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THE FEEDING HABITS OF THE SINUATE PEAR BORER
IN RELATION TO CONTROL PRACTICES

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ABSTRACT

The sinuate pear borer (*Agrilus sinuatus* Oliv.) is one of the serious insect enemies of the pear, not only in this country but in certain parts of Europe as well. This borer may attack any part of the tree above ground, the resulting damage being indicated not only by the direct mechanical injury caused by the insect itself but, what is at times even more serious, by a characteristic canker like development that usually follows along the course of the mine. This secondary injury may at times extend far beyond that directly caused by the insect.

Control measures that have been developed in Europe as well as in this country in the past have been directed primarily against the immature stages of the insect and depend largely on the removal or destruction of the larva in its mine or upon the use of repellents or mechanical barriers designed to prevent or discourage egg-laying.

On account of the generalized nature of the attack and the difficulty of locating the borers in any but young, smooth-barked trees, these methods have not been altogether satisfactory, particularly when applied to mature plantings.

Preliminary feeding experiments carried out with the beetles indicate that the insect in this stage feeds rather freely on the foliage of the pear as well as on that of various other host plants. Further observations brought out the fact that the insects not only feed in the adult stage on pear foliage but that they were also quite susceptible to arsenical poisoning. These preliminary findings suggested the possibility of control by the use of properly timed arsenical sprays.

Orchard spraying tests with arsenicals directed against the adult, together with a better understanding of the life history of the insect, seem to warrant the following recommendations for the protection of pear plantings subject to borer attack:

1. The destruction, so far as practicable, of all wild host plants as well as other possible hosts that may harbor the insect, such as old and worthless pear and quince trees in the immediate neighborhood of the pear planting to be protected.

2. The systematic removal of all borers where the presence of the insect may be indicated on young or smooth-barked trees.

3. Thoro spraying with an arsenical, preferably lead arsenate, at the rate of 4 or 5 pounds to 100 gallons, the first application to be made sometime about June 10, followed by a second treatment approximately 2 weeks later. In particularly difficult situations where invasion by beetles from surrounding plantings is to be feared a third application, to be made a week or 10 days after the second, may sometimes be warranted.
THE FEEDING HABITS OF THE SINUATE PEAR BORER IN RELATION TO CONTROL PRACTICES

HUGH GLASGOW
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INTRODUCTION

The sinuate pear borer (*Agrilus sinuatus* Oliv.) ranks as one of the major pear pests not only in those sections of this country where it has become established, but also in certain parts of Europe. In localities where the insect is especially prevalent it may completely ruin a young pear planting in a very few years, the long sinuous mines of the larva, together with the secondary canker formation that usually accompanies the work of the borer, resulting in damage to the tree out of all proportion to the size of the insect.

Pear borer injury is particularly noticeable in the case of young, smooth-barked trees where the splitting of the bark and the prominent, discolored, canker-like areas that develop along the course of the mines indicate the presence of the insect in a very striking fashion. Altho the work of the borer may be largely masked in more mature plantings by the thick, roughened bark of older trees, the damage in such cases may be no less serious. Such plantings in badly infested sections may lose steadily in vigor until they become wholly unproductive, often without the grower suspecting the true nature of the trouble. Unlike many of the borers attacking cultivated fruits, where the injury is likely to be more or less localized, the larva of the sinuate pear borer may be found infesting all parts of the tree from the base of the trunk to the smaller branches. On account of this habit, together with the ability of the insect to increase rapidly under favorable conditions, it has always been an exceedingly difficult pest to combat by methods ordinarily used in the control of common fruit tree borers.

The studies to be reported here were undertaken a number of years ago with the primary object of throwing some light on the feeding habits of the adult and the possible bearing this might have on shaping control practices.
Various operations for the control of the insect had been suggested and while some of these, if consistently carried out, were very helpful in lessening the amount of injury, none were wholly satisfactory, particularly in mature orchards. These operations were for the most part merely adaptations of European practices which proved inapplicable to conditions under which pears were grown in the Hudson Valley.

While not much accurate information bearing on the food relations of Agrilus adults was available at the time these studies were undertaken, it was felt that a more detailed knowledge of the activities of the sinuate borer in the adult stage might suggest control measures better adapted to fruit growing conditions in this country.

THE ADULT

The adult (Fig. 1) of the sinuate pear borer is a slender, active beetle averaging perhaps one-third inch in length and of a brilliant, iridescent, coppery red or purple color.

The mature borer passes the winter in a specially constructed pupal chamber in the sapwood of the tree, the presence of such cells usually being indicated by large, discolored canker-like areas (Fig. 2) on the bark immediately above them. From these pupal chambers the beetles may commence to appear the latter part of May or early in June. This emergence period is likely to extend thruout the greater part of June, stragglers sometimes appearing even much later than this, altho the peak of the emergence should in most cases occur around the middle of the month.

The beetles are to be found commonly on the bark or leaves on the sunny side of the tree. They are particularly active during the warmer parts of the day, running or flying about in the bright sunlight, but as they are easily disturbed they are not likely to be noticed unless special search is made for them.

