A STUDY OF THE BIOLOGY OF THE APPLE MAGOT (*Rhagoletis pomonella*) TOGETHER WITH AN INVESTIGATION OF METHODS OF CONTROL.

James Franklin Illingworth

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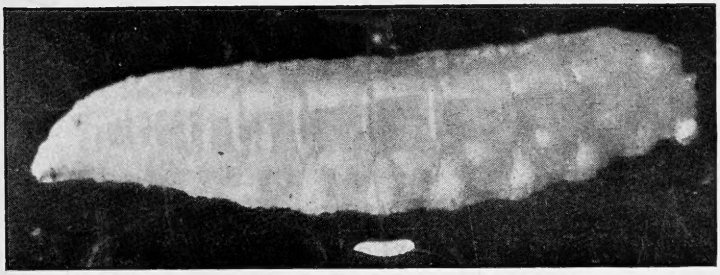
Under the direction of

GLENN W. HERRICK



By JAMES F. ILLINGWORTH

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CONTENTS

A STUDY OF THE BIOLOGY OF THE APPLE MAGGOT (*Rhagoletis pomonella*), TOGETHER WITH AN INVESTIGATION OF METHODS OF CONTROL*

JAMES F. ILLINGWORTH

In the census of 1910, New York ranks first among the States in the production of apples; and when all orchard fruits are taken into consideration, California alone surpasses her. According to this census there are 11,248,000 bearing apple-trees in the Empire State, with an annual production of about 25,409,000 bushels. Even with this immense crop the cash returns are comparatively small, $13,343,000 being the value of the apple crop in 1909. Neglected orchards are found on every hand; in only a few regions are careful cultural methods practiced.

Orchard pests are particularly abundant in the State, the apple being subject to the attacks of over three hundred and fifty species of insects. While comparatively few of these do serious injury, a single species may sometimes become so abundant as to destroy 95 per cent of the crop in individual orchards.

In certain sections where it is present, the apple maggot is one of the most serious insect pests attacking the fruit of the apple. Unlike the codling moth and many other insect enemies of the orchard, which have come to the United States from foreign countries, the apple maggot is a native of North America. Feeding at first on wild haws, or thorn apples, the species attracted but little attention until the injury to cultivated apples was noted.

Although the change of feeding habits brought this insect into immediate recognition over half a century ago as a most serious pest of the fruit of the apple, no adequate control measures have been devised. The usual remedy — destroying the windfalls — is so laborious that in most cases enough larvæ have escaped to continue the spread of the pest. Even when hogs were entrusted with the duty of gathering up the drops, there was often little, if any, decrease of the pest in following years. Card (1908)† records many maggots in Early Harvest apples even after hogs had the run of the orchard during the previous year.

OBJECT OF THE STUDY

It was, then, with a hope of discovering some more efficient method of control that a serious study of the biology of the apple maggot was under-

*Also presented before the Faculty of the Graduate School of Cornell University May 29, 1912, as a major thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

† Dates in parenthesis refer to bibliography.

taken. A careful review of the literature on fruit-flies gave the writer suggestions that were of great value in the work. In fact, the thought that there might be a second brood from the early-maturing larvæ came to him from a study of those species that produce several broods in a season in warmer climates. Also, the successful spraying experiments in Italy and South Africa offered encouragement.

In order that the number and time of maturity of the eggs might be clearly understood, a series of careful dissections were made of the flies. Living specimens were under almost constant observation in the field and in the laboratory, and in this way the writer was able to become familiar with the feeding habits of the adult flies.

CONVENIENCES OF LOCATION

In working out this problem the writer was most fortunate in having an abundance of the pest " right at the door," so to speak. The trees in the insectary yard had been badly infested with the apple maggot for years; and many of the orchards near Ithaca were more or less uncared for, hence almost without exception they contained this pest. Since no time was wasted in traveling long distances after material, the work went forward rapidly and with more satisfactory results than would otherwise have been possible. The growing season of 1910 was nearly over when the problem was started, but the entire seasons of 1911 and 1912 were spent in the field, watching the flies and conducting experiments. As is usually the case at the end of a season's work, there are still several questions that have not been wholly cleared up. These will be mentioned in succeeding pages.

METHODS OF WORK

Most of the appliances used in connection with the study are described in the several sections that follow. It may be of interest to other workers on similar problems to describe here in some detail certain of these appliances, although they are by no means new.

In order to obtain definite data on the emergence of the larvæ after the fruit fell from the trees, the drops were picked up daily. At first these were placed in tight-bottomed boxes so that each morning the larvæ found in the bottom of the boxes might be recorded. This process necessitated handling every apple every morning and soon became a considerable task. Shortly, a plan was hit upon which gave much relief in this work. Trays with quarter-inch-mesh screen bottoms were used to receive the fruit picked up each morning. These trays were then placed over boxes with tight bottoms, so that all maggots emerging from the fruit would fall through the screen into the lower box, from which they could easily be

removed and counted. The data blanks were kept attached to the individual trays. In this way it was possible to keep account expeditiously of the daily emergence from thousands of apples.

Larvæ that were to be permanently preserved were killed by dropping into boiling water, heat being applied until they sank to the bottom. By this treatment the larvæ are fully expanded and remain white when placed in alcohol. Specimens thus treated have a most natural appearance — the head and spiracles being extended as seen when the larvæ are feeding — and are in good condition for photographing.

The observations of the habits of the living flies and most of the dissections were made under a Zeiss binocular microscope. With this instrument one is able to make continuous observation without the fatigue that comes from the constant use of an ordinary dissecting microscope or hand lens.

The drawings were all made in outline with the camera lucida, so as to get the exact proportions, and were colored with india ink in varying dilutions in water. By applying color in this way with a brush, one can accomplish results very quickly. The lightest tone is first applied over the whole drawing; this is followed by darker and darker tones, until in some cases the pure ink is used for the solid black parts.

THE NAME

The family Trypetidae at first contained two genera: (1) *Trypeta* — five segments of abdomen before the borer; (2) *Dacus* — four segments of abdomen before the borer. Dr. H. Loew, in his monograph of European Trypetidae (1862), split up the genus *Trypeta* into a number of smaller groups, one of which was *Rhagoletis*. He sometimes referred to these groups as genera, but often as subgenera, as pointed out by Coquillett (1899). *Rhagoletis* is given as a subgenus in the Catalog of the Diptera of North America by Baron C. R. Osten Sacken (1878). Coquillett (1899) says, " By changing some of the species, however, the greater part of the groups proposed by Loew are well worthy of being considered as valid genera." *Rhagoletis* is now recognized universally as a valid genus — Doane (1898) and Aldrich (1909).

The apple-maggot fly was described by Walsh in 1867 from six males bred from eastern apples, July 15 to 23; and from two males and one female bred from Illinois haws July 23 to 28. He used the specific name *pomonella*, which is still maintained. He evidently disregarded the newer subdivision as given above, for he used the old genus *Trypeta*. Subsequent writers up to the time of the paper by Doane (1898) seem to have followed this precedent, for we find the insect constantly referred to as *Trypeta pomonella*.

The common name, " apple maggot," given by Walsh, is still the one in most general use throughout the country. In New England the insect is often referred to as the " railroad worm," from the habit of the larvæ of tunneling beneath the skin of the fruit. There has been considerable confusion among fruit-growers through the use of the term " worm," any larvæ found in the fruit being called " apple worms." Therefore it would appear best to use the distinctive name " apple maggot."

HISTORY OF THE APPLE MAGGOT

Distribution and injury

The work of the apple maggot was well known in orchards in various parts of the northeastern United States for years before the species was described. Walsh (1868) quotes the following paragraph, which appeared in the circular of the Oneida Community (November 12, 1866), published at Wallingford, Conn.:

" Two months ago we were congratulating ourselves on a fair crop of winter apples. To all appearances they were freer from worms than we had known them in this section for years. But alas! our hopes are again blasted. Although the *apple worm* (the larva of the codling moth, *Carpocapsa pomonella*) is not so numerous as in some seasons, the *apple maggot* seems to be as prolific as ever. Two weeks ago we overhauled two hundred and fifty bushels of apples that we had gathered and placed in store for winter use, and of that number we threw out fifty bushels, most of which had been rendered worthless, except for cider or hogs, by one or the other of the above-named insects; and still the work of destruction goes on. The *apple worm* by this time has ceased his work, or nearly so, but the depredations of the *apple maggot* continue up to the present time, converting the pulp of the apple into a mere honeycomb, and rendering another overhauling soon indispensable."

The same author quotes also from an account of the apple maggot by W. C. Fish of East Falmouth, Mass. (December 28, 1866):

" This insect is very numerous in this section of country, being much more abundant in thin-skinned summer and fall apples than in the later varieties. It seems to increase every year. Within a few rods of the house in which I am writing, stand five or six trees of the old-fashioned variety called Hightop, or Summer Sweets. On these trees the crop of apples is annually rendered worthless by this insect, which tunnels the fruit in all directions. Apples which, when taken from the tree, appear sound, would in the course of a few weeks, as soon as they became mellow, be found to be alive with these pests, sometimes to the number of six or more in each apple, although not commonly as many as that. I have

found that, in most cases, the fruit had been previously perforated by the larva of the codling moth (*Carpocapsa pomonella*) before becoming inhabited by this insect."

Doctor Trimble (1867), the State Entomologist of New Jersey, says that "this new and formidable enemy of the apple prevails generally throughout the Hudson River country, but has not yet reached New Jersey."

It is evident that the apple maggot was well established in Vermont previous to the year 1865, from the statements of Calvin Ward, of that State, which were published in Practical Entomologist II, pp. 20–21. Mr. Ward complained of larvæ boring his apples in all directions, and said that this pest did more injury to the fruit in the preceding few years than did all other insects combined. In 1865 it injured his apples to the extent of one half their value.

Walsh received living pupæ during the winter of 1866 from Massachusetts, Connecticut, and Long Island, rearing the flies, which emerged in July, 1867. These, he showed conclusively, were the same as flies that he had reared from Illinois haws five or six years previously. He discovered also that the species was new, and published the original description in the American Journal of Horticulture, Boston, in December, 1867.

Subsequent to this date the pest has gradually increased, spreading to new sections. Riley (1872), in a published reply to a letter from J. H. Spatter, of Keene, N. H., gave the first record of the flies working in that State. The first reference from Maine is also by Riley (1876) in answer to a letter from P. M. Augur. Professor Comstock (1882) reported the apple maggot from Ithaca, N. Y., in 1881. Professor Cook (1884) recorded the pest from Michigan and Wisconsin for the first time, stating that apples from Shiawassee county, Michigan, were entirely ruined by apple maggots, and that the insects were also common in several other counties of the State. He received specimens from Delavan, Wis., the previous year, where the pest was reported as very injurious. The first reference from New Jersey is by E. Williams (1889), who considered it the worst pest of the apple at Montclair and said that the maggots were first noticed about a dozen years before. Professor Osborn (1891) stated that there were many reports of damage from this pest in Iowa during the previous year, the belief being that it was introduced from Missouri. The same year Professor Weed (1891) reported considerable damage to fruit in Delaware county, Ohio.

Doctor Howard (1894) gave a record which indicates the southern limit, through the discovery of larvæ of the well-known apple maggot of the Northern States in an apple from Waynesville, N. C. What appears

to be the western limit is recorded by Professor Gillette (1896). Apples grown at Colorado Springs were found to be infested — the pest being introduced, it is supposed, through eastern apples. The first appearance in Canada was reported by Doctor Fletcher (1897), infested apples having been received August 31, 1896, from Dr. D. Young of Adolphustown, Lenox county, Ontario. By 1902, as stated by Professor Lochhead (1903), this pest had become very abundant in Prince Edward county, in some orchards more than one half of the fruit having been destroyed. The rapid spread of the insect in Canada and the record of infestation at Como, Quebec, in 1903, were given by Doctor Fletcher (1905); and later (1907) the still wider range and the severe outbreak at Woodstock, New Brunswick. Professor Washburn (1903) included the apple maggot among the apple insects of Minnesota.

Referring to the bibliography, it will be noted that the multiplication of references indicates that the pest has gradually increased and spread from the several localities named above, especially those in the northern regions. It is interesting to note that, although the flies were first described from Illinois haws, only the single record by Cordley (1889) shows an attack on cultivated apples in that State.

Host plants

Only two other published records have been found, of flies being reared from haws: Professor Comstock (1882) bred them from a species of *Crataegus* growing on the agricultural grounds at Washington; and Professor Cook (1884) reported them as well known in the thorn apples of Michigan, Wisconsin, and Illinois. Professor Harvey, in his extended study of the flies in Maine, found none breeding in haws. Although careful observations have been made for two seasons at this station, no flies were discovered on haws here. The Bureau of Entomology of the United States Department of Agriculture has for several years collected fruit of the various species of *Crataegus* from many parts of the country, but in no instance has that bureau found an infestation of the apple maggot. It would therefore appear that this insect has abandoned its native food-plant.

Several of the earlier reports of the larvæ feeding on wild crab-apples seem not to have been based on observations. The only authentic records that the writer has been able to find are by Riley (1872) and Fletcher (1906). Fletcher states that crab-apples are badly infested, but that the fruit does not fall from the tree. Professor Harvey thought it improbable that this fruit would be used by the insect, for the reason that it is rather green and hard during the period of flight and oviposition of the flies. It is now known that the period of the flies in the field is much longer

than Harvey supposed, extending even up to the time of heavy frosts; therefore the relative immunity of crab-apples can be explained only by the abundance of softer, sweeter varieties of apples, for which the flies show a decided preference.

Harvey (1893) records rearing the flies from Vermont pears and states that the apple maggot is known to work in pears in Maine. Doctor Britton (1906) records the apple maggot working in huckleberries in Connecticut during August, 1904, the flies being reared. Doctor Smith (1910) also records the infestation of this fruit, the flies having been bred from larvæ found on huckleberries growing in southeastern New Jersey.

The three published records of this species infesting plums and cherries in northern Michigan are doubtful, since the flies were not reared and it is very probable that the larvæ observed were those of the closely allied species *R. cingulata* Loew, now commonly known as the cherry fruit-fly. Professor Cook (1889), in a brief discussion of the apple maggot, concludes with the following paragraph:

"This year I have received plums and late cherries from Northern Michigan attacked by this same insect. So far as I know, this insect has not been previously reported as infesting either of these fruits."

Professor Cordley (1889) and Professor Davis (1889) evidently recorded the same observation, noting that only the larvæ and pupæ were seen.

The injury to cultivated apples has become widespread and leads to the principal economic consideration of this pest. Practically all varieties grown in infested localities are affected, although there is considerable difference in the relative amount of infestation. Sweet summer and autumn varieties are attacked to the greatest extent; yet the hard, acid, winter sorts are not immune and are often rendered unmarketable. Professor Harvey (1889) prepared a long list of varieties showing their relative infestation in Maine. Such a list, made as complete as possible from the literature and brought up to date, is believed to be of importance and is given below. The varieties that have actually been used in experiments at this station are marked with an asterisk.

VARIETIES OF APPLES, WITH RELATIVE INFESTATION BY THE APPLE MAGGOT

Variety	Flavor			Time of maturity	Remarks
	Sweet	Sub-acid	Acid		
Alexander	....	....	+	Autumn	Sparingly infested
Bailey Sweet	+	....	....	Autumn	Sparingly infested
*Baldwin	....	+	....	Winter	Sparingly infested
Benoni	....	+	....	Autumn	Badly infested

VARIETIES OF APPLES, WITH RELATIVE INFESTATION BY THE APPLE MAGGOT (*cont.*)

Variety	Flavor			Time of maturity	Remarks
	Sweet	Sub-acid	Acid		
*Bough	+	....	....	Summer	Badly infested
Bullock	....	+	....	Autumn	Sparingly infested
Calvert	....	+	....	Autumn	Sparingly infested
Canada Baldwin	....	+	....	Winter	Sparingly infested
Catshead	....	+	....	Autumn	Sparingly infested
*Chenango	....	+	....	Autumn	Sparingly infested
Danvers	+	....	....	Winter	Sparingly infested
Dayton	....	+	....	Winter	Sparingly infested
Derby	....	+	....	Winter	Sparingly infested
*Detroit Red	....	+	....	Autumn	Sparingly infested
Diana	....	+	....	Autumn	Sparingly infested
*Dyer	....	+	....	Autumn	Sparingly infested
*Early Harvest	....	+	....	Autumn	Badly infested
Esopus	....	+	....	Winter	Badly infested, Vermont. Perkins (1893)
Fall Jenneting	....	+	....	Autumn	Badly infested
*Fall Pippin	....	+	....	Autumn	Badly infested
Fameuse	....	+	....	Autumn	Badly infested
Franklin Sweet	+	....	....	Autumn	Badly infested
Garden Royal	....	+	....	Autumn	Badly infested
Golden Ball	....	+	....	Winter	Sparingly infested
Golden Russet	....	+	....	Winter	Badly infested, Fletcher (1896)
Golden Sweet	+	....	....	Autumn	Sparingly infested
*Gravenstein	....	+	....	Autumn	Badly infested
Grimes	....	+	....	Winter	Sparingly infested
Haley	....	+	....	Winter	Sparingly infested
*Henderson	+	....	....	Autumn	Badly infested
Hightop Sweet	+	....	....	Summer	Badly infested
Hurlbut	....	+	....	Autumn	Badly infested
Irish Peach	....	+	....	Autumn	Sparingly infested
Jersey Sweet	+	....	....	Autumn	Badly infested
Jewett Red	....	+	....	Winter	Badly infested
*King	....	+	....	Winter	Badly infested
King Pippin	+	....	....	Summer	Badly infested
Lady Sweet	+	....	....	Winter	Sparingly infested
*Maiden Blush	....	+	....	Autumn	Sparingly infested
Mexico	....	+	....	Autumn	Sparingly infested
Mother	....	+	....	Winter	Badly infested
*Munson	+	....	....	Autumn	Sparingly infested
New York Sweet	+	....	....	Summer	Badly infested
*Northern Spy	....	+	....	Winter	Badly infested
*Oldenburg	....	+	....	Autumn	Badly infested
Paradise Sweet	+	....	....	Autumn	Badly infested
Porter	....	+	....	Autumn	Badly infested
*Pound Sweet	+	....	....	Winter	Badly infested
*Primate	....	+	....	Summer	Badly infested
Pumpkin Sweet	+	....	....	Autumn	Badly infested
Ramsdell	+	....	....	Winter	Sparingly infested
*Red Astrachan	....	....	+	Summer	Badly infested
*Rhode Island	....	....	+	Winter	Sparingly infested
Ribston	....	....	+	Winter	Sparingly infested
Rolfe	....	+	....	Winter	Sparingly infested
Russell	....	+	....	Summer	Badly infested
Shiawassee	....	+	....	Winter	Badly infested, Como, Que. Fletcher (1903–1904)

VARIETIES OF APPLES, WITH RELATIVE INFESTATION BY THE APPLE MAGGOT (*concl.*)

Variety	Flavor			Time of maturity	Remarks
	Sweet	Sub-acid	Acid		
Somerset	....	+	....	Autumn	Sparingly infested
Sops of Wine	....	+	....	Summer	Badly infested
*Swaar	....	+	....	Winter	Sparingly infested
*Sweet Russet	+	....	....	Winter	Sparingly infested
Tetofski	....	....	+	Summer	Badly infested
*Tolman	+	....	....	Winter	Badly infested
Tompkins King	....	+	....	Winter	Sparingly infested
*Twenty Ounce	....	+	....	Autumn	Badly infested
*Wagner	....	+	....	Winter	Badly infested
Wealthy	....	+	....	Autumn	Badly infested
*Westfield	....	+	....	Autumn	Sparingly infested
*Williams	....	+	....	Summer	Sparingly infested
Winesap	....	+	....	Winter	Badly infested, Canada. Fletcher (1896)
Winthrop Greening	....	....	+	Autumn	Badly infested, Canada. Fletcher (1896)
Yellow Bellflower	....	+	....	Autumn	Badly infested, Canada. Fletcher (1896)

Of course the relative infestation of varieties may vary somewhat in different parts of the country, but it has been found to agree very closely in New York State with Professor Harvey's observations, referred to above. The writer has found no variety that is known to be immune, although the hard winter sorts soften so little before cold weather comes on that probably most of the larvæ fail to develop. Even in many of the Baldwins that were cut open during December, the old, partly-healed, brownish channels of the larvæ were found, but there was no further sign that the maggots were still in the apples and the fruit showed no exit holes.

