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LATHROP, F.H., NICKELS, C.B. 1 OF 1

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TECHNICAL BULLETIN No. 275 FEBRUARY, 1932

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THE BIOLOGY AND CONTROL OF THE BLUEBERRY MAGGOT[1] IN WASHINGTON COUNTY, ME.

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CONTENTS

INTRODUCTION

In the summer of 1925 the Bureau of Entomology established a laboratory in Washington County, Me., under the direction of A. L. Quaintance, for the purpose of conducting an investigation of the

[1] *Rhagoletis pomonella* Walsh; order Diptera, family Trypetidae.

[2] The junior writer was associated with this project from the beginning of the season of 1926 until the close of the season of 1928. R. F. Sazama assisted in the work during the season of 1925, and L. C. McAlister, jr., assisted during the season of 1929. The following field assistants were employed during the summers of the years indicated: Donald L. Collins, 1926; R. C. Newton, 1927, 1928, 1929; Ross F. Nigrelli, 1927; B. J. Rudquist, 1928, 1929; C. W. Lacaillade, jr., 1928; R. B. Whitten, 1928; H. A. Peterson, 1929; C. H. Geissler, 1929. Appreciation should also be expressed for the generous cooperation of the Maine State Department of Agriculture and of the department of entomology of the Maine Agricultural Experiment Station. The writers regret that they are unable to give specific credit for the analyses for arsenical residue which are utilized in this bulletin. It is known that some of them were made in the insecticide division of the Bureau of Chemistry and Soils, and it is probable that others were made in the insecticide laboratory of the old insecticide and fungicide board.

biology and control of the blueberry maggot. A summary of the results of this investigation, from the establishment of the laboratory in 1925 until the close of the season of 1929, is presented in this bulletin.

THE BLUEBERRY INDUSTRY AND LANDS

In many respects the blueberry industry of northeastern Maine stands unique in American agriculture. As a commercial development, blueberry culture in this section seems to have begun some 50 or 60 years ago. The industry slowly developed as the timberlands were cleared and as lumbering decreased in importance. The production of blueberries has progressed largely without scientific study or direction until recent years, and, as necessity demanded, methods were developed which in many instances are peculiar to this crop and to this section. Any effort to combat the blueberry maggot efficiently must take into account the conditions under which the blueberries are produced.

TOPOGRAPHY AND GROUND COVER OF THE BLUEBERRY LANDS

The blueberry lands consist of high, fairly level plateau land or of moderately sloping to steep hillsides, all of which show the effects of glaciation. (Pl. 1.) The soil is mostly of a sandy nature intermixed with gravel, and the surface is frequently studded with numerous bowlders and rock outcrops. (Pl. 2, A.) On most of the productive blueberry land there is a surface layer of organic matter from 1 to 3 or more inches in depth, over the sandy soil.

For the most part the trees have been removed from the blueberry land. Some of the land still bears old snags here and there, or occasionally scattered trees—relics of the coniferous forests that once covered the land. These lands are now characterized by a typical acid-soil vegetation, with such plants as lambkill (*Kalmia angustifolia* L.),[3] bunchberry (*Cornus canadensis* L.),[3] bearberry (*Arctostaphylos uva-ursi* L.),[3] mountain cranberry (*Vaccinium vitis-idaea minor*) and other species, in addition to the blueberries and huckleberries. Gray birch and alder "sprouts" spring up abundantly on the blueberry land, and sweetfern (*Comptonia peregrina* (L.) Coulter) often forms a dense cover. Much labor is required to keep the weed bushes from overrunning the land and crowding out the blueberries.

The blueberries are produced by native plants which have come onto this land entirely by natural dissemination. Two species[4] produce the commercial blueberry crop. These are the lowbush blueberry (*Vaccinium angustifolium* Ait.),[3] and the Canada blueberry (*V. canadense* Kalm),[3] often known locally as the low sweet blueberry and the sourtop blueberry, respectively. As would be expected, a number of varieties of blueberries are found in this section, and some authorities recognize one or more additional species. The blueberry plants grow to a height of 6 to 12 inches. On most of the land the stand of plants is exceedingly patchy and irregular.

[3] Plants identified by F. V. Coville, Bureau of Plant Industry, U. S. Department of Agriculture.
[4] The highbush blueberry (*V. corymbosum* Ait.) occurs commonly in Maine along the borders of streams and ponds, but the fruit of this species is not utilized commercially in this section.

CULTURAL PRACTICES

On the whole, the blueberry land usually receives little culture. It is customary to mow the weed bushes on the better land every third year, during the fall preceding burning. On some of the land the weed bushes are mowed each fall in order to give the blueberry plants better opportunity for growth.

Every third year an attempt is made to burn over the blueberry land. (Pls. 3 and 4.) This is done in early spring, after the snow is off, but before the frost is out of the ground, and while the plants are still dormant. Favorable conditions for burning usually occur during April or the first week in May. By removing the portions of the plants above the surface of the soil, burning serves as a pruning process, stimulating new growth. As the berries are produced on growth of the preceding season, there is no crop produced on burned-over land during the summer immediately following the burn. The second summer following the burn marks the production of the first berries, usually an abundant crop. The second crop is usually less abundant than the first, although the relative productiveness of the two crops varies with the seasons and with the characteristics of the land. Succeeding crops diminish rapidly if the land remains unburned, and the land soon becomes practically nonproductive where it is not burned over. Each landowner attempts to burn about one-third of his blueberry land each spring, so as to have an approximately constant area in bearing every season.

The facility with which land can be burned varies greatly with the season. Some seasons are favorable for burning, and it is easy to burn over the land thoroughly. Other seasons are unfavorable, and there may be only one or two days during the burning period when the fire will run well over the land without leaving numerous skips. Usually the wild land on the barrens is poorly burned, patches and streaks of unburned bushes being left throughout the burned-over area. On the better land, many of the growers spread hay during the fall, to insure a thorough burn the next spring. The hay is spread uniformly in a thin layer, usually from one-half ton to 1 ton of hay per acre being used.

Most of the blueberries produced in this section are used in the canning factories. The berries are picked by means of metal rakes. (Pl. 2, B.) Picking usually does not begin until practically all of the berries are ripe; then the land is picked clean. The berries are put through a hand winnowing machine in the field to remove most of the leaves and débris which are gathered with the berries. After this preliminary cleaning, the berries are placed in half-bushel boxes for transportation to the factory.

HISTORY OF THE BLUEBERRY MAGGOT

The blueberry maggot (*Rhagoletis pomonella*) is apparently a native insect that has been present in the New England area for many centuries. Maggots have been observed in blueberries in Washington County, Me., from the earliest recollections of the oldest inhabitants. During the early years, when blueberries were of little or no commercial value, this insect attracted slight attention. As the blueberry crop increased in commercial importance, the blueberry maggot became more and more troublesome. In the season of 1924 the situation became actue, and, because of the heavy infestation of the blueberries, the canning factories were severely hampered in their operations. As no method was known for removing the infested berries from the pack, it appeared for a while that the development of the industry would be permanently retarded.

The first published record of *Rhagoletis pomonella* infesting berries appears to have been issued by Britton (*4*) [5] in 1906 when he reported finding this species infesting huckleberries in Connecticut. Smith (*16*) reported the species as occurring on huckleberries in New Jersey in 1909. Woods (*19*) recorded the occurrence of the species on blueberries in Washington County, Me., in 1914, and again discussed the insect briefly in a treatise (*20*) on the blueberry insects in Maine the following year. O'Kane (*10*) recorded the occurrence of the species on *Vaccinium corymbosum* in New Hampshire in 1914. Patch and Woods (*11*) in 1922 published the most comprehensive study of the species as a blueberry pest that has appeared. The authors discuss briefly the results of four years of observation on the biology and control of the blueberry maggot in Washington County, Me.

INJURY

The primary injury to the blueberry industry resulting from blueberry maggots arises from their presence among the canned berries. The presence of the maggots is probably not injurious to the health of persons consuming the berries; nevertheless, any such foreign matter is unsightly in a food product and certainly lessens its value as an appetizing delicacy. Regulations issued by the United States Department of Agriculture, under authority of the pure food laws, declare an excessive number of maggots to be an adulteration and prohibit the sale of such products in interstate commerce.

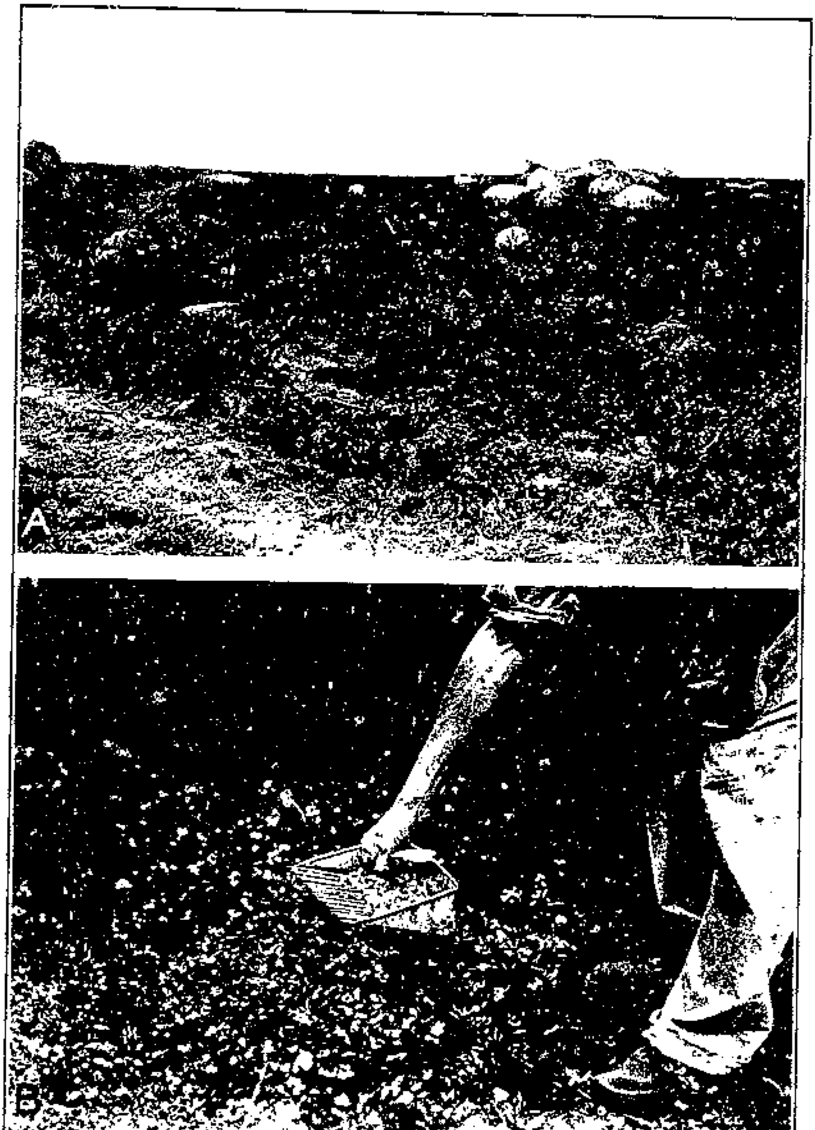
There are other forms of injury caused by the maggot that are often overlooked by blueberry producers and canners. It is not exceptional to find areas in which 10 to 15 per cent of the berries are infested by maggots. The destruction of berries caused by such infestation is not apparent to the growers and is therefore likely to be overlooked. Many of the infested berries drop to the ground before the area is picked, others are crushed in the boxes on the way to the factory, and those which remain must be washed out to remove the maggots at the cannery. Loss results from the additional factory processes required in removing the maggots, from the shrinkage of the berries as they are processed to remove the maggots, and from the slowing down of the canning operations during the rush season.

When badly infested berries are picked, large numbers of berries are very soft and "mushy" (pl. 5, A) as a result of the feeding of the larger maggots, and many of the soft berries break down en route to the factory. Upon arrival at the factory, the contents of the boxes frequently present a most unsightly appearance. The berries, wet with the juice of the crushed fruit, are troublesome to handle, and it is difficult to winnow them and to pick them over by hand, as is usually done in the factory.

[5] Italic numbers in parentheses refer to Literature Cited, p. 75.

TWO TYPES OF BLUEBERRY LAND IN WASHINGTON COUNTY, ME.

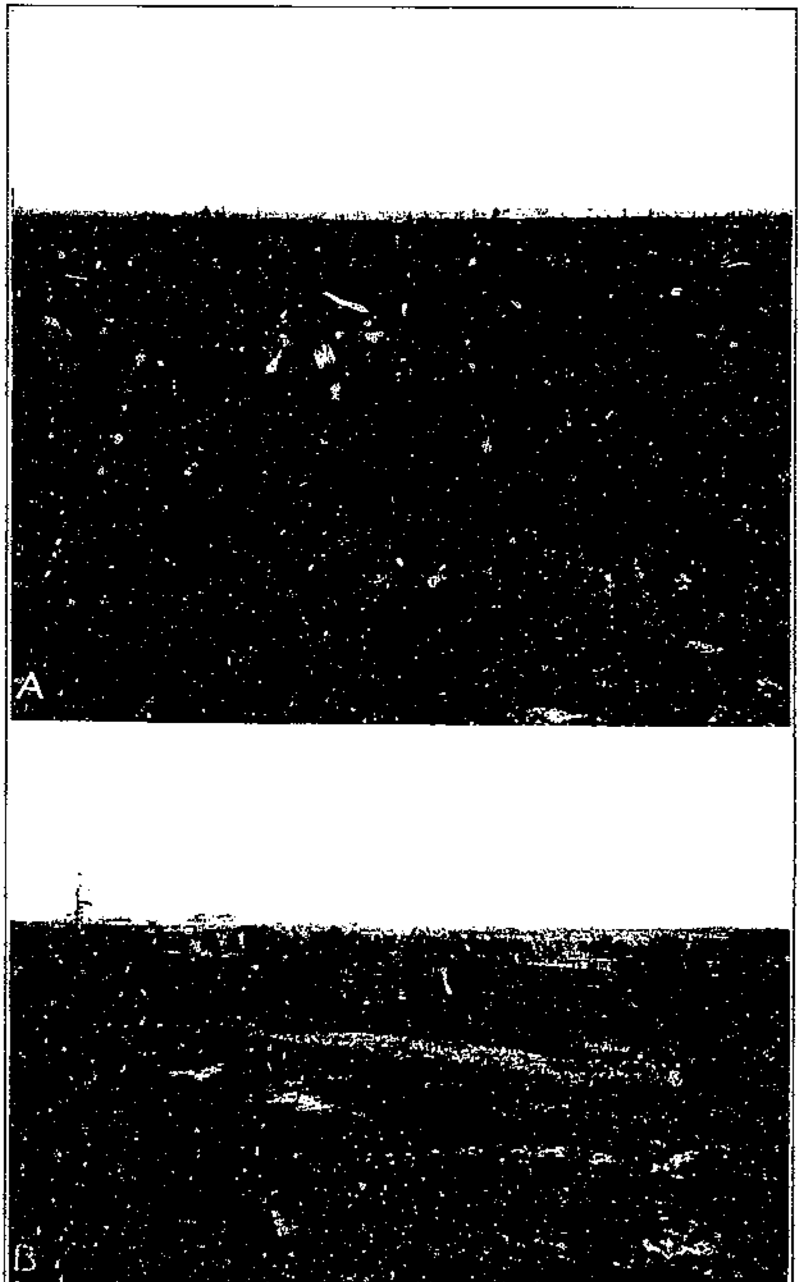
A, Level land excellent for dusting by airplane or by ground machine; B, hill land with scattered trees, difficult to dust by airplane.



A, Excellent blueberry land studded with numerous bowlders, sometimes difficult to dust with ground machine; B, rake used for picking blueberries in eastern Maine

BURNING BLUEBERRY LAND

A, Blueberry land mowed and hayed, ready for burning; B, hayed blueberry land in process of burning.



BURNED BLUEBERRY LAND

A, Blueberry land immediately after thoroughly burning; B, poorly burned blueberry land, showing skips which the fire missed.

ECONOMIC IMPORTANCE OF BLUEBERRY-MAGGOT INFESTATION

Blueberry production and canning have become probably the most valuable industries in Washington County, and are of considerable importance throughout the coastal section of eastern Maine. The total income from blueberries is said to be more than $1,000,000 annually in Washington County, and is an important source of livelihood for a considerable portion of the population. Anything which interferes with the industry is likely to cause great economic loss and is justly looked upon with alarm by the people of this section.

It is impossible to estimate accurately the total loss due to maggot infestation in this section. In one factory for which records (Table 1) are available, 42.1 per cent of the berries received in 1926 required processing to remove maggots; in 1927, 57.6 per cent; in 1928, 37.9 per cent; and in 1929, 28.2 per cent of the berries received were processed to remove maggots. This factory received a large proportion of its berries from heavily infested areas, and the percentage of berries processed for maggot removal is undoubtedly somewhat higher than the average for the county. It is estimated that during each year for which records are available, from 4.5 to 10.2 per cent of the total quantity of berries received by this factory were destroyed as a result of processing for maggot removal. This is a substantial loss to the factory, and to this should be added the cost of processing and the inconvenience caused during the rush season.

TABLE 1.—*Records from one blueberry cannery in Washington County, Me.*[1]

Year	Total berries received	Berries requiring no processing for removing maggots		Berries requiring slight to moderate processing		Berries requiring prolonged processing		Total berries processed for removing maggots		Estimated shrinkage of berries during processing for removing maggots	
	Bushels	*Bushels*	*Per cent*	*Bushels*	*Per cent*	*Bushels*	*Per cent*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
1926	17,418.0	10,085.0	57.9	3,346.5	19.2	3,986.5	22.9	7,333.0	42.1	1,299.5	7.5
1927	17,098.0	7,249.0	42.4	4,414.0	25.8	5,425.0	31.8	9,839.0	57.6	1,747.4	10.2
1928	10,174.5	6,318.5	62.1	2,378.5	23.4	1,477.5	14.5	3,856.0	37.9	652.3	6.4
1929	12,575.0	9,027.5	71.8	2,922.5	23.2	625.0	5.0	3,547.5	28.2	563.4	4.5

[1] Data presented in this table are from the official records of the State inspector in charge at the factory, and are published through the courtesy of the proprietors.

The blueberry maggot probably occurs in most of the important blueberry-producing areas of the United States, and wherever it occurs this insect constitutes a threat against the development of the blueberry industry.

FRUITS INFESTED

The original technical description (*18*) of *Rhagoletis pomonella* was based upon a series of flies, some of which were reared from apple and others from Crataegus. Since the original description, the species has been reported as occurring on a number of other fruits, including cranberries (*12*), peaches,[6] pears (*13*), plums (*6*), huckle-

[6] Reported by P. H. Millar in U. S. Dept. Agr., Bur. Ent. Insect Pest Survey Bul. Vol. 9, No. 8, p. 326. 1929. [Mimeographed.]

berries (*Gaylussacia baccata*) (*4*), and on blueberries (*Vaccinium pennsylvanicum*, *V. canadense*, *V. vacillans* (*16*), and *V. corymbosum* (*10*).

During the course of the investigations here recorded, *R. pomonella* has been found infesting many of the common berries indigenous to eastern Maine. A complete list of fruits from which adults were reared or which were found infested with maggots at Cherryfield, Me., is given below.[7]

Blueberries:
- *Vaccinium angustifolium* Ait.; (maggots and adults).
- *V. canadense* Kalm; (maggots and adults).
- *V. corymbosum* L.; (maggots and adults).

Black huckleberry:
- *Gaylussacia baccata* (Wang) C. Koch; (maggots and adults).

Bunchberry:
- *Cornus canadensis* L.; (maggots and adults).

Chokeberry:
- *Aronia melanocarpa* (Michx.) Britton; (maggots).

Mountain cranberry:
- *Vaccinium vitis-idaea minus* Lodd; (maggots).

Dwarf service berry (or sugar pear):
- *Amelanchier bartramiana* (Tausch) Roem.; (maggots).

Wintergreen:
- *Gaultheria procumbens* L.; (maggots).

In the above list there are several plants which may have an important relationship to the blueberry-maggot problem. Huckleberries grow quite commonly in association with the blueberries, but usually are not so abundant as the blueberries. Huckleberries have frequently been observed to be heavily infested with maggots. The huckleberries are not picked, but remain upon the plants until frost, and may serve as a reservoir of maggot infestation on areas where they grow abundantly.

The dwarf service berry, locally known as sugar pear, is frequently found on the blueberry land, but is most abundant on lower, poorly drained soil, rather than on commercial blueberry land.

The bunchberry is frequently abundant on commercial blueberry land. This plant may bear fruit every season, even on the newly burned land, and the berries are often abundant on blueberry land during the summer immediately following burning. This suggests that bunchberries may sustain the maggots on the burned-over land and thus serve to increase infestation of the new berry crop the second year after burning.

Wintergreen berries and chokeberries are common on the blueberry land, but the comparatively slight extent to which these berries have been found infested indicates that they are not important reservoirs of infestation by the maggot.

SPECIES INVOLVED

The original technical description of *Rhagoletis pomonella* was made by Walsh (*18*) from six males bred from eastern apples, July 15–23, and two males and one female bred from Illinois haws, July 23–28. Since the time of the original description in 1867, the species has been shown to be widespread throughout most of the northeastern United States

[7] The plants in this list, with the exception of mountain cranberry and wintergreen, were identified by F. V. Coville. The word "maggots" after the plant name indicates that the fruit was found to be infested by maggots that were apparently *R. pomonella*; the word "adults" after the name indicates that adult flies of *R. pomonella* were reared from maggots found in the fruit.

and eastern Canada, and has been found to infest a considerable number of fruits. The principal fruits infested, however, are apple, haw, blueberry, and huckleberry. The species was notorious as an apple pest for many years before it was technically reported as occurring on huckleberry and blueberry.

IDENTITY OF THE BLUEBERRY MAGGOT AND THE APPLE MAGGOT

Adults of *R. pomonella* reared from huckleberries and blueberries are noticeably smaller in size than those reared from apples and haws, but

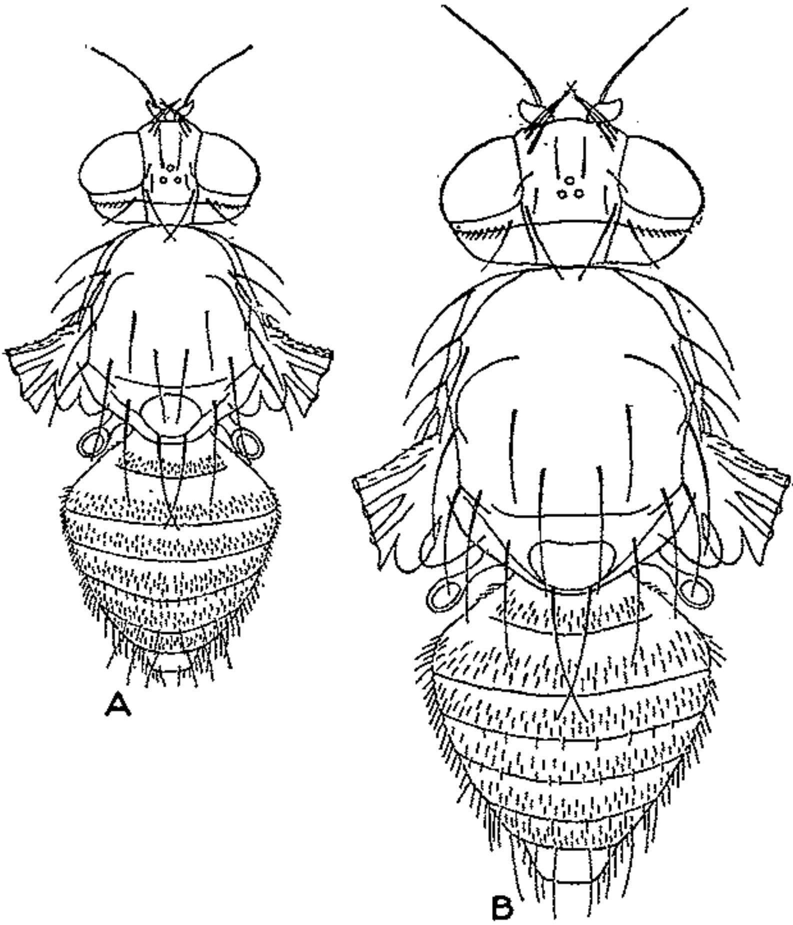


FIGURE 1.—Adults of *Rhagoletis pomonella* (with wings cut off): A, Blueberry form; B, apple form; showing the great similarity of structure and difference in size. × 35

no definite structural characteristics have been reported to differentiate the specimens reared from the two types of fruits. (Fig. 1.)

Several interesting and important questions continually arise. Is the form of *R. pomonella* infesting apples and haws specifically identical with the form infesting huckleberries and blueberries? If the two forms are not identical, how may they be separated? If the forms from the several fruits are specifically identical, which is the original host, and is there continual and free interchange of the insect between the hosts? These questions are considered in the discussion that follows.

STRUCTURAL CHARACTERISTICS

Several closely related species in the genus Rhagoletis have been separated upon the basis of very slight structural differences. Specimens of *R. pomonella* reared from apple and from blueberry were therefore carefully examined, and painstakingly compared, detail with detail, to discover, if possible, even the slightest structural differences. The resemblance between individuals of the two forms is remarkable, and no structural characteristics whatever could be discerned by which the forms might be separated.

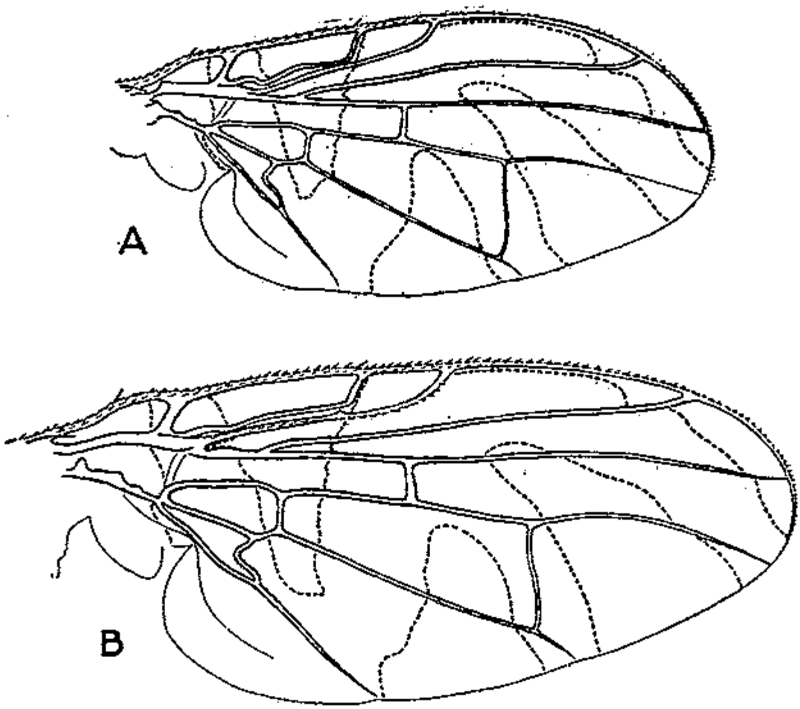


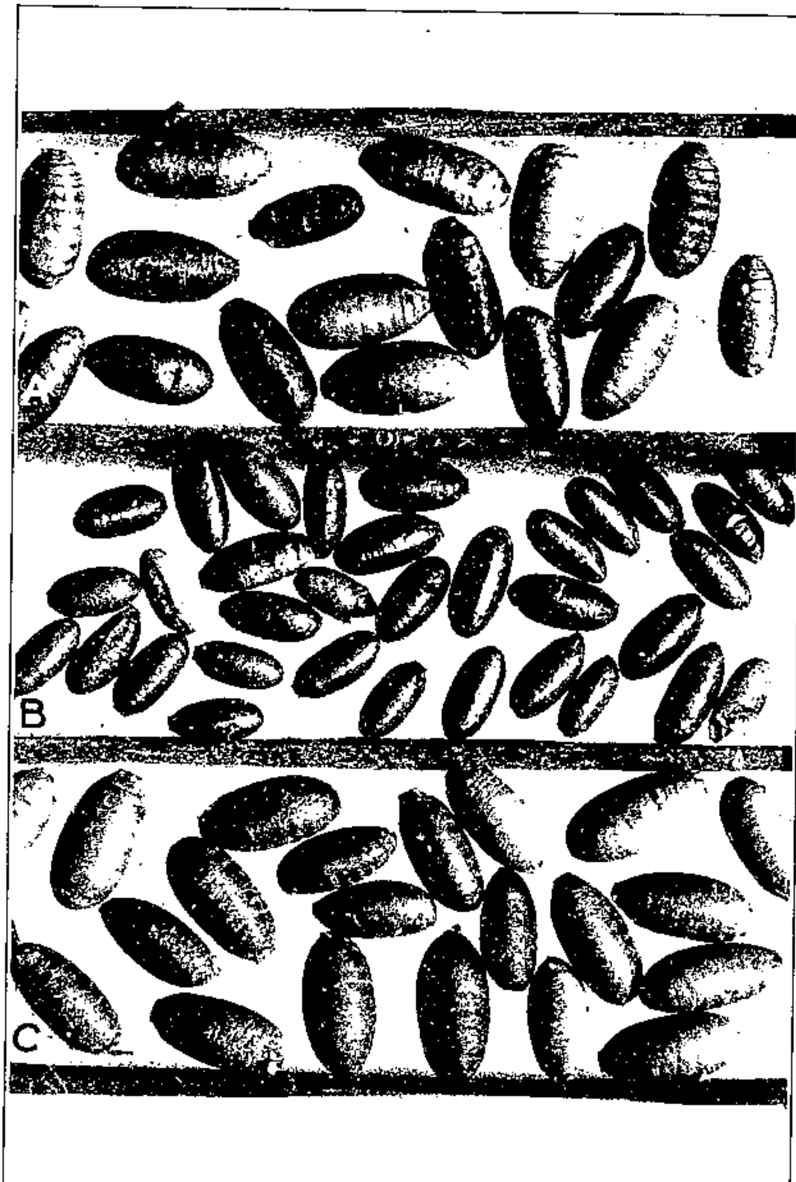
FIGURE 2.—Wings of *Rhagoletis pomonella*: A, Wing from blueberry form; B, wing from apple form; showing relative size and structure. × 35

MEASUREMENTS

The blueberry form of *R. pomonella* is smaller than the apple form, in every stage, although no morphological differences have been observed. Measurements were made of several structures in an attempt to determine whether or not variations in proportions could be detected. Measurements of the length and diameter of a large series of puparia from the two forms showed no significant difference in the proportions of the respective forms. (Pl. 6.) Measurements of the ratio between the width of head and the length and width of wing of adult females showed a slight difference, which, upon statistical analysis, barely fails to be significant. (Fig. 2.) It is interesting to

INJURY CAUSED BY BLUEBERRY MAGGOT

A, Infested blueberries, showing the holes eaten in the skin of the berries by the maggots. Note the collapse of the berries in the last stages of infestation; B, egg puncture in the skin of a blueberry. Magnified 20 times.