Mating and oviposition ordinarily do not begin until 10 days or a week after the emergence of the beetle. Dissections of female beetles at different ages have shown that the ovaries are only slightly developed at the time the insect escapes from the pupal cell, the eggs ordinarily not maturing until after the insect has fed for a considerable time. The female deposits her flattened, scale-like eggs singly, cementing them to the bark, more commonly in crevices or in slight depressions, at any point from the trunk and larger branches to high up on the smaller twigs.
The beetles, altho very active creatures, are comparatively long lived, individuals having been kept in cages supplied with food and water for between 1 and 2 months.

FEEDING EXPERIMENTS AND HOST PREFERENCES OF THE BEETLE

As a preliminary to proposed orchard spraying experiments, to be directed against the adult stage of the insect, a series of cage studies was carried out which was intended to shed light on the general activities of the beetle, more particularly in regard to its feeding habits and host preferences. These studies were planned with the idea of clearing up, as far as possible, some of the following points bearing on this general problem:

1. Does the sinuate borer feed in the adult stage, and if so do the beetles feed to an extent that would make orchard spraying experiments with arsenicals worthy of trial?

2. Assuming that the beetles feed, what are their host preferences and how soon after emergence do they start feeding in relation to the pre-oviposition period?

3. What are the reactions of the beetles to arsenical sprays? Do they differentiate between sprayed and unsprayed foliage and how resistant are they to the commonly used arsenicals?

In studying the feeding reactions of the adult of the sinuate borer the findings to be reported are based almost entirely on cage studies. In the course of the studies caged beetles were supplied from time to time with foliage, flowers, and other materials that might possibly serve as food for the insect. It soon became apparent from such preliminary observations that the beetles were not primarily flower feeders, for while they were sometimes observed to nibble at the petals of certain flowers they showed a marked preference for foliage, feeding to an extent that had hardly been anticipated when the studies were first undertaken.

The beetles were found to feed on the foliage of most of the plants regularly infested by the larvae, and on a few not known to harbor this stage of the insect. Distinct preferences were shown for certain types of foliage. The beetles either refused or fed very sparingly on the apple, and even when kept without food for several days could not be induced to feed on peach, plum, cherry, grape foliage, or on the foliage of certain shade trees. The insects fed sparingly on rose and spirea, but they ordinarily refused these when
Fig. 1.—Life Stages of the Sinuate Pear Borer.

A, egg; B, newly hatched larva; C, mature larva; D, pupa; E, adult male; F, adult female.

given a choice. Of the host plants known to harbor the larva, the beetles seemed to show a distinct preference for the pear, but also fed freely on hawthorn, mountain ash, and cotoneaster foliage. The
Fig. 2.—Work of Sinuate Borer on Pear.

At left the typical checking and distortion of the bark that commonly appears along the course of the mine, ending in a canker-like area immediately above the pupal chamber. Right, the same branch with bark removed showing course of mine with position and construction of pupal chamber. Center, larva of sinuate pear borer slightly enlarged.
pubescence of the quince appeared to be rather distasteful to the insects, altho they accepted this freely enough when allowed no choice.

The following brief notes having to do with one of these cage tests may be worth recording here in some detail as they give a fairly good picture of the general feeding reactions of the beetle. The small cage used in the test was approximately 22 inches high by 15 inches across. In it was placed a small, potted Clapp Favorite pear on which the foliage was well developed. On June 12, 30 beetles that had emerged June 8 to 12 were placed in this cage. In the case of some of these beetles, feeding commenced almost at once and continued actively for a period of nearly 20 days, or until June 30 when the test was discontinued.

On June 16, which was a bright, sunny day, foliage from three different types of Crataegus were placed in this cage, together with fresh pear foliage. Foliage of the American mountain ash, Japanese quince, apple, raspberry, elm, and Carolina poplar was also introduced, together with blossoms from a number of plants including those of the Kieffer pear and the red raspberry. The small pear tree had been badly defoliated by this time, altho a few of the leaves were still intact. The material being tested was allowed to remain in the cage for a period of 48 hours, after which it was removed and fresh foliage introduced.

On examination at the end of the 48-hour period it was found that of the three types of hawthorn foliage, two\textsuperscript{1} had been eaten freely by the beetles which seemed to accept this as readily as pear. The third,\textsuperscript{2} of which the leaves were glossy and rather firm in texture, showed only slight feeding and was clearly not very acceptable to the beetles.

The mountain ash leaves were eaten readily, altho the pear and Crataegus foliage appeared to be preferred. This apparent preference, however, was not very clear cut.

The apple leaves were not touched by the insects, altho they had purposely been placed in the most favorable position in the cage. During the course of the test insects were frequently observed resting on the apple leaves and occasionally a beetle would be seen to pinch the edge of one of these leaves with its mandibles as tho

\textsuperscript{1}Crataegus Oxyacantha and C. punctata.
\textsuperscript{2}C. crus-galli.
inclined to feed on it, but actual feeding apparently never took place as the apple leaves were all intact when removed from the cage. It is apparent that, given a choice, the beetle would feed little if at all on apple foliage under orchard conditions and that apples growing near pears need not greatly complicate the problem of control where sprays are to be directed against the adult of the insect.

The raspberry, elm, and Carolina poplar showed no indication of feeding. The petals of both the raspberry and pear blossoms were nibbled slightly in places, but the other floral parts were not touched by the beetles. There was some feeding evident on the Japanese quince, altho the leaves of this plant seemed to be less palatable to the beetles than those of the pear, hawthorn, and mountain ash.