SERIOUSNESS OF THE PEST

To estimate the total damage done by an insect pest of this kind is a difficult matter, but some idea of its seriousness may be obtained from the statements of leading writers on the subject. As far back as 1884, as indicated above, Professor Cook reported some varieties of Michigan apples entirely ruined. In 1896 Professor Perkins stated that the apple maggot was one of the most troublesome pests of Vermont. Professor Card (1900) said that it was one of the most serious pests of the apple in Rhode Island. Professor Lochhead (1903) reports more than half of the fruit as injured in some of the orchards of Ontario. The increasing destructiveness in New Hampshire orchards is clearly shown by Professor Sanderson (1907), who states that the apple maggot is a pest almost equal

to the codling moth, making apple production almost impossible in many sections. Professor O'Kane (1910) reports ninety-five per cent of the orchards of the State more or less infested.

L. Cæsar, of Ontario Agricultural College, states in a letter to the writer dated October, 1911, that the insect is found over a large part of the province but is much worse in towns and villages. The same is true of conditions in New York State so far as the writer's observations have gone, the entire crop often being a total loss due to infestation of the apple maggot when the trees are partially neglected and unsprayed. On the other hand, almost no complaints have been heard of the pest in well-cared-for orchards.

OTHER FRUIT-FLIES

The family Trypetidæ contains a considerable number of fruit-infesting species. Since their life history, methods of attack, and means of control are similar, it is important that some of them be considered briefly. Exotic species have been most destructive, and it is desirable to guard against their introduction here as well as to learn something of methods that have been used in successfully combating them.

According to Froggatt (1908), the olive fly (*Dacus oleae*) has been such a serious pest in southern Europe that the Italian government offered a reward of 6,000 lire (nearly $1,200) for a remedy. The same authority (1909) states that the loss to the olive crop of Italy for 1908 alone was $5,000,000. Professor Berlese (1905) met with great success in the use of poisoned bait against this pest.

The Mediterranean fruit-fly (*Ceratitis capitata*) is widely scattered over the earth and it is very fortunate that it has not yet been introduced into the United States. This is the pest that is doing so much damage, not only in the Mediterranean countries but also in Australia, South Africa, Hawaii, Bermuda, and other places. This species is a very general feeder, attacking almost every variety of fruit available, even to the fruit of the wild cactus, solanum berries, and the like. C. W. Mally (1909) reports almost complete control of this species by the use of poisoned bait.

Mexico has an orange worm (*Anastrepha* [*Trypeta*] *ludens*) which is a serious pest in several localities of that country. Although California has placed an embargo on the importation of Mexican fruit, the infested oranges are received into the eastern markets. On November 16, 1911, some of these were included in a purchase at a store in this locality; the larvæ were fully developed, so that they pupated within a day or so in soil in a flowerpot in which they were placed. No effective remedy seems to have been used against this pest.

In the United States there are several other fruit-flies doing more or less damage. The cherry is attacked by two species, *Rhagoletis cingulata*

Loew in some parts of the Eastern States, and *R. fausta* O. S., first recorded from the Northwest by Aldrich (1909). Two species are also known to attack currants and gooseberries — *Epochra canadensis* Loew, and the new species, *R. ribicola*, described by Doane (1899) from the Northwest.

LIFE HISTORY AND HABITS

Time of appearance of flies

Recognizing the importance of knowing just when the flies begin to emerge in the spring, several experiments were started in order that their results might be compared with observations in the field. The ground in the insectary yard was smoothed off and two large out-of-door cages were set up on September 28, 1910. In the first cage three hundred Tolman Sweet apples, and in the second cage one hundred Northern Spy apples, were placed on the ground. Both varieties were badly infested with the maggots. These apples were exposed to all the conditions natural to the orchard, except that the cages were not placed under the trees and the grass had been removed from the place where the cages stood. Although observations were continued daily, beginning June 1, 1911, no flies appeared until July 27, when a male emerged in the first cage; on July 29, a male and a female emerged. These three flies were the only results from the experiments. It is difficult to account for the hundreds of larvæ that went into the soil and did not emerge. It is known that these apples contained many maggots at the time that they were put into the cages, for some apples of the same dropping were placed in boxes in the insectary and from these an average of over three larvæ per apple emerged. Professor Card reported a similar difficulty in rearing the flies in outdoor cages in Rhode Island. If such a large proportion were normally destroyed under orchard conditions, it would appear that the pest would soon be naturally controlled. The suggestion arises that possibly the grass in the orchards offers considerable protection to the pupæ in the soil, since the pest appears to do most damage where the trees are standing in sod.

Beginning with the season of 1911, the first flies observed were on West Hill, Ithaca, N. Y., in the Hook orchard. Although these were not found until July 4 they must have emerged some time previously, for they were already ovipositing in Bough and Red Astrachan apples. The fruit was about one and one half to two inches in diameter and the ground was already scattered with windfalls, due largely to the infested condition of the fruit. On cutting the Boughs, many of the eggs were located and some of the tiny channels of the larvæ already showed plainly. It was easy to find the egg punctures (Fig. 19) on this white-skinned fruit, and by carefully raising a bit of the peel the eggs were usually found; where they had hatched, the empty shell still remaining. It would appear,

then, that some of the eggs were deposited at least a week before and that the flies probably emerged about the middle of June. As has been shown by dissections, the eggs are two or three weeks in developing in the ovaries after the flies have emerged.

Observations were continued daily on the later varieties of apples. The flies did not begin to appear on the Maiden Blush tree in the insectary yard until July 21 and they were found ovipositing the next day. It was of much interest to find the first flies of the season for the Tolman Sweet tree appearing on July 27 — the very day that the first fly emerged from these apples in the breeding-cages in the insectary yard, as noted above. This observation is in accord with results reached by several other investigators, who have found that the flies seem to adapt the time of their emergence to the proper stage in the development of the particular fruit in which their maggots fed. The writer's observations have not been carried far enough along this line to come to any definite conclusions, but the fact that the flies emerged so much later from the Tolman Sweet apples than from the earlier sorts mentioned above seems to be a very good indication of such an adaptability. On the 28th of July the flies were found very abundant on the fruit of the late varieties — Twenty Ounce, Baldwin, Fall Pippin, Detroit Red, Rhode Island, and Swaar. Hence, the indication is that the flies emerge, in the vicinty of Ithaca, from the middle of June up to August 1. Later observations bring out the fact that there are second-brood flies which begin emerging soon after the latter date, so that there is an almost continuous new supply of flies from June up to the time of heavy frosts.

Feeding habits

The flies on the Bough apples were observed for several hours each day in order to enable the writer to become familiar with their habits. Dozens of them were placed in inverted jelly-glasses, which were found to make the most satisfactory cages. The flies require a constant, although moderate, supply of water, and by this means of confinement nearly the correct humidity is secured. The flies were fed daily with fresh slices of apple, which they ate with avidity. The glasses were cleaned often in order to keep any bacterial or fungous growth from developing in them. When a drop of water was placed inside, the flies quickly gathered around and drank greedily. In cages where this moisture was not furnished the flies died in a few days, even though they were supplied with food.

The flies are very tame, and even in the orchard they will permit one to observe them with the lens while they are feeding or ovipositing. Both males and females were seen to feed rather constantly from the surface of the fruit. As they walk about they extend the proboscis, applying the broad surfaces of the labella directly to the fruit as if tasting here

and there. Now and then the head is raised, the mouth-parts are extended, and a large drop of saliva is forced out between the lobes of the labella and applied at once to the surface gum of the fruit. This liquid is evidently used as a solvent for the substances on the surface of the apple, for it is spread over the waxy coat and sipped off again, the process being repeated from time to time. The surface gum is apparently the only food taken when the flies are in the orchard, for when they go to the leaves it appears to be for rest and for shelter from the weather.

The mouth-parts of the apple-maggot fly seem to be very similar in structure to those of the common house-fly; and the excellent description of the mouth-parts and feeding habits of the latter insect, appearing in Doctor Howard's new book " The House Fly — Disease Carrier " (page 27), would apply equally to the pest under consideration. Since the feeding of the flies is considered of so much importance in control measures, it is interesting to quote from the above-mentioned description:

" The mouth parts are very complicated, but form in the main a proboscis which is not fitted for piercing but for sucking. . . . . This organ can be retracted and expanded to a certain extent. It is somewhat complicated in structure and consists of an upper and a lower portion, the upper portion bearing two curved bristly lobes. The lower portion or true haustellum expands at the tip into two lobes which are called the oral lobes. On their under surface they have transverse chitinous bars which are called false tracheæ (pseudotracheæ). The presence of these hard ridges under the oral lobes fit it to a certain extent for rasping solid food. The orifice to the haustellum occurs between the lobes.

" In feeding upon fluid or semi-fluid substances, the oral lobes are simply applied to the surface and the fluid is sucked up. When, however, they feed upon soluble solids the process is somewhat different. Doctor Graham-Smith has carefully watched them feeding upon crystals of brown sugar, and has done this through the Zeiss binocular microscope. He states that the oral lobes of the proboscis are very widely opened and closely applied to the sugar. Fluid (saliva) seems to be first deposited on the sugar and then strong sucking movements are made. Doctor Graham-Smith watched a fly sucking an apparently quite dry layer of sputum. It put out large quantities of saliva from its proboscis and seemed to suck the fluid in and out until a fairly large area of the dry layer of sputum was quite moist; then as much as possible was sucked up and the fly moved away to another spot. The same observer noticed that flies which had the opportunity of feeding either on fluid or partly dried milk often chose the drier portions, and states that under natural conditions they can often be seen sucking the dried remains near the top of a milk jug. They constantly apply their mouth parts to the surface over which they are walking, attempting to suck up some nutrition, and

under certain conditions the imprints of their oral lobes can afterwards be made out under the lens."

This habit of the flies of tasting the surface of everything was shown whenever they were collected in the field. They at once applied the expanded labella to the glass and walked about as if feeding from the inner surface, although the collecting vials were supposed to be clean. Also, when the flies were kept in the jelly-glasses they spent considerable time in sipping the moisture that had been deposited on the inside of the glass. Inclosing the flies in thin vials made it possible to place them under the Zeiss binocular microscope and to observe in detail the working of the mouth-parts.

How the eggs are laid

Ovipositing was observed many times in the field. Since the flies are so tame, one can watch this interesting process at close range with the lens. Just before ovipositing, the female often turns around and around, apparently searching over the surface of the fruit. Sometimes she sidesteps several times, then extending the ovipositor she places the tip of it on the fruit, and, rising high on her legs, she gradually probes to the desired depth. The puncture is made at an angle of about forty-five degrees with the surface, as is shown in the magnified section of the apple with the egg in situ. (Fig. 23.) About a minute is required to cut the opening and lay the egg. During the last half of the minute, the fly stands almost motionless. While the egg is passing downward it can be observed with a lens as it passes the clear space on the side of the sheath where there are no tubercles. Finally, when the egg is in place in the fruit, the ovipositor is quickly withdrawn and the fly walks about feeding from the surface, often turning and eating the bit of juice that flows from the puncture. Several minutes pass before another egg is deposited. One fly, observed on a warm morning, deposited six eggs in half an hour and several other flies were seen to oviposit a second time three or four minutes after an egg was laid.

The punctures when first made are very difficult to see with the naked eye, but in a short time the wound darkens and shows as a small brown speck, easily seen on light-colored apples although a lens is required to distinguish it from the many other specks on the epidermis. The puncture appears rather round when magnified, the margin somewhat corky; usually there remains a distinct opening, although this may be filled up in some cases by the corky plug. The punctures are located in all sides of the fruit; there are seldom any punctures at the ends near the stem or the calyx. In the Bough apples it was easy to count the punctures and an average was taken of twenty specimens. These showed eleven to thirty-six punctures each, mostly located on the light-colored side although there were always some punctures on the exposed side.

Another apple was found later with forty-four punctures, some of them not more than one sixteenth of an inch apart. This specimen was photographed (Fig. 19) with the live fly on it.

In order that the number of eggs produced during the lifetime of a single individual might be shown with some degree of exactness, careful dissections were made of the ovaries of mature females. As shown in Fig. 32, masses of tracheæ and connective tissue surround these organs, making it rather difficult to separate and extend the egg-tubes so that they can be studied under the microscope. The great number of egg-tubes was at once apparent, there being twenty-four in each ovary. As in flies generally, the nurse cells are contained within the so-called egg, and the egg-tube is composed merely of a terminal filament, a germarium, and a series of eggs gradually increasing in size up to the fully developed form. (Fig. 33.) Surrounding each series is a delicate membrane, so fragile that it is a difficult task to separate the egg-tubes from the entangling tracheæ and connective tissue without dislodging the fully developed eggs; only occasionally is an entire series, with the terminal, mature egg, separated. Usually, after the tracheæ are removed the ripe eggs are seen scattered about and free from the inclosing membrane of the egg-tube.

The maximum number of eggs observed in an egg-tube was six, although oftener there were only four or five besides the germarium. Professor Harvey (1889) figures six or seven in the series. However, the total number of eggs produced is in no way dependent on the number found in the ovaries at any one time, even though a large figure is obtained if five to seven be taken as an estimate for each of the forty-eight egg-tubes. As was discovered in later dissections, the germaria are constantly producing new eggs as long as the flies are active. Again, none of the dissections of flies that had been ovipositing for some time showed shorter egg-tubes, except when the flies were in poor condition through confinement. Hence, the writer would conclude that the flies are able to continue ovipositing during the remainder of their activity after they once begin, three or four hundred eggs being a moderate estimate for each female.

In order to learn what period must elapse after the flies emerge before the eggs are mature and ready for ovipositing, two methods were used: (1) Flies of known ages were confined in breeding-cages and careful observations made to determine when the first eggs were laid; (2) daily dissections of flies were made from the time that they emerged until ripe eggs were found in the ovaries. In both cases, the flies were those that emerged as a second brood in the outdoor cages. The flies in the first series of experiments were observed copulating when eight to ten days old and ovipositing on the twenty-fourth day.

It was with more difficulty that the second part of these experiments was worked out. At first some trouble was experienced in finding the

egg-tubes in the ovaries of the newly emerged flies, but after using the Zeiss binocular microscope in conjunction with the compound microscope the surprising discovery was made that there were really no developing eggs until after the fourth day. Instead, a tiny transparent mass was found in each ovary, which, when placed in a drop of water and pressed down under a cover glass, was seen by the aid of the compound microscope to consist of the twenty-four germaria and terminal filaments. Each germarium showed a distinct, slender thread extending from the distal end. (Fig. 34.) Similar dissections were then performed from day to day and a series of drawings made of the important changes in the development of the egg-tubes. It was found that about four days were required for any marked change to take place, so drawings were made of each of these stages. About the eighth day the first egg began to pinch off from the end of the germarium, the twelfth day another, the sixteenth day a third, and so on until the complete egg-tube, with the mature egg at the end, was covered in twenty to twenty-four days. During these observations it was noted also that the development of the eggs was hastened when the flies were kept warm, and hindered when the flies became cold on cool days. Hence, in very warm weather in early summer the development of the eggs may take place in two weeks after emergence.

Hatching

In order to determine the time required for the eggs to hatch, newly-made egg punctures were marked and the fresh eggs removed and placed in a bit of apple pulp. This was placed in a hollow slide, covered with a cover glass, and kept in a moist chamber, so that the eggs could be observed from time to time under the microscope. In this way the young larvæ were seen to emerge in two to six days, according to the temperature. For some time before hatching, the chitinous hooks can be seen through the eggshell at the pointed end. When the larva is ready to emerge from the egg, the shell is torn open in an irregular manner and the larva works its way out, using its hooks vigorously. The larva at once begins feeding in the characteristic manner, rasping off the pulp and absorbing the juice and fine particles of the fruit, which are sucked into the mouth. Although the larvæ of the flies have no real opposable jaws, the strong chitinous hooks (Figs. 30 and 31), attached as they are to a supporting skeleton in the head and well supplied with muscles, are exceedingly effective. They cut their way here and there through the pulp, often working just beneath the skin of the fruit, in which case the outline of the burrow can be clearly seen (Fig. 20) on the surface of light-colored varieties. These brown markings on the skin gave origin to the name "railroad worms."

If the apples are actively growing when the larvæ begin their work in them, the burrows are very difficult to find for they heal as fast as made. The young larvæ, being just the color of the pulp, are hard to locate, hence they are seldom found in apples just picked from the tree. A little later the healing burrows are shown as corky threads extending here and there through the pulp; a condition often observed in green apples on the market. If these are packed away for a while, they are soon discovered to be badly mined and worthless. (Figs. 21 and 22.) As the apples soften a little the larvæ grow very rapidly, and in a week or so they are able to entirely break down the pulp, even working into the core.

Length of larval period

A number of varieties of apples were used in determining the length of the larval period. A single specimen was selected in each case, in which a newly hatched maggot was found by raising a bit of the peel just around the puncture. If an apple is taken which shows the puncture just beginning to turn brown, it is easy to locate the young larva at about the time that it escapes from the egg. When difficulty was found in obtaining an apple with a single maggot or egg in it, the newly hatched larva was transferred to a fresh apple. These apples were then placed in separate boxes and examined daily to note the time of emergence, which is shown in the following table:

LENGTH OF LARVAL PERIOD

Variety	Date of hatching	Date of emerging	Larval period (days)
Bough	July 4	July 16	12
	July 14	July 30	16
Maiden Blush	July 26	Aug. 9	14
	July 26	Aug. 13	18
Twenty Ounce	July 27	Aug. 14	18
Northern Spy	July 22	Aug. 10	19
Fall Pippin	July 27	Aug. 20	24
Pound Sweet	Aug. 30	Sept. 24	25
Oldenburg	Aug. 25	Sept. 19	25
Tolman	July 27	Aug. 22	26
Baldwin	Aug. 31	Oct. 2	32
Rhode Island	Aug. 14	Oct. 2	49
	Aug. 24	Nov. 20	88

It will be seen from the above table that the growth of the larva varies greatly. Under the most favorable conditions, a ripening fruit and warm weather, the larva may be fully developed and emerge within two weeks from the time that the egg hatches; while if the fruit is very hard and green or the weather cold, growth slows down and the time of emergence is put off for months. Lintner (1885) gives a note from Doctor Goding, of Ancona, Mich., which states that he had larvæ leaving the apples in January and that others which were kept in a cooler room did not change to pupæ until March.

In only one case has the writer found that the larvæ leave the fruit while it is hanging on the tree. That was with a Chenango apple, which was supported more or less by the branches. It had two exit holes. Usually the presence of the larvæ in the fruit hastens the ripening, and the fruit drops prematurely.

The exit holes left by the larvæ (Fig. 21) have very irregular, ragged outlines — a fact which is especially true in fruit that contains several larvæ. When an apple contains a single larva, the pulp is not greatly broken down and the maggot escapes by cutting a fairly round opening about two millimeters in diameter.

If the apples are attacked by any of the rot fungi the decay may destroy the fruit before the larvæ have finished feeding, in which case they may not try to escape to the soil but may shorten up to form the puparia inside the decomposed pulp. This is particularly true in the case of a black-rot that leaves the fruit a dry, hardened mass — twenty-eight puparia having been taken from a single specimen.

