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THE GIPSY MOTH ON CRANBERRY BOGS.

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CONTENTS.

INTRODUCTION.

While the gipsy moth (*Porthetria dispar* L.) has been in Massachusetts since 1868, that section of the State in which the cranberry industry is established was nearly immune from the ravages of this insect until 1913. About this time, however, owing to favorable conditions, the infestation increased very rapidly in the southeastern part of the State, and occasional complaints were heard regarding injury to cranberry bogs in certain sections of Bristol, Barnstable, and Plymouth Counties. These conditions, and the importance of the cranberry industry, were sufficient causes to warrant a study of the habits of the gipsy moth on this new food plant. Under the direction of A. F. Burgess, in charge of moth work in New England, the writer began a study of the problem in 1916, the results of which are recorded in this bulletin, together with suggestions in regard to methods of control which may be adopted in cases where this pest becomes a menace to cranberry bogs.[1]

ARTIFICIAL CRANBERRY BOGS.

The locations in which cranberries may be grown vary considerably in regard to natural conditions. In Massachusetts, the State with which this investigation more particularly deals and in which more than half of the total crop is produced, the cultivated, or artificial, bogs are constructed in locations where, perhaps, the cranberry once grew naturally, but not necessarily so. They are, however, always located in natural depressions of the land, varying in size from less than an acre to more than 100 acres, in natural swamps or bogs, in which the water table is constantly near the surface of the soil. To protect the plants against damage from frost or against insect injury, it has been found desirable to provide for flowing the bogs with water. Where this can be done the bog is called a wet bog; where not, a dry bog. Each has its advantages; but as a rule wet bogs are preferred.

HOW BOGS BECOME INFESTED WITH GIPSY MOTHS.

The topography of the cranberry-producing sections of Massachusetts is characteristic of the glacial drift of Cape Cod. It is broken by low rolling hills, interspersed with bogs, ponds, and meadows. The uplands immediately surrounding the cranberry bogs, often from 10 to 50 feet high, frequently well wooded, furnish ideal conditions for wind dispersion of first-stage gipsy moth larvæ, the principal means by which both wet and dry cranberry bogs become infested.

When trees are allowed to grow close to and overhang the bog, larvæ may drop or spin down from the branches and reach the cranberry vines. When heavy infestations obtain in the wooded borders and are not destroyed, defoliation is likely to occur, and the larvæ may crawl from the upland onto the bog in search of food and cause serious damage, as these large larvæ feed upon both new and old foliage, even eating the bark from the vines. These are the three principal ways (wind, dropping, and crawling) by which

[1] The writer wishes to express his appreciation to A. F. Burgess, Dr. J. N. Summers, and I. T. Guild for their helpful suggestions and advice, which have added materially to the accuracy and value of this paper, and to the last for the map and upland trench drawings; to F. H. Mosher for notes relative to the killing of the embryo in gipsy moth eggs by winter flooding of cranberry bogs; to W. N. Dovener for the enlarged drawing of the terminal bud of the cranberry plant; and to C. E. Hood for the preparation of the photographic illustrations—all of the Bureau of Entomology; to Dr. H. J. Franklin, superintendent of the cranberry substation of the Massachusetts State Experiment Station, Wareham, Mass., for valuable information relative to the growth of the cranberry plant and bog management; and to J. W. Smith, meteorologist in charge of the U. S. Weather Bureau at Boston, Mass., and his assistants for information relative to wind currents, temperature, and the setting up and management of the recording instruments.

cranberry bogs become infested with gipsy moth larvæ. In view of the fact that cranberry foliage is not a very favored food which gipsy moth larvæ seek by choice, and as the bog does not offer favorable conditions for reproduction of the moths from year to year, it is obvious that wind dispersion is an important, if not the most important, factor to be considered in studying the infestation of bogs.

WIND DISPERSION OF GIPSY MOTH LARVÆ.

HISTORY.

The first investigations of wind dispersion of the first-stage gipsy moth larvæ were made in 1910 by A. F. Burgess and recorded in Bulletin No. 119 of the Bureau of Entomology. These investigations established the fact that the young gipsy moth caterpillars, soon after they emerged from the egg, were carried considerable distances by the wind. This was the first indisputable explanation of the origin of isolated infestations in woodlands, as well as those that were frequently located in territory outside of the known infested area. The spread of this insect in a northeasterly direction year by year, it was found, was due to the fact that the wind usually blows from the southwest at the time when the young caterpillars first reach the tops of the trees.

In 1913–14 C. W. Collins carried on a series of experiments to determine the distance young caterpillars would be carried by the wind. The results of these experiments are recorded in Bulletin No. 273 of the U. S. Department of Agriculture, in which it is shown that under favorable conditions the small caterpillars were carried 13½ miles. Later experiments have demonstrated that they may be carried 20 miles, and it is probable that under the most favorable conditions the spread is even greater.

SELECTION OF A BOG FOR EXPERIMENTAL PURPOSES.

Several bogs in the cranberry region were examined and the one that seemed best suited for the experiments was in the northern part of Carver, Plymouth County, Mass. This bog was approximately oval in form, about 3,600 feet long and 2,000 feet across at its widest part. The bordering uplands were typical of the region, consisting of elevations, from 10 to 50 feet in height, well wooded with pine, oak, birch, and some maple, with a few stands made up mainly of oak and birch. Egg clusters of the gipsy moth were found in these bordering woodlands, and were particularly plentiful on the western border. Some sections of this area were already in bog, one portion was in process of reconstruction, and the remainder was the bed of a pond that had recently been drained for the purpose of converting the whole area into one large cranberry bog. (Pl. I, Fig. 2.)

OBSERVATIONS ON WIND DISPERSION.

To determine the number of caterpillars blown upon this bog, traps were located at points shown on the map (Fig. 1) and continuous observations taken during the period in which the larvæ