The beetles usually start feeding from the edge of the leaf and may continue until the midrib is reached. Even when several beetles attack a single leaf they seldom destroy it completely, but usually leave ribbons of leaf tissue separating the various areas that have been eaten. The insect usually rests on the upper surface of the leaf when feeding, and appears to accept mature leaves just as readily as the tender, newly opened ones. They do not appear to attack the opening buds or to gnaw at the bark of the tender twigs, but confine their feeding almost entirely to the leaves.

On June 21 a fresh lot of foliage was introduced into this cage, the list including apple, peach, plum, sweet cherry, poplar, and mountain ash. When removed 48 hours later on June 23 both the pear and the mountain ash foliage showed extensive feeding, but the others had all been avoided by the beetles. These do not appear to be in any way offensive to the insect, however, as the beetles were observed to rest on them as readily as on the pear or hawthorn, but they clearly cannot be classed as acceptable food plants for the beetle.

On June 25 a quantity of Kieffer pear foliage, together with willow, ash, and Spiraea was placed in the cage. The Kieffer pear was accepted at once. Within 2 hours the leaves showed a great deal of feeding; in fact the variety seemed to be somewhat more acceptable to the beetle at this time than the Clapp Favorite, altho this apparent preference for the Kieffer may have been due to some slight difference in freshness of the foliage. The willow leaves, as well as those of the ash, Spiraea, and oak, remained untouched and showed
FIG. 3—Feeding Done by 30 Adults of *Agrilus sinuatus* Oliv. in a Period of 10 Days on Small Potted Pear Tree.

Beetle much enlarged.
not the slightest indication of feeding when removed on June 27, altho in other tests the beetles had at times been observed to feed slightly on Spiraea.

By June 28 the second of the potted trees being largely defoliated, it was removed and photographed (Fig. 3), a third tree being introduced at this time, together with another lot of willow, ash, Spiraea, and rose foliage. When this cage was discontinued on June 30 and the final examination made, all but 4 of the 30 beetles were still alive and active, while eggs were being deposited in considerable numbers on the bark of the young tree and even on the sides of the cage. Of the foliage introduced on June 28, the willow, ash, Spiraea, and oak had been untouched, altho a few of the rose leaves had been slightly gnawed by the insects. Practically all the feeding during the last 2 days had been confined to the leaves of the recently introduced pear tree, some of which were almost completely riddled by the beetles.

Examples of typical feeding on the foliage of a number of the host plants of the beetle are shown in Figs. 4 to 10, inclusive. These include foliage from the pear, hawthorn, mountain ash, cotoneaster, quince, Japanese quince, and serviceberry. The small potted pear tree shown in Fig. 3 will give some idea of the amount of leaf surface that may be consumed by the beetles in feeding. A total of 30 beetles were confined on this tree for approximately 10 days. At the end of this period, even tho other foliage had been introduced in the meantime, the tree itself, as shown in Fig. 3, was practically stripped of foliage, many of the leaves having been completely eaten down to the midrib. Several such leaves do not show in the photograph, however, since

**Fig. 4.—Pear Foliage Showing Typical Feeding by Adults of *Agrilus simulates* Oliv.**
they had completely dried and fallen to the bottom of the cage before the tree was removed and photographed.

In an attempt to provide a more accurate gauge on the amount of leaf surface actually consumed by the beetles, a group of five females was selected and carried thru a carefully controlled set of feeding experiments. These beetles were confined separately in small cages, each individual being given a single pear leaf on which it was allowed to feed for a definite period. At the end of the allotted time the five leaves were removed, fresh ones substituted for them, and a photographic record made showing the amount of leaf surface actually consumed by each of the five beetles. This procedure was repeated until four consecutive series of leaf records were obtained, the entire period covered being approximately 5 days.

The time allowed was not the same in all cases since the first set of leaves represented 36 hours of feeding as does also the fourth, while the beetles were allowed to feed for approximately 24 hours in the case of the second and third of these sets. The amount of feeding in the last three of these tests is shown by means of photographs in Figs. 11, 12, and 13. In photographing each lot of leaves a beetle was included to indicate the amount of leaf surface consumed by each beetle in relation to the size of the insect. The beetles used in these tests were all females. They were not recently emerged individuals, but were all several days old and had commenced normal feeding before the tests were started.
The five beetles selected for the test were kept without food for 3 days. They were supplied with water, however, and during a part of each day the cages in which they were confined were placed in the direct sunlight in order to stimulate as much activity on the part of the insects as possible. When first introduced into their respective cages, the beetles all commenced feeding in a relatively short time. While the first of these four feeding tests may not have been typical, coming as it did immediately after a fast period, the three later records shown in Figs. 11, 12, and 13, should indicate with fair accuracy the normal rate of feeding of active female beetles.

The leaves in each set when photographed were consistently arranged in the same order with respect to the particular insect that had done the feeding.

Toward the end of a bright, warm day during which the beetles have been particularly active they are apt to commence feeding greedily as the light becomes less intense and void quantities of dark-colored, rod-shaped pellets of excrement that often accumulate on the leaves or at the bottom of

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**Fig. 6.—Mountain Ash (Sorbus americana).**

Feeding by adult of *A. sinuatus* Oliv.

