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The Apple Flea-weevil, *Orchestes pallicornis* Say (Order Coleoptera; Family Curculionidae)

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and
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ERRATA

Page 57, statistical headings: for *Year 1920* read *Year 1910;* for *Year 1909* read *Year 1920*; in the ratio heading, for *1909* read *1920*, and for *1920* read *1910*. The entries in the Year columns should change places.

Page 85, line 13 from bottom, for *87* read *86*.

Page 88, line 20, delete *red*.

Page 115, line 6, over the column of figures read *Acres*.

Page 136, line 5, for *135* read *131*.

Page 145, *First table*, 4th column, for *35.97* read *33.40;* last column, for .052 read .0418.

Second table, second column, for .2158 read .2004; 5th column, for .1131 read .0977; last column, for .0926 read .0772.

Last table, second column, for .714 read .663 and for total read $4.710; 5th column, for .374 read .323 and for total read $2.201; the last column, for .307 read .256 and for total read $1.700.

Page 146: *First table*, second column, for 8.02 read 7.45 and for total read 52.92; third column, for 3.45 read 2.88 and for total read 19.10; 4th column for 19.28 read 17.90 and for total read 127.18; last column, for 8.29 read 6.92 and for total read 46.35.

Second table, for 43.02 read 38.66.

Last table, for 8.0 read 6.7.

Page 382, line 10 from bottom, for *Platythemis* read *Plathemis*.

Page 385, in list, the specific names of No.'s 33, 35, and 40 should end in *us* instead of *a*.

Pages 445 (line 4), 448 (line 4), 449 (line 23), 454 (line 8 from bottom), read *Belostomidae* for *Belostomatidae*.

Page 457, line 21, for *cornutus* read *cornuta*.

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Article I.—*The Apple Flea-weevil, Orchestes pallicornis Say (Order, Coleoptera; Family, Curculionidae).** By W. P. Flint, S. C. Chandler, and P. A. Glenn.

Historical

The apple flea-weevil was described by Thomas Say in 1831, from specimens taken in Posey county, Indiana. At that time it was not considered an economic pest. Seventy years later Dr. S. A. Forbes reported in the Transactions of the Illinois State Horticultural Society (1901) that the beetle had been found fairly numerous at a number of points in southern Illinois by Mr. E. S. G. Titus, but no damage to orchards was noticed until 1905 and 1906, when some was reported from the southern and western parts of the state.

In Ohio the insect was not known as an orchard pest until about 1907, when it attracted attention in two adjoining commercial orchards near Delaware, Ohio, in the central part of the state.

The first account of its life history and habits appeared (under the authorship of Mr. C. A. Hart) in 1911 in the 26th Report of the Illinois State Entomologist,† and the first published record of severe damage by the insect was published in 1912 by Dr. S. A. Forbes in the Transactions of the Illinois State Horticultural Society. During that season the weevil appeared in large numbers at several points in southern Illinois and caused damage amounting to a destruction of 25 per cent. to 50 per cent. of the leaf surface of the apples in a number of well-sprayed orchards. It was reported as occurring throughout the state but as doing no appreciable damage in the northern section. In this paper Dr. Forbes, in view of its membership in the weevil family, its infestation of the apple, and its thickened hind thighs and flea-like power and habit of making long leaps when disturbed, gave the species the vernacular name of the apple flea-weevil, and by this name it is now generally known.

During the past decade it has become so destructive over a large area in Illinois and in a limited section of Ohio that serious study of the life history and control of the pest has been made by both the Illinois Natural History Survey and the Ohio Agricultural Experiment Station, and the present publication is issued to set forth the results of these studies.

* The data upon which this article is based, were accumulated for the most part independently by the Illinois Natural History Survey and the Ohio Agricultural Experiment Station and each had made plans to publish. It was found, however, that by combining the data and cooperating in the preparation of a report a much more complete treatment of the subject would be possible. The resulting papers, substantially equivalent, although not necessarily identical in all particulars, are to be published in Bulletin 372 of the Ohio Agricultural Experiment Station, with J. S. Houser as author, and in the Bulletin of the Illinois State Natural History Survey, with authorship as shown herewith.

† In this paper the insect was erroneously identified as *Orchestes canus*, and the remarks concerning its distribution relate to that species.

Distribution

As just indicated, the apple flea-weevil is generally distributed over Illinois and is particularly destructive in the central and southern sections. In Ohio it has been found at Delaware in large numbers, at Wooster and Steubenville in small numbers, and, in correspondence, has been reported from Cincinnati, O., California, O., and Chillicothe, O. It is probably very sparsely distributed over the greater part of the state, but is destructively abundant only in an area of about a square mile near Delaware, in the central part of the state.

In Indiana, according to Prof. J. J. Davis, of the Indiana Experiment Station, it is not on record as doing any notable injury.

In correspondence, Prof. C. R. Crosby, of Cornell University, reports finding the weevil in several New York orchards, though not in destructive numbers.

The general distribution of the species in North America as given by Blatchley and Leng in the "Rhynchophora or Weevils of North Eastern America", is as follows: "Frequent throughout Indiana . . . . several localities in New Jersey and Staten Island; . . . . Ranges from Nova Scotia and Quebec through New England to Oregon, south to Texas."

From this record of its wide distribution it appears to be a native insect which is not normally troublesome but which is quite capable of becoming a pest of prime importance when conditions brought about by particular practices especially favor its increase. A detailed discussion of this point will be found later on in this article.

Description

Adult Beetle

The apple flea-weevil is of insignificant size and appearance (see Figures 1 and 2). The beetle is shining black and scarcely a tenth of an inch long. It has a curved snout and the hind legs are strongly developed for jumping. Say's original description of the species is as follows: "Black, antennae rufous with a black tip. Inhabits Indiana. Body black, densely punctured; rostrum lineated and punctured; antennae dull rufous, the club darker black; thorax confluently punctured; elytra with punctured striae, the interstitial lines somewhat rough and flat; thighs with a short acute tooth. Length one-tenth of an inch. Var. a. Tarsi piceous. This species is very abundant."

Blatchley and Leng in their "Rhynchophora or Weevils of North Eastern America" describe the species as follows: "Elongate-oval, humeri prominent. Black, shining, sparsely clothed with very short grayish-yellow hairs; antennae and tarsi reddish-brown; club dusky. Beak stout, scarcely as long as head and thorax, coarsely and sparsely punctate. Head finely granulate, sparsely and coarsely punctured. Thorax as broad at middle as long, sides feebly rounded, disc coarsely, very densely

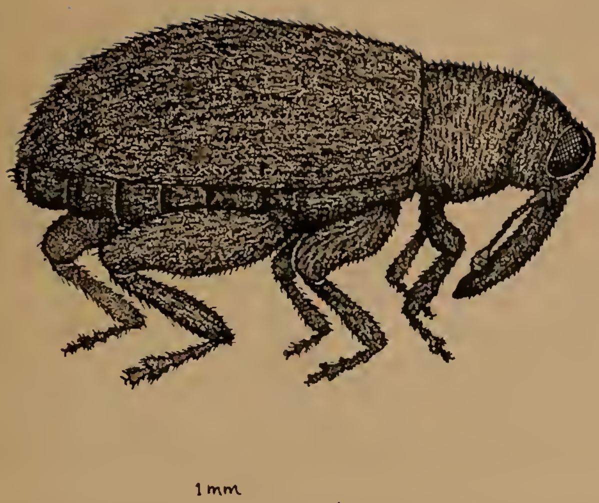

Fig. 1. Adult beetle of the apple flea-weevil. (Magnified 25 diameters.)

