tuber moth with larvæ from the same egg masses.*

Eggs hatched.	Number of mature larvæ.	Dates between which they appeared.	Number of days in emergence period.
1913.			
Nov. 5	41	Dec. 16 and Jan. 4	19
Dec. 3	8	Feb. 3 and Feb. 21	18
1914.			
Jan. 2	7	Mar. 2 and Mar. 28	26
Feb. 2	11	Mar. 16 and Apr. 4	19
Mar. 19	67	Apr. 21 and May 2	12
Apr. 1	23	May 1 and May 12	11
May 4	18	June 2 and June 10	8
June 19	47	July 6 and July 14	8
July 5	20	July 21 and July 27	6
Aug. 4	38	Aug. 18 and Aug. 23	5
Sept. 1	44	Sept. 21 and Sept. 30	9
Oct. 4	19	Nov. 3 and Nov. 16	13

As has been suggested, the rapidity of growth of the larva seems not to be influenced by the amount of food. Larvæ developing in leaves, stems, or petioles, grew more rapidly than those in the tubers. In these experiments the larvæ were kept on potted plants indoors, and those in tubers were placed in a breeding jar beside the plant. The experiments were carried on under the same temperature, but the larvæ in the leaves were more exposed to changes in temperature, and whether the greatest difference in the time of development was caused by a variation in temperature or a difference in the character of the food, it would be hard to determine. It seems probable, however, that the larvæ in the potato tops had the most succulent food, and that this made some difference in the time of development. The results of the experiments are shown in Table 2.

TABLE 2.—*Length of larval stage of potato tuber moth; comparison of larvæ reared on tubers and larvæ reared on potato tops.*

LARVÆ REARED ON TUBERS.

Eggs hatched.	Larvæ mature.	Larval stage.
		Days.
Nov. 10, 1915	Dec. 13	33
July 5, 1914	July 14	16

LARVÆ REARED ON POTATO TOPS.

Eggs hatched.	Larvæ mature.	Larval stage.
Nov. 10, 1915	Dec. 7	27
July 5, 1914	July 18	13

The process of molting is similar to that in other lepidopterous larvæ, the skin splitting down the dorsum of the first few segments, and the larva working its way out through this opening. By far the greater time is taken up in preparation for molting and in resting after the operation.

LEAVING THE TUBER.

When the larvæ become mature they usually leave the tuber for pupation. If they remain in their channels they come out toward the opening, so that the head of the pupa is just under the skin of the potato. When the larvæ leave the tuber they are very active and seldom remain exposed very long. If they are disturbed in any way they throw themselves about until they reach shelter of some kind. They are especially active when parasites are near, and should the latter approach, contort themselves rapidly until the parasite has disappeared.

When a suitable place for pupation is discovered, an operation which may consume from an hour to a day, the larva begins a cocoon at once, working so rapidly that very soon it is covered with a thin mesh. If disturbed, it will often leave its partially completed cocoon and seek another place to pupate. Sometimes one larva will interfere with another spinning a cocoon to such an extent that the partially constructed cocoon will be deserted by both. Parasites, however, cause the desertion of the greatest number of cocoons by attempting oviposition before the cocoon is completed.

Cocoons containing pupæ of the tuber moth were noted in an old bin in the following places: (1) In the eyes of potatoes; (2) between potatoes (where they touched or almost touched); (3) between potatoes and bin walls; (4) between potatoes and sacks; (5) in folds of sacks; (6) in cracks in bin walls; (7) in nail holes of bin walls; (8) on bin walls; (9) in rubbish on floor; (10) on open floor (mostly naked); (11) in end of burrow with cocoon partly protruding; (12) in old burrows under dry skin of potatoes.

In the field, where the larvæ were working on potato tops, the pupæ were noted in the following places: (1) In curled dried leaves on the plant; (2) under clods and rubbish, and (3) protruding from old burrows in the stem.

Under field conditions most of the pupæ were found in the dried leaves which still clung to the potato plant.

After the larva has completed its cocoon it spends a period varying from two days to a week or more before changing to the pupa. The larva becomes greenish all over and sometimes takes on a faint blue tinge. It also becomes much shortened and constricted at the segments, and loses nearly all its activity. This stage varies very much with the temperature, being much shorter in summer than in winter. The larva is helpless at this time and can not move within its cocoon sufficiently to ward off the attacks of parasitic enemies. During this period the greatest amount of parasitism of the mature larva takes places.

THE PUPA.

As the time of pupation approaches, the skin on the dorsum of the anterior segments of the larva splits, and the pupa works the skin off in a short time. The cast skin occupies a small space in the posterior end of the cocoon.

The pupa when newly formed is white with greenish markings. It soon begins to darken and in a few hours' time is uniformly dark brown. When first formed it remains quiet until it becomes hardened, but is very sensitive and if disturbed turns itself around by moving the tip of its abdomen in a circle. The hooks at the tip of the abdomen are sometimes fastened in the cocoon, so that even if part of the anterior end of the cocoon is torn off, the pupa will not necessarily be dislodged. Just before emergence it is quite active and turns itself around quickly if disturbed. As the time for emergence approaches the pupa becomes still darker in color and is less active.

The period of pupation varies greatly with the temperature and even when under constant temperature. Lots of pupæ formed on the same day vary to such an extent that the last to emerge often requires twice as long as the first. Experiments undertaken to determine the influence of sex on the length of the pupal period gave entirely negative results, as both sexes were practically evenly divided at all periods of emergence.

Extreme variations for the pupal period indicated 8 days for July and 56 days for December and January. Variations during one month include 12 days for the shortest and 29 days for the longest period.

Even where the pupal stage is of the longest duration the ratio of this to the increased length of the other stages of the moth remains so nearly constant that it seems development within the pupa must continue all the time, though, of course, at a greatly reduced rate. For this reason this longer pupal stage must be classed as retarded development and could hardly be termed true hibernation.

THE ADULT.

EMERGENCE.

The skin of the pupa splits along the dorsum of the thorax, and the moth by contracting itself draws its head from the pupal case. From this time on it is never quiet, contracting and expanding its abdomen and withdrawing its legs from their cases on the venter of the pupa. When the legs are free and the body has started to move in the case, the whole insect is free within a few moments. The freshly emerged adult generally moves very little until it has expanded its wings to their normal size. Sometimes the latter process is quite slow, but generally within a short time the wings reach beyond the tip of the abdomen. Even after development is apparently complete the moth prefers not to attempt flight for some time, but if disturbed either feigns death or seeks a place of concealment with a characteristic jerky running movement.

For some time after emergence the adult spends most of the time in hiding, but if sweetened water is placed near it the insect will feed readily.

HABITS OF THE MOTH.

Under field conditions the habits of the insect are well adapted to protect it until the eggs are deposited. During the day the adult hides beneath rubbish, or if the fields are clean, under clods of earth. Its coloring is very protective, and it is difficult to locate the adults even after they have been observed to alight. They seldom fly in the field during the brighter hours of midday, unless disturbed, and then the flight is short and jerky, and on alighting they seek concealment. When they fly to the potato vines they hide beneath the leaves, so that they are seen with difficulty. Under field conditions they have not been noted to take food. The activity increases with the temperature, being greatest during warm nights.

PROPORTION OF THE SEXES.

The proportion of the sexes during the year remains very nearly constant and almost equal. Pupæ selected at random at various times of the year gave the results shown in Table 3.

TABLE 3.—*Proportion of sexes of the potato tuber moth.*

Month.	Number of pupæ.	Male.	Female.	Not emerging.
January	127	69	51	7
April	200	111	86	3
July	200	95	104	1
October	100	52	43	5

REPRODUCTION.

Mating takes place within a day or two after emergence. During the summer months this time may even be reduced. Sexual attraction is quite strong, the males being readily attracted to the females. Pairs may mate several times, frequently promiscuously. Mating is most common during the morning and evening. Mating pairs have been noted in the field, generally under clods and rubbish, at temperatures of from 59° to 65° F.

Oviposition takes place within from 24 to 48 hours after mating. Generally only a few eggs are deposited the first night, from 10 to 20 in number. The maximum number is deposited the second, third, and fourth nights. Oviposition by a female when fed on sweetened water may last for two weeks, but even in these cases it will be found that over half of the eggs were deposited before the fifth night.

The following record gives the oviposition record of an average pair:

October 7.—Pair mating.
October 8.—7 eggs deposited.
October 9.—31 eggs deposited.
October 11.—57 eggs deposited.
October 12.—39 eggs deposited.
October 14.—34 eggs deposited.
October 15.—5 eggs deposited.
October 17.—11 eggs deposited.
October 18.—3 eggs deposited.
October 19.—0 eggs deposited.
October 22.—Female dead.

Oviposition takes place almost altogether at night, especially during warm nights. On cool dark days eggs are sometimes deposited, but these are few in number and very seldom are two found placed together. When the moths are kept in darkened cages they deposit a few eggs during the day, but even here the greater part of oviposition takes place at night.

Adults in the act of ovipositing on potatoes were very commonly noted. The female generally sought the eye of the potato and after turning around a few times settled down and remained quiet for a few moments. Just before oviposition the tip of the abdomen was moved around slightly until a suitable place was found, then the abdomen was contracted rapidly by drawing in the tip and the egg was extruded.

The egg when first deposited is viscid, and translucent white, but hardens in a very short time. Generally the adult moves about after oviposition until another satisfactory place is found, but the same adult may deposit most of a night's quotum of eggs in the same place. In case the adult discovers a narrow deep crack in the tuber the eggs are often placed within it in a chain. When the breeding jars are covered with cheesecloth it is always found that some eggs are deposited on the cloth. This is in corroboration of the fact stated by Picard (83), that oviposition is stimulated by a roughened surface.

RELATION OF FOOD TO OVIPOSITION.

Experiments to test the effect of feeding on oviposition show that both the period of oviposition and the number of eggs laid may be increased by feeding. In these experiments some of the moths were kept in dry vials, some in vials with a little water, and others in vials with sugar water. Those kept with water were under conditions more like those outdoors, while the ones in dry vials would be under extreme laboratory conditions.

The results are shown in Table 4.

TABLE 4.—*Relation of food to oviposition of the potato tuber moth.*

Nature of experiment.	Number of adults.	Total eggs deposited.	Average number of eggs per female.
Without food	10	1,138	114
Water	10	1,472	147
Sweetened water	10	2,094	209

Temperature also has a very important effect, not only on the rapidity with which eggs are laid, but on the number as well. During the winter months, when the nights become cool, very few eggs are deposited by an adult, and these are well scattered. The period of oviposition is longer during a season of cool nights, but even this does not make up for the fewer eggs laid, as will be seen in Table 5.

TABLE 5.—*Effects of temperature on oviposition of the potato tuber moth.*

Pair of adults mating.	Oviposition period.	Total eggs laid.
	Days.	
January	17	109
April	14	247
June	8	262
August	9	294
November	13	142

September and October also showed large egg records, 27 out of 35 adults under observation depositing over 200 eggs each.