Puparia

The larvæ normally go into the soil to pupate if they are where they can do so, and pass the winter in this dormant state. In the fall of 1910, the soil under a number of badly infested trees was carefully examined and many puparia were found. From these observations it is evident that the depth to which the larvæ enter the soil depends largely on its character; in heavy clay the puparia are usually found directly beneath the fruit, while in sandy soil they are frequently found at a depth of two inches. Larvæ placed in a tumbler of loose soil, three inches deep, burrowed to the bottom of it before changing to puparia.

The larvæ emerging from the apples in the boxes, after crawling around for an hour or so, shortened up, forming puparia in the bottom. In this way the writer was able to get hundreds of larvæ and pupæ while making his records from drops.

Second brood

Since it was found from the literature that closely related fruit-flies in warmer countries produced several broods during the growing season,

it was thought best to start a series of experiments in order to learn whether there might possibly be a second brood of flies from the apple maggot. In these experiments larvæ from the experiments noted above were used. Since all the experiments were so successful, they will be given in as much detail as their importance seems to warrant.

First experiment.— July 21, 1911. A cylinder jar with cloth cover was placed on clean soil at the base of the plum tree near the insectary door. About sixty larvæ that had emerged from Primate apples were placed on the soil inside.

Sept.	1, 1911.	One female fly emerged.
	7,	One female fly emerged.
	9,	One female fly emerged.
	11,	Two female flies emerged.
	15,	One female fly emerged.
Oct.	25,	One female fly emerged.
July	2, 1912.	One female fly emerged.
	5,	One male and three female flies emerged.
	6,	Three female flies emerged.
	8,	Five female flies emerged.
	9,	Five female and two male flies emerged.
	10,	Three female and two male flies emerged.
	11,	Three females and one male emerged.
	13,	Two females and one male emerged.
	15,	One female and two male flies emerged.
	17,	One male fly emerged.
	18,	One male fly emerged.
	20,	One male fly emerged.
	22,	One male fly emerged.

Second experiment.— July 21, 1911. About two dozen larvæ from Red Astrachan apples were put into a flowerpot filled with moist soil, in the insectary, and covered with a cylinder jar. The soil became dry, and water was applied on September 2, 1911. In about half an hour a female fly was seen to emerge from the surface of the soil; she was very light-colored, and the wings were mere buds; the ptilinum was still extended, pushing the antennæ forward and downward. The fly worked for about an hour getting the wings expanded, all the while rubbing them lengthwise with her feet while they grew larger and darker. It was about two hours before she developed the normal black color of the adults. When placed on a slice of apple, she began feeding at once with avidity.

Sept.	4, 1911.	Six flies emerged—four females and two males.
	5,	One female emerged.

Sept.	7, 1911.	One female emerged.
	11,	Two females emerged.
	15,	One female and two males emerged.
	19,	One female emerged.
	22,	One male emerged.
	24,	One male emerged.
Oct.	2,	One male emerged.

Third experiment.— July 21, 1911. Twelve larvæ from Primate apples were placed in a flowerpot filled with moist sandy-loam soil, and covered with a cylinder jar. The soil was moistened when it became dry.

Sept.	4, 1911.	One male emerged.
	24,	One female emerged.

Fourth experiment.— July 21, 1911. A large field cage was placed under the Primate tree and the soil inside was covered with the infested fruit from the tree.

Sept.	20, 1911.	Four females emerged.
	22,	Eight females and one male emerged.
	23,	Two females emerged.
	24,	One male and two females emerged.
	25,	One male and one female emerged.
Oct.	16,	Two females emerged. (There had been several very heavy frosts.)
July	5, 1912.	One male fly emerged.
	10,	One male and one female fly emerged.
	11,	One female fly emerged.
	13,	One male and two female flies emerged.
	15,	Three males and one female emerged.
	16,	Two males and one female emerged.
	20,	One male fly emerged.

Fifth experiment.— July 21, 1911. A small field cage was placed under the cherry tree in the insectary and a bucketful of badly infested Red Astrachan apples was put into the cage.

Sept.	11, 1911.	Two females and two males emerged.
	12,	One male emerged. (Cold and rainy.)
	13,	One female emerged. (Cold and rainy.)
	16,	Two females and two males emerged.
	17,	Two females and one male emerged.
	19,	One male emerged.

Sept.	22, 1911.	One male emerged.
	23,	Two females emerged. (Cold night.)
	24,	Three females emerged.
	25,	One female and one male emerged.
	30,	Two females emerged.
July	10, 1912.	One female emerged.
	11,	Four females and three males emerged.
	13,	Twelve females and seven males emerged.
	15,	Twelve females and twelve males emerged.
	16,	Six females and ten males emerged.
	17,	Ten females and seven males emerged.
	18,	Three females and six males emerged.
	19,	None. (Cool and rainy.)
	20,	Seven females and three males emerged.
	22,	One female and four males emerged.
	24,	One female emerged.
	28,	Two males emerged.
	30,	One male emerged.
Aug.	1,	One male emerged.
	5,	One female emerged.
	15,	One male emerged.
	19,	One male emerged.
	24,	One male emerged.

Sixth experiment.— Aug. 1, 1911. A number of larvæ were placed in a flowerpot filled with moist sandy-loam soil, in the insectary, and covered with a cylinder jar. The soil was moistened when it became dry.

Sept.	12, 1911.	One male emerged.
	13,	One female emerged. (Cold day.)
	16,	Thirteen females and one male emerged.
	17,	Six females and two males emerged.
	19,	Five females and five males emerged.
	20,	Three males emerged.
	22,	Two females and four males emerged.
	24,	Three females emerged.
	25,	One male emerged.
Oct.	2,	One male emerged.

Further experiments.— Several other experiments, which will be mentioned in another place, produced second-brood flies but the above will serve to show the general results. All the experiments except the fourth were located away from the infested trees, so that there was no possibility

of the flies' being late in developing from the first brood. In the first, second, third, and sixth experiments, larvæ were put on soil, and the flies that emerged could have come only from these. The writer wishes to emphasize these points because doubt has been expressed that these were second-brood flies.

It is to be noted from these experiments, however, that only about thirty per cent of the larvæ which entered the soil emerged as second-brood flies, the others passing the winter in the soil. Those in flowerpots evidently became too dry or too cold, for the flies failed to appear during the season of 1912. It is interesting to note that the flies emerged a little more quickly in the first experiment, which was under perfectly natural conditions, than from the soil in flowerpots. This is probably due to the fact that in the latter case the soil dried out several times.

Length of life of the flies

A series of experiments were conducted to determine how long the flies live. First-brood flies that were ovipositing in the orchard were collected and confined in inverted jelly-glasses on the writer's desk. The glasses were kept well cleaned and fresh paper was put under them from time to time. It was soon learned that the flies preferred having sliced apple to sucking the gum from the outside, so they were given fresh pieces every morning. It was also found necessary to supply them with water from time to time, although the moisture from the fruit sometimes condensed on the inside of the glass and the flies were often observed sipping it. The females continued ovipositing, putting the eggs into the section of apple, and in one case an egg was laid on the paper; this egg proved to be fertile, being hatched out in a bit of apple pulp on a hollow slide. The males lived about five weeks and the females six, after confining them; it is not known, of course, how old they were when captured. It is very likely that they live longer in nature.

All the flies that emerged from the experiments noted above as second brood were confined in a similar way, each day's result being kept in a separate glass. These flies began copulating when eight days old. This process was observed with some care, which was made possible by the flies being so closely confined. The male springs on the back of the female, placing his fore feet on the front of her abdomen and his second pair out on her wings. He waits until she extends the ovipositor before the penis is drawn out of its pocket, where it lies coiled away under the fifth abdominal tergite. The writer was unable to observe just how he managed to bring the coiled and spring-like penis into position and enter the opening of the ovipositor, as this was so quickly done. When once

united, the tip of the ovipositor seemed pressed into the cavity between the tiny appendages of the last abdominal segment of the male. They were able to fly about freely, and remained attached in this way for twenty to thirty minutes. When they separated the ovipositor and penis were quickly retracted, and the flies went about feeding as usual.

The flies first began ovipositing in apples, which were provided for them in the glasses, at twenty to twenty-four days of age, as is noted above; therefore this length of time was required for the eggs to mature in the ovaries after the flies emerged.

The flies of the second brood began dying after a confinement of thirty days, the nights being cold (October 15); the last lived fifty days and died on November 6.

TECHNICAL DESCRIPTION

The female

General color shiny black, marked with white; length, maximum 6.5 mm., minimum 5 mm., average 6.25 mm.; spread of wings, average 12 mm.

Head.— Light brown above, blending into pale lemon-yellow on lower face; sides of face and hind margin of eyes white. Eyes bright green, with rich brown and sometimes steel-blue reflections, in life; but dull, dark green, with purplish reflections, in pinned specimens. Antennæ orange, .5 mm. long. Prominent black hairs border the distal front margin of the first segment, and cover the inner face and outer distal margin of the second; the third segment is flattened on its inner face and rounded without, pubescent; arista dark brown, two-jointed, slender, with fine pubescence. The usual frontal bristles present; all black except a small, yellowish white, erect pair (postvertical) located behind the ocelli. Mouth large, broad; proboscis and palpi lemon-yellow, both covered with a yellowish pubescence; palpi short, not extending outside the anterior edge of the mouth.

Thorax.— Shiny black; a white stripe extending along each side from the humeral callus to the base of the wing and the white alula. The dorsum marked with four silvery gray longitudinal stripes, arranged in pairs, confluent in front and very slightly divergent posteriorly; the pairs separated by a median broad space that shows the shiny black of the rest of the thorax; the two stripes of each pair separated posteriorly by a very narrow, similar, black interval, in which is a prominent black bristle near the posterior end of the inner stripe, which is considerably shorter than the outer one; the silver-gray appearance of the stripes is due to a snow-white pile, this making a sharp contrast with the rest of the thorax, which is black. The scutellum prominent, raised, bearing

the usual two pairs of black bristles; top flattened and pearly white, sides and base black.

Legs.— Middle pair longest, about 4.5 mm.; femora and tibiæ about equal, 1.5 mm.; tarsi somewhat shorter, 1.3 mm. Front pair shortest, about 3.8 mm. Femora black with lighter ends, the front pair often lighter; tibiæ and proximal segments of tarsi, straw color; distal segments covered with black hairs, giving the feet a black appearance.

Wings.— Length 4.5 to 5.5 mm.; width 2 to 2.5 mm.; the smaller sizes being from wings of males and dwarfed females. Four irregular dark bands cross the hyaline membrane of the wing: the first lies near the base of the wing and joins the second near the posterior margin; the last three are connected near the middle of the anterior margin of the wing and diverge widely toward the posterior margin. Professor Harvey has suggested that these markings resemble the picture of a turkey: the end nearest the body representing the head, with a clear spot usually present for the eye, the second band the body, the third the legs, and the fourth the tail, which reaches nearly to the tip of the wing. (Fig. 17.) The entire wing is covered with a very fine pubescence, which is white in the hyaline parts and black in the bands. The entire margin of the wing, and the vein R_1 on the upper surface, are armed with small black bristles, as is characteristic of the genus.

Abdomen.— Shiny black; four rather uniform white bands bordering the posterior margins of the second, third, fourth, and fifth tergites; the scattered pile of the first of these bands is white, that of the rest black as on other parts. The abdomen without the ovipositor is a little longer than broad; it is composed of seven segments; the tergites of the first and second are so closely fused in this family that they were formerly considered as a single segment (Loew, 1873), although the sternites are clearly defined. The first two segments rapidly widen to the third, which is the broadest; the fourth, fifth, and sixth narrow abruptly to the seventh, which is in the form of a truncate cone, with no indication of the union between the tergite and the sternite, the two being so closely fused as to form a solid, chitinous protection for the ovipositor, and also to act as a firm attachment for the several sets of muscles which manipulate this organ and support the egg-tube within. At first this seventh segment was thought to be the ovipositor (Loew, 1873), which is described as " very broad but short " and having a black pubescence; the real ovipositor being observed and described later (Harvey, 1889).

Ovipositor.—This organ (Figs. 26 and 27) is very slender and terminates in a sharp point. When not in use it is entirely retracted within the last abdominal segment. The general structure is horn-like, hard, and chitinous, with a groove on the lower surface which is covered by two chi-

tinous rods or flaps extending from the sheath about halfway to the tip. These flaps are attached at the sides to the main body of the ovipositor by thin, transparent membranes, their function being to guide the egg in its passage downward. The sheath is a thin membrane that attaches the ovipositor to the last abdominal segment. It bears many triangular, chitinous projections on its surface; these are arranged in definite rows that extend backward each way from a median line, above and below, the lower surface being the more beautiful. There is a triangular space on each side, at the base of the sheath, with no tubercles. When the ovipositor is retracted it carries the sheath with it, as in pushing in the end of the finger of a glove — the whole sheath and ovipositor being finally concealed within the seventh abdominal segment.

The male

As shown in Fig. 16, the male has the same general appearance as the female but is considerably smaller. Length, 4 to 5 mm.; the principal difference in length is in size of abdomen, which shows only five of the seven segments, the sixth and seventh (Figs. 28 and 29) being retracted beneath the fifth, and white bands terminating only the second, third, and fourth tergites.

Harvey states that there are only five segments in the male, but he evidently overlooked the two terminal segments. The sixth segment is usually entirely covered by the fifth, and the seventh tergite can barely be seen extending behind the caudal margin of the fifth. The sixth tergite is very unsymmetrical, on the left side extending downward and meeting the sternite, while on the right there is only a small, triangular part at the top, chitinized, due to the position of the coiled penis which rests against that side. The seventh segment bears a pair of chitinous appendages, which aid in copulation. Extending from the caudal end of the seventh segment is the rectum, which is covered with stiff hairs and remains outside the body at all times; it can be seen as a noticeable light-colored speck in even the living flies. Within the sixth and seventh segments is a chitinous framework which supports the very long, chitinous penis—an organ which extends in almost a complete circle around the caudal end of the body, to the back, when partly uncoiled (Fig. 29). Ordinarily the penis remains in a tight coil in a pocket under the fifth tergite, just to the right of the median line (Fig. 28). The spiral, chitinous rod in the penis makes it difficult to straighten out when the fly is dead, and causes the soft margin on the inner part of the circle to pucker, forming overlapping folds. Near the end is a rectangular part with a chitinous center, and terminating the penis is a spiral brush with numerous, somewhat stiff hairs. The other markings are as in the female.

Internal genitalia of female

Careful dissections were made of the reproductive system, in order to determine the time of development and the number of eggs. The ovaries are spherical masses made up of numerous egg-tubes (Fig. 32), as is common among flies. The egg-tubes are surrounded by connective tissue and are tied together by closely anastomosing tracheæ; the oviducts are short and lead into the vagina, which also receives the ducts from the three spermathecæ and the pair of accessory organs on the dorsal surface (Fig. 32). The vagina has a cluster of tiny papillæ also on the dorsal surface, the function of which the writer has been unable to determine. Two sets of muscles extend from the sides of the vagina to the chitinous walls of the seventh abdominal segment, which entirely surrounds this organ and holds it firmly in place. Another set of muscles, similarly attached, controls the movements of the ovipositor. The vagina gradually narrows and seems to unite with the intestine just before it passes into the chitinous covering of the ovipositor. Whether these two tubes actually unite or are only fastened together very closely with the connecting tissue, the writer is unable to state from the dissections made. This condition does not exist in other flies; although the two organs often open to the outside very near together, they have separate openings in all cases known to the writer.

The egg

The mature egg (Figs. 23 and 40) is pearly white when taken from the ovary, but shows a distinct cream color after being in the fruit for a short time. The shape is fusiform, almost four times as long as wide; the pedicellate end being gently rounded, the other end more pointed. The pedicel is short, not much, if any, longer than wide. The eggshell around the pedicel is covered with reticulate markings having the appearance of cells, with raised papillæ extending from their margins giving a spinose appearance. The markings and papillæ are distinctly darker near the pedicel and extend for only about one fourth of the total length of the egg, where they are gradually lost in the smooth surface of the remainder of the shell. Measurements of a large series show the following sizes: length, .8 to 1 mm.; width, .2 to .3 mm.; the shorter eggs usually having the greater width. The developing larva can be clearly seen within the egg; the black rasping apparatus, or head, being in the pointed end of the egg, the posterior part toward the pedicel.

The larva

The larva (Fig. 24) is white or cream-colored unless it is feeding on green pulp from near the skin of the fruit, in which case the food shows

through the skin of the larva, giving a greenish cast. The body is made up of fourteen segments; the ninth, tenth, and eleventh are thickest, those from the ninth to the first rapidly tapering to the small, pointed head. From the eleventh segment the body decreases very gradually to the last segment; this has the dorsal half cut off, leaving a sloping surface on which is located the pair of caudal spiracles. Below the sloping part the body ends squarely, giving it the appearance of being cut off. On each side of the dorsal surface, at the union of the third and fourth segments, is a conspicuous outgrowth. By the aid of the microscope this structure is seen to be made up of a double row of about twenty papillæ extending from the margin of a funnel-shaped structure that is attached to a bulb-like enlargement at the base. These structures are the *cephalic spiracles*, which open into the pair of longitudinal tracheæ extending caudad to the last segment of the body, where they end in the caudal spiracles mentioned above. Only two branches connect this pair of longitudinal tracheæ, the first at the junction of the fourth and fifth segments and the other just in front of the last segment. When the head is fully extended, the black hooks are clearly seen protruding from the lower surface of the front segment. These hooks are attached to a black or brown framework inside the second, third, and fourth segments. This structure (Figs. 30 and 31) can be clearly seen through the skin by transmitted light, especially when the larva is young. The first three segments of the body are usually withdrawn into the fourth whenever the larva is disturbed; in this condition the cephalic spiracles appear to be at the anterior end of the body and the rasping apparatus cannot be seen. This is the condition seen normally in the anterior part of the puparium. There are two pairs of sensory papillæ on the front of the first segment. Length of larva, 7 to 8.5 mm.; width, 1.75 to 2 mm.

The pupa

As in most flies, the pupal stage is passed within the larval skin, the maggot shortening up and becoming inactive. The shape (Fig. 25) is a long oval, a little more than twice as long as wide and tapering about equally at the two ends. The head segments being retracted, the cephalic spiracles protrude from the front margin. The posterior end is slightly contracted but not enough to cover the caudal spiracles, which remain exposed. The color, at first light yellow as in the larva, changes in a few hours to a yellowish brown, becoming darker with age. Within two days the real pupa formed inside the larval skin, in all cases observed. Fletcher (1905) states that the pupa forms inside the puparium only a few days before the perfect insect appears the next summer. The pupa, when removed from the puparium, is pure white; the legs and wing buds

closely folded toward the ventral side; the head also tipped ventrally so as to economize space. Length of puparia, 4 to 5 mm.; width, 2 to 2.5 mm.

METHODS OF CONTROL

Picking up windfalls

Since the larvæ usually remain in the fruit for some time after it falls from the tree, the standard remedy for years has been to destroy the drops. In the control of a pest it is customary to look for the point of least resistance in the life cycle, at which to make the attack. Hence, it is most natural that this remedy should be applied; for if all the fallen fruit is destroyed before the larvæ emerge from it and go to the soil to pupate, there will be none left to continue the pest. In practice, however, there has always been the difficulty that some of the fruit was left on the ground too long, and some of the maggots escaped. Keeping the fruit picked up became a very burdensome task, and, in the case of large orchards, so expensive that few carried it out. An added difficulty also arose from the fact that there are usually many scrubby apple trees in near-by neglected fields, in this part of the country. The fruit of these trees, being invariably infested with the apple maggots and left to decay on the ground, offers a continual source for renewing the pest in well-cared-for orchards.