Fig. 2. Adults of the apple flea-weevil. (Magnified 10 diameters.)

and shallowly punctured. Elytra oblong-oval, at base two-thirds wider than thorax, striae feebly impressed, their punctures coarse; intervals flat, coarsely rugose, sparsely and finely punctate. Length 2.5—3 mm." [1/10 to 1/8 inch.]

EGG

The egg is about .7 mm. (1/35 inch) long, and about half as thick, pearly white, with ends rather abruptly rounded. It is deposited by the beetle within the midvein or one of the larger veins of the leaf and hence can not be seen unless it is very carefully dissected from the leaf tissues.

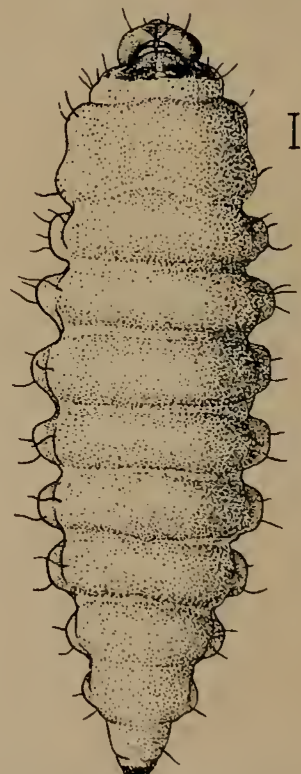

FIG. 3. Full-grown larva of the apple flea-weevil, seen from above. (Magnified 25 diameters.)

LARVA

The larva when full grown measures about one-fifth of an inch in length, and is about one-fourth as broad at its widest part. From the head backward the sharply defined segments gradually increase in width until midway of the body, whence they narrow rapidly toward the anal tip. As might be expected of a typical leaf-mining larva, the body is distinctly flattened. The color is dirty white. (See Figures 3 and 4.)

PUPA

The pupa is at first white, but gradually becomes darker as it approaches the adult stage. It is about three-fifths as long as the larva, regularly oval, and about half as wide as long (see Figure 4).

FIG. 4. Larvae and pupae removed from mines.
(Magnified 6 diameters.)

Life History and Habits

The apple flea-weevil passes the winter in the adult, or beetle, stage. Early in July the beetles begin to secrete themselves for the remainder of the summer, the fall, and the following winter under leaves, plant refuse, in the mulch or sod of orchards, or under any other object which will afford protection, but as far as we know, not in the soil proper. By far the greater number seek shelter in apple orchards, but they have been found hibernating in negligible numbers in bunch-grass (Andropogon sp.), blue grass, and trash along hedge rows, and under wild crabs. They show no preference for any side of the tree, but are more numerous where the cover is densest. In partially cultivated orchards they are most abundant in hibernation near the trunk of the tree, as is shown by the following table.

According to this table there were from 1400 to 1700 beetles hibernating under each apple tree in heavily infested orchards of this type.

The heavily infested Ohio orchards had not been cultivated for many years, and a heavy blue-grass sod covered the ground, forming a dense layer of partly decayed vegetation over the entire surface (see Figure 5). Under such conditions the beetles may be found in abundance throughout the orchard, in larger numbers, however, under the trees than elsewhere.

FIG. 5. The heavy sod mulch of the Glenn Sonners (old Vergon) orchard, Delaware, Ohio, in which the beetles hibernated.

RELATIVE POSITIONS OF HIBERNATION IN PARTLY CULTIVATED SOUTHERN ILLINOIS ORCHARDS, 1919, 1920, AND 1921

Location of area	No. of sq. ft. examined	Average No. beetles per sq. ft.
1st sq. ft. from tree	205	28.4
2d " " " "	205	22.6
3d " " " "	205	14.6
4th " " " "	9	10.1
5th " " " "	5	6.6
6th " " " "	6	3
7th " " " "	3	1
8th " " " "	3	0

On unusually warm days of winter or spring when the temperature remains for several hours at 60° or 70° some of the beetles emerge, but they return if the weather cools. At Olney, Ill., during a four-year period, there was nearly a month's difference in the dates when weevils began to leave their winter shelter. In 1921, movement from hibernation began on March 15; in 1918, March 25; in 1919, April 8; and in 1920, March 23. No precise data were obtained in Ohio, but such information as we have, indicates that in the main the beetles are from two to three weeks later in leaving their winter quarters at Delaware, Ohio, than in southern Illinois.

The time of their appearance in spring is not always contemporaneous with the appearance of the leaves. During some seasons they come out in considerable numbers before the foliage is developed and cluster on the swelling buds as if waiting for the leaves to appear. On the other hand, in some seasons the leaves are three-quarters of an inch long before the beetles are abroad. If there are one or two days of exceedingly warm weather before the foliage starts, the beetles appear in advance of the leaves, whereas if the foliage is developed by normal weather the leaves are from ½ to ¾ inch long before the beetles leave their winter quarters. The above observations apply particularly to orchards which are in sod.

In leaving their winter shelter many of the beetles crawl up the trunk of the tree, but most of them crawl to the tip of grass blades or other objects and thence take flight to the branches above. Their flight is erratic and fortunately they do not travel long distances on the wing, and they seem unable to take flight if even a moderate breeze is blowing. If the wind is fitful they cling to their swaying perches, not attempting flight until a lull comes, whereupon great numbers will spring into the air almost simultaneously.

After emerging in spring the beetles begin to mate and to feed upon the swelling buds or expanding leaves. When the foliage is a little further developed egg-laying commences. For this the female seeks the midvein or one of the laterals on the under side of the leaf, and after making a suitable cavity with her snout, deposits therein a tiny egg, closing the cavity afterwards with a bit of excrement.

The eggs hatch in about a week and the newly emerged larva begins feeding in the blind end of the tunnel in which it lies, and proceeds thence to mine out the inner substance of the leaf. At first the mine is threadlike, lengthening in the general direction of the edge of the leaf, and gradually increasing in width. At the edge of the leaf the mine takes on a somewhat blotchlike form and when completed is about two-thirds the size of a dime. The mine is rather conspicuous because the leaf tissue on both its upper and lower sides dies and turns brown.

On an average the larva becomes full grown in seventeen days, whereupon it causes an expansion in a part of the upper and lower surfaces of the mine which takes the form of a blister a little less than

FIG. 6. Injury to the developing foliage by the apple flea-weevil (left) and a normal twig of the same variety taken from the same orchard at the same time. This injury is done by the old adult weevils which have passed the winter in the sod mulch.

a quarter of an inch in diameter. In this swelling the larva changes to the pupal stage, which averages five or six days in duration.