EFFECT OF FERTILITY ON OVIPOSITION.

Unfertilized females were isolated at different seasons of the year to test the effect on oviposition. Almost all of these deposited eggs at some time during their lives, but the eggs were deposited irregularly and in much smaller numbers.

Table 6 shows some of the greatest variations to be found in this connection.

TABLE 6.—*Oviposition of the potato tuber moth by virgin females.*

Female No.	Period between emergence and oviposition.	Total number eggs.	Period of oviposition.	Length of life.
	Days.		*Days.*	*Days.*
1	5	13	7	17
2	1	51	1	2
3	3	6	5	13
4	7	44	9	22
5	4	1	1	11
6	5	18	16	21
7	5	29	13	18
8	4	9	6	12
9	....	0	....	28
10	6	32	10	17

Examination of this table will show also that oviposition was delayed longer after emergence than in the case of fertilized females.

POSSIBLE PARTHENOGENESIS.

To corroborate the observations on parthenogenesis cited by Picard regarding this insect (83), unfertilized females were isolated during spring and fall, and all the eggs deposited were carefully watched. In these experiments 54 females deposited a total of 486 eggs, of which 324 were laid during September and 162 during April and May. None of the eggs hatched, showing that while parthenogenesis may exist, it is not very common.

LENGTH OF LIFE.

Pairs of adults isolated proved that the length of life of the male is shorter than that of the female. This proved to be the case in 221 out of 275 experiments carried out for egg records. In nearly every case where the female died first the egg record was poor, indicating that the female was abnormal to begin with. The length of life varies with the temperature, the warmest season giving the shortest life records. This is even more pronounced where the adults are not fed.

The extremes noted for length of life were, for the male 1 to 14 days, and for the female 2 to 22 days, in cases where the pairs had mated. In experiments using unmated individuals the length of life for the male varied from 3 to 31 days, and for the female, 2 to 28 days.

In the case of the male which lived 31 days no food was given, and the individual was kept in a dry vial. This record was made during November when the weather was cool.

A fairly average record of a pair of adults which mated October 29, 1914, is as follows:

October 31.—40 eggs.
November 1.—63 eggs.
November 2.—28 eggs.
November 4.—41 eggs.
November 5.—18 eggs.
November 8.—19 eggs. Male dead.
November 10.—6 eggs.
November 12.—3 eggs.
November 13.—0 eggs. Female dead.

SEASONAL HISTORY.

NUMBER OF GENERATIONS.

The number of generations in one year, as might be expected, is subject to the wide irregularity shown in the separate stages, and to temperature and other natural influences.

By taking the first to emerge from each brood, six generations are theoretically possible. In reality this would include five complete generations, and the beginning of the sixth.

By starting several generations in each month for almost three years, it was possible to determine the average length of generations for the different months of the year.

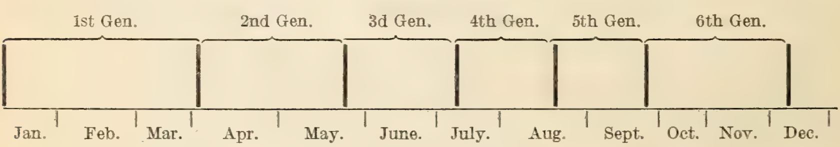
Table 7 gives the results obtained:

TABLE 7.—*Length of generations of the potato tuber moth.*

Month of starting generation.	Approximate length of generation.	Month of starting generation.	Approximate length of generation.	Month of starting generation.	Approximate length of generation.
	Days.		*Days.*		*Days.*
January	90	May	50	September	45
February	75	June	40	October	70–75
March	65	July	30–35	November	92
April	55	August	30–35	December	95

Consecutive generations for a year, using the first to emerge, may be plotted as follows:

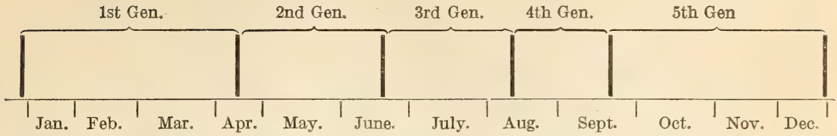
Plot A.



This shows plainly that even in the more severe years six generations may be obtained, using the first to emerge from each brood.

By using the last to emerge from each brood, the number of generations is reduced as the following plot shows.

Plot B.



The gradual emergence of adults from a generation the larvæ of which all hatched on the same day may be shown from the examples which follow, one from midsummer and the other from midwinter.

TABLE 8.—*Emergence of adults of the potato tuber moth from two generations, the eggs of one hatching on July 7 and those of the other on December 8.*

Average mean temperature 72° F.		Average mean temperature 51° F.	
1914		1914	
July 7.	Eggs hatched.	Dec. 8.	Eggs hatched.
		1915	
Aug. 1.	2 adults emerged.	Mar. 7.	2 adults emerged.
Aug. 3.	21 adults emerged.	Mar. 9.	4 adults emerged.
Aug. 5.	18 adults emerged.	Mar. 10.	2 adults emerged.
Aug. 6.	4 adults emerged.	Mar. 11.	1 adult emerged.
Aug. 8.	1 adult emerged.	Mar. 12.	6 adults emerged.
Aug. 10.	2 adults emerged.	Mar. 13.	3 adults emerged.
Aug. 11.	0 adults emerged.	Mar. 14.	3 adults emerged.
		Mar. 16.	1 adult emerged.
		Mar. 18.	4 adults emerged.
		Mar. 20.	1 adult emerged.
		Mar. 23.	1 adult emerged.
		Mar. 30.	0 adults emerged.

The records given above show plainly the difference in number of generations which may be caused by taking the first to emerge or the last to emerge in each life cycle. If the first eggs deposited by the "first to emerge," and the last eggs deposited by the "last to emerge" are taken for the second generations, the difference will be increased to such a degree that almost a month will elapse between the time of starting the two generations.

Taking generations throughout the year gives the following periods (Table 9). The records are for 1914, and were made at Pasadena, Cal.

TABLE 9.—*Variation in life cycle of the potato tuber moth.*

Month started.	Eggs laid.	Adults emerging.		Greatest number emerg-ing.	Length of life cycle.
		First.	Last.		
1914.					*Days.*
January	Jan. 4	Apr. 6	Apr. 30	Apr. 10	91
February	Feb. 11	Apr. 25	May 13	Apr. 29	73
March	Mar. 18	May 18	May 31	May 21	61
April	Apr. 15	June 9	June 20	June 12	55
May	May 16	July 4	July 16	July 7	49
June	June 14	July 24	Aug. 3	July 27	40
July	July 13	Aug. 15	Aug. 23	Aug. 17	33
August	Aug. 17	Sept. 19	Sept. 27	Sept. 22	33
September	Sept. 14	Oct. 29	Nov. 10	Nov. 1	45
1913.					
October	Oct. 14	Dec. 24	Jan. 14	Dec. 31	71
November	Nov. 7	Feb. 7	Feb. 22	Jan. 13	92
December	Dec. 12	Mar. 19	Apr. 10	Mar. 25	97

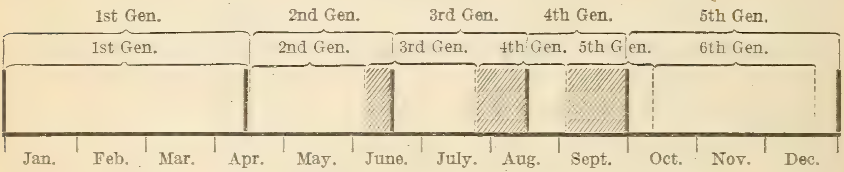
In examining this table it must be borne in mind that the results given are for a particular year, and great variations are possible from similar months in other years. One example will be sufficient to illustrate this point: During the middle of April, 1914, the mean temperature averaged about 66°, and during this time eggs of the tuber moth were hatching in from 8 to 9 days. During the same period of 1915, with the average mean temperature about 59° F., the egg stage lasted from 12 to 14 days. All stages of the insect vary so greatly that it is difficult to foretell how long a generation will take.

OVERLAPPING OF GENERATIONS.

From the foregoing examples it is evident that all stages of the tuber moth exist throughout the year in Southern California, and consequently the broods can not be distinguished. Many writers have estimated the numbers of broods or generations by the abundance of moths at different times of the year. If conditions are considered, it may be seen that food and temperature govern this condition. In summer, with an abundant food supply, the insect multiplies with great rapidity, adults become abundant, and the impression of the emergence of a brood is given. If plots A (p. 28) and B (p. 29) are compared, the overlapping of generations may be understood.

By placing one over the other as in plot C, the shaded areas show the time adults are emerging. The broken lines are from plot B.

Plot C.



This diagram indicates that although the generations may secure an even start at the beginning of the year, by late summer and fall the first to emerge from the fifth generation are appearing at a time when there are still adults from the fourth generation emerging. This explains the presence of all stages of the insect at all times of the year, and indicates that from the economic side a knowledge of the life history of the moth is of little importance, except as it shows the possibilities of reproduction.

HIBERNATION.

During the discussion of the effect of temperature on the various stages of the tuber moth the impression was given that there is no hibernation for any length of time in southern California. This is surely the case under normal conditions, though possibly there is no noticeable development for a few days at a time when the average mean temperature is low.

Experiments were carried on in the storage rooms of an ice company at Pasadena to determine if low temperature acting for some time would kill the various stages of the moth or whether they could hibernate successfully. For these experiments the following stages were taken: Adults, pupæ, mature larvæ in cocoons, and eggs. Two experiments were carried on at the same time. One lot was kept at 32° F. for three weeks, while the other lot was kept for 35 days at a temperature of 38°–40° F.

The results are summarized in Table 10:

TABLE 10.—*Effect of low temperatures on stages of the potato tuber moth.*

Time.	Temperature (constant).	Adults.	Pupæ.	Mature larvæ.	Eggs.
21 days	32° F.	Most alive and active	Alive	Alive	Alive.
35 days	40° F.	Over half were dead	do	do	Do.

In the cases where the various stages were alive they developed normally when taken from storage. In both experiments development was stopped in all stages while the material was in storage. These results show that the tuber moth may hibernate successfully where conditions demand it and that no development takes place below 40° F. Prof. Picard (83) says that no development takes place below 50° F.

DISSEMINATION.

The tuber moth is disseminated by two means, natural and artificial. Of these two the former (by flight of the moth) is much the slower and, as it can hardly be controlled, is relatively unimportant. The most important spread of the tuber moth takes place through the movement of infested potato tubers. In this way the insect is assured of an abundance of food, and since the tubers are not allowed to freeze, the temperature is always favorable. In interstate and international shipments the moth is given every opportunity to spread and has probably been introduced at some time into every civilized country on the globe.

It is even possible that a careful inspection will show that it is established in many localities where it is now unknown. This is especially likely to be the case in districts where the climate is cold and wet and therefore unfavorable for the insect's normal development.