Early in this work it became evident that the larvæ remained much longer in the hard winter fruit after it dropped, than they did in the softer summer varieties. Thinking, as the writer did then, that picking up the drops was the only adequate method of control, the importance was at once recognized of a more definite knowledge as to just how long the larvæ remained in the fruit after it had fallen from the tree. In other words, how often is it necessary to pick up the fallen fruit for a given variety, in order to keep any of the larvæ from escaping to the soil? With a view to obtaining comprehensive results, individual trees of sixteen of the common varieties of apples were used. These were all badly neglected and were known to have been thoroughly infested with apple maggots in previous years. As indicated in the table on page 158, the varieties selected gave all gradations from those of early summer to those of late fall and winter.

As to the methods of work, all the drops were picked up daily, those from each tree being placed in separate boxes or in screen-bottom trays. Data blanks were kept in the boxes with the fruit, and on these the number of larvæ that had emerged were recorded each morning. Sometimes the fruit became decayed before all the larvæ were matured and the writer had some difficulty in getting a complete record of infestation, for the

FIG. 16.— *Rhagoletis pomonella, male*

FIG. 17.— *Wing of Rhagoletis pomonella*

FIG. 18.— *Rhagoletis pomonella, female. Natural size and enlarged*

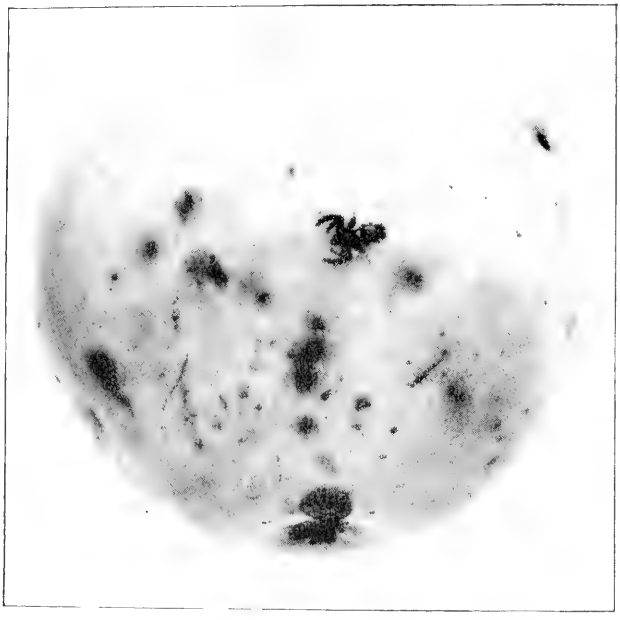

FIG. 19.— *Female fly on apple, slightly enlarged*

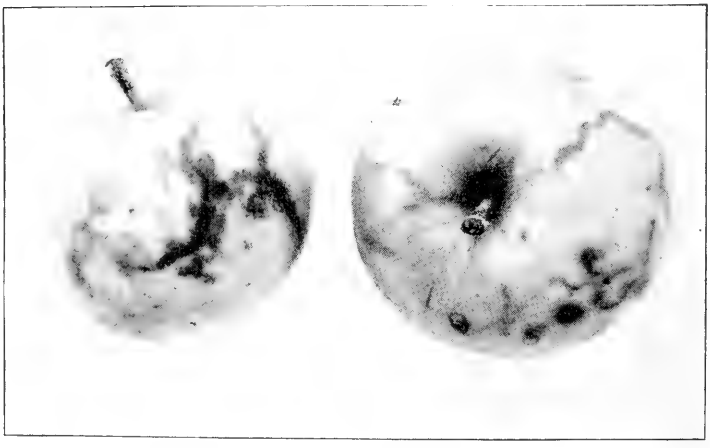

FIG. 20.—*Tunnels of larvæ showing through skin of Early Harvest apples*

FIG. 21.— *Exit holes of larvæ in Primate apples*

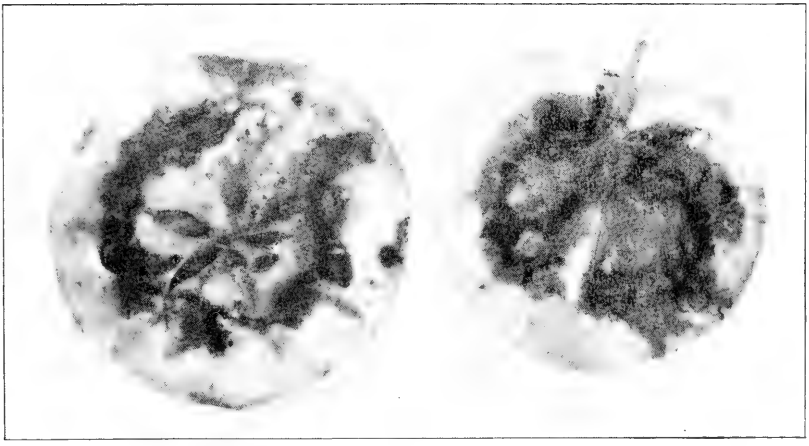

FIG. 22.— *The same apples, cut open*

FIG. 23.— *Egg in situ, greatly enlarged*

FIG. 24.— *Maggots, lateral and dorsal views, enlarged*

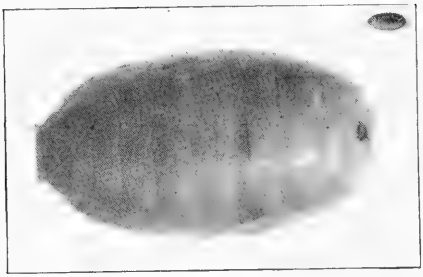

FIG. 25.— *Puparium, natural size and enlarged*

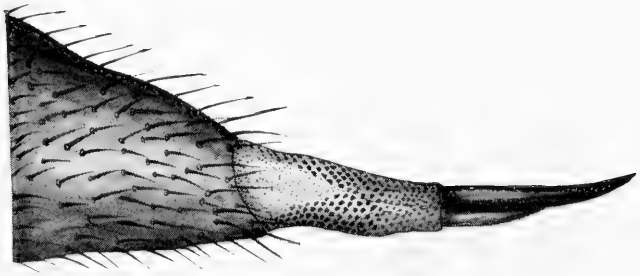

FIG. 26.— *Ovipositor of female, side view*

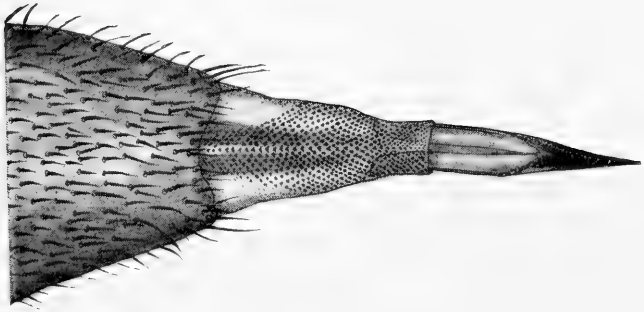

FIG. 27.— *Ovipositor of female, ventral view*

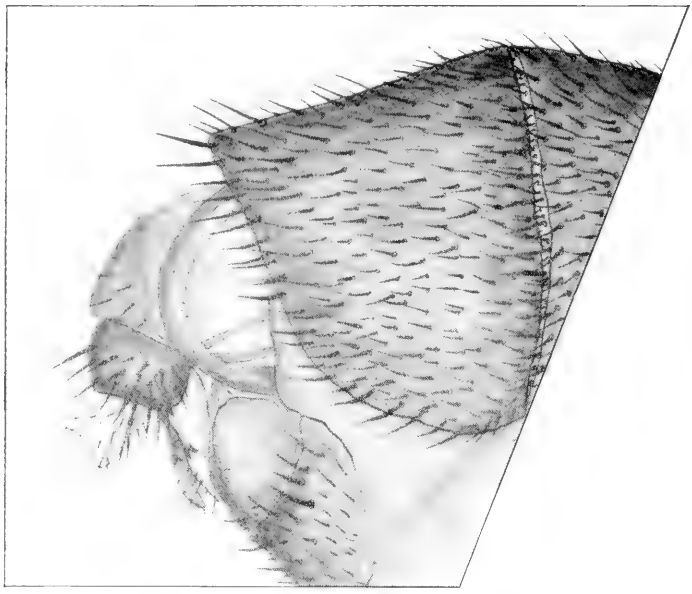

FIG. 28.— *End of abdomen of male, slightly distended. Greatly enlarged*

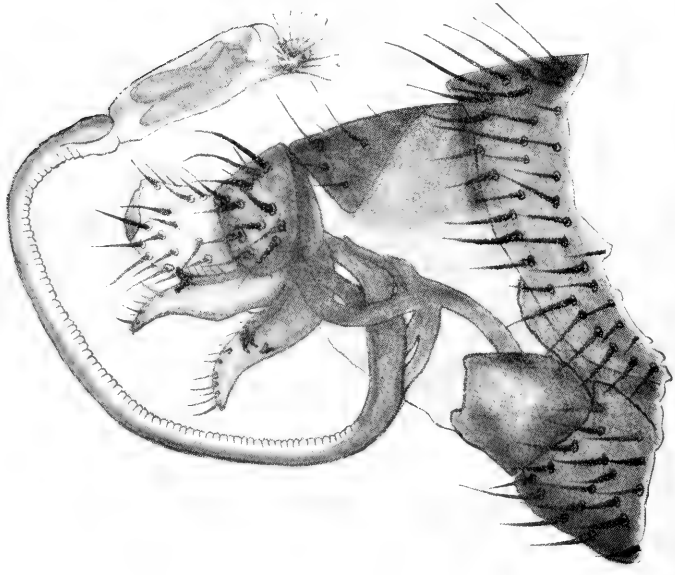

FIG. 29.— *End of abdomen of male, with genital organs uncoiled*

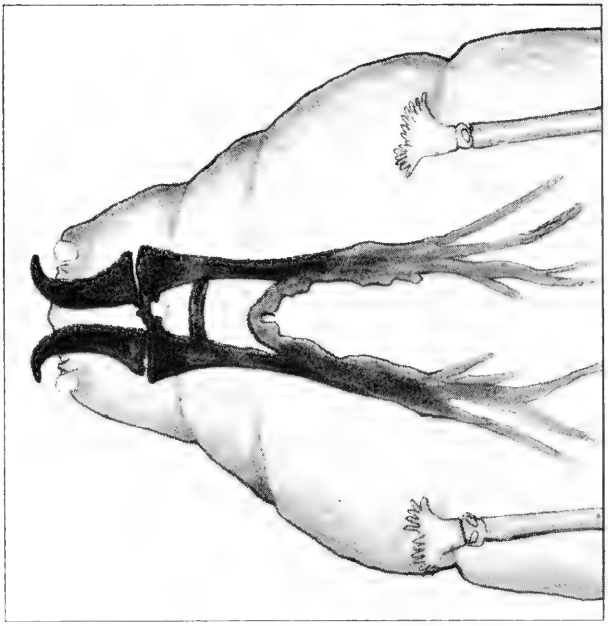

FIG. 30.— *Cephalic part of maggot, showing arrangement of chitinous hooks. Dorsal view*

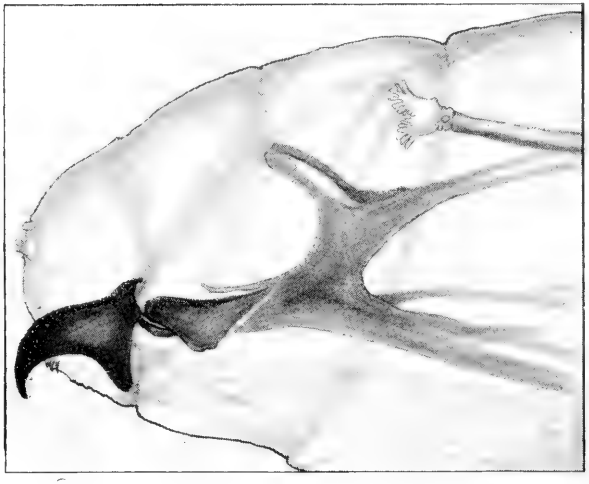

FIG. 31.— *Cephalic part of maggot, lateral view*

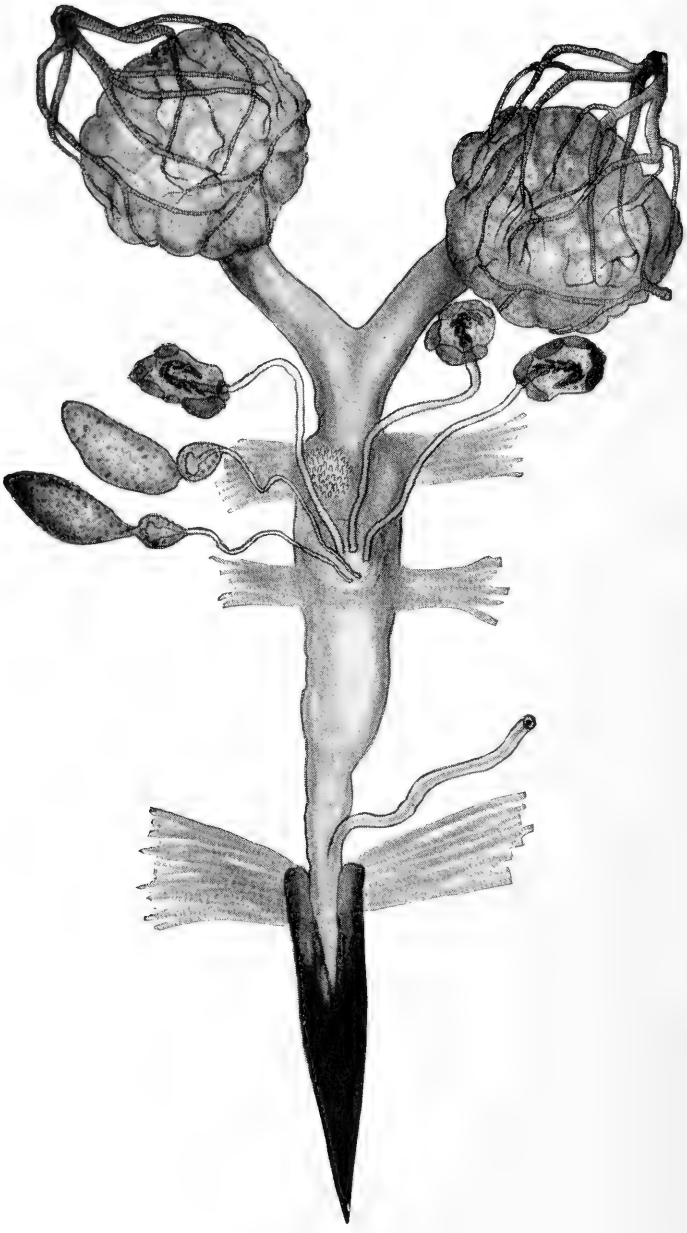

FIG. 32.— *Reproductive organs of female, enlarged*

FIG. 33.— *Fully developed egg-tube*

FIG. 34.— *Egg-tubes one to four days after female emerged*

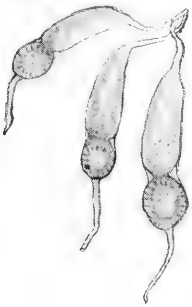

FIG. 35.— *Egg-tubes four to eight days after female emerged*

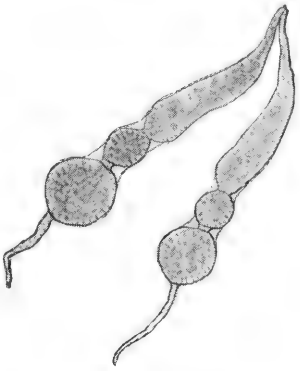

FIG. 36.— *Egg-tubes about twelve days after female emerged*

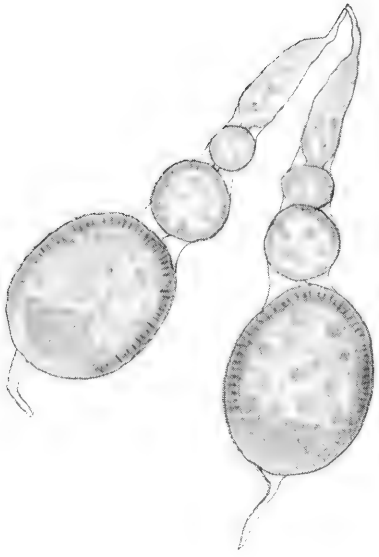

FIG. 37. – *Egg-tubes about sixteen days after female emerged*

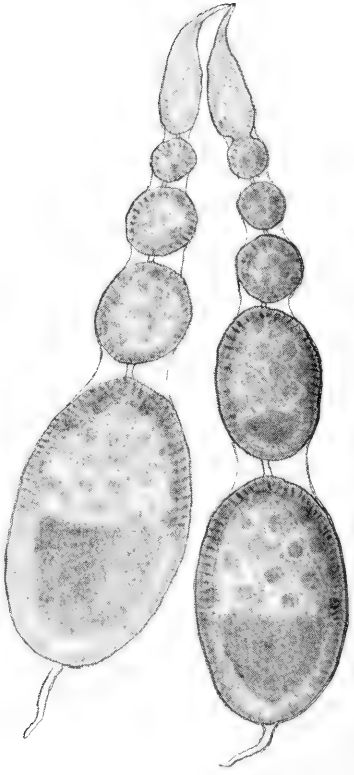

FIG. 38.— *Egg-tubes from flies twenty days old*

FIG. 39.— *Egg-tube fully developed — twenty-four days*

FIG 40.— *Mature egg*

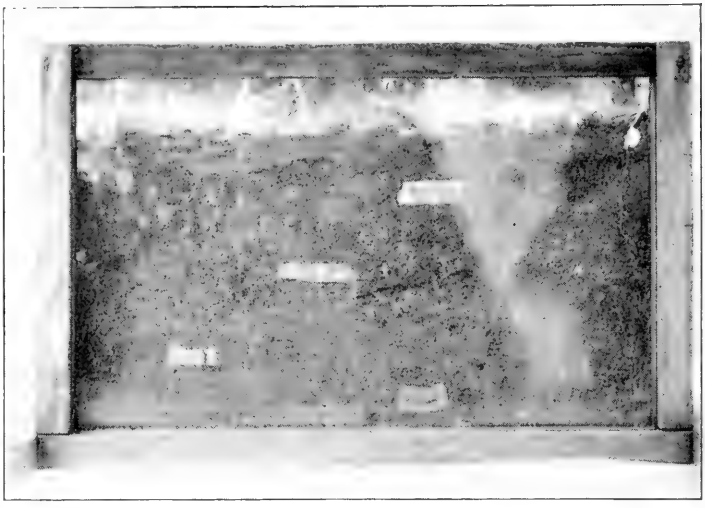

FIG. 41.— *Root cage, for observing buried pupæ*

FIG. 42.— *Tunnel in soil of root cage made by fly attempting to escape*

late-developing larvæ often pupated inside the rotten fruit. In order to overcome this difficulty, these apples were opened and the pupæ searched out and removed.

In the early summer apples the larvæ began to emerge three to five days, according to variety, after the fruit fell from the trees. The number of larvæ emerging each day gradually increased up to a maximum on the eleventh to the fifteenth day, after which time the number rapidly fell off — the last emergence being on the twenty-third day.

In the early autumn varieties the first larvæ emerged six to twelve days after the drops were picked up; the maximum emergence being on the twelfth to the seventeenth day, and the final emergence about the twenty-eighth day.

The winter fruit showed a wider range in the time of emergence of the larvæ, due possibly to the different degrees of hardness of the varieties tested. The Northern Spies, in which the larvæ began to emerge on the eleventh day, were affected with brown- and bitter-rot, which hastened the ripening and undoubtedly hurried the development of the larvæ. In the fruit that remained hard throughout the test, the first larvæ emerged twenty-two to twenty-six days after the fruit fell; the maximum emergence was about twenty-five to thirty days, and the last larvæ that succeeded in developing remained in the fruit to a maximum of seventy days in the case of the Rhode Islands.