The adults leave their mines during the latter part of May in southern Illinois, and in central Illinois and in central Ohio during the fore part of June. Since there is but one brood per year the beetles which appear in summer survive the winter in hibernation. They feed for approximately a month before retiring to their winter quarters. This feeding period is also the principal migration season, but as the insect is not a strong flier its spread from one orchard to another is surprisingly slow.

The beetles have been found in winter quarters as early as June 15 in southern Illinois, and by mid-July most of them are so concealed. In the Ohio territory and in central Illinois this period is practically complete by August 1, but a few are abroad until early fall. The movement to hibernating quarters is more prolonged than that from these quarters in spring. The time of year for the retreat of the beetles is influenced by the weather, hot weather hastening it, and cool, cloudy weather during the summer months delaying it.

Character of Injury and Extent of Damage

The damage done by the apple flea-weevil consists in the feeding punctures of the weevils and the mines of the larvae. If the weevils have emerged when the buds are just beginning to show green they injure the expanding buds by inserting their beaks into them and, if sufficiently abundant, may prevent their opening. As the leaves open, the beetles continue their feeding, cutting holes entirely through the tender foliage, and occasionally at this stage destroying it outright (see Figure 6). Still later, after the leaves have become full grown, the weevils feed for the most part on the under side, though occasionally one is seen feeding on the upper leaf-surface. They eat out the soft tissue, leaving the epidermis of the opposite side, thus making shallow pits about a twenty-fifth of an inch in diameter. The unconsumed epidermis turns brown a few days after the injury, and later breaks away, leaving a hole in the leaf, and when the attack is severe the tree looks as if it had been riddled with bird shot. Leaves on which several weevils have fed will have from a third to half the surface destroyed. When injured to this extent they drop prematurely, and the punctures also afford easy access for the spores of various fungi. Upwards of 2000 beetles are frequently found on a single tree, and as each weevil makes from ten to twenty feeding punctures a day, it is easy to understand the amount of injury which can be done in the course of a month's feeding. (See Figures 7 and 8.)

The mining of the leaves by the larvae is perhaps a little less destructive in its effect on the host than the feeding of the adult beetles. (See Figure 9.) Where two, three, or even more mines occupy a single leaf, it is rendered almost wholly, if not entirely, functionless. In heavily infested orchards, however, one may find three or four mines to a leaf, and 25 per cent. to 30 per cent., or even more, of the leaf surface is destroyed. From both kinds of injury, in the course of two or three seasons the trees in heavily infested orchards become unthrifty

FIG. 7. Injury to apple foliage by the feeding of the adult beetles in midsummer. The beetles may, when sufficiently abundant, make lace-work of the foliage.

and incapable of a vigorous growth or the production of fruit buds. If the attack continues the lower limbs die, since these are always much more severely injured than the upper ones; the tree is more susceptible to the effects of late spring frosts or other adverse conditions; and the orchard becomes generally unprofitable. (See Figure 10.)

Still another effect is the killing back of all new growth or water-sprouts arising from the main branches of the tree. Under some conditions this might be considered a beneficial rather than harmful effect, but it is the practice of some orchardists to utilize these growths in the upper parts of old trees for starting a new top after the original tree becomes too tall. (See Figure 11.)

The weevil has been on the increase in Illinois since 1910 and 1911. In 1913 and 1914 at least 25 per cent. of the orchards in southern Illi-

FIG. 8. A view taken when looking up through the foliage of an apple tree following severe midsummer injury by the feeding adult beetles. The leaves look as if riddled by fine shot. Olney, Ill., July, 1915.

nois were infested to an extent to cause at least moderate injury to the trees. Many orchards which were well sprayed and partly cultivated lost at least a third of their leaf surface before the middle of July. During the last five years the damage has not been so general, but several localities have suffered every season for the past ten years.

The owner of the first orchard in Ohio to become seriously involved had been following for some years a new method of soil management. The trees were growing in sod and each year the grass was mowed and

FIG. 9. Larval mines of the apple flea-weevil in apple leaves.

spread under them. Later, due to shading by the trees, insufficient grass was produced for mulching, and for some years straw or other roughage was hauled in and spread under the trees. During the past few years no mulching has been done and a heavy grass sod has developed. This method has furnished almost ideal hibernating quarters for the beetles, and this is now believed to have caused the outbreak in the Vergon orchard as well as that in the adjoining one owned by the Delaware Apple Company. In these two orchards, containing about seventy acres, the beetle has been increasing in abundance since 1907 and

FIG. 10. Trimming away of dead or valueless lower branches because of successive seasons of flea-weevil injury. Orchard of the Delaware Apple Co., Delaware, O.

has taken a toll of thousands of dollars of profits. Strangely, however, it has not become a pest in any of the other orchards of the Delaware section. The fact that these two orchards are somewhat isolated by a bend in the Olentangy River from the others of the section doubtless has had much to do in restricting the spread of the beetle. Moreover, none of the other orchards have afforded such ideal hibernating quarters as have these two.

The sum total of the injury by the apple flea-weevil is much less in Ohio than in Illinois. The Ohio territory affected seriously is not over a square mile in extent while in central and southern Illinois several hundred square miles are involved.

FIG. 11. The killing of all water-sprouts by beetles feeding on aged apple-trees makes it impossible to rejuvenate the orchard by growing lower tops.

Hosts

By all odds the cultivated apple is the chief host of the apple flea-weevil in Ohio and Illinois. That this is fortunate is evident, since any insect pest which thrives equally well on one or more uncultivated hosts renders its control on cultivated species more difficult. However, the apple flea-weevil is known to feed in the larval or the adult stage on a number of other hosts. What were presumably larvae of this species were seen mining the leaves of the winged elm *(Ulmus alata)*, American elm *(Ulmus americana)*, and elder (Alnus sp.) at Falls Church, Va., and hazelnut *(Corylus americana)*, at Wooster, Ohio. Larvae were found mining the leaves of quince in Illinois and Ohio, choke cherry *(Prunus virginiana)* and hawthorn *(Crataegus mollis)* in Ohio and adults were reared from the infested leaves. Lastly, the beetles were seen feeding on the leaves of the wild crab *(Pyrus coronaria)* in Ohio and Illinois, and are reported by others as feeding on the leaves of willow and on the flowers of service berry (Amelanchier).

In no instance has a wild or unusual host been found severely infested by either the mining larvae or the feeding beetles, even when growing in the immediate vicinity of severely infested apple trees.

Natural Checks on Multiplication

Probably the most effective factor in natural control is the white muscardine fungus (*Sporotrichum globuliferum* Speg.), a well-known fungus parasite of insects, the spores of which germinate on the surface of the beetle, sending their threadlike mycelium into and throughout its tissues and causing its death. It continues to thrive on the carcass and in time its white growth entirely envelops it. During the extremely wet summer of 1915, weevils covered with this fungus could be found literally in thousands under the loose scales of bark on the trunks of apple trees and in the cover around the bases of the trees in Illinois orchards (see Figure 12). The dampness caused by repeated rain had been very favorable to the development of this fungus in orchards that had been heavily infested for several seasons previous, and in some of them the flea-weevil was almost entirely exterminatd. In an orchard at Plainview, Illinois, where at least 30 per cent. of the leaf surface was destroyed in 1914, a careful search of nearly two hours was required to find a single weevil in 1916. No appreciable damage has been done in this orchard during the past five years, although the weevils are now becoming more abundant and were present in considerable numbers during the summer of 1921. It is, however, only during prolonged periods of wet weather that this fungus has ever been an important factor in the control of the flea-weevil. Such general prevalence of this disease has never been observed in Ohio orchards, although beetles dead with it are very commonly encountered there.