PUPARIA OF RHAGOLETIS POMONELLA

A, From apples; B, from blueberries; C, from haws.

note that in each series of measurements the two forms of the insect were quite distinct in size, with very little overlapping.

COMPARATIVE DISTRIBUTION OF THE APPLE MAGGOT AND THE BLUEBERRY MAGGOT

The known distribution of the apple maggot is discussed in detail by Porter (*13*). The principal area of infestation extends from the western borders of the Dakotas eastward to the Atlantic Ocean, and from Nova Scotia southward to New Jersey and Pennsylvania. The range of the insect extends southward along the Allegheny Mountains through Virginia into the Carolinas and Georgia.

The apple maggot is seldom a serious pest in Virginia, but samples of huckleberries from Blacksburg[8] showed severe infestation by maggots apparently similar to *R. pomonella*.

In North Carolina the apple maggot has been recorded (*7*) but is evidently rare. In South Carolina the insect is practically unknown as an apple pest. Huckleberries collected in the mountains of Oconee County,[8] S. C., showed a moderate infestation by maggots, and huckleberries from Orangeburg County,[8] S. C., yielded a few maggots apparently similar to *R. pomonella*.

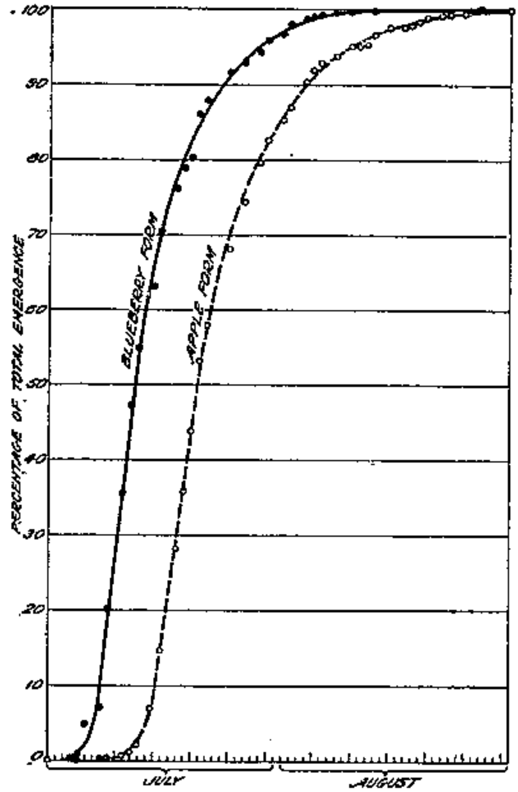


FIGURE 3.—Emergence of blueberry-maggot flies as compared with the emergence of apple-maggot flies, Cherryfield, Me., 1927

In Iowa huckleberries are uncommon, but the apple maggot is sometimes a serious pest.

In South Dakota huckleberries are rare, but the apple maggot is widespread (*14*), although not usually a serious pest.

COMPARISON OF HABITS

The blueberry maggot and the apple maggot are apparently very similar in habits. Patch and Woods (*11*) called attention to the more sluggish habits of the adults of the apple form.

[8] Specimens of infested huckleberries were obtained from Blacksburg, Va., through the cooperation of W. J. Schoene; from Clemson College, S. C., from J. A. Berly; and from Orangeburg County, S. C., from Felix Shuler, jr. Thanks are also due H. E. Hodgkiss and Tom A. Brindley for samples of infested huckleberries from Pennsylvania and Wisconsin, respectively.

In order to study the comparative emergence periods of the two forms, two plots were marked off, about 10 feet apart, under conditions apparently similar. During the season of 1926 1 bushel of heavily infested blueberries were placed on one plot; on the other plot were placed 2 bushels of badly infested Yellow Transparent apples. Records of the adults emerging from the two plots during the season of 1927 indicate that the apple-maggot flies emerged about seven days later than the blueberry flies in the near-by cage. (Fig. 3.)

The egg of the blueberry maggot resembles the apple-maggot egg in every way except in size. There is one noticeable difference, however, in the manner of oviposition. The eggs from Yellow Transparent apples were found lying in the flesh of the apple approximately their full length distant from the puncture in the skin of the fruit. The eggs are easily removed from the flesh of the apple with-

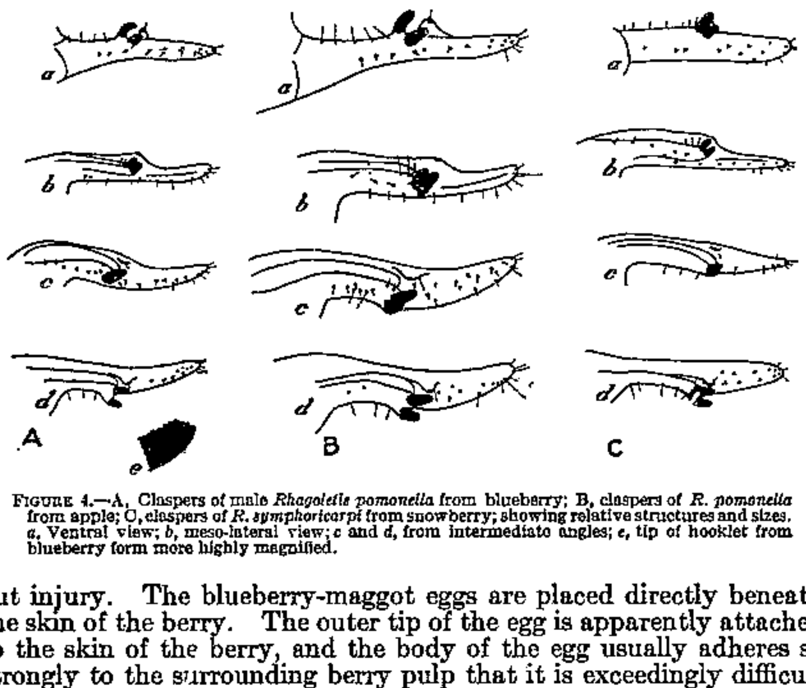


FIGURE 4.—A, Claspers of male *Rhagoletis pomonella* from blueberry; B, claspers of *R. pomonella* from apple; C, claspers of *R. symphoricarpi* from snowberry; showing relative structures and sizes. *a*, Ventral view; *b*, meso-lateral view; *c* and *d*, from intermediate angles; *e*, tip of hooklet from blueberry form more highly magnified.

out injury. The blueberry-maggot eggs are placed directly beneath the skin of the berry. The outer tip of the egg is apparently attached to the skin of the berry, and the body of the egg usually adheres so strongly to the surrounding berry pulp that it is exceedingly difficult to separate the egg from the berry tissue without rupturing the egg.

The habits of the larvae in apple and in blueberry appear similar in every way. The process of pupation likewise seems identical in the two forms.

RELATED SPECIES

There are several very closely related species, separated from *R. pomonella* by very slight structural differences. (Fig. 4.) *R. symphoricarpi* Curran infests the snowberry on the Pacific coast; *R. zephyria* and *R. tabellaria* Fitch attack the native blueberries and whortleberries on the Pacific coast, and are separated from *R. pomonella* by only slight structural differences. Adults of *R. symphoricarpi* have been found in apple trees in British Columbia, where this species was for a while mistaken for *R. pomonella*. However, the species on the Pacific coast have never been observed to infest apples, and the apple maggot is not known in that section.

TRANSFER OF MAGGOTS FROM ONE FRUIT TO ANOTHER

Unfortunately it is difficult to rear *R. pomonella* in captivity because of the abnormal behavior of the flies in confinement, and it has not been determined whether the blueberry form will oviposit on apple, or whether the apple form will oviposit in blueberry. As a substitute for such cross-rearing, a number of maggots, in the early stages, were removed from blueberries and placed in apples, and a number were removed from apples and placed in blueberries. Probably because of injuries incurred during the manipulation, the death rate was high among the transferred maggots. The maggots from blueberries seemed to thrive on apples when ripe fruit was provided. The apple maggots completely devoured the contents of the blueberries, and it was usually necessary to supply additional berries for the maturing of the maggots.

First-instar blueberry maggots transferred to apple successfully matured and formed puparia, but no adults were obtained. Second-instar blueberry maggots formed puparia, and one adult was obtained. The puparia and the adult were normal in size for the blueberry form.

Puparia were obtained from apple maggots which were transferred in the second instar to blueberries. No adults were obtained. The puparia were normal in size for the apple maggot.

PROBABLE RELATIONSHIPS

Evidently *R. pomonella* is a species native to the northeastern portion of the United States, where it undoubtedly infested the fruits of haws and blueberries and huckleberries before the introduction of apples by the white settlers.

All stages of the species from haws and apples are larger than corresponding stages from huckleberries and blueberries. There is no apparent difference in size between the forms from apple and those from haws.

That *R. pomonella* may exist upon apple independently of the blueberry, or vice versa, is suggested by the fact that the apple maggot is widespread and may be a serious pest in sections where huckleberries and blueberries are uncommon; and huckleberries may be infested where the apple maggot is practically unknown.

It seems probable that the infestation of apples originated from haws rather than from blueberries or huckleberries.

The form infesting haws and the form infesting blueberries undoubtedly had a common phylogenetic origin, but there seems to be no evidence to indicate that there is now a common transfer of infestation from one host to the other. That such transfer may not take place commonly is suggested by the fact that the species *R. symphoricarpi* and *R. zephyria*, inhabiting the Pacific coast, are closely related to *R. pomonella* and must have had a common ancestry, but the Pacific coast forms have never been observed to attack apple.

Probably the blueberry maggot and the apple maggot constitute an example of incipient species formation. Just how far the differentiation has progressed has not been determined. The fact that the adults of the two forms show slight differences in the proportions of certain structures suggests that the separation of the two forms may have progressed to the verge of specific integrity.

SUMMARY OF LIFE-HISTORY STUDIES

In general the seasonal cycle (fig. 5) of the blueberry maggot is similar to that published in accounts of the apple maggot. The blueberry maggot spends the winter in the pupal stage in the upper few inches of the soil. The first flies emerge coincidentally with the ripening of the very first of the blueberries, about July 1 in approximately normal seasons, and the month of July marks the normal period of emergence of the adults in Washington County, Me. Emergence proceeds rapidly during two or three weeks of mid-July, the great bulk of the flies emerging during that period. By August 1

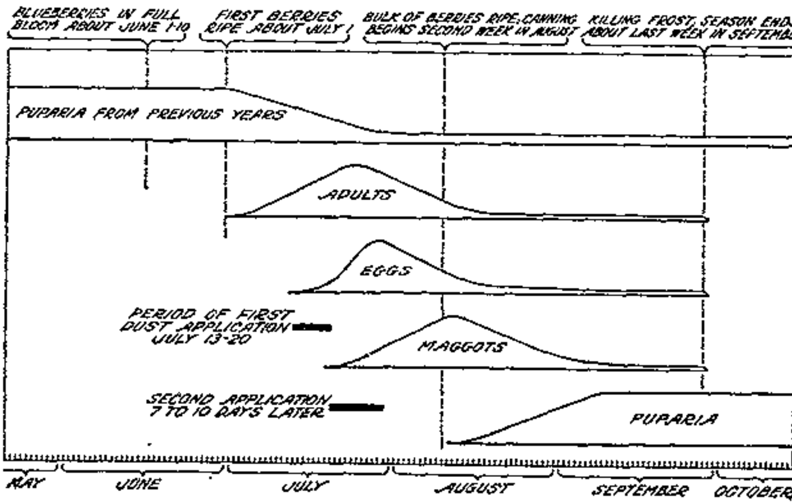


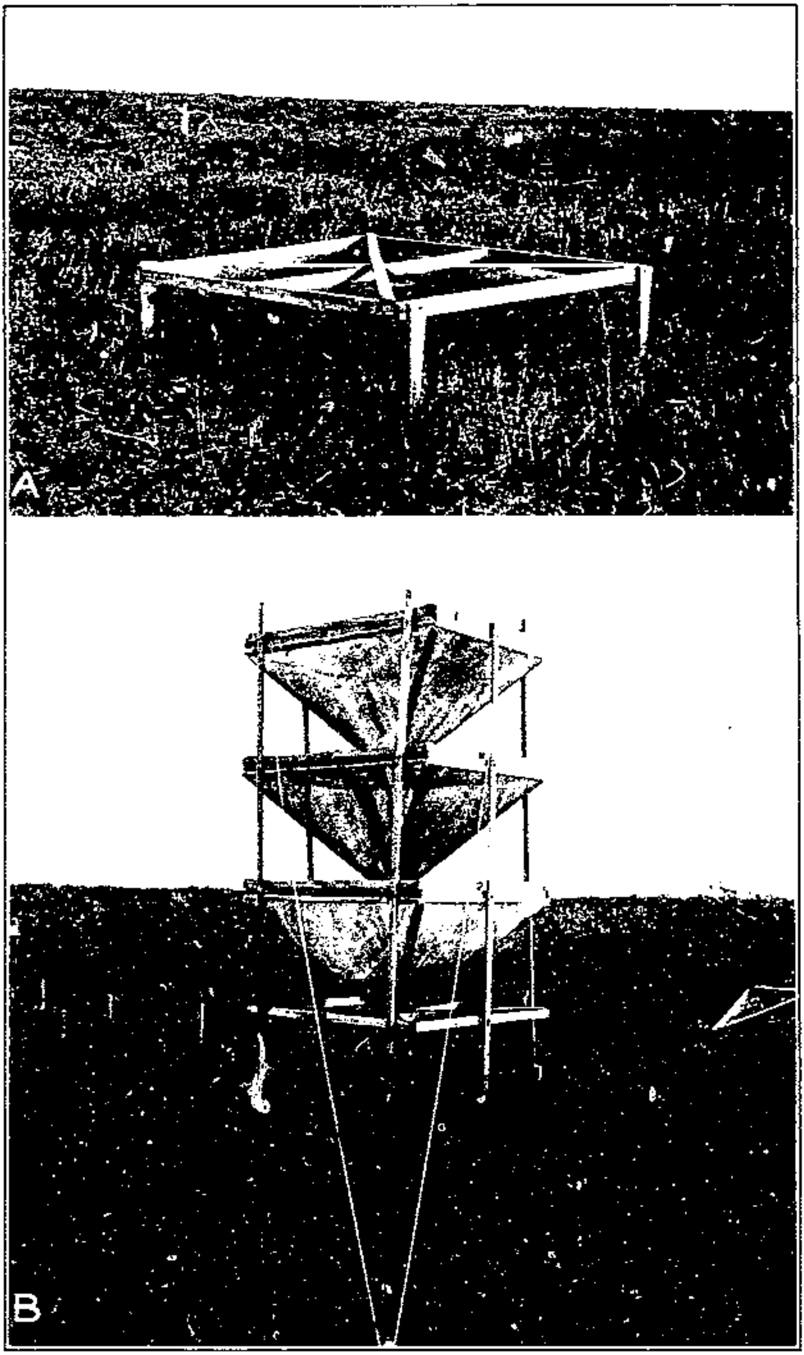
FIGURE 5.—Summary of the life history of the blueberry maggot, Cherryfield, Me.

from 97 to 99 per cent of the flies have emerged. A few flies may emerge in August and early September.

The flies increase rapidly in numbers on the blueberry land as emergence progresses, and are present in maximum abundance about the last week of July. After this time emergence practically ceases, mortality is high, and the abundance of flies in the field declines almost as rapidly as it rose earlier in the season. By mid-August flies are scarce in the field. Adults may be observed in decreasing numbers, however, until killing frost occurs in late September or early October.

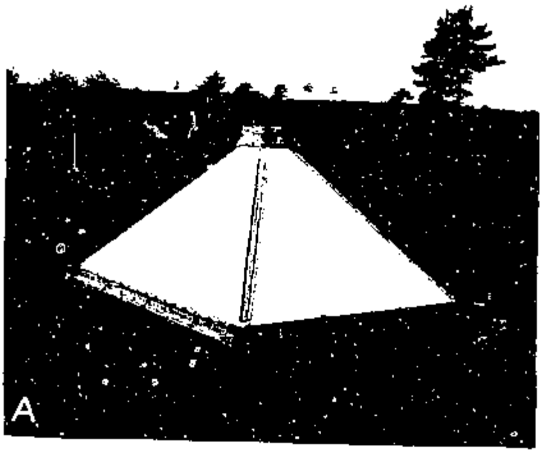
Oviposition begins toward the end of the second week of July, and eggs occur in greatest numbers during the last week in July and the first week in August.

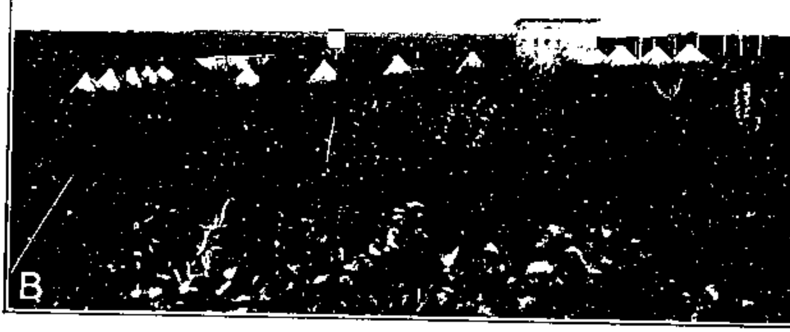
Maggots begin to appear in the berries during the last two weeks of July. They increase rapidly in numbers, and reach the period of greatest abundance during mid-August—just after commercial berry picking gets well under way.



APPARATUS FOR CONCENTRATING PUPAE

A, Wire frame used for holding about 1 bushel of blueberries over a pupation plot; B, multiple concentrator for infesting a pupation plot with a large number of pupae.





EMERGENCE CAGES

A, Emergence cage in position over a pupation plot; B, experimental plot near Cherryfield, Me., showing field laboratory and emergence cages.

During the second week of August the maggots begin to leave the berries and enter the soil to pupate for the winter. From about mid-August until mid-September the decline of maggots in the berries is rapid. By late September the numbers of maggots in the berries are greatly reduced, and the great bulk of the maggots are usually safe in their winter quarters beneath the soil before killing frosts occur.

DIFFICULTIES ENCOUNTERED IN STUDIES OF LIFE CYCLES

When the work with the blueberry maggot was undertaken it soon became apparent that the same difficulties would be encountered in attempting life-history studies with the blueberry form of *R. pomonella* as had been experienced by other workers studying the species as an apple pest. For this reason no very serious attempt was made to rear the species in captivity, and the life-history work was accomplished by the use of more or less indirect methods, based largely upon careful field observations. From the field records, life-history charts were constructed, somewhat in accordance with the method used by Barber (*1*). The fact that the blueberry maggot is single brooded in this section facilitated this procedure and rendered it possible to secure a sufficiently detailed account of the life cycle without employing the rearing methods so frequently used in similar studies with other insects.

Even in field studies, *R. pomonella* is a difficult species with which to work. The flies are shy and inconspicuous, rendering difficult an exact determination of infestation by observation of adults in the field. The eggs are so extremely hard to find that it is practically impossible to make a satisfactory determination of the number present by direct count. The maggots, in their earlier stages, are likewise difficult to find, and infestation is apparent by external examination of the berries only after the maggots have reached an advanced stage. The puparia are formed beneath the surface of the soil, and while the total number per acre may be large, the number of puparia to be found under natural conditions on any area small enough to be examined closely is exceedingly small. These difficulties explain the necessity for the use of indirect methods in undertaking a study of the life history of the blueberry maggot.

EMERGENCE OF ADULTS

METHODS EMPLOYED IN STUDY, AND EMERGENCE RECORDS

During the summer of 1925 preparations were made for obtaining data on the emergence of adults during the next season. Twenty-three rectangular plots, each 4 by 5 feet in size, were laid out on typical blueberry land. During the late summer and early fall, approximately 1 bushel of heavily infested berries was placed on each plot. On 9 plots the berries were placed directly on the soil; on each of the other 14 plots the berries were placed on a wire-screen frame the size of the plot (pl. 7, A) and held by stakes at a height of 12 to 18 inches above the ground. The berries on the plots were not disturbed until freezing weather had occurred, when the screen frames were removed. During the season of 1926 an emergence cage (pl. 8 and fig. 6) was placed over each plot, and daily records were made of the number of flies emerging. By this method large numbers of flies were secured, giving adequate records of emergence.

In the spring of 1926 an attempt was also made to check up on the emergence of flies in the emergence cages by placing several large cages, each 10 feet square, upon areas of heavily infested blueberry land, where it was hoped to secure records of flies emerging from undisturbed soil under more natural conditions. However, so few flies were found in these large cages that the records are of no value.

The results secured in 1926 from the studies of emergence from the 4 by 5 foot plots were so satisfactory that a similar series of pupation

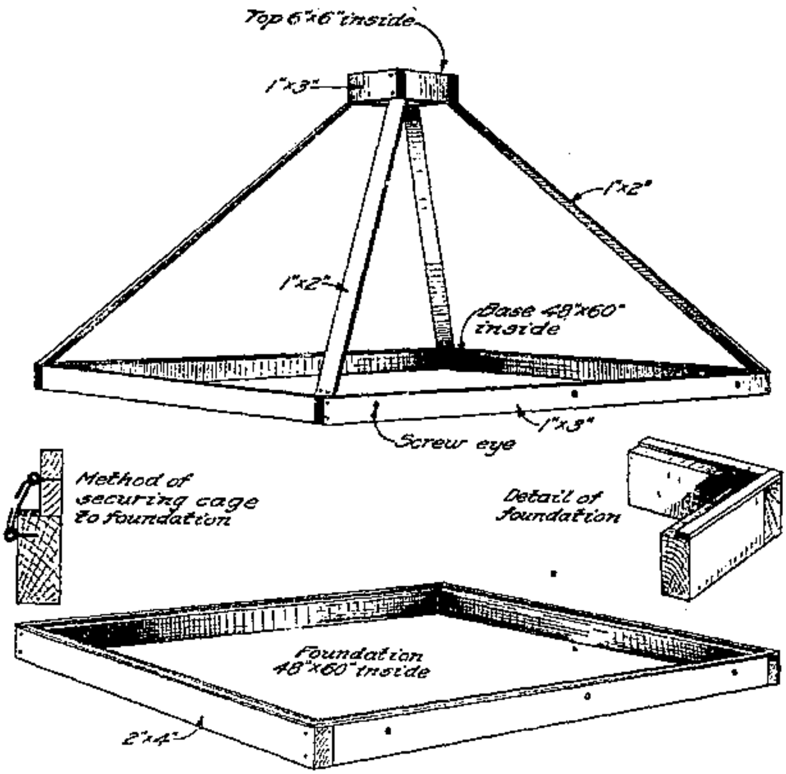


FIGURE 6.—Details of construction of emergence cage used in studying the blueberry maggot in Washington County, Me. The foundation was set securely in the soil, and the cage was fastened to the foundation by means of wires looped through screw eyes

plots was employed each succeeding year. As would be expected, the numbers of flies emerging from the different plots varied considerably. A study of the records seemed to indicate that better results were secured by placing the berries on the wire screens rather than directly on the ground, and during the last two years of these investigations the latter method was used exclusively on the pupation plots.

Beginning at 8 a. m., the flies were removed from the cages daily (with few exceptions) throughout the emergence period. The numbers of flies appearing in the cages, during the peak of the emergence season, were frequently large. In some instances 100 or more flies were removed from a single cage in one day. The largest number of flies removed from one cage in a single day occurred when 793 flies were removed from cage B on July 9, 1927. The next day 657 flies were removed from this same cage. With such numbers emerging, the removal of the flies from the cages presented a problem, and the work of removing the flies was often not completed until noon. This probably introduced some degree of error into the records, but the flies were removed from the cages in the same order each day, which reduced the error to a minimum.

In removing the flies, the wire screen cover was removed from the top of the emergence cage and a small metal cage (pl. 9, A) was put in place. A black tent was then thrown over the emergence cage, darkening the interior, but leaving the small metal cage at the top exposed to light. After 15 to 20 minutes the flies were usually congregated in the small cage, where they were attracted by the light. A metal slide was placed in the bottom of the small metal cage, which could then be removed from the emergence cage without danger of flies escaping. In some cases, especially when the numbers emerging were very large, some of the flies were slow in moving into the small metal cage, and it was often necessary to place the small cage in position a second time. By using considerable care, it was found possible to remove practically all of the flies from the cages even during periods of greatest emergence, and the error caused by flies remaining in the emergence cages must be quite small.

During the seasons of 1926 and 1927 the flies were removed alive from the small cages. This was quite a laborious process and consumed much time when emergence was heavy. It also increased the difficulty of determining the sex of the flies. During the season of 1928, and again in 1929, each small cage containing flies from an emergence cage was placed in a fumigation box containing a heavy charge of calcium cyanide. (Pl. 9, B.) The flies were killed by the gas very quickly, after which it was a simple matter to make the desired counts. The number of emergence cages operated and the number of flies obtained each season are shown in Table 2.

TABLE 2.—*Number of cages operated and number of flies obtained, Washington County, Me., 1926–1929*

Year	Cages operated	Flies obtained
1926	23	3,442
1927	20	31,072
1928	19	2,718
1929	19	3,203
Total	81	40,435

The most striking characteristic of the emergence of the blueberry flies in eastern Maine is the short time during which so large a percentage of the flies emerge. The first emergence normally occurs during the last few days of June or the first week of July. The earliest date upon which a fly was noticed in the cages was in 1927, when one fly was observed on June 20. Emergence begins to increase decidedly during the first 10 days of July, after which it becomes very rapid. The peak of emergence is reached during the middle of the month, and by the first of August from 97 to 99 per cent of the flies had emerged, during each year in which observations were made. After August 1, a few flies continue to emerge until late in the season. The emergence records for the four years covered by the studies are summarized in Table 3.

TABLE 3.—*Comparison of emergence records of flies of the blueberry maggot, Washington County, Me., 1926-1929*

Year	Date of first emergence	Dates upon which the accumulated emergence of flies had reached the specified percentages of the total emergence						Date of last emergence
		10 per cent	25 per cent	50 per cent	75 per cent	90 per cent	95 per cent	
1926	July 5	July 11	July 13-14	July 17-18	July 21	July 24-25	July 26-27	Sept. 8.
1927	June 20	July 8-9	July 11	July 14	July 17-18	July 20-21	July 24-25	Sept. 9.
1928	July 2	July 9-10	July 11-12	July 15	July 17	do	July 23	Aug. 17.
1929	June 28	July 7-8	July 10-11	July 12-13	July 15-16	July 18	July 26	Sept. 24.