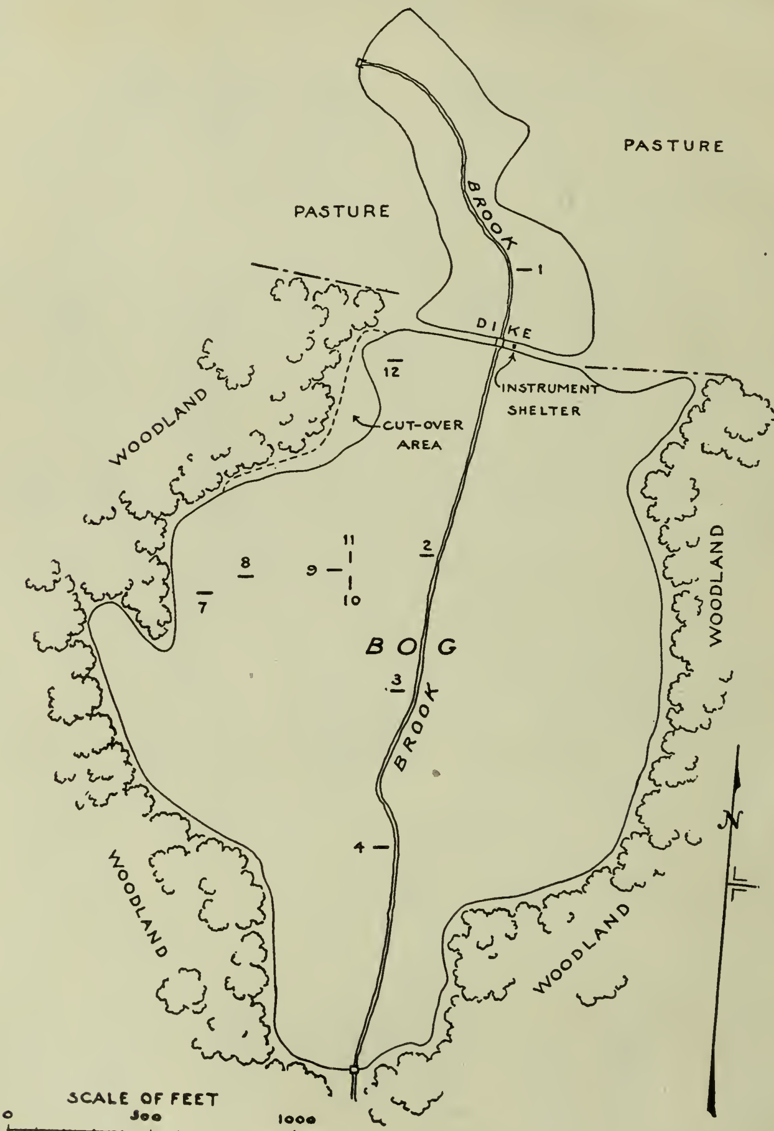

FIG. 1.—Sketch map of Muddy Pond Bog, showing location of traps.

were carried by the wind. Record was made of temperature, with Draper self-recording thermometers, one at the bog level and another at the top of the observation tower described later; and wind

FIG. I.—GIPSY MOTH LARVA DESTROYING ALL PROSPECTS OF A CRANBERRY CROP.

FIG. 2.—GENERAL VIEW OF MUDDY POND BOG, CARVER, PLYMOUTH COUNTY, MASS., LOOKING SOUTH FROM THE DIKE.

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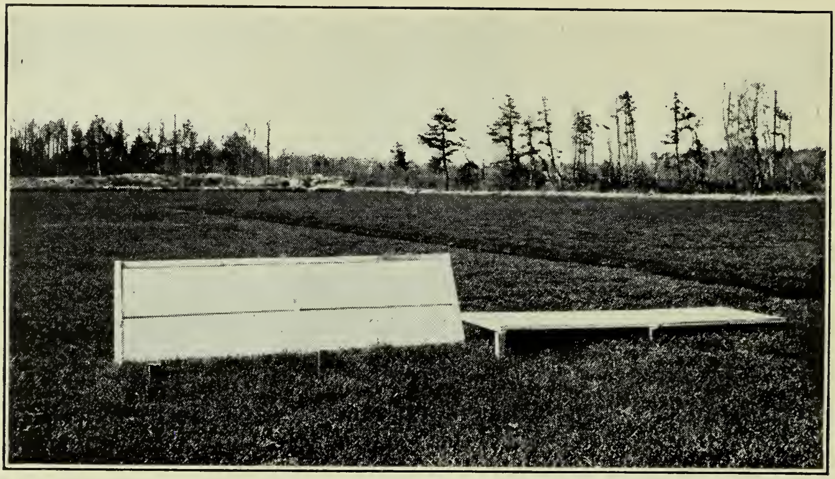

FIG. 1.—HORIZONTAL TRAP USED FOR CAPTURING WIND-BORNE GIPSY MOTH LARVÆ, SHOWING CONSTRUCTION.

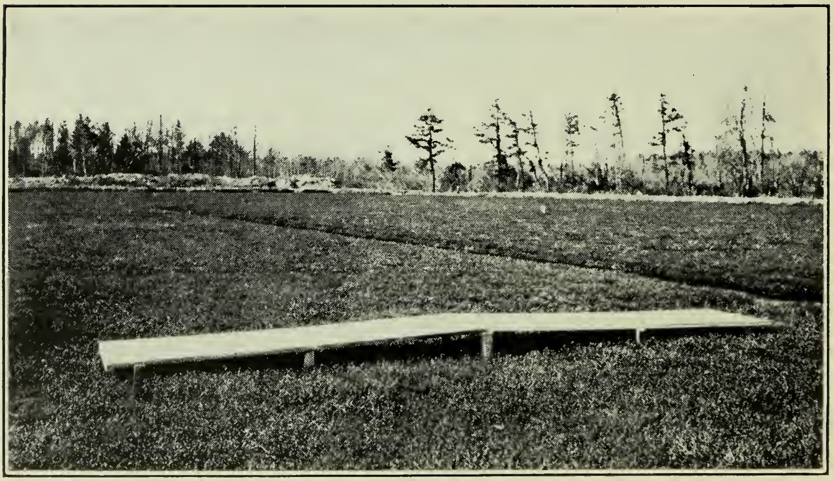

FIG. 2.—SAME TRAP SHOWN IN FIGURE 1 IN PLACE ON MUDDY POND BOG.

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velocity was recorded at a point about 25 feet above the bog level by a Robinson cup anemometer. The direction of the wind was also noted at hourly intervals during the day. The traps made it possible to count the caterpillars falling upon a known area, under given conditions, and at different locations on the bog, and to compare these records from year to year.

DESCRIPTION OF TRAPS.

The traps used by Burgess and Collins in previous wind dispersion experiments were constructed of 1-inch mesh wire poultry fencing, erected in a vertical position, and made in several sizes, their principal object being to demonstrate the certainty of wind dispersion.

A study of the results of these experiments indicates that quite a percentage of the caterpillars, particularly when the wind attained a velocity of 20 miles or more per hour, were blown through the meshes of the wire, notwithstanding the fact that the wire was well covered with commercial sticky tree-banding material. Eight horizontal traps having a solid surface were used in the bog experiments, numbered 1, 2, 3, 4, 7, 8, 9, and 12, and two vertical traps numbered 10 and 11. (Fig. 1.)

The horizontal traps were 20 feet long and 2 feet 8 inches wide, outside measurement. These dimensions were adopted for two principal reasons: First, to facilitate inspection of the surface, and, second, to reduce the danger of wind damage. For convenience in handling, they were made in two sections, each 10 feet long. The framework was made of wood 1 inch thick and 2 inches wide with a strip through the center to prevent the covering from sagging. (Pl. II, Fig. 1.)