In order to obtain a more concise estimate of the relative infestation of the several varieties used in these experiments, the results were summed up for each tree. These results, as given in the last column of the following table, show the average number of larvæ per apple. To illustrate: the "3.6+" at the head of the column means that there was an average of a little over three and six tenths larvæ per apple in the first variety noted.

With the data here given, some definite conclusions may be drawn as to how often the fallen fruit must be picked up and destroyed if this method of control is to be depended on. Since these experiments were begun an article by Professor O'Kane (1911) has appeared, which shows carefully-worked-out data of emergence of the larvæ in New Hampshire. The recommendations that appear at the end of this article, as to how often the drops should be picked up for the varieties considered, agree very closely with results in this locality. Destroying the fallen fruit of summer varieties twice a week permits few, if any, of the larvæ to escape into the soil. The drops of autumn apples may be left on the ground with comparative safety for one week, and the hard winter fruits need be picked up only once in two weeks.

The writer now believes this method of handling the pest to be practicable only in cases when few trees are infested, in localities where there

TABLE SHOWING THE NUMBER OF DAYS THAT THE LARVÆ REMAIN IN THE FRUIT AFTER IT FALLS FROM THE TREE, ALSO THE RELATIVE INFESTATION OF VARIETIES

	Variety	Began experiment	First larvæ emerge (day)	Principal emergence (day)	Last larvæ emerge (day)	Average number of larvæ per apple
Summer	Bough	July 13	3d	11th	18th	3.6+
	Red Astrachan	July 14	5th	12th	16th	1.6+
	Williams	July 18	6th	15th	19th	1. +
	Primate	July 11	6th	14th	23d	3. +
Autumn	Early Harvest	July 18	6th	12th	19th	2. +
	Chenango	July 22	10th	14th	20th	1. +
	Maiden Blush	Aug. 2	7th	15th	28th	3.67
	Oldenburg	Aug. 25	11th	15th	25th	3. +
	Twenty Ounce	July 27	10th	17th	26th	3. +
	Fall Pippin	July 27	12th	16th	24th	2. +
Winter	Northern Spy	Aug. 10	11th	14th	28th	2. +
	Swaar	Aug. 19	12th	17th	28th	1. +
	Tolman	Aug. 10	12th	16th	26th	3. +
	Pound Sweet	Aug. 30	22d	25th	28th	2.
	Rhode Island	Aug. 14	23d	28th	70th	2.
	Baldwin	Aug. 30	26th	30th	49th	1.54

are no other near-by infested trees. This view is held, not only because of the difficulties pointed out above, but also because of the danger of larvæ escaping after the drops have been picked up. It becomes necessary to destroy all the larvæ in infested fruit. The only safe methods of doing this that have been suggested are by cooking, making into cider, or burning. The first and the last are rather expensive, and most persons do not care to "drink his broth" when made into cider.

It is very likely that many of the larvæ escape into the soil when the apples are fed directly to stock, especially if there is an abundance of fruit on hand and it is not eaten up clean at once. It has been demon-

strated that burying is unsafe. Gurney (1908) records experiments in which the Mediterranean fruit-fly (*Ceratitis capitata*) escaped from depths of six, eight, ten, and twelve inches.

Burying puparia

In order to determine whether plowing under the drops would be a means of control, puparia were buried at different depths, in a gravelly-loam soil placed inside glass cylinders set in the ground. These cylinders were six, nine, and twelve inches long, the tops covered with lantern chimneys to catch the emerging flies. Although fifteen puparia were placed in each cylinder only two flies emerged — one from twelve inches deep and the other from six inches. This at first sight would lead one to conclude that the flies found difficulty in escaping. In other cages, however, where the larvæ were permitted to enter the soil as they left the fruit, very few flies, and in some cages none, emerged after passing the winter. Therefore, since even a single fly emerged from a depth of twelve inches, the writer concludes that burying is not a certain remedy. Recent experiments by Doctor Stiles gave some interesting data along this line; the larvæ of house-flies (*Musca domestica*), buried to a depth of four feet in clean, unsterilized sand, emerged, and another undetermined fly of the same genus emerged from a depth of six feet.

In order to observe the activities of the flies as they attempted to escape from the soil, puparia were buried at various depths in a root cage (Fig. 41), being placed against the glass and the soil being packed against them. One of these cages was kept inside the insectary, and another outside in the yard where the conditions were more nearly natural. The soil in the cage inside became very dry several times during the winter, and an examination of the puparia in August, 1911, showed that those near the surface had dried up, and that those lower down in the cage had emerged from the pupa cases but had lost their way and were unable to escape. The cage in the yard showed a path (Fig. 42) where one of the flies had burrowed along next to the glass in its attempt to escape, but it had finally died after digging for about three inches. None of the flies succeeded in emerging from the soil. Too much importance must not be placed on this point however, since the soil was clay, and the flies may have been hindered by being against the glass.

Citronella oil, kerosene, and quassia

Froggatt (1909) speaks of citronella oil as being very attractive to two species of fruit-flies — genus *Dacus* — in India. After this oil was spread over the leaves the flies became so thick around it that a thousand were captured with a few sweeps of the net.

When the flies were very abundant in the trees during July, the writer covered several of the leaves and apples in the Bough and Primate trees with citronella oil and placed a shallow dish of it in the branches. Careful observations were made during the next two days and not a single fly was observed to come near the oil. It apparently acted as a deterrent, as it is said to do in the case of mosquitoes. The oil burned the fruit, causing the coat to turn brown and apparently die.

The use of kerosene for the Mediterranean fruit-fly in Australia has been strongly recommended by Compere (1907) and by Gurney (1908), numerous flies being caught in saucers exposed in the trees. The first-named author describes also a self-feeding kerosene trap that has proved very effective. In the experiments here described, kerosene was placed in saucers in the trees where citronella oil had been tried and some was also applied on the fruit where the flies were ovipositing. The only result noted was that the flies appeared to avoid the kerosene as they had avoided the citronella oil.

Quassia is a recognized fly-poison, although used commonly by man as a medicine. A sweetened decoction was made by soaking quassia chips, and this was sprayed on the fruit and foliage in the cage experiments. The flies ate the sweetened, bitter liquid freely but no harm came to them. Similar negative results are recorded by Lounsbury (1899) from his use of quassia with fruit-flies in South Africa.

Cold-storage

Several published records indicate that the larvæ of fruit-flies and some other pests are destroyed by continual low temperature. Hooper (1907) describes experiments in which the maggots resisted a temperature of 38° to 44° F.; when the temperature was lowered to 33° to 35° F. all the maggots were dead in fifteen days, but the infested fruit was left for three weeks in order to insure safety.

An experiment was started on July 30, 1911, with a view to determining the effect of cold on the growth of larvæ. Primate apples, with larvæ about one fourth grown, were used. One half of the apples were put into the ice-box of a home refrigerator, and the other half were left in a box in the house at ordinary summer temperature. At the end of the first week many of the apples in the house were rotting and the larvæ were emerging; those in the ice-box were unchanged, although the larvæ were found to be alive. At the end of the second week, most of the apples in the house were a mass of rot and all the larvæ had emerged; there was no change in the larvæ in the ice-box. At the end of the third week, the remaining fruit was removed from the refrigerator. It showed no decay, and on cutting the apples the larvæ were found to be still alive but hardly

any larger than when they were put in, having worked but slightly in the fruit. All the apples were cut up in finding and noting the condition of the larvæ; therefore, unfortunately, none were saved so as to see whether they would continue to develop when placed at ordinary temperature again. The activity of these larvæ was apparent, however, after the apples were cut and remained open for a short time in the warm air, so doubtless they would have completed their development had they been permitted to do so.

This experiment is of little real value because the temperature was so variable, the ice being melted some days for several hours before a fresh supply was put in. It shows, however, that cold-storage would be an important factor in retarding the growth of the very young larvæ until the fruit could be utilized, even if the temperature were not low enough to kill them outright.

Cultivation

Thorough cultivation of the orchard would appear to be of value in combating a pest of this kind. The pupæ normally located, an inch or so under the surface, would necessarily be much disturbed by plowing and frequent cultivation. Careful experiments by Professor Card (1905) serve to show that burying the pupæ deeply, as would be done if the orchard were plowed in the spring, is of little avail. The writer's experiments in burying pupæ, described above, gave similar results.

In several of these experiments it was discovered that the larvæ and puparia offered little resistance to drying. If left in the bottoms of the boxes in the warm air of the room, they were found to be dry and dead after a few days. This observation suggested the experiment of trying the effect of dry soil on the newly emerged larvæ. Thirty-two of these larvæ were placed on the surface of a jar of road dust on July 30, 1911. They crawled about for some time as though they did not like it, but finally, after about half an hour, all had disappeared from sight beneath the surface. On August 3, on removing some of the puparia from the dust it was found that they were poorly formed and some of them were dry and hard. On August 9, all the puparia were sorted out of the soil and found to be entirely dried up, so that they were empty shells.

The larvæ in this experiment had gone only an inch or so into the dry soil; therefore it is thought that cultivation, whereby a surface mulch of dry dust is maintained during the season of emergence of the larvæ, will be an important factor in destroying the pest.

Pupation without soil

Frequently, in the literature of this subject, the statement is found that the larvæ go to the bottoms of the boxes to pupate and that they

are in this way scattered to new regions. In the same papers wonder is expressed that the flies have not been spread faster over the country, since the fruit of infested regions goes to many localities where the pest is still unknown. Harvey (1889) said that he thought there was little to fear from maggots which transformed in the bottom of the barrels, and that his observations indicated that pupæ kept in a warm room, and not covered with earth, would not emerge. This is certainly an important point for consideration in the distribution of the pest. If the puparia in the bottoms of packing boxes and barrels resist the unnatural conditions and are able to emerge as usual, certainly the rapid spread of the pest might be expected, and even its spread to distant sections where the fruit is shipped.

In order that data might be obtained on the development of the flies when the larvæ were not permitted to enter the soil, the following experiments were started:

1. July 24, 1911. A box of apples was placed in the cool storeroom of the insectary basement, so that the larvæ might emerge under usual storage conditions. On August 9, 1911, the apples were mostly decayed; these were removed, and forty of the puparia from the bottom were transferred to a small box and left in the storeroom. The experiment with the road dust, described under " Cultivation," suggested that these puparia might also be dried up inside; hence, on August 20, 1911, they were all opened and found to be entirely dried so that the shells were empty.

2. July 26, 1911. Two hundred and fifty puparia that were taken from the writer's experiments on variety infestation were placed in a box in the basement storeroom at the insectary. Some of these puparia had been found in the decayed fruit, where they had pupated. These were to be kept in the storeroom until the next season, in order to see whether any of them would emerge. Three second-brood flies emerged in 1911—the first, a female, on September 17, and the other two, males, on October 2 and 19, respectively. On July 8, 1912, another male fly emerged, but all the others proved too dry to escape. Other observations of pupæ formed inside the decayed fruit confirm the opinion that the four flies which emerged came from puparia taken from the fruit, and that none of the larvæ which emerged from the fruit to form the puparia were able to pupate before they became too dry.

3. August 2, 1911. Fifty-seven puparia from the bottom of a box of apples, which had been standing in the room by the writer's desk, were placed in a Syracuse watch-glass and covered with another glass. Twenty-two puparia that had formed inside decaying apples were removed and placed in a second watch-glass, and covered in the same manner as the

first. On September 1, 1911, it was found that eight flies had emerged in the second watch-glass — six females and two males. Two more emerged later — a female on the 9th and a male on the 19th of September. Not a single fly appeared in the first watch-glass, so on September 22 all the puparia were opened and were found to be empty shells.

These results would indicate strongly that the larvæ cannot resist drying either before or after they form the puparia, but that after the pupæ are formed drying is not necessarily fatal to the insect. On dissecting puparia that had formed inside the decayed fruit, and also some that had formed in moist soil, it was found that the change to the pupa had taken place within about two days. Hence, it would appear that the principal danger in the storage boxes and barrels does not lie in the puparia which have escaped from the fruit, but in the rotten apples which are usually thrown out. Even though these decayed remains of the fruit may have become dry and hard, as is frequently the case in the storeroom, they may contain living pupæ and should be burned.

It is hoped that further experiments may be undertaken in order to determine whether the air becomes moist enough, from the evaporation of the fruit in tightly packed boxes and barrels, to permit the emerging larvæ to pupate. This moist condition may prevail in some storage houses. However, if spraying to destroy the flies is resorted to, there will probably be no pupæ to contend with in the packing-boxes.

Poisoned bait

It was at once apparent, from observations of the feeding habits of the flies, that they could be easily destroyed if the fruit were coated with some kind of poison. As already shown, the flies continually moisten and sip up the surface gum of the apple. Most insects, and flies generally, are known to be fond of sweets, so it is a common practice to use poison in a sweetened mixture in destroying them. Berlese (1905) reported gratifying success from the use of a sweetened arsenate against the olive fly in Italy. The mixture contained the following: 65 parts molasses, 31 parts honey, 2 parts glycerin, and 2 parts arsenite of soda. Before its use, this stock mixture was diluted with 10 parts water. Although only a small quantity of this preparation was used on each tree, the value of the sweets and the glycerin made it expensive, and later experiments have been conducted to develop a poisoned bait at lower cost.

Poisoned baits have also proved very effective against the Mediterranean fruit-fly in South Africa, as reported by Lounsbury (1907) and Mally (1909). The importance of these experiments warrants a brief summary:

When C. W. Mally entered on the work of the newly established office of Eastern Province Entomologist, which was created in 1903 under the Government Entomologist of South Africa, C. P. Lounsbury, the fruit-fly problem was taken up as one of the important subjects for investigation. The results of these early observations were given by Mr. Mally (1904), when he reported the probable value of an entirely novel control measure — that of destroying the adult flies by a very light sprinkling of a poisoned sweet over the trees. Various obstacles preventing, Mr. Mally was unable to make a striking demonstration of the value of this remedy until the season of 1909. A severe outbreak of the pest in a commercial peach orchard was so thoroughly controlled that the fruit maturing later was marketed under the guarantee of freedom from maggots. The infestation of fruit on the treated trees fell from fifty per cent to less than one per cent, while that on untreated trees a few hundred yards away increased until practically every fruit was involved. The remedy developed by Mr. Mally, after a long series of tests of the attraction of various sweets to the flies, is a simple one and requires no expensive equipment. The ingredients for the poisoned bait may vary greatly, but Mr. Mally recommends:

Sugar or molasses	$2\frac{1}{2}$ pounds or 25 pounds
Paste arsenate of lead	3 ounces or 2 pounds
Water	4 gallons or 40 gallons

A light sprinkling of about a pint of the mixture to each ten-years-old tree was applied with a common brass garden-syringe. Mr Mally states that the bait does not need to remain in liquid condition in order to be available for the flies. Even films of sweet that were so thin that they merely gave the leaves a glossy appearance were so perfectly removed by the flies that not a visible trace was left. Mr. Mally found that when honey was used in the bait the bees were attracted, but that they did not come to the molasses. It was thought advisable to apply the spray every ten to fourteen days while the flies were in the field, and to renew it after each rain.

Mr. Mally found that the flies did not drop dead immediately after feeding on the bait, although the poison began to take effect in a short time and their destruction was completed in about twenty-four hours. But during this time the poisoned flies showed that they were too sick to think of depositing eggs. The same fate awaited the fresh flies as they emerged from the ground. The fact that they must feed for a number of days before the eggs are sufficiently mature to be deposited gives ample time for them to find the bait.

Being much encouraged by the success of these experiments, the writer decided to try here the effects of poisoned baits on apple-maggot flies.

As has been noted above, several of the varieties of apples in the insectary yard were badly infested. The Primate apples were already full of larvæ, and the flies were still abundant in the tree when the following experiments were begun:

1. On July 19, 1911, a poisoned bait was made up, as described by Mally, and about a pint of this mixture was sprayed on the lower leaves and fruit of the Primate tree. It at once attracted a swarm of yellow-jackets and flies, but the fruit-flies were slow in coming. Later, however, several were seen sipping from the surface of the poisoned apples. These flies were then collected and confined in jelly-glasses, in the same manner that the writer had been keeping flies which had eaten no poison. Yellow-jackets were confined in the same way in order to see when they would succumb to the poison. The flies lived twenty to thirty-six hours, and some of the yellow-jackets were still alive after two days, when they were turned out.

These experiments were repeated several times for a week, with no difference in results. The hornets gradually became very scarce, however, so possibly they died after a time. While they were feeding they were observed to spit out, from time to time, a small white chunk of the insoluble arsenate that they had strained out with the hairs on their tongues. This led to the belief that the flies might be performing a similar straining process and thus avoiding the poison. Quick results were desired, so that the flies would fall over soon after eating the poison. A soluble poison was sought, and the following fly destroyer, as given by Merck, was tried:

Potassium arsenate.....	1 part or 1 pound
Sirup.....	4 parts or 4 pints
Water.....	45 parts or 45 pints

2. On July 22, 1911, this was applied in the same way with a small hand-spray, about a pint to the lower branches of the twenty-years-old Maiden Blush tree. The flies had been abundant and ovipositing on this tree for the past two days. They were observed to feed on the sprayed fruit shortly after and were collected in glasses, where they became paralyzed in about fifteen minutes and in half an hour they were dead. Live flies were found on the tree the next day, however, although none were observed ovipositing. Two female flies were found dead — one on a leaf and the other on a poisoned apple, both hanging by their claws. A second application of the spray was made on the 26th of July, and not a single fly could be found on the tree after that date although observations were often continued for an hour at a time and many flies could be found on near-by unsprayed trees. No bees were seen at any time feeding on the poisoned bait — a condition of affairs that seemed rather strange, since there are several swarms in the insectary yard.

The soluble arsenate burned the leaves somewhat, but so few were affected that this was of little consequence. The apples began to drop on August 1, and were picked up daily throughout the season, a careful record being kept of the larvæ that emerged. The first of the maggots appeared on August 9, 1911, and the number emerging from the first drops gradually increased up to the 18th, after which time they became less and less, the last appearing on August 23.

The drops of successive days after August 2 showed a rapid decrease in the number of larvæ emerging, up to August 15. All the fruit from that date to the end of the season was absolutely free from larvæ.

From an untreated tree of the same variety in another field, the writer gathered one hundred and eighty drops on August 23; from these apples four hundred and sixty-seven larvæ emerged during September. This is an infestation of 2.59 larvæ per apple, while one hundred and fifteen drops of the same date from the treated tree failed to show a trace of a single maggot.

Hence it is quite evident that the flies deposited no eggs in the fruit of the sprayed tree after the application of July 26.

These results with the Maiden Blush apples were so marked that it seems best to give here the daily record of drops and of emergence of larvæ. This is shown in the table on the following page.

In the spraying experiments during 1912 most gratifying results were obtained. The first flies were found on Red Astrachan apples on July 2. These trees had been thoroughly infested for a number of years and most of the fruit was left on the ground the previous season, hence another attack would naturally be expected. Indeed, the field cage in the insectary, which contained about a pailful of Red Astrachan apples, developed an abundance of the flies, as is shown in the description of the fifth experiment, page 148. On July 3, 1912, these early apples were sprayed with the sweetened arsenate bait. This season less molasses was used than in former experiments, the final recommendation being:

Cheapest molasses.....	1 pound or 25 pounds
Arsenate of lead.....	3 ounces or 5 pounds
Water.....	4 gallons or 100 gallons

It was the intention to apply this mixture three times; the applications to be ten days apart, beginning when the first flies appeared on the trees. Several rains, however, made five sprayings necessary. From time to time the emerging flies were found on the sprayed trees; often they were seen feeding on the bait. These flies were collected and they invariably died within a few days. Also, several times dead flies have been found clinging to the leaves on the trees.