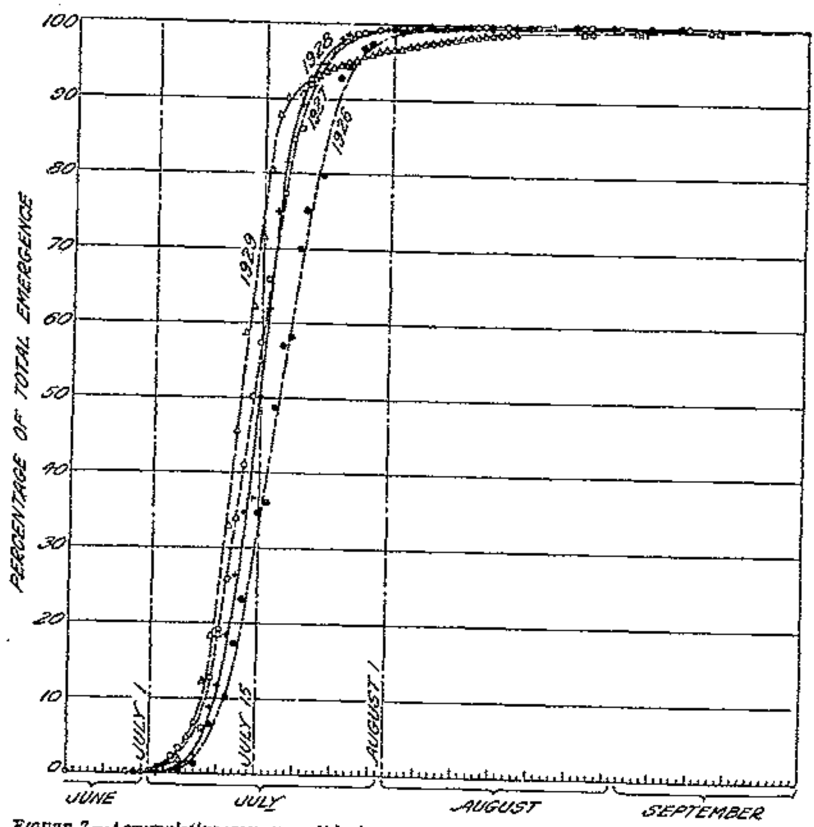
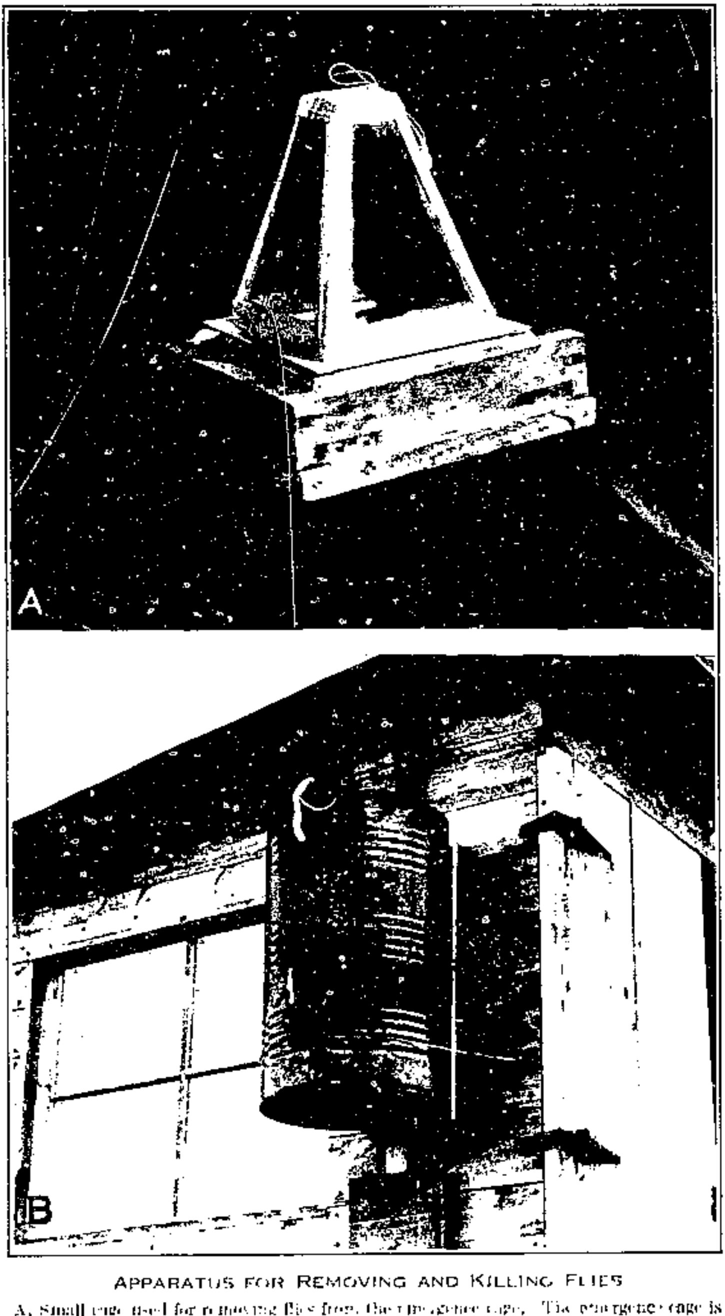


FIGURE 7.—Accumulative emergence of blueberry-maggot flies, Cherryfield, Me., 1926, 1927, 1928, 1929

The variation in emergence dates from one season to the next has proved to be much less than was expected. This close uniformity is shown graphically in Figure 7. The curves plotted on this chart show that the extreme differences in emergence during the four years of this study are a matter of only a few days. This



APPARATUS FOR REMOVING AND KILLING FLIES

A, Small cage used for removing flies from the emergence cage. The emergence cage is covered with a black tent. B, small fumigation chamber for killing flies from the emergence cages.

agrees with Brittain's (*2*) observations on the emergence of the apple maggot in Nova Scotia. In commenting upon the emergence of the flies he states: "It is evident that whatever the difference in the early spring—whether the season is early or late—the time of emergence of the apple maggot is approximately the same."

If they are found to hold true during a large percentage of seasons, this apparent constancy of the dates of emergence and the shortness of the emergence period will be of great importance from the standpoint of control. The fact that the flies emerge so nearly in accord-

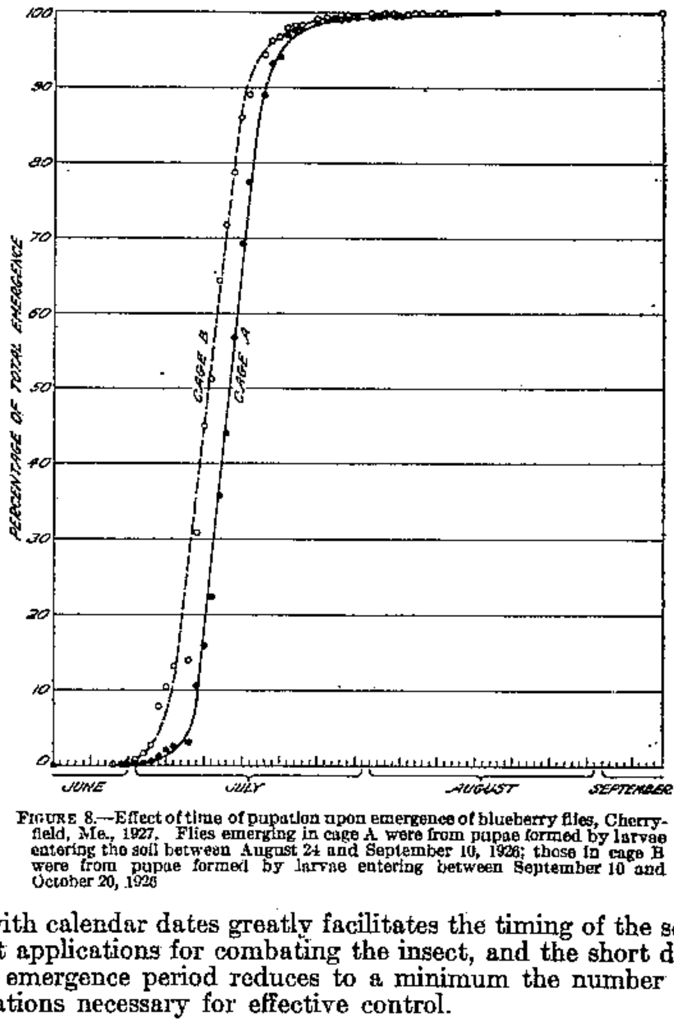


FIGURE 8.—Effect of time of pupation upon emergence of blueberry flies, Cherryfield, Me., 1927. Flies emerging in cage A were from pupae formed by larvae entering the soil between August 24 and September 10, 1926; those in cage B were from pupae formed by larvae entering between September 10 and October 20, 1926

ance with calendar dates greatly facilitates the timing of the schedule of dust applications for combating the insect, and the short duration of the emergence period reduces to a minimum the number of dust applications necessary for effective control.

EFFECT OF TIME OF PUPATION UPON EMERGENCE OF ADULTS

In the fall of 1926 a device (pl. 7, B) was constructed which permitted placing a large quantity of heavily infested blueberries over a single pupation plot. This device with 4 bushels of blueberries was placed on plot A on August 24, 1926. On September 10 the apparatus with the blueberries was moved to plot B, where it was allowed to stay until October 20. Plot A therefore contained a large number of pupae, the larvae of which had entered the soil between August 24 and September 10. Plot B contained pupae formed by larvae which entered the soil between September 10 and October 20. During the season of 1927 a total of 3,937 flies emerged from plot A and 4,674 from plot B. The emergence records from the two plots during the season of 1927 are summarized in Table 4. Contrary to expectation, the emergence from plot B was from two to four days earlier than the emergence from plot A. The emergence from these two plots is illustrated graphically in Figure 8.

TABLE 4.—*Effect of time of pupation upon date of emergence of adults, Washington County, Me., 1927*

Cage	Period of pupation	Date of first emergence	Dates upon which the accumulated emergence of flies had reached the specified percentages of the total emergence						Date of last emergence
			10 per cent	25 per cent	50 per cent	75 per cent	90 per cent	95 per cent	
A	1926 Aug. 24–Sept. 10.	June 20	July 9	July 11–12	July 13–14	July 15–16	July 18–19	July 20–21	Aug. 18.
B	Sept. 10–Oct. 20.	June 28	July 5	July 8–9	July 10–11	July 13–14	July 16–17	July 18–19	Sept. 9.

PROPORTION OF THE SEXES

During the seasons of 1928 and 1929 a careful record was kept of the sex of all flies removed from the emergence cages, except for an insignificantly small number which escaped observation. The records for the two seasons are summarized in Table 5. It is probable that on an average the proportion of males to females is about equal. The emergence from all cages in 1928 was 45.44 per cent female; in 1929 it was 56.53 per cent female. The flies emerging during the second and subsequent seasons showed about the same ratio of males to females as did the flies issuing during the first season after pupation. The sexes were about equal in the emergence cages, but in the field usually the males were observed to outnumber the females. Caesar and Ross (*5*), working with the apple maggot, found an excess of females in the emergence cages, while in the orchard more males than females were observed.

TABLE 5.—*Proportion of sexes of blueberry flies emerging from all cages observed during 1928 and 1929*

Year of pupation	Emergence during 1928				Emergence during 1929			
	Males	Females	Total	Percentage of females	Males	Females	Total	Percentage of females
1928					1,254	1,689	2,943	57.39
1927	623	570	1,193	47.78	68	61	129	47.29
1926	831	634	1,465	43.28	67	57	124	45.97
1925	29	31	60	51.67	3	3	6	50.00
Total	1,483	1,235	2,718	[1] 45.44	1,392	1,810	3,202	[1] 56.53

[1] Percentage of the total.

EMERGENCE DURING THE SECOND, THIRD, AND FOURTH SUMMERS AFTER PUPATION

A number of workers reporting upon the biology of the apple maggot have recorded the fact that a certain percentage of the pupae will remain quiescent in the soil until the second summer after pupation, when the adults emerge. In order to obtain information regarding the extent to which the blueberry form of this insect may delay emergence to the second and subsequent seasons after pupation, emergence cages were placed on several of the plots during successive seasons.

Each spring, before the cages were placed on any of the emergence plots, the blueberry blossoms were carefully removed from each plot, so that no fruit was produced in the cage during the emergence period. The cages were examined once or twice, subsequently, for berries, to make sure that the removal had been complete. This prevented the possibility of maggots developing within the emergence cages. In the routine of removing the flies from the cages, the berries were trampled from the bushes surrounding the cages, and the soil was packed hard for a distance of 4 to 6 feet about each cage. It seems exceedingly unlikely that any maggots migrated into the cages from the outside.

The first pupation plots were established in 1925, and emergence records were maintained on four of the plots. During each of the four seasons after the plots were established, flies in diminishing numbers were observed to emerge. Eight pupation plots established in 1926 were observed for emergence during 1927, 1928, and 1929; and two plots established in 1927 were observed during 1928 and 1929. The data obtained from these plots are summarized in Tables 6, 7, and 8. "Second season" flies issuing during 1927, 1928, and 1929 represented 19.68 per cent, 7.11 per cent, and 11.97 per cent, respectively, of the emergence during the first season.

TABLE 6.—*Summary of the records of emergence of flies during four years in four cages covering pupae formed in 1925*

Year	Emergence	Percentage of 1926 emergence
1926	1,113	
1927	219	19.68
1928	60	5.39
1929	6	.54
Total	1,398	

TABLE 7.—*Summary of the records of emergence of flies during three years in eight cages covering pupae formed in 1926*

Year	Emergence	Percentage of 1927 emergence
1927	20,607	
1928	1,466	7.11
1929	124	.60
Total	22,197	

TABLE 8.—*Summary of the records of emergence of flies during two years in two cages covering pupae formed in 1927*

Year	Emergence			Percentage of 1928 emergence		
	Male	Female	Total	Male	Female	Total
1928	571	507	1,078			
1929	68	61	129	11.91	12.03	11.97
Total	639	568	1,207			

The capacity of the species to carry over in the soil for two or more seasons has an important bearing upon the blueberry-maggot problem. The ability to lie dormant in the soil during the summer following burning of the blueberry land, and to emerge in time for the first blueberry crop, undoubtedly hastens the reinfestation of the new crop of berries after burning. Were it not for this factor, burning the blueberry land would probably be much more effective in reducing infestation by the maggot than has proved to be the case.

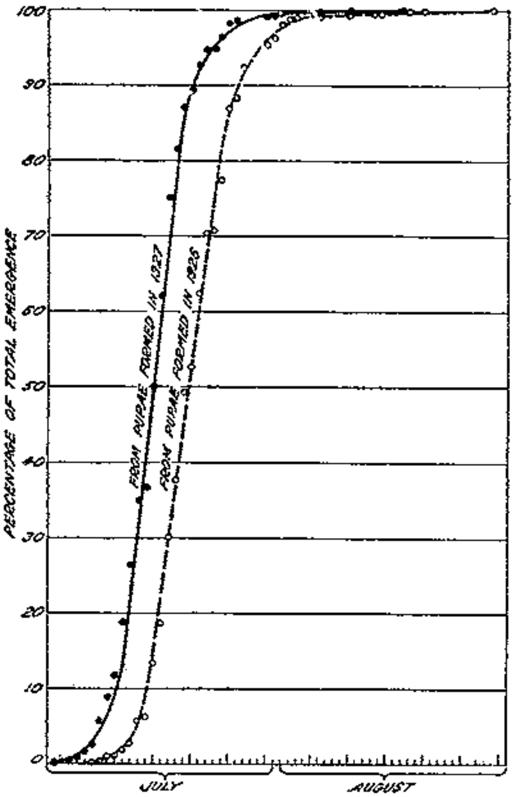


FIGURE 9.—Comparative dates of emergence (during 1928) of flies which had hibernated one winter and those which had hibernated two winters. Curve of emergence from pupae formed in 1926 is based upon records of 1,466 flies; curve of emergence from pupae formed in 1927 is based upon records of 1,113 flies

TIME OF EMERGENCE OF CARRY-OVER FLIES

The flies emerging from land bearing the first crop of berries following a burn consist almost entirely of individuals which have carried over in the soil for two winters. It is therefore important to know if the emergence of the carry-over flies coincides with the emergence of flies which have hibernated only one winter.

During only one season were carry-over flies secured in sufficient numbers to give a reliable indication of the dates of emergence. During 1928 1,466 flies emerged from pupae which had formed in the soil in 1926. The emergence curve of the carry-over flies, as compared with the regular emergence of 1928, is shown in Figure 9. The carry-over flies emerged about four to six days later than the flies which had spent only one winter in the soil.

EMERGENCE OF FLIES DURING A 24-HOUR PERIOD

Porter (*13*) found that the apple-maggot flies emerged mostly during the daylight hours. In order to determine the time of day that the blueberry flies appear, observations were made on two cages at Cherryfield, during a period of 24 hours. At 5 p. m., and again at 9 p. m., July 16, 1929, all the flies were carefully removed from the two cages. At 3 o'clock the next morning the flies which had emerged during the night were collected, and the cages were removed from their foundations. Constant watch was maintained, and the flies were captured as soon as they emerged from the soil. The records obtained are shown in Table 9. The heaviest emergence occurred between 7 and 10 a. m. Emergence was less in the afternoon, and only one fly emerged between 9 p. m. and 3 a. m.

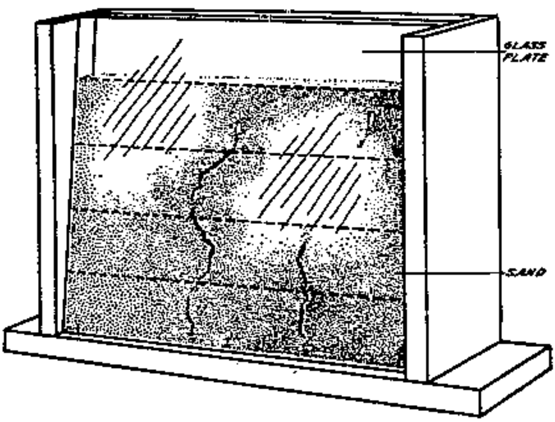


FIGURE 10.—Glass-front box for observing blueberry flies during process of emerging through sand

TABLE 9.—*Emergence of flies in two cages during a period of 24 hours*

Time	Number of flies emerged			Time	Number of flies emerged		
	Males	Females	Total		Males	Females	Total
5 to 9 p. m.	4	2	6	10 to 11	0	2	2
9 p. m. to 3 a. m.	1	0	1	11 to 12 noon	3	2	5
3 to 4 a. m.	0	0	0	12 to 1 p. m.	3	3	6
4 to 5	9	5	14	1 to 2	1	1	2
5 to 6	2	3	5	2 to 3	2	1	3
6 to 7	1	3	4	3 to 4	1	1	2
7 to 8	4	7	11	4 to 5	0	1	1
8 to 9	9	6	15				
9 to 10	16	8	24	Total	56	45	101

DETAILED OBSERVATIONS ON EMERGENCE

When the fly is ready to emerge, the anterior end of the puparium is burst along the sutural lines. When the insect creeps out of the puparium, the wings are not expanded, and the integument of the body is soft and nonpigmented. For the purpose of observing the process of emerging, a glass-front observation box (fig. 10) was constructed, in which puparia were buried at depths varying from 1 to 4 inches. The insects appeared to have no difficulty in emerging through sand or peaty loam from a depth of 4 inches.

A number of flies were observed during the journey upward through the soil. The trails of several flies are shown in Figure 11.

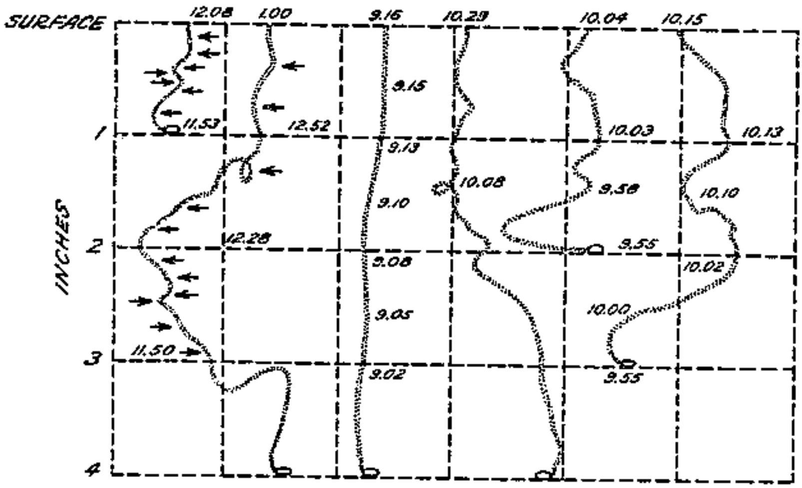


FIGURE 11.—Routes taken by blueberry flies emerging through sand. The arrows indicate the direction of the light

The rate at which the flies moved through the sand varied considerably with different individuals. In one instance, in which the fly moved almost steadily upward in a straight line from a depth of 4 inches, the insect was observed to climb upward 3 inches in 14 minutes. Another individual, ascending from the same depth, was observed to occupy 70 minutes in moving upward 3 inches.

FIGURE 12.—A, Emerging blueberry fly with ptilinum inflated; B, appearance of ptilinum in different stages (1 to 5) of inflation. × 18

During the process of emerging, the flies work their way through the soil by elongating and contracting the body. The bladderlike ptilinum is almost continually expanded and contracted. (Fig. 12.) When deflated, this structure seems capable of a slight lateral movement. The function of the ptilinum seems to be to clear a way for the insect, but actual progress is apparently made mostly by the body movements. Probably the bristles of the thorax and abdomen are important in helping the insect upward. The legs are carried in a passive posture, extending along the ventral surface of the abdomen, and they appear to take little or no part in propelling the insect, except to prevent a backward movement.

The path of the insect is often tortuous. Progress is, of course, in a generally upward direction, but the movement is at times horizontal, or even downward for short distances.

The emerging fly seems to be activated mainly by the stimulus of negative geotropism. However, the insect seems to show also a positive phototropism, and the course of an ascending fly may be modified by moving the observation box so that the light falls first from one side, then from the other. (Fig. 11.)

When the fly reaches the surface of the soil, it can crawl rapidly, but is unable to fly because the wings are not yet expanded. The following records were made of two flies which were observed in the laboratory.

Fly No. 1	June 5, 1928
10.29 a. m.	Emerged from the soil.
11.06	Apparently fully expanded but not hardened.
11.28	Insect not yet fully colored. Did not fly when disturbed, but moved to another leaf.
11.44	Not yet fully colored. Wings whitish and not transparent; veins not colored.
11.55	Color seems to be increasing more rapidly.
12.08 p. m.	Insect nearly fully colored.
12.45	Insect fully colored. Flew to window.

Fly No. 2	June 9, 1928
9.16 a. m.	Emerged from the soil.
9.36	Wings elongated nearly full length, still shrunken at the apex.
9.46	Wings fully expanded.
9.52	Wings becoming transparent. Body still lacks color.
10.50	Fly fully colored, capable of flight.

HABITS OF THE ADULTS

The behavior of the flies in the field may be studied only by careful observation. The adult is shy and restless; it appears suspicious of all other creatures, and any moving body attracts immediate attention. The fly orients itself to face any moving object and can be induced to execute a turn by slowly moving the hand in a circle with the fly at the center.

The flies have never been observed in great numbers in the field. Their "suspicious" nature seems to induce them to lead a solitary existence. Only during periods of copulation have two individuals been observed together. At other times each fly remains by itself and seems constantly on guard to avoid all other moving creatures.

The flies move by short, quick darts from leaf to leaf or from one plant to another, and have seldom been observed to make a nonstop flight of more than a few inches. On this point there is some room for uncertainty, however, for the fly is so quick in action and so swift in flight that it vanishes the instant it takes wing. Upon alighting, the insect suddenly reappears. As Patch and Woods (*11*) so aptly state: "The adults suddenly appear on the berries seemingly as if they had just sprung into existence * * *"

In captivity the flies do not react normally, and it seems that observation of the flies confined in cages has little value as an index to their behavior in the field.

The blueberry fly feeds in a manner similar to the house fly. In the field the flies may be observed frequently lapping moisture or particles from the blueberry foliage. If approached with due caution, the fly may be induced to feed upon a finger moistened with saliva or with the juice of a crushed blueberry. While feeding upon a finger, the fly seems to lose much of its shyness, and will usually remain for a minute or two, during which time it may be observed closely.

The feeding habit of the fly is of course important from the standpoint of control, for in promiscuously feeding over the surface of foliage dusted with calcium arsenate the fly is likely to consume a fatal quantity of the arsenic.

The flies seem inclined to frequent clumps of sweet fern, especially about the bases of birch or alder sprouts on the blueberry land. The effect of this habit is reflected in a higher average infestation of the berries growing in such locations, as compared with that of berries from open spaces on the blueberry land. The difference in infestation of berries from open spaces and from bushy areas is shown in Table 10.

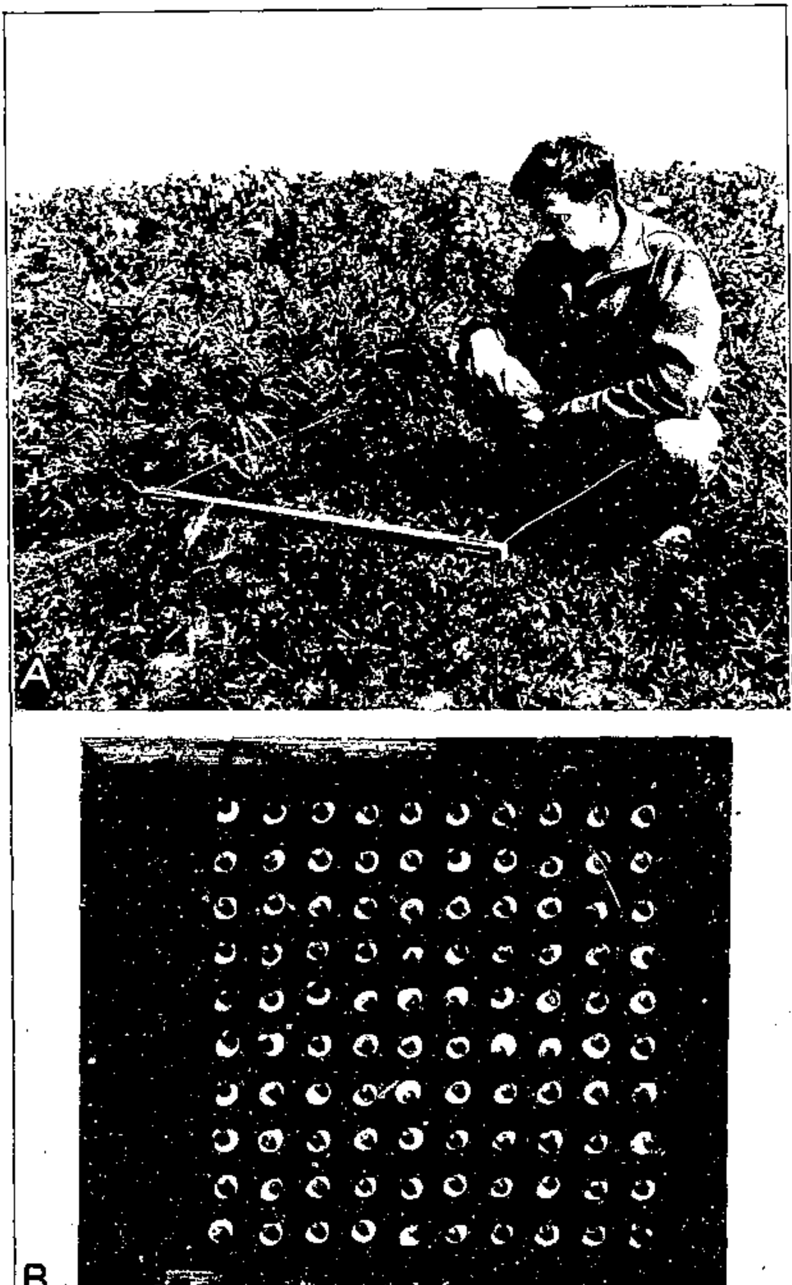
TABLE 10.—*Difference in infestation of berries from bushy areas and from open spaces, 1927*

Plot	Number of 100-berry samples from each class	Maggots per 100 berries— In samples from open spaces	Maggots per 100 berries— In samples from bushy areas	Plot	Number of 100-berry samples from each class	Maggots per 100 berries— In samples from open spaces	Maggots per 100 berries— In samples from bushy areas
1	10	4.20	7.40	5	50	2.43	7.52
2	24	1.15	1.45	6	20	.35	1.50
3	50	5.10	11.88				
4	20	3.50	11.55	Average		2.79	6.88

LONGEVITY AND OCCURRENCE OF FLIES IN THE FIELD

METHODS OF STUDY AND FIELD COUNTS

To ascertain the seasonal fluctuations of the fly population in the field, a method was devised which appears to have given fairly satisfactory results. Five light counting frames were constructed (pl. 10, A), each of which inclosed an area of approximately one ten-thousandth of an acre, for making quantitative determinations of the flies in the field. In the summer of 1927 observations were made on plot No. 2. Ten counting areas, each 100 feet square, were laid off in the check area of this plot, and 10 in the treated area (for details of treatment applied see plot 2, Table 23). Five men experienced in observing the flies in the field were employed in making the counts. Each man was equipped with a counting frame, and, preparatory to making an observation, each selected within the first counting area a place which looked especially favorable for finding flies. It seemed desirable in each case to select places especially favorable for the flies. By so doing, larger numbers of flies were observed. Since the observers were more likely to overlook flies than to report more flies than were actually present, it was thought that counts made in especially favorable spots would give a more accurate estimate of the fly population than similar counts made in supposedly average locations. As soon as each man had set down his counting frame in a location suitable for counting, a signal was given, and for a period of two minutes the area included within the counting frame was studied intently in a search for flies. At the expiration of two minutes another signal was given, and the number of flies found in that area was recorded. Whenever it was possible to do so, the sex of the flies was noted. After some experience, observers could usually determine the sex of the flies, but this was not always the case, and the counts obtained are not strictly accurate in this respect.



APPARATUS USED IN COUNTING FLIES AND BERRIES

A, Making a field count of blueberry flies by means of a counting frame; B, counting board used for counting samples of blueberries from experimental plots.