Cotton cloth was first used for covering the frame, but this was not satisfactory, owing to its tendency to sag and hold rain water. Wall board was substituted, and proved very effective. Supporting stakes were driven into the bog at such height that when the frame was nailed to them, the two sections sloped from the center toward either end, in order to shed all moisture. (Pl. II, Fig. 2.)

The upper surface of the wall board was given a coat of outside white paint, which helped materially in distinguishing the small gipsy moth larvæ from the myriad of midges and other insects that are caught upon the trap. After the paint was dry the surface was marked off into 64 oblong sections 8 inches wide and 15 inches long. This made it possible to be sure that the whole surface was inspected and saved considerable time in making collections of larvæ that were caught on the trap.

Finally, the whole surface was covered with a coating of commercial sticky tree-banding material about one-fourth inch in thickness to serve as a trap for the caterpillars.

Later, improvements were made by setting the traps practically level, with an additional center support running longitudinally and serving as a ridge, which gave a slight pitch to either side, forming a perfect watershed. They were also raised to stand about 2 feet above the bog surface, particularly to facilitate inspection.

No. 10, the solid-surface vertical trap, was constructed of wall board, with the upper edge of the trap 9 feet above the surface of the bog. Twelve 8-inch holes were cut through the wall board and covered with ¼-inch mesh wire screen in order to reduce the force of the wind, but more particularly to prevent a cushion of air from forming in front of the trap. The whole surface, wall board and wire, was given a coating of commercial sticky tree-banding material as in the case of the horizontal traps. (Pl. III, Fig. 1.) Trap No. 11 was constructed in the same manner as No. 10, with the exception that three-fourths inch mesh wire netting was used for a surface. (Pl. III, Fig. 2.) All traps, with the exception of Nos. 10 and 11, were erected with the longer dimensions running east and west. Nos. 10 and 11 were erected vertically, facing east and west. In order to obtain information regarding the number of caterpillars and how far they were blown onto the bog, these traps were located at varying distances from the bog border.

RECORD OF TRAP OBSERVATIONS.

Trap observations have yielded information in regard to the number of caterpillars carried by the wind and as to the conditions under which they are carried.

The time of hatching the gipsy moth caterpillars is governed by the temperature. It is evident that in order to control infestations on bogs careful attention must be given to this factor. (See Table 1.)

TABLE 1.—*The variation of time in hatching and dispersion of gipsy moth caterpillars during the period covered by observations at Muddy Pond Bog, Carver, Mass.*

Year.	First hatching noted.	First larvæ taken on traps.	Time of maximum dispersion on traps.	Time between first hatching and maximum dispersion.	Time between first trap record and maximum dispersion.
				Days.	*Days.*
1916	May 9	May 22	May 25–26	16–17	3–4
1917	19	26	June 3, 4, 5	15–17	8–10
1918	7	10	May 15–16	8–9	5–6
1919	6	15	May 18, 19, 20	12–14	3–5

As a result of these observations it will be seen that the time of greatest dispersion follows from 13 to 14 days after hatching. It should be noted, however, that on uplands independent observations have shown that this period is shorter.

With the exception of the year 1917, the woodland surrounding Muddy Pond Bog was lightly infested with the gipsy moth. During that year there were a few scattered pockets on the western edge of the bog where a medium infestation existed. No heavy infestations were noted during the years that these experiments were conducted. The results of the observations for 1917 may therefore be taken as illustrating what might reasonably be expected in any similar infestation, and are given in detail in Table 2.

TABLE 2.—*Trap record for the season of 1917 giving the total number of gipsy moth larvæ taken from each trap and total for each day of dispersion, Muddy Pond Bog, Carver, Mass.*

Trap No.	May.		June.											Total.
	26	31	1	2	3	4	5	6	7	8	9	10	14	
1	0	4	3	4	24	8	8	3	0	0	0	0	0	54
2	4	(1)	12	12	(1)	43	(1)	35	(1)	3	0	4	(1)	113
3	3	(1)	10	11	(1)	38	8	8	(1)	2	(1)	(1)	(1)	80
4	(1)	(1)	(1)	22	(1)	11	(1)	10	(1)	1	(1)	(1)	(1)	44
7	16	11	26	28	169	135	46	10	10	4	2	7	1	465
8	11	15	17	12	86	149	54	11	4	5	2	7	0	373
9	5	4	9	3	58	47	20	3	2	1	2	3	2	159
Total	39	34	77	92	337	431	136	80	16	16	6	21	3	1,288

[1] No examinations made.

From Table 2 it will be noted that the largest numbers of larvæ were taken from the traps nearest the border of the bog, the number gradually diminishing as the distance from the border increased.

It is interesting to note the results secured on the two vertical traps. On No. 10, which was constructed of wall board, 255 larvæ were caught, while on No. 11, which was a wire trap, only 121 were secured. As these two traps were placed in equally favorable locations, it is evident that many larvæ passed through the wire screen. It is probable that wire treated with commercial sticky tree-banding material but having one-fourth-inch mesh would be much more effective. It is also interesting to note the difference between the number of larvæ taken on horizontal trap No. 9 and vertical trap No. 10. They had the same number of square feet of surface exposed, and although they were located near together, 159 were taken on the former and 255 on the latter. This shows conclusively that the number of wind-borne larvæ caught on a vertical surface is not a fair index of the number that will drop on a horizontal area of the same size. The density of infestation on low vegetation, when insects are carried by the wind, should be determined by horizontal rather than vertical traps.

A total of 1,288 first-stage larvæ were taken on 385 square feet of horizontal trap surface, or an average of 3.3 larvæ per square foot.

Table 3 summarizes the information secured on the horizontal traps exposed on Muddy Pond Bog during the years 1916 to 1919. It will be noted that the number of larvæ caught in 1917 far exceeded the total for any other year. This was largely due to a slightly heavier infestation and more favorable weather for wind dispersion when the larvæ were in the first stage.

TABLE 3.—*Wind dispersion data for gipsy moth larvæ collated for the four-year (1916–19) period.*

Year.	Number of horizontal traps.	Trap surface.	Total number of larvæ trapped.	Number of larvæ taken per square foot of trap surface.	Days of dispersion.	Days of heaviest dispersion.	Larvæ taken on days of heaviest dispersion.	Percentage of total number trapped.
		Sq. ft.						
1916	4	240	111	0.4	15	2	72	64.8
1917	7	385	1,288	3.3	20	5	1,076	83.5
1918	9	500	132	.2	15	5	97	73.4
1919	1	55	197	3.9	13	5	172	87.3