TABLE SHOWING EFFECTS OF SPRAY ON MAIDEN BLUSH APPLES (1911)

Date of drops	Number of drops	Record of emergence of larvæ																															Total number of larvæ	Average number of larvæ per 100 apples
		August																										September						
		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4						
August 2	120	1	2	..	5	5	6	6	8	6	10	9	6	3	..	2	*3	..	..	..	..	..	..	..	..	..	..	..					72	60.0
August 3	148	..	..	..	1	6	5	4	18	6	14	6	5	10	1	2	..	..	..	..	..	..	..	..	..	..	..	..					78	52.7
August 4	121	..	..	..	..	..	..	1	2	6	8	6	5	2	5	4	*5	..	..	..	..	..	..	..	..	..	..	..					44	36.4
August 5	137	..	..	..	..	..	..	1	1	7	8	5	5	5	7	5	*12	..	..	..	..	..	..	..	..	..	..	..					56	40.9
August 6	114	..	..	..	..	..	..	..	..	..	..	..	2	1	2	..	6	7	..	2	2	..	1	..	1	..	..	..					24	21.0
August 7	116	..	..	..	..	..	..	..	..	2	2	..	..	..	2	..	5	4	4	1	1	2	3	..	1	..	..	*3					30	25.9
August 8	87	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	1	3	1	2	2	..	1	..	..	..					13	14.9
August 9	75	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	1	1	..	..	..	2	..	..	1	..	..					8	10.7
August 10	45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..					2	.04
August 12	58	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..					0	0
August 13	63	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	..	1	..	..	1					5	.08
August 15	101	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	1					2	.02
August 16 to September 4	1,464	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..					0	0

*These were puparia found in the decayed apples.

Date of drops	Number of drops	Record of emergence of larvæ for check																															Total number of larvæ	Average number of larvæ per 100 apples
		September																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	28	30						
August 23	180	10	38	34	12	14	20	39	52	24	13	49	30	32	12	8	16	0	12	10	0	9	9	0	10	7	6	1					467	259

On July 20, 1912, the flies began to appear on the Maiden Blush apples. This was just one day ahead of the previous year's record. Referring to the table of the Maiden Blush experiment of 1911, it will be seen that all the drops were picked up daily; therefore these flies must have come from some of the other trees, which are some distance away. Evidently, picking up the drops was not effective in this case, when other infested trees were near by. On August 5, 1912, the Red Astrachan apples were ripening and showed no trace of the maggots, and none of the flies were then to be found on the tree. Hence it would appear that the period of emergence was past for the early fruit and the trees had escaped an infestation.

The writer has found the most practical method of applying the bait to be by means of a hand syringe (Figs. 43 and 44). This is a common brass garden-syringe of English make, and is the same kind that Mally used in his experiments in South Africa. It can be purchased from most of the large seedsmen. This syringe holds just a pint, which is enough for a tree of moderate size. The process is very simple and even a small orchard of fifty trees may be treated without further expense for apparatus.

Slight difficulty was experienced in controlling the flies on a seedling variety of sweet apples. Showers came up nearly every afternoon during the period that the poisoned bait was being applied to the tree, and this may account for the fact that a few of the flies came to maturity and were able to oviposit in the fruit. Even in this case, however, the fruit was vastly improved over former years.

If the conditions are such that the flies do not succumb readily to this treatment, the use of the soluble potassium arsenate is advisable as previously described.

Codling-moth spray

More recent observations in the commercial orchards led to the belief that even the codling-moth spray of arsenate of lead would control the apple maggot, if thoroughly applied as is commonly done for the second spray — say the latter part of June, this being just the time to reach the newly emerging flies in this locality. As has been noted above, the flies must feed for two or three weeks before they are ready to oviposit. All this time they have in which to eat poison, so that even a very slowly-working dose would destroy them before they could do any damage. In order to test this, small twigs of apples were sprayed with arsenate of lead, 2–50, just as is used for codling moth, and these sprayed fruits were enclosed in cages with flies, other cages being used for checks. Daily, and in some cases several times a day, the foliage and fruit were given a mist spray of water to represent dew and to supply the necessary moisture

FIG. 43.— *Method of applying poisoned bait*

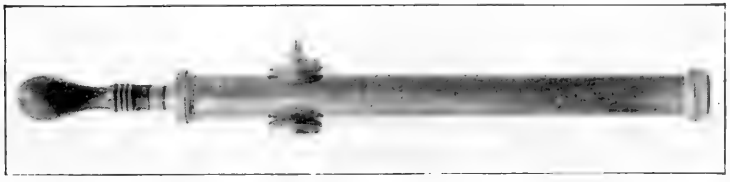

FIG. 44.— *The brass garden-syringe used in the experiments*

for the flies. The writer thinks, also, that the natural moisture on the sprayed fruit in the field makes it easier for the flies to get the effect of the poison. As noted in the life history, the flies are able to dissolve most substances on the surface by using the saliva that they force out of their mouths from time to time while feeding.

The results were most satisfactory, for in the poison cages half of the flies were dead after two days and in three and a half days the last one had succumbed, while all were alive in the check cages. This experiment was repeated several times without any material change in the results. Although a laboratory test can never be conclusive, these results are very encouraging for further trials in the field.

Professor L. H. Bailey states that his orchard near Willow Creek was infested with the apple maggot before the trees were sprayed by a power machine for codling moth. The writer visited the orchard early in September, 1911, and the manager, Mr. Higgins, stated that the worthless fruit was usually left under the trees, as only sound fruit was disposed of. Mr. Higgins also said that he had never seen a trace of the pest since they had used the power sprayer and covered the whole orchard. After cutting dozens of fallen apples of the varieties most susceptible, only one larva was found and that was in a Sweet Russet. In a neglected orchard in the neighborhood, every variety was found to be badly infested, even the Kings, Greenings, and Baldwins. Subsequent observations in other sprayed orchards confirm the above. No reports of this pest ever come from the Lake Ontario region, where orchards are generally well cared for and sprayed.

L. Cæsar, of the Canadian Agricultural Experiment Station at Guelph, Ontario, wrote on October 16, 1911, that this pest was found in Ontario over a large part of the province but that in no county, so far as was known at that time, was there any appreciable amount of damage done to commercial orchards, and that the insect was far worse in towns and villages than in the open country.

CONCLUSIONS

The writer's results and observations would indicate that the thorough-going orchardist will possibly have but little to fear from this insect, for it appears very probable that in spraying and caring for his orchard, as he must do in order to avoid other pests, he will incidentally destroy this one.

In towns or cities where there is, here and there, a tree badly infested, the most practicable remedy would appear to be the poisoned bait; using only a small amount, which may be applied with an inexpensive hand-spray. For early varieties the first application should be made about July 1; for later apples it should be made toward the end of July, or when the flies appear.

SUMMARY

Distribution

The principally infested districts extend from New Brunswick, Quebec, and Ontario, south to Pennsylvania, with a single record from North Carolina; westward to Iowa and Wisconsin, with brief mention in Minnesota, South Dakota, and Colorado.

Host plants

Haws and wild crab-apples appear to have been the original foods. Subsequent records show cultivated fruits to be attacked, principally apples, although pears, cultivated crab-apples, and huckleberries are also included.

Seriousness of the pest

The pest is generally distributed in unsprayed, neglected orchards throughout its range. Damage is often reported of half, sometimes the whole, crop. From New Hampshire, ninety-five per cent of the orchards are reported as infested.

Other fruit-flies

Related species have done serious damage to the fruit industry of other countries. Methods used in the control of these exotic species are likely to prove of value here.

Life history

The flies begin to emerge the latter half of June and continue up to August 1. They feed by constantly sipping the surface gum of the fruit, often moistening the surface, if dry, with a drop of saliva. The eggs are laid singly in punctures made in the skin of the fruit by means of the very slender ovipositor. The eggs hatch in two to six days, depending on the temperature. The larvæ feed in the pulp of the fruit for two weeks to two months or more, depending on the hardness of the fruit and on the temperature. The pupa stage is usually spent in the ground, one or two inches beneath the surface, although puparia are often found within decayed fruit. The pupal period may last for only about a month for the early-emerging larvæ, but it continues over the winter in late varieties.

Second-brood flies.— Flies emerged, from the first to the last of September, from larvæ which went into the ground in July. Only about one third of these early pupæ developed second-brood flies; the others remained dormant during the winter and began emerging July 2, 1912.

Length of life of the flies.— Although the flies lived in confinement for thirty to fifty days, they probably last much longer under natural conditions.

Reproductive system.— Three or four hundred eggs are produced during the lifetime of the fly; these develop in succession and are deposited as soon as mature.

Methods of control

Picking up windfalls may rid the orchard of the pest if consistently followed up, but it is a laborious process. Even the destruction of drops by hogs is sometimes ineffective.

Several experiments have shown that the flies are able to emerge when buried deeply in the soil, hence plowing in the fall or spring cannot be counted on for a remedy; and covering the infested fruit in pits is not recommended.

Citronella oil, kerosene, and quassia are apparently worthless with these flies.

Cold-storage stops the development of the larvæ and may kill them if long continued.

Larvæ failed to pupate in dry soil, their bodies shriveling and dying within the puparium; hence cultivation may prove of value by keeping a dust mulch in the surface.

There is little to fear from larvæ that go to the bottoms of boxes and bins, as they were found drying in all cases observed and none were found emerging.

Poisoned bait.— Sweetened arsenate of lead proved effective but was rather slow, so that in the writer's early experiments soluble potassium arsenate was tried. This killed the flies in thirty minutes. Subsequent observations indicate that the arsenate of lead alone may control this pest if applied thoroughly to the fruit, as is done for the codling moth.

Experiments during the season of 1912 showed gratifying results from the use of the following mixture:

Cheapest molasses	1 pound
Arsenate of lead	3 ounces
Water	4 gallons

This should be applied when the flies first emerge and repeated every ten days while the flies are in the field; and it must be renewed after each rain. The writer has not had an opportunity to try arsenate of lead, without sweetening, on a block of infested trees; but in the case of a commercial orchard that was affected, he would place considerable confidence in the effectiveness of this remedy. The main object in any case, however, is to keep poison on the trees during the time of principal emergence of the flies, so that they can get it before the eggs are mature and ready to be laid.

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Mr. Ward writes from Vermont that a small legless worm, about one quarter inch long, bored his apples very badly in 1865; fully one half their value was destroyed.

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Brief notes on habits.

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States that this new and formidable enemy of the apple, the apple maggot, prevails generally throughout the Hudson River country, but has not yet reached New Jersey.

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Flies reared from Illinois haws, five or six years previously. Larvæ from winter apples received from Wallingford, Conn., November, 1866; July, 1867, flies emerged. December 28, 1866, a further supply of maggots from East Falmouth, Mass.; July, 1867, flies emerged. During the same winter pupæ were received from North Hempstead, Long Island; July, 1867, flies emerged.
Apple maggot compared with codling moth. " The eggs inserted by the ovipositors of these flies into the flesh of the apple."
Description of fly, from six males bred from eastern apples July 15 to 23, two males and one female bred from Illinois haws July 23 to 28.

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Brief reference to record of *Trypeta pomonella* by Walsh, as destructive to stored apples.

1872. Riley, C. V.— The apple-maggot fly. American Agriculturist, vol. 31, pp. 263–264, illus.
In answer to a letter from J. H. Spatter, Keene, N. H. (first record from this State). Comparative description of apple-worm moth and apple-maggot fly, with figures showing work of each insect and the several stages. Remedies suggested: Cover the ground entirely with flagstones or brick. Cover the ground with salt, ashes, or lime. Destruction of infested fruit. Cultivation in spring.

*Original not seen.

1873. Loew, H.— T. pomonella. Monograph of the Diptera of North America, Part III, pp. 265–268. Smithsonian Institution, Washington.
Excellent description of the fly, made from a single specimen. Places this species in the subgenus *Rhagoletis*, which he had formed for European specimens in 1862 — Monograph of European Trypetidae.

1874. Glover, T.— Manuscript notes from my journal, Diptera, p. 58, pl. ix, fig. 14.
Brief reference to authorities on *Trypeta pomonella*.

*1876. Riley, C. V.— Apple maggot. New York Semi-Weekly Tribune, December 15.
Answer to letter of P. M. Augur; description of larva and adult; ravages, food plants, habits, and means of control; literature of the subject.

1878. Osten Sacken, C. R.— Cat. Dip. N. A., 2d ed., p. 191. Smithsonian Institution, Washington.
Brief statement giving authorities. In this work *Rhagoletis* is considered as a subgenus of the old genus *Trypeta*.

1880. Riley, C. V.— Amer. Ent., vol. 3, p. 160.
A brief note regarding change in feeding habit of the apple maggot, from haws to cultivated apples.

1882. Comstock, J. H.— The apple maggot. Rept. U. S. Comm. Agr., 1881–1882, pp. 195–198, 1 pl. See same in author's edition, pp. 3–6.
A discussion of the importance, as compared with codling moth; description of larva, pupa, and adult. Remedies: Destroy drops, and use sweet varieties as traps, destroying all fruit from these trees.

1882. Treat, M.— The apple maggot. Injurious insects of the farm and garden, p. 164, illus.
Brief account of insects and their work.

1883. Harlow, S. C.— Trans. Maine Pom. Soc., 1882, p. 108.
Work of the apple maggot increasing. Works on Golden and Hightop Sweet, Danver's Winter Sweet, Gravenstein, Jenneting, and Porter.

*1883. Lintner, J. A.— The apple maggot. Bul. LXXV, N. Y. (Geneva) Agr. Exp. Sta. Also, 2d Ann. Rept. N. Y. St. Ent., 1885, pp. 117–125.
General notes on life history and distribution.

1883. Riley, C. V.— The apple maggot or railroad-worm. Stoddart's Encyclopædia Americana, vol. 1, p. 135.
Brief description, habits, and remedy by destroying infested fruit.

1883. Saunders, W.— The apple maggot. Insects injurious to fruits, pp. 135–136, illus. See also second and third editions.
Brief description, habits, and life history.

1883. Anonymous.— The apple maggot. 26th Rept. Maine Bd. Agr., 1882, pp. 409–412. Also, Trans. Maine St. Pom. Soc., 1882, p. 101.
Extracts from paper by Professor Comstock in Rept. U. S. Dept. Agr., 1882.

1884. Cook, A. J.— The apple maggot. Country Gentleman, vol. 49, p. 857.
A half-barrel of apples from Shiawassee county, Michigan, entirely ruined, also common in apples about Lansing. In 1883 apples from Delavan, Wis., infested. Insect well known in thorn apples in Michigan, Wisconsin, and Illinois, for years; but this is the first time that it is known to have attacked Michigan apples. The apples infested ripen early and fall. These should be quickly destroyed.

1884. Cutting, H. A.— The apple maggot. 8th Rept. Vt. St. Bd. Agr., 1883–1884, pp. 259–263, illus.
Reprint of Comstock's paper, 1881.

*Original not seen.

1884. Gardiner, R. H.— 27th Rept. Maine Bd. Agr., 1883, p. 332. Also, Trans. Maine St. Pom. Soc., 1883, p. 30.

Reports the apple maggot very destructive to Talman Sweet, Red Astrachan, and Mother apples, but not to other trees.

1884. Gilbert, Z. A.— 27th Rept. Maine Bd. Agr., 1883, pp. 363–364. Also, Trans. Maine St. Pom. Soc., 1883, p. 61.

Discusses apple maggot as a new and serious enemy. Reports damage to tart apples, such as Benoni, as well as sweet. No remedy known.

1884. McLellan, T. S.— 27th Rept. Maine Bd. Agr., 1883, p. 345. Also, Trans. Maine St. Pom. Soc., 1883, p. 43.

Reports another destructive insect, a new " worm " which appeared five or six years ago in Maine apples. Three years ago the early sweet apples were affected. Haley, Hurlbut, Nodhead, Primate, and Porter more or less infested.

1885. Blossom, L. H.— 28th Rept. Maine Bd. Agr., 1884, p. 368. Also, Trans. Maine St. Pom. Soc., 1884, p. 70.

Reports the apple maggot as a newcomer; in sweet apples, both fall and winter. Remedy: Gather and cook infested apples and feed to hogs.

1885. Cook, A. J.— The apple maggot. Rural New Yorker, vol. 44, pp. 86–87, illus.

This pest doing considerable damage in Michigan. Brief notes on life history, with figures from Comstock. Remedy: Allow stock to feed on drops.

1885. Cook, A. J.— The apple maggot. 14th Ann. Rept. Mich. St. Hort. Soc., 1884, pp. 200–203, illus.

This pest was destructive to apples in Wisconsin in 1883, and generally distributed in Michigan in 1884; at least six counties heard from. Brief notes on life history and comparison with codling moth. Remedy: Poisons placed on fruit of no value for this pest. Sheep or hogs in orchard to destroy drops.

1885. Lintner, J. A.— The apple maggot. 2d Ann. Rept. N. Y. St. Ent., pp. 117–124, illus.

General notes on life history and distribution. Dr. F. W. Goding, of Ancona, Mich., states that he has seen the larvæ eating the fruit of Michigan apples in January, but that soon after they entered the earth and changed into pupæ. Some that were kept in a cooler room did not change until March. From the earliest pupæ, flies were obtained about February 1. (Fruit Growers Journal, Cobden, Ill., April 30, 1885.)

Other species of similar habits:

1. The apple fly (*Drosophila* sp.?) matures in August and there is another generation. Packard's Guide to the Study of Insects, p. 414; Saunders' Insects Injurious to Fruits, p. 137.
2. Apple midge (*Molobrus mali*), pupa distinct, remains within the apple.

1888. Augur, P. M.— The apple maggot. Trans. Maine St. Pom. Soc., pp. 101–102. Also bound with 31st Rept. Maine Bd. Agr., 1887–1888.

Reports serious trouble with this pest; some varieties of apples ruined. States that *after thorough spraying with arsenicals the pest practically disappeared.* The following quotation is interesting:

" To our surprise, those varieties which had hitherto been badly affected by the maggot, last fall we found almost completely exempt as they were for codling moth. We found occasionally a specimen, enough to show that we still had it, but not enough to interfere with the marketing the fruit. . . . . I would not say but our exemption from the maggot may be due to some circumstance that we do not understand. It is not proved yet that it is owing wholly to the application of poison to our trees, but we are strongly inclined to think that that had a considerable influence. If we know just how the insect feeds and the season of its appearance and disappearance, it will be of great benefit to us. . . . I should say without hesitation that I have so much confidence that the insecticide had an effect in ridding us of the maggot that if the codling moth was entirely gone, I should still use the poison for the apple maggot. . . . . It seems, as far as our experience is concerned, that we had nearly escaped it."

1888. Braun, C.— Trans. Maine St. Pom. Soc., pp. 84–85. Also bound with 31st Rept. Maine Bd. Agr., 1887–1888.

Gives brief outline of habits of the apple maggot.

1888. Knowlton, D. H.— Trans. Maine St. Pom. Soc., pp. 9–10. Also bound with 31st Rept. Maine Bd. Agr., 1887–1888.

Reports the apple maggot increasing rapidly in the State. Some of the fruit-growers *advocate spraying the trees with arsenates*; others, feeding the infested fruit to stock.

1889. Cook, A. J.— The apple maggot. 2d Ann. Rept. Mich. Agr. Exp. Sta. pp. 96–97. See same in Rept. Mich. St. Bd. Agr., 1888–1889.

This pest troublesome for several years in Michigan. The remedy of feeding affected fruit to stock proved successful. Plums and late cherries from northern Michigan said to show attack of this same insect.

1889. Cordley, A. B.— The apple maggot. Orchard and Garden, vol. II, p. 192, illus.

Comparison with codling moth. Records apples infested in Michigan, Wisconsin, and Illinois. Also abundant on hawthorn everywhere in Michigan. Notes larvæ and pupæ found in plums and cherries from northern Michigan.