**Fig. 7.—Cotoneaster (Cotoneaster sano-yorica).**

Feeding by adult of *A. sinuatus* Oliv.
Fig. 8.—Quince (Cydonia oblonga). Feeding by adult of *A. sinuatus* Oliv.

<table>
<thead>
<tr>
<th>Leaf series</th>
<th>Amount of feeding shown in Figs.</th>
<th>Hours of feeding</th>
<th>Pellets of excrement voided by each beetle</th>
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<tr>
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<tr>
<td>4</td>
<td>13</td>
<td>36</td>
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</table>

The results of the counts are given in Table 1.

In a corresponding series of feeding tests in which male beetles were used, the feeding seemed to go on at approximately the same rate as with the females. This statement is based on the number of pellets of excrement voided by the beetles, altho the amount of leaf surface actually consumed was the cage in considerable amounts.

In the quantitative feeding experiments just discussed this accumulation of excrement suggested an additional way of checking on the amount of leaf surface consumed and the exact number of pellets of excrement voided by each of the five beetles was accordingly counted and recorded in the case of all five of the lots.

Fig. 9.—Japanese Quince (*Chaenomeles lagenaria*). Feeding by adult of *A. sinuatus* Oliv.
often appreciably less in the case of the male beetles. When allowance is made for their relatively smaller size, the rate of feeding of the two sexes was fairly comparable. No photographic record was made of the leaf series in which male beetles were used, but the counts are shown in Table 2.

The record is comparable to that shown in Table 1 and represents the feeding of three males during three consecutive 24-hour periods.

It will be noted that while the amount of leaf surface consumed by the beetles varies somewhat with the different individuals and in

**Table 2.—Rate of Feeding by Adult Males of Agrilus sinuatus Oliv. as Shown by Number of Pellets of Excrement Voided by the Beetles.**

<table>
<thead>
<tr>
<th>Leaf series</th>
<th>Hours of feeding</th>
<th>Pellets of excrement voided by each beetle</th>
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<tr>
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</tr>
<tr>
<td>3</td>
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<td>96</td>
</tr>
</tbody>
</table>

the different groups of leaves photographed, the rate of feeding was, on the whole, surprisingly consistent throughout the entire series and indicates that the feeding by the beetles is not sporadic but may be expected to continue at a fairly uniform rate.

**FEEDING HABITS OF THE BEETLES IN RELATION TO THE PRE-OVIPOSITION PERIOD**

In any spraying program to be directed against the adult stage of an insect the success of the operation naturally hinges largely on the length of the pre-oviposition period and the relation this bears to the amount of food consumed and the age at which the insect may be expected to commence feeding.
Fig. 11.—The Amount of Feeding Done by Five Adults of *A. spinarius* During a Period of 24 Hours.

Each leaf represents the work of a single beetle. See continuation of this series in Figs. 12 and 13.
Fig. 12.—The Amount of Feeding Done by Five Adults of *A. sinuatus* 
During a Period of 24 Hours.

Each leaf represents work of a single beetle. Continuation of series in 
Figs. 11 and 13.
Fig. 13.—The amount of feeding done by five adults of *A. sinuatus* during a period of 36 hours.

Each leaf represents the work of a single beetle. Continuation of series in Figs. 11 and 12.
In the case of the sinuate pear borer the interval between emergence and the beginning of egg deposition seems to be somewhat variable, depending largely on the character of the weather and the condition of the beetle at the time it escaped from the pupal cell. It was noted that beetles emerging during a cool, cloudy period sometimes remained relatively sluggish for several days. In such cases the pre-oviposition period may be considerably longer than when the insects emerge on warm, bright days. When this occurs the insects are apt to be quite active as soon as they appear, flying or running about rapidly in the bright sunlight. Such beetles may even commence feeding the same day they emerge, altho commonly several days may elapse before active feeding really starts.

The character of the wood from which the beetles emerge appears also to influence greatly the activity of the insect immediately after its escape from the pupal cell. In case the infested tree has died or the wood about the pupa cell has thoroly dried, the beetle on escaping is apt to be fully colored and active as soon as it appears and in its development may be several days ahead of individuals emerging from pupal cells in rapidly growing trees, particularly where, as sometimes happens, actively growing scar tissue has built up over the pupal cell.

After emerging, if the day is warm and bright, the beetle may in some cases commence feeding in a comparatively few hours. This early feeding is not very noticeable as a rule and amounts to little more than a slight nibbling along the margins of the leaf. Within 2 or 3 days, however, especially if the weather is warm and the insect has been active in the meantime, it begins its normal feeding. This continues during the life of the beetle which may last for a month or more. Being an exceedingly active creature, the beetle when caged requires an abundance of water and normally feeds and drinks several times a day except during cool, cloudy periods when it is likely to be sluggish and to feed little if at all. An example of early feeding by the beetles, which took place the same day the insect emerged, may be seen in Fig. 14.