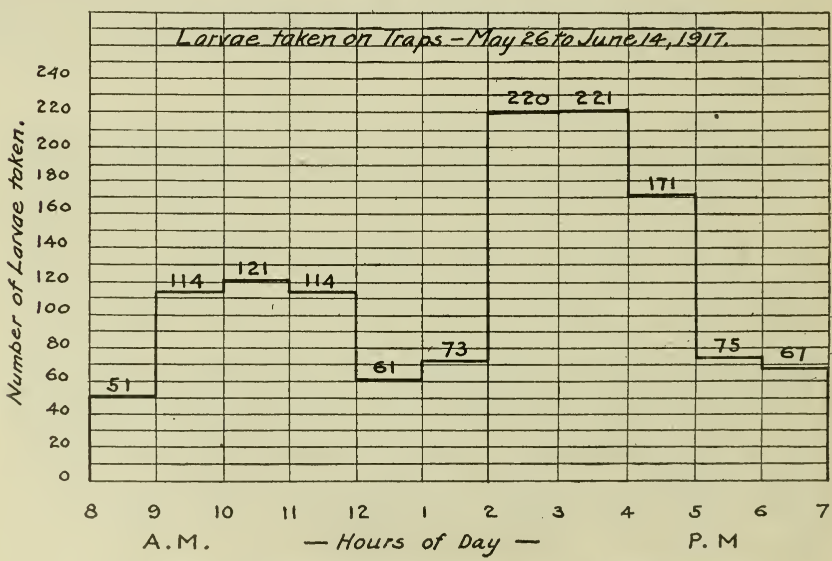

FIG. 2.—Showing two daily periods of maximum wind dispersion.

Figure 2 shows graphically the number of first-stage larvæ taken on the traps during the whole time of dispersion in 1917. This shows very clearly the important fact that there are two daily dispersion

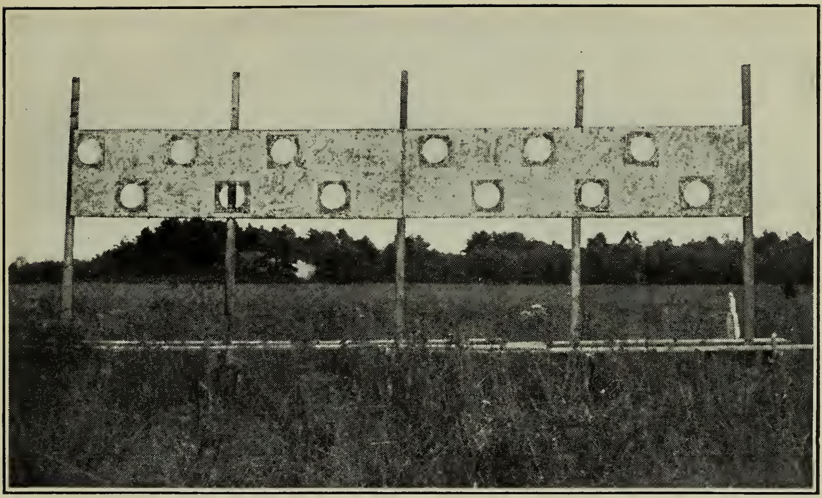

FIG. 1.—VERTICAL TRAP NO. 10, SHOWING CONSTRUCTION.

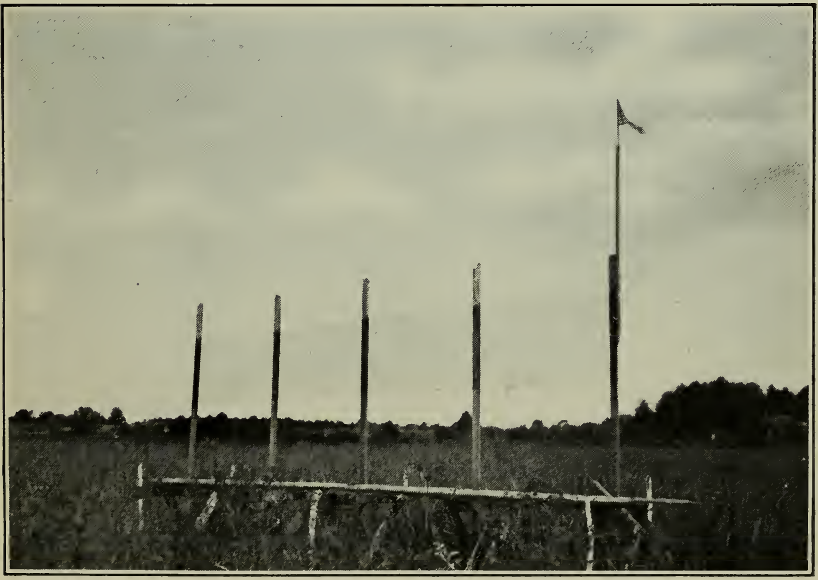

FIG. 2.—VERTICAL TRAP NO. 11, CONSTRUCTED OF WIRE POULTRY FENCING.

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TOWER SURROUNDING WHITE OAK TREE, FROM WHICH THE FEEDING HABITS OF FIRST-STAGE GIPSY MOTH LARVÆ WERE STUDIED.

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periods, viz, 9 a. m. to 12 m. and 2 to 5 p. m.;[2] and, furthermore, the observations of four consecutive years give substantially the same results. The small number of larvæ dispersed from 12 m. to 2 p. m. is not due to lack of favorable conditions either of temperature or wind velocity, for the mean temperature and wind velocity for that period of the day have both been found very favorable for heavy dispersion. The two periods of dispersion are due to a movement in search of food and are discussed more fully under the heading "Feeding habits on white-oak foliage" (p. 10).

The data from the traps secured from 1916 to 1919 prove that in order to have caterpillars dispersed in large numbers it is essential to have, first, a "medium" to "heavy" infestation; second, a temperature above 70° F.; third, a wind velocity of from 8 to 15 miles per hour. It has been found that a fairly steady wind blowing 10 to 12 miles per hour will disperse more larvæ, other conditions being favorable, than wind of higher velocity which blows intermittently.

FEEDING HABITS ON CRANBERRY FOLIAGE.

Experiments have determined that under laboratory conditions gipsy moth larvæ can not be successfully carried through the several stages on cranberry foliage alone. This information was obtained in 1914 by F. H. Mosher and recorded in Bulletin No. 250 of the U. S. Department of Agriculture. In obtaining this information Mr. Mosher used feeding trays devised by W. F. Fiske, formerly of the Bureau of Entomology, with cranberry foliage inserted in crook-necked vials, filled with water, in order to keep the food fresh.

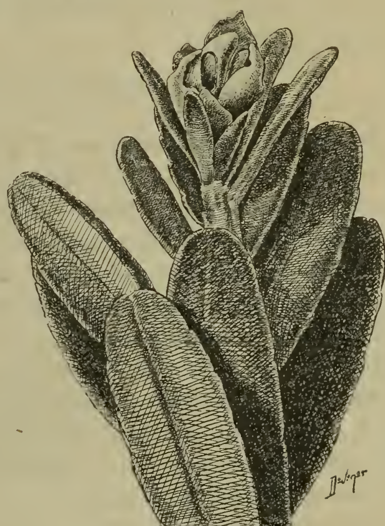

FIG. 3.—Terminal bud of cranberry plant showing injury caused by first-stage gipsy moth larvae.

