UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1032

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. ▼ April 25, 1922

THE BLACKHEAD FIREWORM OF CRANBERRY

ON THE PACIFIC COAST

BY

H. K. PLANK

Scientific Assistant, Fruit Insect Investigations

In cooperation with the Washington Agricultural Experiment Station, with Technical Description by CARL HEINRICH, Bureau of Entomology

CONTENTS

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THE BLACKHEAD FIREWORM[1] OF CRANBERRY ON THE PACIFIC COAST.

By H. K. PLANK,[2] *Scientific Assistant, Fruit Insect Investigations,* in cooperation with the Washington Agricultural Experiment Station. (With technical description by CARL HEINRICH, *Bureau of Entomology.*)

CONTENTS.

INTRODUCTION.

Numerous complaints from Washington cranberry growers, received by the Bureau of Entomology and the State College of Washington, led the two institutions to make a cooperative investigation of cranberry pests in the Pacific Northwest in 1918 and 1919. In this joint undertaking the writer represented the Bureau of Ento-

[1] *Rhopobota naevana* Hübner; order Lepidoptera, family Olethreutidae. Determined by Carl Heinrich, of the Bureau of Entomology.

[2] Appointed Collaborator, Tropical and Subtropical Fruit Insect Investigations, July 1, 1920.

mology and, successively, A. Spuler, Miss Orilla Miner, and Miss Flora A. Friese the State College of Washington.

IMPORTANCE OF THE BLACKHEAD FIREWORM.

The blackhead fireworm proved to be the most important cranberry pest of western bogs, and at the time the ravages of this insect were first observed by the writer it was causing an estimated loss of approximately 40 per cent of the combined crops of Washington and Oregon. In 1918 this loss was reduced to approximately 15 per cent and in 1919 to approximately 5 per cent, principally as a result of a better knowledge of the life history and habits of the insect and more general adoption of effective methods of control.

This bulletin reports the results of an investigation of the life history and habits of the blackhead fireworm in the States of Washington and Oregon which was conducted during the years 1918 and 1919 from laboratory headquarters at Seaview, Wash. During this period various methods of control were studied and thoroughly tested under actual bog conditions.

THE CRANBERRY INDUSTRY ON THE PACIFIC COAST.

The town of Seaview, Wash., is located practically in the center of the cranberry-growing district on the Pacific coast. In the State of Washington this district comprises most of the peninsula of Pacific County, in the southwestern corner of the State, directly north of the mouth of the Columbia River. Here the industry was started on a commercial scale in the early eighties by a French gardener named Chebot, who set out about 35 acres to the McFarlin, Native Jersey, Early Black, and Cape Cod Beauty varieties. Cuttings of most of these varieties were brought in from Wisconsin, New Jersey, and Massachusetts bogs. Some cuttings, especially of the McFarlin variety, were doubtless brought in from Marshfield, Oreg., where a Mr. McFarlin had started a bog 10 years previously with his own selection of vines from the East, which bear his name. Extensive planting, however, did not take place until 1912, from which time up to 1915 large areas in southwestern Washington were drained, cleared, and made available for cranberry culture.

Approximately 700 acres of cranberries are now in bearing in southwestern Washington, with about 1,500 acres of peat land still available for cranberry culture. In Oregon and the remainder of Washington there is possibly a total of 1,500 additional acres of cranberry land, about 300 acres of which in Oregon (in Clatsop and Coos Counties) are now in bearing. Practically all the bogs of the Pacific coast are sphagnum peat of various ages and thicknesses, found generally in swales between shore-sand ridges of slight elevation.

FEATURES OF BOG MANAGEMENT.

Although considerable water sometimes collects on the Pacific coast bogs, especially during winter, as a result of the heavy rains from September or October to April, flooding as a distinct part of cranberry bog management is rarely practiced in that section of the country. Few bogs on the Pacific coast have a good supply of water suitable for flooding purposes, and the mild winter climate in the principal cranberry-growing region seems to obviate the necessity of protecting the vines from winter injury. Principally is this true in southwestern Washington. As a consequence many terminal buds, especially on the warmer bogs, start to unfold shortly after the vines reach maturity in September and October and a certain amount of growth usually takes place during the warmer periods of the winter. It rarely happens, however, that any material damage is done by frost.

Covering the bog with water, usually from about November 15 to March 1, is practiced only to a limited extent in Oregon, but where this procedure is followed good results are usually secured. In the southern sections of the State it is almost necessary to cover the bogs with water during this period in order to keep the terminal buds from pushing forth during the warmer periods of the winter and meeting probable damage from frost during the late winter and spring.

The application of sand once every few years, as practiced on many eastern cranberry bogs, is not practiced on the coast, but probably could be employed with benefit. Inasmuch as the majority of the bogs are located between sand ridges, an abundant supply of good sand is readily available should its use become desirable.

PHENOLOGY OF THE CRANBERRY ON THE PACIFIC COAST.

The growth of the cranberry vine on the Pacific coast bogs is exceedingly variable, as will be borne out by the data presented in Table 1. This is probably because these bogs are for the most part managed as dry bogs. The relatively variable weather in that section of the country is also doubtless reflected in the early growth, blooming, and fruiting of the cranberry. It is for these reasons chiefly that no exact dates can be given for the various stages in the phenology of the cranberry in that region.

An attempt has been made, however, after a long series of frequent observations, to determine as closely as possible the approximate dates when these stages occur in their greatest abundance. These dates are presented, therefore, in Table 1 for the earliest growing varieties, such as Early Black and McFarlin, and for the latest-growing varieties, such as Howe. There seems to be considerable variation in the growth of the varieties belonging to these two classes, the height of each stage in the growth of the latest varieties generally coming a month after that of the earliest varieties.

TABLE 1.—*Phenology of the cranberry on unflowed bogs on the Pacific coast, based on observations at Seaview, Wash., 1918 and 1919.*

Stage of development.	Approximate date of occurrence of the height of each stage on—	
	The earliest varieties.	The latest varieties.
Buds breaking and new growth beginning to push forth	Apr. 6	May 7
New upright growth ½ inch to ¾ inch long	Apr. 10	May 14
Blossoms in "hook stage"	May 12	June 14
Vines in full bloom	June 9	June 30
Blossoms falling and berries setting	June 30	July 30

Such local influencing conditions as depth of vines, depth of the underlying peat, or protection from the strong northwest wind which commonly blows during much of the early growing season will, of course, cause wider local variations than those here given. The limits of each phenological stage are even more variable than the height, it being not uncommon, for instance, to find blossoms on some vines as early as May 12 and on others, many not yet fully opened, by July 15. An early spring, too, would have the effect of somewhat advancing the dates given in this table and a late one would probably delay the early stages a little, but the later stages, such as blooming and setting of berries, would probably be delayed to a less extent.

INTRODUCTION OF THE BLACKHEAD FIREWORM INTO THE NORTHWEST.

Although the blackhead fireworm is found on the wild cranberry [3] as far as 2 miles from any cultivated vines, the severest infestations in Washington and Oregon are on bogs planted originally with vines from Wisconsin, New Jersey, and Massachusetts. A study of the history of the cranberry industry on the Pacific coast and of the

[3] Specimens growing wild in southwestern Washington were submitted to Dr. F. L. Pickett, of the Washington Agricultural Experiment Station and were determined by him as the common western cranberry, *Oxycoccus* (*oxycoccus*) *intermedius*, with the following note: "This is a little coarser than the small cranberry of the East, and bears slightly larger berries."

origin of the cuttings used furnishes convincing evidence that large numbers of the eggs of this pest were brought into this region on the leaves of cuttings from bogs in these three States. These cuttings, principally from Massachusetts bogs, were used extensively in planting a large number of bogs set out in Washington and Oregon between 1912 and 1915, which was about the time the blackhead fireworm became a pest of considerable importance in the regions from which these cuttings were imported.

After the newly planted bogs had made sufficient growth, it was the practice to mow them and use the cuttings thus obtained to plant other areas, as these cuttings could, of course, be obtained at less cost and in better condition than those from the East. So, helped in this way, the blackhead fireworm spread over practically the entire region. Once established on a bog it was a matter of only a few seasons until this pest had overrun nearly every part of it and caused considerable damage almost before the owner was aware of its presence.

DISTRIBUTION.

The blackhead fireworm is found on nearly every cranberry bog on the Pacific coast. It has long been a pest of the cranberry in New Jersey, Massachusetts, and Wisconsin, where it now causes as much damage as any other cranberry pest and often more. According to Fernald,[4] it has also been found on the cranberry in New York and California.

FOOD PLANTS.

Numerous small larvæ resembling very closely in appearance those of *Rhopobota naevana* were found feeding on some common bog plants, such as "buck brush"[5] and "sweet gale."[6] None of these proved to be the blackhead fireworm; and, so far as known on the Pacific coast, *Rhopobota naevana* feeds only on the cranberry, both native[7] and cultivated.[8]

DESTRUCTIVENESS.

The injury to the cranberry by the blackhead fireworm is caused by the feeding of the larvæ, or worms, on the buds, foliage, blossoms, and fruit throughout the growing season. It is very characteristic and quite unmistakable; there is no other pest of the cranberry on the Pacific coast the work of which is similar in all respects

[4] Fernald, C. H. A Synonymical Catalogue of the Described Tortricidae of North America North of Mexico. *In* Trans. Amer. Ent. Soc., v. 10, p. 48. 1882.

[5] Specimens of this plant were identified as *Spiraea douglasii* by Dr. F. L. Pickett, of the Washington Agricultural Experiment Station.

[6] Also identified by Dr. Pickett as *Myrica gale*. "It belongs to the bayberry group."

[7] *Oxycoccus (oxycoccus) intermedius*, the common western cranberry.

[8] *Oxycoccus macrocarpus*, the common cultivated cranberry.

to that of the blackhead fireworm, nor has the cranberry there any other pest which annually destroys so much as this one.

The young larvæ start to feed on the newly growing tips shortly after they hatch, in the months of April and May, and continue their work throughout the growing season, attacking in greater or less severity the buds, blossoms, and later the berries, injuring the berries by boring into them and causing them to shrivel and dry and often to fall from the vines. The most noticeable feature of the attack of the fireworm during the middle or latter part of the summer is the burnt appearance of the vines which results from the work of this insect, suggesting the name fireworm. Since the terminals are most affected, few if any fruit buds are set when the vines are badly infested, and as a result nearly all the crops of the current season and of the following year are destroyed by the feeding of the larvæ during a single season. The vines, while never completely killed, are very much stunted and by the end of the summer are left stripped of the majority of the leaves. They are often brittle, and in the case of long-standing infestation are short and scrubby with numerous short and crooked branches as a result of being prevented from making a natural terminal growth. From this condition they do not usually return to their normal productiveness until good control work has been in force for several years.

NUMBER OF GENERATIONS.

By rearing the insect from the winter egg stage in an outdoor shelter it was found that it passes through two generations and sometimes a partial third. For example, the hatching of the winter eggs starts the first generation, and the resulting larvæ which change into pupæ and moths also belong to the first generation.

The eggs that these moths lay start the second generation. Contrary to the behavior of this pest in the East, only about four-fifths of these eggs hatched to form a second generation the same season in which they were deposited. The remaining one-fifth did not hatch until the following spring.

All the eggs deposited by the moths resulting from the second set of individuals are known as the eggs of the third generation. So far as is known, in eastern cranberry regions the eggs of this generation do not hatch until the following spring. On the Pacific coast, however, it was found that about one-third of the eggs of this generation hatched late in the summer, forming a third generation of larvæ. Because of adverse weather conditions toward the latter part of the season, none of these larvæ developed into pupæ and moths. This generation is therefore called a partial or incomplete generation.

DESCRIPTION OF STAGES AND HABITS.

THE EGG.

The egg of the blackhead fireworm is smooth, slightly elliptical, with the center partially raised and rounded. It measures approximately 0.65 millimeter wide, or about the size of the head of a very small pin. When first laid it has a slight opalescent sheen and a light lemon-yellow color which changes to a deeper yellow in about two weeks. The hatched egg is more inconspicuous, being transparent and appearing much like a small drop of albumin which has dried on the leaf. (Fig. 1.)

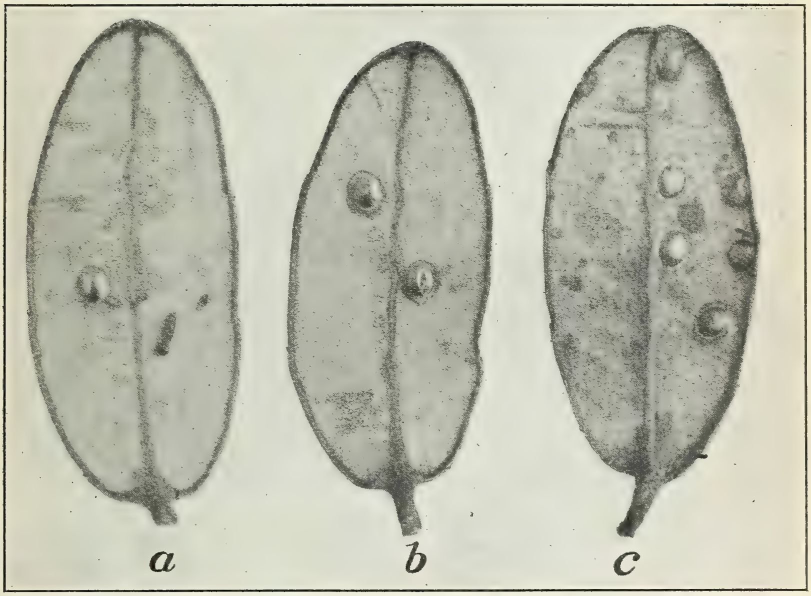


FIG. 1.—Eggs of the blackhead fireworm moth on the undersides of the cranberry leaves, enlarged 7.5 times: *a*, Winter eggs; *b*, eggs in the "black-spot" or first stage of development; *c*, hatched eggs.