The beetle responsible for this feeding, a large female, escaped from the pupal cell at about 7:45 a. m. It was fully colored and very active at the time it emerged and continued flying and running about the cage for several hours or as long as it was exposed to the direct sunlight. By 4 p. m. of the same day, 8 hours after it left
the pupal cell, this individual was observed nibbling at the edge of a pear leaf on which it was resting. This feeding continued at intervals of perhaps 30 minutes until, as shown in Fig. 14, an appreciable amount of leaf surface had been eaten by the insect. While the area consumed at this feeding was not great it might well have caused the death of the beetle if the leaf had carried a heavy film of spray residue.

Under insectary conditions it has usually taken 10 days or even longer after emergence for the females to commence depositing eggs, a point that is of the utmost importance in connection with any spraying program to be directed against the adult stage of the insect. The notes from one rearing cage test are given at this time as they are fairly representative and have a direct bearing on the point in question. The cage to be considered contained six beetles, three females and three males, that had emerged during June 6 and 7. They were introduced into the cage the afternoon of June 7, together with a small potted pear tree having an abundance of foliage.

*June* 8.—Beetles quite active during afternoon of June 8 when cage was exposed to direct sunlight, but so far there are no evidences of feeding.

*June* 9.—Cloudy today and beetles are sluggish, apparently no feeding.

*June* 10.—Several leaves noticed today with evidences of slight feeding around edges. No extensive feeding as yet.

*June* 11.—Beetles have commenced to feed freely on foliage today. One leaf almost half eaten.

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**Fig. 14.—Early Feeding by Adult of *Agrilus sinuatus* Oliv. on Pear Leaf.**

Note feeding on right-hand margin of leaf.
June 12-15.—Beetles still feeding freely on foliage, but no evidence of egg laying.

June 16.—Feeding continues and one pair of beetles observed mating today for first time.

June 18.—No eggs found, but one female was observed running about cage in an excited fashion extruding the ovipositor from time to time and occasionally stopping to push the tip into irregularities in the bark of the pear tree. Evidently no eggs were deposited today.

June 19.—The same female was observed behaving as on the preceding day. She was removed and placed in small cage with pear twig for closer observation, but altho she repeatedly thrust her ovipositor into cracks in the bark of the pear twig no eggs were found after 40 minutes when she was returned to main cage. The other two females were now behaving in a similar manner and will probably start egg laying soon.

June 20.—No eggs were to be found today.

June 21, 2 p. m.—Two females were removed and placed in small cage with pear twig. By 5 p. m. three eggs had been deposited on the twig by one of these females.

June 22.—Females are now all depositing eggs and are busily engaged in testing with their ovipositors every crevice and irregularity in the bark of the young tree for places in which to deposit their eggs.

June 29.—Dull and cloudy today. Females seem to be doing an unusually large amount of feeding. They feed for a period of 5 or 10 minutes and then rest for several minutes, after which feeding is resumed. They are consuming a surprisingly large amount of leaf surface, more than on any previous day.

July 2.—One of the females is apparently dying. When dissected 22 full-sized eggs were found in ovaries.

July 11.—A second female seems to be dying. Ovaries contained 11 eggs.

July 16.—Last of the three females found dead today on bottom of cage. Dissection showed 19 eggs in ovaries. During the period the cage was maintained, a total of 52 eggs was deposited, most of which were placed in irregularities in the bark of the small pear trees, altho a few were found on the sides of the cage.

From these and other similar observations it would appear that the adult of the sinuate pear borer is capable of living for a month or more during which time it may be expected to feed to an appreciable extent on pear and other foliage. Extensive feeding does not ordinarily commence at once on emergence, but only as a rule after a period of activity on the part of the beetle often covering several days. Since the beetles do not usually commence depositing eggs for 10 days or more after emergence, there is an intervening
period of several days when the application of arsenical sprays should be most effective. On account of the relatively long life of the beetle, however, and the prolonged period during which the females may be depositing eggs, such spray might well be of considerable value even when applied long after egg laying had commenced.

**SUSCEPTIBILITY OF BEETLES TO ARSENICALS**

Preliminary tests carried out to determine the reactions of the insect to sprayed foliage indicated that the beetles were quite susceptible to arsenical sprays. Beetles confined on foliage sprayed heavily with lead arsenate were found to show little or no discrimination in choosing between clean leaves and foliage carrying a heavy deposit of lead arsenate. Individuals that had started feeding at a point comparatively free from spray deposits were frequently observed to continue thru a spot where a drop of spray had dried leaving an exceptionally heavy deposit of the arsenical without seeming to notice its presence. It was apparent that the beetles were not noticeably repelled by the arsenical as so frequently happens with many other types of insect pests. As might be expected under such conditions, the mortality was relatively high among the insects feeding on sprayed foliage, the beetles dying much more rapidly than might have been the case if there had been a greater tendency to avoid leaves or those areas carrying a heavy load of the arsenical.

The figures given in Table 3 serve to illustrate the general reaction of the beetles to lead arsenate sprays. In this particular test, 10 active beetles were placed in each of two cages, one containing normal pear foliage, the other foliage that had previously been sprayed with lead arsenate at the rate of approximately 6 pounds to 100 gallons.