Bog observations have shown that the young first-stage larvæ begin their feeding on cranberry by attacking the contents of the terminal buds. They first eat through or between the bud scales, and then consume the tender undeveloped leaves within, leaving nothing but a shell formed by the bud scales. (Fig. 3.) By the time the caterpillars have reached the second stage the terminal buds not already

[2] All observations recorded in this bulletin were made according to Eastern standard time.

destroyed will have expanded into new shoots, and feeding is then confined almost entirely to the stems of these shoots, not to the leaves and buds. (Pl. I, Fig. 1.) In this way a large percentage of the new growth may be entirely destroyed, provided the infestation is sufficiently heavy. The same habit of feeding is continued through the later stages, until the supply of new growth is exhausted, then the older leaves may be attacked, and the vines stripped, provided, again, that the caterpillars are numerous enough to be forced to seek this less attractive food.

It is obvious that a few caterpillars can do a great amount of damage, first to the terminal bud from which is produced the season's fruit, and second by causing a branching growth of the plant. This damage to the terminal bud may occur before the owner realizes that his bog is infested.

FEEDING HABITS ON WHITE OAK FOLIAGE.

In the observations made in 1916–19 concerning the dispersion by wind of first-stage gipsy moth larvæ, it became evident, from the count of larvæ taken from the traps, that there are two periods of the day during which maximum dispersion occurs. From this fact it was inferred that there are, correspondingly, two daily periods of activity, as the larvæ would be more likely to be carried by the wind when crawling over leaf surfaces, limbs, or trunks of trees than when at rest. To verify this inference it was decided to make a study of the habits of first-stage larvæ as they are found in tree tops, where the earliest feeding usually appears, and where also the relation between the feeding habits and wind dispersion could be more satisfactorily studied.

A white oak about 30 feet high was selected near the border of Muddy Pond Bog. Around this tree was erected a tower 16 feet square at the base, 8 feet square at the top, and 25 feet high. A flooring was placed around the branches on top of this tower, thus bringing the upper 5 feet of the terminal branches in position for close examination and observation of the movements of young larvæ. (Pl. IV.)

On May 19, 1919, when observations were started, the leaves on this tree had begun to unfold, some of which would measure an inch in length, giving considerable protection to the young larvæ, as well as supplying food. It was found that the first feeding by first-stage gipsy moth larvæ after reaching the foliage was confined to the leaf hairs, principally on the underside of the leaves. After feeding in this manner for a day or two they began to feed on the tissue of the leaf, later eating through the tissue. The information relating to the feeding periods of first-stage gipsy moth larvæ, collated for the whole period of observation, furnishes what can be considered as a continuous record from 3.45 a. m. until 7.30 p. m. These observations determined that feeding began soon after daylight, gradually increasing as the temperature increased, until it reached its maximum from 9 to 11 a. m. when it began to diminish, reaching a minimum during the midday, then gradually increasing again, reaching its maximum from 3 to 5 p. m., and gradually decreasing after this hour, a majority of the larvæ seeking shelter on the underside of the leaves by 7 p. m. Wind dispersion records cited show practically no movement of small caterpillars between 11 a. m. and 3 p. m., the period when there is practically no feeding and very little activity.

INJURY BY A GIVEN NUMBER OF LARVÆ.

When a new cranberry bog is planted the vines are usually set in rows 12 inches apart, and the same distance in the row. The increase of the vine area is by runners radiating out from each plant, in all directions, eventually forming a dense mass of vines over the whole bog surface. From these runners upright shoots grow, and under normal conditions increase in height by growth from a terminal bud, and it is upon this new growth that the fruit is borne each season. It is evident that any injury to the terminal buds reduces the amount of fruit in proportion to the number of buds destroyed. With the object in view of obtaining some definite information on this question an experiment was undertaken to determine the amount of damage to cranberry vines that would result from a heavy infestation of gipsy moths. Three pens were built 3 feet square, inside measurement, with sides $2\frac{1}{2}$ feet high. On the outside of each pen, 6 inches from the top, four strips of board were attached at an angle of 30 degrees. Each pen was then forced into the bog about 6 inches and the sand firmly tamped both inside and outside of pens to prevent escape of larvæ. On the underside of this overhang and 6 inches from the top on the inside of each pen bands of commercial sticky tree-banding material were applied in order to prevent the escape of larvæ that were placed on the square yard of vines inclosed and to prevent other insects from gaining entrance to the pen. (Pl. V, Fig. 1.)

From year to year during the period covered by these studies varying numbers of first-stage larvæ have been placed in these pens each season and the injury to the vines, as well as the feeding habits of the larvæ on cranberry foliage, has been carefuly noted.

The results of these experiments have shown that an infestation of two larvæ to the square foot has destroyed nearly all the new growth of cranberry foliage. An infestation averaging one larva to the square foot would materially reduce the crop and would necessitate flooding or spraying in order to prevent damage

Plate VI, Figure 1, shows a section of the surface of the vines in the above-mentioned pen and when compared with Plate VI, Figure 2, showing a similar area just outside of the pen, on the bog proper, with the vines in full bloom, the loss of the new growth is manifest.

MORTALITY OF FIRST-STAGE LARVÆ.

General observations on Muddy Pond Bog, particularly in connection with the pen experiments, have shown that there is a varying percentage of mortality among the several larval stages of the gipsy moth, after they reach the cranberry vines. This mortality is probably greatest in the first stage, owing to several factors. The principal factor is reduced vitality, since larvæ hatching from egg masses that were deposited upon conifers or other nonfavored food species had used up a considerable percentage of their vitality in searching for food before they were blown from the tree onto the vine surface. Their vitality was further reduced in crawling over the vines before approaching starvation finally forced them to feed upon the buds or new stalks of the cranberry vines. While in this weakened condition the larvæ are more susceptable to cold, particularly when accompanied by rain. That there is quite a difference between the temperature at the tops of trees and that at the bog surface was demonstrated by the use of recording thermometers. The platform at the top of the tower constructed around the white oak tree on which feeding observations were made was about 50 feet above the bog level. A comparison of the thermometer records made at the top of the tree and at the surface of the bog shows that the temperature averaged 5.2° F. cooler at the bog surface than at the top of the tree for the night period during the 6 days of heaviest wind dispersion, viz, May 25 to 30, inclusive. From 6 p. m. May 29 to 5 a. m. May 30 the average temperature was 11.3° F. lower at the bog surface than at the top of the tower. At 1 a. m. May 30 it was 15° F. lower at the surface of the bog than in the tree top, the maximum difference in the locations during the period. This was the coldest night of the period, and gave the greatest range of temperature. The above temperatures were obtained from the thermometers in latticed shelters.