As soon as the number of flies had been recorded, the frame was picked up, moved to another location in the same count area, and at the signal the second area included within the limits of the counting frame was searched for flies for a period of two minutes. After the results of the second count on the first area had been recorded, the men moved to the second 100-foot square, where the process was repeated; two counts being made by each man in each of the count areas. When counts had been made in all of the areas, a total of 100 counts had been secured from the check plot and 100 for the dusted plot. As the area of each count was one ten-thousandth of an acre, a total area of one one-hundredth of an acre had been examined in the check plot and an equal area in the treated plot when all of the

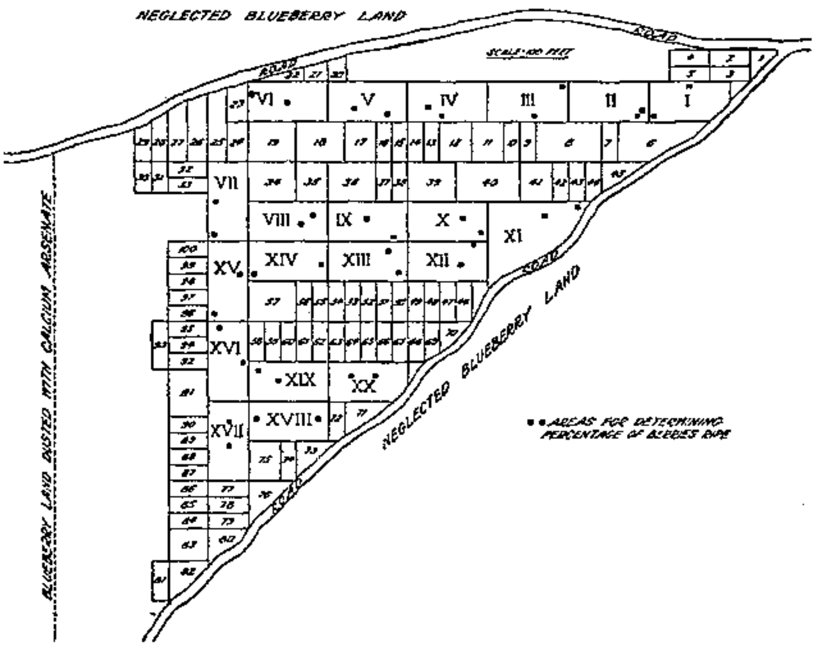


FIGURE 13.—Field plot laid off for biological studies of the blueberry maggot, Cherryfield, Me., 1929. I to XX, areas in which fly counts were made; 1 to 100, plots from which samples of berries were taken for studies of maggot population; the small black squares indicate 40 areas upon which the percentage of ripe berries was determined throughout the season

counts were completed. Hence the total number of flies found on the check plot or on the treated plot multiplied by 100 represented the number of flies present per acre.

Similar counts were made in the check area and in the treated area of plot 1 G during the season of 1928 (for details of treatment applied see plot 1 G, Table 28). During the summer of 1929 similar observations were made on the check area of this same plot, but counts were not made in the treated area during that season. Twenty count areas, each 50 by 100 feet in size, were laid off. (Fig. 13.) This gave a total of 200 counts on untreated land, and increased the accuracy of the counts made on this area.

The results of these counts for the three years are indicated in Tables 11, 12, and 13. The counts made on plot 2 in 1927 were made on land bearing the second crop of berries after burning. The counts made on plot 1 G in 1928 were on land bearing the first crop of berries after the land was burned over, and the counts made on this same area in 1929 were on land bearing the second crop after burning.

TABLE 11.—*Numbers of flies per acre as shown by field counts on plot 2,*[1] *1927*

Date	Estimated number of flies per acre	
	Check plot	Treated plot
July 28 [2]	7,400	4,200
Aug. 3	3,700	100
Aug. 16	500	200
Aug. 26	100	200

[1] For data concerning applications of calcium arsenate on this plot see Table 23.
[2] On July 28, 50 counts were made on the check plot and 50 on the treated plot; 100 counts were made on the check plot and 100 on the treated plot on all other dates.

TABLE 12.—*Numbers of flies per acre as shown by field counts on plot 1 G,*[1] *1928*

Date [2]	Estimated number of flies per acre							
	Check plot				Treated plot			
	Males	Females	Undetermined	Total	Males	Females	Undetermined	Total
July 13	0	0	0	0	0	0	0	0
July 18	400	100	300	800	0	0	0	0
July 24	1,200	400	300	1,900	100	200	0	300
July 31	500	1,000	600	2,100	0	0	0	0
Aug. 4	600	0	0	600	0	0	0	0
Aug. 13	300	100	0	400	0	0	0	0
Aug. 29	200	0	0	200	0	0	0	0

[1] For data concerning applications of calcium arsenate on this plot see Table 28.
[2] One hundred counts were made on the check plot and a like number on the treated plot on each date indicated.

TABLE 13.—*Numbers of flies per acre as estimated from field counts on experimental plot, 1929*

Date [1]	Estimated number of flies per acre				Average of counts on two days
	Males	Females	Sex undetermined	Total	
July 8	50	200	0	250	200
July 9	100	50	0	150	
July 11	100	300	0	400	525
July 12	300	300	50	650	
July 22	2,850	1,100	600	4,550	4,750
July 23	2,800	1,800	350	4,950	
July 29	2,400	1,950	650	5,000	4,675
July 30	2,600	1,400	350	4,350	
Aug. 6	1,050	900	150	2,100	2,075
Aug. 7	1,700	300	50	2,050	
Aug. 13	1,050	300	0	1,350	1,350
Aug. 14	750	600	0	1,350	
Aug. 21	400	150	0	550	525
Aug. 23	350	100	50	500	
Aug. 27	150	50	0	200	200
Aug. 28	100	100	0	200	

[1] Two hundred counts were made on each date indicated. All counts were made on land that had not been dusted; no counts were made on dusted land this season.

In interpreting the results of the population studies it was found possible to correlate the numbers of flies found in the field with the records obtained from the emergence cages. It was assumed that emergence on the areas on which the field counts were made was very similar to the emergence in the cages. This assumption was probably correct, for plot 2, on which field counts were made in 1927, is located within 2 miles of the emergence-cage plot and is on land fairly similar to that on which the emergence cages were located. There can be little question about the emergence on plot 1 G being comparable to the emergence in the emergence cages, for the field counts on this area were taken within a few hundred feet of the emergence cages.

If the numbers of flies per acre, as shown by the field counts during the years 1927, 1928, and 1929 be plotted, it will be noticed that the number of flies found in the field increases as emergence progresses. Later, as emergence declines and the rate of mortality increases, the number of flies in the field decreases. This suggested the possibility of making a chart by superimposing the data from the field counts upon the emergence curves.

To do this, the emergence curve for each season was first plotted. It was assumed that the numbers of flies in the field increased in direct proportion to the accumulated emergence of flies and therefore the increase of fly population follows approximately the curve of accumulated emergence for a period equal to the average length of life of the flies in the field. After the flies begin to die, the curve of fly population falls below the emergence curve.

The theoretical number of flies present in the field on any date may be determined by ascertaining the total percentage of accumulated emergence on that date, and subtracting from that number the percentage of flies that have died by that date.

This may be expressed by the formula:

Flies present = flies emerged − flies dead.

This entire equation is expressed in terms of percentage of total emergence for the season. In working with this formula, the percentage of flies emerged is determined from the records obtained from the emergence cages. The percentage of flies dead on any date is represented by the percentage of flies which had emerged on a date preceding the given date by a number of days equal to the average length of life of flies in the field. For example, to determine the percentage of flies dead on August 6, 1929, assuming the average length of life to be 24 days, count back 24 days, to July 13, on which date 58.89 per cent of the flies had emerged. Theoretically all of these flies would be dead on August 6, and should be subtracted from the percentage of flies emerged on August 6 (97.93) to obtain the theoretical percentage of flies present (39.04) on this date. The theoretical curve of occurrence was plotted in this way for each season. (Figs. 14, 15, and 16.)

Both the emergence curve and the curve of theoretical occurrence, as discussed above, are computed on a percentage basis, while the records of the field counts are based on the numbers of flies per acre. In order to superimpose one of these series of records upon the other, it was necessary to reduce the theoretical curve of occurrence and the field counts to a common basis. The curve of theoretical occurrence was plotted in the manner described above, using an arbitrary number of days which was thought to approximate quite closely the average length of life in the field. A cross was then placed on the occurrence curve at its intersection with each date upon which a fly count was made in the field.

Assuming that the results of the field counts are most nearly accurate when a large number of flies are present, the point on the emergence curve corresponding with the largest number of flies obtained in a field count was assumed to be correct and to represent

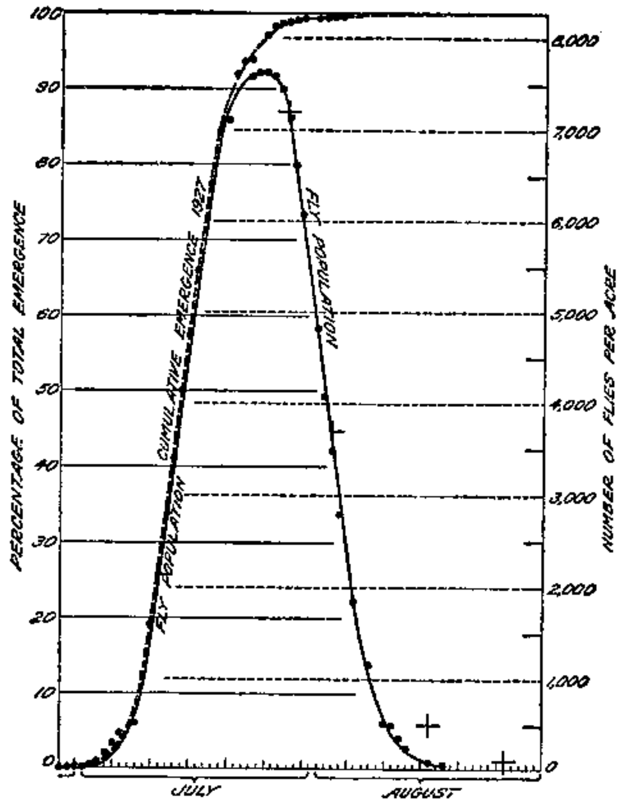


FIGURE 14.—Occurrence of blueberry flies, Cherryfield, Me., 1927. The broken line represents accumulative emergence for 1927; the solid line indicates theoretical occurrence of flies; crosses indicate results of field counts of the fly population

the number of flies per acre indicated by the fly count for that date. For example, the point of intersection of the population curve with July 22–23 for the season of 1929 [9] was assumed to represent 4,750 flies per acre. A scale was then constructed by marking off the distance from this point to the base of the chart into 4,750 equal divisions. This scale is shown on the right of the chart. (Fig. 16.) It is now possible to ascertain whether the theoretical occurrence curve and

[9] During the season of 1929 field counts of adults were made twice a week, usually on two successive days. In plotting the curve for this season the average of these two counts was used and was placed on the curve half way between the dates of the counts.

the numbers of flies observed in the field counts (other than the count assumed to be correct) coincide properly. If the records from the field counts are found to lie above the theoretical curve to the right of the peak, the average length of life of the flies used for plotting the occurrence curve is not long enough. If the records from the field plots lie below the theoretical curve to the right of the peak, the length of life assumed in plotting the occurrence curve is too

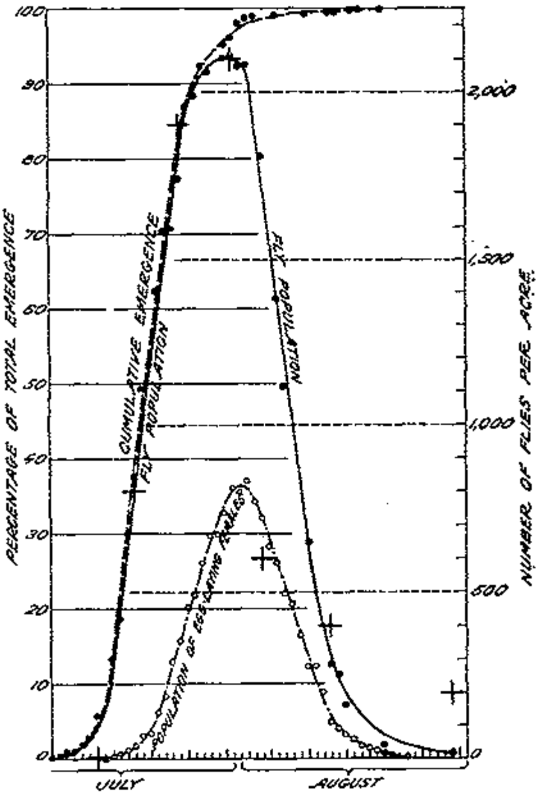


FIGURE 15.—Occurrence of blueberry flies, Cherryfield, Me., 1928. The broken line with dots represents accumulative emergence for 1928; the solid line with dots indicates theoretical occurrence of flies; broken line with circles indicates theoretical occurrence of egg-laying females. (The plot used in 1928 bore the first crop of berries following a thorough burn in 1927, therefore the flies emerging on this land had pupated in 1926; hence the emergence curve used is based upon the emergence of flies from pupae formed in 1926, see Fig. 9)

long. By plotting a few curves of occurrence, each based on a different average length of life of adults in the field, a curve may be found which fits all of the points to best advantage. It may then be argued that the assumed average length of life indicates approximately the correct average duration of life of the flies in the field, and the theoretical curve of occurrence, based upon this average length of life, gives a reasonably accurate picture of the seasonal fluctuation of the field population of flies.

LONGEVITY STUDIES

It was determined, by the method outlined above, that the average duration of life of the flies in the field was close to 19 days in 1927 and in 1928. During the season of 1929 the average life of the flies (24 days) was somewhat longer than that indicated in the two preceding seasons.

During the latter part of the season the length of life of adults in the field apparently increases. This apparent increased duration of life late in the season is indicated on the charts (figs. 14, 15, and 16) by the fact that the numbers of flies in the field after the middle of August usually exceeded the theoretical curve by a considerable num-

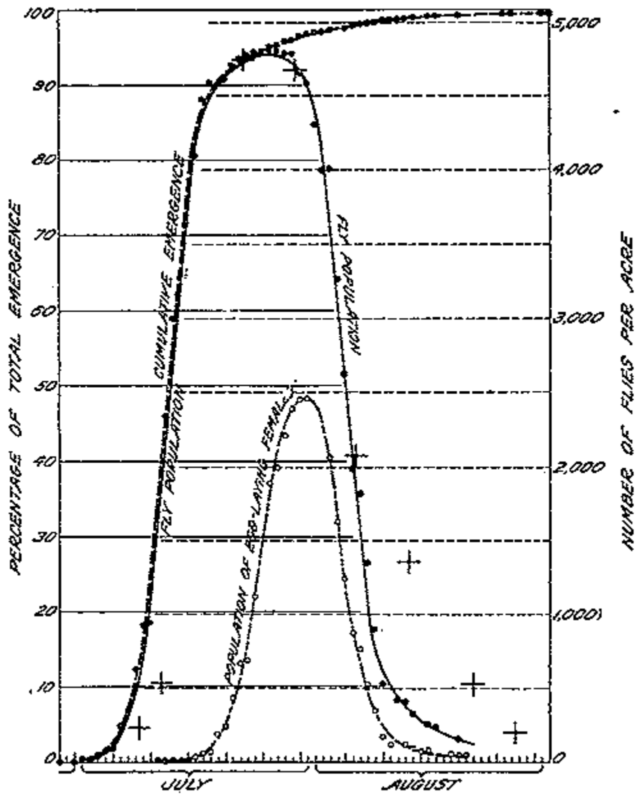


FIGURE 16.—Occurrence of blueberry flies, Cherryfield, Me., 1929. The broken line with dots represents accumulative emergence for 1929; solid line with dots indicates theoretical occurrence of flies; broken line with circles indicates theoretical occurrence of egg-laying females

ber. This is paralleled by the observations on the apple-maggot flies made by Porter (*13*), who states: "Apparently on account of the cooler weather in the fall the average length of life of flies of the second brood was greater than that of those of the first brood."

It seems probable that there is an actual increase in the average length of life of the blueberry flies late in the season, as indicated on the charts. It should be borne in mind, however, that field observations of this nature tend to be influenced by minimum quantities early in the season, and by maximum quantities late in the season. It is probable, therefore, that the apparent lengthening of the life of the flies late in the season is due in part to the presence of the comparatively few individuals which survive for an abnormally long time and which tend to accumulate toward the end of the season.

A number of workers have attempted to determine the duration of life of the apple-maggot flies by confining them in cages of various kinds. The results of these attempts have generally proved unsatisfactory because of the abnormal behavior of the flies in captivity and because of the high mortality of the flies under artificial conditions. Although the field methods used in the present study are subject to certain criticisms, it seems evident that the results produced are superior to those obtained by confining the flies in cages. This conclusion is confirmed by the results of previous workers in studies of the apple maggot (O'Kane (*10*), Illingworth (*8*), Porter (*13*)), as well as by cage studies conducted during the course of these investigations with the blueberry maggot.

OCCURRENCE OF FLIES IN THE FIELD

The charts (figs. 14, 15, and 16) give an interesting picture of the seasonal fluctuation of the blueberry flies. The outstanding features brought out by these studies are (1) the rapid rise of the fly population in the field as emergence progresses, (2) the surprisingly definite peak of abundance, (3) the sharp decline after the peak has been passed, and (4) the rather short period during which the flies are abundant in the field.

In the summer of 1927 the field counts were not begun until just after the flies had reached the peak of abundance, so that it was not possible to trace the increase of flies in the field by means of the field counts. In 1928 the field counts were begun early in the season, as shown in Figure 15. The rise of flies, as indicated by the field counts, coincided very closely with the theoretical increase of flies, as indicated by the emergence-cage records. The field count made on August 3, 1928, falls far below the theoretical number of flies which would be expected on that date, but the count made on August 13 falls very close to the theoretical number. The discrepancy on August 3 is difficult to explain; it may have been due to poor weather conditions for counting, to inaccuracy, or to an unusually high death rate among the flies as a result of heavy rains.

During the early part of the season of 1929 the fly counts in the field lagged behind the theoretical curve, but the decline in the numbers of flies agrees quite closely with the theoretical curve.

While it is undoubtedly unwise to accept the results of theoretical estimates of this kind as being strictly accurate, it appears that this work has produced results about as truly representative of conditions in the field as it is practicable to obtain by any method available. It seems probable that, as a whole, the picture presented by these charts approximates, with reasonable accuracy, the conditions occurring in the areas under observation.

OVIPOSITION

In making detailed studies of *R. pomonella* as an apple pest, most workers have experienced difficulty in observing oviposition by the flies, although a number of observations of oviposition in orchards have been reported. Illingworth (*8*) seems to have been most successful in inducing the flies to oviposit in captivity. Patch and Woods (*11*) observed oviposition by a blueberry fly under laboratory conditions, and recorded a description of the process. During the course of these investigations of the blueberry maggot, oviposition by captive flies has been observed once or twice, and also several times flies in their native habitat have been observed in the act of oviposition. However, observations of oviposition have been too few to provide a satisfactory basis for establishing the period of oviposition or for estimating the probable abundance of eggs in the field.

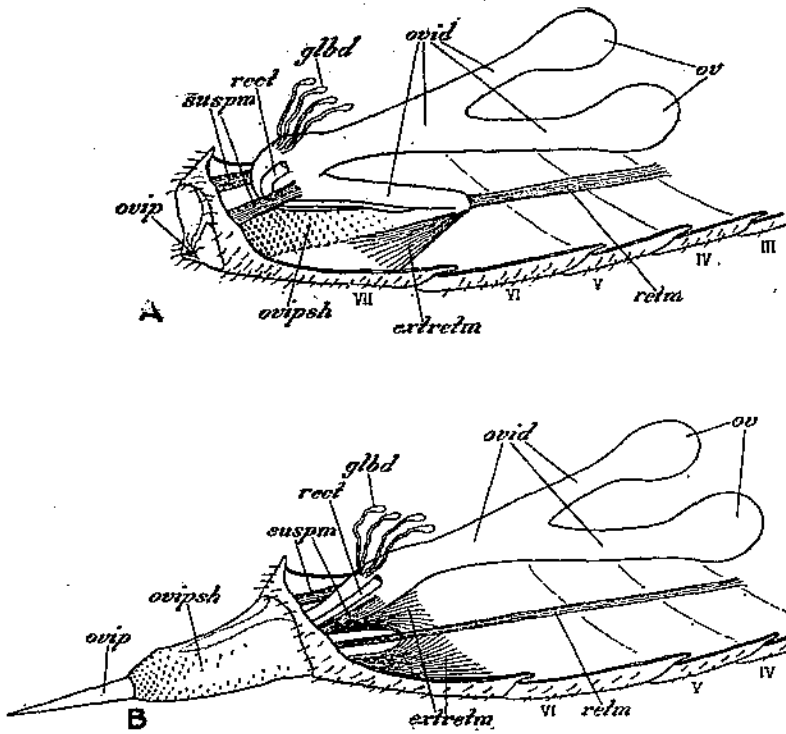


FIGURE 17.—Reproductive system of the newly emerged female blueberry-maggot fly: A, With ovipositor retracted; B, with ovipositor extended. *gl bd*, Glandular bodies; *ext ret m*, extensor-retractor muscle of the ovipositor; *ov*, ovaries; *ovid*, oviducts; *ovip*, ovipositor; *ovip sh*, sheath of ovispositor; *rect*, rectum; *ret m*, retractor muscle of the ovipositor; *susp m*, suspensory muscle, holding the oviduct in place

Illingworth (*8*) estimated the length of the preoviposition period of the apple-maggot flies by determining the period necessary for the development of the ovaries. By dissecting females of known age he was able to trace the development of the ovaries and to determine approximately when egg laying would begin.

Dissection of blueberry flies which had been kept in captivity in field cages and in the laboratory was unsatisfactory. The ovaries of captive flies had made no development even when the flies were 14 days old, and when the flies were dissected the ovaries had the same appearance as those from newly emerged flies. (Fig. 17.) The ovaries of egg-laying females captured in the field showed normal development (fig. 18), but of course the age of captured flies was unknown.

The male (fig. 19) probably matures in ample time for fertilizing the egg-laying females.

In the life-history work accomplished during the seasons of 1927, 1928, and 1929 it was noticed that the first eggs appeared in the field from 10 to 15 days after the first flies emerged. It appears from these observations that the average preoviposition period is about 12 to 13 days, although there is undoubtedly some fluctuation during the course of the season. The length of the oviposition period of the flies varies with the length of the preoviposition period and the total length of life of the flies. In these studies the average duration of the oviposition period varied from 6 to 11 days.

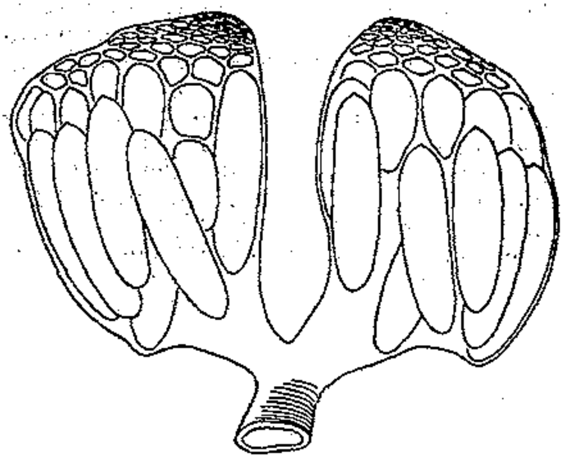


FIGURE 18.—Ovaries from mature blueberry-maggot fly captured in the field

During the seasons of 1928 and 1929 accurate records were kept of the numbers of flies of each sex emerging in the cages. By plotting a curve in a manner somewhat similar to that described for the curve showing the total number of flies, the occurrence of females of egg-laying age was estimated, as shown in Figures 15 and 16. The abundance of egg-laying females was of course much lower than the total number of flies occurring in the field. The peak of abundance of egg-laying females occurred somewhat later than the peak of the total fly population.

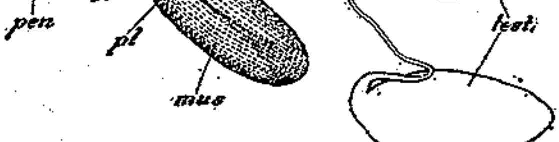


FIGURE 19.—Reproductive system of the male blueberry-maggot fly, ventrolateral view: *ac gl*, Accessory glands; *bl*, bladderlike portion of the seminal pump; *cl*, clasper; *mus* muscular portion of the seminal pump; *pen*, penis; *pl*, chitinous rod or plunger of the seminal pump; *rect*, rectum; *spd*, spermaduct; *test*, testes; *vd*, vas deferens

The curve indicating the theoretical population of egg-laying females shows characteristics similar to the curve of the total fly population. There is a rapid increase in the gravid females as the flies reach egg-laying age. The peak is fairly definite, and is followed by a sharp decline as the death rate increases.

It is interesting to note the increased abundance of females of egg-laying age during the season of 1929 as a result of the longer average duration of life of the flies of that season. The peak of occurrence of egg-laying females coincides approximately with the period of highest rate of oviposition in the field.

STUDIES OF MAGGOT POPULATIONS AND THE INCUBATION PERIOD

METHODS OF PROCEDURE

Direct observations of the eggs of the apple maggot to determine the length of the incubation period have been made by several workers. However, owing to the difficulty of obtaining eggs of known age for observation, the number of records is small. Moreover, it is generally reported that the eggs do not seem to behave normally under observation, with the result that the accuracy of the observations on this point is more or less in question. During the course of this work a limited number of eggs of the blueberry maggot were dissected from blueberries, and an attempt was made to determine the incubation period by direct observation. Most of the eggs failed to hatch. A few records were obtained, but the variation was so great that it leads to the belief that the eggs were not developing normally.

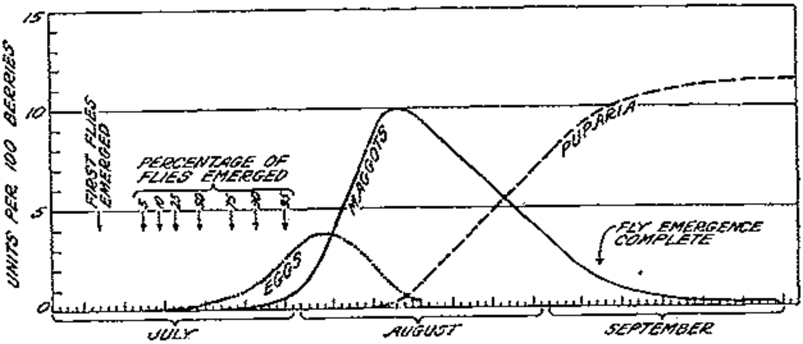


FIGURE 20.—Activity of the blueberry maggot, Cherryfield, Me., season of 1928. Fluctuations of field populations of eggs and maggots, and progress of pupation, shown in relation to emergence of flies. The first flies appeared in the field two or three days earlier than the emergence records indicate, making the preoviposition period approximately 10 days

The most satisfactory information which these investigations yielded on the length of the incubation period was obtained by indirect methods in connection with studies of field populations of maggots. Throughout the season of 1928 and again in 1929 large samples of berries were collected periodically in the field. These samples were brought into the laboratory and divided as accurately as possible into two similar series. One series, representing half of the samples, was processed immediately to determine the number of maggots present per 100 berries. The other series was retained in the laboratory for two weeks in order that all of the eggs present in the berries might hatch. At the end of two weeks the berries of the second series were processed and the number of maggots present per 100 berries was determined. The difference between the number of maggots present in the first series and the number present in the second series was assumed to be the number of eggs which were present at the time that the berries were picked. By taking such samples at intervals throughout the season, it was possible to determine with reasonable accuracy the numbers of eggs present and the numbers of maggots present during the season. The results of these studies are given in Figures 20 and 21.

Methods for studying the field populations of eggs and maggots were developed in greatest detail during the summer of 1929, and it seems worth while to describe in detail the procedure followed during that season. Beginning just prior to the first oviposition of the season, samples of berries were picked at weekly intervals from a plot of blueberry land laid off especially for the purpose. (Fig. 13.) This plot had been used for similar studies in 1928, although the work was not quite so systematically performed during that season. The land was thoroughly burned over in the spring of 1927; in 1928 it bore the first crop of berries; and in 1929, the second crop after the burn. The berry crop was rather light each year, and there was apparently little difference in yield between the first crop and the second crop. As studies were continued on this land until frost occurred, the berries were not picked, and the yield was not accurately determined.

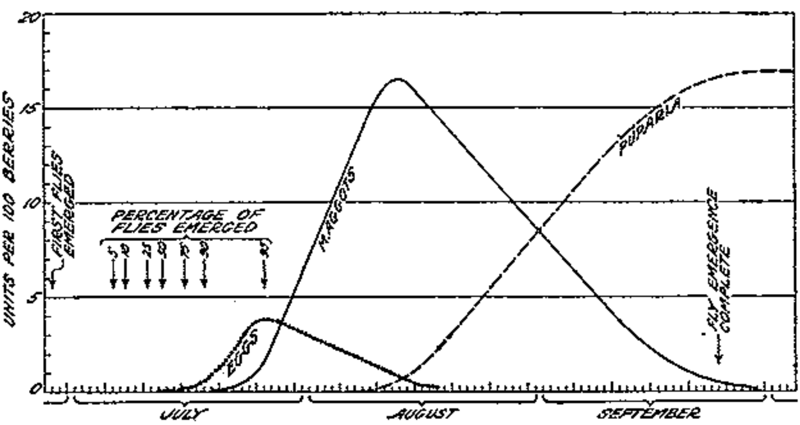


FIGURE 21.—Activity of the blueberry maggot, Cherryfield, Me., season of 1929. Fluctuations of field populations of eggs and maggots, and progress of pupation, shown in relation to emergence of flies

On the experimental plot 100 small sampling areas were marked off by heavy white cord. The minimum size of these plots was 20 by 50 feet. Some of the plots were made two, three, or four times this size where the berries were sparse. (Fig. 13.) On each plot there was a sufficient yield so that the number of berries on the land was not materially reduced by the samples collected during the course of the work, and conditions on the plot were not modified to an important extent by the experimental procedure.