Feeding by the insects commenced in most cases shortly after they had been placed in the cages and continued in the case of the control until the experiment was discontinued at the end of 2 weeks. The beetles on the sprayed foliage in general fed freely in the beginning, but after the first day this feeding practically stopped and by the second day they appeared noticeably more sluggish than those in the control cage. Instead of running about actively and congregating on the sunny side of the cage as in the case of normal beetles, many of them continued to crawl about in a listless manner, some obviously having difficulty in moving the legs as tho partially paralyzed.
By the end of the second day five of the beetles that had fed on the sprayed foliage were either dead or were resting on the bottom of the cage so badly paralyzed that they were unable to crawl about. Some, however, still showed enough life to move the legs slightly when disturbed. Three more beetles were found dead in this cage the morning of the third day. The two remaining beetles, a male and a female, lived until the eighth day of the experiment. Toward the end they were very sluggish and apparently did not resume feeding after the first day. These two beetles may well have been less active in the beginning than the others and may have eaten less of the foliage as indicated by the slowness with which they succumbed to the poison. In this test no record was kept of the actual amount of feeding done by each individual.

In the control cage one of the beetles was found dead at the end of the second day, possibly having been injured in handling, but the other nine remained alive and continued feeding for the 2 weeks during which these cages were maintained. From these and other experiments that have been carried out from time to time, it is apparent that the beetles not only feed to a considerable extent on sprayed foliage but are also susceptible to arsenical poisoning to a marked degree.

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<th>Treatment</th>
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<th>SECOND DAY</th>
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<th>EIGHTH DAY</th>
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<td>9</td>
<td>1</td>
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*Pear foliage sprayed with lead arsenate at the rate of 6 pounds to 100 gallons.

**RELATED PESTS**

While the following observations bearing on the feeding habits of the bronze birch borer (Agrilus anxius) and the flat-headed hickory borer (Dicerca obscura) and their reaction to arsenical sprays are fragmentary and have no direct bearing on the main problem, they are included here as it is thought they may be of supplementary interest.
From a number of specimens of *D. obscura* collected from shag-bark hickory September 6, two individuals, a male and a female, were placed in each of two small cages. The exact age of these beetles was not known, but when supplied with fresh hickory foliage they were found to feed readily on it, consuming an area of leaf surface each day often considerably greater than that of the insect itself. When offered pear foliage this was refused by all but one female which fed but slightly on one of the leaves.

They were next supplied with *Crataegus* foliage for 48 hours, and altho they seemed to feed on this somewhat more freely than on the pear, it was accepted much less readily than the hickory. The insects were frequently observed to bite out small pieces from the *Crataegus* leaves and drop them from their mandibles instead of swallowing them.

**SPRAYING TESTS WITH DICERCA OBSCURA FABR.**

On September 20 these same four beetles, after they had been kept without food for 24 hours, were supplied at 11:30 a. m. in one cage with fresh hickory leaves that had been sprayed with lead arsenate at the rate of 6 pounds to 100 pounds, while the other cage containing clean hickory leaves was kept as the control. The beetles commenced feeding almost at once and by 3 p. m. of the same day had in most cases eaten away an area of leaf surface almost as great as the beetles themselves.

The heavy deposits of the arsenical left where droplets of the spray had dried were eaten directly thru (Fig. 15), as in the case of the sinuate borer, without any attempt apparently being made to avoid them. The beetles commenced feeding

**Fig. 15.—Feeding by Adult of Dicerca obscura Fabr. on Hickory (Carya ovata).** Normal leaflet on left; sprayed leaflet on right. Each leaflet represents feeding by one female during 48-hour period.
at the margin of the leaf and continued in the same place often until the midrib was reached and even severed in the case of one of the large females. It is evident that the spray residue on the leaves, even when heavy, is not distasteful to the beetles as in several cases such areas could have been avoided by the insects moving to one side but a fraction of an inch.

Early in the course of this test the two beetles in the sprayed cage appeared to feed just as readily as those in the control. By 4:30 p.m., however, they had both stopped feeding and while still active did not show any inclination to continue. The following notes give the history of the two cages.

**Sept. 21, 8 a.m.**—Both the beetles in the sprayed cage are still alive and active but have eaten no more since the afternoon of the preceding day. The larger beetle, which has eaten nearly twice as much as the male, is now practically dead. It can still move its legs weakly but refuses to walk. The male, while clearly not normal, can still walk about readily but shows no desire to feed.

**Sept. 21, 1 p.m.**—The smaller beetle is still active. The female was found on its back in bottom of cage apparently dead. When warmed slightly it became active once more and crawled about almost as readily as the male. Neither has fed since yesterday, altho the pair in the control cage are feeding normally. When replaced in cage the female again became motionless.

**Sept. 22, 8 a.m.**—Both beetles are lying on their backs with legs extended and rigid. The female was apparently dead, but when warmed was again able to move its legs about in an aimless fashion but could not walk. The male is still alive and able to crawl sluggishly about when warmed, but when replaced in cage became quiescent again. Neither beetle has attempted to feed since the first day, altho supplied with fresh unsprayed hickory foliage.

**Sept. 22, 4 p.m.**—Female now dead. Male can still move legs when warmed but not able to walk.

**Sept. 24, 9 a.m.**—Both beetles apparently dead. The pair in the control cage appear perfectly normal in every way.

**FEEDING TESTS WITH *AGRILUS ANXIUS* GORY**

On June 24, six adults, five females and one male, were captured on white birch and transferred to cage with birch leaves. On June 28, it was noted that the beetles did not appear to feed readily on birch foliage, in fact there was no evidence of feeding on the leaves.