There is also a high mortality among first-stage gipsy moth larvæ on cranberry bogs due to disease, predacious enemies, and other causes that are not well understood. All of these agencies, together with the rather unfavorable nature of the cranberry foliage as a food, combine to bring about an enormous reduction of the wind-blown larvæ.

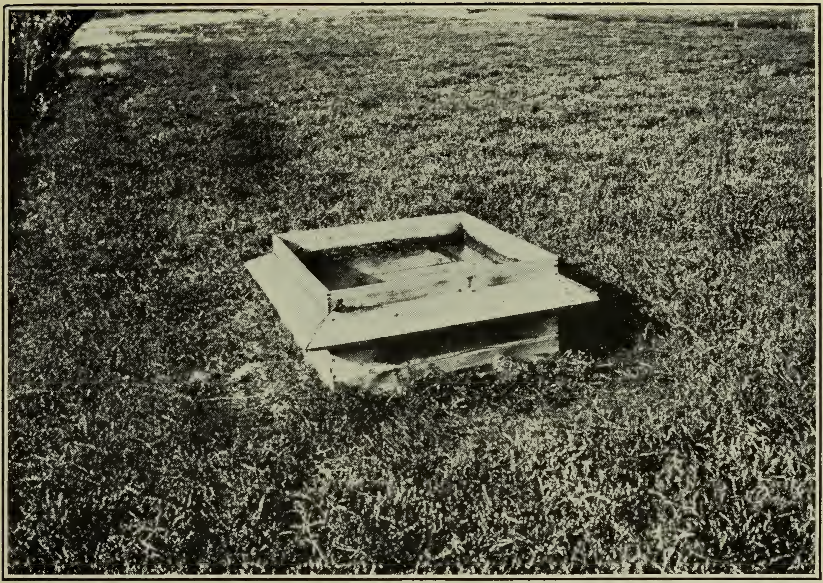

FIG. 1.—PEN USED TO CONFINE GIPSY MOTH LARVÆ WHILE STUDYING THE INJURY CAUSED BY THEIR FEEDING ON CRANBERRY PLANTS.

FIG. 2.—SHOWING AN UNEVENLY GRADED CRANBERRY BOG FLOWED TO DESTROY WIND-BORNE GIPSY MOTH LARVÆ. EXPOSED PORTIONS SHOULD BE SPRAYED TO INSURE COMPLETE PROTECTION.

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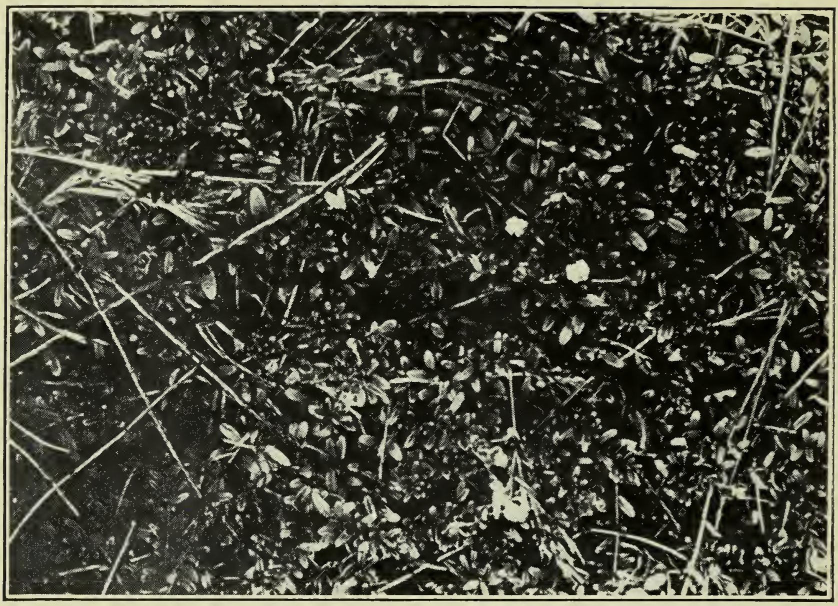

FIG. 1.—SECTION OF CRANBERRY FOLIAGE INSIDE OF PEN, SHOWING INJURY CAUSED BY 36 GIPSY MOTH LARVÆ. NOTE ABSENCE OF BLOOM. PHOTOGRAPHED JULY 12, 1917.

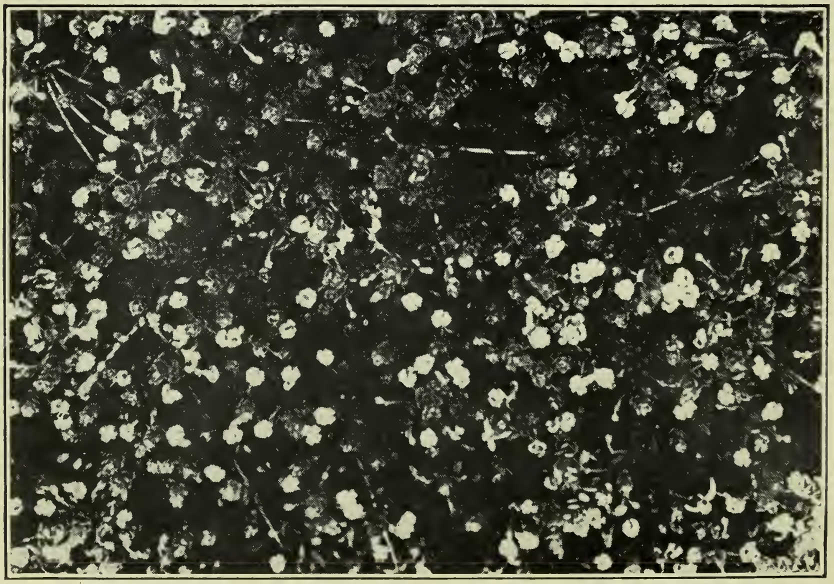

FIG. 2.—SECTION OUTSIDE OF PEN WHERE NO FEEDING BY GIPSY MOTH LARVÆ OCCURRED. PHOTOGRAPHED JULY 12, 1917.

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RECOVERY OF CRANBERRY VINES FROM GIPSY MOTH FEEDING.

The soils of cranberry bogs are bound to vary in different bogs, owing to location, character of the peat constituents, and variation in grading. Often it is necessary to remove nearly all the peat in some sections of a bog in order to get the proper grade. When such conditions occur there is an uneven distribution of water; consequently the resulting crop will vary and the recovery of vines after injury will vary.

Muddy Pond Bog would be rated as a dry bog during the whole period that observations have been carried on. Whenever defoliation has occurred it has meant the loss of a crop for two years. After the buds or new growth were destroyed the vines would make a second growth from dormant buds, but would not form fruit buds. The second year, if no feeding occurred, the vines would make a normal growth and develop strong fruit buds, which would produce a heavy crop of berries the second year from defoliation, provided no climatic or insect injury prevented. Observations on wet bogs with a controllable water supply have shown that when the vines suffer the loss of the terminal fruit bud or of the later new growth, they usually make quick recovery, putting forth a strong second growth, and develop vigorous fruit buds. In a number of such instances a heavy crop of fruit has been produced the year following.