In collecting a series of berry samples for estimating the maggot population, a counting board (pl. 10, B) was taken into the first 20 by 50 foot sample plot, and berries were picked to fill the 100 holes in the counting board. Only ripe berries were picked, and every effort was made to have the sample as truly representative as possible by picking from all parts of the plot and taking berries of all sizes. When 100 berries had been collected, they were placed in a half-pint fiber container known as an "oyster bottle." This process was repeated on each sample plot until 100 samples, each containing 100 berries, had been collected. In the laboratory 100 empty fiber containers were arranged in a single row, forming a large hollow square, and the containers were numbered from 1 to 100. Taking one of the field samples, and beginning with container No. 1, one berry was placed in each container, the last berry from the field sample going into container No. 100. The first berry of the next field sample was placed in container No. 2, and again one berry was placed in each of the 100 containers, the last berry going into container No. 1. The berries from all of the field samples were distributed in this way, the first berry from each field sample being placed in the next succeeding laboratory container. As a result of the process there were secured 100 samples of 100 berries each, which, it seems, should be approximately homogeneous. A coin was tossed to determine whether the samples bearing the odd numbers or the even numbers should be processed immediately for maggot counting.

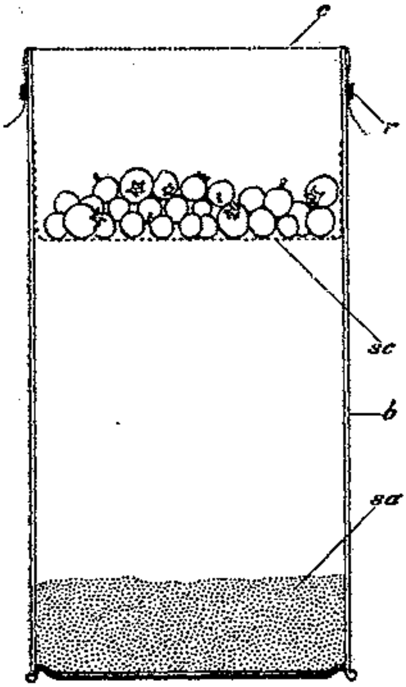


FIGURE 22.—Diagram of container for keeping "delayed" samples of blueberries in the laboratory for two weeks before making the maggot counts. *b*, Fiber container or "oyster bottle"; *c*, cheesecloth cover; *r*, rubber band; *sa*, sand to retain puparia; *sc*, wire screen to hold blueberries

The 50 samples that were to be kept for two weeks were placed on wire screens set into quart "oyster bottles" containing sand in the bottom, and covered with a piece of cheesecloth secured by a rubber band. (Fig. 22.) At the end of two weeks the berries were processed, the sand was sifted, and the total number of maggots in the berries and of puparia in the sand was recorded.

RELATION OF THE PERCENTAGE OF RIPE BERRIES TO THE MAGGOT POPULATION IN THE FIELD

Eggs of the blueberry maggot have been found only in ripe berries; hence, only ripe berries were picked for field samples. The flies begin to deposit eggs when comparatively few of the berries are ripe. During the early part of the egg-laying season a relatively small number of ripe berries are present for receiving the eggs. As the flies apparently seek out the ripe berries for egg laying, the comparatively few ripe berries present may be rather heavily infested, although on the area under observation the entire population of maggots may be very small. If samples of ripe berries are collected from an area at intervals throughout the season, and the number of maggots present determined, the resulting data will indicate the infestation of the ripe berries on the respective dates, but the data may not indicate closely the maggot population of the field. Because of the variation in the number of ripe berries present from time to time, the data from the berry sample should be corrected if a true picture of the maggot population of the field throughout the season is desired. For example, suppose it were found that there was an average infestation of 5 maggots per 100 berries in a series of samples taken when 20 per cent of the berries were ripe. In another series of samples, taken when 40 per cent of the berries were ripe, an average of 10 maggots per 100 were present. Then it should be recognized that when the second series of samples was taken the maggot population of the field was four times as great as when the first series was taken, for there were not only twice as many maggots present per hundred ripe berries but there were twice as many ripe berries on the plot.

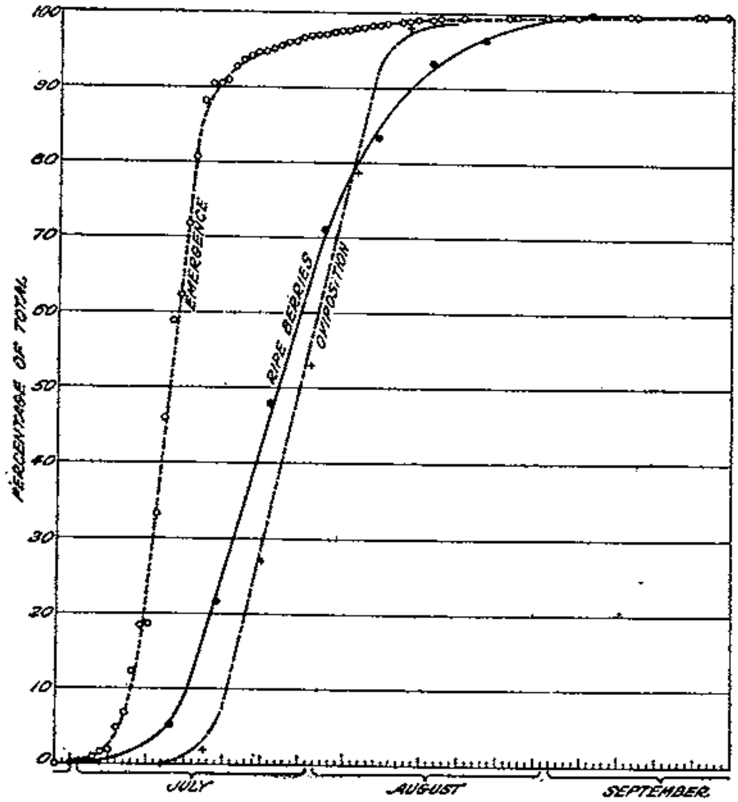


FIGURE 23.—Emergence of blueberry-maggot flies and oviposition in relation to the percentage of blueberries ripe, Cherryfield, Me., 1929

In order to make the necessary corrections to compensate for the increasing numbers of ripe berries, the percentages of ripe berries were estimated on the plot on which the population studies were made in 1928. In 1929, in order to estimate more accurately the percentages of ripe berries throughout the season, 40 small plots, each approximately 4.67 feet square, were established at points well distributed over the area under observation. (Fig. 13.) Beginning on July 13, all ripe berries were picked from each of these plots at weekly intervals and the numbers recorded. The picking was continued until no berries remained upon the plots. The records obtained (fig. 23) give an accurate picture of the ripening of the berries on the plot. The data derived from the maggot-population studies during the seasons of 1928 and 1929, including the corrections necessary to compensate for differences in the number of ripe berries, are presented in Table 14.

TABLE 14.—*Results of maggot-population studies, 1928 and 1929*

Date	Percentage of berries ripe	Units per 100 berries: Original data: Maggots and eggs	Original data: Maggots	Original data: Eggs	Corrected data: Maggots and eggs	Corrected data: Maggots	Corrected data: Eggs
1928							
July 20	5	6.65	0.36	6.29	0.33	0.02	0.31
July 25	10	10.73	.53	10.20	1.07	.05	1.02
July 30	25	10.95	1.74	9.21	2.09	.44	2.55
Aug. 13	85	10.35	11.73	−1.38	8.80	9.97	−1.17
Aug. 20	90	11.30	8.25	3.05	10.17	7.43	2.74
Aug. 27	95		5.69			5.41	
1929							
July 8	2	0	0	0	0	0	0
July 12	4	0.07±.13	0	0.07±.13	0.0028		0.0028
July 13	5					0	
July 17–18	17	1.94±.13		1.84±.13	0.33		0.31
July 19	22		0.10±.03			.02	
July 24–25	42	0.70±.14		8.02±.19	4.07		3.35
July 25	43		1.68±.13			.72	
July 30–31	62	15.16±.34		4.88±.40	9.40		2.82
July 31	64		10.28±.31			6.58	
Aug. 5	78	17.08±.36		2.02±.53	13.32		1.27
Aug. 6	80		15.06±.39			12.05	
Aug. 12	89	19.32±.40		.86±.60	17.20		.59
Aug. 13	90		18.46±.45			16.61	
Aug. 19	95	14.90±.35		−.54±.46	14.15		−.52
Aug. 20	95		15.44±.29			14.67	
Aug. 26	98	9.02±.28		−1.06±.42	0.46		−1.01
Aug. 27	98		10.68±.31			10.47	
Sept. 2	100	8.28±.23		−.30±.36	8.28		−.30
Sept. 3	100		8.58±.28			8.59	
Sept. 9	100		5.16±.38			5.16	
Sept. 16	100		1.80±.18			1.80	

RESULTS OF FIELD STUDIES OF EGG AND MAGGOT POPULATIONS

The results of the studies of egg and maggot populations for the seasons of 1928 and 1929 may be plotted as shown in Figures 20, 21, 23, and 24.

The method of constructing Figures 20 and 21 is explained in Figure 24. The curve A–B–C represents the total population of maggots and eggs present throughout the season and is based upon data obtained from the berry samples that remained in the laboratory for two weeks before the maggots were counted. The curve D–E–F represents the field population of maggots only, and is based upon data obtained from the berry samples which were processed immediately.

LENGTH OF THE INCUBATION PERIOD

The horizontal distance measured between the curve D–E (fig. 24), representing the maggot population, and the curve A–B, representing the combined population of maggots and eggs, indicates the length of the incubation period. This applies to the period beginning about July 19, when the first eggs hatch, and ending about August 9, when pupation begins; after pupation has begun, this method can no longer be used to determine the length of the incubation period. Measurements made on the charts at intervals indicate that the incubation period during the seasons of 1928 and 1929 varied from a maximum of about eight days to a minimum of two days. During the season of 1928 the incubation period varied from a maximum of eight days to a minimum of about four days. In 1929 the eggs seemed to develop more rapidly; the maximum incubation period this season was seven days and the minimum was two days.

It is probable that the fluctuation in length of the incubation period is influenced by temperature, but the data collected are not sufficient to give a reliable indication of the influence of temperature upon the length of the incubation period.

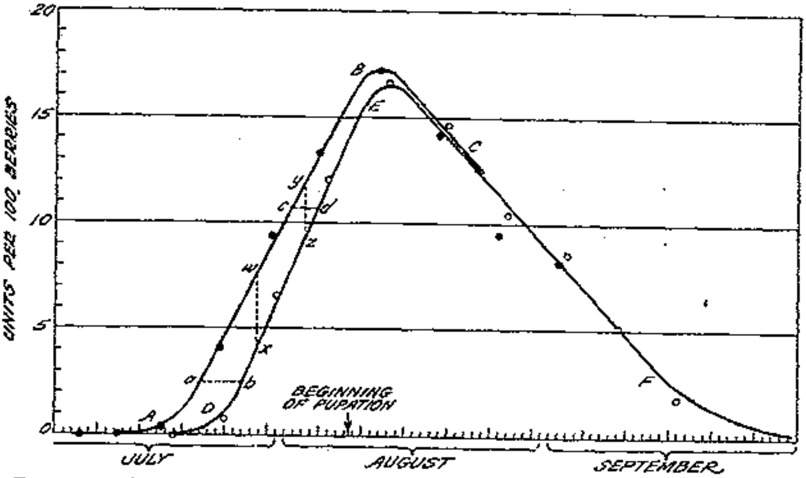


FIGURE 24.—Method of constructing chart shown in Figure 21. Curve A–B–C indicates the field population of maggots and eggs as determined by examinaton of the "delayed" berry samples. Curve D–E–F indicates the field population of maggots only, as determined by the immediate examination of samples of blueberries. The approximate number of eggs present on any date may be determined by measuring the vertical distance between the two curves on the given date—for example, the distances *w–x* and *y–z*. The approximate duration of the incubation period may be determined by measuring the horizontal distance between the two curves—for example, the distances *a–b* and *c–d*. The increase in the total field population of maggots and eggs (curve A–B) is due entirely to the numbers of eggs being deposited. Hence the daily rise of the curve A–B indicates the rate at which eggs are being deposited. None of these methods applies after pupation begins. The beginning of pupation is determined by field observations, and the progress of pupation is determined by the decline of the line E–F

SEASONAL FLUCTUATIONS IN MAGGOT POPULATION

In 1928 the first maggots appeared in the berries on the experimental area about July 22. The increase in the numbers of maggots was gradual until about August 1, when there was a population of 1 maggot per 100 berries. The increase of maggots during the first half of August was rapid, and the peak was reached about August 13–14. After this time the decrease in the numbers of eggs and the increase in the numbers of mature maggots leaving the berries caused a rapid decline in the number of maggots present. By August 27–28 the number of maggots present in the field had declined 50 per cent, and the rate of decline increased steadily until about the second week of September, when the maggot population had decreased to about 1.05 maggots per 100 berries. After mid-September the decrease was gradual and continued until heavy frost killed the maggots remaining in the berries.

During the season of 1929 the rapid rise in the number of maggots began somewhat earlier than in the preceding year. The peak of 16.05 maggots per 100 berries was reached about August 12–14, after which the decline was rapid throughout the rest of the season. A few

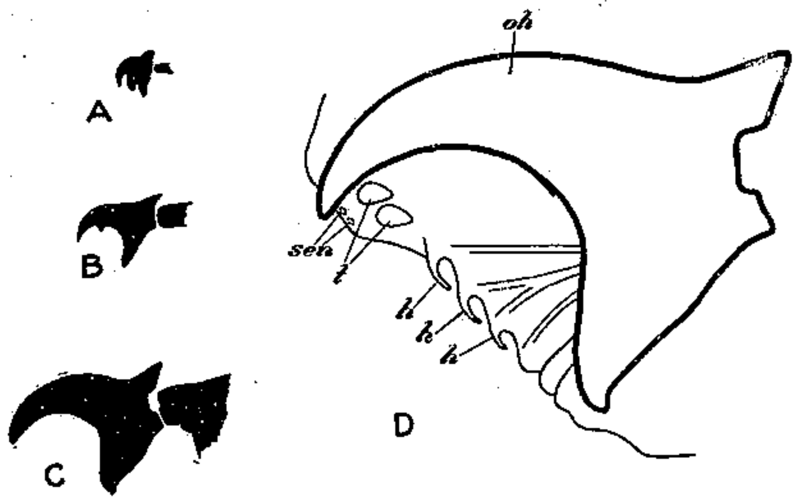


FIGURE 25.—Mouth parts of the blueberry maggot: A, Oral hook of first instar; B, oral hook of second instar; C, oral hook of third instar; D, oral orifice of third instar, viewed in optical section. *t*, Chitinized teeth; *oh*, oral hook; *h*, hooklet; *sen*, sensory nerve endings

maggots still remained in the berries when killing frost occurred during the last few days of September.

The seasonal fluctuations of eggs, maggots, and puparia during 1928 and 1929 are illustrated in Figures 20 and 21.

DURATION OF MAGGOT INSTARS

During the season of 1929 maggots were secured in berry samples from the experimental plot in sufficient numbers to permit fairly accurate determinations of the relative numbers of the three instars[10] present on the dates when samples were taken. The results of these observations are shown in Figure 27. It will be noted that the first maggots appeared about July 19 and that the first specimens of the second instar occurred eight or nine days later on July 27–28. The first specimens of the third instar appeared about three or four days later. The first pupation took place about August 8–10, indicating

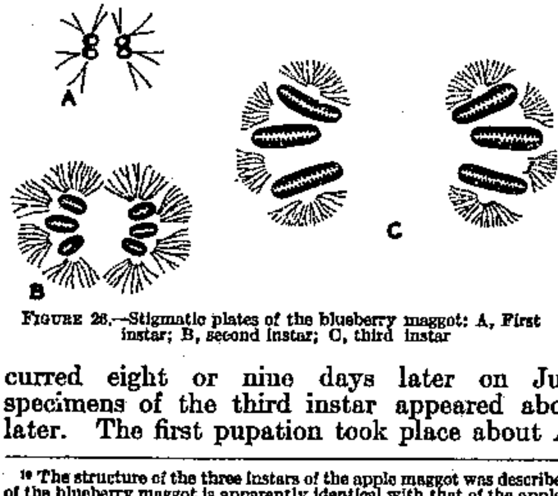
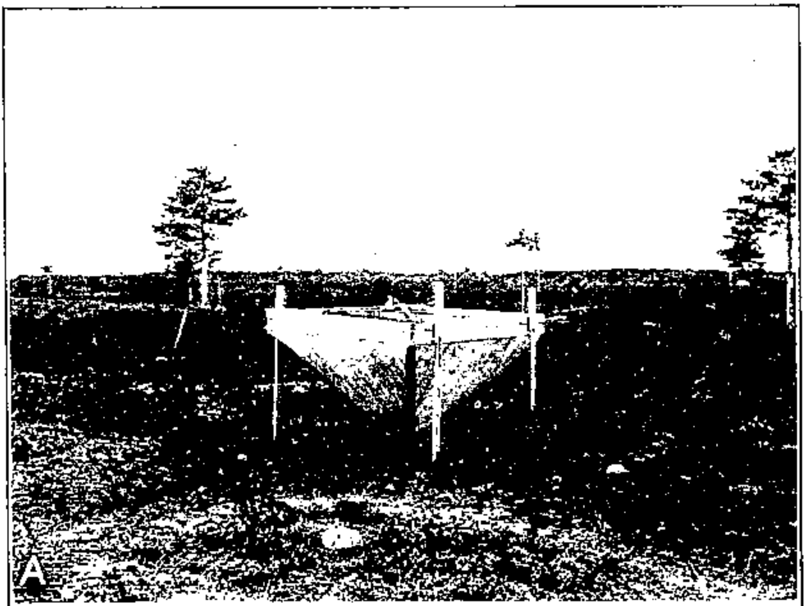
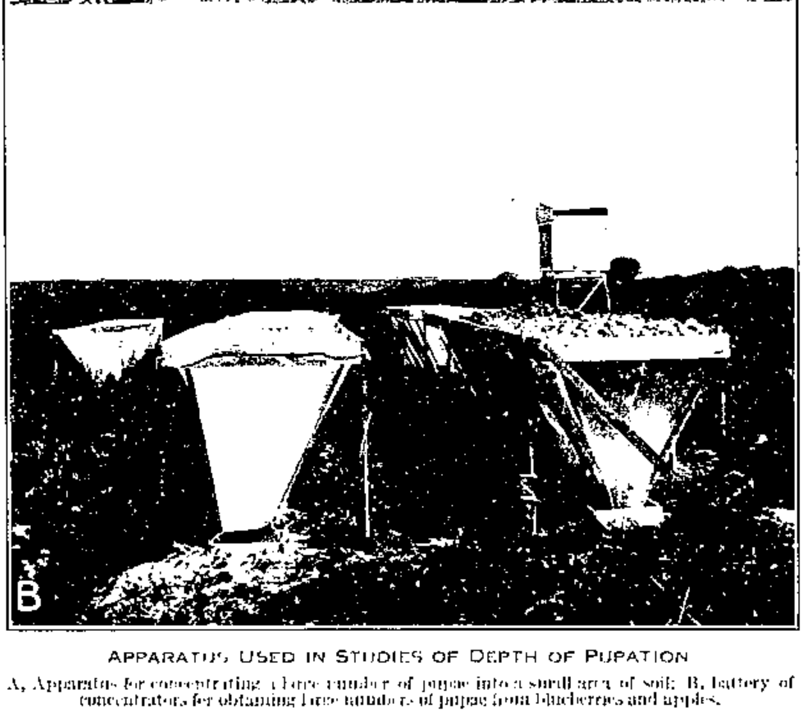


FIGURE 26.—Stigmatic plates of the blueberry maggot: A, First instar; B, second instar; C, third instar

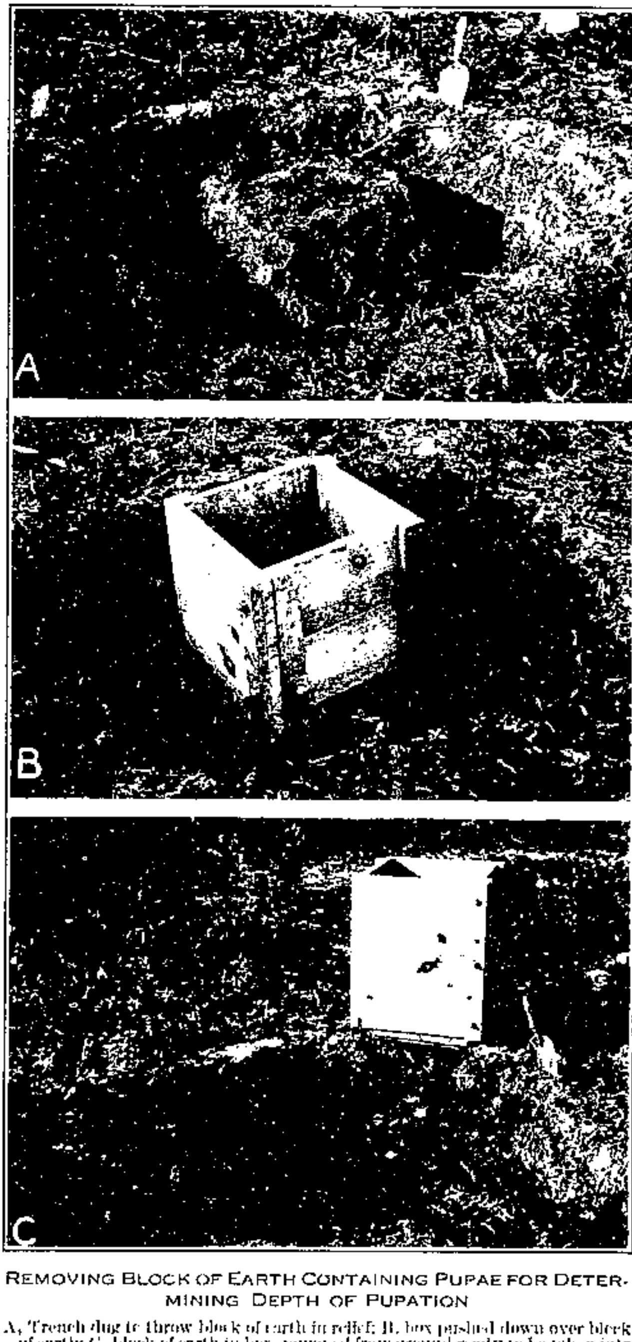
[10] The structure of the three instars of the apple maggot was described by Snodgrass (*17*). The structure of the blueberry maggot is apparently identical with that of the apple maggot. With a little practice the instars may be separated without difficulty, as indicated by Snodgrass. Some of the details of structure of the three instars are shown in Figures 25 and 26.





APPARATUS USED IN STUDIES OF DEPTH OF PUPATION

A, Apparatus for concentrating a large number of pupae into a small area of soil; B, battery of concentrators for obtaining large numbers of pupae from blueberries and apples.



REMOVING BLOCK OF EARTH CONTAINING PUPAE FOR DETERMINING DEPTH OF PUPATION

A, Trench dug to throw block of earth in relief; B, box pushed down over block of earth; C, block of earth in box, removed from ground ready to be taken into the laboratory.

a total length of larval life of 20 to 22 days. The larval period appears to be longer toward the end of the season and undoubtedly varies considerably. If the berry remains undisturbed on the plant, the maggot remains in the berry until the pulp is completely devoured. If the berry dries as a result of unusually warm weather, or if it is thrown to the ground and battered by heavy rains, the maggot is forced to leave the berry sooner than would otherwise be the case. Probably the fluctuation in the number of maggots of the third instar present throughout the season as indicated in Figure 27 is due to factors of this kind.

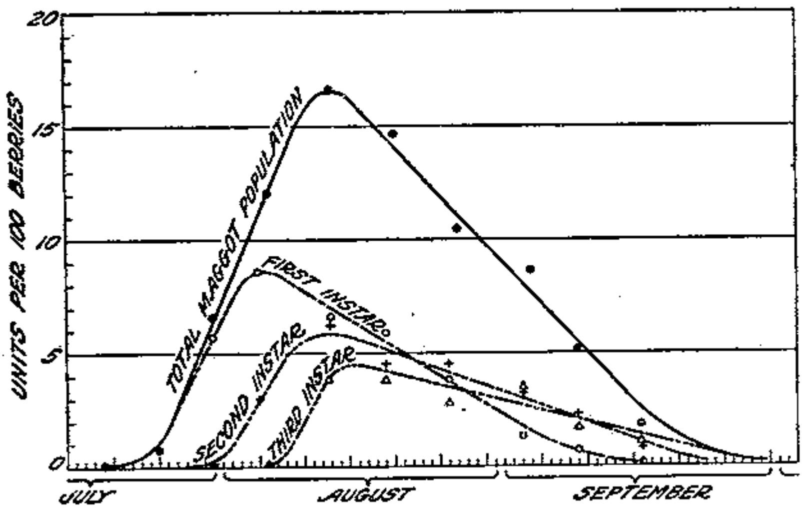


FIGURE 27.—Field population of blueberry maggot, Cherryfield, Me., 1929, showing fluctuations of proportions of the three instars

PUPATION

During the course of these investigations several modes of procedure were used in attempts to determine the time and rate of pupation. The first consisted of gathering samples of berries periodically in the field, bringing them into the laboratory, and placing them on screen trays over funnels. The maggots, as they left the berries to pupate, fell into the funnels and were collected in cups of sand placed beneath the funnels. It was found, however, that this method gave no reliable indication of the time of pupation in the field. The berries in the laboratory neither dried up nor were battered by rain, and the maggots remained in these berries much longer than would have been the case in the field. The next attempt consisted of placing cans of sand beneath bunches of berries in the field and examining the sand periodically to determine the number of puparia which had formed. Theoretically, this method should give highly satisfactory results, but in practice it was found that the normal infestation in the field is so low that the number of maggots collected in this way is too small to give an accurate indication of the rate of pupation in the field.

The most reliable indicator of the rate of pupation seems to be the rate of decline of maggots in the berries on the experimental plot, as shown by the charts. (Figs. 20 and 21.) It is possible that the rate of decline in maggots may be due to some extent to berries dropping from the plants several days before the maggots leave the berries to pupate. An attempt was made during the season of 1929 to determine the extent to which this factor operates, by collecting large numbers of berries from the ground beneath the plants at intervals and observing them to note the length of the time that the maggots remained within the berries after the fruits had dropped. The results of the observations indicate that the maggots may remain in the dropped berries several days before pupation takes place. However, many maggots drop out while the berries are on the plants, or soon after the berries drop from the plants, and it is doubtful whether the fact that some of the maggots remain in the berries for several days after the berries drop to the ground would materially alter the records of pupation indicated in Figures 20 and 21.

THE DEPTH OF PUPATION

At the outset of the investigation in 1925, evidence had accumulated which seemed to indicate that the process of burning over the blueberry land was destructive to the pupae beneath the soil. One of the first investigations undertaken by the laboratory was a series of studies to determine definitely the value of the burning process from the standpoint of maggot control. Two parallel studies were conducted—(1) a determination of the depth at which the insect pupates in the soil, to ascertain whether the puparia are close enough to the surface to be affected by the flames or the heat produced in burning over the land, and (2) a study of the soil temperature produced by the burning process.

The first attempt to determine the depth at which pupation takes place was made by sifting soil taken from beneath blueberry plants growing on the barrens. This attempt met with the same difficulties reported by Patch and Woods (*11*). In soil containing a normal infestation, the number of puparia obtained by sifting is too small to yield results of value. In order to obtain worth-while results it seemed desirable to have a large number of maggots pupate within a limited area of soil. Records of the depth of pupation of a significant number of individuals could then be obtained with a minimum expenditure of time and labor. During the first few days of September, 1925, a device was constructed for concentrating a large number of pupae in a limited space. (Pl. 11.) The device consisted of a cheesecloth funnel, or concentrator, 4 by 5 feet on the upper end, and 6 inches square on the lower end. Over the larger end of the funnel was placed a wire-screen tray, and the whole apparatus was supported by stakes so that the small end rested on the surface of the soil, and the screen tray on the upper end was approximately level and about 3 feet above the ground. The apparatus was placed on typical blueberry land, and on September 5 a little more than one-half bushel of heavily infested berries was placed on the tray. Observations were made from time to time; very few maggots were seen descending the apparatus, and it seemed improbable that any considerable number of puparia would be found in the soil beneath the funnel.

On October 12 the apparatus was dismantled, and the puparia were carefully removed from the soil at the apex of the funnel. A total of 1,389 puparia was obtained.

In counting the puparia, the débris from the surface of the area under observation was first removed. Next a trench about 3 inches wide was dug to a depth of 8 inches, leaving a block of earth 12 inches square containing the puparia from the concentrator. The first and then the second half inch of soil was carefully removed from the block; after this the soil was removed in layers 1 inch thick, until a total depth of 6 inches had been reached. The numbers of puparia in the various layers were then carefully determined. The results are shown in Table 15.