MORTALITY OF THE STAGES.

The mortality in the various stages must be considered from the standpoint of whether the insect is working on potato tops or on stored potatoes. Under field conditions as a leaf miner the mortality is so high that an increase of the insect from this source is highly improbable. Rains and sudden changes in climatic conditions kill many of the larvæ, and the large number of predacious and parasitic enemies further reduce the numbers of the insect. The figures will be considered later with the discussion of natural enemies.

When the insect attacks stored tubers the percentage of insects developing safely is very high. Figures show that practically all the eggs deposited hatch. In storage there is always an abundance of food and all stages are protected from most of their enemies, so most of the larvæ develop successfully.

POSSIBLE RATE OF INCREASE.

The theoretical rate of increase for the tuber moth is very rapid. Taking 150 as the average number of eggs deposited and counting half the adults as females, the progeny of one pair would give about 60,000,000 adults at the end of the fourth generation.

While this theoretical rate is seldom even approached, it serves to show that under favorable conditions for reproduction the insect may increase to damaging numbers in a short time.

NATURAL ENEMIES AND CHECKS.

Where the tuber moth works as a leaf-miner on the potato tops, its numbers are kept down very well by its enemies and climatic changes. Its numerous parasitic enemies play the most important part, rains and cold weather probably come second in point of importance, and the predacious enemies last.

In southern California the parasitic enemies of the tuber moth form a fine series and work on every stage. The egg and pupa each has its parasite, while several attack the partially grown larvæ and at least two the mature larvæ.

Only three of these work on the tuber worm infesting potatoes, and here they are only partially effective. The burrowing habit of the larva protects it from parasites except while spinning its cocoon and pupating. Parasites are also hampered by the storage of potatoes. Altogether it is doubtful if parasites could be of practical importance when the insect infests stored tubers. Certainly the stored potatoes examined have discouraged such a belief.

Experiments to ascertain the percentage of parasitism in the potato tops show that the parasites, taken altogether, are valuable in the control of the tuber moth. The impracticability of direct methods of control necessitates the use of all possible measures to limit the number of moths before harvest. This is well accomplished by the parasites, resulting in lessened injury to the leaf surface and diminishing the number present to infest the potatoes just before and during harvest.

PARASITES.

Parasites vary in effectiveness. During 1914 *Habrobracon johannseni* (fig. 16) was the most effective, and the following list probably gives them in the order of their importance for that year:

Habrobracon johannseni Vier.
Chelonus shoshoneanorum Vier.
Sympiesis stigmatipennis Girault.
Campoplex phthorimaeae Cushm.
Bassus gibbosus Say.
Apantales sp. (Chttn. No. 2230^{07}).
Microgaster sp. (Chttn. No. 2230^{08}).
Nepeira benevola var. *fuscifemora* Cushm.
Zagrammosoma flavolineatum Cwfd.

During early 1915 *Dibrachys clisiocampae* Fitch was discovered, and while not so well distributed, it seems to be well fitted to be an

Fig. 16.—Empty cocoon of the potato tuber moth (large one) and cocoons of its parasite, *Habrobracon johannseni*. Much enlarged. (Original.)

effective enemy. Ranking the parasites in the order of their importance for 1915 would give them the following order:

Dibrachys clisiocampae, *Sympiesis stigmatipennis*, *Campoplex phthorimaeae* — Of about equal importance.
Apanteles sp. (Chttn. No. 2230^{07}).
Habrobracon johannseni.
Chelonus shoshoneanorum.
Bassus gibbosus.
Microgaster sp.
Nepeira benevola var. *fuscifemora*.
Zagrammosoma flavolineatum.

The last four species in each list were relatively unimportant during both years in the districts from which material was collected for study. These were as easily reared in confinement as most of the others, and there seems to be no reason why they should not be important equally with other species which oviposit in the tuber larva where it occurs as a leaf-miner.

DIBRACHYS BOUCHEANUS RATZ.[1]

This well-known and cosmopolitan secondary parasite (fig. 17) emerged from the tuber-moth material collected during 1912, 1913, and 1914, and, as shown by dissection, from both *Habrobracon johannseni* and *Chelonus shoshoneanorum*, the former seeming to be its favorite host. This species was reared from the egg in the laboratory, where it attacked the mature larvæ of its hosts after they had spun their cocoons. Where the cocoons were not too thick to prevent it from reaching its host the parasite would often feed at the wounds caused by its ovipositor.

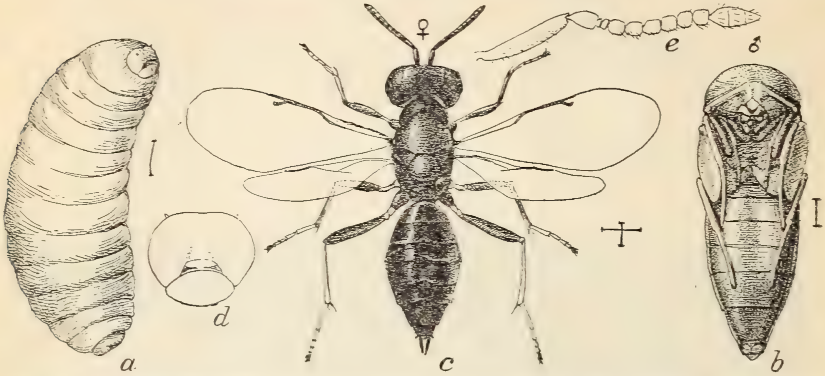


FIG. 17.—*Dibrachys boucheanus: a,* Larva; *b,* pupa; *c,* adult female; *d,* head of larva; *e,* antenna of male, highly magnified. Greatly enlarged. (After Howard.)

When reared under laboratory conditions the hyperparasites increase rapidly, but under field conditions their numbers are not as large in proportion to the host as might be expected. During 1912 and 1913 the percentage of parasitism ran as high as 50 per cent in the case of *Habrobracon johannseni*. With *Chelonus shoshoneanorum* the average was much lower, the highest running 29 per cent. During 1914 the percentages in both cases were much reduced, and while greater numbers of its two hosts were reared than in the previous year, *Dibrachys boucheanus* was noted on only a few occasions.

FIG. 18.—*Zagrammosoma flavolineatum:* Adult male, with lateral view of head. Much enlarged. (Original.)

[1] Chittenden No. 2230°°.

During 1915 the parasitism averaged slightly over 1 per cent, as two individuals of *Dibrachys boucheanus* were reared, while 172 specimens of *Habrobracon johannseni* issued in the parasite cages.

Three or four specimens were commonly noted in one host, and in the material reared under laboratory conditions a single hyperparasite was rarely reared from one host.

The following record shows the development of a fall generation:

1913.
October 27.—*D. boucheanus* parasitizing mature larvæ of *H. johannseni.*
November 8.—*D. boucheanus* larvæ mature.
November 14.—*D. boucheanus* larvæ pupating.
December 7.—2 *D. boucheanus* adults issued.
December 8.—7 *D. boucheanus* adults issued.
December 10.—4 *D. boucheanus* adults issued.
December 11.—1 *D. boucheanus* adult issued.
Life cycle 40 days at average mean temperature of 62° F.

ZAGRAMMOSOMA FLAVOLINEATUM CWFD.[1]

During 1914 and 1915 *Zagrammosoma flavolineatum* (figs. 18, 19) was noticed issuing from cages containing some *Phthorimaea operculella*

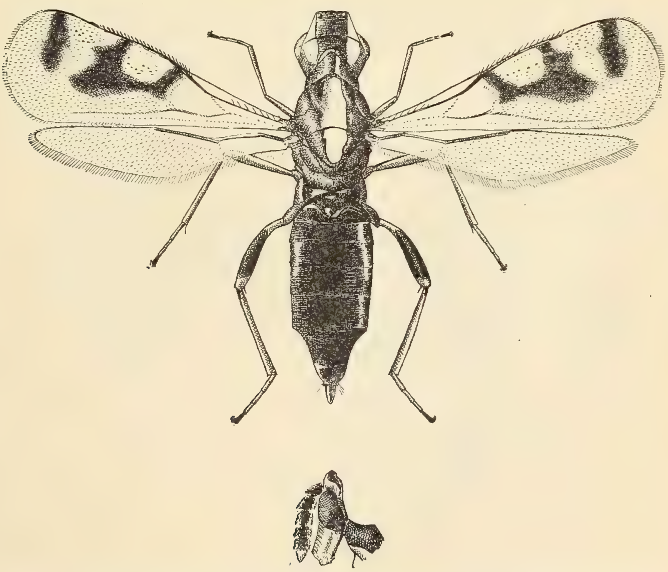


FIG. 19.—*Zagrammosoma flavolineatum:* Adult female, with lateral view of head. Much enlarged. (Original.)

material. Efforts to rear it from the tuber moth were failures at first, so numerous tuber-moth larvæ were taken from leaf mines and placed on tubers so that there might be no danger of getting mixed material. No specimens of this parasite emerged in these cages, and it was supposed that it was issuing from some other host.

[1] Chittenden No. 2230[01].

Finally a parasite pupa was noted in a leaf mine with the remains of a tuber-moth larva. When the adult issued it proved to be *Zagrammosoma flavolineatum*. More experiments were carried on, using only material where the tuber-moth larvæ occurred as leaf-miners and were less than half grown. The parasite was seen to oviposit in these larvæ, and it was successfully reared through to the adult.

This parasite thus far has not proved to be of much importance, and seems unpromising, as the adult is so slow and deliberate in its movements that a tuber-moth larva in a large mine can move about and often escape the ovipositor of the parasite.

The following record gives the length of its life cycle:

1915.
August 17.—*Zagrammosoma flavolineatum* ovipositing in tuber-moth larva.
August 29.—1 *Zagrammosoma flavolineatum* adult issued. (Male.)
August 30.—2 *Zagrammosoma flavolineatum* adults issued. (Males.)
August 31.—1 *Zagrammosoma flavolineatum* adult issued. (Male.)
September 1.—1 *Zagrammosoma flavolineatum* adult issued. (Female.)
September 2.—2 *Zagrammosoma flavolineatum* adults issued. (Male and female.)
Life cycle 13 days at average mean temperature of 75°F.

SYMPIESIS STIGMATIPENNIS GIRAULT.[1]

During 1914 and 1915 tuber-moth material collected at Pasadena during late fall gave great numbers of a small parasite, the male of which (fig. 20) had branched antennæ. At about the same time an examination of mines on potato leaves often showed a parasitic larva (fig. 21) feeding externally on a partially grown larva of the tuber moth. When these were reared they proved identical with those issuing in the parasite cages.