HIBERNATION.

The eggs are laid by the parent moth singly or in groups on the underside of the cranberry leaves; rarely, a few eggs will be found deposited on the upper surface of the leaves. On the badly infested bogs as many as 10 or 12 eggs may be found on the underside of a single leaf. The majority of the wintering eggs are usually deposited on the leaves on the lower portions of the vines, the short, low uprights near the ground generally containing the greatest number of eggs. During picking season and the following winter, many of these leaves are dislodged from the vines, and it is not an uncommon thing to find them on the bog floor bearing numerous eggs. An infestation may easily be distributed from one part of a bog to another by these leaves drifting from place to place over the bog in and on the water which sometimes collects during the winter time. Instances were noted in which numerous egg-bearing leaves had been washed into a corner of a bog, where they almost covered the vines. These eggs, being the first affected by rising temperatures, were the first to hatch in the spring, and the young larvæ had almost completely destroyed the surrounding uprights before eggs elsewhere in the bog had hatched.

Incubation and Hatching.

The first signs of incubation are noted as the black head and thoracic shield of the developing larva begin to show through the chorion or eggshell. As development progresses the young larva may be seen to move within the egg and finally, as it grows in vigor, to rupture the egg wall at a point over its mandibles and gradually escape by means of a wriggling sidewise motion through this slitlike opening, which is near the top of the upper surface of the egg. (Fig. 1, *b*, *c*.) It usually takes from about 3 to 5 minutes for the larva to free itself entirely from the eggshell.

Factors Influencing Hatching and Development.

(*a*) *Temperature.*—Temperature has the greatest influence on the fireworm eggs as well as on the other stages. This varies more than is generally supposed among different bogs, depending upon location.

(*b*) *Depth of vines.*—Another very important factor which tends to retard or hasten development of fireworm eggs is the depth of the vines in which they are deposited. A bog with thin vines will warm up more readily in the spring and maintain a higher temperature generally throughout the season than a bog with rather thick vines. Observations show, for instance, that on bogs with thin vines, hatching generally starts during the first warm days of spring (sometimes late in March or in early or mid-April), reaches its maximum early (say towards the latter part of April), and produces moths in maximum numbers in the middle or late part of June. On a thickly vined bog, in the same locality, however, and under similar conditions of temperature and moisture, hatching, while it may start about the same time as it does on the thinly vined bog, will be only desultory until the vines have warmed up considerably. Hatching in maximum numbers may not take place then until the middle or latter part of May. This in the absence of a winter flooding distributes hatching, on bogs with a medium or heavy growth of vines, over a considerable period.

(*c*) *Drainage.*—During the winter or rainy season more or less water usually accumulates on the majority of the cranberry bogs on the Pacific coast. On those which are not quickly and easily drained this winter water remaining on the bog late in the spring causes the vines and the fireworm eggs to be rather slow in developing, with a consequent grouping of the hatching and development of the first generation of larvæ.

THE LARVA.

The newly-hatched larva of the blackhead fireworm (fig. 2, *a*) is about 0.1 mm., or a little over one-thirty-second of an inch in length; at first it has a pale yellow color which turns to a darker yellow with age, and has a relatively large dark brown or black head, accentuated by the thoracic shield, the first segment back of the head, which is nearly as dark as the head; hence the name "blackhead."

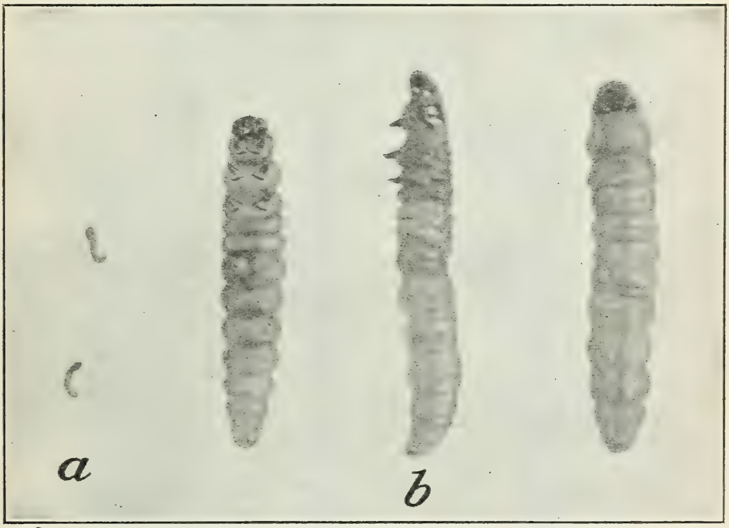


FIG. 2.—The blackhead fireworm: Views of the larva, enlarged 7.5 times: *a*, Newly hatched larvæ: *b*, dorsal, lateral, and ventral views of full-grown larvæ.

When fully grown (fig. 2, *b*) the larvæ measure about 6.5 mm., or about one-fourth inch in length, and are dark greenish yellow with a coat of darker olive green above. The head and thoracic shield are black. The larvæ are very active from the time they are about one-fifth to one-fourth grown and vigorously wriggle from their galleries when disturbed, falling to the ground and quickly concealing themselves among the trash and leaves beneath the vines by a characteristic sidewise and backward movement of the body. They are provided with three pairs of thoracic legs, four pairs of abdominal legs, and one pair of anal legs. Depending upon the weather and the time of the season, the blackhead fireworm spends from 10 to about 75 days in the larva state.

Feeding Habits.

A newly hatched larva begins feeding shortly after it leaves the egg, but may wander about for from 15 minutes to half an hour before taking any food. It usually starts feeding on the underside of the leaves, generally near the eggshell from which it has just emerged. At first it bites into the epidermis of the leaf, and, mixing the nibblings with the thread of silk which it spins continuously from several points beneath its lower lip, soon covers itself with a

Fig. 3.—The blackhead fireworm: Characteristic work of the newly hatched larvæ on the underside of cranberry leaves.

greenish brown material which has the appearance of fine sawdust. For a time it continues to chew into the leaf, feeding principally between the upper and lower surfaces, acting in many respects like a leaf-miner. (See fig. 3.) This is particularly characteristic of the early-hatched larvæ of the first generation. The larvæ of this generation which hatch later, and usually those of later generations hatched in warmer weather after the new growth is well out, proceed almost directly to the tip, spending very little time as leaf-miners.

Depending upon the prevailing temperature and the condition of the weather at this time, the young larva in a somewhat dormant condition spends two weeks, more or less, in its burrow, feeding only when the weather is warm and favorable. If the weather is warm it will be quite active and may stay in its burrow only two or three days. On badly infested bogs it is a common thing to find the underside of the lower leaves on the vines badly chewed and full of burrows. The majority of instances of this type of injury are doubtless caused by the larva hatching early in the spring before the bogs have become sufficiently warm to permit active feeding, and also by those hatching late in the fall, as is often the case on account of the bogs being exposed to the weather the year round.

At the approach of warm weather, or after the young larva has grown larger and stronger, it leaves its burrow and proceeds toward the tip of the upright. Here, if the weather should turn cool, it starts to feed in the whorl of leaves about the terminal fruit bud and incloses itself in a loosely constructed web of frass and silk, either between two terminal leaves or between the bud and the adjoining leaf, where it awaits more favorable conditions which may cause the terminal bud to break and grow. As these conditions become intensified the larva proceeds to web up the unfolding leaves as it feeds on and skeletonizes them from within. From about the latter part of May or the beginning of June this injury is noticeable to the casual observer, many of the short, new uprights assuming a withered and bent-over appearance at the tip, similar to those shown in the accompanying illustration (fig. 4).

As the weather becomes warmer and the vine growth increases the fireworms, the majority of which at this time (about early June) may be nearly one-half to three-fourths of an inch long, feed rapidly on the leaves in their web galleries, gradually extending them or moving to an adjacent tip or upright as new food is needed. The vines gradually assume the characteristic dried, light yellow-brown appearance, and as feeding continues the bog begins to look as though a fire had swept over it, scorching the tips of the vines, which by midsummer are dry, reddish brown, and often nearly leafless; whence the name "fireworm."

On a vigorously growing bog the late-hatched larvæ of the first generation often feed upon the unfolding blossoms and newly formed berries, sometimes causing them to drop from the vines. In their feeding the young larvæ frequently burrow into the blossoms at a point near the base of the petals and feed on the floral organs within, or they may bore into the ovary directly from the outside. This feeding is first noticed about the time when the blossoms are in the "hook stage" or about the beginning of June on the early bogs. At this time a few very small larvæ usually may be seen eating into the blossoms or berries, as described above; later on, both large and small larvæ may attack the berries, eating into them where the berries touch one another or the leaves or an adjoining upright. (See fig. 5.)

The second generation of worms makes its appearance in considerable numbers the latter part of July. These larvæ not only feed upon the foliage, like those of the first generation, but they also web it up more, feed longer, and move from place to place much oftener than do the larvæ of the first generation. Especially on bogs

FIG. 4.—The blackhead fireworm. Early work of the larvæ in the tips: *a*, Entire new tip destroyed; *b*, showing how the tip leaves are webbed together; *c*, an uninjured upright.

making little new growth they may extend their feeding to the old foliage, including many of the old uprights in their webs. In addition, many of them may also feed extensively throughout the remainder of the season on berries of all sizes. It does not seem to make much difference whether the berries are webbed up or not; in fact, the majority of the berries attacked are not webbed up at all. (See fig. 5.) The injury done by the second generation of larvæ is, therefore, very striking. The third generation of worms is not very distinct from the second and not quite so numerous; but occurring later in the season, when the vines are maturing, these larvæ feed principally on the berries, and therefore do more immediate damage to the crop if any remains on the vines.

The result of the work on all three generations is not only the destruction of the current season's crop or its material reduction but also the loss of a considerable proportion of the crop the following year, the setting of fruit buds being largely prevented by the attack of the larvæ on the terminals. It will thus be seen that the fireworm in one season can very materially reduce the cranberry crop of two seasons.

Fig. 5.—The blackhead fireworm: Injury of the larvæ to the berries. The large berry on the upright is uninjured.

Place of Pupation.

After the larvæ have reached their full growth they usually leave the webbed uprights and descend to the trash and leaves beneath the vines, where they inclose themselves between several old leaves in more or less loosely constructed cocoons, typical specimens of which are shown in figure 6. Sometimes, however, especially in the case of the larvæ of the first generation, some may spin themselves up within a thin cocoon in the tips of the uprights, as shown in figure 7. Very often some larvæ, after feeding in a cluster of berries, will spin their cocoons and also pupate on the inside of one of them, or they may fasten their cocoons between the berries, mixing their silk with frass and any skeletonized leaves available. This is commonly true of the larvæ of the second generation. It is not very unusual, therefore, to find some berries with the empty pupa cases protruding from a hole in the side. The great majority of the larvæ of all generations, however, descend to the ground to pupate.

The Cocoon.

As previously referred to, the cocoon of the blackhead fireworm is composed of strands of silk which the larva fastens to any surrounding objects, as frass, leaves, or berries, and more or less loosely draws

Fig. 6.—The blackhead fireworm: Typical cocoons formed out of dead cranberry leaves beneath the vines. The ones in the top row have been opened to show the interior; those in the lower row show the empty pupa cases protruding. All slightly enlarged.

about itself preparatory to pupation. The interior of the cocoon is shown in figures 6, 7, and 8. It is in cocoons similar to these that the larvæ pass through a resting period followed by a final molting of the larval skin. This resting and molting, during which the pupa or chrysalis is formed, is called pupation.

THE PUPA.

The pupa or chrysalis of the fireworm is about 5.5 mm. or a little less than one-fourth inch long by 1.5 mm. or about one-sixteenth inch wide, and of a light amber yellow color immediately after casting the larval skin. This color soon changes to a deeper amber brown, and in pupæ about to change to adults the color is a very deep amber approaching almost black. The pupæ are not usually encountered without a rather close examination of the leaves and trash beneath the vines in which, as already mentioned, most of the individuals of all generations pupate. (See fig. 8.)