TABLE 15.—*Depth of pupation of the blueberry maggot, Washington County, Me., 1925*

Depth of layer [1]	Puparia	Proportion of total	Cumulative proportion of total
	Number	*Per cent*	*Per cent*
Surface	52	3.74	3.74
First half inch	247	17.78	21.53
Second half inch	844	60.76	82.29
Second inch	244	17.57	99.86
Third inch	2	.14	100.00
Total	1,389		

[1] No puparia were found in the fourth, fifth, and sixth inches of soil.

The results of the study indicated that a surprisingly large proportion of the puparia were found within the first inch of soil. The fact that the puparia were located so near the surface of the soil tended to strengthen the theory that many of the pupae were destroyed by the heat produced in burning over the blueberry land.

To confirm the results of the study of 1925, four concentrators were established during the season of 1926. These were placed in locations which included a wide range of soil conditions. One bushel of heavily infested blueberries was placed on each apparatus.

During late fall, after pupation was complete, the concentrators were dismantled, and the number of puparia in the soil under each was counted. In removing the soil from beneath the concentrator, a 12-inch square was marked on the soil under the apex of the funnel before the apparatus was removed from the spot. As soon as the apparatus was removed, the débris from the surface of the marked area was carefully removed and placed in a suitable container. The soil was then carefully cut away from about the area which had been marked off, leaving a block of earth 12 inches square and extending down to a depth of 12 inches, unless rock occurred before this depth was reached. A wooden box (pl. 12) of suitable dimensions was then forced down over the block of earth containing the puparia from the concentrator, and the entire block was removed and taken into the laboratory for examination. The block of earth was carefully divided into half-inch horizontal sections, and the number of puparia found in each half inch of soil was counted.

The results of the studies of 1926 (fig. 28) confirmed the results of 1925 and definitely established the fact that a very great proportion of the pupae overwinter at a slight depth in the soil. The results are shown in Table 16. An average of 96.72 per cent of the puparia were found within 1 inch of the surface of the soil. Four puparia were found, under concentrator No. 1, at a depth of 7½ to 8 inches. Puparia of the apple maggot have been reported by O'Kane (*10*) at a depth of 5 inches, and by Porter (*13*) at 4 to 5 inches. Brittain and Good (*3*) reported finding larvae at the bottom of a cage containing 12 inches of soil. The record of puparia found in block No. 1 at a

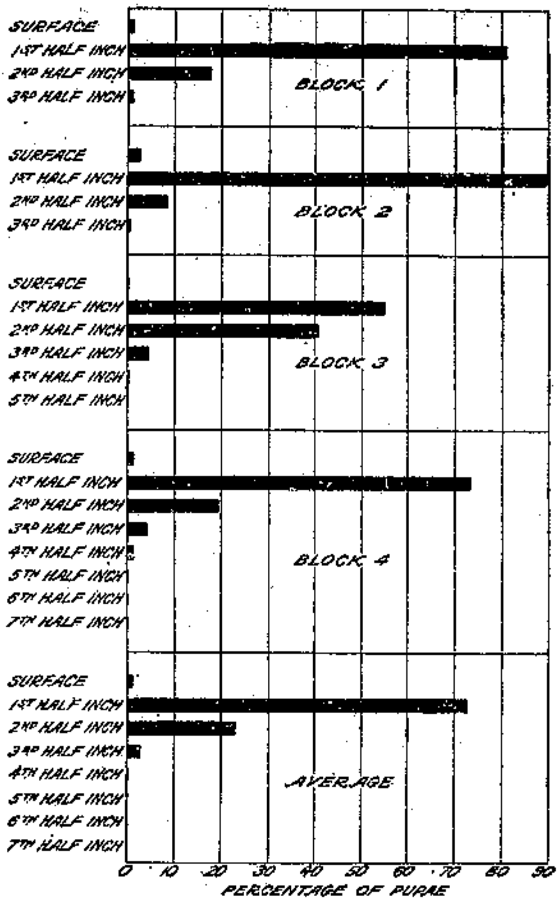


FIGURE 28.—Depth of pupation of the blueberry maggot on typical blueberry land, Cherryfield, Me., 1926

depth of 7½ to 8 inches may be valid, but the fact that the four puparia found at this depth were so much deeper than any of the other puparia makes it appear barely possible that the four specimens in question may have dropped from some of the upper layers of soil during the operation of separating the layers of soil in the laboratory. Except for the four puparia just noted, none was found below 3½ inches.

TABLE 16.—*Depth of pupation of the blueberry maggot, Washington County, Me., 1926*

Depth of layer [1]	Block 1			Block 2			Block 3		
	Puparia	Proportion of total	Cumulative proportion of total	Puparia	Proportion of total	Cumulative proportion of total	Puparia	Proportion of total	Cumulative proportion of total
	Number	*Per cent*	*Per cent*	*Number*	*Per cent*	*Per cent*	*Number*	*Per cent*	*Per cent*
Surface	17	0.95	0.95	29	2.29	2.29	5	0.25	0.25
First half inch	1,440	80.67	81.62	1,130	89.05	91.34	1,108	54.74	54.99
Second half inch	309	17.31	98.93	106	8.35	99.69	820	40.51	95.50
Third half inch	15	.84	99.77	4	.31	100.00	84	4.15	99.65
Fourth half inch							6	.30	99.95
Fifth half inch							1	.05	100.00
Sixteenth half inch	4	.23	100.00						
Total	1,785			1,269			2,024		

Depth of layer [1]	Block 4			Total		
	Puparia	Proportion of total	Cumulative proportion of total	Puparia	Proportion of total	Cumulative proportion of total
	Number	*Per cent*	*Per cent*	*Number*	*Per cent*	*Per cent*
Surface	27	1.27	1.27	78	1.08	1.08
First half inch	1,557	73.37	74.64	5,235	72.71	73.79
Second half inch	416	19.60	94.24	1,651	22.93	96.72
Third half inch	88	4.15	98.39	191	2.65	99.37
Fourth half inch	25	1.18	99.57	31	.43	99.80
Fifth half inch	6	.28	99.85	7	.10	99.90
Sixth half inch	2	.10	99.95	2	.03	99.93
Seventh half inch	1	.05	100.00	1	.01	99.94
Sixteenth half inch				4	.06	100.00
Total	2,122			7,200		

[1] Each block was examined to a depth of 12 inches, except block 3, in which rock was reached at a depth of 10 inches.

EFFECT OF SOIL TYPE UPON DEPTH OF PUPATION

During the season of 1926 concentrators 1, 2, and 3 were placed in three situations on typical blueberry land which varied to a normal extent in drainage, but otherwise were not greatly different. No. 1 was on a level, rather poorly drained area. No. 2 was near the edge of high, well-drained plateau land. No. 3 was intermediate in drainage. The soil in all of these locations was a sandy loam with a surface layer of organic matter to a depth of 1½ to 2 inches.

Concentrator No. 4 was placed in a draw which in rainy seasons formed the bed of a stream. It was at the extreme edge of blueberry growth, and adjoined a hackmatack swamp. The soil was moist, and was springy underfoot.

The concentrator operated in 1927 (Table 17) was placed over a box of sand. The box was provided with a cloth bottom and was set in the ground at a depth of about 6 inches to provide normal moisture.

The results, as indicated in Figure 28, show that under normal conditions there is little variation in the depth at which the blueberry maggots pupate. Most of the maggots pupate in the organic surface layer of the soil and above the dense mat of blueberry roots. It is evidently difficult for the maggots to penetrate the mat of blueberry roots, and the depth of pupation as shown in Figure 28 seems to vary with the depth at which the root mass occurred.

The maggots penetrated somewhat deeper in sifted sand (fig. 29), but even there 99.65 per cent of the pupae were within 2 inches of the surface. One pupa was found at a depth of 3 to 3½ inches.

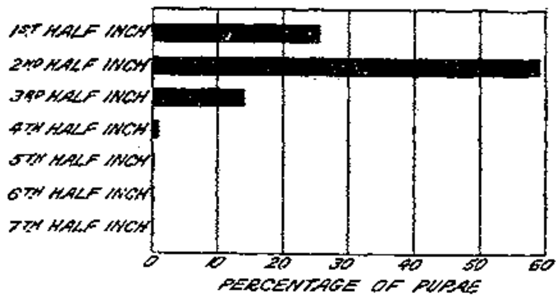


FIGURE 29.—Depth of pupation of the blueberry maggot in sifted sand, Cherryfield, Me., 1927

TABLE 17.—*Depth of pupation of the blueberry maggot in sifted sand, Washington County, Me., 1927*

Depth of layer	Puparia	Proportion of total	Cumulative proportion of total
	Number	*Per cent*	*Per cent*
Surface	0	0	0
First half inch	432	25.50	25.50
Second half inch	1,005	59.33	84.83
Third half inch	237	13.99	98.82
Fourth half inch	14	.83	99.65
Fifth half inch	4	.23	99.88
Sixth half inch	1	.06	99.94
Seventh half inch	1	.06	100.00
Total	1,694		

NATURAL ENEMIES

The alert attitude of the blueberry flies gives them the appearance of being constantly on guard against some enemy that may be ready to pounce upon them. Probably the defensive attitude of the flies is well founded, for several enemies have been observed preying upon them.

Probably the most important enemies of the adult blueberry flies are two species of large ants, *Formica fusca* L. and *F. exsectoides* Forel (determined by W. M. Mann). Both of these ants are abundant on much of the blueberry land. The nests are apparently started in or under the dead roots of birch and alder sprouts. As the colonies of ants increase in size, characteristic mounds are formed. The fully developed mound may be approximately 12 inches high and 2 or 3 feet in diameter. *F. fusca* is entirely black and is probably somewhat more abundant on the blueberry land. *F. exsectoides* has a red head and thorax and black abdomen; it is apparently not quite so abundant on the blueberry land. It is slightly larger than *F. fusca*, the nests are somewhat larger, and the individuals are more pugnacious if their nests are disturbed.

Both of the species of ants were very destructive to blueberry flies confined in cages on the blueberry land. Whenever it was attempted to confine a number of flies in a cage, the ants were observed running about the cages with flies in their jaws. At first it was thought that the ants were taking only the dead flies which had dropped to the bottom of the cage. Only brief observation was required to prove that the ants were also capturing the living flies. In a number of instances the black ants were observed to spring some distance in an attempt to capture the flies. The black ants were more troublesome to the flies in the cages than were the red heads, probably because the blacks were more numerous. It was necessary to protect the cages by sticky barriers to exclude the ants.

Probably ants catch many flies in the field, but no such capture was observed. In many cases ants in the field were observed in their haphazard wanderings to prowl very close to the flies. The flies always escaped easily, and the ants seemed to respond in no way to the proximity of the flies. The isolated habit of life of the flies and their constant alertness undoubtedly greatly reduce the effectiveness of the ants as destructive agents.

During the course of four or five summers' work with the blueberry maggot, small spiders have several times been observed feeding upon the blueberry flies, and a number of the flies have been observed enmeshed in spider webs among the blueberry plants. One small spider captured while feeding upon a blueberry fly was determined, by C. R. Shoemaker, to be *Philodromus rufus* Walck., of the family Thomisidae.

It is probable that spiders dispose of a good many blueberry flies during the course of a season, but no study has been made to determine the effectiveness of spiders in destroying the flies.

Two species of small hymenopterous parasites, *Opius melleus* Gahan and *O. richmondi* Gahan (determined by A. B. Gahan), have been found effectively attacking the blueberry maggot. Records from the emergence cages indicate that *O. melleus* is by far the more important species and that the number of *O. richmondi* is insignificant in comparison.

Two methods were used to determine the percentage of parasitism: (1) Collecting flies and parasites issuing in emergence cages, and determining the number of flies and parasites and computing the percentage of parasitism from these data, and (2) examining puparia under the binocular microscope to determine the percentage of pupuria which contained parasite larvae.

The estimation of percentage of parasitism based upon the relative numbers of flies and parasites which appear in emergence cages is subject to error, due to the fact that both the flies and parasites may remain in the soil for several years before emerging. However, this method is probably sufficiently accurate for most purposes. The examination of the puparia gives greater accuracy, but the process is tedious and time-consuming. In no case has a lot of puparia been observed to be entirely free from parasitism. Table 18 summarizes the records from the emergence cages during 1927. Parasitism in the different cages varied from 1.37 per cent to 29.66 per cent. The average for all of the cages was 10.7 per cent.

TABLE 18.—*Parasitism of the blueberry maggot by Opius melleus, based on records from emergence cages, 1927*

Cage	Number of parasites	Number of flies	Total of flies and parasites	Percentage of parasitism	Cage	Number of parasites	Number of flies	Total of flies and parasites	Percentage of parasitism
A	462	3,937	4,399	10.50	9	997	2,365	3,362	29.66
B	65	4,676	4,741	1.37	10	302	1,101	1,403	21.53
1	17	1,192	1,209	1.41	11	566	2,498	3,064	18.47
2	42	2,564	2,606	1.61	12	142	2,447	2,589	5.49
3	82	1,401	1,483	5.53	13	297	1,567	1,864	15.93
4	90	1,085	1,175	7.66	14	64	405	469	13.65
5	20	475	495	4.04					
6	169	1,738	1,907	8.86	Total or average	4,040	30,853	34,893	10.70
7	38	711	749	5.07					
8	687	2,691	3,378	20.34					

An examination of 10 lots of puparia obtained from infested blueberries in the season of 1927 indicated (Table 19) an average of 29.17 per cent parasitized. The lowest parasitism recorded from examination of these puparia was 3.28 per cent, and the highest was 49.42 per cent.

TABLE 19.—*Parasitism of the blueberry maggot by Opius melleus, based on puparia examined, 1927*

Lot No.	Nonparasitized puparia	Parasitized puparia	Total puparia	Percentage parasitized	Lot No.	Nonparasitized puparia	Parasitized puparia	Total puparia	Percentage parasitized
1	207	133	340	39.12	8	92	23	115	20.00
2	139	85	224	37.95	9	103	93	196	47.45
3	94	24	118	20.34	10	130	127	257	49.42
4	58	19	77	24.58					
5	149	39	188	20.75	Total or average	1,170	601	1,771	29.17
6	139	56	195	28.72					
7	59	2	61	3.28					

LIFE HISTORY OF OPIUS MELLEUS GAHAN

The life history of *Opius melleus* may be outlined briefly as follows: The winter is spent as full-grown larvae within the puparia of the host. Pupation takes place in midsummer, shortly before the emergence of the adult. The adult parasites emerge during late July and August, just as the blueberry maggots are present in large numbers in the berries.

The female parasite pierces the berry with her long ovipositor and places the egg directly in the body of the maggot within the berry. Eggs and larvae of the parasites are found most often in maggots of the third instar, but occasionally occur in maggots of the second instar.

The parasite larva develops in the body cavity of the host, without apparent injury to the maggot until after the puparium is formed.

There is apparently but one generation of *Opius melleus* a year in the vicinity of Cherryfield. A certain number of the parasites do not emerge during the first summer after the eggs are deposited, but remain in the soil to emerge during subsequent seasons. Adult parasites have emerged each season in cages that have been under observation for four seasons.

CONTROL

CULTURAL PRACTICES

BURNING

When investigation of the blueberry maggot was begun in 1925 it was believed by many of the blueberry growers that the periodical burning over of the blueberry land aided in maggot control by destroying the pupae overwintering in the soil. This seemed logical and was supported by the general observation that the first crop of berries produced after the land was burned over was usually less heavily infested by maggots than the berries of the succeeding crops. In order to ascertain definitely the effects of burning upon the overwintering pupae, experiments and observations were begun in the spring of 1926 and were continued each spring throughout the course of the work.

Observations on the methods of blueberry culture showed that progressive growers, in preparing to burn over the better portions of the blueberry land, spread hay on the land, usually at the rate of about one-half to 1 ton per acre. A series of small plots was therefore arranged upon which hay was placed at rates ranging from one-half ton to 2 tons per acre. The plots were on typical blueberry land, and they were burned over on a favorable day when blueberry land in the vicinity was being burned. Readings were made of the soil temperature immediately before the plots were burned and again immediately after the fire had passed over them. It was learned that even in the case of plots receiving hay at the rate of 2 tons per acre there was no appreciable rise in the temperature of the soil at the depth of 1 inch.

In the spring of 1926 two plots were selected upon each of which approximately 1 bushel of heavily infested berries had been placed during the preceding fall. Each of these plots was 4 by 5 feet in size. On one of these plots was placed a covering of hay approximately 6 inches deep, and over this was placed a generous supply of kindling. The resulting fire was comparable to the heat of a furnace. Immediately after the fire had died down sufficiently to allow access to the plot, temperature readings were made by means of soil thermometers set to a depth of about 1 inch. The soil temperature had been raised to 94° F., as compared to 60° before the burning. A record of the flies emerging from this plot during the regular emergence period later in the season indicated that there was a noticeable reduction in the number of flies that emerged, as compared with the number emerging from the other plots which had not been burned over. However, the fact that a goodly number of flies emerged from this plot showed that even such intense heat was not entirely effective in destroying the pupae in the soil.

On another 4 by 5 foot plot, upon which infested blueberries had been placed in 1925, considerably more hay was added than the blueberry growers of this section ordinarily put on, and the soil temperature at the depth of 1 inch was raised to 82° F. Records of the number of flies which emerged from this plot indicate that there was no marked destruction of the pupae on this plot as a result of the fire.

In addition to this experimental work, many readings were made of the soil temperatures during the burning operations conducted by

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commercial berry growers of this section. In no case was the temperature of the soil at the depth of 1 inch observed to be appreciably raised as a result of the burning process. It is quite evident, therefore, that while a small percentage of the pupae that pass the winter on the surface of the soil may be destroyed by the heat of the fire, the direct effect of the customary burning over of blueberry land is negligible so far as maggot control is concerned.

The importance of the burning over of blueberry land in relation to the control of the blueberry maggot results from the fact that the newly burned area produces no berries during the following summer. If the burning is thoroughly done, the destruction of the crop is so complete that there are no berries on the area in which maggots can be produced during this season. The flies emerging on such land must either migrate to productive land or die without producing maggots.

The effectiveness of this "starving out" process is reduced if the burning is not thoroughly done or if the area burned over is so small that flies may readily migrate in from old areas during the season of the first berry crop. The fact that from 5 to 20 per cent of the flies remain in the soil until the second spring to reinfest the new crop of berries probably accounts for a large part of the infestation of the new berry crop and is to a considerable extent responsible for the ineffectiveness of burning as a control for the blueberry maggot.

MOWING

It has been generally observed that land that is well mowed, so as to retard the growth of the weed bushes, and is generally well cared for yields better crops of berries and that the berries are usually less heavily infested with maggots as a result of the care.

The care of the land stimulates the growth of the blueberry plants, and, on soil of good fertility, greatly increases the yield of berries. As the berries increase in numbers more rapidly than the maggots, the percentage of berries infested tends to decrease as the care of the land improves. On the very best blueberry land where the sprouts and sweetfern have been almost entirely removed, and the land yields excellent crops of berries, the maggot seldom if ever seems to be excessively abundant. From a horticultural viewpoint it seems that it may be profitable to give large areas of blueberry land moderate care. However, it is doubtful if it would be profitable on very much of the land, under the present methods of blueberry production in Washington County, to attempt a complete control of the blueberry maggot by means of cultural practices alone.

WASHING TO REMOVE THE INFESTED BERRIES

During the summer of 1924 the blueberry maggot became an acute problem in the blueberry industry of Washington County. The first effective attempt to relieve the situation was the development of processes for the removal of the infested berries at the canneries. A successful method was worked out by B. J. Howard and C. H. Stephenson of the United States Department of Agriculture, Bureau of Chemistry and Soils. The method consists essentially of treating the infested berries in a large cylindrical sieve of heavy wire, about 4 or 5 meshes to the inch. (Pl. 13.) The cylinder is partially submerged in running water and revolves on its longitudinal axis at moderate speed. The berries remain in the revolving cylinder for varying lengths of time, depending upon the degree of infestation; berries with a comparatively low infestation require only a short treatment, while heavily infested berries require prolonged treatment to reduce the maggot count sufficiently.

The friction of the sides of the wire cylinder breaks down the soft berries containing the maggots. The maggots, together with the skin and pulp of the infested berries, are washed free into the water and are drained off in the overflow.

The washing machine enabled the canners to cope with the maggot situation, and practically every cannery in Washington County is now equipped for washing berries to remove the maggots. The method is subject to criticism, however, for the washing process breaks down not only the berries containing maggots, but also a considerable portion of the sound berries. No data are available to show accurately the loss of berries resulting from the washing process. Canners of considerable experience in operating the machines estimate the destruction at 10 to 50 per cent of the berries put into the machines. The destruction of berries varies in direct proportion to the length of time that it is necessary to process the berries. Table 1 shows an estimate of the loss of berries as a result of the washing process in one factory.

Because of the destruction of the berries during the washing process, combined with the expense and inconvenience involved, the blueberry men prefer, if possible, to combat the maggot in the field, rather than to treat the infested berries in the cannery.

DUSTING

The successful results secured during recent years by a number of workers (Severin (*15*) in Maine, Brittain and Good (*3*) in Nova Scotia, Porter (*13*) in Connecticut, and others elsewhere), using arsenical applications for combating the apple maggot, immediately suggested the use of similar treatments for the control of the blueberry maggot. Even a cursory study of the blueberry lands of eastern Maine indicated that large-scale applications of spray would probably be impracticable. Insecticide tests were therefore limited to dust applications.

RESISTANCE OF THE BLUEBERRY PLANT TO INSECTICIDE INJURY

Preliminary tests during the summer of 1925 demonstrated that the blueberry plants are fairly resistant to injury from calcium arsenate and lead arsenate when applied in dust form. More careful tests made since 1925 have given more definite information concerning the effects of insecticides upon blueberry foliage. In one test calcium arsenate dust was applied to blueberry plants at rates of 6, 12, 15, 18, and 20 pounds per acre without apparent injury in any case.

During the course of the experimental dusting to control the blueberry maggot, numerous complaints have come from blueberry growers, who have observed the dusted areas, that the dust was causing injury to the plants, resulting in defoliation on large areas. Undoubtedly injury and defoliation have occurred on spots in the dusted areas where the poison was accidentally applied in excessive quantities. Upon careful study, however, it usually appeared that there was as much defoliation of plants on untreated areas as occurred on the dusted land, and that the injury apparently was due to some other cause rather than to the effects of the insecticide. Weather conditions may have an important influence upon the injury produced by arsenical insecticides, and careful observations along this line should be continued.

Besides calcium arsenate, the following dusts were applied to blueberry bushes in small plots at the rates of 6 and 8 pounds per acre without apparent injury to the foliage: Lead arsenate, magnesium arsenate, and barium carbonate.

Calomel dust, similar to the material used for treating lawns for certain diseases, produced slight injury to the blueberry plants when applied at the rates of 6 and 8 pounds per acre.

Commercial sodium fluosilicate, cryolite, and artificial cryolite, applied at the rates of 6 and 8 pounds per acre, caused severe injury to blueberry foliage. Within 24 hours the blueberry foliage showed severe injury, and the final result was complete defoliation of the dusted plants.

METHODS OF DETERMINING RESULTS OF DUST TREATMENT

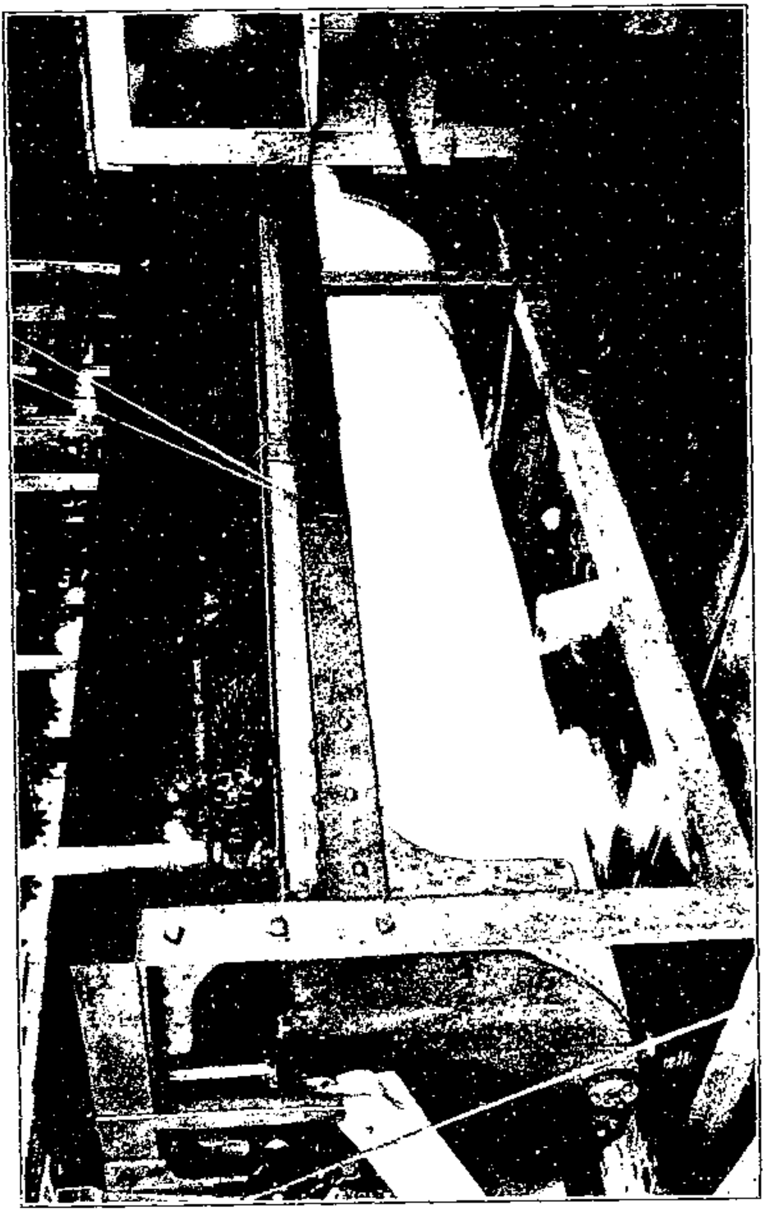
The results of each experiment for the control of the blueberry maggot were determined by counting the number of maggots in a series of samples taken at well-distributed points in the treated area and from a similar series of samples taken in an untreated area. The counts obtained from samples taken in the treated area were compared with the maggot counts obtained from a similar series of berries taken from a near-by area which received no treatment and was selected because of its apparent similarity to the dusted plot.

All of the experimental plots were more or less covered with birch and alder bushes and sweetfern. These weed bushes as well as the blueberry plants were irregularly distributed on the plots, hence portions of each plot were very bushy, while other portions were relatively free from weed bushes. It was soon found that on an average the blueberries from bushy places were more heavily infested than berries from the open places. In order to equalize this factor, one-half of the samples of berries from each dusted plot were picked from bushy areas and one-half from open areas, and the same procedure was followed on each check plot.

Although it has not seemed advisable to attempt to determine the effectiveness of the dust treatments by means of fly counts, examinations of dusted blueberry land two days after the application revealed many dead flies on the ground. Fly counts on dusted and check areas showed a significant difference in the numbers of flies present. (Fig. 30.)

COUNTING THE MAGGOTS

To determine the number of maggots present in a sample of blueberries, the natural impulse is to pick each berry open with the fingers and examine the pulp of the berry to see if a maggot is present. This method was tried at the outset of the work in 1925; it was soon found inadequate. Too many of the smaller maggots escaped detection even when the berry was examined under the binocular microscope, and examining the individual berries was far too slow a process to be applied to large-scale work.



LARGE WASHING MACHINE IN BLUEBERRY CANNERY FOR REMOVING MAGGOTS FROM INFESTED BERRIES

A, Counting maggots from blueberry samples. B, maggots as they appear in the black counting pan

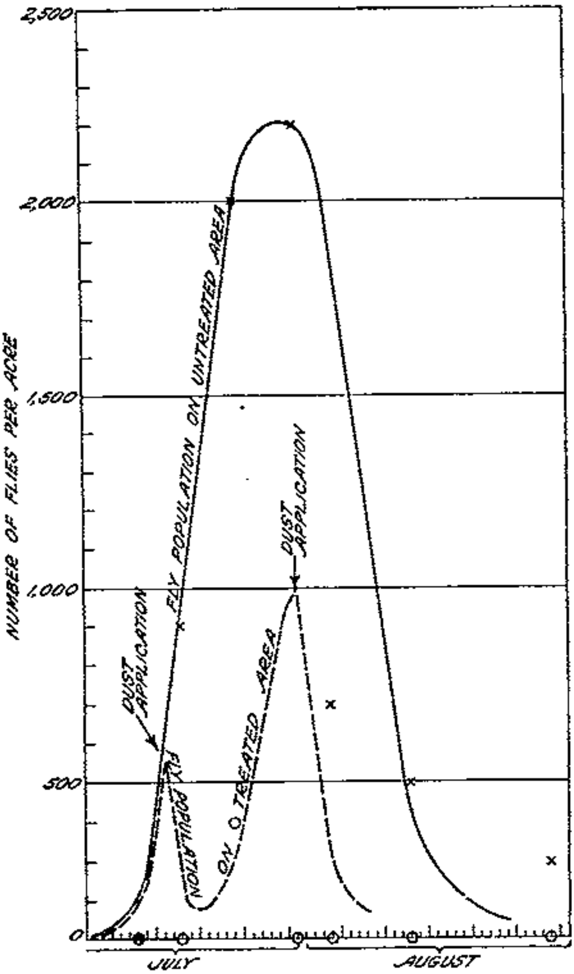


FIGURE 30.—Decrease of fly population as a result of two applications of calcium arsenate, Cherryfield, Me., 1928. The solid line represents the fly population of untreated check area of plot 1 G. The broken line represents theoretical fluctuations of fly population on treated portion of plot 1 G. Crosses indicate results of field counts of flies on the check area. Circles indicate results of similar counts on the treated area. Arrows indicate dates of application of calcium arsenate dust. Note the method used for constructing the curve for the treated area. The fly populations increased with equal rapidity on both plots prior to the first treatment. Following the first dust application, there was a sharp decline in the fly population of the treated plot. After the poison was removed from the foliage by weather, the fly population of the treated plot began building up rapidly. The second poison application again reduced the fly population, and, as emergence was practically complete, there was no further increase of flies on the treated plot during the season. The curves represent total fly populations. The reduction of egg-laying females on the treated plot is much more complete than the reduction of the total population

After some experimentation, a method of counting the maggots was adopted which consisted of a modification of a process devised by B. J. Howard, of the Food and Drug Administration. In more or less modified form the method devised by Howard is used by the inspectors in the blueberry canneries of eastern Maine.