1889. Davis, G. C.— A new departure by the apple-maggot. Ohio Farmer, November, p. 291.

Records occurrence in plums and cherries in Michigan. Only larvæ and pupæ seen.

1889. Harvey, F. L.— The apple maggot. Bul. 2, s. s., Maine Agr. Exp. Sta., pp. 1–5.

Brief notes on life history.

Control — Useless methods: 1. Spraying. 2. Feeding with poisoned sweets. 3. Sticky fly-papers. Preventive measures: 1. Keep in grass and burn grass in fall. 2. Plowing in spring. 3. Avoid sandy soil and sheltered locations for orchards. 4. Prevent by law the importation of fruit from infested districts. Direct methods: 1. Catch flies. 2. Destroy windfalls, also infested fruit, (a) in market, (b) stored. 3. Burning or feeding infested fruit. 4. A radical method: Destroy the entire crop for one season. Let the fruit almost mature, and then destroy by feeding to stock.

1889. Harvey, F. L.—The apple maggot. Rept. Maine Agr. Exp. Sta., 1888, p. 175. Also bound with 32d Rept. Maine Bd. Agr., 1888–1889, p. 139.

Description of fly. Newly hatched larvæ observed August 1, apples one inch in diameter. Remedies: Plowing, destruction of windfalls. Spraying does no good.

1889. Maynard, S. T.— Trans. Maine St. Pom. Soc., p. 56. Also bound with 32d Rept. Maine Bd. Agr., 1888–1889.

Brief notes on habits of the apple maggot, with remedy by destroying infested fruit.

1889. Perkins, G. H.— Trypeta pomonella Walsh. 2d Ann. Rept. Vt. Agr. Exp. Sta., 1888, pp. 135–138.

This pest not long known in Vermont. History and description of insect. Eggs deposited *on* the fruit at the end of summer. In most sections chiefly in early apples, although not true in Vermont, where the late fall and winter varieties suffered most. This insect more abundant in New England but also reported from Mississippi Valley and over most of the Northern States. In some cases entire crop destroyed.

1889. Pope, C. S.— Trans. Maine St. Pom. Soc., p. 26. Also bound with 32d Rept. Maine Bd. Agr., 1888–1889.

Reports the apple maggot as widespread; working in sheltered places and around buildings.

1889. Williams, E.— Trypeta pomonella in New Jersey. Garden and Forest, October 30, p. 527.

Records the apple maggot at Montclair, N. J., infesting trees of Jersey Sweet and Golden Sweeting. Considers it the worst pest of the apple. "First noticed about a dozen years ago."

1889. Committee.— Trans. Maine St. Pom. Soc., p. 117. Also bound with 32d Rept. Maine Bd. Agr., 1888–1889.
The apple maggot distributed over a large part of the State in sheltered areas, not generally injurious to fruit in large orchards.

1890. Harvey, F. L.— The apple maggot. Rept. Maine Agr. Exp. Sta., 1889, pp. 190–241, pl. i-iv.
Reprint of monograph on this insect.

1890. Anonymous.— A peach pest in Bermuda. Ins. Life, vol. 3, pp. 5–8, illus.
Brief history of *Ceratitis capitata*. This species has infested the peaches of Bermuda for twenty-five years. Larvæ that entered the soil on April 23 emerged as flies on May 9.

1891. Osborn, H.— The apple maggot. Bul. 13, Iowa Agr. Exp. Sta., pp. 109–113, illus.
Many reports of damage from this pest in the State during the past year. Condensed statement and figures from Harvey's account. It is thought that the pest was introduced from Missouri.

1891. Riley, C. V.— Professor Harvey's bulletin on the apple maggot. Ins. Life, vol. 3, pp. 253–255, illus.
A review with figures from Professor Harvey's report on the apple maggot.

1891. Weed, C. M.— The insect record for 1890. 9th Ann. Rept. Ohio Agr. Exp. Sta., p. lxiv.
The apple maggot reported as doing damage in Delaware county.

1891. Anonymous.— Some of the most common fungi and insects, with preventives. Bul. 35, N. Y. (Geneva) Agr. Exp. Sta., p. 623.
Brief note on habits of the apple maggot.

1892. Osborn, H.— Insects of the season in Iowa. Bul. 26, Div. Ent., U. S. Dept. Agr., p. 62.
Reports indicate that the apple maggot was common in some parts of the State during the year 1890, but not reported in 1891. This leads to the supposition that it may not thrive under Iowa conditions.

1892. Saunders, W.— Insects injurious to fruits, second edition, pp. 135–136, illus. See also third edition.
Brief description of the apple maggot and its habits.

1893. Chambliss, C. E.— Some injurious insects of the apple. Bul. Tenn. Agr. Exp. Sta., vol. vi, no. 1, p. 26.
The apple maggot mentioned as injurious to the apple.

1893. Harvey, F. L.— Rept. Maine Agr. Exp. Sta., 1892, p. 99.
Records work of apple maggots in Vermont pears; also known to work in pears in Maine.

1893. Osborn, H.— The apple maggot. Rept. Iowa St. Hort. Soc., 1892, pp. 112–113, illus.
Occasional reports of damage by the insect, from various parts of Iowa. Brief notes on habits; illustrated from Harvey. Remedy: Destroy infested fruit by feeding to swine, or cover with a foot or more of earth.

1893. Weed, C. M.— The apple maggot or railroad worm. 3d and 4th Ann. Repts. N. H. Agr. Exp. Sta., pp. 254–255.
Brief notes on life history and comparison with codling moth. Remedy: Destruction of infested fruit.

1894. Harvey, F. L.— Rept. Maine Agr. Exp. Sta., 1893, p. 148.
Brief note on the apple maggot. Still doing much damage to the apples of Maine and adjoining States.

1894. Howard, L. O.— The apple-maggot in North Carolina. Ins. Life, vol. 7, p. 279.

Apples from Waynesville, N. C., contained larvæ of *T. pomonella*. Recorded for a new locality.

1894. Perkins, G. H.— The apple maggot. 7th Ann. Rept. Vt. Agr. Exp. Sta., 1893, pp. 130–135.

Description of life history and figures from Harvey's report. "The larvæ may change to pupæ in fruit."

1894. Snow, W. A.— Descriptions of North American Trypetidae, with notes. Kans. Univ. Quart., vol. 2, pp. 159–174, 2 pl.

R. pomonella is briefly noted on page 164. The next species that is here described as similar to the above, *R. zephyria*, is probably only a variation of *R. pomonella*, as pointed out by Doane (1898). Described from three males from southern California. Smaller than *R. pomonella*. The fourth band fills out to the tip of the wing to a greater extent; the hyaline space between the second and third bands reaches the fourth vein, while in *pomonella* it ends some distance below. Length, 2.5 to 3 mm. Two other males from the same locality show varietal differences in wing.

1896. Gillette, C. P.— 9th Ann. Rept. Colo. Agr. Exp. Sta., 1896, p. 145.

The apple maggot taken at Colorado Springs. This pest doubtless introduced in infested apples from the East.

1896. Harvey, F. L.— Rept. Maine Agr. Exp. Sta., 1895, Part II, p. 93.

The apple maggot continues to be a great pest. Spreading. Several report holding the pest in check by destroying windfalls.

1896. Perkins, G. H.— Apple maggot. 9th Ann. Rept. Vt. Agr. Exp. Sta., 1895, p. 118.

One of the most troublesome pests of the State. No very satisfactory remedy discovered. Destroy windfalls by feeding to swine. Spraying not effective.

1896. Weed, C. M.— The codling moth and the apple maggot. Bul. 35, N. H. Agr. Exp. Sta., pp. 31–35, illus.

The apple maggot compared with the codling moth. Brief notes on life history of the apple maggot. "The flies continue to emerge all summer." "Spraying does not prevent the injuries of the apple maggot." Control by destroying windfalls.

1896. Weed, C. M.— Bul. 40, N. H. Agr. Exp. Sta., p. 92.

The crop of apples so large that the injury from maggots is not noticed.

1896. Willis, J. J.— Apple maggot. Gardeners' Chronicle, ser. 3, vol. 20, p. 331.

Brief notes on habits and life history. Remedy: Destroy windfalls.

1896. Williston, S. W.— Trypetidae. Manual of the families and genera of North American Diptera, second edition, pp. 119–123. See also third edition.

Gives general characters of family.

1897. Fletcher, J.— Insects injurious to Ontario crops in 1896. 27th Ann. Rept. Ent. Soc. Ont., 1896, pp. 65–67.

This is the first time that the apple maggot has appeared in Canada; infestation in orchard of Dr. D. Young, at Adolphustown, Ont. Notes on life history and remedies from Harvey's paper.

1897. Fletcher, J.— The apple maggot. Report of the Entomologist and Botanist. Rept. Exp. Farms Can., 1896, pp. 256–258, illus.

Brief notes on life history. "The pupa state assumed only a few days before the perfect insect appears." Brief history of distribution and importance. Infested apples received from Dr. D. Young, Adolphustown, Ont., north of Lake Ontario, August 31, 1896. Remedies: Spraying with poisons useless. Destruction of windfalls.

1897. Harvey, F. L.— Notes on the insects of the year. 12th Rept. Maine Agr. Exp. Sta., 1896, p. 120.

The apple maggot almost disappeared in some localities where it was very bad before. Hard winter during past two years may have destroyed pupæ. Flies fragile and easily injured.

1898. Doane, R. W.— A new Trypetid of economic importance. Ent. News, vol. 9, pp. 69–72.

Gives table for separating the species of the genus *Rhagoletis* that have been discovered since the publication of Loew's monograph.

NOTE.—Refers to *R. zephyria* Snow as being indistinguishable from *R. pomonella* Walsh, although the description was drawn from three males from California, the only difference being in size.

1898. Fletcher, James.— The apple maggot. Report of the Entomologist and Botanist. Rept. Exp. Farms Can., 1897, p. 201, illus.

This pest not increased during past year. The ground under infested trees was well plowed and cultivated. Remedy: Destroy windfalls.

1898. Howard, L. O.— Danger of importing insects. Ybk. U. S. Dept. Agr., 1897, pp. 529–552, illus.

The Mexican orange-fly (*T. ludens*) and a peach fly (*T. acidusa*) discussed fully; also the Mediterranean fruit-fly (*Ceratitis capitata*). Brief mention of the apple maggot, page 546.

1899. Beach, S. A., Lowe, V. H., and Stewart, F. C.— Common diseases and insects injurious to fruits. Bul. 170, N. Y. (Geneva) Agr. Exp. Sta., pp. 395–396.

Brief notes on habits of the apple maggot. Pest spreading in this State. Remedies: Destroy windfalls and plow in fall.

1899. Coquillett, D. W.— Notes and descriptions of Trypetidae. Journ. N. Y. Ent. Soc., vol. 7, pp. 259–268.

Contains a synopsis of the genera.

1899. Doane, R. W.— Notes on Trypetidae, with descriptions of new species. Journ. N. Y. Ent. Soc., vol. 7, pp. 177–193, 2 pl.

Gives the habitat of *R. pomonella*: Massachusetts, Colorado, South Dakota, not known to occur in Washington (State).

"In Ent. News, vol. ix, no. 3, 1898, I set forth my reasons for believing that the segment usually referred to as the ovipositor in this family is really the last abdominal segment, and in drawing up the description of *R. ribicola* referred to it as such. Further study of the group gives additional evidence in support of this view, but in order to avoid confusion I have followed the usual custom and referred to this segment as the ovipositor."

1899. Fletcher, J.— Recent additions to the list of injurious insects of Canada. Trans. Roy. Soc. Can., 2 ser., 1899–1900, sect. iv, p. 223.

Brief note on habits and distribution of the apple maggot. Control by destroying windfalls and spading soil.

1899. Froggatt, W. W.— Notes on fruit-maggot flies, with descriptions of new species. Agr. Gaz. N. S. Wales, vol. 10, pp. 497–504, 3 pl.; also, Misc. Publication No. 303, N. S. Wales Dept. Agr.

A description of the apple maggot at end of the paper. Control: Destroy infested fruit by boiling. Cultivation may help, as also will letting fowls have the run of the orchard. A trap made by placing a candle in a can and surrounding it with kerosene proved rather successful in catching the adult flies, when lighted and placed under the infested trees at night.

1899. Harvey, F. L.— Insects of the year. 14th Rept. Maine Agr. Exp. Sta., 1898, p. 127.

"Was not as prevalent as usual, though doing considerable damage in some parts of the State."

1899. Lounsbury, C. P.— Fruit fly. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1898, pp. 37–40.

Ceratitis capitata infests a wide range of fruits: solanum, grape, prickly pear, apple, peaches, and the like. Remedies: Covering trees with nets successful but expensive. Destruction of windfalls. Repellents valueless. Experiments proved sweetened water solutions of quassia to be of no value in destroying flies, which fed greedily on it although the taste on the fruit was lasting and disagreeable.

1900. Card, F. W., and Adams, G. E.— 13th Rept. R. I. Agr. Exp. Sta., 1899–1900, pp. 247–248.

The apple maggot is one of the most serious pests of the apple in this locality. Experiments of plowing light, sandy soil showed a slight decrease of infestation, although untreated trees were adjoining.

1900. Harvey, F. L., and Munson, W. M.— Apple insects of Maine. 15th Rept. Maine Agr. Exp. Sta., 1899, pp. 136–140, 1 pl. Also published in 1899 as Bul. 56, Maine Agr. Exp. Sta.

Description of the various stages of the apple maggot, life history, and remedies. "The only chance is to destroy the larvæ and pupæ. This is the only reasonable and practicable treatment."

1900. Lounsbury, C. P.— The fruit fly. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1899, pp. 35–36.

Extended experiments with *Ceratitis capitata* show no parasites. The flies are thought to live over the winter, although this has not been demonstrated. Adults lived in confinement sixteen weeks.

1900. Smith, J. B.— *Rhagoletis pomonella*. Insects of New Jersey, 1899, p. 687.

"Montclair, the apple maggot locally injurious; but seems confined to very few varieties."

1901. Card, F. W., and Adams, G. E.— 14th Rept. R. I. Agr. Exp. Sta., 1900–1901, p. 227.

Further experiments in controlling the apple maggot by deep spring plowing of light, sandy soil not encouraging; fully seventy-five per cent of the fruit affected. Untreated trees near by.

1901. Fuller, C.— The fruit fly. 1st Rept. Govt. Ent., Natal Dept. Agr., pp. 70–74, 1 pl., illus.

Ceratitis capitata ranks first among fruit pests of Natal. Infests a wide range of fruits — plums, peaches, apricots, nectarines, apples, oranges, mandarins, mangoes, loquats, guavas, and the like. Four to six eggs placed in a single puncture; several punctures on a single fruit. Life history similar to that of *R. pomonella*. Remedies: Feeding to pigs unsafe, as many maggots fall on ground and escape. Covering trees with net recommended. Flies probably pass the winter among the leaves of evergreens, loquats, and the like.

1901. Lounsbury, C. P.— Fruit fly. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1900, pp. 47–48.

Experiments being made to carry the adults over winter in outdoor cages. One fly lived over.

1901. Anonymous.— The codling moth or apple maggot. Gardeners' Chronicle, ser. 3, vol. 29, p. 32.

A confusion of the apple maggot with the codling moth, which is the insect described in this article.

1902. Banks, N.— Principal insects liable to be distributed on nursery stock. Bul. 34, n. s., Div. Ent., U. S. Dept. Agr., pp. 44–45, illus.

Brief notes on life history of the apple maggot. Illustrations from Harvey. Also, brief note on cherry fly (*R. cingulata*).

1902. Card, F. W.— Improving an orchard. Bul. 83, R. I. Agr. Exp. sta., pp. 149–151.

Brief account of work on the apple maggot. Control by destroying windfalls and experiments of deep plowing to bury larvæ — inconclusive.

1902. Fuller, C.— The fruit fly. 2d Rept. Govt. Ent., Natal Dept. Agr., 1901, pp. 20–21, illus.

Ceratitis capitata possibly has several broods extending from November to July — at least nine months of the year. Flies live thirty to forty days in confinement. Egg stage four days, larval twenty-five days, pupal seven to eleven days. Many maggots remain in fruit to pupate (guavas). Copulation when flies were six days old.

1902. Lindsay, J.— The fruit fly. Queensland Agricultural Journal, vol. ii, pp. 21–23.

Best success by collecting a few oranges, which first ripened, smearing them with a preparation like "tanglefoot," and placing them on the ground under the trees in the evening. The flies were caught in large numbers, while attempting to oviposit.

1903. Lochhead, W.— Insects of the season. 33d Ann. Rept. Ent. Soc. Ont., 1902, p. 67.

Brief note on the apple maggot. Very abundant; in some orchards more than half the fruit injured.

1903. Walsh, B. D.— The apple-maggot fly. First annual report on the noxious insects of the State of Illinois, second edition, pp. 36–42.

"This report has long been out of print and this edition is issued because of the value of the material."

1903. Washburn, F. L.— Apple maggot. Bul. 84, Minn. Agr. Exp. Sta., p. 76. Published also as 8th Ann. Rept. St. Ent. Minn.

Brief reference to remedies by destroying windfalls and spraying with arsenicals; figure of fly.

1904. Cartwright, W.— Notes on two insects. Journ. Khediv. Agr. Soc. and School, vol. 6, pp. 17–19.

The larvæ of *Trypeta capitata* were found injuring oranges by feeding on the pulp of the fruit. In controlling this pest, destroy fallen fruit and treat the soil under infested trees with ferrous sulfate and then water.

1904. Chittenden, F. H.— The principal injurious insects of 1903. Ybk. U. S. Dept. Agr., 1903, pp. 563–566.

Reports the apple maggot as unusually injurious in Ohio and New Hampshire, and many apples injured in other regions found on sale in District of Columbia.

1904. Compere, G.— Introduction of the fruit fly parasite. Journ. Dept. Agr. West Austr., vol. 12, pp. 68–72.

"The Staphylinidae beetles beyond question destroy the major part of the fruit-fly maggots in Brazil, and also destroy a great number of parasites as well, eating every maggot with which they come in contact, not discriminating between those parasitized and those that are not. . . . In Brazil as in India, nature's forces controlling these destructive fruit-flies is complete." This beetle never established in Australia.

1904. Mally, C. W.— The fruit fly. Agr. Journ. Cape Good Hope, vol. 28, pp. 647–662, 1 col. pl., illus.

C. capitata bred through the year. Some have not obtained results from destruction of fallen fruit. Little to be hoped for from natural enemies.

1904. Osborn, H.— Observations on some of the insects of the season in Ohio. Bul. 46, Bur. Ent., U. S. Dept. Agr., p. 88.

Records fruit infested by apple maggot in the market at Columbus; may have come from outside localities. Professor Hine has observed the pest working in fruit from northwestern Ohio.

1904. Patch, E. M.— Apple-maggot and other insects. Bul. 109, Maine Agr. Exp. Sta., pp. 169–178, illus.

Brief description of the several stages of the apple maggot, notes on life history, and the like. Control by destroying windfalls.

1905. Berlese, A.— A probably effective method of destroying *Ceratitis capitata* and *Rhagoletis cerasi*. Redia, vol. 3, pp. 386–388.

The gratifying success from the use of poisoned bait against the olive fly leads the author to believe that the same treatment will be effective against other fruit-flies.

1905. Card, F. W., and Stene, A. E.— The apple maggot. 17th Rept. R. I. Agr. Exp. Sta., 1903–1904, pp. 191–201.

The apple maggot one of the most troublesome pests in Rhode Island. Control by destroying windfalls is expensive. Pupæ from winter apples produce flies the following July 24 to August 15. Experiments in burying pupæ proved to be of no value. Frequent tillage in early summer may be of some value.

1905. Fletcher, James.— The apple maggot. Report of the Entomologist and Botanist. Rept. Exp. Farms Can., 1904, pp. 238–239, illus.