The pupæ wriggle considerably when first picked up, moving the end of the abdomen in a circular motion, but they have no power of locomotion such as the larvæ have. Just before the moth is ready to emerge, and in order that it may do so without hindrance, the pupa,

FIG. 7.—The blackhead fireworm: Pupa in cocoon spun in a tip of a cranberry upright. Enlarged 6 times.

by means of this wriggling motion and with the aid of a number of small backwardly directed spines arranged in double rows around the back of each segment of the abdomen, forces itself out through the end of its loosely spun cocoon until the thorax and the tips of the wing pads are free of the edge of the cocoon. (See last specimen at right in lower row of fig. 6.)

The duration of the pupa stage varies from 10 to about 65 days, depending upon the weather and the time of the season.

THE ADULT.

The adults, or moths, of the blackhead fireworm are conspicuous because of their habits of flight; when disturbed they often rise in very large numbers. Upon close examination they are found to be small in size, measuring in length from the tip of the head to the tip of the wing on the average about 6 or 7 mm., a little over one-fourth of an inch, or about the same length as the mature larvæ. With the wings spread they measure about 10 mm. across, or a little over three-eighths of an inch.

The moths (fig. 9) differ somewhat in color, seeming to vary especially according to age. The first pair of wings of freshly emerged

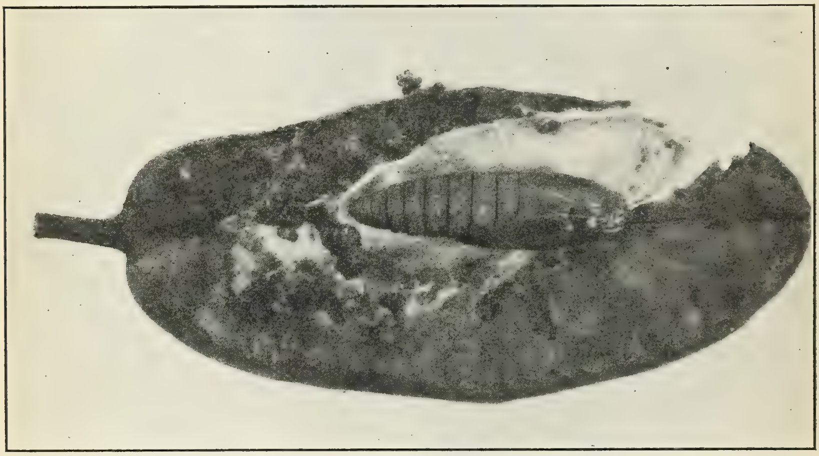


FIG. 8.—The blackhead fireworm: View of pupa and interior of cocoon. Enlarged about 7.5 times.

and unrubbed specimens have a ground color above of deep silver gray, with irregular markings of brown, which often give them a golden-brown sheen. Characteristic markings of a single row of short alternating brown and silver-gray bars running diagonally to the front margin are found on the first or upper pair of wings. The second or lower pair of wings of the female are without characteristic markings; those of the male have an irregular dark spot on the underside near the front margin. The second or lower pair of wings of both male and female have a fringe of long, bristlelike scales extending from near the tip along the back margin to the body. The abdomen is medium and slender, depending on the sex, female specimens having a somewhat broader and shorter abdomen than the males. The abdomen and the legs are covered with dark silver-gray scales, which often have a light golden-brown sheen. The antennæ are about one-half the length of the body and more or less bristlelike.

The adults live from 3 to 33 days after they emerge, and during this time eat little or nothing, except, perhaps, a little nectar from the blossoms, or water in the form of dew or rain.

Habits of Flight.

After the moth emerges from the pupal case it rests for a short time, during which the wings are spread and dried. It then starts to fly and moves rather swiftly in a short, jerky, darting motion, making usually only short flights from place to place over the vines. Particularly on heavily infested bogs the moths are very conspicuous for their habits of flight. They will often be seen to rise in large numbers when disturbed, as by spraying or by a person walking through the vines on a warm afternoon, suggesting to some the appearance of a cloud.

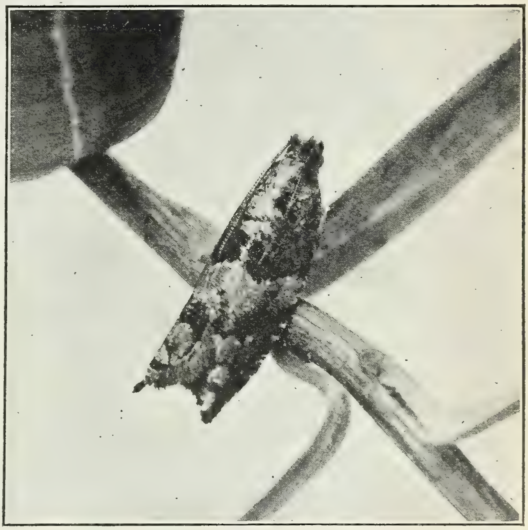


Fig. 9.—The adult or moth at rest on a cranberry upright. Enlarged about 6 times.

Periods of Activity.

A few moths may generally be seen flying from tip to tip almost every hour of the day from the time of their first appearance in June until late in September and October, but the time of day they are most active is from about 3 o'clock in the afternoon until after dusk. During this period, especially if the weather is warm, they may be seen to rise in the air for a few feet, making their characteristic short, jerky flights.

Migration.

It is in the moth stage principally that the blackhead fireworm spreads itself over the bog or invades an adjoining one. The moth, however, flying only short distances, would not naturally migrate more than several yards from its original region of activity; but, helped by the wind, it is possible for it to be carried as far as several hundred feet in one flight, and it is thus that bogs neighboring badly infested ones, especially to the leeward, may become badly infested in a few seasons.

Other ways in which the fireworm is disseminated over a bog have been mentioned, namely, in the egg state, on leaves floating over the bog in the winter water (p. 7–8), and also on cuttings (p. 4–5).

Proportion of Sexes.

In 1918, of 158 moths of the first generation emerging in the insectary, 81, or 51 per cent, were males, and 77, or 49 per cent, were females; of 59 moths of the second generation, 24, or 41 per cent, were males, and 35, or 59 per cent, were females. In 1919, of 101 moths of the first generation emerging in the insectary 53, or about 52 per cent, were males, and 48, or about 48 per cent, were females; of 52 moths of the second generation 24, or 46 per cent, were males, and 28, or 54 per cent, were females. This shows a slight predominance of males over females in the first generation and the opposite in the second generation.

Copulation.

Copulation usually occurs shortly after emergence. Of those pairs observed in the rearing shelter, one was found copulating the same day it emerged, two the day after emergence, and one pair did not copulate until 7 days after emergence. The same pair was never seen to copulate more than once.

The period of copulation varies in length, the minimum period observed being 1 hour and 26 minutes and the maximum 26 hours and 55 minutes. The male of one pair observed was noted dead and still attached to the female 3 days after copulation was first observed.

Oviposition.

Egg-laying commences shortly after copulation, usually within a few days. During oviposition the female rather quickly pushes the egg out through the tip of the abdomen, which she holds very close to the underside of the leaf. Here the egg, a soft, plastic drop, settles over the surface and soon assumes its ordinary flat, oval shape. The outermost covering, which is rather moist when the egg is first laid, dries and cements the egg to the leaf and gives it its appearance of being glued on. (See fig. 1, *a*.)

Time of Day When Oviposition Occurs.

Eggs may be laid at almost any hour of the day and evening when the weather is warm and fair. However, in order to determine the time of day when the moths were depositing eggs in largest numbers, 32 males and 42 females of the first generation were collected from a cranberry bog on July 15, 1918, and immediately confined as follows in three battery jars 9 inches high by 5 inches wide: Jar No. 1 contained 12 males and 12 females; jar No. 2, 10 males and 12 females; jar No. 3, 10 males and 18 females. Each jar was provided with a few inches of slightly moist sand on the bottom, an abundance of clean cranberry uprights, and a sponge moistened with a weak solution of sugar and water for food and moisture,

Every 3 hours from 2 a. m. to 9 p. m. daily until July 20 the uprights in each jar were replaced with fresh ones and the eggs on them and on the side of the jar counted and recorded. The sponge was also moistened daily.

The number of eggs found deposited at each examination is summarized in Table 2. As will be noted therein, eggs were laid during every period between examinations, but the largest number of eggs was deposited between 3 p. m. and 9 p. m., 663, or 39.6 per cent of the total, being deposited between 3 and 6 p. m., and 650, or 38.8 per cent, between 6 and 9 p. m. The smallest numbers were deposited in the 12-hour period between 9 p. m. and 9 a. m. It will be noted further that the time of day during which eggs were deposited in largest numbers is also the period of greatest activity on the bog.

TABLE 2.—*Number of eggs of blackhead fireworm moth deposited every 3 hours from 6 a. m. to 9 p. m. by moths of the first generation confined in battery jars; Seaview, Wash., July 15 to 20, 1918.*

Period of deposition.	Number of eggs deposited.	Per cent of total deposited.	Period of deposition.	Number of eggs deposited.	Per cent of total deposited.
9 p. m. to 6 a. m.	78	4.6	3 p. m. to 6 p. m.	663	39.6
6 a. m. to 9 a. m.	8	.5	6 p. m. to 9 p. m.	650	38.8
9 a. m. to 12 noon	67	4.0			
12 noon to 3 p. m.	209	12.5	Total	1,675	100.0

The number of eggs found deposited at each examination is shown in graphic form in figure 10, together with a curve showing the hourly temperature during the period of the experiment. Attention is here drawn to the influence of the temperature on egg-laying. It will be noted that the largest number was deposited between 3 and 6 p. m. on July 16, a few hours after the highest temperature, namely, 75° F., was recorded.

SEASONAL HISTORY.

It was noted that larvæ of the first generation appeared in greatest abundance on the bogs about the latter part of May, the pupæ toward the middle of June, and the moths about the first or second week in July.

Because of the overlapping of the generations, one can scarcely do more than speculate as to the date of occurrence of the stages of the second and third generations on the bogs; and the latest dates of the occurrence, particularly of the moths of the first generation and all the stages of the second and third generations, could only be obtained, therefore, by rearing methods.

NATURAL ENEMIES.

PARASITES.

INSECTS.

Although numerous very small wasplike insects (members of the order Hymenoptera) can be seen flying over the tops of the vines on

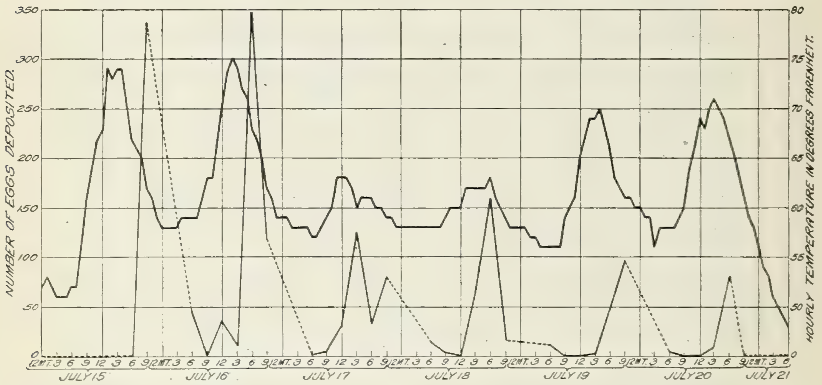


FIG. 10.—Egg deposition by blackhead fireworm moths of the first generation. Records every three hours from July 15 to 20; Seaview, Wash., 1918.

badly infested bogs on warm, clear days, none of these could be reared from collections of the eggs and larvæ of *Rhopobota naevana* from various bogs. Circumstances indicate very strongly, however, that the blackhead fireworm on the Pacific coast is parasitized, to a certain extent at least, although not as much as on some dry cranberry bogs in the East.

FUNGOUS DISEASE OF THE PUPÆ.

From about the beginning or middle of August it is very common to find, especially on the older and more badly infested cranberry bogs, areas of 3 to 5 inches or more in diameter of old leaves beneath the vines which have the appearance of being smeared with a floury-white substance. Closer examination of these areas will show that this whitish appearance is due to the fruiting growth of a parasitic fungus,[9] which attacks and kills the pupæ concealed in their cocoons in these old leaves. This fungus is shown growing from the

[9] Determined by Dr. A. T. Speare, of the Bureau of Entomology, as a species of Spicaria.

cocoon in the lower row of specimens in figure 11. The specimens in the top row have been dissected from the loosely constructed cocoons and show the fungous disease growing on the pupæ.

While this disease certainly causes the death of a large number of pupæ on bogs where it is prevalent, not too much reliance should be placed on it in the control of the fireworm, since the greatest part of the damage by the fireworm is done to the vines before the time when the fungous disease is growing rapidly. The weather also may or may not be favorable to its rapid growth, and hence its killing power and spread are likely to vary considerably from one season to another.

FIG. 11.—Fungous disease, a species of Spicaria, growing from the blackhead fireworm pupæ in their cocoons. Slightly enlarged.

PREDACIOUS ENEMIES.

SPIDERS.

On the cranberry bogs of the Pacific coast spiders of various kinds are found in very large numbers and doubtless devour many fireworm larvæ and moths.

INSECTS.