One female was observed on the 28th depositing eggs and by evening had laid a total of 10 eggs. This cage was maintained until
July 8 when the eggs commenced to hatch. The female observed ovipositing on June 28 laid a total of 28 eggs, but notwithstanding this there has been practically no feeding, the only evidence being a slight nibbling along the edges of two of the leaves. Four of the beetles were still alive on July 8, but as they could not be induced to feed on the birch foliage to an appreciable extent the cage was discontinued and no test with arsenicals was carried out in the case of this species. Apparently, the adult of *A. anxius* does not feed as extensively as that of *A. sinuatus* and should therefore be more difficult to control by arsenical sprays. This test, however, was quite limited, including as it did only six beetles, and the general conclusions as to amount of feeding might have been different if more insects had been used.

**ORCHARD SPRAYING TESTS**

With the work having to do with the feeding reactions of the adult as a background, the studies on the sinuate borer were extended to include experiments in the use of arsenical sprays applied under orchard conditions. On account of the active habits of the beetle the experimental orchards were not divided into treated and untreated blocks in the conventional way as when dealing with more sedentary types of insect pests. Instead, the plan followed was to locate the tests in fairly well isolated orchards already infested by the borer that were not likely to be subject to heavy beetle invasion from the outside, and by spraying the entire planting consistently for a number of years to measure the efficiency of the treatment by the general reduction in borer population of the orchard as a whole. While the method followed was perhaps rather crude, the results over a period of years were quite encouraging and indicate that the use of properly timed arsenical sprays should go far towards holding the insect in check. The history of one of these experimental orchards is given below.

This orchard, a planting of Bartlett pears, on the farm of De Witt C. Haight, Croton Falls, N. Y., contained about 300 trees. The orchard was set in 1914, and being fairly well isolated the borer was not noticed attacking the young trees until the summer of 1916. Spraying was not started until the spring of 1917 when the trees were 3 years old. At this time a careful tree to tree examination showed 22 trees infested, or over 7 per cent of all the trees in the
orchard, 6 of the 22 infested trees showing two mines each. The orchard was sprayed heavily on June 8 using lead arsenate at the rate of 6 pounds to 100 gallons, this treatment being repeated approximately 10 days later on June 17.

The following season, 1918, the orchard was sprayed again with lead arsenate at the same rate on June 5 and again on June 16. When examined on June 5, out of the 300 trees in the orchard but a single one was found to show fresh work of the borer.

In 1919 the spraying was continued as in the two preceding seasons except that but one application was made on June 16. When examined at this time the orchard was apparently free from the borer, no recent mines having developed, altho there were several infested hawthorn trees near by in an adjoining pasture.

In 1920 a single application was made on June 14, but no examination was made for the borer. The following year, 1921, a careful examination was made of this orchard when it was found that five of the trees showed evidence of recent borer work, indicating that a single application is probably not enough to insure protection from from the insect. As a partial check on this sprayed block, an orchard of 225 trees of the same age and variety located approximately 1 mile distant was kept under observation. This orchard was never sprayed at any time for the borer and was very well situated to serve as a check on the sprayed block since it was much more isolated and had considerably less chance to become infested from the outside. When examined in 1917 none of the 225 trees in this orchard showed any indication of borer work, while, on the other hand, the insect was already increasing rapidly in the sprayed block.

The check orchard was not examined in 1918, but in 1919, 12 trees were found to harbor the borer, and it is safe to say that had this orchard not been so well isolated the infestation would certainly have been much heavier by this time.

When the last examination of the two orchards was made in 1921 the infestation in this untreated block had increased from 12 trees in 1919 to 69 in 1921, or over 30 per cent of the original stand, with every indication that within the next few years most of the trees in this orchard would be attacked by the borer. As a result of experience gained in such field tests, together with a more complete knowledge of the general activities of the insect, it is suggested that the two beetle sprays be timed so that the first application comes
about the tenth of June, depending somewhat on the season, to be followed by another from 10 days to 2 weeks later. Experience by practical growers has seemed to indicate that such a schedule is well adapted to the protection of commercial pear plantings, particularly if this procedure is supplemented by reasonable care in removing the borers wherever their presence may be indicated on the younger smooth-barked trees and in eliminating old and worthless trees that may serve as breeding places for the insect. While the above schedule should answer well under ordinary conditions, in particularly difficult situations a third application made 10 days or 2 weeks after the second might be considered.

The following excerpt from a letter recently received from A. J. Schaefer of Plattekill, N. Y., is reproduced here as it has a direct bearing on this subject. This statement summarizes the experience of a practical fruit grower, extending over a period of nearly 10 years, in the use of arsenical sprays for the control of the sinuate borer. In his letter Mr. Schaefer says:

“In 1925 our three pear orchards containing 13 acres were generally infested by the sinuate borer. The following autumn we went over the trees and grubbed out all the borers we could find. Since then the trees have had two annual applications of arsenate of lead, the first shortly after petal fall and the second about July first. Within two years after we began the above spray program we could notice a definite improvement in the appearance of the trees, and in looking over the trees for borers fewer new evidences were found. We have continued this spray program and it is now difficult to find any borers.