The pest has never done much harm in Canada. Brief description of life history and work. Noticed first at Como, Quebec, by R. W. Shepherd in 1903. Brief notes on the life history and control by destroying drops. Useless to spray with arsenicals. The pupa forms inside the puparium only a few days before the perfect insect appears the next summer.

1905. Isaac.— Mexican orange worm (*Trypeta ludens*) in Mexico. Report of the Commissioner appointed to investigate the prevalence of *Trypeta ludens* in Mexico. Cal. St. Hort. Comm., illus.

Control: Burning, burial, hand-picking, chickens under trees, spraying with sweet— an infusion of *Haplophyton cimicidum* sweetened with sugar, two pounds herb boiled with an equal amount of sugar. The flies eat this with avidity and soon fall to the ground.

Parasite: An ichneumon fly.

1905. Lounsbury, C. P.— Natural enemies of the fruit fly. Agr. Journ. Cape Good Hope, vol. 29, October.

Sixty-five hundred dollars furnished by the several South African colonies to investigate the parasites of Bahia, Brazil. A staphylinid beetle said to be a complete parasite of the Mediterranean fruit-fly (*C. capitata*). Nearly all the fruit on the trees was found to be punctured by the flies. About thirty-eight per cent parasitized by wasp (*Opiellus trimaculatus*), and this is effective only on small fruits with thin pulp, such as cherry and the like. None of the beetles were found. May have been the wrong season. Fruit had to become rotten and fall to the ground before beetles could destroy maggots. Returned to Africa without getting a single effective parasite.

1906. Britton, W. E.— Apple-maggot infesting huckleberries. 5th Rept. St. Ent. Conn., 1905, p. 260.

Apple maggot was found infesting huckleberries during August, 1904; flies reared.

1906. Card, F. W., and Blake, M. A.— Apple-maggot. 18th Rept. R. I. Agr. Exp. Sta., 1904–1905, pp. 197–198.

Insects were partially controlled by hogs in orchard. Thoroughly cultivated orchard had many injured apples.

1906. Felt, E. P.— Apple maggot. 21st Rept. N. Y. St. Ent., p. 91.

Very common and destructive pest of early apples. More abundant in sheltered hollows than on hillsides; probably affected by wind currents.

1906. Fletcher, James.— The apple maggot. Report of the Entomologist and Botanist. Rept. Exp. Farms Can., 1905, pp. 184–185.

The outbreak at Como, Quebec, in 1903–1904 has since spread to many orchards. *Crab-apples badly infested*; this fruit does not fall from the tree.

1906. Fuller, C.— Cold storage as a factor in the spread of insect pests. Natal Agricultural Journal and Mining Record, vol. 9, p. 656.

The fruit-fly maggots may remain alive in peaches kept at a temperature of 39° to 40° F. for a period of one hundred and twenty-four days.

1906. Lounsbury, C. P.— Natural enemies of injurious insects. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1905, pp. 98–99.

Reports expedition to Bahia, Brazil, to investigate natural enemies of fruit-flies. No parasites were obtained.

1906. Mally, C. W.— Fruit fly. Rept. Govt. Ent. for half-year ended December 31, 1904, Cape Good Hope Dept. Agr., pp. 9–10.

Ample evidence to show that these flies breed through the winter when there is fruit for them. The frosts seem to have no effect on adult. Indications are that none of the flies survive the winter as puparia in soil. None emerged.

1906. Patch, E. M.— Insect notes for 1906. Bul. 134, Maine Agr. Exp. Sta., pp. 221–222.

Apple maggot clearly defined in order to avoid popular confusion with codling moth.

1907. Berlese, A.— New experience with the olive fly. Coltivatore, vol. 53, pp. 487–490.

After a continued test of the mixture containing sugar and an arsenical salt, the author believes that this remedy has been definitely proved to give better results than any other which has been tried.

1907. Berlese, A.— The history of certain insect pests of the olive. Redia, vol. 4, p. 180, 3 pl., illus.

In combating the olive fly, excellent results obtained for a number of years from the use of a mixture containing molasses 65 parts, honey 31 parts, glycerin 2 parts, and arsenite of soda 2 parts.

1907. Bethune, C. J. S.— Insect affecting fruit trees. Bul. 158, Ont. Dept. Agr.

Destruction of apple maggot by pigs or sheep in orchards; pick up drops, and so forth.

1907. Chillis, M. de.— The destruction of the olive fly. Coltivatore, vol. 53, pp. 8–11.

The mixture previously recommended, while effective, is rather too expensive. The author therefore experimented with the following and obtained good results: 50 parts molasses, 48 parts grape juice, 2 parts arsenite of soda (crystals).

1907. Compere, G.— Kerosene remedy and the fruit fly. Journ. Dept. Agr. West Austr., vol. 15, pp. 244–245, 1 pl.

A self-feeding kerosene trap has been devised, which seems to have been fairly effective in catching the fruit fly. The odor of kerosene attracts the fly.

1907. Cuboni, G.— Results obtained by Berlese and Silvestri in combating the olive fly. Bol. Quind. Soc. Agr. Ital., vol. 12, pp. 226–232.

Successfully combated by the use of a mixture containing 65 parts molasses, 31 parts honey, 2 parts glycerin, and 2 parts arsenate of soda. Before using, this stock mixture is diluted with 10 parts water.

1907. Dreyer, T. F.— Poison bait for the fruit fly. Agr. Journ. Cape Good Hope, vol. 31, pp. 192–194.

Gives a good translated description of Berlese's experiments. It is believed that the following formula will be best for South Africa:

1 pound arsenate of lead
5 gallons sirup
25 gallons water

Notes the use of this first by Mally in 1903–1904.

1907. Felt, E. P.— Apple maggot or railroad-worm. Country Gentleman, vol. 72, p. 640.

A brief general account, with special reference to control by destroying drops and by other methods. Use of sweet variety for trap, and entire destruction of the fruit before it is ripe.

1907. Fletcher, J.— Apple maggot. Evidences of the Entomologist and Botanist before the Select Standing Committee on Agriculture and Colonization, 1906–1907, pp. 134–135. Ottawa, Canada, 1907.

The apple maggot has done more harm during the past year than at any previous time. Distributed in Quebec, New Brunswick, and Ontario. This pest first appeared in Canada in 1878, in the Bay of Quinte district.

1907. Fletcher, James.— The apple maggot. Report of the Entomologist and Botanist. Rept. Exp. Farms Can., 1906, p. 219.

This pest becoming more abundant and rapidly spreading to new localities. Severe outbreak at Woodstock, New Brunswick.

1907. Hood, C. E.— The apple maggot or railroad worm. Cir. 3, Mass. Agr. Exp. Sta., illus.

Distribution from Maine to North Carolina and west to Minnesota and Wisconsin. Brief description of life history and control by destroying windfalls.

1907. Hooper, T.— Cool storage and fruit fly. Journ. Dept. Agr. West Austr., vol. 15, pp. 252–253.

The maggots lived in previous experiments resisting temperature of 38° to 44° F. In the present experiment a temperature of 33° to 35° F. was tried. The eggs appeared fresh when taken out, but failed to hatch. Fifteen days was found to be the limit at which the maggots or eggs lived, so the infested fruit was left in for three weeks in order to insure safety.

1907. Lounsbury, C. P.— Fruit fly. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1906, pp. 83–85.

The season of 1906 was the worst for fruit-flies. The adults are thought to survive the winter. Peaches, plums, grapes, nectarines, apples, pears, quinces, oranges, pomegranates, loquats, prickly pears, and other fruits infested. Cold-storage appears to be fatal to maggots. A temperature of 38° to 40° F. killed all maggots in three weeks. Experiments with sweetened sprays proved encouraging.

1907. Lounsbury, C. P.— The fruit fly. Agr. Journ. Cape Good Hope, vol. 31, pp. 186–187.

The pest can be controlled by spraying the trees with the following:

1 pound arsenate of lead
2 gallons molasses
25 gallons water

The maggots of the fruit-fly are killed by a temperature of 38° to 40° F. for three weeks.

1907. Marchal, P.— Combating the olive fly. Bul. Mens. Off. Renseig. Agr. [Paris], vol. 6, pp. 927–931.

Two methods have been proposed for controlling *Dacus oleae*: (1) Spraying with a mixture of molasses, honey, glycerin, and arsenate of soda. (2) Improved cultural operations. Unimproved olive trees should be destroyed.

1907. Quinn, G.— Fruit maggot fly pests. Journ. Dept. Agr. So. Austr., vol. 10, pp. 701–710, illus.

Mention is made of the habits of the apple maggot, among other fruit-flies (page 701). The remedies not very satisfactory. A poisoned bait used in Italy has given fairly good results. "Kerosene appears to attract the flies and may be used to trap them."

1907. Sanderson, E. D.— Report of the Department of Entomology. Bul. 129, N. H. Agr. Exp. Sta., p. 264.

The apple maggot is almost equal to the codling moth, making apple production well-nigh impossible in many sections.

1907. Slingerland, M. V.— The more urgent problems of insect control. Bul. 196, Office Exp. Stas., U. S. Dept. Agr., pp. 104–109.

Real original research can be done on a study of life history and remedial measures of the apple maggot, and so forth (page 107).

1908. Card, F. W.— 20th Rept. R. I. Agr. Exp. Sta., 1906–1907, pp. 211–212.

Records many maggots in Early Harvest apples even after hogs had the run of the orchard the previous year. Experiments in burying apples and spading failed for some reason to show results.

1908. Felt, E. P.— Apple maggot or railroad-worm. 23d Rept. St. Ent., 1907. Bul. 124, N. Y. St. Mus., pp. 33–34.

This pest becoming more apparent each year, worse on sweet apples; presence of maggots hastens ripening. Breeding continues until late fall. Winter varieties show corky trails. A spray to control the pest wished for. Remedy: Destroy windfalls. Pest worst in sheltered hollows. Use sweet variety for trap.

1908. Froggatt, W. W.— Progress report. Agr. Gaz. N. S. Wales, vol. 19, pp. 663–672.

Six thousand lire (1 lira = 19.3 cents) offered by the Italian government as a reward for the discovery of a remedy for the olive fly (*Dacus oleae*). Berlese used a sweetened bait with marked success, but it is expensive and washes off. He is now trying jars with bundles of cotton threads trailing down to draw out the sirup and serve as a resting-place for the feeding flies. Berlese's mixture (Dacacide):

40 parts molasses
40 parts honey
2 parts arsenic
18 parts water

1908. Garman, H.— Other insects attacking apple. Bul. 133, Ky. Agr. Exp. Sta., p. 62.

Brief notes. Not found in Kentucky except in fruit on the market.

1908. Gurney, W. B.— Gosford-Narara fruit fly and codling-moth control experiments. Agr. Gaz. N. S. Wales, vol. 19, pp. 581–584.

Flies not susceptible to spraying or fumigating. Control by destroying windfalls, scalding empty packing-cases. Life history of the Mediterranean fly (*C. capitata*). Four to fourteen eggs in a single puncture; hatch in a few days, feed two to six weeks, pupate in ground. Sometimes drop from hanging fruit. Flies emerge in one to two weeks. Flies were reared from pupæ buried 6, 8, 10, and 12 inches deep. Two hundred adult flies captured in a single saucer of kerosene exposed in the trees.

1908. Lounsbury, C. P.— The fruit fly. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1907, p. 56.

In experiments with the fruit-fly (*Ceratitis capitata*) in which boxes were kept at a temperature of 38° to 40° F. for twenty-one days, all of two hundred and sixty-six maggots were found to be dead when examined, and two pupæ discovered failed to develop.

1908. Mally, C. W.— The fruit fly — paraffin remedy vs. poisoned bait. Agr. Journ. Cape Good Hope, vol. 32, pp. 609–611.

The flies were not attracted to paraffin oil so much as to pineapple juice and molasses. Bees were attracted to honey when sprayed on a hedge near a hive, but paid no attention to other sweets. Poisoned bait affords greater protection than does the exposure of vessels of paraffin oil.

1908. Quaintance, A. L.— The apple maggot or railroad worm. Cir. 101, Bur. Ent., U. S. Dept. Agr., illus.

One of the chief insect enemies of the apple. A native American species. Natural food, *Crataegus*. Spread is slow. One generation annually. New locality, Dyberry, Pa. Remedies: Destroy windfalls and cultivate.

1908. Stene, A. E.—The apple maggot. Rept. R. I. St. Nursery Inspector, pp. 30–31, illus. Also bound with 23d Rept. R. I. St. Bd. Agr., 1907.

Brief description of habits and life history. Remedy: Destroy infested fruit.

1908. Williston, S. W.— Manual of North American Diptera, third edition, pp. 282–287, illus.

A brief description of the family *Trypetidae*, with key to genera.

1909. Aldrich, J. M.— The fruit infesting forms of the dipterous genus Rhagoletis, with one new species. Canadian Entomologist, vol. 41, pp. 69–73, illus.

Notes on the distinguishing characters of the genus *Rhagoletis*, with a table of species and a plate showing wing characters. Agrees with Doane (1898) that *R. zephyria* Snow is indistinguishable from *R. pomonella* Walsh. Aldrich has specimens of *R. pomonella* collected in Colorado.

"The typical forms of Rhagoletis in N. America are distinguished by their black color, the scutellum conspicuously white or yellow and bearing four bristles, the wings with cross bands, which may be somewhat oblique and curved; the anterior cross-vein is situated about the middle of the discal cell; first vein bristly along its whole length, the third vein only at base.

"*R. intrudens* n. sp. described from one female that emerged at Ottawa, 19, VI, 1907, from pupa sent from Victoria, B. C., works on sour cherries — may be the same that works in Idaho cherries, but not bred out yet." NOTE.—This is a synonym for *R. fausta* O. S.

1909. Bethune, C. J. S.— The apple maggot. 34th Ann. Rept. Ont. Agr. Coll. and Exp. Farm, 1908, p. 31.

This pest doing considerable damage in Prince Edward county. Found in other districts, but does not seem to spread rapidly. Destruction of fallen fruit will doubtless control the pest.

1909. Froggatt, W. W.— New South Wales report on parasite and injurious insects. 1907–1908. Sydney, N. S. Wales.

This reports the various fruit-flies investigated during an extended trip around the world. Citronella oil very attractive to two species of fruit-flies (genus *Dacus*) in India. Brief description of apple maggot on page 74. Irrigation destructive to fruit-flies, when the ground is flooded about the trees. It was discovered in 1907 that a dish of kerosene placed in the orchard was very attractive to the Mediterranean fruit-fly. Thousands were taken in a few days. Wherever this was tried it had the same results. The oil had no charms for the Queensland fruit-fly.

Five million dollars loss to olive crop in 1908 in Italy due to the fruit-fly (*Dacus oleae*).

General account of the family *Trypetidae*, page 77. Page 78, destructive genera: 1. *Dacus*. 2. *Ceratitis*. 3. *Trypeta*. 4. *Carpomyia* (melon fly). 5. *Anastrepha* (Brazil fruit pest). 6. *Rhagoletis*. Page 103, Bermuda: Destruction of all fallen fruit shows good results. Page 112: Mexican fruit-fly (*I. hideus*). Page 114: Apple maggot, brief description.

1909. Froggatt, W. W.— Fruit flies. Farmers' Bul. 24, N. S. Wales Dept. Agr., illus.

The material in this bulletin is largely taken from the author's report on parasitic and injurious insects, 1907–1908. A summary is here given of the various fruit-flies of the family *Trypetidae*. The apple maggot is referred to on pages 4 and 5 and described on pages 55 and 56.

1909. Mally, C. W.— Poisoned bait for fruit fly. Agr. Journ. Cape Good Hope, vol. 34, pp. 620–633, 1 col. pl., illus.

A practical test of the poisoned-bait method of destroying the fruit-fly, conducted from January to April, 1909, in continuation of work conducted during 1903–1904,

indicated that the pest can be almost completely controlled under orchard conditions by means of a very light sprinkling of a poisoned bait over the trees. In experiments reported, the following formula was used: Sugar, 2 pounds; arsenate of lead, 4 ounces; cold water, 4 gallons. This was applied with a common brass garden-syringe, throwing the liquid in small drops over the trees, 1 to 1½ pint for each ten-years-old tree. The bait was applied every ten days, and after each rain. This work was done on stone fruits, but the same fly infests the apple later in the season. House-flies are also largely destroyed with this bait.

1909. Anonymous.— The Mally fruit fly remedy. Agr. Journ. Cape Good Hope, vol. 34, pp. 578–581, 1 col. pl., illus.

Sugar or cheap molasses, 25 pounds
Paste arsenate of lead, 2 pounds
Water, 40 gallons

One pint applied, with a hand sprayer, to each tree.

1910. Lounsbury, C. P.— Fruit fly remedy. Rept. Govt. Ent., Cape Good Hope Dept. Agr., 1909, pp. 88–89.

Records gratifying success in using poisoned bait as follows:

Arsenate of lead, 2 pounds
Sugar, 25 pounds
Water, 40 gallons

1910. O'Kane, W. C.— The apple maggot. Bul. 151, N. H. Agr. Exp. Sta., pp. 42–44.

Ninety-five per cent of the apple orchards of the State infested. One or two varieties practically immune. Seventy-one varieties of apples investigated. Eggs laid from July 2, extending probably into September. Baldwin apples badly infested, gathered during October, failed to mature a single maggot. Spraying experiments, using arsenic, molasses, and water. Spraying in several orchards. In most results negative. Infested trees, untreated, near by. Also, spray not applied so often as it should have been. In one instance the infested tree stood alone (August Sweet) and the fruit had been worthless for years. After treatment the tree yielded practically perfect fruit.

Possibly more than one species of this fly in the orchards.

1910. Patch, E. M., and Johannsen, O. A.— Apple-tree insects of Maine. Maine Agr. Exp. Sta., pp. 49–51, illus.

Notes on life history of the apple maggot, methods of control by feeding windfalls to stock, also baiting in some apple orchards with a few trees of Tolman Sweet apples; these being destroyed before the larvæ escape. "No use to try to destroy the pest by spraying."

1910. Smith, J. B.— The insects of New Jersey. Rept. N. J. St. Mus., 1909, p. 802, illus.

Montclair: The apple maggot locally injurious but seems confined to a very few varieties. Found also in the light, sandy pine barrens of southeastern New Jersey at Weymouth and DaCosta. These flies were bred from larvæ found on huckleberries, by V. A. E. Daecke, of Harrisburg, Pa.

1911. Cook, A. J.— Three alarming insect pests. Pomona Coll. Journ. Ent., vol. 4, pp. 576–577.

Mexican fruit-fly (*T. ludens*) and Mediterranean fruit-fly (*C. capitata*) mentioned as enemies to be carefully guarded against.

1911. Hewitt, C. G.— The apple maggot. Report of the Dominion Entomologist. Rept. Exp. Farms Can., 1910, pp. 238–240.

Brief comparative notes on other flies of the family *Trypetidae*. Notes on work of apple maggot and control by destroying drops. The destruction of fruit-flies by means of poisoned bait by Berlese in Italy and Mally in South Africa noted. Maggots killed if fruit is kept in cold-storage for a number of weeks.

1911. O'Kane, W. C.— The apple maggot or railroad worm. Cir. 14, N. H. Agr. Exp. Sta., illus.

Cannot be poisoned by sprays as used for codling moth. Control by picking up drops: early varieties twice a week, fall varieties once a week, winter varieties once in two weeks. May use hogs or sheep to clean up drops. There is some possibility that a few of the worms may stay in the ground for two years.

1911. O'Kane, W. C.— Control of the apple maggot by picking up drops. Journ. Econ. Ent., vol. 4, pp. 173–179, diagram.

Early varieties, by picking up drops twice a week 97.6 per cent maggots destroyed. Fall varieties, by picking up drops once a week 99.6 per cent maggots destroyed. Late fall and winter varieties, by picking up drops once in two weeks 98.2 per cent maggots destroyed.

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