METHODS OF CONTROL.

The first requisite in the fight against a noxious insect is an accurate knowledge of its life history and all that pertains to its increase or decrease in the field. It is usually found that at some particular stage of its life it is more vulnerable than at any other. After this stage has been determined, the most effectual measure for control or extermination can be employed

Observations on the mortality of first-stage gipsy moth caterpillars have demonstrated the fact that soon after hatching from the protective egg mass they are very susceptible to injury by cold, and large numbers are destroyed at this time; particularly is this true should beating rains occur accompanied by low temperatures. *At this stage of their development they are most readily killed by a thorough application of an arsenical poison, and a comprehensive grasp of this fact is of vital importance to cranberry growers for efficient and economical control of this pest on cranberry bogs.*

HOW TO DETECT AN INFESTATION.

It is very difficult to detect first-stage gipsy-moth larvæ on cranberry foliage owing to their habit of dropping to the surface of the bog when the vines are disturbed. One may obtain an approximate idea of the degree of infestation on his bog by either of the following methods, the accuracy of the estimate depending upon the care taken in performing the operation.

Pan Method.

Place a bright tin pan carefully among the vines, holding it with the right hand, inclined to the right at an angle of 45 degrees. With the left hand give the vines directly in front of the pan two or three quick slaps; then remove the pan and note the number of gipsy moth larvæ taken. Repeat this operation every 10 or 20 feet, until the whole bog is covered. By keeping a record of the number of larvæ taken and the number of times the pan was used, one may estimate the degree of infestation quite accurately.

Insect Net Method.

The degree of infestation on bogs may be determined also by the use of an insect net. Care should be taken to make even sweeps with the net, covering the same amount of vine surface with each sweep. By counting the number of larvæ taken after making a number of sweeps and estimating the area of vine surface covered by each sweep, one may estimate the infestation on the bog as a whole. The accuracy of this estimate will depend on the care taken in making the sweeps and the percentage of bog area covered. Whichever method is used, the line of collection should be from the shore line of the bog toward the center, as the infestation is usually heaviest nearer the shore.

CONTROL ON WET BOGS.

It has been demonstrated that no hatching occurs from gipsy moth egg masses placed among cranberry vines on bogs that are flowed from December 1 to May 1, while check experiments have shown normal hatching. It has also been found that egg masses placed under sand on dry bogs fall only 6 per cent below normal hatch.

These determinations were made during the winter of 1915 to 1916 and in 1917 by F. H. Mosher, who carried on experiments at North Saugus, Mass., and East Carver, Mass., to obtain information on this phase of gipsy moth investigations.

It is, therefore, evident that the methods of control adopted by the cranberry grower must be governed by the kind of bog infested, whether wet or dry. Owners of cranberry bogs located near an abundant supply of water, where flooding either by gravity or pumps can be quickly accomplished, have at hand the cheapest and most effective method for the control of this pest: First, by winter flowing, by means of which the partially developed larvæ in all eggs deposited on the bogs during the previous season are destroyed; and, second, by holding the flowage until after the maximum time of wind dispersion has passed, which will result in drowning the young caterpillars that fall in the water. It is probable that the low temperature of the water is an important factor in the death of the caterpillars. It may be desirable to hold the winter flowage late, say from the 1st to the 15th of June, in order to control the blackhead cranberry worm (*Rhopobota naevana* Hbn.). When this is found desirable, it is evident that the gipsy moth infestation may be controlled at the same time. It is also probable that some of the other cranberry insects may be controlled in combination with efforts against the gipsy moth.

Observations have demonstrated that the maximum dispersion of first-stage larvæ of the gipsy moth occurs about 13 or 14 days after the first hatching is noted, but this period varies with the season; if there are 5 or 6 days when the temperature ranges from 75 to 85° F., or higher, rapid hatching will occur, and if it continues quite warm, the larvæ will reach the tops of trees sooner, resulting in an earlier dispersion. The best guide to determine when this may occur is the development of white oak leaves. When the leaf buds begin to unfold it is safe to assume that the temperature has been high enough to cause hatching of gipsy moth eggs.

Should the spring be late and the average temperature be low before hatching, and continue so after hatching, then the dispersion period will be correspondingly delayed, and extended over a longer period; in any case, however, there is a time of maximum dispersion, and this will occur, as stated, about 13 or 14 days after the first hatch. The closer the bog owner watches the upland conditions the better able he will be to control effectually an infestation on his bog.

In control by flooding, only complete submergence is effectual. If through lack of sufficient water, or irregularities in the surface of the bog, there are sections where a considerable number of vine terminals are out of water (as shown in the right center of Plate V, Figure 2, and to a less degree through the central section), even with a light to medium infestation on a bog these terminal shoots become actual life rafts for hundreds of larvæ that have crawled up the vines as the flooding gradually progressed, or reached them as the larvæ were blown over the surface of the water by the wind. When any considerable number of these terminal shoots project above the water it is imperative that the larvæ be brushed from the vines by using a common hand hayrake, drawing and pushing the vines under water several times with the back of the rake head. Unless this is done, there is likely to be considerable damage on these partially submerged sections of the bog. In the immediate foreground and on the right of Plate V, Figure 2, there will be noted sections of the bog entirely out of the water. Flooding will not control an infestation in such cases. These must be controlled by spraying.

CONTROL ON DRY BOGS.

Gipsy moth infestations on dry bogs can be controlled only by intelligent application of some arsenical poison, either in the wet or dry form. It is probable that with more efficient apparatus for the application of dry poison, it will be the most economical and satisfactory way of applying poison to cranberry foliage. The leaf of the cranberry vine being glabrous, it is very difficult to get poison spray to adhere in sufficient quantities for satisfactory results unless the poison is applied in mist form. *Great care should be taken not to allow the mist to continue long enough in one section to reach beyond the dew point. If this should occur, the liquid will run off, leaving only a very thin deposit of the poison on the leaves, not enough to destroy the larvæ present.*

Observations have shown that in case of an infestation on a dry bog, resulting from egg masses deposited the previous season, it is imperative that the application of poison should be made soon after hatching is noted on the uplands, and also that it should be applied in a mist form in order that the largest amount of poison possible may settle on the terminal bud. It is important that the bud be covered thoroughly in order that the larvæ may get enough poison to cause death before they can eat so far into the buds as to cause injury. Six to eight pounds of arsenate of lead paste (or one-half of this amount of dry lead) to 100 gallons of water should effectually control gipsy moths in the first two larval stages if properly applied.