The procedure for determining the results obtained on the experimental plots was as follows: The required number of berries, usually 100, was carefully counted by means of a counting board. (Pl. 10, B.) After the berries had been counted, the sample was weighed.[11] The weighed berries were poured into a wire-screen cylinder about 3 inches in diameter and 9 inches high. The cylinder was made of good quality galvanized-wire screen, 5 meshes to the inch, and the bottom was closed by the same material. The cylinder containing the berries was placed in a small aluminum saucepan containing enough water to float the berries. The saucepan was placed on a kerosene stove, and the water containing the berries was boiled for about two minutes. While the water was heating and boiling, the berries were gently crushed by means of a wooden pestle. The water and berries were violently agitated to free the maggots from the berry pulp and to wash them free into the water. The water containing the maggots, together with more or less berry pulp and seeds, was then poured into a No. 10 can (or a battery jar of about the same capacity) and diluted with water to fill the container about two-thirds full. The wire-screen cylinder, containing most of the berry skins, was agitated in the water in the No. 10 can to wash free any maggots that might possibly have adhered to the residue of berry skins.

A small portion of the water from the No. 10 can, containing the maggots, was poured into a shallow, black-bottomed pan—an ordinary biscuit pan was used—and diluted with a little more water. The contents of the pan were carefully examined for maggots, which showed up in strong contrast on the black bottom of the pan. (Pl. 14.) As soon as all of the maggots in the pan had been counted the pan was emptied, and another portion was poured in from the container. The total number of maggots found in all of the water from the No. 10 can represented the number of maggots in the sample of berries. A tag bearing a serial number and all necessary data followed each sample throughout the entire process, so that there was no danger of samples becoming mixed.

DUSTING EXPERIMENTS IN 1926

In 1926 experiments in dusting for the control of the blueberry maggot were undertaken on a fairly large scale. Because of the roughness of the blueberry land and the lack of uniformity of the crop, and also because of the likelihood of migration of flies from the surrounding land on to the dusted plots, it was considered impractical to carry on dusting experiments on very small plots. During the season dust was applied to six plots, the smallest having an area of 1.15 acres

[11] Counts of the number of maggots per 100 berries gave an accurate index to the relative infestation of the treated and untreated plots, but such counts gave no close indication of the number of maggots per No. 2 can. As the number of maggots per No. 2 can is the basis of estimates used by the canners, it seems desirable to express results from the experimental treatments on this basis as well as on the basis of maggots per 100 berries. Twenty ounces of raw berries are considered equivalent to one No. 2 can of the processed berries. Hence, by weighing the samples of berries from the experimental areas, the results may be expressed as maggots per No. 2 can.

and the largest having an area of 4.82 acres. No plot measured less than 200 feet in length or width. Each plot was carefully selected to include land as nearly uniform as it was practicable to obtain, and each had a history of heavy infestation during past seasons. The plots were rectangular in shape, and were laid off by means of compass and tape. Each plot was marked off in squares by stakes set at 50-foot intervals in each direction and was divided into lanes 50 feet wide by means of heavy white cord extending across the plot on each line of stakes. This marking served to guide the men in applying the dust and also indicated the sampling points at picking time. A portion of each plot was dusted, and a comparable area was reserved, untreated, as a check plot.

The plots were dusted by means of crank-type hand dust guns. In dusting the plots, three men worked abreast. Together they covered a strip 25 feet wide, making one trip across the plot and back to dust one 50-foot lane. The dust was applied during the early morning hours, when the atmosphere was calm and while the plants were wet with dew, except in the case of plot 6, which was dusted in the afternoon. An attempt was made to apply the dust as nearly as possible at the rate of 6 pounds per acre, but it was found very difficult to gauge the application accurately, and the amount of dust actually applied usually ran considerably higher than 6 pounds per acre. Plots 1, 2, and 3 received four applications of dust during the season, and plots 4, 5, and 6 received three applications. Plots 1 to 4, inclusive, were dusted with calcium arsenate, plot 5 was dusted with lead arsenate, and plot 6 received lead arsenate in the first application and calcium arsenate in the last two applications. Complete data concerning the dates of application, material used, and time consumed are given in Table 20.

TABLE 20.—*Data relating to plots dusted in 1926*

Plot No.	Area dusted	Date of application	Time of application	Material used	Quantity applied per acre	Time required per acre
	Acres		*A. M.*		*Pounds*	*Man-hours*
1	2.75	July 21	5.00-6.00	Calcium arsenate	9.80	1.09
		July 27	5.00-5.55	do	8.35	1.00
		Aug. 4	5.00-5.45	do	7.26	.82
		Aug. 12	5.05-5.30	do	5.44	.45
2	1.15	July 22	5.20-6.55	do	9.58	1.52
		July 28	5.20-5.55	do	12.20	1.52
		Aug. 5	5.50-6.10	do	7.84	.87
		Aug. 13	6.05-6.40	do	8.71	1.52
3	1.72	July 23	5.20-5.50	do	9.93	.87
		July 29	5.15-5.55	do	8.13	1.16
		Aug. 6	5.15-5.35	do	7.55	.58
		Aug. 14	6.05-6.30	do	8.71	.73
4	2.20	July 24	5.10-5.50	do	11.40	.91
		July 2	5.15-6.05	do	8.71	1.14
		Aug. 10	5.25-6.00	do	7.79	.80
5	2.75	July 27	6.15-7.10	Lead arsenate	5.80	.99
		Aug. 4	6.05-6.40	do	5.08	.63
		Aug. 12	5.55-6.25	do	6.89	.64
			P. M.			
6	4.82	July 28	2.30-4.40	do	7.26	1.08
		Aug. 6	4.55-6.00	Calcium arsenate	8.71	.67
		Aug. 10	2.57-4.20	do	8.09	86

RESULTS OF DUSTING IN 1926

Results were obtained by examining a series of samples, each containing 500 berries collected from points well distributed over each treated plot, and a similar series from each check plot. No sample was taken either in the check plot or in the treated plot nearer than 50 feet from the margin of the dusted area. The records of these examinations are contained in Table 21. The reduction in infestation due to the dust applications was in general quite satisfactory. The greatest reduction was obtained on plot 4, on which a control of 99 per cent was secured. This plot received three applications of calcium arsenate. The lowest reduction in maggots occurred on plot 5, with a control of 42 per cent. This plot received three applications of lead arsenate. It is doubtful if the comparatively unsatisfactory results obtained on this plot were due to the use of lead arsenate. Nevertheless, the comparison certainly does not indicate that lead arsenate is superior to calcium arsenate, and as the latter is much cheaper there is a distinct advantage in its use.

TABLE 21.—*Results of dusting for control of the blueberry maggot, Washington County, Me., 1926*

Plot No.	Applications			Maggots per 500 berries		Reduction in maggots per 500 berries	Maggots per No. 2 can		Reduction in number of maggots per No. 2 can
	Number	Material	Date	Check plot	Treated plot		Check plot	Treated plot	
				Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1	4	Calcium arsenate.	July 21, 27; Aug. 4, 12	32.3±3.9	1.13±0.5	96.5± 1.6	153.6±18.7	7.6± 3.4	95.0± 2.6
2	4	do	July 22, 28; Aug. 5, 13	27.5±4.3	2.3±0.6	91.6± 2.5	104.2± 5.0	10.8± 2.9	89.6± 2.3
3	4	do	July 23, 29; Aug. 6, 14	44.5±6.2	6.1±1.3	86.3± 3.5	255.4±34.9	36.1± 8.6	85.8± 3.9
4	3	do	July 24; Aug. 2, 10	38.7±5.9	0.4±0.2	99.0± 1.7	209.3±30.0	2.0± 0.8	99.0± .4
5	3	Lead arsenate.	July 27; Aug. 4, 12	15.0±2.7	8.7±1.8	42.0±15.6	72.8±12.6	35.4± 6.9	51.4±12.6
6	3	do; calcium arsenate.	July 28; Aug. 6, 10	53.5±4.6	16.1±3.1	69.9± 6.4	255.9±22.3	79.1±13.7	69.1± 6.0

The season of 1926 seemed especially favorable for the control of the blueberry maggot by means of dust applications. Atmospheric conditions during the dusting period were favorable, and a study of Table 22 indicates that there was only slight rainfall during the effective period of the treatment. The application of dust by means of hand guns proved much more practical than was anticipated at the outset of the work. It was apparent, however, that because of the time and labor involved, hand-duster methods are applicable only to very small areas and that if control of the maggot by dust applications were to be placed on a practical basis it would be necessary to devise some cheaper and more rapid means for applying the dust. It was also apparent that it would be necessary to reduce the number of applications, if the method were to be applied to any but the more productive blueberry land.

TABLE 22.—*Summary of rainfall records for five days following each dust application for control of the blueberry maggot, Washington County, Me., 1926*

Plot No.	First application				Second application			
	Date	Rainless days following	Rains within five days following	Precipitation	Date	Rainless days following	Rains within five days following	Precipitation
		Number	*Number*	*Inch*		*Number*	*Number*	*Inch*
1	July 21	1	1	0.05	July 27	2	1	0.03
2	July 22	[1] 0	1	.05	July 28	1	1	.03
3	July 23	6	0	----------	July 29	0	2	.11
4	July 24	5	0	----------	Aug. 2	0	2	.10
5	July 27	2	1	.03	Aug. 4	2	2	.18
6	July 28	1	1	.03	Aug. 6	0	3	.19

Plot No.	Third application				Fourth application			
	Date	Rainless days following	Rains within five days following	Precipitation	Date	Rainless days following	Rains within five days following	Precipitation
		Number	*Number*	*Inch*		*Number*	*Number*	*Inch*
1	Aug. 4	2	2	0.18	Aug. 12	0	2	0.08
2	Aug. 5	1	2	.18	Aug. 13	0	1	.02
3	Aug. 6	0	3	.19	Aug. 14	6	0	----------
4	Aug. 10	0	3	.09	Aug. —	----------	----------	----------
5	Aug. 12	0	2	.08	Aug. —	----------	----------	----------
6	Aug. 10	0	3	.09	Aug. —	----------	----------	----------

[1] 0 indicates rain within 24 hours after application.

DUST APPLICATIONS IN 1927

During the season of 1927 a large power duster (similar to the machines used for orchard dusting) mounted on a heavy farm wagon was employed to distribute the dust. The plots, as indicated in Table 23, were considerably larger than those employed in 1926. The largest plot dusted by means of the power machine had an area of 16.07 acres, while the smallest measured 3.44 acres. The average area of the plots treated by means of the power duster in 1927 was 11.66 acres, and the total area dusted was 58.31 acres. Again the plots selected for dusting had a history of heavy maggot infestation, and each area selected was as nearly uniform as possible with respect to topography, stand of berries, degree of burn, etc. The plots were marked off in 100-foot squares by rows of stakes, which served as guides in dusting and in collecting the berry samples at picking time.

TABLE 23.—*Data relating to plots dusted with calcium arsenate in 1927*

Plot No.	Area dusted	Date of application	Time of application	Calcium arsenate used per acre	Area dusted per hour
	Acres		*a. m.*	*Pounds*	*Acres*
1	3.44	July 13	5.30–5.60	9.50	10.3
		July 29	5.09–5.19	3.37	20.6
2	11.02	July 13	4.15–5.00	9.46	14.7
		July 29	4.15–4.45	3.45	22.0
3	15.15	July 19	4.37–5.18	4.22	22.2
		July 31	4.13–4.47	4.02	26.7
4	16.07	July 21	5.10–6.15	9.33	14.8
		July 27	4.20–4.52	4.79	30.1
5	12.63	July 22	4.40–5.35	6.49	13.8
		July 26	4.35–5.25	5.62	15.2

The duster crew consisted of three men—one man to drive the team, one man to handle the nozzle from the rear of the duster, and one man to observe the work and to indicate the route for the driver. In making the application, the duster was driven across the blueberry land at 100-foot intervals. As the duster proceeded along its route, the nozzle of the machine, pointing backward and slightly upward, was kept constantly moving from side to side. In this way it was found possible to throw the dust cloud to a distance of 50 feet on each side of the machine, thus dusting a strip 100 feet wide. At first it was feared that the team and wagon would trample down an excessive quantity of blueberries. It was soon found, however, that the injury from this source was so slight as to be negligible. The applications were made during the early morning hours, while atmospheric conditions were favorable and the plants were covered with dew. Calcium arsenate was used for all applications this season. Table 23 indicates the dates of the applications, material used, area dusted, and the rate at which the work was accomplished.

During the season of 1927 the results were obtained by collecting a series of 100 samples, each containing 100 berries, from 100 points well distributed over each dusted plot and a similar series of samples from each check plot. These samples were picked by hand, approximately 100 berries being collected from an area 10 feet square at each sampling point. These berries were taken into the laboratory, where exactly 100 berries were counted from each field sample, and the number of maggots was determined for each sample. Table 24 shows that on the whole the percentage of reduction of maggots in the berries was satisfactory. The most favorable results were obtained on plot 4, with a reduction of 94.7 per cent, and the least favorable on plot 3, with a reduction of 35.3 per cent.

TABLE 24.—*Results of dusting for control of the blueberry maggot, Washington County, Me., 1927*

Plot No.	Date of applications	Maggots per 100 berries		Reduction in maggots per 100 berries	Maggots per No. 2 can		Reduction in maggots per No. 2 can
		Check plot	Treated plot		Check plot	Treated plot	
		Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1	July 13, 29	5.8±1.0	2.5±0.7	56.9±14.2	90.9±15.4	27.6±6.3	69.6±8.6
2	July 13, 29	22.0±1.0	2.4±0.2	89.1± 1.1	321.2±14.0	32.3±2.8	89.9± .9
3	July 19, 31	8.5±0.6	5.5±0.4	35.3± 6.5	151.4± 0.5	87.7±6.3	42.1±4.2
4	July 21, 27	7.5±0.8	0.4±0.1	94.7± 6.5	92.2± 9.8	5.9±1.4	93.6±1.7
5	July 22, 28	5.0±0.4	0.8±0.0	84.0± 1.2	65.7± 4.6	11.6±1.2	82.3±2.2

Weather conditions during the season of 1927 were less favorable for the control of the maggot by dust applications than during 1926. The season of 1927 was rainy (Table 25), and the precipitation during the dusting period was heavy. In the case of plot 3 (Table 24), on which the poorest results were obtained, there was a precipitation of 3.58 inches within five days after the first application and 0.35 inch within five days after the second application, and rain fell within 24 hours after each application. In the case of plot 4, on which the best results were obtained, there was 2.79 inches of rain within five days of the first application and 0.2 inch within five days after the second application. Two days without rain followed the first application, and after the second application there were four days without rain.

TABLE 25.—*Summary of rainfall records for five days following each dust application for control of the blueberry maggot, Washington County, Me., 1927*

Plot No.	First application				Second application			
	Date	Rainless days following	Rains within five days following	Precipitation	Date	Rainless days following	Rains within five days following	Precipitation
		Number	*Number*	*Inches*		*Number*	*Number*	*Inch*
1	July 13	4	2	0.35	July 29	2	2	0.35
2	July 13	4	2	.35	July 29	2	2	.35
3	July 19	[1] 0	3	3.58	July 31	0	2	.35
4	July 21	2	2	2.79	July 27	4	1	.20
5	July 22	1	2	2.79	July 28	5	0	.00
6	July 16	1	8	1.26	July 28	3	2	.35
7	July 16	1	3	1.26	July 28	3	2	.35

[1] 0 indicates rain within 24 hours after application.

It had been suggested that the addition of powdered sugar to the calcium arsenate might make the material attractive to the blueberry flies, thereby increasing the effectiveness of the material. Accordingly, two plots, of 2.75 acres each, were treated by means of hand dusters. On plot 6 two applications of calcium arsenate were made. On the same dates plot 7 received applications of calcium arsenate with which XXXX confectioners' sugar had been thoroughly mixed at the rate of 1 pound of sugar to 20 pounds of calcium arsenate. At picking time, when results of the treatment were compared, it was found that the percentage of reduction in infestation was not quite so satisfactory on the plot receiving the application of calcium arsenate with the addition of sugar as on the plot receiving calcium arsenate alone. The results of the treatments are shown in Table 26. Because of the low initial infestation this experiment is probably not conclusive; however, it does not indicate that the addition of sugar is especially beneficial, and as very satisfactory results were obtained in other experiments without the addition of sugar, no further work along this line was undertaken.

TABLE 26.—*Comparison of results of dusting with calcium arsenate alone and with calcium arsenate and confectioners' sugar (20 to 1), 1927*

Plot No.	Material [1]	Maggots per 100 berries [2]			Maggots per No. 2 can		
		Check plot	Treated plot	Reduction	Check plot	Treated plot	Reduction
		Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
6	Calcium arsenate alone	0.9±0.1	0.3±0.0	66.7± 3.7	14.68±2.1	4.4±1.2	70.0 ±9.2
7	Calcium arsenate and confectioners' sugar (20 to 1).	.9± .1	.6± .1	33.4±13.3	14.68±2.1	7.9±1.7	46.2±13.9

[1] First application July 16; second application July 28.
[2] Forty samples, each containing 100 berries, were examined from the dusted plot and from the check plot.

DUSTING WORK OF 1928

In the spring of 1928 it appeared that applications of calcium arsenate gave promise of becoming a practical method for combating the blueberry maggot. In view of this fact, it seemed desirable to conduct an investigation to ascertain the most expeditious method for applying dust to the blueberry land on a large scale. Because of the necessity for applying the dust within a short space of time, because of the large areas devoted to blueberry growing, and because of the favorable topography, it seemed that this project offered an exceptional opportunity for the employment of airplane dusting. (Pl. 1, A.) Accordingly, 13 plots (Table 27) were laid out to be dusted by means of airplane. These plots varied in area from 35.81 acres to 102.84 acres, the average area was 58.34 acres, and the total area of the airplane plots was 758.48 acres. As four of the plots received two applications of dust, the total area actually dusted by airplane was 1,016.52 acres.

TABLE 27.—*Record of flying time and calcium arsenate used in airplane dusting for control of the blueberry maggot, Washington County, Me., 1928*

Plot	Area of plot	Applications	Total area dusted	Approximate distance from landing field to plot	Trips made	Estimated flying time to and from plots	Flying time consumed in applying dust	Total flying time	Dust carried each trip	Total dust applied [1]
	Acres	*Number*	*Acres*	*Miles*	*Number*	*Minutes*	*Minutes*	*Minutes*	*Pounds*	*Pounds*
1A	43.16	2	86.32	4	4	34	19	53	145	580
2A	102.84	2	205.68	9	8	160	42	202	170	1,360
3A	70.72	2	141.44	4	8	150	29	179	116	928
4A	41.32	2	82.64	2	4	16	18	34	140	560
5A	78.05	1	78.05	1½	3	26	14	40	170	510
6A	52.34	1	52.34	8	2	40	15	55	170	340
7A	68.87	1	68.87	8	2	40	9	49	224	448
8A	74.38	1	74.38	5	2	32	9	41	170	[2] 340
9A	36.73	1	36.73	5	2	32	8	40	120	240
10A	40.40	1	40.40	8	2	40	14	54	135	270
11A	67.95	1	67.95	7	3	54	17	71	150	450
12A	35.81	1	35.81	1¼	2	12	13	25	120	240
13A	45.91	1	45.91	½	2	12	13	25	150	300
Total	758.48		1,016.52			[3] 648	[4] 220	[5] 868		6,566

[1] It was attempted to apply 6.5 pounds of dust per acre. In most cases slight excess was added to allow for wastage.
[2] By mistake plot 8A received only 4.57 pounds of dust per acre. The average for all other plots was 6.61 pounds per acre.
[3] 10 hours, 48 minutes.
[4] 3 hours, 40 minutes.
[5] 14 hours, 28 minutes.

Experimental work with the ground machine in 1928 included five plots ranging in area from 8.03 to 15.95 acres, with an average area of 11.91 acres and a total area of 59.56 acres. Table 28 gives complete data concerning dates of application, area of plots, material used, and the rate at which dust was applied.

TABLE 28.—*Data relating to plots dusted with horse-drawn power duster, 1928*

Plot No.	Area dusted	Date of application	Time of application	Calcium arsenate used per acre	Area dusted per hour
	Acres		*a. m.*	*Pounds*	*Acres*
1G	15.95	July 16	5.15–5.50	8.40	27.3
		July 31	4.10–4.55	6.08	21.3
2G	10.33	July 18	5.15–5.50	7.16	17.7
		July 29	4.35–5.10	11.62	17.7
3G	13.77	July 19	8.20–9.13	4.65	15.6
		Aug. 3	4.35–5.35	8.88	13.8
4G	11.48	July 22	4.40–6.10 [1]	7.40	11.5
5G	8.03	July 27	4.35–5.03	8.34	17.2

[1] Actual dusting time was 60 minutes; 30 minutes was lost because of interruption of the work.

A complete account (*9*) of the dusting work of 1928 has been published as a comparative study of the use of the airplane and the ground machine for dusting blueberry land.

The results were determined on all of the plots dusted by ground machine and on six of the plots dusted by airplane. (Tables 29 and 30.) The six plots of the airplane series, upon which results were determined, were selected because of favorable conditions for studying the results or because of a desirable range of topography, etc.

RESULTS OF DUST APPLICATIONS IN 1928

TABLE 29.—*Results of dusting with ground machine for control of the blueberry maggot, Washington County, Me., 1928*

Plot No.	Applications		Maggots per 100 berries			Maggots per No. 2 can		
	Number	Date	Check plot	Treated plot	Reduction	Check plot	Treated plot	Reduction
			Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1G	2	July 16, 31	3.8±0.2	0.4±0.1	89.5±2.7	53.6±2.5	6.2±0.8	88.4±2.4
2G	2	July 18, 29	4.6±0.3	0.3±0.1	93.5±2.2	70.9±4.1	4.4±0.8	93.8±1.2
3G	2	July 19, Aug. 3	2.9±0.2	0.5±0.1	82.8±3.6	37.6±3.0	6.1±0.8	83.8±2.5
4G	1	July 22	6.8±0.5	1.1±0.1	83.8±1.9	107.0±6.5	16.5±1.3	84.6±1.5
5G	1	July 27	12.8±0.5	7.5±0.5	41.4±4.5	228.7±9.0	135.1±8.0	40.9±4.2
Average of 2-application plots					88.6±2.9			88.7±2.1
Average of 1-application plots					62.6±3.5			02.8±3.2

On the plots receiving two applications of dust from a ground machine, the percentage reduction in number of maggots ranged from a minimum of 82.8 per cent to a maximum of 93.5 per cent, with an average reduction of 88.6 per cent. The plots receiving only one application of dust showed less favorable results. The results on plot 4G, however, indicate that one well-timed application made under favorable conditions may be very effective. The average reduction in maggots on the two plots given one application of dust by a ground machine was 62.6 per cent. Complete results are shown in Table 29.

TABLE 30.—*Results of airplane dusting for control of the blueberry maggot, Washington County, Me., 1928*

Plot No.	Applications		Maggots per 100 berries			Maggots per No. 2 can		
	Number	Date	Check plot	Treated plot	Reduction	Check plot	Treated plot	Reduction
			Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1A	2	July 17, 30	7.5±0.4	1.6±0.2	78.7±11.7	100.6±5.0	21.3±2.0	78.8± 2.8
2A	2	July 18, 29	4.6±0.3	0.4±0.1	91.3± 2.2	70.9±4.1	6.0±0.9	91.5± 1.4
3A	2	July 18, 28	3.0±0.2	0.7±0.1	76.7± 3.7	51.0±3.6	12.5±1.4	75.5± 3.2
5A	1	July 21	1.0±0.1	1.2±0.1	−20.0±15.6	12.6±1.1	15.5±1.3	−23.0±14.0
8A	1	do	3.2±0.3	3.1±0.3	3.1±13.1	54.4±4.1	47.4±3.0	12.9± 9.7
11A	1	July 27	2.1±0.2	1.1±0.1	47.6± 6.9	37.6±2.5	19.0±1.9	47.0± 6.1
Average of 2-application plots					82.2± 7.2			81.9± 2.0
Average of 1-application plots					10.2±12.5			12.6±10.0

Two applications of dust by airplane (Table 30) also resulted in a satisfactory reduction in the number of maggots present in the berries. The plots receiving two applications of calcium arsenate by airplane showed an average reduction in number of maggots per 100 berries of 82.2 per cent, a minimum reduction of 76.7 per cent, and a maximum reduction of 91.3 per cent.

A single application by airplane does not appear to yield such satisfactory results. The best result secured on a plot receiving one application by airplane was a reduction of 47.6 per cent. The average reduction on the three plots receiving single applications by airplane was 10.2 per cent.

A summary of weather records for the dusting season of 1928 is given in Table 31.

TABLE 31.—*Summary of rainfall records for five days following each application of calcium arsenate for the control of the blueberry maggot, Cherryfield, Me., 1928*

Plot No.	First application				Second application			
	Date	Rainless days following	Rains within 5 days following	Precipitation	Date	Rainless days following	Rains within 5 days following	Precipitation
		Number	*Number*	*Inches*		*Number*	*Number*	*Inch*
1A[1]	July 17	1	2	0.08	July 30	4	1	0.06
2A	July 18	[2]0	3	1.21	July 29	0	1	.33
3A	do	0	3	1.21	July 28	0	2	.43
5A	July 21	2	3	1.48				
8A	do	2	3	1.48				
11A	July 27	1	2	.43				
1G[1]	July 16	2	2	.08	July 31	3	1	.06
2G	July 18	0	3	1.21	July 29	0	1	.33
3G	July 19	4	1	1.13	Aug. 3	0	3	.44
4G	July 22	1	3	1.48				
5G	July 27	1	2	.43				

[1] Series A, airplane plots; series G, ground-machine plots.
[2] 0 indicates rain within 24 hours after application.

COMPARATIVE EFFECTIVENESS OF GROUND MACHINE AND AIRPLANE

When calcium arsenate dust is applied under favorable conditions it appears that applications by means of a ground machine and an airplane should be about equally effective in controlling the blueberry maggot. That this is actually true is indicated by plots 2A and 2G, which were dusted by an airplane and a ground machine, respectively. These two plots were located within a few hundred feet of each other, and a single check area served for both plots. The land was level, free from trees, and in every respect favorable for airplane work. The treatments by airplane and by ground machine were applied on the same mornings, July 18 and 29, each plot receiving two applications during the season. Although the application of dust by the ground machine was considerably heavier than that made by the airplane, the percentage of reduction of maggots was not materially different in the two plots, the maximum being 91.3 per cent on the airplane plot and 93.5 per cent on the ground-machine plot. (Tables 29 and 30.)

DUSTING IN 1929

Because of the impractical nature of airplane dusting under the conditions of blueberry culture in Washington County, Me., the airplane work was not continued in the summer of 1929. During this season five plots (Table 32) were dusted by means of a horse-drawn power machine. The plots ranged in area from 14.92 to 22.73 acres, with an average of 17.58 acres, and a total area of 87.92 acres. The work during the summer of 1929 was considerably hampered by bad weather conditions, which delayed the application of the dust. Atmospheric conditions were often unsatisfactory when the dust was applied to the plots. Weather conditions following the applications were rather favorable for the treatments as the rainfall was light. (Table 33.)

TABLE 32.—*Data relating to plots dusted with horse-drawn power duster, 1929*

Plot No.	Area dusted	Date of application	Time of application	Dust used per acre	Area dusted per hour
	Acres		*a. m.*	*Pounds*	*Acres*
1	22.73	July 23	4.10–5.30	6.81	17.0
		July 29	5.00–6.00	6.55	22.7
2	20.43	July 25	3.45–4.55	6.06	17.5
3	14.92	July 26	4.15–5.00	6.70	19.9
4	14.92	July 22	3.35–4.25	6.70	17.9
		July 28	4.25–5.20	6.70	10.3
5	14.92	July 22	4.45–5.40	6.70	16.3
		July 28	5.35–6.15	6.70	22.4

TABLE 33.—*Summary of rainfall records for five days following each dust application for control of the blueberry maggot, Washington County, Me., 1929*

Plot No.	First application				Second application			
	Date	Rainless days following	Rains within five days following	Precipitation	Date	Rainless days following	Rains within five days following	Precipitation
		Number	*Number*	*Inch*		*Number*	*Number*	*Inch*
1	July 23	1	1	Trace.	July 29	[1] 0	2	0.11
2	July 25	4	1	0.11				
3	July 26	3	1	.11				
4	July 22	2	1	Trace.	July 28	1	2	.11
5	do	2	1	Trace.	do	1	2	.11

[1] 0 indicates rain within 24 hours after application.