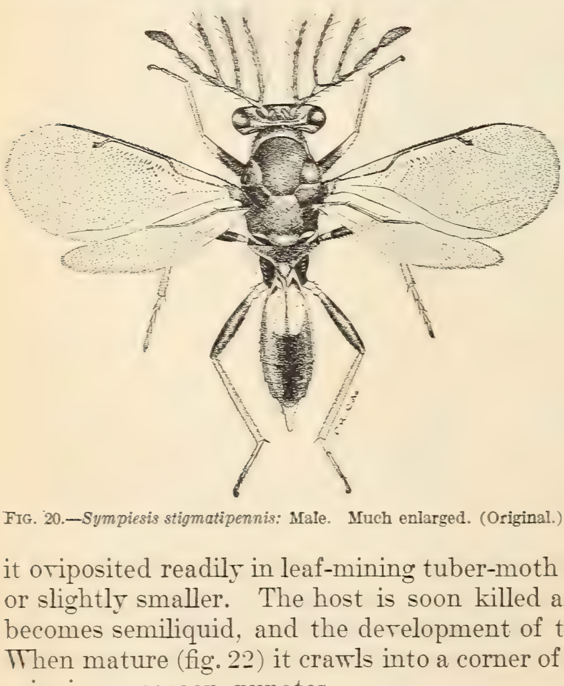


FIG. 20.—*Sympiesis stigmatipennis:* Male. Much enlarged. (Original.)

The parasite was reared with ease in the laboratory, and it oviposited readily in leaf-mining tuber-moth larvæ when half grown or slightly smaller. The host is soon killed and within a short time becomes semiliquid, and the development of the larva is very rapid. When mature (fig. 22) it crawls into a corner of the mine and, without spinning a cocoon, pupates.

[1] Chittenden No. 2230[02].

The pupa (fig. 23) is very flat and black. Several individuals may issue from one host. Under field conditions about equal numbers of males and females issued, but in the laboratory males greatly predominated. Mating takes place as soon as the adults issue, and oviposition shortly after. The females (see fig. 24) probably obtain moisture from the wounds made in the epidermis of the leaf by their ovipositors, as they were often noted after oviposition to back up and apply their mouth parts for some time to the hole made in the leaf. As the tuber-moth larva had generally moved away by this time, it could not have been possible for it to have obtained food from the wound in the larva.

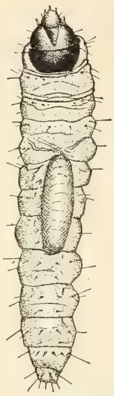


FIG. 21.—*Sympiesis stigmatipennis:* Immature larva feeding on larva of tuber moth. Much enlarged. (Original.)

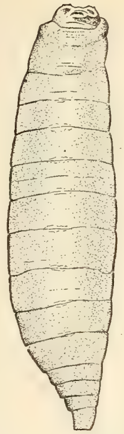


FIG. 22.—*Sympiesis stigmatipennis;* Mature larva. Much enlarged. (Original.)

FIG. 23.—*Sympiesis stigmatipennis:* Pupa. Much enlarged. (Original.)

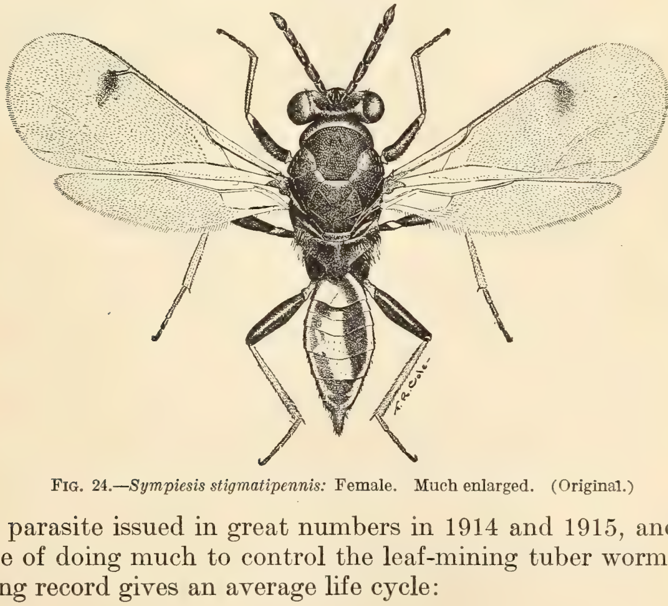


FIG. 24.—*Sympiesis stigmatipennis:* Female. Much enlarged. (Original.)

This parasite issued in great numbers in 1914 and 1915, and gives promise of doing much to control the leaf-mining tuber worm. The following record gives an average life cycle:

1915.
January 26.—Tuber-moth larva parasitized by *Sympiesis stigmatipennis.*
February 21.—3 *Sympiesis stigmatipennis* adults issued. (Males.)

1915.
February 23.—1 *Sympiesis stigmatipennis* adult issued. (Female.)
February 25.—3 *Sympiesis stigmatipennis* adults issued. (Males.)
Life cycle 26 days at average mean temperature of about 52° F.
Longest life cycle noted, 45 days.

CAMPOPLEX PHTHORIMAEAE CUSHM.[1]

During 1913 a very few adults of this species (fig. 25) were reared from tuber-moth material collected near Puente, Cal. These specimens could not be reared in the laboratory. In 1914 and 1915 the parasite became very abundant, and was reared from tuber-moth larvæ, proving it to be a parasite of this species.

FIG. 25.—*Campoplex phthorimaeae;* Adult female, with lateral view of abdomen. Much enlarged. (Original.)

Tests under laboratory conditions showed that it oviposits in the tuber-moth larvæ only where they act as leaf-miners, and prefers those about half grown. The adult has been noted ovipositing both in the field and in the laboratory. It is so active that the tuber-moth

[1] Chittenden Nos. 2230[03] and 2230[013].

larva seldom escapes. The parasitized tuber-moth larva is readily detected when it becomes mature and seeks a place to pupate. A large dark or reddish spindle is apparent, filling most of its abdomen, and the larva is very restless and seldom stays in one place long enough to spin a cocoon. Finally the host loses all power of locomotion and dies, and within a few hours the mature parasite larva (fig. 26) forces its way through the skin of its host and begins spinning its cocoon (fig. 27). As the parasite larva is almost the size of its host, only one develops on each tuber worm.

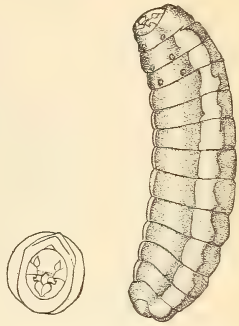


FIG. 26.—*Campoplex phthorimaeae;* Lateral view of mature larva with view of face. Much enlarged. (Original.)

The cocoon is completed within a day or two. It is very heavy, ellipto-cylindrical in shape, light gray, and with a lighter band around the middle. The pupa, removed from its cocoon, is shown in figure 28.

FIG. 27.—Cocoon of *Campoplex phthorimaeae,* parasite of potato tuber moth. Much enlarged. (Original.)

This parasite assisted greatly in reducing the numbers of the tuber moth in the potato tops during 1914 and 1915.

An average life cycle is given below:

December 15, 1914.—Tuber-moth larva parasitized by *Campoplex phthorimaeae.*

February 5, 1915.—1 *Campoplex phthorimaeae* adult issued. (Male.)

February 6, 1915.—1 *Campoplex phthorimaeae* adult issued. (Female.)

Life cycle 52 days at an average mean temperature of about 54° F.

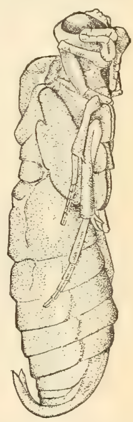


FIG. 28.—*Campoplex phthorimaeae:* Lateral view of pupa. Much enlarged. (Original.)

HABROBRACON JOHANNSENI VIER.[1]

This is probably the best known parasite of the tuber moth, both where it occurs as a leaf-miner and as a pest of stored potatoes. It is well distributed, having been reared from tuber-moth material collected over most of southern California.

It oviposits in the mature larva of the tuber moth after it has spun its cocoon. As many as 13 parasite larvæ have been observed to develop on a single host. The adult female is very active, but seems to prefer to work only in the light, for the parasite has never been reared from material kept in darkened bins.

The larvæ may develop either externally or internally, the host seeming to depend on the position of the egg. After the tuber-moth

[1] Chittenden No. 2230[04].

larva has been parasitized it does not pupate, but soon breaks down and becomes semiliquid.

The mature larva spins a light but tough white cocoon within the cocoon of its host, thus being well protected. This apparently

FIG. 29.—*Chelonus shoshoneanorum:* Adult female. Much enlarged. (Original.)

explains its comparative immunity from the secondary parasite *Dibrachys boucheanus.*

The adult feeds quite often at the oviposition wounds of its host. The adults are very hardy and the female is long lived. One female lived from July 19 to September 21, 1914, a period of 64 days, and in this time 291 adults were reared from this one specimen. When the

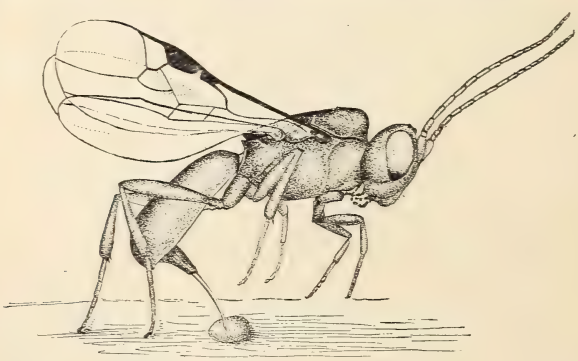


FIG. 30.—*Chelonous shoshoneanorum:* Female ovipositing in egg of tuber moth. Much enlarged. (Original.)

mortality of the stages under laboratory conditions is considered, it will be seen that this species is quite prolific. This female was fed sweetened water four times during this period. The life cycle varies from 10 to 38 days in length.

The record of a shorter life cycle follows:

1913.
September 15.—Tuber-moth larva parasitized by *Habrobracon johannseni.*
September 18.—Parasite larvæ nearly mature.
September 19.—Parasite larvæ spinning cocoons.
September 20.—Parasite larvæ pupating.
September 25.—4 parasite adults issued.
September 26.—17 parasite adults issued.
Life cycle 10 days at an average mean temperature of 78° F.

CHELONUS SHOSHONEANORUM VIER.[1]

This parasite (fig. 29) has been consistently abundant every year from 1912 to the present time. Efforts to rear it from the larvæ and pupæ of the tuber moth failed, and, at the suggestion of Dr. Howard, the insect was placed with eggs of the tuber moth. Oviposition (fig. 30) took place at once, the parasites usually feeding on the moisture which collected at the wound caused by the ovipositor.

The eggs of the tuber moth hatched normally, and the young larvæ at once burrowed into the tuber. Later the mature tuber-moth larvæ began to leave the tuber and start their cocoons. Some of the larvæ appeared restless and darkened spindles were noticeable in their bodies (fig. 31), quite similar to those in the case of *Campoplex phthorimaeae.* None of the larvæ pupated, and soon the mature parasite larva (fig. 32) emerged and spun its white cocoon within the cocoon of its host.