FIG. 12. Photograph taken at the base of an apple tree after some of the covering leaves had been removed to show the adult apple flea-weevils dead with the muscardine fungus. About 2/3 natural size. Small white spots are dead beetles embedded in the fungus which killed them. Olney, Ill., Oct. 18, 1915.

Another controlling agency is a group of tiny hymenopterous parasites, of which several species have been bred. These busy little creatures parasitize either the larva or the pupa in the mine, ultimately causing the death of their host. We have never seen such wholesale destruction as that due to the muscardine fungus, but these parasites are undoubtedly an important factor in checking the activities of the insect. For example, on June 12, 1919, material taken at Delaware, Ohio, was found to be 23 per cent. parasitized, and on June 23, 1921, material taken at Wooster, Ohio, was found to be 20 per cent. parasitized. The following species have been reared:

From mines of the apple flea-weevil in apple, *Zatropis incertus* Ashm.*, Epiurus sp.†, *Derostenus pallipes* Gahan*; from those in choke cherry, Pleurotropis sp.*; from those in hawthorn, Sympiesis sp.*, and Eulophid gen. and sp.*

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* Determined by A. B. Gahan, U. S. Bureau of Entomology.
† Determined by R. A. Cushman, U. S. National Museum.

Artificial Control

During the last eight years, experiments have been made in Illinois and Ohio to develop effective methods of control by banding, summer spraying with arsenicals, summer spraying and dusting with contact insecticides, burning in hibernation, spraying and dusting with insecticides in hibernation, poisoned baits offered as the insects are leaving hibernation, and cultivation of the soil.

BANDING

It was at first thought that the emerging beetles crawled up the trunk of the tree in spring and this suggested the possibility of destroying them by the use of sticky bands. Preliminary experiments with tree-tanglefoot bands placed singly about the trunks of the trees at varying heights and doubly at various distances apart, developed the fact that while fairly large numbers of beetles were caught on the bands, there were about as many on the upper as on the lower where two bands were used, showing that many of the beetles flew to the upper parts of the tree instead of crawling up the trunk. Nevertheless a number of experiments with bands were made, with results of which the following is typical:

On April 10 to 14, 1914, a band of tanglefoot three inches wide was applied to the trunks of 500 mature Ben Davis trees in an orchard of 600 trees which averaged ten to twelve inches in diameter. The loose bark was scraped from the trunks and the tanglefoot was applied with a wooden paddle directly to the bark, three rows in the center of the experimental block being left untreated as a check. (See Figure 13.)

On April 20 the trees banded on the 10th and 14th averaged 250 and 200 weevils per band, respectively, but there were many weevils on the opening leaves of the trees. May 5 there was an average of 700 weevils per band, and June 15 practically the same. The insects were distributed quite uniformly over the bands, showing that many had been caught by alighting on the bands and not in crawling up the trunks.

As a supplementary experiment, on April 20, three bands, 18, 12, and 3 inches wide, were placed on one tree at a distance of 2, 8, and 18 feet from the ground, respectively. On May 5 the widest band contained over 1500 weevils; the band 8 feet from the ground, 35 weevils; and that 18 feet from the ground, 4 weevils.

To ascertain whether any benefit had been derived from the banding a number of leaves were taken at random from the banded and unbanded trees, and the larval mines were counted. The results are tabulated as follows.

	Banded with 18", 12", and 3" bands	Banded with 3" bands	Unbanded in same orchard	Unbanded in near-by orchard
Percentage of leaves with larval mines	10.3	16.3	23	36
Average number of larval mines per leaf	1—10	1—6	1—4	1—3

Fig. 13. A single wide band of tanglefoot placed around the trunk of an apple tree. Banding did not prove an effective control, but might be used under unusual conditions.

A man could band from 18 to 20 trees an hour, and it required one and a half to two ounces of tanglefoot to make a three-inch band around a mature Ben Davis apple-tree. The expense of banding would be about $3 per acre.

The results scarcely warrant reliance on this method as a satisfactory control, but it may be serviceable when one of the more satisfactory control measures to be discussed later can not be used.

SUMMER SPRAYING WITH ARSENICALS

Since the larvae of this species are leaf-miners they can not be killed by arsenical sprays, and since the adults feed mainly on the under side of the leaf an arsenical applied to the under surface, theoretically should be effective; but orchards sprayed regularly with arsenicals and fungicides are as severely injured as those not sprayed at all. It was the purpose of our experiments to ascertain whether it was possible to devise an arsenical formula or a method of application such that the weevil could be reached.

Obviously, such a spray should be applied when all the beetles in the orchard are feeding on the leaf surfaces. This occurs first when the beetles leave their winter shelter as the foliage is expanding, and again about mid-June when the insects have just become mature and have left the mines. Many preliminary experiments were made with arsenical sprays in combination with soap and flour paste as spreaders, and with lime-sulfur and Bordeaux as fungicides. Adult weevils inclosed in cages attached to branches of apple trees the foliage of which had been sprayed on both sides with arsenate of lead usually all died within a week.

The repellent effect of fungicides.—Early in the course of summer-spraying, leaves were sprayed with arsenate of lead and water, and arsenate of lead in combination with either soap, flour paste, lime-sulfur, or Bordeaux. When given a choice of these leaves and unsprayed leaves the beetles fed about as freely on those sprayed with arsenate of lead and water, either alone or combined with soap or flour paste, as they did on unsprayed leaves, but they avoided leaves sprayed with arsenate and water in connection with lime-sulfur or Bordeaux. It is possible, therefore, that the addition of lime-sulfur or Bordeaux to the arsenical, as is the regular orchard practice, renders the treatment ineffective by repelling the weevils before they are effectivly poisoned. The following experiment emphasizes this view:

Adjoining rows of apple trees in a commercial orchard were sprayed with an upshoot spray, one row with arsenate of lead and water and the other with arsenate of lead and Bordeaux. Two days later many dead weevils were on the ground under the trees sprayed with arsenate of lead and water but hardly any under those sprayed with arsenate of lead and Bordeaux. All the spraying had been done on the same day and in the same manner and the weevils were equally abundant on the two rows of trees, and the difference in results was evidently due to the absence of Bordeaux in the one case and its presence in the other. This would explain the ineffectiveness of the usual orchard-spraying program in controlling the apple flea-weevil as it is the custom to combine fungicides with the arsenical in the spray mixture.

Supplementary applications of arsenical sprays.—In an orchard which had been sprayed according to the regular schedule for the codling-moth eight trees were given an additional or supplementary spray according to the following formula:

Arsenate of lead paste	3 lbs.
Flour	8 lbs.
Water	50 gal.