A large number of "ladybugs" are also seen on cranberry bogs, and their presence there sometimes causes alarm to a grower who is not familiar with their habits. One species, the California red ladybird beetle,[10] is very common, and both larvæ and beetles can be seen actively walking over the tips of the cranberry uprights any

[10] Specimens determined by Mr. E. A. Schwarz, of the Bureau of Entomology, as *Coccinella californica* Mann.

time throughout the summer. The ladybird beetles, with few exceptions, are beneficial insects; the adults of this species have been observed to feed readily on the larvæ of the blackhead fireworm in captivity, and in the field doubtless consume large numbers of this insect.

CONTROL EXPERIMENTS.

Since most of the cranberry bogs on the Pacific coast can not be provided with a sufficient supply of water for use in control work, insect pests on these bogs should be combated largely by the application of insecticides in the form of a liquid spray. This method seems especially desirable against the fireworm after a study of its habits and methods of feeding. It may also be necessary to do more or less spraying for certain fungous diseases at various times throughout the season, and some of the dates for these applications may correspond to a great extent with the time of application in the control of the fireworm. The grower, therefore, can combine the materials used for the control of the fireworm with those necessary for fungous diseases whenever the times for these two applications coincide, and thus save the expense of separate applications.

All the control experiments against the blackhead fireworm were arranged, therefore, so as to include tests under actual bog conditions of several methods of spraying the eggs, larvæ, and adults with a number of promising insecticides, both with and without spreaders, at various times throughout the season. These sprays were applied by the types of nozzles shown in figures 12, 13, and 14, all the tests being so planned as to shed some light on questions concerning the number of applications, the best materials to be used, the amount of spray material which should be used per acre, and the most effective manner of applying it.

MISCELLANEOUS SPRAYING EXPERIMENTS.

In Table 3 is given an outline and the results of the miscellaneous spraying experiments conducted on Howe vines on the Portland-Seaview Cranberry Co. bog at Seaview, Wash., in 1919. Very similar experiments were performed on this bog in 1918, but the severe infestations previous to that season had so reduced the bearing power of the vines that few blossoms were set in 1918, and the results therefore were not wholly dependable. They showed, however, a decided increase in control by the use of insecticides combined with spreaders, such as soap or glue, as compared with the same insecticides applied without the addition of these wetting agents. They also suggested that a solution of 40 per cent nicotine sulphate, used at the rate of 1 part to 1,000 parts of water, with the addition of fish-oil soap at the rate of 2 pounds to 50 gallons and applied at the rate of about 300 gallons per acre, might be just as effective as the same kind of a solution in which the nicotine was used at the rate of 1 part to 800 parts of water and applied at the rate of about 200 to 250 gallons per acre.

The miscellaneous spraying experiments conducted on this bog in 1919 were therefore planned in the light of the results of the previous season.

Time and Number of Applications.

The odd-numbered plats, I to XV inclusive, received 3 applications on the dates shown in Table 3. The first application (May 13 and 14) was made to catch the largest possible number of small larvæ in and near the tips of the uprights before they had a chance to web up the new unfolding leaves. The new growth at this time was approximately three-fourths of an inch long. The second application, June 12, was made to kill the next lot of larvæ hatching after the first application and came about the time when the majority of the blossoms were in the "hook stage." In order to catch the late-hatching larvæ the third spraying was made July 1 and 2 as the vines were approaching full bloom. The even-numbered plats, from II to XVI inclusive, and plat XVII, received in addition to these applications just described one more application (July 16 and 17) about the time the moths were flying on this bog in greatest abundance. The purpose of this fourth application was to kill these moths and also any larvæ which had moved into the tips at this time.

While the frosts of May 4, 5, and 6 somewhat reduced the crop on nearly all the plats, the comparative results, as obtained by the examination of the berries from 3 circular areas of about 100 square inches, each picked at random over each of the plats, strengthen the observations made of these plats at various times throughout the season.

Table 3.—*Outline of miscellaneous spraying experiments in the control of the blackhead fireworm on the Portland-Seaview Cranberry Co. bog at Seaview, Wash., 1919.*

Plat No.	Spray materials, dosage, etc.	Number of gallons used calculated per acre per application.					Total number of berries examined.	Total number of berries free from injury.	Gain over check.
		May 13 and 14.	June 12.	July 1 and 2.	July 16 and 17.	Average per application.			
								Per cent.	Per cent.
I	40 per cent nicotine sulphate, 1-1,000+fish-oil soap, 2-50	380	300	320	....	333	388	92.52	15.50
II	40 per cent nicotine sulphate, 1-1,000+fish-oil soap, 2-50	380	300	320	480	370	402	95.52	18.50
III	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50	330	280	280	....	297	735	93.74	16.72
IV	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50	330	280	280	480	342	737	97.42	20.40

TABLE 3.—*Outline of miscellaneous spraying experiments, etc.*—Continued.

Plat No.	Spray materials, dosage, etc.	Number of gallons used calculated per acre per application.					Total number of berries examined.	Total number of berries free from injury.	Gain over check.
		May 13 and 14.	June 12.	July 1 and 2.	July 16 and 17.	Average per application.			
								Per cent.	*Per cent.*
V	40 per cent nicotine sulphate, 1-600 + fish-oil soap, 2-50	295	270	270	....	278	820	91.21	14.19
VI	40 per cent nicotine sulphate, 1-600 + fish-oil soap, 2-50	295	270	270	500	333	485	94.22	17.20
VII	Powdered arsenate of lead, 2½-50+fish-oil soap, 2-50	340	300	260	....	300	401	83.04	6.02
VIII	Powdered arsenate of lead, 2½-50+fish-oil soap, 2-50	340	300	260	450	337	172	76.16	.96
IX	Nicotine oleate, 1-300	295	270	270	....	278	433	91.45	14.43
X	Nicotine oleate, 1-300	295	270	270	320	289	862	91.99	14.97
XI	40 per cent nicotine sulphate, 1-800+glue, 1-200	290	280	310	....	293	703	83.64	6.62
XII	40 per cent nicotine sulphate, 1-800+glue, 1-200	290	280	310	620	375	600	86.16	9.14
XIII	Nicotine oleate, 1-400	300	320	350	....	323	1,012	92.29	15.27
XIV	Nicotine oleate, 1-400	300	320	350	660	407	1,061	91.42	14.40
XV	Nicotine oleate, 1-500	330	380	320	....	343	793	87.64	10.62
XVI	Nicotine oleate, 1-500	330	380	320	600	407	827	92.38	15.36
XVII	"Phenol compound" No. 1, 1-500	420	560	320	560	460	628	73.56	3.46
XVIII	Check, untreated	....	....	....	....	....	74	77.02	....

NOTE.—Mist nozzles as shown in figure 13 used for all applications, with hand barrel spray pump giving pressure of 50 to 100 pounds.

NICOTINE SULPHATE.

The conclusions drawn by Scammell [11] regarding the effectiveness and safety of 40 per cent nicotine sulphate in the control of the blackhead fireworm were borne out in the work on the Pacific coast. Of the various strengths used, 1 part to 800 parts of water with 2 pounds of fish-oil soap to each 50 gallons of solution, applied 4 times, seemed to give the highest percentage of cranberries free from fireworm injury; it will be noted in Table 3, however, that 4 applications of this material, used 1 to 1,000, gave nearly as great a gain over the check. The fact that it gave a higher percentage of clean fruit than 1 to 600 was probably due to the fact that there was a larger setting of fruit on this plat and perhaps a somewhat lighter infestation than on the one treated with the solution of the strength of 1 to 600.

NICOTINE OLEATE.

Nicotine oleate was made by stirring together the proportions of a 40 per cent solution of free nicotine and oleic acid according to the directions given by Moore [12] as follows:

[11] Scammell, H. B. A New Method of Controlling the Blackhead Fireworm. *In* Proc. 47th Ann. Conv. Amer. Cranberry Growers' Assn. (Aug. 26, 1916), p. 8–12; Cranberry Insect Problems and Suggestions for Solving Them, U. S. Dept. Agr., Farmers' Bul. 860, p. 4–9, 1917.

[12] Moore, William. A Promising New Contact Insecticide. *In* Journ. Econ. Ent., v. 11, no. 3, p. 341–342, 1918.

Two and one-half parts of a 40 per cent nicotine solution unites with $1\frac{3}{4}$ parts of commercial oleic acid or red oil. Four and one-fourth parts of this soap will then contain 1 part of nicotine or will equal $2\frac{1}{2}$ parts of the 40 per cent nicotine solution.

It will thus be seen that nicotine oleate is a *nicotine soap* made from a fatty acid and nicotine; as such it has the spreading properties of a soap and in addition it is a contact insecticide which can generally be used in place of the ordinary 40 per cent nicotine sulphate and soap solution for cranberry spraying. It could not be mixed, however, with *hard water* or combined with Bordeaux mixture or any other alkaline solutions; and since it takes $4\frac{1}{4}$ parts of the nicotine oleate to equal in nicotine content $2\frac{1}{2}$ parts of the 40 per cent nicotine solution, *about twice as much nicotine oleate as 40 per cent nicotine sulphate* had to be used to equal one part of the latter.

A spray material of this character, which has combined in it both soap and nicotine, would greatly facilitate the control of the fireworm, if not materially reduce the cost, wherever its use is practicable. Solutions of the strengths used seemed to spread equally well over the cranberry foliage. As shown in Table 3, it was used at the rate of 1 part to 300 parts of water, 1 to 400, and 1 to 500, about equal, respectively, to 1 to 600, 1 to 800, and 1 to 1,000 of the 40 per cent nicotine sulphate formulas. Both three and four applications were made of each strength. The largest percentage of fruit free from fireworm injury seemed to be obtained where nicotine oleate was used at the rate of 1 to 500 and applied four times. There is very little difference between the results of this plat (plat XVI) and those secured on plat XIII where nicotine oleate 1 to 400 was applied three times. This is partly explained by the fact that the fireworm infestation was more thinly scattered over the former plat than over the latter. The results where nicotine oleate was used at the rate of 1 to 300, while apparently very satisfactory, are not so good, considering all factors, as where it was used at the rate of 1 to 400.

Arsenate of Lead.

As in 1918, arsenate of lead proved to be of little or no value in the control of the fireworm, the foliage being badly eaten and nearly all the berries destroyed by the worms, even where four applications were made with the addition of soap.

Wetting Agents or "Spreaders."

That the presence in the spray liquid of some material like soap, which will make it wet or spread over the smooth, waxy foliage of the cranberry, seems to make considerable difference in the control results obtained was plainly shown by the preliminary experiments of 1918 previously referred to. In 1919, therefore, a comparison of the kinds of spreaders was made and in these tests glue, 1 pound to 200 gallons, and nicotine oleate at the strengths mentioned above were checked against fish-oil soap, 2 pounds to 50 gallons. As will be observed in Table 3, the use of glue gave the poorest control of the three groups of plats III and IV, XI and XII, and XIII and XIV, in all of which the strength of the nicotine was approximately the same; nicotine oleate was next; and fish-oil soap, 2 to 50, gave the best results.

Observations made immediately after these spreaders were applied showed that glue spread the solution fairly well over the old foliage, but failed to carry it into the small, new leaves at the tip, the region of greatest activity of the young larvæ; nicotine oleate spread very satisfactorily over both old and new foliage, but did not seem to go as far into the unfolding buds and leaves as did the solution containing fish-oil soap, which, moreover, might be one reason for the superior control secured where fish-oil soap was used as a spreader.

It was observed that fish-oil soap used at this strength would often carry the solution containing it into the very center of the group of small unfolding leaves at the tip of the upright and enable the solution to find its way into the loose web of any small larvæ which might be working therein.

"Phenol Compound No. 1."

A proprietary compound used primarily as a disinfectant and containing a large amount of crude carbolic acid was tested against the fireworm. This material mixes in all proportions with water, making a milky white solution which gives off a strong, characteristic carbolic-acid odor. It was used at the rate of 1 part to 500 parts of water and sprayed directly into the tips of the vines, as on the other plats. As will be noted in Table 3, little or no control was secured.

DEMONSTRATION SPRAYING EXPERIMENTS.

The results of a series of demonstration spraying experiments, conducted on the bogs belonging to H. M. Williams & Sons, at Ilwaco Junction, Wash., in 1919, are presented in Table 4. The material found most effective in previous tests, namely, 40 per cent nicotine sulphate, 1 to 800, with soap 2 to 50, was used in all these experiments.