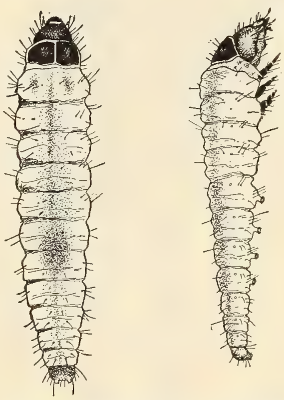


FIG. 31.—Larvæ of tuber moth parasitized by *Chelonus shoshoneanorum.* Much enlarged. (Original.)

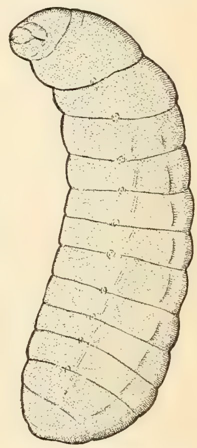


FIG. 32.—*Chelonus shoshoneanorum:* Mature larva. Much enlarged. (Original.)

This parasite promises to be of value in controlling the tuber moth in the field. It apparently does not work in darkened bins.

The life cycle is divided as follows:

1914.
July 26.—Tuber-moth eggs parasitized by *Chelonus shoshoneanorum.*
July 31.—Tuber-moth eggs hatched.
August 16.—Chelonus larvæ mature.
August 18.—Chelonus larvæ pupating.
August 26.—1 Chelonus adult issued.
August 27.—3 Chelonus adults issued.
August 28.—2 Chelonus adults issued.
Life cycle 31 days at an average mean temperature of about 72° F.

---

[1] Chittenden No. 2230^{05}.

BASSUS GIBBOSUS SAY.[1]

Bassus gibbosus (figs. 33–35) attacks the half-grown tuber worm in leaf mines. Like *Zagrammosoma flavolineatum*, it is apparently of minor importance, and probably for the same reason.

Adults placed on potato leaves containing larvæ of the tuber moth attempted oviposition, but frequently without success. The parasite is rather slow in oviposition, and the larva within the mine is given opportunity to escape the ovipositor.

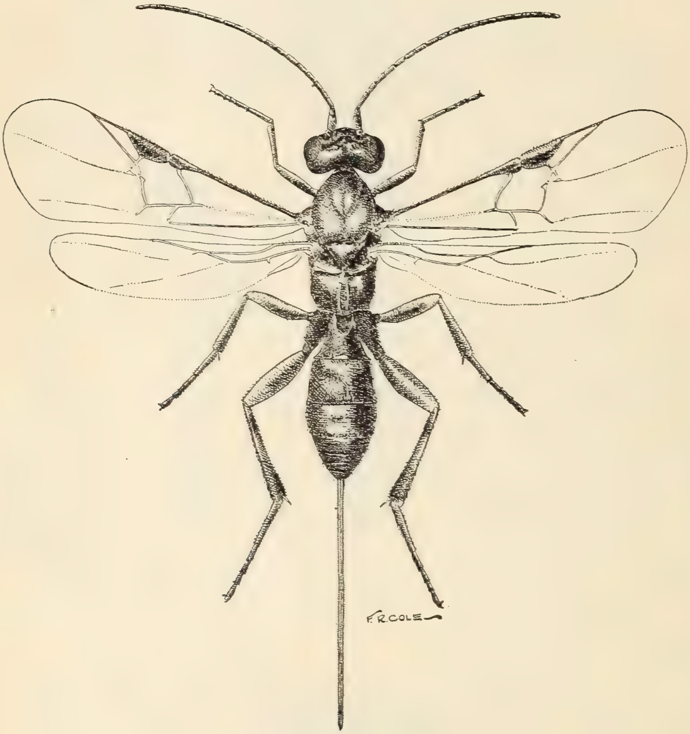


FIG. 33.—*Bassus gibbosus:* Adult female. Much enlarged. (Original.)

This parasite appears in the greatest numbers during the late fall and winter. For this reason its life cycle is of rather long duration, as the following record shows:

1915.

February 8.—Tuber-moth larvæ parasitized by *Bassus gibbosus*.
April 2.—1 parasite issued. (Male.)
April 3.—1 parasite issued. (Female.)
April 7.—1 parasite issued. (Male.)
Life cycle 53 days at an average mean temperature of about 53° F.

The parasite seems to be well distributed throughout southern California.

[1] Chittenden No. 2230^{06}.

APANTELES SP.[1]

This small active parasite (figs. 36–38) was not observed until 1914, and seems quite scarce except in the vicinity of Pasadena. The half-grown leaf-mining tuber-moth larvæ are attacked. When the parasite has discovered a leaf mine, it cautiously examines it until it has located the position of the tuber-moth larva. The parasite then quickly inserts its ovipositor in the mine. In case it strikes the larva, it oviposits; otherwise it quickly withdraws its ovipositor, inserting it again in a new place. This is repeated until the larva is parasitized, although the difficulty in locating the larva may require a second examination of the mine. Should the parasite discover a larva, however, it seldom leaves until it has been successful in oviposition.

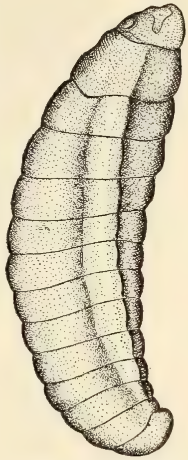


FIG. 34.—*Bassus gibbosus*: Mature larva. Much enlarged. (Original.)

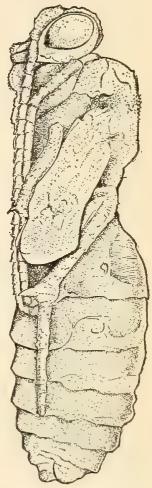


FIG. 35.—*Bassus gibbosus:* Pupa. Much enlarged. (Original.)

This Apanteles is a most promising parasite. The record of an average winter life cycle follows:

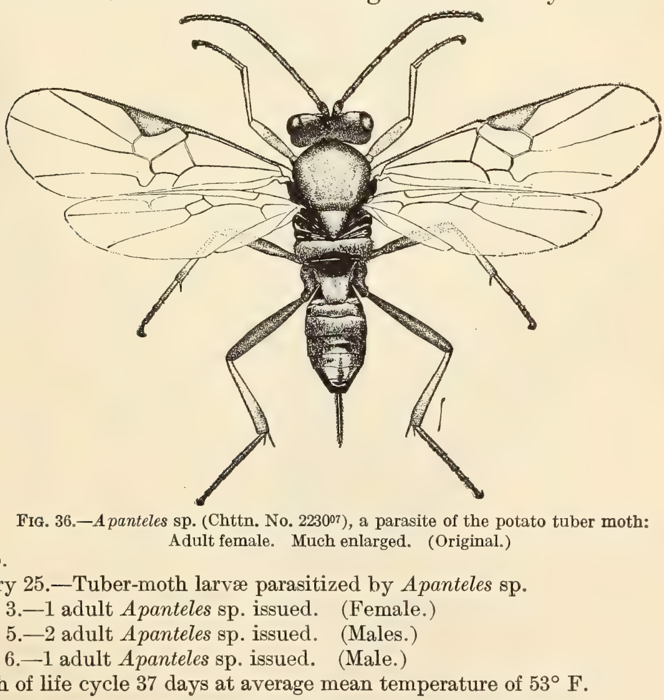


FIG. 36.—*Apanteles* sp. (Chttn. No. 2230^{07}), a parasite of the potato tuber moth: Adult female. Much enlarged. (Original.)

1915.

January 25.—Tuber-moth larvæ parasitized by *Apanteles* sp.
March 3.—1 adult *Apanteles* sp. issued. (Female.)
March 5.—2 adult *Apanteles* sp. issued. (Males.)
March 6.—1 adult *Apanteles* sp. issued. (Male.)
Length of life cycle 37 days at average mean temperature of 53° F.

[1] Chittenden No. 2230^{07}.

MICROGASTER SP.[1]

This, the most active parasite attacking the tuber moth, prefers half-grown leaf-mining larvæ. This parasite seems the best fitted naturally to be a dangerous enemy of the tuber moth, but during three years' observation has not reached expectations.

The adults (fig. 39) are readily reared at any time from late summer to spring, but never in large numbers. The adult has the shortest length of life of any observed. Even when fed, only one individual lived as long as 11 days. It seems to be fairly well distributed through the San Gabriel Valley.

FIG. 37.—Lateral view of mature larva of *Apanteles* sp. (Chttn. No. 2230^{07}), with view of fan at left below. Much enlarged. (Original.)

The record of a typical life cycle follows:

1915.

August 18.—Tuber-moth larvae parasitized by *Microgaster* sp.

September 3.—1 adult issued. (Male.)

September 4.—2 adults issued. (Male and female.)

September 6.—1 adult issued. (Male.)

Life cycle 16 days at an average temperature of 73° F.

DIBRACHYS CLISIOCAMPAE FITCH.[2]

The last well-ascertained parasite of the tuber moth was *Dibrachys clisiocampae* Fitch. During 1913 one female was reared from tuber-moth material, but could not be bred through, and as no more issued, it was given up.

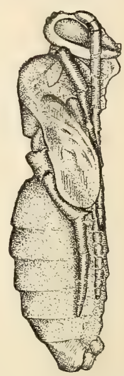


FIG. 38.—*Apanteles* sp. (Chttn. No. 2230^{07}): Lateral view of pupa. Much enlarged. (Original.)

In the winter of 1914 specimens were captured on potato foliage, and it was later noticed breeding on stored potatoes in the insectary. The parasite oviposits in the mature larvæ in cocoons, and in pupæ and issues from both stages, but usually from the mature larvæ. This parasite works both in the field and in storage. It seems to prefer piles of potatoes, working all through them, and also has been noted to oviposit in dark bins. The egg is shown in figure 40.

The adult (fig. 41) is persistent, and if driven away from a cocoon will return again and again until it oviposits. Fourteen mature larvæ (fig. 42) have been reared from one host. These pupate (see fig. 43) without spinning cocoons, and within the cocoon of their host. The parasite does not seem to be very well distributed, having been found only in Whittier and Pasadena, Cal. It seems at first glance to be the most effective parasite of the tuber moth, but probably this is not the case. It is not as effective as others under field conditions,

---

[1] Chittenden No. 2230^{08}.

[2] Chittenden No. 2230^{09}.

FIG. 39.—*Microgaster* sp., a parasite of the potato tuber moth: Adult female. Much enlarged. (Original.)

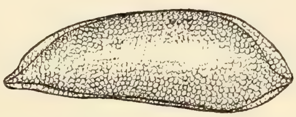


FIG. 40.—*Dibrachys clisiocampae:* Egg, lateral view. Greatly enlarged. (Or ginal.)