The spraying was done at a pressure of 150 lbs. with a Friend 45°-angle nozzle, one hose being operated from the tower and the other from the ground, a special effort being thus made to cover both surfaces of the leaves. On the following day 647 dead beetles were counted on 90 square feet of canvas spread under one of the trees. Very few weevils remained on the trees receiving the extra spraying, though they were present in large numbers on adjoining trees which had received the spray of the normal program. On the second day following the application an average of but one weevil was found to every 24 leaves on the extra-sprayed trees, and one on every 6 leaves of those adjoining —a reduction of about 75 per cent. in the number of weevils because of the spray. Eight days after the application the extra-sprayed trees had an average of one weevil to 29 leaves, and the others had one weevil to 6 leaves. The infestation was decreasing on the extra-sprayed trees but not on those not sprayed, although the former were exposed to reinfestation from their neighbors.

Spraying both the upper and lower leaf-surface vs. spraying the upper surface only.—Adjoining the plot of eight trees just discussed, in which both surfaces of the leaves were sprayed, an eight-tree plot was sprayed at the same time with the same mixture, but in this only the upper surface of the leaves was covered. Two days after the application there was an average of one weevil to 13 leaves on the sprayed side, and one weevil to 5 leaves on the unsprayed side. The sprayed side of the leaves was thus much less infested than the unsprayed side, and the leaves sprayed on both sides were still less so, since, as will be recalled, these averaged one weevil to 24 leaves. This difference seems sufficient to warrant spraying both sides of the leaves if this supplementary application of an arsenical is made without the addition of a fungicide.

Tests of different poison formulae.—Two series of tests were made to determine the value of different arsenical combinations, a spray gun being used to throw the spray upward through the tree, and thus to cover both leaf surfaces.

In the first test canvas was spread under the trees to catch the dead weevils. These were collected and counted daily with results shown by the following table.

Materials	Average number of dead weevils per square foot				
	24 hours	26 hours	48 hours	72 hours	Total
Powdered arsenate of lead........2 lbs Lime ....1½ lbs Water ....50 gal	1.7		1.3	.8	3.6
Same formula as above	1.2		.6	.6	2.6
Powdered arsenate of lead........1 lb. Water ....50 gal	2.4	1			

The estimated number of weevils per tree killed in 72 hours was 1628; and five days after the spraying it was estimated that about 50 per cent. of the weevils had been killed on the sprayed trees. No difference was seen between trees sprayed with arsenate of lead at 2 lbs. and at 1 lb. to 50 gallons of water.

In the second test, sprays described in the following table were applied May 2, when the foliage was well developed, and again May 14. For a comparison of results a conical cheese-cloth net, 3½ feet deep and 3 feet across the mouth (see Figure 14), was suspended, following the second application, under a representative tree in each plot, and daily records were kept of the dead beetles. The tip of the net was anchored to a peg driven in the ground by a cord long enough to permit the branch to sway and at the same time to prevent the bag from whipping and fraying in the wind. The accompanying table shows the formulae used and the daily catch.

This experiment was defective in the fact that the small number of trees used and their close proximity permitted the passage of beetles from one tree to another after the sprays were applied, as is shown especially by the appearance of dead beetles under two of the check trees. It is plain, however, that the poison sprays took considerable effect, and the sprayed trees were obviously less injured by the weevils than the check.

Early summer application of the arsenical.—In one instance a spray of arsenate of lead 1 lb., lime 2 lbs., and water 50 gallons was applied to the young leaves with a spray gun at a pressure of 200 to 225 lbs. when the weevils were just emerging from hibernation and before many eggs had been laid. After 24 hours, 48 dead weevils were collected from 192 square feet of canvas spread under the tree, and after 26 hours more, 22 additional weevils were collected.

Materials Used	Daily Catch of Beetles																			Total
	May																	June		
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	
Arsenate of lead powder.......... 3 lbs. Water .... 50 gal.	4	2	15	2	2	5	0	*	3	0	0	0	0	0	0	1	0	0	1	35
Arsenate of lead powder.......... 3 lbs. Molasses (black strap cane syrup).......... 1¼ gal. Water .... 48¾ gal.	9	7	3	5	4	4	0	*	1	0	1	0	1	1	0	0	0	0	0	36
Calcium arsenate powder.......... 2 lbs. Hydrated lime.......... 4 lbs. Water .... 50 gal.	3	4	6	3	2	5	0	*	5	0	0	1	1	2	2	1	0	0	1	36
Arsenate of lead powder.......... 3 lbs. Copper sulphate.......... 4 lbs. Hydrated lime.......... 6 lbs. Water.......... 50 gal.	0	0	14	3	2	3	7	*	2	0	1	2	4	1	1	0	0	0	1	41
Arsenate of lead powder.......... 3 lbs. Soap (common laundry).......... 2 lbs. Water .... 50 gal.	3	6	1	0	1	5	7	*	1	0	1	1	0	0	0	1	0	0	0	27
Check – unsprayed	0	0	0	5	0	4	0	....	0	0	0	0	0	0	0	0	0	0	0	9

* Raining; no records.

In this test, and in others which we have seen, the chief difficulty with an early seasonal application of arsenicals to the expanding foliage is that when the leaves are unfolding and growing rapidly the weevils can select trees which are free from arsenic. This is particularly true if the beetles are abroad in abundance when the leaf buds are just breaking, and here an additional difficulty is encountered in that there is not enough leaf surface on which the poison can be lodged and held.

FIG. 14. Inverted cloth cone suspended from trees sprayed with arsenicals to test the effectiveness of the several poisons tried.

The residual effect of summer spraying with arsenicals.—One of two adjoining orchards, both badly infested, was treated the second week in June with an upshoot spray of arsenate of lead without a fungicide, at a time to poison the weevils as they left their summer mines and began to feed. The foliage of both orchards at this time was so badly injured by the weevils that it was difficult later to see that any good had been done by the spray; but the following spring, after the adults had emerged from their winter quarters, the number of weevils was very noticeably smaller in the sprayed orchard. To determine definitely the difference in numbers in the two orchards, counts were made from a large number of buds on trees in adjoining rows in the two orchards, and in each orchard on the third and fifth rows from these adjoining rows. In the sprayed orchard 329 weevils were found on 4800 buds, and in the unsprayed orchard 1052 weevils on the same number. Thus over two-thirds of the weevil population was destroyed in the sprayed orchard. Had the spray been applied two weeks earlier, no doubt much injury to the foliage would have been prevented, and in all probability the reduction of infestation the following year would have been equally great.

Summary on summer spraying with arsenicals.—In brief, the general conclusions which may be drawn from the summer application of arsenicals and arsenicals in combination with fungicides are as follows:

In all of the trials save one, a decided repellent effect was obtained when either lime-sulfur or Bordeaux mixture was used in connection with the arsenical, and in this one exception a kill was obtained equal to that following the use of arsenicals alone. In every instance where arsenicals were applied, some killing resulted, but it is an open question whether the percentage of beetles killed or repelled warranted the cost of the extra application. The kind of application required, that is, spraying the under side of the leaves, is wasteful of both material and labor, and is therefore more expensive than the usual application in which no effort is made to cover anything but the upper surface. The only occasion in which extra summer applications of arsenicals might possibly prove profitable would be in excessively severe outbreaks where a partial control might prevent extreme weakening of the trees.