TABLE 4.—*Outline of spraying experiments in the control of the blackhead fireworm on the H. M. Williams & Son's bog at Ilwaco Junction, Wash., 1919.*

Plat No.	Spray materials, dosage, nozzle, and variety of cranberry.	Number gallons used per acre per application. First, May 2–6.	Second, May 20–21.	Third, June 13–17.	Fourth, July 9–10.	Average per application.	Total number of berries examined.	Berries free from fireworm injury. Unfertilized and immature.	Total number free.	Gain over check.	Yield per acre.	Gain in yield over check.
								Per ct.	*Per ct.*	*Per ct.*	*Bush.*	*Bush.*
A....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, mist nozzle, Howe variety.	378	378	418	.....	391	1,071	54.44	89.35	30.27	31.32	18.52
B....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, Bordeaux nozzle, Howe variety.	457	666	444	.....	522	1,355	58.67	89.74	30.66	46.98	34.18
C.....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, "spray gun," Howe variety.	300	389	257	417	341	1,238	62.52	93.05	38.10	56.99	40.88
D....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, "spray gun," Howe variety.	300	389	257	.....	315	1,499	54.30	84.25	29.30	75.06	58.95
E....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, "spray gun," McFarlin variety.	300	327	267	268	290	1,075	45.30	87.72	46.16	176.88	161.85
F....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, "spray gun," McFarlin variety.	300	327	267	.....	298	1,162	41.22	77.45	35.89	124.65	109.62
G....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, Bordeaux nozzle, McFarlin variety.	563	697	884	643	697	1,345	69.00	91.97	50.41	168.84	153.81
H....	40 per cent nicotine sulphate, 1–800 + fish-oil soap, 2–50, mist nozzle, McFarlin variety.	499	388	499	554	485	2,343	56.50	93.81	52.25	364.26	349.23
1.....	Check on lee of plats A and B, Howe variety, untreated (for check on plats A and B).	.....	.....	.....	.....	.....	479	44.88	59.08	....	12.80	....
2.....	Check on lee of plats C and D, Howe variety, untreated (for check on plats C and D).	.....	.....	.....	.....	.....	626	43.93	54.95	....	16.11	....
3.....	Check on lee of plats F and H, McFarlin variety, untreated (for check on plats E, F, G, H).	.....	.....	.....	.....	.....	474	33.55	41.56	....	15.03	....

Here an effort was made to test the three types of nozzles, namely, the Bordeaux, the mist type, and the spray gun, on as large a scale as possible, and to approach commercial spraying conditions. The plats selected ranged in approximate size from one-fourth to one-half acre and included the Howe and McFarlin varieties. These were previously badly infested with the fireworm and yielded few or no berries in 1918. Figures 12, 13, and 14 show these three types in actual use, and Table 4 shows the number of gallons per acre used in spraying with each type of nozzle, with a pressure of about 250 pounds at the tank. A stationary power outfit was used for all the applications, pipes being used to convey the spray liquid from the pump to the plats.

Plats A and B constituted one section, containing about an acre of vines, C and D another to the south, and E, F, G, and H a third to the east of C and D. Since the infestation of these three sections varied somewhat it was thought advisable to have a check plat measuring 1 by 2 rods for each section. As noted in Table 4, they were placed to leeward of the plats of which they acted as checks to prevent the unnatural spread of moths over the plats. These were numbered 1, 2, and 3, respectively.

The percentages of berries free from fireworm injury, as shown in Table 4, were obtained from an examination of the berries picked at harvest time from five circular areas of approximately 100 square inches each, selected at random on each sprayed plat. Berries were examined from three such areas on each of the check plats.

The yield of each plat was obtained by measuring its entire crop as picked at harvest time. Plats A, B, C, and D were picked with a scoop, and plats E, F, G, and H were picked by hand. The first four plats included vines of the Howe variety and the last four, vines of the McFarlin variety, all of which had reached the age of normal bearing.

Time and Number of Applications.

The first three applications were made at practically the same time for all plats, since the growth of the two varieties on these plats was very much the same. The first application was made on May 2 to 6, about the time when the largest number of buds were pushing forth but had not exceeded a growth of approximately three-fourths of an inch. This was the time when the young larvæ were appearing in very large numbers but before many of them had got beyond reach of the spray.

The second application was made May 20 and 21, when many blossoms were in the hook stage, and was timed so as to catch the next lot of larvæ before they could conceal themselves in the new growth.

The third came June 13 to 17, when the vines were nearly in full bloom. It was designed to kill any late-hatching larvæ of the first generation which might have been injuring the blossoms and newly forming berries.

Plats C, E, G, and H received a fourth application on July 9 and 10 at about the time many berries were already set. This application was intended to kill any very late-hatching larvæ and the moths which appeared on the bogs in largest numbers about this time.

The Bordeaux Nozzle.

The Bordeaux nozzle is modeled so as to deliver a forceful, driving spray in the shape of a fan. The nozzle is so arranged that the intensity of the fan-shaped spray can be regulated as desired. In

FIG. 12.—Bordeaux nozzle equipment used in spraying experimental plats: *a*, Nozzles held to show delivery of fan-shaped spray on a horizontal plane; *b*, nozzles held in proper position for delivering spray to vines.

spraying plats B and G with this type of nozzle, an effort was made to hit on a nearly horizontal plane the underside of all the leaves, as well as to penetrate the vines and wet thoroughly with the spray solution all parts of the uprights, including the tips, by directing a forceful stream of spray, as shown in figure 12 *b*. The main idea was to wet the eggs and also to catch the young larvæ in their burrows on the undersides of the lower leaves, as well as to wet any larvæ in the tips at the time.

As will be observed in Table 4, three applications with this nozzle on Howe vines in plat B at an average rate of 522 gallons per acre resulted in a gain in yield of 34.18 bushels per acre over the untreated plat; 89.74 per cent of the berries examined from this plat were free from injury by the fireworm. On the McFarlin vines in plat G four applications at an average rate of 697 gallons per acre, with this type of nozzle, produced a gain of 153.81 bushels per acre over the check and 91.97 per cent of the sample berries were free from fireworm injury. The small yields of plats A and B were due largely to the fact that since the vines in this section had been very badly infested the previous season, they produced very scanty bloom, and they also appeared to suffer more from frost on May 4, 5, and 6 than the other plats.

The Mist Nozzle.

The mist nozzle used was of the eddy-chamber or whirlpool-disk type. somewhat larger than the Vermorel and without the center-cleaning punch of the latter. It is so constructed internally as to throw a medium fine mist in the form of a hollow cone of spray which, depending upon the pressure of the liquid, measures from 12 to 18 inches in diameter about a foot from the nozzle. The outfit, as shown in figure 13, was made from galvanized iron pipe one-fourth to three-eighths of an inch in diameter on which four nozzles were placed 11 inches apart and the whole attached to the end of an ordinary 8 or 10 foot bamboo spray pole. The first nozzle on the end was set close to the pipe and each succeeding one was set 1 inch farther away than the preceding so that all would be the same distance from the vines when the rod was held by the operator in proper position for spraying.

The applications with this type of nozzle on plats A and H were made with the primary idea of filling the terminal whorl of old leaves and the new unfolding leaves at the tip of the upright with the nicotine sulphate and soap solution. As will be seen in figure 13, this spray was delivered on a more or less vertical plane, and no special effort was made to hit the underside of the leaves, entire dependence being placed on a thorough soaking of the tips of the uprights, which was quickly and easily done with this type of nozzle.

On the Howe vines in plat A, three applications, at an average rate of 391 gallons per acre, with the mist nozzle produced a gain in yield of 18.52 bushels per acre over the check; 89.35 per cent of the berries picked from sample areas were free from fireworm injury. On the other hand, the same type of nozzle used on McFarlin vines in plat H, with four applications at the rate of 485 gallons per acre, produced a gain over the untreated vines in this section of 349.23 bushels per acre, 93.81 per cent of the berries examined being free from fireworm injury.

Fig. 13.—Mist nozzle equipment used in spraying experimental plats.

The Spray Gun.

The spray gun (fig. 14) comprises usually a very large nozzle of the eddy-chamber type attached to a piece of tubing of varying length, fitted with a device for regulating at will the size and volume of the spray delivered through the nozzle. It is of larger capacity than the ordinary mist nozzle of the eddy-chamber type and is intended to be used only on power outfits where the pressure can be maintained at 200 pounds or over. In these experiments this type of nozzle was used at full-capacity opening with a medium-sized disk and threw a stream of spray about 15 to 20 feet long, which broke up into a medium fine mist before it reached the vines.

In the use of the spray gun on plats C, D, E, and F an effort was made to fill the tips of the uprights with the spray liquid and also to hit the undersides of the leaves by holding the nozzle close enough to the vines so that the liquid would be delivered on a nearly horizontal plane. In this position the uprights would be bent over slightly and the tips as well as some of the lower leaves given a thorough wetting.

As seen in Table 4, three applications with this type of nozzle on the Howe variety (plat D) resulted in an increase of 58.95 bushels per acre over check, and 84.25 per cent of the berries examined were free from fireworm injury. Four applications on the same variety on the adjoining plat (plat C) resulted in a gain in yield of only 40.88 bushels over the check, doubtless because of the thin setting of blossoms on this plat, but 93.05 per cent of the fruit examined from the sample areas was free from fireworm injury.

FIG. 14.—Spray-gun used in spraying experimental plats. Shows size of stream of spray used, with medium-sized disk at full capacity.

On the McFarlin variety (plat F) three applications gave a gain of 109.62 bushels per acre over the untreated vines, 77.45 per cent of the examined fruit being free from fireworm injury. Four applications (plat E) gave better results, a gain of 161.85 bushels over the untreated vines, 87.72 per cent of the examined fruit being sound.

THE THREE TYPES OF NOZZLES COMPARED AS TO ECONOMY OF TIME AND MATERIAL.

With the Bordeaux outfit (fig. 12) it took about 1½ hours to spray an acre, an average of 609 gallons being necessary for a thorough application. It was necessary to walk about 24 times across the acre, which was in the form of a square. With the mist outfit (fig. 13), it took about 1 hour to spray an acre, 438 being the average number of gallons used for a thorough application. Approximately 12 trips were necessary across an acre with this outfit. In point of time and material the spray gun was the most economical, requiring only 35 or 40 minutes to spray an acre, with an average of 375 gallons for an application. It was necessary to make only 6 to 8 trips with one spray gun across an acre.

Effect of the Nicotine-Sulphate-and-Soap Solution on the Cranberry Plant.

Although 40 per cent nicotine sulphate in the proportion of 1 part to 800 parts of water with fish-oil soap at the rate of 2 pounds to each 50 gallons of solution was applied to the vines when they were almost in full bloom, no decided decrease in the setting and maturity of the berries seemed to occur on those plats on which the spray was not applied forcefully or on a nearly horizontal plane. It will be noted, however, in Table 4 that the percentage of unfertilized and immature berries, i. e., the very small, dried, and undeveloped ones, but which were free from fireworm injury, was slightly, and in some cases considerably, increased in all the sprayed plats except F as compared with the respective untreated ones, the three plats with the highest percentage of berries of this kind being plats B, C, and G. Some explanation of this may possibly be found in the fact that in two of these plats, namely, B and G, the spray was applied forcefully with the Bordeaux nozzle on a nearly horizontal plane, which probably could have seriously affected the fertility of the blossoms, as in some cases they were almost blown from the uprights. Plat C received four rather forceful applications with the spray gun, and this also may in a measure account for the high percentage of unfertilized berries picked from this plat.

It is generally recognized among cranberry growers and others familiar with cranberry culture that the presence of a large amount of wet weather during the blooming period sometimes results in a small crop of berries. Whether or not the wet weather causes a decreased crop by preventing the ordinary pollenization by insects or by destroying the fertility of some blossoms still seems to be a matter of conjecture. Since all the plats were affected by the same set of natural conditions, however, it would seem logical to suppose that the spraying of the vines while the blossoms were open with a type of nozzle which delivered a forceful spray on a more or less horizontal plane, and which thus thoroughly wet the floral organs, might have caused the comparatively small crop on the plats thus treated, by the sterilization and mechanical destruction of the blossoms.

On the other hand, a certain rather beneficial effect in addition to the control of the fireworm was observed from the use of the nicotine-sulphate-and-soap solution, especially on the McFarlin variety. On plats E, F, G, and H, but particularly on H, it was noticed that the berries were generally much larger and the vines of a brighter green than those on the other plats. Wherever this spray solution was used it seemed to have a fertilizing or stimulating effect on the vines, making them grow more luxuriantly and produce larger sized berries than they otherwise would have done.

RECOMMENDATIONS FOR CONTROL.

REFLOWING.

As recommended by Scammel,[13] reflowing, where it is possible to do it properly, will doubtless be as effective in controlling the blackhead fireworm on the Pacific coast as elsewhere. While no experiments were performed along this line on the Pacific coast, yet for the benefit of those growers who may be able to equip their bogs for reflowing and wish to employ this method of control, it might be stated that the proper time to reflow for the fireworm is when the majority of the larvæ of the first brood are about full grown, as at this time they can be more easily and quickly killed than in any other stage.[14] On the bogs in the vicinity of Seaview, Wash., the majority of the larvæ of the first brood are full grown near the middle or latter part of May, but if the bog is winter flowed, i. e., covered with water in the wintertime, this date would vary according to the date this winter flood was drawn from the bog. In reflowing, the water should completely cover the vines and be held there for at least 48 hours in order to kill the greatest number of larvæ. Any grass or other objects projecting above the surface should be removed so that the larvæ can not crawl up to the tops and thus escape the flood.

SPRAYING.

Spraying with a solution of 40 per cent nicotine sulphate and water, with soap as a spreader, has been found to be the most effective method of controlling the blackhead fireworm on the Pacific coast.