FIG. 41.—*Dibrachys clisiocampae:* Adult female. Much enlarged. (Original.)

and on stored potatoes conditions are such that any parasite is of doubtful value. In addition, it seems to have one unfortunate habit, that of becoming at times a hyperparasite on *Campoplex phthorimaeae*. This habit is so unusual, however, as to be unimportant.

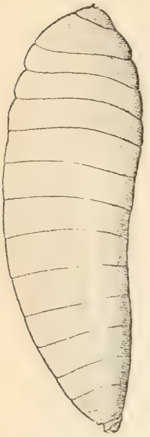


FIG. 42.—*Dibrachys clisiocampae:* Mature larva. Much enlarged. (Original.)

The record below gives the length of a life cycle:

1915.

August 8.—Tuber-moth larvæ parasitized by *Dibrachys clisiocampae*.

August 16.—Parasite larvæ mature.

August 18.—Parasite larvæ pupating.

August 25.—4 parasite adults issued. (Male and female.)

August 26.—7 parasite adults issued. (Male and female.)

August 27.—1 parasite adult issued. (Female.)

Length of life cycle 13 days at an average mean temperature of 75° F.

OTHER PARASITES.

Other parasites [1] were reared from time to time in small numbers from tuber-moth material collected in the San Gabriel Valley. They never became at all common. Efforts to rear them in the laboratory have been unsuccessful thus far. Both have been seen on occasion to oviposit in small leaf-mining tuber-moth larvæ, but no parasites have issued, and so they have not as yet been proven to be parasites of the tuber moth.

NEPEIRA BENEVOLA VAR. FUSCIFEMORA CUSHM.[2]

For some time this parasite (fig. 44) was considered identical with *Campoplex phthorimaeae* Cushm. The differences noted seemed to be variations within the species. While Mr. Cole was making drawings of the parasites, he noted that there were three separate types.

Nepeira benevola var. *fuscifemora* Cushm. closely resembles *Campoplex phthorimaeae*, both in appearance and life history, but has never become as abundant as the latter. It oviposits in half-grown leaf-mining tuber-moth larvæ.

Larvæ parasitized November 12 have given adult parasites December 12, a length of life cycle of 30 days, at an average mean temperature of about 63° F.

FIG. 43.—*Dibrachys clisiocampae:* Pupa, lateral view. Much enlarged. (Original.)

PERCENTAGE OF PARASITISM.

The percentage of parasitism has fluctuated so greatly in the time it has been under observation that it is difficult to give even approximate figures. The lowest parasitism noted was 40 per cent and the highest was 95 to 100 per cent. The

[1] Chittenden Nos. 2230°10 and 2230°11.

[2] Chittenden No. 2230°12.

parasites are undoubtedly of value in limiting the increase of the tuber moth while it works in the tops, thus decreasing infestation of the tubers.

FIG. 44.—*Nepeira benevola:* Adult female. Much enlarged. (Original.)

A review of the parasites shows that they attack the tuber moth under the following conditions:

On leaf-mining tuber moth.	On storage tubers.
[1] 2230^{01}. *Zagrammosoma flavolineatum.*	
2230^{02}. *Sympiesis stigmatipennis.*	
2230^{03} and 2230^{013}. *Campoplex phthorimaeae.*	
2230^{04}. *Habrobracon johanseni.*	[1] 2230^{04}. *Habrobracon johanseni.*
2230^{05}. *Chelonus shoshoneanorum.*	[1] 2230^{05}. *Chelonus shoshoneanorum.*
[1] 2230^{06}. *Bassus gibbosus.*	
2230^{07}. *Apanteles* sp.	
[1] 2230^{08}. *Microgaster* sp.	
2230^{09}. *Dibrachys clisiocampae.*	[1] 2230^{09}. *Dibrachys clisiocampae.*
[1] 2230^{012}. *Nepeira benevola* var. *fuscifemora.*	

[1] Of doubtful importance.

PREDATORS.

Predacious enemies of the tuber moth appear economically unimportant and will be considered very briefly.

Triphleps insidiosus Say and the larva of *Chrysopa californica* Coq. have on a few occasions been noted to destroy the eggs and newly hatched larvæ. As both these insects prefer aphids to the tuber moth, and as aphids are generally present on the potato tops, it seems that the destruction of the tuber-moth eggs and larvæ is more accidental than natural.

Several species of spiders which are found in the fields spin webs in which dead tuber moths have been noticed, and in a few cases the spiders have been observed killing moths caught in the webs.

ARTIFICIAL CONTROL.

INDIRECT METHODS, GOOD FARMING.

A study of the literature of the tuber moth shows that many writers, beginning with Capt. Berthon (1), have recommended good farming and careful harvesting and storing of tubers as the best remedies against the tuber moth. The powers of reproduction of this insect have given weight to these arguments, and a study of cultural methods in relation to tuber-moth infestation has proved the correctness of their recommendations.

Through the kindness of Mr. S. S. Rogers, of the University of California, the writer was enabled to compare the results of different cultural methods. The test field, situated near Van Nuys, Cal., had every conceivable variation in culture. Planting depth varied from 2 to 16 inches. Each plat contained both flat and ridged culture and was harvested in three parts, so that each variation in culture had early, medium, and late harvesting.

The results may be briefly summarized as follows:

Taking the entire field as an average, the percentage of infestation in the plats having ridged culture was 8 per cent less than in those having flat culture.

In the same way the plats harvested early had 4 per cent less infestation than those harvested at the medium period and 9 per cent less than those harvested late.

In the experiments with depth of planting results were even more striking. In the plats planted 2 inches deep (many tubers were exposed) the vines were dead, and the percentage of infestation of the tubers varied from 98 to 100. From this the percentage of infestation became steadily less, as the depth of planting was increased, until at a depth of 6 inches a minimum was reached, several plats giving entirely clean potatoes and the average of infestation being low. In the plats where deeper planting was used, the potatoes seemed to grow as near the surface as where 5 to 6 inches planting depth was used, and consequently there was no difference in freedom from the moth.

Results from the experiments as to time of planting varied so greatly that it was evident several other factors have more to do with determining infestation than the time of planting. The same might be said of the variety test, except that the tubers of varieties where the vine stayed green the longest suffered least from the moth.

On an average the results show the value of the recommendations given for fighting the tuber moth by culture.

These may be stated as follows:

(1) Plant as deep as practicable (5 to 6 inches).

(2) Use ridge culture, *i. e.*, ridge the rows (fig. 45).

(3) Harvest as early as possible.

(4) Harvest before the potato tops become so dry as to drive the partially grown larvæ to descend and work on the tuber.

In harvesting the tubers, several rules must be followed to keep the tubers from infestation:

(1) The sacks should *never* be covered with potato tops, as the larvæ leave these when they wilt, and enter the potatoes.

FIG. 45.—Potato field showing careful hilling. Walker, Cal. (Original.)

(2) The sacks should be sewed as soon as possible and hauled from the field.

(3) Potatoes should never be left in the field or exposed to the moth over night.

(4) All cull potatoes should be gathered up within two weeks and either fed to stock at once or destroyed. If left in the field they are a menace to the neighbors, and to the grower himself, for the following crop.

After the potatoes are harvested they should be marketed at once, unless the grower has storage facilities and is willing to take the trouble to treat the potatoes.

While there are good reasons for destroying the potato vines yet there appear to be even better reasons for not doing so. Destroying the potato vines kills all stages of the tuber moth within, but it also kills the parasites. The tuber moth is more apt to pupate under clods and rubbish in the field than are any of the parasites, hence the destruction of potato tops would be a more serious check to the parasites than to the tuber moth. It seems that if growers destroy waste tubers and keep the rest protected so that the tuber moth must breed on potato tops, the parasites will keep the tuber moth from becoming dangerously abundant.

DIRECT CONTROL METHODS.

Experiments were made to determine a cheap practical method of treating tubers infested with the tuber moth. As the tuber takes up odors and flavors readily, and retains them for indefinite periods, only a few methods were tried.

The only promising unobjectionable applications tested were formalin dilutions and water used as dips, and carbon disulphid and hydrocyanic-acid gas as fumigants. Of these four, the only one which was at all successful was carbon disulphid.

Carbon disulphid naturally has many advantages as a fumigant for potatoes. It does not injure the tubers, it can be applied for long periods and thus penetrate thoroughly, and finally, it is heavier than air and if liberated at the top will go entirely through a pile to the floor. Various dosages and periods were used for fumigation, but it was early apparent that for all-around results the material should be used at the rate of 2 pounds to 1,000 cubic feet, and fumigation should last 48 hours. At this strength the larvæ and adults, and practically all the pupæ and eggs, will be killed, and the long exposure to the vapor insures thorough penetration.

If potatoes are to be stored they should be fumigated promptly. Cheap gas-tight bins may be made by lining temporary structures with tarred paper and painting the seams. If the tubers are noticeably infested the fumigation should be repeated in a week in summer, or in two weeks in winter. Careful watch should be kept, and if the tuber moth is still working, another fumigation should be given.

In fumigating with carbon disulphid the liquid should be placed on top of the sacks in shallow tin pans, and care should be taken not to expose the gas to fire, as it is explosive when mixed with air and ignited.

OTHER REMEDIES.

TRAPPING THE ADULTS.

As the adult is attracted to light, some authors recommend trapping with lanterns. This remedy is of questionable value, as not all the adults could be trapped, and there is much doubt as to whether the numbers could be sufficiently reduced to make a difference at harvest time. In this connection it must be remembered that it is the multiplication of the insect in storage that causes practically all the loss.

QUARANTINE.

Quarantine as a method of keeping out the tuber moth has attracted considerable attention in the Western States in recent years. A quarantine of one district against another when the tuber moth is established in both places is of little value, as the numbers of this insect in any one year are not influenced as greatly by its numbers the preceding year, or by any that might be introduced, as by food and climatic conditions. The great interstate shipment of potatoes throughout the West proves that the potato question is a factor which affects many of the people living in those States, and a hasty or ill-advised quarantine might cause losses which would more than offset any advantages to be gained from it.

In conclusion it should be said that while the tuber moth is always a menace in warmer climates, it is by no means a fatal potato pest, and its damage, if not totally eliminated, can at least be minimized by rational farming methods and a knowledge of the habits of the insect. For this reason whenever there has been an outbreak of the moth in a new district the conditions[1] in this district should be studied and means devised to prevent a recurrence of injury.

SUMMARY.

(1) The tuber moth injures the potato by destroying the leaf surface and tunneling in the substance of the tuber.

(2) Its life history is variable, but in southern California all the stages exist at all times of the year.

(3) The numbers of the insect should be reduced by practicing good farming and leaving no tubers exposed for the insect to work on.

(4) Potatoes should be harvested and marketed as rapidly as possible, unless the grower has facilities for storage and is prepared to treat the potatoes if necessary.

(5) Once the tubers become infested the best way of ending the damage is to fumigate with carbon bisulphid, using 2 pounds to 1,000 cubic feet of air space (measured before storing the tubers) and allowing 48 hours for fumigation.