If during the first stage only light winds prevail, dispersion will be minimized, and the central areas of medium or large sized bogs may not become infested to such a degree that spraying will be necessary over the whole area. Careful tests should be made by the pan or net method to determine the degree of infestation along the bog border nearest the infestation on the upland, should there be any, and spraying operations governed accordingly. This applies to wet bogs in case it is not desirable to control an infestation by flooding.

Should a bog be infested with the later larval stages of the gipsy moth, from whatever cause, the only recourse is to spray with a strong solution of arsenate of lead—using from 12 to 15 pounds of lead paste to 100 gallons of water, and using the same care in application as advised for the first larval stage.

CONTROL ON UPLANDS.

After the gipsy moths have reached the second stage, and all danger of wind dispersion is reduced to a minimum, heavy infestations may occur on the uplands in the vicinity of cranberry bogs, and if heavy enough to cause defoliation the caterpillars, in their march for a supply of food, may move in the direction of a bog, and owing to the large amount of food necessary to maintain the hordes of larvæ, may become a serious menace to the bog itself.

There are several methods of control that may be used to advantage in such an emergency, and one or more of those mentioned below should be adopted in order to protect the bog.

The woodland border of the bog may be cut back for the space of 100 feet or more, and possibly the section of woodland from the edge of this cutting to the infested area may be sprayed. If, however, this distance should happen to be only a few hundred feet, the spraying would not accomplish the desired result, because only a few of the thousands of larvæ present would consume enough of the poisoned foliage to cause death. The others would march on in search of more food.

When such conditions occur, an open ditch on the upland, back from the bog border, may be dug, 12 to 15 inches deep and 18 inches wide, the earth being thrown toward the oncoming horde of larvæ, and the side of the ditch nearer the bog being made perpendicular. At the top of this perpendicular side a board about 1 foot wide should be placed at an angle of 45 degrees, overhanging the ditch, supported by stakes driven into the soil; earth should be banked on the outside of this board in such a way as to close up all spaces at the base of the board caused by the irregularities of the surface of the ground. The undersurface of the board and supports should be well smeared with a commercial sticky tree-banding material before being placed in position. The larvæ upon reaching this band will fall into the ditch, and should be sprinkled with crude oil from an ordinary watering pot. In case of extremely heavy infestations it may be necessary to clean out the mass of dead larvæ before the last hordes reach the ditch. (Fig. 4.)

If a protective belt is already cut around the bog it is highly desirable that all sprout growth be kept down by bruising the sprouts from the stumps for two or three years, using a dull ax with which to perform this operation, mowing all other small growth close to the ground, and burning all the débris. This well-cleaned border may help greatly in controlling some of the other insects that breed on the upland border, thereby reducing their ravages on the bog itself.

When light infestations are present and the immediate upland border is clear of overhanging brush, border ditches may offer all necessary protection, provided they are in proper condition. To be effectual they should not be less than 15 inches wide and from 15 to 20 inches deep with the bog side of the ditch perpendicular and as smooth as possible, in order to give little foothold to the crawling larvæ. If not detrimental to the vines or crop, a few inches of water should be maintained in the ditch with a little crude oil on the surface. The larvæ dropping from the land side into the ditch will become smeared with oil and suffocate. Should some larvæ reach the bog side and attempt to crawl up the smooth surface, being weakened by partial suffocation they will drop back into the oil bath.

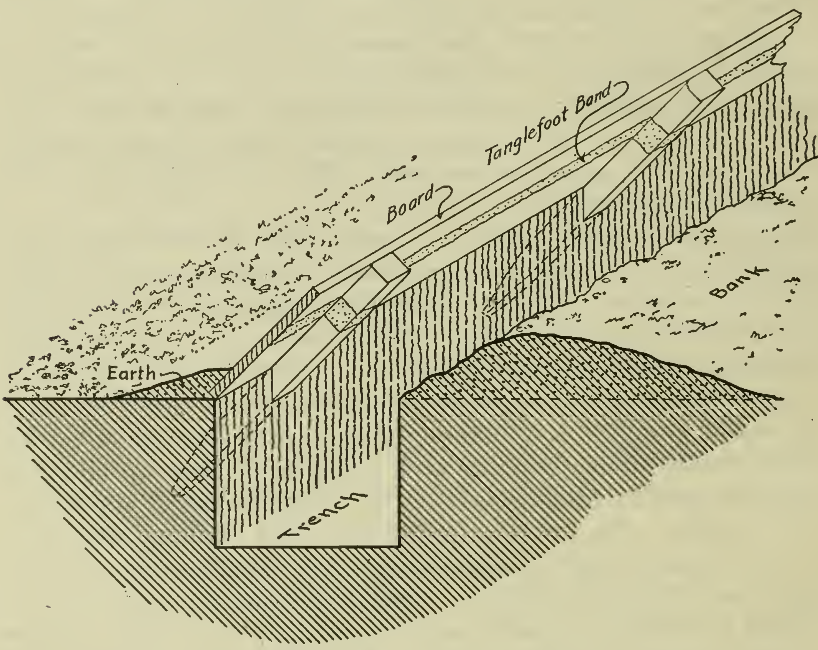

FIG. 4.—Cross section of an upland trench, with board in position.

Should the infestation prove too heavy to be controlled by the oil and water a board about 1 foot wide may be set against the smooth surface of the bog side of the ditch, resting on stakes driven in the bog at an angle of 45 degrees, care being taken to make tight joints. The underside of the board and stakes should be smeared with a good coat of commercial sticky tree-banding material. It is obvious that with an infestation heavy enough to require the use of the board, the ditch might have to be frequently cleared of the dead bodies of the larvæ in order to remain effective.

The method to be used for the control of an upland infestation must be decided by the owner of each bog. He must be governed by the condition and particular surroundings of the bog in question. Any of the foregoing methods should give satisfactory results if attended to properly.

SUMMARY.

Infestations of gipsy moths upon cranberry bogs are due principally to wind dispersion of first-stage larvæ, which occurs only when conditions of wind velocity and temperature are favorable. The time when maximum dispersion prevails is usually not longer than from two to five days. Because of the activity of the young caterpillars in seeking food there are two daily periods of maximum dispersion, between 9 a. m. and 12 m. and between 2 and 5 p. m.

Mortality of first-stage larvæ is very great, large numbers perishing from low temperatures, unfavorable food, predacious insects, and disease. The embryos in all gipsy moth eggs deposited on cranberry bogs are killed by winter flowage, when the bogs are flowed from December 1 to May 1.

Upon deciduous foliage in general the feeding of the first-stage larvæ is upon the leaf hairs, but the injury to cranberry plants is caused by feeding upon the terminal buds, and later upon the new growth. As a rule vines recover more quickly from injury upon wet bogs than upon dry ones.

Flooding is the most effective method of control upon wet bogs; but spraying is the only method which can be employed on dry bogs. *In order to obtain the most satisfactory results, spraying should be done before wind dispersion begins.*

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