How to Prepare the Nicotine Sulphate Spray.

Any nicotine solution containing 40 per cent of nicotine sulphate is suitable in the preparation of this spray, and any kind of soap *free from uncombined oils or greases* may be used as a spreader. The proportions found most effective against the fireworm are: One part of 40 per cent nicotine sulphate to 800 parts of water, with 2 pounds of soap to each 50 gallons of the liquid. Solutions containing a greater proportion of nicotine sulphate than 1 to 800 will do no

[13] Scammel, H. B. Cranberry Insect Problems and Suggestions for Solving Them. U. S. Dept. of Agr., Farmers' Bulletin 860, p. 7–8. 1917.

[14] Ibid, p. 8.

harm, but on the other hand will give no better control, and if used at the rate of 1 part to 1,000 parts of water with the above proportion of soap, about one-third to one-half more gallons per acre should be used and then only on light infestations.

To make 200 gallons of this material the tank should be run about three-fourths full of water while washing through the sieve 8 pounds of the soap, which should be previously broken up in warm water or otherwise thoroughly softened. One quart of the 40 per cent nicotine sulphate should then be poured slowly into the tank with the remainder of the water necessary to make up the 200 gallons while the whole solution is being thoroughly agitated to insure proper mixing of the ingredients. It is then ready to be applied to the vines.

The nicotine sulphate is added last and in a diluted form to prevent the precipitate which forms when concentrated solutions of nicotine sulphate and soap are brought together and which decreases the effectiveness of the spray solution.

If these materials are to be combined with Bordeaux mixture, the proportions of nicotine sulphate and soap and the process of mixing is the same as though water were used to make the solution as described above. Nicotine sulphate can be mixed with lime-sulphur solutions in all the usual proportions, but *no soap should be added to a solution containing lime-sulphur or any other similar compound*, else a disintegration of the ingredients will take place which will not only weaken the effectiveness of the combination but also may cause severe injury to the cranberry vines.

The Amount to be Used Per Acre.

Depending on the severity of the infestation, not less than 250 to 300 gallons of this solution should be used in spraying an acre of vines, as good control can not usually be secured with a less amount than this. If it is preferred to use 40 per cent nicotine sulphate at the rate of 1 to 1,000, rather heavy applications will have to be made, less than 400 or 500 gallons per acre never being used.

Type of Nozzle.

The use of a nozzle, preferably of the large eddy-chamber type shown in figure 13, equipped with a disk, throwing a *medium-fine* mist which will quickly and easily wet the terminal whorl of leaves on the tip of the uprights, is to be recommended. The Vermorel type of nozzle is too small and throws too fine a mist (fig. 15), most of which is driven away by the wind and thus fails to give the desired results. The spray gun should be used only on very large and thinly infested bogs and then great care must be taken to see that no uprights are missed and that a uniform application is made with the pressure at the tank never less than 200 pounds per square inch.

Pressure.

The pressure need not be higher than about 200 or 250 pounds at the tank, depending upon the size and length of pipe or hose through which the liquid has to be forced and the number and kind of nozzles used.

Time and Number of Applications.

For vines which are only lightly infested three applications are recommended. The *first* of these should come when the new upright growth is from one-half to three-fourths of an inch long; that is,

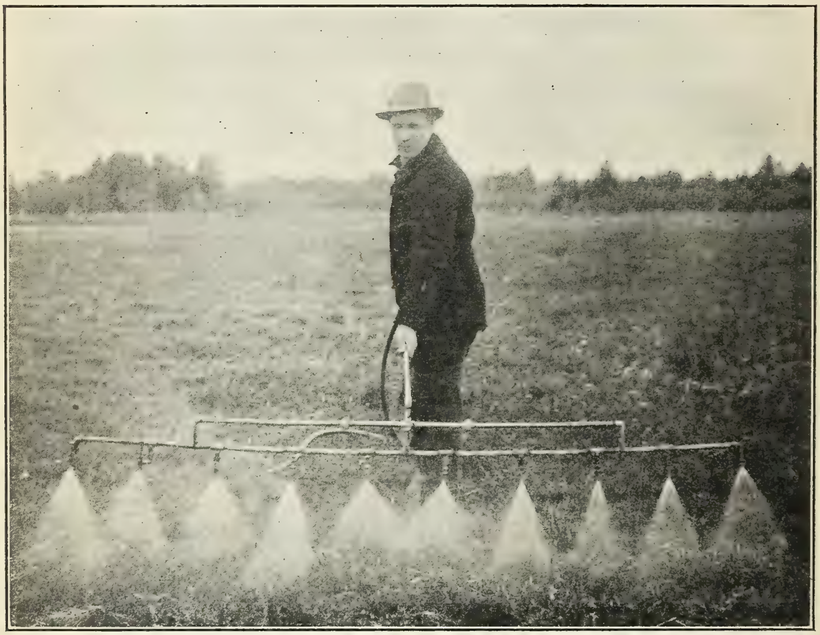


Fig. 15.—A spray boom for holding 10 Vermorel nozzles. Note the unevenness of the spray cone and the necessity of considerable walking and dragging of hose over vines in spraying. Not a good type of outfit to use.

when large numbers of the young larvæ are proceeding to and some working in or near the new unfolding leaves at the tips of the uprights. The *second* should be applied shortly after the first blossoms appear, or, in other words, at the early "hook stage." This may come from 10 days to 3 weeks after the first application, depending on the weather; it is designed to kill the next group of larvæ before they conceal themselves in the new growth. The *third* application should be made when the vines are in full bloom, or about 2 weeks after the second application, the object being to keep the young larvæ from destroying blossoms and newly forming berries.

Vines which are rather heavily infested will require the first year all three applications, as outlined above, and an additional *fourth* application, which should be made during the first two weeks of July. This last spray is designed to give protection, both to the berries and to the upright tips in which the fruit buds for the following year's crop are forming, against late hatching larvæ of the first generation and the first larvæ of the second generation. It is also designed to kill many of the moths of the first generation, and it should, therefore, be timed so as to come within the limits mentioned, as it is about this time that the moths are flying in largest numbers. By careful spraying with an outfit like that shown in figure 13, one application at this time will clean a bog of fireworm moths and thus prevent a large number of the eggs of the second generation from being deposited.

Kind of Equipment.

A 50-gallon wheel-barrel outfit, with a strong pump, will usually be found sufficiently large for bogs up to several acres in extent. For larger bogs the power outfits of various sizes will be most economical, and in order to avoid dangerous delays at spraying time one should be sure that the parts are not only durable but easily accessible and replaceable as well.

Any arrangement of nozzles and manner of spraying the bog that will insure thorough application of the spray as previously outlined and at the same time cause a minimum injury to the vines from walking or dragging the hose over them will be satisfactory.

After a consideration of the factors which influence the hatching and development of the blackhead fireworm (see pages 8–9), it would seem reasonable to suppose that a covering of water held over the vines until late in the spring, say until about April 10 to 15, together with the thinning out of thickly vined bogs, would have a very beneficial effect. It would also facilitate good control work by grouping the hatching of the larvæ. In view of the fact that it is also considered a good horticultural practice on the Pacific coast, this method of bog management in connection with spraying is to be recommended wherever it is practicable, especially on bogs which are badly infested with fireworms.

SUMMARY AND CONCLUSIONS.

The blackhead fireworm (*Rhopobota naevana* Hübner) is the most important pest of the cranberry on Pacific coast bogs. It is found also on native cranberry vines well isolated from cultivated bogs, but was doubtless introduced on these cultivated bogs on cuttings from eastern cranberry districts. So far as known on the Pacific coast, it feeds only on the cranberry.

The phenology of the cranberry in that locality is quite variable. Usually on the earliest varieties, such as the McFarlin and Early Black, buds begin to break and the new growth begins to push forth about the beginning of April. The new upright growth is about three-fourths of an inch long by the middle of April, the blossoms are in the "hook stage" in about a month more, and full bloom comes about the beginning of June. The late varieties, such as the Howe, are more variable, but the new growth starts the beginning of May and attains three-fourths of an inch in about a week. The majority of the blossoms are in the "hook stage" about the middle of June and fully opened by the latter part of June or early July.

Almost none of the bogs on the Pacific coast are ever completely covered with water, and the seasonal temperature is comparatively equable. These conditions, coupled with the small number of parasites, enable this pest to be very destructive, the larvæ feeding on the buds, foliage, blossoms, and fruit throughout the growing season.

The insect passes the winter in the egg stage. The eggs are quite small, smooth, and slightly oval, with the center slightly raised or rounded. They are lemon and orange yellow and are deposited singly or in small irregular groups on the undersides of the cranberry leaves. The young larva on hatching leaves the egg through a rent near the edge of the upper side and then feeds for a few days on the leaf or leaves near by. Later it proceeds to the tip of the upright, there feeding on the unfolding buds and blossoms.

By rearing the insect from the egg stage in an outdoor shelter where conditions were maintained which approached those naturally found on the cranberry bog, it was found that there are annually two full generations and sometimes a partial third. Temperature, depth of vines, and drainage are the three most important factors in the hatching and development of the fireworm.

The mature larva is very active, is about one-fourth of an inch long, dark greenish yellow, with a coat of dark olive-green above, and with head and thoracic shield varying from light brown to black. The ravages of the larvæ result in a burnt appearance of the vines, as if a fire had swept over the bog. Hence the common name "blackhead fireworm."

Nearly all the larvæ change to pupæ in loosely constructed cocoons in old leaves and trash beneath the vines. The pupa is a little less than one-fourth of an inch long and of a brownish amber color.

The adult or moth moves in quick, jerky flights, is about the same length as the mature larva, and has characteristic markings of a single row of short, alternating brownish and silver-gray bars running diagonally to the front margin of the first pair of wings. The males have an irregular dark area near the front margin on the underside of the second or lower pair of wings.

Naturally the moths do not migrate more than a few yards, but, helped by a strong wind, it is possible for them to be carried as far as several hundred feet at a flight. In the egg stage, the fireworm can be disseminated over a bog in two other ways—namely, on leaves floating on the water which naturally gathers on the bog in the winter time and on leaves on cuttings used in planting.

Egg laying usually commences from one to several days after copulation and closely follows the temperature, the largest number being deposited between 3 and 9 p. m.

The larvæ of the first generation appear on the bogs in greatest abundance about the latter part of May, the pupæ toward the middle of June, and the moths about the first or second week in July.

A fungous disease which attacks the pupæ in their cocoons in the old leaves beneath the vines is responsible for the death of a large number, especially on old and badly infested bogs. Spiders and ladybird beetles also kill a large number of the fireworm moths and larvæ.

Control experiments seeking to establish the best kind of spray materials, the proper number of applications, and the most effective manner of applying them, were conducted on small and large scales under natural bog conditions. Forty per cent nicotine sulphate at the rate of 1 part to 800 parts of water, with the addition of fish-oil soap at the rate of 2 pounds to every 50 gallons, used at the rate of about 300 gallons to the acre, was found to be the most effective spray material against the fireworm. Forty per cent nicotine sulphate, used at the rate of 1 part to 1,000 parts of water with the addition of fish-oil soap, 2 pounds to every 50 gallons, was nearly as effective.

Nicotine oleate made by mixing $2\frac{1}{2}$ parts of a solution containing 40 per cent *free nicotine* with $1\frac{3}{4}$ parts of commercial oleic acid, or red oil, and used at the rate of 1 part to 400 parts of water, applied three times at the rate of about 300 to 400 gallons per acre, was found nearly as effective as 40 per cent *nicotine sulphate* 1 to 800 with fish-oil soap 2 to 50, applied three times at the minimum rate per acre. Arsenate of lead proved of little or no value in the control of the fireworm. Fish-oil soap, 2 pounds to 50 gallons of solution, was a much better spreader for spray solutions on cranberry foliage than glue, which was used at the rate of 1 pound to 200 gallons. One compound containing a high percentage of crude carbolic acid and usually employed as a disinfectant gave little or no control.

Demonstration spraying experiments were conducted in which 40 per cent nicotine sulphate 1 to 800, with fish-oil soap 2 pounds to 50 gallons, was used. Four applications on McFarlin vines, in which the eddy-chamber mist type of nozzle was used, gave the best results, producing the largest yield of berries and the highest percentage of berries free from fireworm injury.

The spray gun, used in spraying McFarlin vines four times, gave the next highest yield, but the third highest percentage of uninfested fruit of this variety.

The results of four applications with the Bordeaux type of nozzle on the McFarlin variety ranked third in yield and second in percentage of uninfested McFarlin berries.

No very definite conclusions based on yield can be drawn from the experiments of spraying on the Howe variety on account of injury by the fireworm on the plats in 1918 and frost in the spring of 1919. Of the Howe plats receiving three applications, however, the one sprayed with the Bordeaux type of nozzle resulted in the highest percentage of fruit free from fireworm injury, that sprayed with the mist type of nozzle was second, and that with the spray gun was third.

Four applications with the spray gun on the Howe variety gave the highest percentage of uninfested fruit of all the plats on which the spray gun was used.