(6) Clean or uninfested potatoes should be kept away from the moth.

(7) Potatoes should never be left in the ground after they are ripe and where the soil is dry.

(8) When tubers are infested and facilities are lacking for storing in bins, the progress of infestation can be checked by holding the potatoes in cold storage. The temperature should be about 37° to 40° F. This should be adopted only as a temporary method in keeping potatoes from deteriorating in value while they are being held for a rise in price.

---

[1] This refers especially to various methods of storing potatoes.

BIBLIOGRAPHY.

(1) BERTHON, CAPT. H.
1855. On the potato moth. *In* Papers and Proc. Roy. Soc. Van Diemen's Land, v. 3, pt. 1, p. 76–80.

(2) WALKER, FRANCIS.
1864. List of the Specimens of Lepidopterous Insects of the British Museum, s. 6, pt. 30, p. 1024. London.

(3) CHAMBERS, V. T.
1872. Micro-Lepidoptera. *In* Canad. Ent., v. 4, no. 10, p. 191–195 (p. 193).

(4) ——— ———.
1873. Micro-Lepidoptera. *In* Canad. Ent., v. 5, no. 9, p. 173–176 (p. 176).

(5) ZELLER, P. C.
1873. Beiträge zur Kenntniss der nordamericanischen Nachtfalter, besonders der Microlepidopteren. Abt. 2, p. 63. Also *In* Verhandl. K. K. Zool. Bot. Gesell. Wien, 1873, Bd. 23, p. 201–334 (p. 262–263).

(6) BOISDUVAL, J. A.
1874. Note sur une nouvelle maladie des Pommes de terre. *In* Jour. Soc. Cent. Hort. France, s. 2, t. 8, p. 713–714.

(7) RAGONOT, E. L.
1875. [Note.] *In* Bul. Soc. Ent. France, t. 5, s. 7, p. xxxv–xxxvii.

(8) CHAMBERS, V. T.
1878. Tineina. *In* Canad. Ent., v. 10, no. 3, p. 50–54 (p. 51.)

(9) MEYRICK, E.
1879. Occurrence of *Lita solanella*, Bsd., in Australia. *In* Ent. Mo. Mag., v. 16, p. 66.

(10) RAGONOT, E. L
1879. *Gelechia tabacella.* *In* Bul. Soc. Ent. France, t. 9, s. 5, p. cxlvi–cxlvii.

(11) MEYRICK, E.
1880. On a microlepidopterous insect destructive to the potato. *In* Proc. Linn. Soc. N. S. Wales, v. 4, p. 112–114.

(12) TEPPER, J. G. O.
1882. The destructive potato moth. *In* Trans. Roy. Soc. So. Aust., v. 4, p. 57.

(13) COOKE, M.
1883. Injurious Insects of the Orchard, etc., 472 p. (p. 313–315), 775 illus. Sacramento.

(14) MEYRICK, E.
1885. Descriptions of New Zealand Micro-Lepidoptera. *In* New Zeal. Jour. Sci., v. 2, 1884–1885, p. 589–592 (p. 590).

(15) RAGONOT, E. L.
1885. [Note.] *In* Bul. Soc. Ent. France, t. 5, s. 6, p. cxi–cxii.

(16) MEYRICK, E.
1886. Description of New Zealand Micro-Lepidoptera. *In* Trans. and Proc. N. Zeal. Inst., 1885, v. 18, n. s., p. 162–183 (p. 166).

(17) KOEBELE, ALBERT.
1890. Report of a trip to Australia to investigate the natural enemies of the fluted scale. U. S. Dept. Agr. Div. Ent. Bul. 21, o. s., rev., 32 p., 16 fig.

(18) TRYON, HENRY.
1890. Report on insect and fungus pests. Ann. Rpt. Dept. Agr. Brisbane, 1889–1890. 238 p. (p. 175–181), illus.

(19) OLLIFF, A. S.
1891. The potato moth (*Lita solanella*, Boisd.). *In* Agr. Gaz. N. S. Wales, v. 2, p. 158–159.

(20) [Note.]
1891. *In* Insect Life, v. 3, no. 11/12, p. 435.

(21) DREW, W. L.
1892. On the date of introduction of the potato tuber-moth. *In* Insect Life, v. 4, no. 11/12, p. 396.

(22) OLLIFF, A. S.
1892. Entomological notes. *In* Agr. Gaz. N. S. Wales, v. 3, p. 698–703; 828–832.

(23) RILEY, C. V., and HOWARD, L. O.
1892. The potato tuber moth. (*Lita solanella* Boisd.). *In* Insect Life, v. 4, no. 7/8, p. 239–242.

(24) FRENCH, C.
1893. A Handbook of the Destructive Insects of Victoria. Pt. 2, 222 p. (p. 147–154), col. pl. 15–36, 20 fig.

(25) RILEY, C. V.
1893. Report of the entomologist. *In* Ann. Rpt. U. S. Dept. Agr. 1892, p. 153–180 (p. 156), 12 pl.

(26) WIGHT, R. A.
1893. The potato-tuber moth (*Lita solanella* Boisd.). *In* Insect Life, v. 5, no. 3, p. 163–164.

(27) [Notes.]
1893–1894. *In* Insect Life, v. 6, no. 2, 3, 5, p. 59, 275, 373.

(28) KIRK, T. W.
1894. Report of the acting biologist. *In* 2nd Ann. Rpt. Dept. Agr. New Zeal., p. 47–106 (p. 88–90), fig. 1.

(29) ——— ———.
1895. Report of the biologist. *In* 3rd Ann. Rpt. Dept. Agr. New Zeal., p. 101–162 (p. 141), illus.

(30) LEA, A. M.
1897. The potato moth (*Lita solanella*, Boi.). *In* 4th Ann. Rpt. Bur. Agr. West. Aust., 1897, p. xxxi.

(31) MCCARTHY, G.
1897. A new tobacco pest. N. C. Agr. Expt. Sta. Bul. 141, 2 p., 2 fig.

(32) QUAINTANCE, A. L.
1898. Insect enemies of tobacco in Florida. Fla. Agr. Expt. Sta. Bul. 48, p. 150–188, 16 fig.

(33) HOWARD, L. O.
1899. The tobacco leaf-miner or "split worm" (*Gelechia solanella* Boisd.). *In* U. S. Dept. Agr. Yearbook, 1898, p. 137–140.

(34) LOUNSBURY, C. P.
1899. Cape Good Hope Dept. Agr., Rpt. Govt. Ent., 1898, 64 p. (p. 48), 9 pl.

(35) HOWARD, L. O.
1900. The principal insects affecting the tobacco plant. U. S. Dept. Agr. Farmers' Bulletin 120, 32 p. (p. 19–22), 25 fig.

(36) KIRK, T. W.
1900. Potato-moth, potato tuber-moth, potato-grub. (*Lita solanella.*) New Zeal. Dept. Agr. Leaflets for Farmers, no. 16, 3 p., 1 fig.

(37) CLARK, W. T.
1901. The potato-worm in California (*Gelechia operculella*, Zeller). Cal. Agr. Expt. Sta. Bul. 135, 30 p., 10 fig.

(38) FULLER, CLAUDE.
1901. First report of the government entomologist, 1899–1900. Natal Dept. Agr., 143 p. (p. 62–64), illus.

(39) STAUDINGER, O., und REBEL, H.
1901. Catalog der Lepidopteren des Palaearctischen Faunengebietes. Thiel 2, p. 146, no. 2636.

(40) BORDAGE, E.
1902. Etude sur les principaux insectes nuisibles au Tabac à la Réunion. *In* Rev. Agr. Réunion, no. 3, p. 103–112.

(41) DYAR, H. G.
1902. A List of North American Lepidoptera. U. S. Nat. Mus. Bul. 52, p. 502.
(42) LEA, A. M.
1902. Remedies for Insect and Fungoid Pests of the Orchard and Farm. Dept. Agr. Tasmania. 38 p. (p. 8.).
(43) MEYRICK, E.
1902. A new genus of Gelechiadae. *In* Ent. Mo. Mag., v. 38, p. 103–104.
(44) FROGGATT, W. W.
1903. The potato moth (*Lita solanella*, Boisd.). *In* Agr. Gaz. N. S. Wales, v. 14, no. 4, p. 321–326, 1 col. pl.
(45) HOLLAND, W. J.
1903. The Moth Book. p. 425. New York.
(46) LEA, A. M.
1903. Remedies for Insect and Fungus Pests of the Orchard and Farm. Dept. Agr. Tasmania. ed. 2, 53 p. (p. 9–10), illus.
(47) [Correspondence.]
1903. *In* Agr. Jour. Cape Good Hope, v. 22, no. 6, p. 717–719.
(48) DEWAR, W. R.
1904–1905. Orange River Colony Dept. Agr. 1st Ann. Rpt. Govt. Ent. 58 p. (p. 27–29), 10 fig.
(49) DESPEISSIS, A.
1905. Annual report of the horticultural and viticultural expert. *In* Jour. Agr. West. Aust., v. 12, pt. 6, p. 531–545.
(50) FROGGATT, W. W.
1905. The farmer's garden and its enemies. *In* Agr. Gaz. N. S. Wales, v. 16, pt. 10, p. 1034–1040, illus.
(51) FULLER, CLAUDE.
1905. The potato moth. *In* Natal Agr. Jour. and Min. Rec., v. 8, no. 9, p. 873–876, 1 pl.
(52) VAN DINE, D. L.
1905. Insect enemies of tobacco in Hawaii. Hawaii Agr. Expt. Sta. Bul. 10, 16 p., 6 fig. (p. 7–8, fig. 3).
(53) JOHNSTON, C. M. G.
1905–1906. Biological division. *In* 2nd Ann. Rpt. Dept. Agr. Orange River Colony, p. 243–261 (p. 252), illus.
(54) FRENCH, C.
1906. The potato moth (*Lita solanella* Boisd.). *In* Jour. Dept. Agr. Victoria, v. 4, pt. 10, p. 577–582, 1 col. pl.
(55) HERRERA, A. L.
1906. Invasion de gusanos en los Estados del Centro de la Republica. Com. Par. Agr. Mexico Circ. 45, 14 p. (p. 6).
(56) KOTINSKY, J.
1906. The tobacco splitworm, an enemy of tomato, eggplant, and poha in Hawaii. *Phthorimaea operculella*, Zell. *In* Hawaii Forester and Agr., v. 3, no. 7, p. 200–201.
(57) LOUNSBURY, C. P.
1906. Tobacco wilt in Kat River Valley. *In* Agr. Jour. Cape Good Hope, v. 28, no. 6, p. 784–803, illus.
(58) CRAW, A.
1907. Report on horticultural quarantine inspection work. *In* Hawaii Forester and Agr., v. 4, no. 6, p. 176–178, fig. 10, 11.
(59) ——— ———.
1907. Inspection of importations. *In* 4th Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, p. 79–84.