SUMMER APPLICATIONS OF CONTACT INSECTICIDES

Our experiments with summer contact insecticides were all of a preliminary character and need only be summarized briefly. With the exception of the last named, they were all made in June after considerable damage had been done by the new brood of adults. The insecticides used, were scalecide, a mixture of scalecide and soluble sulfur, Lasher's soap, black leaf forty, kerosene emulsion, and nicotine dust. Neither of the first two proved effective at strengths which did not injure the foliage.

Lasher's soap.—Twelve heavily infested trees were sprayed with a solution of Lasher's soap, 10 lbs. to 100 gallons of water. A heavy rain interrupted the work after the tenth tree had been sprayed. Spraying the trees causes the weevils to drop, and nearly all were driven from the trees. A canvas, spread under one of the trees before the spraying began, caught no less than 24,000 weevils, but most of them, though apparently dead, showed signs of life when disturbed. Some were inclosed in a bottle for observation, but less than 8 per cent. recovered. Two days later two more trees were sprayed with what remained of the solution, under the same conditions except that in this case there was no rain. The canvas under one of the trees was blackened with the adults which fell. These, however, were more lively than those in the former trial, and most of them gradually recovered. Only one fifth of the original number remained on the canvas two days later, and many of these were alive. It was concluded that this soap was worthless as an insecticide against the apple flea-weevil, and no further experiments with it were made. Possibly the heavy rain had something to do with the high mortality in the first instance.

Nicotine sulphate liquid.—A number of low-hanging branches were sprayed with the "black leaf forty" brand of nicotine sulphate, prepared as follows:

Black leaf forty	½ ounce
Laundry soap	2 ounces
Water	2 gallons

A canvas was spread under the tree to catch the weevils as they dropped. Some of them showed signs of life and were sprayed again while lying on the canvas. Three hours later all were dead.

Kerosene emulsion.—Branches infested with the weevil were sprayed in the same manner with kerosene emulsion at strengths of 5 per cent., 7½ per cent., 10 per cent., and 15 per cent. The 5 per cent. emulsion did not kill the beetles outright, and it was necessary to spray them as they lay on the canvas to insure their death; but the stronger emulsions apparently killed all the adults hit by them.

To test further the effectiveness of kerosene emulsion, 30 trees were sprayed with a 5 per cent. and 20 trees with a 7½ per cent. emulsion. Two canvases, each 15×30 feet, were spread under the trees while the spraying was in progress, each with a 1×4 inch board along one end as a convenience in moving it from tree to tree (see Figure 15). A man or a boy was needed to handle each of the canvases. As soon as the spraying of a tree was finished the canvas-men dragged the canvas quickly to the next tree, and little delay was occasioned.

The weevils fell on the canvas in large numbers, and here they were sprayed again, practically all of them being thus killed. After the ninth tree was sprayed counts were made of the dead weevils in two areas of a square foot each, 250 weevils being found on one square foot and 300 on the other. It was estimated that there were not less than 80,000 weevils on the canvases, indicating an average of nearly 9000 per tree which were killed by the treatment.

After the spraying was completed, counts were made to determine the comparative numbers of weevils on sprayed and unsprayed trees close together. On unsprayed trees 236 weevils were counted on 1650 leaves and on sprayed trees 40 weevils on 2300 leaves; or .143 and .018 weevils per leaf respectively—a decrease of about 90 per cent. in the number of weevils.

The trees in this orchard were trimmed high and the soil was well cultivated, hence there was nothing to interfere with the movement of the canvases. In another orchard, however, in which the branches hung low, many touching the ground, it was found entirely impracticable to handle the canvases. However, satisfactory results should be obtained with a 7½ per cent. emulsion without the use of the canvas.

FIG. 15. In spraying with some of the contact insecticides it was found of advantage to spread a canvas under the tree while the insecticide was being applied. The fallen beetles were soaked by the liquid and death was more likely to result. The canvas was divided into two parts and an edge of each was nailed to a strip of wood to facilitate handling.

Dusting with nicotine.—The dust used in this experiment was one containing 1½ per cent. of free nicotine, and the application was made with a large-size new model Niagara duster operating at full speed. The work was done about 10 a. m. on a bright sunny day at a temperature of about 70°. The overwintering beetles were feeding in abundance on the newly developed foliage, and were doing noticeable damage.

The application was ineffective, large sheets spread beneath the dusted trees having on them no dead beetles after 10 hours, although the disturbance caused by the operation had caused a considerable dropping of beetles and many were covered with dust. Moreover, beetles placed in the original dust-container in which a little of the material remained, were still alive after 4 hours, unless they had meantime been lying directly in the dust. Such beetles survived one or two hours, but then showed no signs of life.

Summary on summer applications of contact insecticides.—The most promising of the contact insecticides used as summer applications was 7½ per cent. kerosene emulsion. The 5 per cent. emulsion gave fair results when sheets were spread under the trees and the beetles which fell thereon were drenched. If the emulsions had been applied about the middle of April, after the hibernating adults had migrated to the trees and before any considerable number of eggs had been deposited, no doubt a very great reduction in the number of the new brood and in injury to the foliage would have resulted. A spray applied at this time, when there is little foliage on the trees, would also be effective against aphids.

DESTROYING THE BEETLES IN HIBERNATION

As has been shown previously, the adult beetles hibernate in trash in the orchard, and do not go into the ground, and since the period of their retirement is of long duration—from late summer to the following April or May—an excellent opportunity is afforded for effective work, and the following methods were given trial.

Paradichlorobenzene.—Successful use of this material against the peach-tree borer suggested its use against the apple flea-weevil while in hibernation, and it was scattered broadcast under the spreading branches of old apple trees growing in a heavy sod-mulch. The application was made April 12, a few days before the beetles left winter quarters, at rates of 2, 4, 6, 8, and 12 pounds to a tree. It was evidently of no value, since the beetles were quite as abundant on these trees after the beetles emerged, as on their untreated neighbors.

Hydrated lime.—Hydrated lime at the rate of 25 and 50 pounds per tree was scattered under the spreading branches of 25-year old apple trees growing in heavy sod. The application was made April 27 as the beetles were becoming active, and it was thought that they might perish in passing through the dust, but trap cages placed over representative areas under the trees so treated, collected considerable numbers of beetles, indicating that the application had little if any merit.

Fuel oil.—Trees growing in the same orchard in which the immediately preceding experiment was made, were treated with fuel oil spread by means of a common garden-sprinkling can at the rate of 2 and 4 gallons to the tree. The quantities used will not properly cover such an area, and the cost of a sufficient treatment would be prohibitive. Undoubtedly some beetles were destroyed, but the gross effect on the beetle population of the trees was not noticeable. If the oil were applied in sufficient quantity, perhaps 10 gallons per tree, control could probably be secured, since trap cages used on areas so treated yielded no beetles, but possible injury to the trees which might result, still renders the method of doubtful economy.