Generally speaking, four applications gave better results than three.

On bogs that can be reflowed, a complete covering of the vines with water for not less than 48 hours during the middle or latter part of May is recommended as a help in the control of the fireworm. Since most of the bogs on the Pacific coast, however, are managed as dry bogs, spraying with 40 per cent nicotine sulphate 1 to 800, with the addition of fish-oil soap at the rate of 2 pounds to every 50 gallons, is recommended as the most feasible method of control of the black-head fireworm in that locality.

Between 250 and 300 gallons of this material should be used per acre. In making up the nicotine sulphate spray, the fish-oil soap should be mixed with about half the quantity of water and the required amount of nicotine sulphate added with the remainder of the water to prevent the formation of a precipitate which decreases the effectiveness of the spray solution and which might also clog the nozzles and possibly injure the vines. This spray solution can be combined with Bordeaux mixture or lime-sulphur in the usual proportions, in which case the process of mixing is the same as though water were used. *No soap, however, should be added if the mixture contains lime-sulphur.* The large eddy-chamber type of nozzle, throwing a medium fine mist, at a pressure of about 200 pounds at the tank, should be used; other types of nozzles may not only give unsatisfactory results but may also injure the blossoms. The spray gun should be employed only on lightly infested bogs.

Vines which are lightly infested should have three applications of the nicotine sulphate spray, the first one when the new upright growth has reached a length of about three-fourths of an inch, the second when the blossoms are in the early "hook stage," and the third when the vines are in full bloom.

Heavily infested vines should have all of these three applications at the times mentioned and an additional fourth application during the first two weeks of July. In the application of this last spray an effort should be made to hit as many moths as possible with the spray solution.

A 50-gallon barrel outfit on wheels, with a strong pump, will be found desirable for small bogs. For bogs larger than several acres in area, power outfits should be used.

In making the applications great care should always be exercised to prevent injury to the vines.

SYSTEMATIC DESCRIPTION OF RHOPOBOTA NAEVANA HÜBNER.

By CARL HEINRICH, *Bureau of Entomology.*

SYNONYMY.

Tortrix naevana Hübner, *in* Samm. Eur. Schmett., v. 5, Tort., pl. 41, fig. 261, 1814.
Tortrix unipunctana Haworth, *in* Lep. Brit., p. 454, 1812.
Lithographia geminana Stephens, *in* List Brit. Mus., Pt. X, Lep., p. 99, 1852.
? *Sciaphila luctiferana* Walker, *in* Cat. Brit. Mus., Lep., ser. 6, pt. 28, p. 342, 1863.
Anchylopera vacciniana Packard, in Guide Stud. Ins., p. 338, 1869.
Rhopobota naevana Staudinger and Rebel, *in* Cat. Lepidop., aufl. 3, theil 2, p. 127, 1901.
Eudemis vacciniana Dyar, *in* List No. Amer. Lepidop., p. 466, no. 5238, 1902.
Rhopobota naevana Dampf, *in* Iris, bd. 21, p. 304–329, 1908.

GENERAL CHARACTERS.

ADULT.

Plate I, A; Plate II, A, B, C.

Thorax smooth. Forewing smooth; termen deeply concaved between veins 4 and 6; apex pointed but not falcate; 12 veins; 7 and 8 stalked; 10 from cell midway between 9 and 11; 9 approximate to 8; 11 from cell at or just before middle of cell; upper internal vein of cell nearly obsolete, when distinguishable, from between 9 and 10; 3, 4, and 5 closely approximate at termen; 2 bent up slightly at outer third; costal fold in male absent. Hindwing with 8 veins; 6 and 7 approximate toward base; 3 and 4 stalked; male with a shading of coarse black scales on underside of wing along upper vein of cell. Male genitalia as figured; harpes undivided, with rudimentary clasper present and on outer surface just above lower margin a row of rather long, stout spines; uncus present, bifurcate, arms widely separated, rather short, weakly chitinized and slipper shaped; gnathos reduced and fusing with socii; socii greatly developed, porrected, extremities meeting in hairy knoblike projection; aedoeagus straight, moderately long, fairly stout.

PUPA.

Plate I, B, C.

Slender, abdominal segments gradually tapering; a double row of spines on dorsum of abdominal segments 3 to 6 inclusive, a single row on abdominal segments 2, 7, 8, 9, and 10; first abdominal segment smooth; wings extending to or slightly beyond ventro-caudal margin of fourth abdominal segment; cephalic end bluntly rounded; vertex distinct, as broad as prothorax; labrum, mandibles, and maxillary palpi well developed; maxillary palpi extending to proximo-lateral angles of maxillæ; maxillæ less than half the wing length; labial palpi half the length of maxillæ; prothoracic femora and mesothoracic coxæ exposed; antennæ and mesothoracic legs not reaching to end of wings; several strong setæ on tenth abdominal segment; a pair of stout setæ on each side of anal rise; anal rise unarmed; body setæ otherwise weak and hardly distinguishable; spiracles slightly reduced; anal and genital openings slitlike in both sexes; cremaster absent.

LARVA.

Plate II, D; Plate III, A–C, E–G.

Cylindrical, slender, very slightly tapering at caudal end. No secondary hair. Legs and prolegs normal. Crochets uniordinal, in a complete circle. Anal fork present, reduced. Prothoracic shield broad, divided. Spiracles round, moderate; that on eighth abdominal segment slightly higher than those on abdominal segments 1 to 7, not over one and one-half times as large, same size as that on prothorax. Skin evenly and appreciably scobinate.

Body setæ moderately long; tubercles broadly chitinized; IV and V on abdominal segments 1 to 8 under the spiracle and approximate; prespiracular shield of prothorax elongate, large, bearing three setæ (III, IV, and V) in a longitudinal line; group VI bisetose on prothorax, unisetose on mesothorax and metathorax, greatly reduced and closely approximate to IV and V on abdominal segment 9; III antero-ventrad of the spiracle on eighth abdominal segment, directly over the spiracle on abdominal segments 1 to 7; IIIa not distinguishable; on thoracic segments 6 setæ in group VII; VII bisetose on abdominal segments 7, 8, and 9; ninth abdominal segment with 9 setæ in a nearly vertical line, paired setæ of group II close together on same chitinization on dorsum, I and III closely approximate; on abdominal segments 1 to 8 II latero-caudad of I; prothorax with II^a slightly higher than I^a, closer to II^b than to I^a, II^b above the level of puncture z; I^b nearer to puncture z than to I^c, II^c about equidistant from I^b and I^c, puncture y directly caudad of I^a, puncture x dorsocaudad of I^a and on the level of II^a.

Head capsule spherical, nearly square in outline viewed from above; slightly wider than long; greatest width well back of middle of head; incision of dorsal hind margin slight, about one-fourth the width of the head; distance between dorsal extremities of hind margin about half the width of the head. Frons broad, triangular, longer than wide, reaching beyond middle of the head. Adfrontal sutures extending to incision of dorsal hind margin. Longitudinal ridge very short, less than one-third the length of the frons.

Ocelli six; lenses well defined.

Epistoma normal.

Frontal punctures close together; well forward of frontal setæ; distance from frontal seta (F^1) to first adfrontal seta (Adf^1) about equal to distance separating adfrontal setæ (Adf^1 and Adf^2); Adf^2 anterior to beginning of longitudinal ridge; puncture Adf^a between and about equidistant from Adf^1 and Adf^2.

Epicranium with the normal primary setæ and punctures and with a row of three ultraposterior setæ and one puncture. Anterior setæ (A^1, A^2, and A^3) in a line with lateral setæ (L^1); anterior puncture (A^a) closely approximate to and posterodorsad of A^2. Posterior setæ (P^1 and P^2) and puncture (P^b) in a line with first adfrontal seta (Adf^1); P^1 about middle of head, on the level of adfrontal puncture and lateral seta (L^1); P^b between and about equidistant from P^1 and P^2; puncture P^a lying between P^1 and L^1, approximate to the latter. Lateral puncture directly posterior to L^1, remote. Ocellar setæ (O^1, O^2, O^3) well separated, forming a right angle; O^1 lying below and between ocelli II and III; O^2 postero-ventrad of ocellus I, in a line with ocelli I and II and seta A^1; O^3 ventrad of O^2, remote; ocellar puncture not distinguishable. Subocellar setæ (SO^1, SO^2, and SO^3) triangularly placed; puncture SO^a approximate to and equidistant from SO^2 and SO^3. Genal puncture (G^a) anterior to the seta (G^1).

Labrum with median incision broadly triangular, rather shallow; median setæ (M^1, M^2, M^3) triangularly placed; M^2 postero-laterad of M^1 and closer to M^1 than to M^3; La^1 directly posterior of and approximate to La^2, behind the level of M^2; La^2 on the level of M^1; La^3 and M^3 on the same level near anterior margin of labrum; puncture approximate and posterior to M^1.

Epipharyngeal shield narrowly bordering the median incision, not sharply defined. Epipharyngeal setæ triangularly grouped, rather close together, narrow, moderately long. Epipharyngeal rods indicated only by their short posterior projections.

Eggs.

Plate III, D.

Oval, flat, scale-like, iridescent; deposited singly.

SPECIFIC DESCRIPTION.

Adult.

Palpi brownish on outer sides, grayish white on inner and upper sides. Face and head grayish, more or less suffused with fuscous. Thorax fuscous. Forewings grayish, cross-marked with fuscous or, in some specimens, dark reddish brown; the brown area forming an outwardly angulated basal patch somewhat marked with gray or whitish scales and covering the basal third of the wing; a similar brown suffusion forming an ill-defined fascia extending from just beyond middle of costa to tornus, considerably wider on dorsum than on costa; a narrow brown terminal line, following the contour of termen and broadening at apex to a distinct brown spot; a fainter angulate brown line from costa dividing the ocellus; on costa six or seven pairs of short, somewhat obscure, white geminate marks separated by distinctly brownish shadings; ocellus metallic gray with longitudinal markings. Hindwings fuscous. Legs fuscous with inner sides white or grayish and tarsi annulated with white. Alar expanse, 9–14 mm.

Pupa.

Length, 5–6 mm.; yellow or yellowish brown, not appreciably darker at extremities but with sutures and caudal margins of abdominal segments brown; dorsal abdominal spines brown, arranged as shown in Plate I, C.

Larva.

When full grown, 10–11 mm. long by 1 mm. broad. Body sordid white; the scobination blackish, giving the entire larva a pale smoky fuscous color; chitinized areas about body tubercles white except on prothorax where they are dark brown, in some specimens almost black; thoracic shield brown or blackish brown; median dividing line pale yellow; chitinized parts of thoracic legs black or blackish brown; anal shield yellowish; anal fork two-pronged, small and easily overlooked; body hairs brown; crochets 36–42, brown, weaker at the cephalic end of the circle and increasing in length toward the caudal margin where the longest are over twice as long as the shortest at the anterior margin (Pl. III, C). Head yellow, more or less suffused with dark brown, especially on ventral side; a distinct brownish patch at posterior lateral angle of epicranium; chitinized parts of trophi black or blackish brown; ocellar pigment black, continuous under the ocelli; lenses white.

EGG.

Shining grayish white; entire surface finely and evenly faceted, smooth.

This species has appeared in our economic literature and lists under the name *vacciniana* Packard, and has been held to be an American species distinct from the European *naevana* Hübner, although the synonymy has been long suspected. A careful comparison of the genitalia and external characters of the two shows them to be one species. Another American species, *Epinotia ilicifoliana* Kearfott, also should be referred to the genus Rhopobota as a variety of *R. naevana*. In genitalia it is identical but differs somewhat in pattern. Dampf, in a very excellent study of their genitalia, has shown the synonymy of the two European forms *naevana* Hübner and *geminana* Stephens.

The larva of *Rhopobota naevana* is easily confused with another cranberry feeder, *Peronea minuta* Robinson, which it superficially resembles. The latter, however, can be at once distinguished by the arrangement of setæ I, II, and III on the ninth abdominal segment and its different anal fork. In *R. naevana* I and III are closely approximated and on a single chitinization and the anal fork is two-pronged and very small; whereas in *P. minuta* I is well separated from III, about equidistant from both II and III, and both I and III are on separate chitinizations and the anal fork is five or six pronged, large, and rather conspicuous.

EXPLANATION OF PLATES.

PLATE I.

Rhopobota naevana:

A.—Adult.
B.—Pupa, ventral view.
C.—Pupa, dorsal view.

Explanation of symbols applied to pupa.

a = antenna.
ao = anal opening.
at = invaginations for anterior arms of tentorium.
cx^2 = coxa of mesothoracic leg.
es = epicranial suture.
f^1 = femur of prothoracic leg.
ge = glazed eyepiece.
go = genital opening.
lb = labrum.
l^1 = prothoracic leg.
l^2 = mesothoracic leg.
l^3 = metathoracic leg.
lp = labial palpi.
md = mandible.
mp = maxillary palpus.
ms = mesothorax.
mt = metathorax.
mx = maxilla.
p = prothorax.
se = sculptured eyepiece.
v = vertex.
1 to 10 = abdominal segments 1 to 10.