(60) Hooker, W. A.
1907. Observations on insect enemies of tobacco in Florida in 1905. *In* U. S. Dept. Agr. Bur. Ent. Bul. 67, p. 106–112 (p. 110).
(61) Kirk, T. W.
1907. Diseases and insect pests of the potato. New Zeal. Dept. Agr. Div. Biol. and Hort. Bul. 7, 40 p. (p. 33), illus.
(62) Lefroy, H. M.
1907. The potato moth. *In* Agr. Jour. India, v. 2, no. 3, p. 294–295.
(63) Howard, C. W.
1908. Notes on Transvaal tobacco pests. *In* Transvaal Agr. Jour., v. 6, no. 24, p. 609–616, pl. 81–82, 4 fig.
(64) Lea, A. M.
1908. Insect and Fungus Pests of the Orchard and Farm, ed. 2, 176 p. (p. 32–33), illus. Tasmania.
(65) Butler, E. D.
1909. The potato. Dept. Agr. N. S. Wales Farmers' Bulletin 27, ed. 2, 16 p., 5 fig.
(66) Gunn, David.
1909. The potato tuber moth (*Gelechia operculella* Zeller). *In* Transvaal Agr. Jour., v. 8, no. 29, p. 80–82, pl. 21.
(67) Main, T. F.
1908. Report upon the entomological work conducted in the District during the year 1907–1908. Dept. Agr. Bombay. 29 p. (p. 3–12).
(68) Houser, J. S.
1909. The tobacco split worm *Phthorimaea operculella* Zell. *In* 2d Rpt. Estac. Cent. Agron. Cuba, Eng. ed., p. 133–139.
(69) Lefroy, H. M., and Howlett, F. M.
1909. Indian Insect Life. 786 p. (p. 535), 84 pl., 536 fig. Calcutta and Simla.
(70) Metcalf, Z. P.
1909. Insect enemies of tobacco. Special Bulletin. Supplement to N. C. Dept. Agr. Bul., v. 30, no. 10, 72 p., 56 fig.
(71) Lefroy, H. M., and Evans, G.
1910. Experiments in the storage of seed potatoes. *In* Agr. Jour. India, v. 5, no. 1, p. 19–28, 1 col. pl.
(72) Cockayne, A. H.
1911. The potato moth. *In* Jour. Dept. Agr. New Zeal., v. 2, no. 4, p. 179–186, illus.
(73) Fletcher, T. B.
1911. Two insect pests of the United Provinces. *In* Agr. Jour. India, v. 6, no. 2, p. 147–159 (p. 154).
(74) Middleton, T. H.
1911. Report to the Secretary. Bd. Agr. and Fisheries, Ann. Rpt. Intelligence Div., 1909–1910, pt. 2, p. 33. London.
(75) ———.
1911. Report to the Secretary. Bd. Agr. and Fisheries, Ann. Rpt. Intelligence Div., 1910–1911, pt. 2, p. 37. London.
(76) Morgan, A. C.
1911. Insect enemies of tobacco in the United States. *In* U. S. Dept. Agr. Yearbook, 1910, p. 281–296, pl. 20, fig. 3–15.
(77) Woodhouse, E. J., and Chowdhury, A. P.
1911. Potato moth at Patna. *In* Jour. Dept. Agr. Bengal, v. 4, no. 4, p. 188–192, 2 pl. (1 col.).
(78) Bordas, L.
1912. Anatomie générale de l'appareil digestif de la larve de *Phthorimaea operculella* Zeller. *In* Bul. Soc. Ent. France, 1912, no. 8, p. 191–193.

(79) BORDAS, L.
1912. Morphologie externe et appareil digestif de la Chenille de *Phthorimaea operculella* Zeller. *In* Compt. Rend. Acad. Sci. Paris, v. 154, p. 450–452; 618–620.

(80) CHITTENDEN, F. H.
1912. The potato-tuber moth. U. S. Dept. Agr. Bur. Ent. Circ. 162, 5 p., 3 fig.

(81) ESSIG, E. O.
1912. The potato-tuber moth (*Phthorimaea operculella* Zeller). *In* Mo. Bul. Cal. Hort. Com., v. 1, no. 6, p. 203–213.

(82) JACK, R. W.
1912. The tobacco miner (*Phthorimaea operculella*). *In* Rhodesia Agr. Jour., v. 10, no. 2, p. 186–190, 3 pl.

(83) PICARD, F.
1912. La teigne des pommes de terre (*Phthorimaea operculella*). *In* Ann. Service des Epiphyties, t. 1, p. 106–176, fig. 10–30.

(84) ——— ———.
1912. Sur la presence en France et sur la biologie de la Teigne des Pommes de terre (*Phthorimaea operculella* Zell). *In* Compt. Rend. Acad. Sci. Paris, v. 154, p. 84–86.

(85) SANDERSON, E. D.
1912. Insect Pests of Farm, Garden and Orchard. 684 p. (p. 289–291), 513 fig. New York.

(86) WOODHOUSE, E. J.
1912. Potato moths in Bengal in 1911. *In* Dept. Agr. Jour. Bengal, v. 5, no. 3, p. 146–150.

(87) CHITTENDEN, F. H.
1913. The potato-tuber moth. U. S. Dept. Agr. Farmers' Bul. 557, 7 p., 4 fig.

(88) ESSIG, E. O.
1913. The potato-tuber moth. *In* Mo. Bul. Cal. Hort. Com., v. 2, no. 9, p. 665–666, fig. 365.

(89) JACK, R. W.
1913. Tobacco miner and stem borer. A correction. *In* Rhodesia Agr. Jour., v. 10, no. 3, p. 355–357.

(90) JARVIS, E.
1913. The potato moth. *In* Queensland Agr. Jour., v. 30, pt. 3, p. 190–191.

(91) VAILE, R. S.
1913. *In* Ann. Rpt. Ventura Co. Hort. Com., p. 15, fig. 9.

(92) VOSLER, E. J.
1913. *Chelonus shoshoneanorum* Vier. *In* Mo. Bul. Cal. Hort. Com., v. 2, no. 11, p. 731.

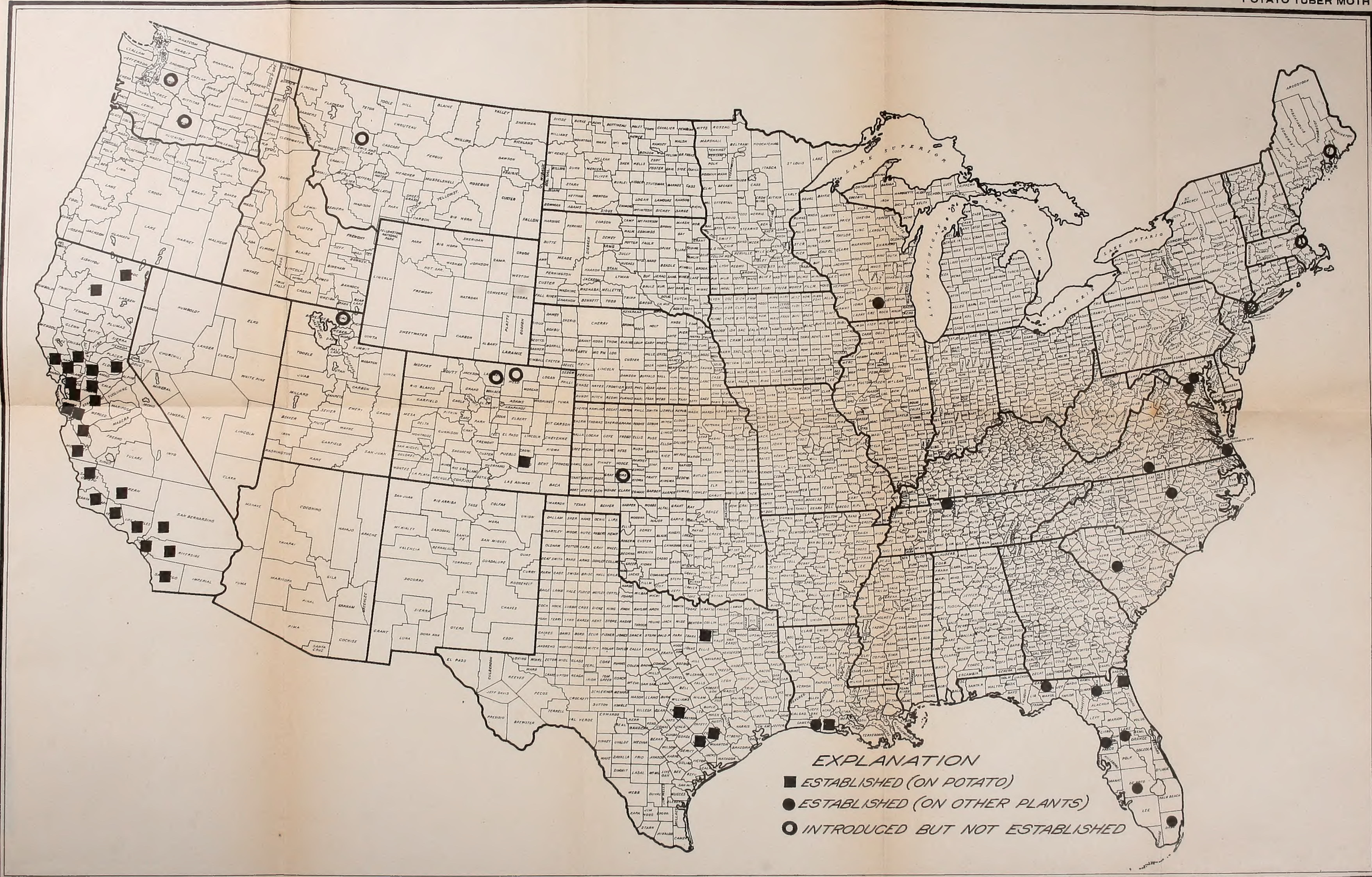
(93) [Note.] Insects injurious to garden crops in France. *In* Rev. Applied Ent., 1913. v. 1, pt. 4, p. 102–103. London.

(94) MORGAN, A. C., and CRUMB, S. E.
1914. The tobacco splitworm. U. S. Dept. Agr. Bul. 59, 7 p.

(95) STOWARD, F.
1914. The potato moth: An experimental investigation into the methods of controlling its ravages in stored tubers. *In* Jour. Nat. His. and Sci. Soc. West. Aust., v. 5, p. 15–19.

(96) ESSIG, E. O.
1915. Injurious and Beneficial Insects of California. Ed. 2 (Supp. Mo. Bul. State Com. Hort., v. 4, no. 4), p. 446–449.

○


EXPLANATION
ESTABLISHED (ON POTATO)
ESTABLISHED (ON OTHER PLANTS)
INTRODUCED BUT NOT ESTABLISHED