Poisoned bran mash.—Since the beetles sometimes leave hibernation before the apple trees are in leaf it was thought that a poisoned bait scattered on the grass under the trees might attract the beetles and destroy them. The standard grasshopper formula was used—bran, 20 lbs.; Paris green, 1 lb.; syrup, 2 quarts; 3 grated lemons; and 3½ gallons of water. Two and a half lbs. of the bait was scattered under the spread of 25-year old apple trees on April 27, when the beetles were becoming active and the foliage was just starting. Not only did the bait fail to attract the beetles in the open, but individuals confined with it did not die from eating it.

Spraying the trash under the trees with a solution of potassium ferrocyanide.—In early April, before the beetles became active, the grass and mulch under apple trees in a badly infested orchard was evenly sprayed with enough of a solution of potassium ferrocyanide to make the mulch quite damp. Two strengths of the solution were tried; one of a pound and another of 2⅓ pounds to 50 gallons of water. It was thought that the fumes might kill the hibernating beetles, but no dead beetles were found in the treated areas, and later on, when the beetles emerged, these trees were as severely attacked as their untreated neighbors.

Spraying the trash with other materials.—In 1919, an orchard at Flora, Illinois, heavily infested with weevils, was selected for a series of experiments to ascertain if wetting the refuse beneath the trees with a contact insecticide would destroy the beetles in hibernation. The orchard had been cultivated down the center of the space between the rows but not within six or eight feet of the trunks of the trees. The litter under the trees was of about the usual depth. During the latter part of November plots were laid out six trees square and the litter under the trees was sprayed with enough of the insecticides to wet thoroughly through the cover to the surface of the soil. The amount applied was 15 gallons per tree.

Before the insecticides were applied, counts were made of the numbers of flea-weevils in hibernation about the bases of a number of trees in each plot. The weevils were also counted under five trees left untreated as a check. During the latter part of February another series of counts was made on the same number of trees in the center of each plot and the number of living and dead weevils was noted. The results of these treatments are given in the following table.

Insecticide	No. trees	After spraying, No. weevils alive in:				After spraying, No. weevils dead in:				
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	% dead
Scalecide 1—15	2	8	0	1	9	19	11	5	35	80
Scalecide 1—10	2	26	8	21	55	35	41	21	97	64
Black leaf forty 1—500	3	68	103	64	235	25	9	26	60	20
Kerosene emulsion 15%	1	0	0	0	0	48	5	3	56	100
Kerosene emulsion 10%	1	3	0	3	6	79	44	22	145	96
Whale-oil soap 1 lb.—10 gal.	5	261	191	115	567	14	12	10	36	6
Lime, 1 pk. per tree	3	125	78	64	267	3	1	3	7	3
Check	5	90	69	80	239	7	1	1	9	4

Summary concerning measures, other than burning, for destroying the beetles in hibernation.—As is shown, none of the immediately foregoing group of materials (see table) even approached satisfactory control save kerosene emulsion. This proved very effective at 10 per cent. strength, and could probably be used with safety. The cost of treating with kerosene emulsion would be approximately $20 an acre and with scalecide $30 an acre.

BURNING IN HIBERNATION

Without use of blow torch.—The possibility of burning the apple flea-weevil in its winter quarters has probably suggested itself to every one having any experience with the pest, and some of our best results in the search for an adequate control have been obtained by this means. Two different methods were used: burning off the trash and leaves in dry weather, and burning with a torch. Success in burning without a blow torch depends largely on the character of the refuse under the trees and its condition as to moisture content. Two tests were made in the Braden orchard at Olney, Ill., with results as shown in the accompanying table.

Another experiment with surface burning was made in early April, 1920, in the orchard of the Delaware Apple Company, at Delaware, O. This orchard was 10 to 12 years old and had been in grass for several years, so that a well-matted sod had developed. When the burning was done the trash was fairly dry, particularly between the tree rows, and dry enough under the trees so that the fire burned a surface layer up to the trunk though it did not consume all the fallen leaves. Immediately under the trees, however, enough burning was done to cause noticeable injury to the lower branches, as the low-headed type of pruning had been practiced. No noticeable decrease in the number of weevils in this section was found after the brood emerged; indeed the seasonal injury was, if anything, greater, for the burning of the surface cover had exposed the beetles to the spring sun, thus bringing them out of hibernation a few days earlier than on the unburned section. As a result, they attacked the foliage with telling effect as it began to expand.

With blow torch.—This type of burning has proven, under some conditions, the most effective of the control measures tried. If the orchard was partly cultivated, thus forcing the beetles to hibernate on a comparatively small area under the trees, the result was excellent, but if the orchard was in sod, affording hibernating quarters throughout the area occupied by the trees, it was found to be of little value.

Two kinds of torches were used for this work, one burning kerosene and one gasoline. The kerosene torch, of a type commonly used for melting asphalt in paving streets, proved the more effective. It is made by the Houck Manufacturing Co., and consists of a 5-gallon tank equipped with an air-pump and gauge for supplying and registering the necessary pressure. The torch proper is connected to the tank by a flexible hose, and is so constructed that the kerosene is vaporized to form an exceedingly hot blue flame from 8 to 12 inches long and about

Date of burning	No. of trees	Before burning, No. of weevils alive in:				After burning, No. of weevils alive in:				% killed
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	
November, 1920	2	24	13	5	42	10	6	4	20	50
February, 1920	3	48	45	21	114	17	14	14	45	71

4 inches wide. One man can operate the machine, stopping occasionally to replenish the pressure by pumping.

In using the torch, all trash and mulch in a circular area some five feet in diameter about the trunk of the tree was burned clean to the dirt. The time required varied with the density and moisture content of the covering. Unless the sod and mulch is especially heavy, effective work can be done in ten to fifteen minutes per tree, but if the sod is very heavy and of long standing, and particularly if it is damp, as much as half an hour will be required for each tree.

Four tests were made: two in the Braden orchard at Olney, Ill.; one in the Tanner orchard at Flora, Ill.; and one in the Vergon orchard at Delaware, O. The following table gives the results obtained in the first three tests.

Further proof that the burning had a marked effect in reducing the number of weevils is seen by contrasting the numbers of mined leaves in the burned and unburned sections the following spring. In the orchard treated at Olney in the winter of 1919-20, 70 per cent. of the leaves in the unburned part and only 34 per cent. of the leaves in the burned area showed larval mines the following spring. At Flora, 28 per cent. of the leaves showed larval mines in the unburned area and 14 per cent. in the burned area.

From examinations made in the Flora orchard at frequent intervals from the time when the beetles started out of their winter quarters in spring it was evident that there had been considerable migration of the insects from the unburned to the burned area.

The fourth test of the blow torch for burning the weevil in hibernation was made at Delaware, O., in the old Vergon orchard, the same type of kerosene torch being used as in the Illinois work. This orchard it will be recalled, had been in grass for many years. Since the lower limbs of the trees had been killed or so weakened by the flea-weevils that they were of little value, they had been removed and the heavy blue-grass sod had become established quite up to the trunks of the trees. Under this condition we found burning difficult, since, if the sod was dampened by rain or snow, at least 30 minutes, and sometimes longer, were required to burn over a circular area five or six feet in diameter, and even after burning for that length of time we occasionally found live weevils within the burned area. Moreover, as shown before, all the weevils were not hibernating within the burned area, but many were in the sod between the tree rows as well as under the spread of the branches, hence it is easily understood why no apparent diminution could be seen the following spring in the burned as compared with the unburned area of this orchard. In this instance, therefore, we were forced to conclude that burning was of little practical value.