PLATE II.

Rhopobota naevana:

A.—Denuded forewing of female moth, showing venation.
B.—Denuded hindwing of female moth, showing venation.
C.—Male genitalia of moth; ventral view of organs spread.
D.—Setal map of first and second thoracic, and third, eighth, and ninth abdominal segments of larva, showing arrangement of body setæ.

Explanation of symbols applied to genitalia.

Ae = ædœagus.
An = anellus.
Cl = clasper.
Cn = cornuti (spines on penis).
Gn = gnathos.
Hp = harpe.
Si = socii.
U = uncus.
Vm = vinculum.

PLATE III.

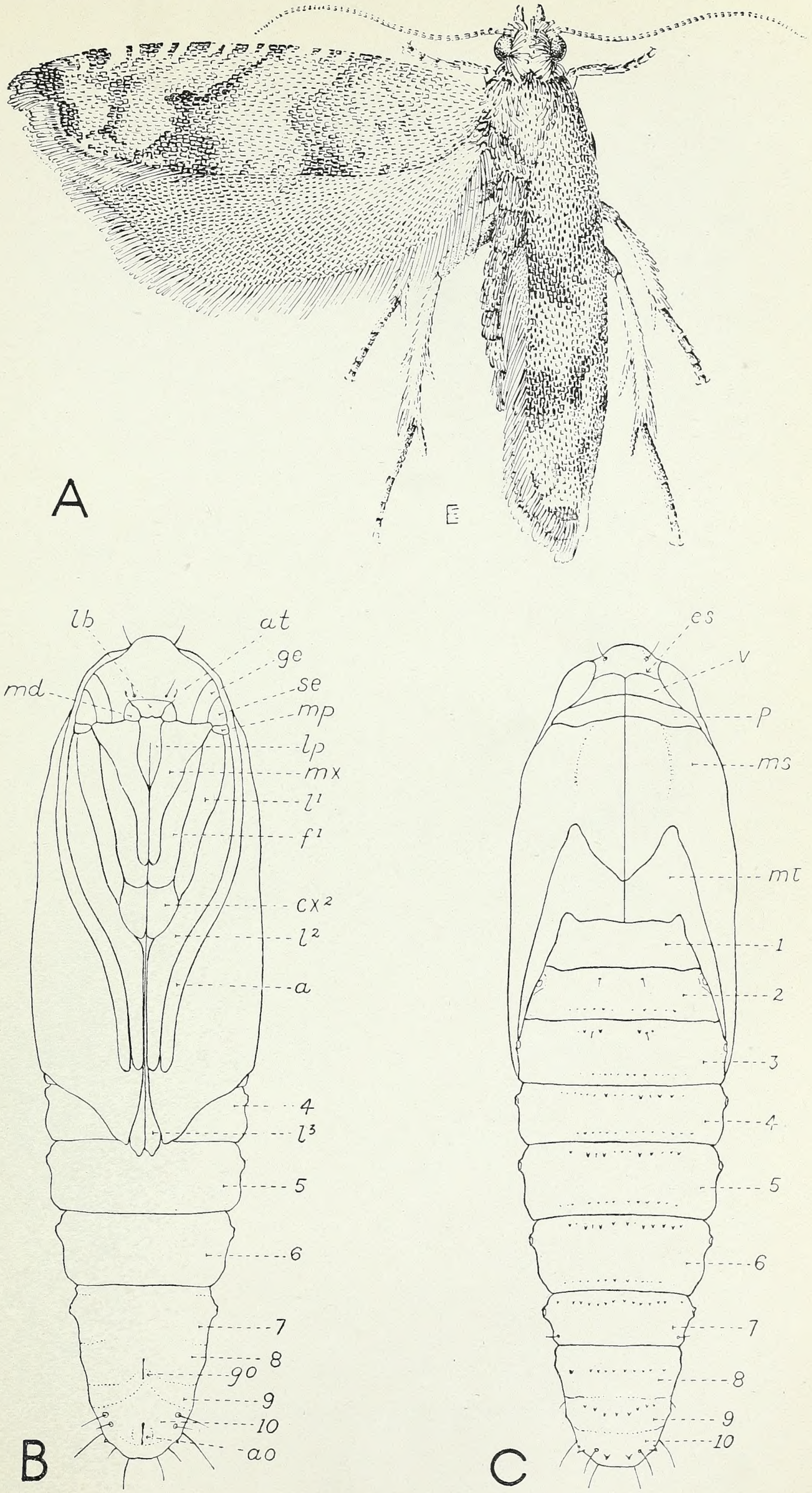
Rhopobota naevana:

A.—Dorsal view of head capsule of larva, showing setal arrangement.
B.—Lateral view of head capsule of larva, showing setal arrangement.
C.—Arrangement of crochets of abdominal proleg of larva.
D.—Egg, greatly magnified.
E.—Ventral view of tenth abdominal segment of larva, showing anal fork.
F.—Labrum of larva.
G.—Epipharynx of larva.

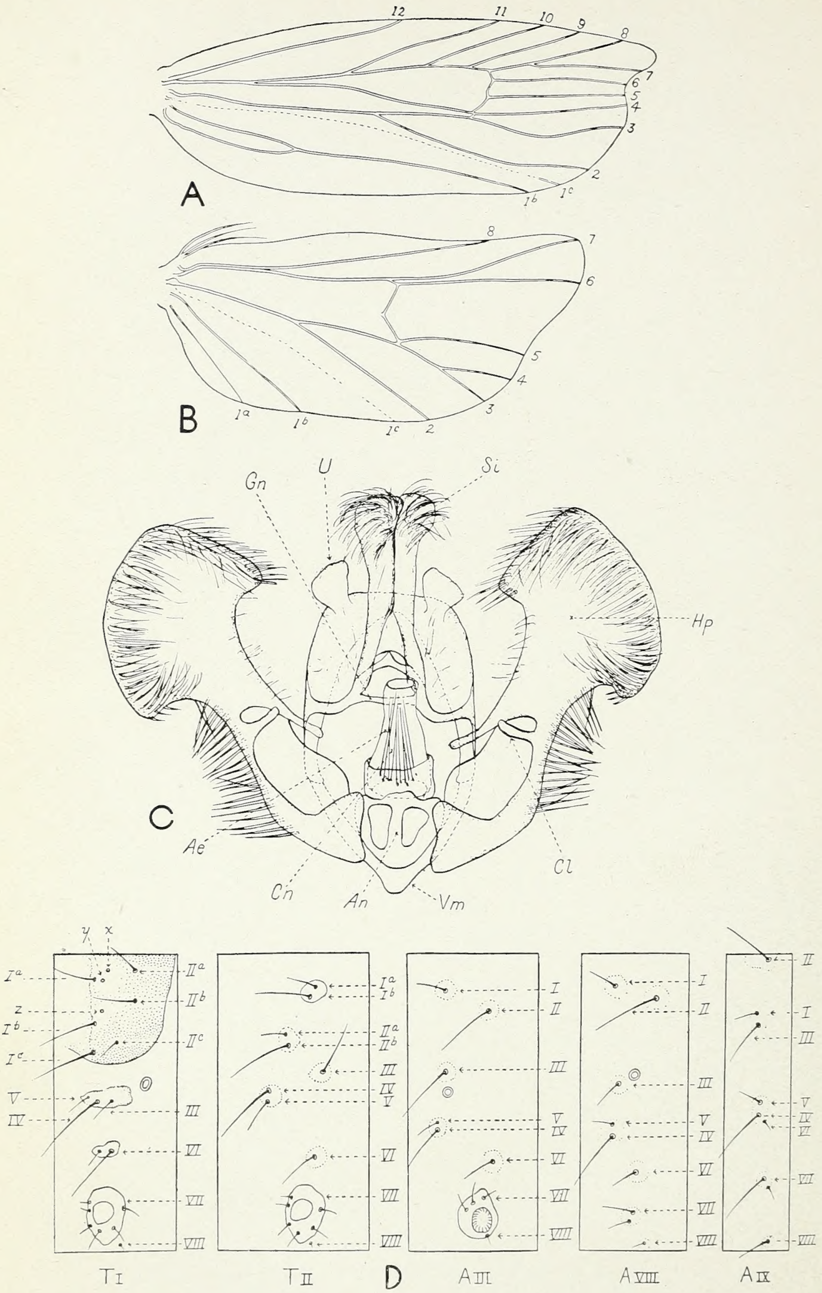
Explanation of symbols applied to larva.

A^1, A^2, A^3, A^a=setæ and puncture of anterior group of epicranium.
Adf^1, Adf^2, Adf^a=adfrontal setæ and puncture of epicranium.
ADFR=adfrontal ridge of larval head.
ADFS=adfrontal suture of larval head.
Af=anal fork.
E^1, E^2=epistomal setæ.
ER=epipharyngeal rod.
ES=epipharyngeal shield.
ET=epipharyngeal setæ.
F^1, F^a=frontal seta and puncture of epicranium.
FR=frons of epicranium.
G^1, G^a=genal seta and puncture of epicranium.
L^1, L^a=seta and puncture of lateral group of epicranium.
La^1, La^2, La^3=lateral setæ of labrum.
Lp=labral puncture.
LR=longitudinal ridge of epicranium.
M^1, M^2, M^3=median setæ of labrum.
O^1, O^2, O^3=setæ of ocellar group of epicranium.
P^1, P^2, P^a, P^b=setæ and punctures of posterior group of epicranium.
SO^1, SO^2, SO^3, SO^a=setæ and puncture of subocellar group of epicranium.
X=ultraposterior setæ and puncture of epicranium.

Drawings on Plates I, II (except C), and III were made under the author's supervision by Miss E. Edmonston, of the Bureau of Entomology. The male genitalia (Pl. II, C) were drawn by Miss Ada F. Kneale, formerly of the Bureau of Entomology.



THE BLACKHEAD FIREWORM OF CRANBERRY.



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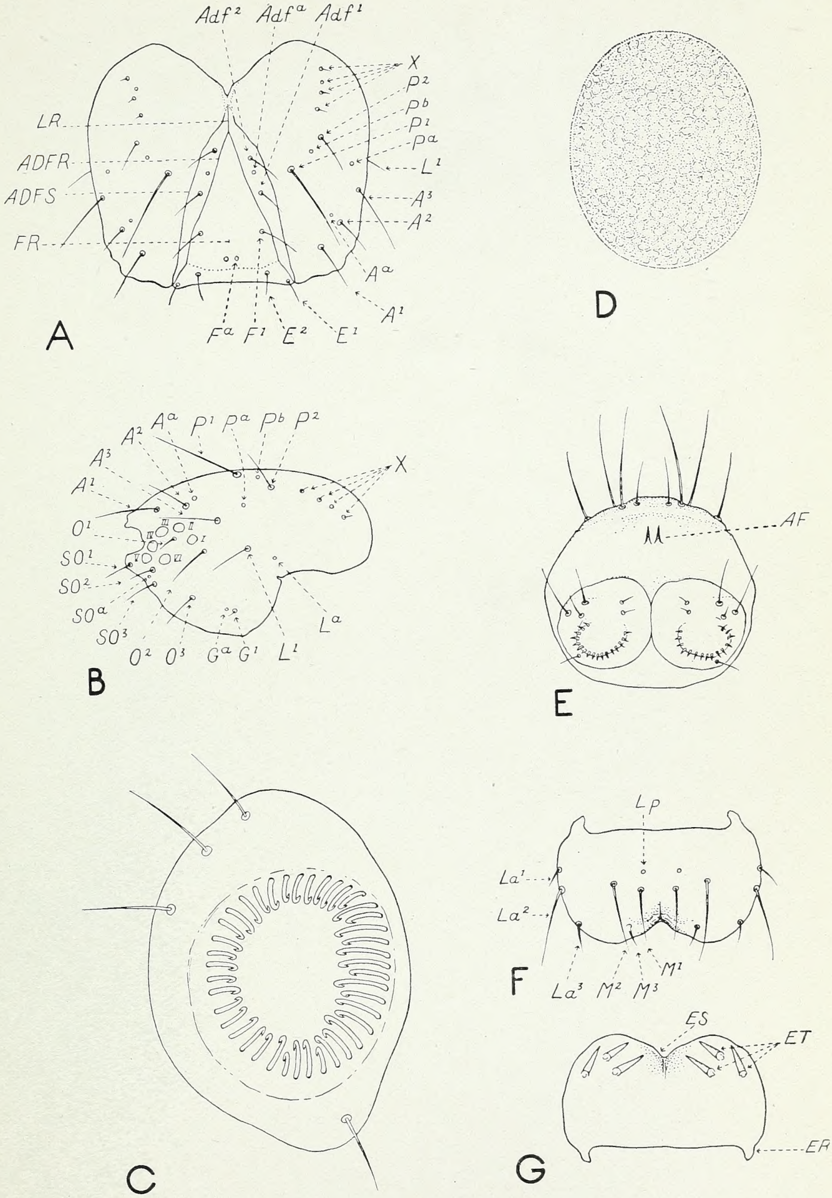

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