“In a later planting of Bosc trees, quite removed from the above orchards, we did not apply any sprays as there was no pear psylla present for the first four years. Soon we began to notice sinuate pear borer injury on the young trunks and so we are now applying the two sprays to these trees the same as in the other orchards.”

SECONDARY EFFECTS OF SPRAYING

In studies having to do with general behavior of the insect, it was observed that on hatching the young larva does not expose itself but burrows directly thru the bottom of the egg into the bark of the tree, filling the abandoned egg shell with pellets of excrement. This habit suggested the possibility of poisoning the newly hatched insect by spraying the bark of the tree heavily with an arsenical previous to egg laying so that the young larva would have to pass thru a film of the arsenical before starting the mine. In the course of cage ex-
periments to test this theory, the bark of small potted pear trees was sprayed heavily with lead arsenate at the rate of 5 pounds to 100 gallons of water.

Females that were actively depositing eggs in the stock cage were transferred to the test cages and allowed to continue ovipositing on the bark of the sprayed trees. These females, since they were needed for other tests, were seldom left in the test cage for more than a few hours at a time and were removed soon after depositing eggs in order to avoid having them feed on the poisoned foliage. Altho these females certainly did no feeding while in the sprayed cage, it was soon noticed that they were very short lived on being removed and commonly refused to resume feeding when replaced on clean pear foliage. In general, such beetles behaved much like those that had fed on sprayed foliage, refusing to feed and often dying in from 1 to 4 days. Altho such beetles were seldom left in the test cage more than a few hours and were never allowed to feed on the sprayed foliage, in their eagerness to find a suitable location for the eggs, they were continually running about over the bark of the sprayed trees and in this way must have accumulated enough of the poison on their feet to provide a fatal dose when grooming themselves as they frequently do.

These observations are of interest in suggesting that under orchard conditions heavy applications of lead arsenate may be of value in reducing the beetle population irrespective of any actual feeding by the insect on the foliage. They also suggest that early applications of an arsenical spray may be of considerable benefit even before the beetles actually commence feeding on the foliage.

**RECOMMENDATIONS**

Most of the methods that have been developed in the past for the control of the sinuate pear borer have been directed chiefly against the immature stages of the insect. These measures depend largely on the removal or destruction of the insect in the larval mine, while others provide for the use of repellents or mechanical barriers to prevent or discourage egg laying.

On account of the generalized nature of the infestation and the difficulty of locating the borers in any but young, smooth-barked trees these methods have not been altogether satisfactory, particularly when mature plantings are involved. The following schedule
of treatment based on the observations recorded in the preceding pages should greatly simplify the problem of control, particularly as it applies to older bearing orchards as well as in the case of young, smooth-barked trees.

Since the sinuate borer feeds regularly in the adult stage and has proved susceptible to arsenical poisoning, it has been found possible to hold the insect in check in commercial plantings by the use of properly timed arsenical sprays. The spray recommended for the control of the sinuate borer is one containing lead arsenate at the rate of 4 or 5 pounds to 100 gallons. Since the peak of the emergence does not ordinarily come until about the middle of June, the first application should be made about the tenth of the month, to be followed by a second approximately 2 weeks later.

In severely infested orchards or where there is a great possibility of beetles migrating into the sprayed planting from neighboring infested trees a third application to be made 10 days or two weeks after the second may be advisable. In most cases, however, the two earlier applications should give satisfactory control if reasonable precautions are taken to eliminate outside sources of contamination. The amount of spray required will naturally depend entirely on the size and age of the trees, but in any case the foliage should be well covered with the arsenical. The efficiency of the treatment should be appreciably increased also if care is taken in spraying to cover the bark of the trunks and larger branches as well as the foliage.

By all means the above spray program should be supplemented by a systematic removal of all borers, particularly during May or early June, whose presence may be indicated on the younger, smooth-barked trees. Every effort should also be made to insure the timely spraying of other pear orchards in the vicinity that may be infested by the borer and to provide for the destruction of all old or worthless trees in the immediate neighborhood of the orchard as well as of wild host plants that might serve as a harboring place for the insect. Old, half dead pear trees that are so frequently found along fence rows are a particularly serious menace to nearby pear plantings since such trees are frequently found to harbor a relatively large borer population.

The borer is able to maintain itself in hawthorn, mountain ash, quince, and several other less common host plants as well as in the pear, and these secondary host plants must naturally be kept in mind in the carrying out of any control program.
Fortunately, the sinuate borer appears to attack the apple rarely, if at all, either in the adult or larval stages, and the immunity of this fruit to infestation simplifies the problem of control in the care of pear plantings.

SUMMARY

The sinuate pear borer has been found to feed readily in the adult stage on pear foliage as well as on that of certain other fruit trees. In feeding the beetle does not seem to be greatly repelled by the presence of arsenical spray residues on the foliage. After feeding on such sprayed foliage for a time, the females ordinarily cease both feeding and egg laying and generally die within a few days.

Based on these findings, orchard tests as well as the experience of practical growers indicate that the insect may be successfully controlled in pear plantings by two applications of a lead arsenate spray, using the arsenical at the rate of 4 or 5 pounds in 100 gallons. The first spray should be applied sometime near the tenth of June, followed by a second approximately 2 weeks later.