Summary on burning in hibernation.—Our experience with this kind of control leads us to believe that surface burning without the

Place and date of burning and other details	No. of trees	Before burning, No. of weevils alive in:				After burning, No. of weevils alive in:				% killed
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	
Braden orchard, Olney, Ill. November, 1920 Torch using 1 gal. kerosene for 2 trees Time: 15 min. per tree	25	319	190	155	664	5	1	2	8	98.8
Braden orchard, Olney, Ill. Torch using kerosene	4	83	68	29	180	2	2	2	6	96.7
Tanner orchard, Flora, Ill. Nov. and Dec., 1919 Torch using 1 gal. gasoline to 7 trees Time: 15 min. per tree	5	222	110	72	404	19	14	7	40	90

use of the blow torch is of little practical value, and under some conditions may prove harmful because of the possible injury to low-hanging branches and because it may result in the weevils leaving hibernation early.

Burning with the blow torch is decidedly effective in partly cultivated orchards where the beetles are forced to concentrate for hibernation around the base of the tree because the spaces between the tree rows are either barren or the covering is not such as to attract the beetles seeking winter quarters. Where the orchard is in heavy sod of long standing, burning is not a satisfactory means of control because so much time is required for the operation and because the beetles do not concentrate around the base of the tree.

CULTIVATION

By all odds the cheapest and most effective control measure tried under Ohio conditions is clean cultivation, the object being either to destroy the insects in hibernation by plowing them under in fall or early winter, or else by summer cultivation to eliminate all sod and refuse in which they could find winter quarters.

In November, 1918, four acres were plowed to a depth of 4 inches in the midst of the Delaware Apple Company's 40-acre orchard at Delaware, Ohio, then owned by Mr. Hudson. This particular four acres was chosen because it was the very worst infested section in the property. It had been in grass for twenty years or more, and a very tough sod had developed. Only 15 to 20 square feet remained unturned about the base of each tree, and part of this was unsuitable for the hibernation of the beetles because it was covered with cinders, and because some of the protecting refuse blew away.

The following summer the injury in the plowed plot was very slight, particularly from the beetles as they left hibernation in spring and from the mining larvae; but it became somewhat greater when beetles of the new generation spread over the cultivated plot from surrounding trees. However, the total injury to trees in the cultivated plot was not of commercial importance.

This original four-acre plot has been kept in clean cultivation up to the present time, and at no time during the four seasons have the beetles caused commercial injury. Indeed during most of the time it has required searching to find evidence of the beetles' presence in the more central parts of the plot. Moreover, the cultivation has proven of benefit to the trees. They have taken on new vigor and have been markedly more productive than trees of the same age and variety where the ground had not been plowed.

In the summer of 1821 the remainder of the orchard was broken up by numerous cuttings with a double disc and Fordson tractor, the latter so covered as to pass under low limbs without injury to them (see Figure 16). The following season saw a marked limitation in the numbers of beetles in the entire orchard, and since the sod was almost if not quite destroyed by cultivation the next year (1922), the injury of the present year (1923) has been almost nothing. The original Vergon orchard adjoining this one, but in which plowing was not done until the fall of 1922, has been very heavily infested, and at this time some of the trees are so weakened that they are in a precarious situation.

FIG. 16. Fordson tractor equipped with a shield for orchard work, designed by E. L. Main, Delaware, O. The boards, being smooth, lifted the limbs without injury.

The resident growers who have watched the practical elimination of the apple flea-weevil from the Delaware Apple Company's orchard are firmly convinced, as have been several trained observers who have watched the work, that cultivation has in this instance effectively controlled the apple flea-weevil and at the same time has been of decided benefit to the trees from the cultural standpoint.

It should be borne in mind, however, that the cultivation has been absolutely thorough, and that the work done with the implements has been supplemented when necessary by the use of hoes and mattocks to kill any sod close to the tree trunks. On the other hand, a lack of supplementary hand-work may account for the fact that the beetle is found in some Illinois orchards which have been only partially cultivated.

General Summary

1. The apple flea-weevil, a native insect generally distributed from Nova Scotia and Quebec to Oregon, Texas, and Virginia, has

been found notably injurious only in southern and central Illinois and in a limited district in central Ohio.

2. It feeds in small numbers, as beetle or larva, on a considerable variety of native trees and shrubs, but is definitely injurious only to the cultivated apple.

3. The adult beetle is a shining black, densely punctate snout-beetle, about a tenth of an inch long. It is readily distinguished by its much thickened hind thighs and by its exceptional power of leaping, like a flea, when disturbed. The white to brownish larva, found only in leaf-mines, is flattened cylindrical, tapering from the middle towards both ends. It is about a fifth of an inch long when full grown, and at its widest part a fourth as wide as long. It hatches from an egg laid in one of the thicker veins of the under side of the leaf, and feeds on the leaf parenchyma, making a closed mine or burrow which is finally expanded at its outer end into a blotchlike blister within which the larva pupates.

4. There is but one generation a year, the newly formed adults of which emerge from their mines in May and June, feed on the leaves for about a month, and then, in June and July, leave the tree to conceal themselves in what are to be their winter quarters, under grass, leaves, and rubbish on the ground. Here they remain until spring, leaving their shelter at about the time of the unfolding of the leaf, creeping up the trunks of the trees, or flying to the branches above, and beginning again to feed on the leaves, in which eggs are presently laid for the next generation. The egg period lasts about a week, that of the larva 17 days, and the pupal period 5 or 6 days.

5. Injury is done by both the larval mines and the feeding-punctures of the beetles, usually made in the under side of the leaf. The maximum effect in badly infested orchards is a destruction of the leafage sufficient seriously to weaken the tree and reduce it to worthlessness.

6. The principal natural checks on the multiplication of the weevils are fungus and insect parasites, the former destroying the beetles by wholesale in wet summers and the latter killing the larvae.

7. Experiments with means of control were made by banding the tree trunks with tanglefoot, spraying or dusting the leaves with poisons or with contact insecticides, burning the hibernating beetles in grass and rubbish under the trees, poisoning them there with sprays and poison dusts and by the use of poison baits, and cultivation of the orchard at a time and in a way to bury the hibernating beetles beyond resurrection or to keep the ground free from cover to which they might retreat in summer for concealment and hibernation.

Thoroughly clean cultivation, carried close to the tree, was the most effective of these means, reducing formidable infestations to insignificance and improving the vigor and productiveness of the trees.

Next to this was a spray of kerosene emulsion containing 7½ per cent. of kerosene, which, properly applied, killed practically all the beetles—as many in one instance as 9000 to the tree.

Burning in hibernation by a powerful kerosene blow-torch, of a kind used to melt asphalt in paving streets, was effective and useful when an orchard had been so cultivated as to concentrate the beetles under the trees, provided that the cover was of a kind to be burned completely at a reasonable expense for kerosene and labor.

None of the various other means and methods with which experiments were made, were sufficiently useful or promising to justify their recommendation.