The results of the experimental work in 1929 are shown in Tables 34 and 35. The initial infestation on the experimental plots during this season was so low that results are scarcely dependable. Even with the unusually low initial infestation, however, there was in most of the plots a very distinct reduction in maggots as a result of the treatments.

On plots 4 and 5 a comparison was made of calcium arsenate alone and a mixture of equal parts of calcium arsenate and hydrated lime. There was very little difference in the results obtained with these two treatments. The infestation on the plot receiving the calcium arsenate-hydrated lime mixture shows a reduction of 55.6 per cent, as compared with 50 per cent on the calcium arsenate plot. While this can hardly be regarded as a significant difference, it suggests that the calcium arsenate-hydrated lime mixture may be satisfactorily used in place of calcium arsenate alone.

TABLE 34.—*Results of dusting for control of the blueberry maggot, Washington County, Me., 1929*

Plot No.	Applications		Maggots per 100 berries			Maggots per No. 2 can		
	Number	Date	Check plot	Treated plot	Reduction	Check plot	Treated plot	Reduction
			Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1	2	July 23, 29	1.9±0.2	0.5±0.1	73.7± 5.9	29.6±3.9	9.6±1.0	67.6± 4.8
2	1	July 25	0.6±0.1	0.5±0.1	16.7±21.7	9.8±1.0	7.6±1.0	22.4±12.9
3	1	July 26	3.6±0.2	4.5±0.3	−25.0±10.8	62.8±3.7	78.4±5.7	−24.8±11.7

TABLE 35.—*Comparison of results from dusting with calcium arsenate and with calcium arsenate-hydrated lime mixture for control of the blueberry maggot, Washington County, Me., 1929*

Plot No.	Material	Maggots per 100 berries			Maggots per No. 2 can		
		Check plot	Treated plot	Reduction	Check plot	Treated plot	Reduction
		Number	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
4	Calcium arsenate	1.8±0.0	0.9±0.1	50.0±5.6	41.0±4.5	21.6±2.1	47.3±7.5
5	Calcium arsenate and hydrated lime [1]	1.8±0.0	0.8±0.1	55.6±5.6	41.0±4.5	15.6±1.4	61.9±5.4

[1] Equal parts.

Dust applications successfully reduced infestation even when the infestation was very low.

COST OF DUSTING

The records of time and labor involved in the experimental dusting are included in the discussion of the work of each season. The data shown are useful in the making of rough, preliminary estimates of the probable cost of treatment on a given tract of blueberry land. There are many factors involved which are not presented in the tables, however, and the data presented do not form a satisfactory basis for estimating accurately the total cost of dusting. For example, weather conditions sometimes prevent the application of dust after the duster is on the ground and the crew is ready for work; moreover, it often requires more time to haul the machine to the land to be treated than it does to make the application. Such difficulties increase the cost of treatment and are proportionately more important when small plots are to be dusted.

Summing up all the experimental applications by means of the horse-drawn power duster for the three years, 1927, 1928, and 1929, a total of 205.79 acres was treated. The dusting outfit, as operated, with two horses, a driver, one man to handle the nozzle, and one man to assist, applied the dust at an average rate of 18.4 acres per hour. In addition to the actual application of the dust, a considerable amount of labor was involved in measuring and marking off the areas to be dusted. Much more time was spent in laying off the experimental plots than is required for commercial dusting. However, the growers have found it practical to make a fairly accurate estimate of the area of the plots to be dusted and to lay off the land rapidly in lanes 100 feet wide, indicated by stakes set in rows.

One commercial firm kept an accurate record of the cost of dusting a total area of 205 acres by means of a standard horse-drawn power duster. Nearly all of the 205 acres received two applications, making a total equivalent to one application on 370 acres. The total cost of operations, including all labor, interest on the investment, and depreciation of machinery, was $303.30. The average cost was 82 cents per acre for each application of dust, including all expense except the cost of the dust. The cost of the calcium arsenate varies with market conditions. During the season in which the estimate of cost was made the calcium arsenate was purchased in large quantities at 6.5 cents per pound.

In the experimental work with the airplane the cost of application greatly exceeded the cost with the ground machine. The excessive cost of the airplane in the experimental work was to be expected, and resulted from the fact that an area of only 1,000 acres was dusted, which did not allow the airplane to operate at maximum efficiency. If large blocks of blueberry land aggregating several thousand acres were to be dusted, the proper type of airplane, efficiently handled, might compete in price with ground machines. However, there seems to be no likelihood that dusting the blueberry lands of Washington County will be organized on a sufficiently large scale in the immediate future to enable the airplane to operate efficiently. The hand dust gun is of course too slow and inefficient to allow of use on large areas. On areas of not more than 5 or 10 acres the hand dust gun may be used if no power machine is available. In the experimental work with hand dust guns it was found that on an average it required one man approximately one hour to dust an acre. The speed of the work will depend upon the roughness of the land and the number of bushes present. On open, level land the work will go rapidly; on rough, bushy land the work will take more time. On the whole, dusting with hand guns is slow, disagreeable work, and is likely to be poorly done. A power duster is more efficient, where it can be operated.

ARSENICAL-RESIDUE STUDIES

Numerous samples of blueberries taken from dusted plots were analyzed to determine the quantity of arsenic which remained upon the berries. The studies were made with three primary objectives in mind: (1) A determination of the quantity of arsenic remaining upon the fruit at harvest time, with the view of ascertaining whether or not the berries from the treated plots contained an excessive quantity of arsenic; (2) a study was made of the uniformity of the distribution of arsenic on the dusted plots; and (3) the determination of the duration of the arsenical coating on the plants and the effect of rain in removing the arsenate.

ARSENICAL RESIDUE ON BLUEBERRIES AT HARVEST TIME

The analyses of samples of blueberries taken from the dusted plots during the seasons of 1926, 1927, 1928, and 1929 are shown in Tables 36 to 39. A study of the results of these analyses shows that in general the residue was not excessive at picking time when the dust was properly applied at rates of 6 to 7 pounds per acre.

TABLE 36.—*Arsenical residue on blueberries from dusted plots, 1926*

Plot No.	Date sample was picked	Applications of dust	Material used	Days since last dust application	Dust applied per acre	Residue of As_2O_3 per pound of berries	Remarks
		Number		*Number*	*Pounds*	*Grain*	
1	Aug. 4	2	Calcium arsenate	8	18.15	0.0096	Picked by hand.
1	do	3	do	0	25.41	.014	Do.
1	Aug. 21	4	do	9	30.85	.036	Picked with rake.
1	do	4	do	9	30.85	.021	Picked by hand.
2	Aug. 31	4	do	18	38.33	.011	Do.
4	Aug. 2	1	do	9	11.40	.0073	Do.
4	Aug. 30	3	do	20	27.90	.027	Do.
5	Aug. 23	3	Lead arsenate	11	17.77	.025	Do.
5	do	3	do	11	17.77	.035	Picked with rake.
6	Aug. 26	3	Lead arsenate (1), calcium arsenate (2 and 3).	16	24.06	.034	Picked by hand.

TABLE 37.—*Arsenical residue on blueberries from dusted plots, 1927*

Plot No.	Dust applied per acre [1]	Date sample was picked [2]	Days since last dust application	Residue of As_2O_3 per pound of berries	Remarks
	Pounds		*Number*	*Grain*	
2	12.91	Aug. 5	7	0.004	Raked. East side.
		do	7	.004	Raked. West side.
		Aug. 13	15	Trace.	Raked. East side.
		do	15	Trace.	Raked. West side.
3	8.84	Aug. 23	23	Trace.	Do.
		do	23	Trace.	Hand picked. West side.
		do	23	Trace.	Hand picked. East side.
5	12.11	Aug. 3	8	.040	Raked. West side.
		do	8	.004	Raked. East side.
		Aug. 10	15	Trace.	Raked. West side.
		do	15	Trace.	Do.
6	13.00	Aug. 4	7	.006	Raked. Entire plot.
		Aug. 11	13	.014	Do.
		Aug. 18	20	Trace.	Do.
		do	20	.007	Hand picked. Entire plot.
7	12.72	Aug. 4	7	.011	Raked. Entire plot.
		Aug. 11	13	.007	Do.
		Aug. 18	20	.007	Do.
		do	20	.007	Hand picked. Entire plot.

[1] Each plot received two applications of calcium arsenate.
[2] Commercial harvest of the berries on the plots began on the following dates: Plot 2, Aug. 21; plot 3, Aug. 23; plot 5, Aug. 14; plot 6, Aug. 18; plot 7, Aug. 18.

TABLE 38.—*Residue on dusted blueberries at time of harvest, 1928*

Plot No.	Date sample was picked	Applications of dust	Days since last dust application	Dust applied per acre	Residue of As_2O_3 per pound of berries
		Number	*Number*	*Pounds*	*Grain*
2A [1]	Aug. 15	2	17	13.2	0.010 .008 .005
3A	Aug. 16	2	19	13.1	.010 .010 .009
5A	Aug. 20	1	30	6.8	.017 .012 .001
8A	Aug. 17	1	27	4.6	Trace. .001 .001
11A	Aug. 16	1	20	6.6	.011 .010 .002 .004
1G [1]	Aug. 15	2	15	14.48	.017 .010
2G	do	2	17	18.78	.034 .038
5G	Aug. 20	1	33	8.34	.014 .010

[1] Series A dusted by means of airplane; series G dusted by means of ground machine.

TABLE 39.—*Arsenical residue on blueberries at harvest time on plots dusted with calcium arsenate alone and with equal parts of calcium arsenate and hydrated lime, Cherryfield, Me., 1929*

Plot No.	Date sample was picked	Applications of dust	Days since last dust application	Dust applied per acre	Residue of As_2O_3 per pound of berries
		Number	*Number*	*Pounds*	*Grain*
1	Aug. 5	2	7	[1] 13.36	0.008 .013 .009
4	do	2	8	[1] 13.40	.014 .009 .015
5	do	2	8	[2] 13.40	.008 .009 .009 .007

[1] Dust on this plot consisted of calcium arsenate alone.
[2] Dust on this plot consisted of equal parts of calcium arsenate and hydrated lime.

In 1926 the total quantities of arsenic applied were large because of the fact that three or four applications were made on each of the plots. As much as 38.33 pounds of calcium arsenate per acre was applied, and applications were continued to within 10 days of picking time in some instances. The highest residue recorded in that season was 0.036 grain of arsenic trioxide (As_2O_3) per pound, which, of course, greatly exceeds the tolerance. However, even such a residue is not surprising in view of the large quantity of dust applied and the fact that in the case just mentioned only nine days had elapsed since the last application was made.

The excessive residue, as well as the cost of making three or four applications, necessitated the reduction of the number of applications of dust to the blueberry land in order to place the process on a practical basis.

In 1927 the number of applications was reduced to two. Table 37 indicates a great reduction in the arsenical residue as a result of the decreased amount of arsenic and the heavier rainfall that followed the dust applications. It will be noted that in no case was there residue enough on the berries at picking time to exceed the tolerance.

In 1926 and 1927 in certain cases parallel samples were taken, one sample being picked by hand and another sample collected by means of a rake. (Pl. 2, B.) In these samples the hand-picked berries ran a little lower in arsenic than the rake-picked berries, suggesting that some of the arsenic was removed by handling. (Tables 36 and 37.)

In 1928 the rainfall during the dusting period was not far from normal, and little difficulty was experienced in respect to arsenical residue on the fruit. In the case of the plots treated by means of airplane the residue as a rule ran exceedingly low, which is probably due to the fact that the distribution tended to be quite uniform on the airplane plots and because a considerable amount of the dust put out by the airplane was blown away from the plots before it settled. On one of the ground-machine plots this season (2 G) an excessive quantity of dust was used in the second application, and the result of this is shown in a greatly increased residue. The two samples taken from this plot contained 0.034 and 0.038 grain of As_2O_3 per pound. This indicates the necessity for very careful observation of the machine while the dust is being applied, to avoid excessive applications of poison.

In 1929 the application of dust to the experimental plots was very carefully regulated, and it was found possible to keep the quantity of dust applied within the limits of 6 to 7 pounds per acre. The dusting period in 1929 was not marked by much rain, and yet the residue was not excessive.

UNIFORMITY OF DISTRIBUTION OF ARSENIC BY GROUND MACHINE

In 1927 a series of samples was taken in a dusted plot to ascertain the uniformity of distribution. The entire blueberry plant was included in the samples, the foliage as well as the fruit. Each sample consisted of sufficient material to fill a quart container, closely packed. In each case one sample was taken on the line the duster traveled, one 10 feet from the duster line, one 20 feet, one 30 feet, and one 40 feet from the duster line. The results of the analyses are shown in Table 40. There is a tendency toward a somewhat greater amount of arsenic on the samples taken nearest the duster line, especially when a heavy application was made or when the sample was taken soon after the application was made. However, on the whole, there is surprisingly little difference in the quantity of arsenic near the duster and at a distance from the duster, showing a somewhat more uniform distribution than was anticipated.

TABLE 40.—*Distribution of dust by horse-drawn power duster and retention of arsenic on blueberry plants, 1927*

Plot No.	Date sample was taken	Days since last application	Dust applied per acre	As_2O_3, parts per million					
				On duster lane	10 feet	20 feet	30 feet	40 feet	Average
		Number	*Pounds*						
2	July 14	1	0.62	35.0	6.0	4.0	12.0	11.0	13.6
2	Aug. 5	7	13.07	5.5	1.9	3.6	3.9	3.6	3.7
2	Aug. 13	15	13.07	3.0	2.0	2.0	2.0	1.0	2.0
3	July 22	3	4.22	1.3	1.3	2.2	1.6	2.8	1.8
5	do	0	6.49	11.2	9.1	9.2	8.7	6.5	8.9
5	July 25	3	6.49	1.3	5.5	2.3	3.5	5.4	3.6
5	Aug. 3	8	12.11	1.3	3.2		6.3	2.2	3.3
5	Aug. 10	15	12.11	4.0	4.0	1.0	1.0	2.0	2.4

RESIDUE ON BERRIES TAKEN FROM A CANNING FACTORY

In 1927 and 1928 samples were taken from lots of berries from dusted land as they were being processed in one of the blueberry canneries. In every case the arsenical residue was extremely low. In connection with this study a small plot 100 by 200 feet was dusted on August 30, much later than the normal dusting season, so as to have a very heavy arsenical residue during the period when the factory was in operation. From this plot 1.25 bushels of berries were picked on September 5 and taken into the factory. The sample taken just before the berries were washed indicated 0.39 grain of As_2O_3 per pound. Immediately after the washing [12] the residue was shown to be reduced to 0.019

[12] The washing machine used in the study discussed in this paragraph was not the type of washer commonly used for removing maggots from the berries in the factory, but was a machine intended primarily for the removal of arsenical residue from the berries. In this machine the berries were first submerged in a vat of water and were then passed through a light spray of water. The process was much less vigorous than the washing process for the removal of maggots, and there was much less loss of berries as a result of the treatment.

grain of As_2O_3 per pound. The berries were then given a second washing to determine to what extent the arsenic could be removed. The sample taken after the second washing contained 0.014 grain of As_2O_3 per pound, indicating that the second washing removed only a small amount of arsenic, as compared with the first washing.

EFFECT OF RAIN IN REMOVING ARSENIC FROM THE BLUEBERRIES IN THE FIELD

Tables 41 and 42 indicate very effectively the extent to which rain removes the arsenical dust. In taking these samples the berries were removed from the plants to avoid complications due to changes in size and weight of the berries. Only the stems and foliage of the plants were analyzed. In the case of plot A and plot B in 1928 there was no measurable reduction in the amount of arsenic on the blueberry foliage until after rain occurred. In the case of plot A the plants ran 578 parts As_2O_3 per million. Following a rain of 1.13 inches, the arsenic dropped to 81 parts As_2O_3 per million. In the case of plot B there was no appreciable reduction of arsenic on the plants from August 14 to 17, but in the sample on August 20, taken after a rain of 0.55 inch, the arsenic had dropped to 54 parts As_2O_3 per million. It is evident that the first heavy rain removes a large proportion of the dust from the blueberry plants.

TABLE 41.—*Retention of calcium arsenate on blueberry foliage, Cherryfield, Me., 1928*

Plot	Date sample was taken	Days since dusting	Rains since last sample	Precipitation since last sample	As_2O_3, parts per million
		Number	*Number*	*Inches*	
A	July 22	0	0	0	578
	July 24	2	1	1.13	81
	Aug. 13	22	13	2.16	19
	Aug. 31	40	7	.88	26
B	Aug. 14	0	0	0	317
	Aug. 15	1	0	0	707
	Aug. 17	3	0	0	376
	Aug. 20	6	2	.55	54
	Aug. 31	17	6	.33	44

TABLE 42.—*Retention of calcium arsenate on blueberry foliage, Cherryfield, Me., 1929*

Date sample was taken	Days since dusting	Rains since last sample	Precipitation since last sample	As_2O_3, parts per million on—	
				Plot 101	Plot 102
	Number	*Number*	*Inch*		
July 12	0	0	0	250	333
July 13	1	0	0	255	458
July 14	2	0	0	233	556
July 15	3	1	.86	26	12
July 20	8	2	.31	8	9
July 22	10	0	0	9	17
July 27	15	0	0	16	13
July 31	19	1	.11	12	12

RECOMMENDATIONS FOR THE CONTROL OF THE BLUEBERRY MAGGOT IN EASTERN MAINE

The results of the experimental work conducted over a period of four years warrant the recommendation of applications of calcium arsenate dust for the control of the blueberry maggot in eastern Maine. Recommendations for making the applications under the conditions of blueberry culture in this section may be summarized as follows:

MATERIAL TO USE

The calcium arsenate dust used for applications on blueberry land is the same high-grade insecticide dust used extensively for the control of the cotton boll weevil and certain other insect pests. It should contain not less than 40 per cent total As_2O_5, not more than 0.75 per cent of water-soluble arsenic pentoxide, and have a bulk test of not less than 80 nor more than 100 cubic inches per pound.

QUANTITY OF DUST TO USE

The calcium arsenate should be applied as nearly as possible at the rate of 6 to 7 pounds per acre. Much less than 6 pounds of dust per acre is likely to be ineffective, while too great a quantity of calcium arsenate increases the danger of injury to the plants, and also is likely to result in excessive residue on the berries at picking time. Great care should be used to distribute the dust as uniformly as possible over the area being treated; otherwise the best results may not be obtained and serious burning of the blueberry plants may result where excessive quantities of the dust are applied.

NUMBER OF APPLICATIONS

On land which produces a sufficient quantity of berries to justify the expense, it is advisable to make two applications of calcium arsenate. On poorer land one application may be advisable. It is not profitable to apply dust to land during the summer following burning, for no fruit is produced during that summer and the destruction of the flies on this land will have no effect upon the maggot infestation during the next summer. In some cases where freshly burned land adjoins bearing land it may be desirable to dust a strip of 100 feet of the burned land immediately adjoining the bearing land to reduce migration of flies from the newly burned area on to the bearing area.

It is desirable to dust as large areas as possible, as this reduces the danger from flies drifting in from unpoisoned areas and also tends to reduce the unit cost of the dusting operations. As far as possible, no blueberries should be left untreated around the borders of the dusted areas.

DATES OF APPLICATION

The constancy of the emergence dates of the flies renders it possible, during approximately normal seasons, to time the applications according to calendar dates. In making the first application, it is desirable to delay the treatment as long as possible after the flies begin to emerge, so that the maximum number of flies will be present when the dust is applied, but the application must be made before an appreciable number of eggs have been deposited in the berries. By referring to the emergence chart (fig. 7) and to the life-history charts (figs. 20 and 21) it will be seen that the period from about July 13 to 20 fits the conditions quite well for the first application. By applying the dust to the earliest land first, and treating later areas last, the best results may be obtained and the dusting period effectively extended.

In timing the second application, it is assumed that the first application was effective in destroying a high percentage of the flies present at the time the dust was applied. The second application should be made before any of the flies that emerge after the first application begin to lay eggs in the berries. In the life-history studies it was found that the preoviposition period was about 13 days. Allowing for a shortening of the preoviposition period during midseason, it seems that the second application of dust should be made from 7 to 10 days after the first, to kill the later flies before they begin to lay eggs. The second application will therefore be applied from July 21 to 30. At the time of the second application from 70 to 99 per cent of the flies will have emerged (fig. 7), and the destruction of the flies should be quite complete without additional applications. On account of danger of excessive residue from late applications, it is usually well to discontinue applications after July 31, and a period of two weeks should elapse between the last dust application and picking time.

Land that is to be dusted only once should receive an application during the period of July 18 to 24.

The dates in the foregoing discussion apply to the blueberry lands of Washington County during approximately normal seasons. In other localities or during abnormally early or late seasons it may be necessary to vary the dates of application.

A thorough study indicates that by very careful examination of samples of berries taken at frequent time intervals, newly-hatched maggots may be detected in the blueberries when the total population of eggs and maggots is still not great. It therefore seems that the detection of the very first newly-hatched maggots in the berries may serve as a practical indicator of the proper time to begin the first application of dust to the blueberry land. By making the observations on the earliest land to be found in the locality, notice may be given the growers of the locality in time to begin dusting operations on their most advanced areas.

For the observations to be effective, the samples should be collected frequently, beginning just as soon as the first berries ripen. Fairly large samples should be used, and the examinations should be carefully done by a trained observer who is thoroughly experienced in finding newly-hatched maggots. For most dependable results in making the examinations the berries should be boiled and the procedure described in this bulletin under the heading "Counting the Maggots" should be closely followed.

This method of timing the beginning of the first application of dust during abnormally early or late seasons seems more satisfactory than attempting to determine the date by observations on the emergence of the flies, for it is difficult to determine, sufficiently early, exactly when the flies begin to emerge in appreciable numbers.

ARSENICAL RESIDUE AT PICKING TIME

A careful study indicates that, in case of applications which are made according to recommendations, not later than two weeks before picking, in which the recommended quantity of calcium arsenate dust is used, and which are followed by normal rainfall, the residue of arsenic on the fruit at picking time is negligible. In very dry seasons the dust may not be washed off so thoroughly. Great care should always be exercised to avoid the application of excessive quantities of dust to the blueberry plants, and the application should be made as uniformly as possible. In any case where there may be doubt about the residue being sufficiently low, the berries should be given a light washing in the factory before canning.

SUMMARY

This bulletin includes a summary of the results of the investigation of the blueberry maggot (*Rhagoletis pomonella* Walsh), in Washington County, Me., from the establishment of the work in 1925 until the close of the 1929 season.

As a commercial development, blueberry culture in eastern Maine began some 50 or 60 years ago, and has progressed largely without scientific direction until recent years. Any effort to combat the blueberry maggot efficiently must take into account the conditions under which the blueberries are produced.

The blueberry lands consist of high, fairly level plateau land or of moderately sloping to steep, rocky hillsides. The soil is usually sandy, with a surface layer of organic matter.

The coniferous forests that once covered most of this land have been removed. The present vegetation of the blueberry land is characterized by typical acid-soil plants. Birch and alder sprouts and sweetfern are abundant on most of the blueberry land, and much labor is required to prevent these weed bushes from crowding out the blueberry plants.

The blueberries are produced by two native species (*Vaccinium canadense* Kalm and *V. angustifolium* Ait.), which have come on to the land entirely by natural dissemination.

The blueberry land receives little care except for more or less haphazard mowing of the weed bushes and burning over every third year. The weed bushes are usually mowed in the fall preceding the burn, and there is a growing practice of spreading a light covering of hay on the better land just after mowing to insure a more thorough burn. During bright, calm weather in the early spring, after the snow leaves, but before the frost is out of the ground, the surface litter is ignited and the fire sweeps the surface of the land clean of vegetation.

No berries are produced on well-burned land during the summer immediately following the burn. The first berries—usually an abundant crop—are produced during the second summer following the burn. During each succeeding season the yield of berries becomes less, until, after a few years, the land becomes practically nonproductive if it is not burned over.

Most of the blueberries produced in Washington County are used in the canning factories. Picking usually does not begin until practically all of the berries are ripe; then the land is picked clean with

metal rakes. After they have been picked, the berries are winnowed in the field and placed in half-bushel boxes for transportation to the factory.

Although the first published record of *Rhagoletis pomonella* infesting berries was that issued by Britton in 1906, the blueberry maggot is apparently an insect native to the New England region. During early years, when blueberries were of little or no commercial value, the maggot attracted slight attention. As the blueberry crop increased in commercial importance the maggot became more troublesome. In the season of 1924 the situation became acute, and it appeared that the development of the blueberry industry would be permanently retarded.

The primary trouble resulting from the blueberry-maggot infestation is that any of the maggots which are not removed by the washing process get into the cans with the berries and render the product unsalable. Other forms of injury caused by the maggot are often overlooked by the blueberry producers and canners. The actual destruction of berries in the field by the maggots is sometimes considerable. When badly infested berries are picked, many of the berries are soft and "mushy" as a result of the feeding of the larger maggots. The soft berries break down during transit to the factory, where the contents of the boxes frequently present an unsightly appearance. The berries wet with the juice of the crushed fruit are troublesome to handle properly in the factory. To these losses should be added the cost of additional factory processes necessary to remove the maggots from the berries before canning.

Blueberry production and canning have become probably the most valuable industries in Washington County, Me.; the total income from the blueberry industry is said to be more than $1,000,000 annually. The industry is important throughout the coastal section of eastern Maine. Anything which interferes with the industry is likely to cause great economic disturbance in this section. The blueberry maggot probably occurs in most of the important blueberry producing areas of the United States, and wherever it occurs this insect constitutes a threat against the development of the blueberry industry.

The original technical description of *Rhagoletis pomonella* was based upon a series of flies some of which were reared from apples and some from haws. Since the original description, the species has been reported as occurring on a number of other fruits, including cranberries, peaches, pears, plums, huckleberries, and blueberries. During the investigations reported in this bulletin, maggots were found infesting three species of blueberries and most of the berries found in association with the blueberries, including the bunchberry, chokeberry, black huckleberry, mountain cranberry, dwarf service berry, and wintergreen. Several of these berries may be of importance as reservoirs of maggot infestation.

The blueberry maggot and the apple maggot are an example of incipient species formation, which has progressed so far that each form can probably exist independently, upon its respective host.

In general the seasonal cycle of the blueberry maggot is similar to that of the apple maggot. The pupae overwinter in the upper few inches of the soil. An average of 96.72 per cent of the pupae were found within 1 inch of the surface.

Flies begin to emerge just as the first blueberries ripen; about July 1 in normal seasons. The month of July marks the period of emergence, and by August 1 from 97 to 99 per cent of the flies have emerged. During normal seasons there is apparently little variation in the dates of emergence.

The field population of flies is characterized by several outstanding features: (1) The rapid rise of flies in the field as emergence progresses, (2) the surprisingly definite peak of abundance, (3) the sharp decline of flies after the peak is passed, and (4) the rather short period during which the flies are abundant in the field.

The preoviposition period averages about 12 to 13 days, and the oviposition period varies from 6 to 11 days. The average length of life of flies in the field was 19 days in 1927 and 1928, and 24 days in 1929. Late in the season the longevity of the flies increases.

Oviposition begins toward the end of the second week of July, and eggs occur in greatest numbers during the last week in July and the first week in August.

The average length of the incubation period of the eggs ranged from two to seven days.

Maggots appear in the berries during the third week of July, and reach greatest abundance during mid-August—just after commercial berry picking gets well under way.

During the second week of August the maggots begin to leave the berries, and, entering the soil, pupate for the winter. From about mid-August until mid-September the decline of maggots in the berries is rapid. By late September the great bulk of the maggots are usually safe in winter quarters in the soil.

The pupae may lie dormant in the soil for as long as four years, and then produce flies. The carry-over of pupae to the second season may be as much as 19 per cent, and is probably sufficient to account for the infestation of the new crop of berries produced during the second summer after the land has been burned over.

Opius melleus Gahan, a small hymenopterous parasite of the maggot, is the most effective natural enemy observed.

Burning over the blueberry land has no direct effect upon the blueberry maggot, but has an important indirect effect. No berries are produced on well-burned land during the summer immediately following the burn, and the maggot population is starved out, except for the pupae which carry over in the soil to the second season.

Regular care of the land—the mowing of the birch and alder sprouts and the removal of sweetfern, combined with thorough burning every third year—stimulates a greatly increased yield of blueberries on good land and tends to reduce the percentage of berries infested. Berries from the very best blueberry land, from which the weed bushes have been almost completely removed, are seldom badly infested with maggots.

It seems unlikely, however, that it would be profitable, under the present methods used in blueberry production in Washington County, to attempt complete control of the maggot by cultural methods alone.

The experimental work conducted at Cherryfield, Me., indicates that dusting the blueberry land with calcium arsenate offers a cheap and effective means of controlling the blueberry maggot.

On areas of a few acres, the dust may be applied by means of hand dust guns. On large areas horse-drawn power dusters are advisable.

The airplane has proved impractical under present conditions in Washington County.

The dust should be applied as nearly as possible at the rate of 6 to 7 pounds per acre at each application. It is usually advisable to make two applications of dust, but in some cases a single application may be used.

The first application should be made during the period of July 13–20; the second application should be made 7 to 10 days after the first application. Land that is to be dusted only once should receive an application during the period of July 18–24. The above dates apply to the blueberry lands of Washington County during normal seasons.

Great care should be exercised to apply the calcium arsenate as uniformly as possible, and not to apply excessive quantities. When the applications have been carefully made, and the quantities recommended have been used, no difficulty with excess arsenic has been experienced at picking time.

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