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# The Flatheaded Apple Tree Borer

# (*Chrysobothris femorata* (Olivier))

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Recommendations on control of the flatheaded apple tree borer are given in Oklahoma Agricultural Experiment Station Circular C-84, "Control of Shade Tree Borers."

ERRATUM: On page 16, for "An average of 44 borers was removed per apple branch . . . " read "An average of 4.4 borers was removed per apple branch . . . "

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## INTRODUCTION

The flatheaded apple tree borer (Figs. 1 to 4) is a common and important insect enemy of devitalized fruit, shade and nut trees, and may also seriously injure many species of ornamental shrubs. It is a very serious pest in Oklahoma because trees are so often handicapped by severe climatic conditions, particularly drought, and are frequently grown in poor soils. The borer is at all times an important enemy of recently transplanted trees.

At the time this investigation began, the borer was unusually prevalent and destructive due to a general low vigor in many trees because of a widespread drought. Moreover, the insect had suffered few if any natural checks to its multiplication. It was not an uncommon sight to see several dozen of the beetles actively running up and down trees during the day, and it was possible to collect several hundred from a few trees in a short time. Unless transplanted trees were properly protected, they were almost sure to be killed or at least severely injured before the first growing season was over.

Because of the seriousness of the situation, a project was set up by the Oklahoma Agricultural Experiment Station to determine the biology of the insect under Oklahoma conditions and to study possible control or preventive measures. Most of the work was done at or near Stillwater. The present bulletin is a report of the results of this investigation.

## REVIEW OF LITERATURE

The flatheaded apple tree borer has long been reported as injurious to fruit and shade trees, particularly those recently transplanted or in a devitalized condition. Saunders (20) in his book, **Insects Injurious to Fruits,** gives general notes on its life cycle and recommends a repellent alkaline wash as a protection. While this borer was known to infest a large number of species of trees, the first comprehensive list was given by Burke (4). Earlier this same author (3) had mentioned that many published records of this species in the West refer to **C. mali** (Horn), a closely related species which he reported in 1919 as occurring in Oregon, California, Nevada, Utah, Colorado and Arizona. Brooks (2) gave further data on geographic distribution, factors predisposing trees to injury, host plants, description of the different stages, and control. Observations on the occurrence of the beetles in pecan groves in Georgia (7), as determined by trapping them on poles coated with a sticky substance, showed that they were most numerous from the middle of May to the middle of July. Fenton and Maxwell (5) reported on the life cycle in Oklahoma.

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* The author wishes to thank the following for their assistance in this project: J. M. Maxwell, Geo. V. Johnson, C. L. Hovey, L. F. Bewick and Abbott Kagan. The photographs were taken by G. A. Bieberdorf, Assistant Professor of Entomology.

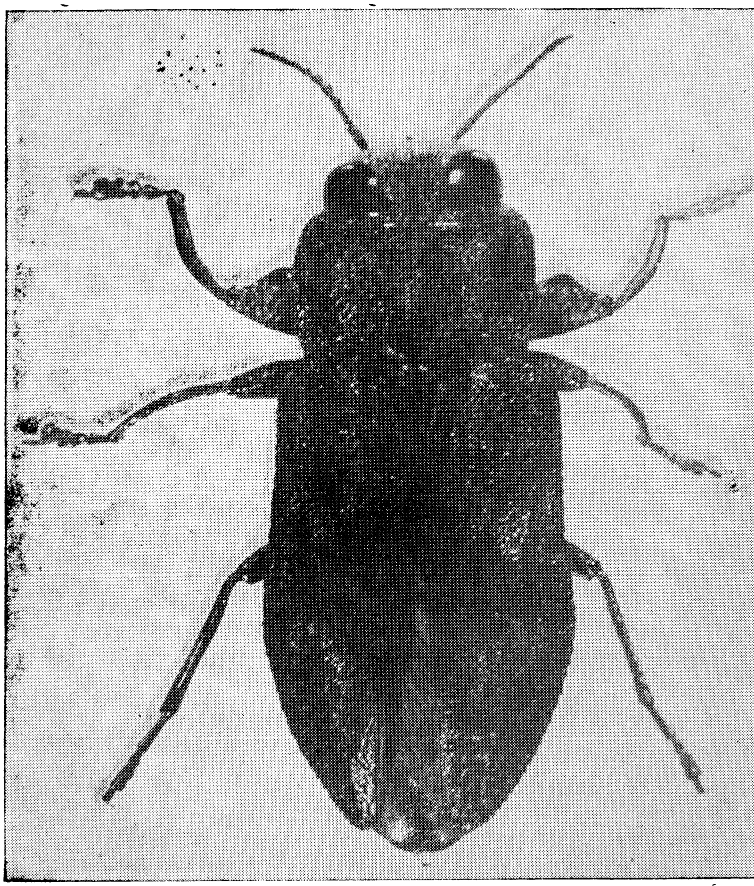

**Figure 1.—Top view of adult of flatheaded apple tree borer.**

The use of repellent tree washes has been frequently recommended and a number of formulae have been tested from time to time. Some authors have reported good success with washes, notably Pettit (16, 17, 18, 19), Hutson (11) and Houser (10). Johnson and Fenton (13) noted that repellent paints applied to growing trees reduced the number of parasitized borers by 33 percent. These authors tested several formulae on cut branches exposed to borer infestation. Several formulae were injurious to the tree; others showed promise and were not injurious. The best non-injurious paint reduced the borer population on apple 65 percent over the check and on walnut 87.9 percent. Fumigant paints were ineffective. The period of exposure of these tests was from three to seven days, so the performance of these washes for a much longer time, as would be necessary to protect living trees adequately, is not known.

**Figure 2.—Side view of adult of flatheaded apple tree borer.**

Another method of protecting trees is by mechanical barriers such as tree wraps. Smith (21) recommended a wire mosquito netting closely encircling the trunk so as not to touch it anywhere, and also tarred paper or newspapers tightly wrapped around the trunk and branches. The use of paper was also recommended by Pettit (16). Brooks (2) recommended burlap wraps. In Georgia (7) it was found that wrapping small pecan trees with unbleached cotton cloth of either heavy or light weight, or wrapping them with butcher's paper, gave good protection; although in a later test (8) poor results were reported with this method. Houser (10) in an extensive test in Ohio found that several types of wrapping paper gave very effective control. He recommended a narrow 4-inch width spiral wrap with the paper overlapping half of its width, and stated that the wrap should be started at the upper part of the trunk and then wrapped downward. In a test in Arkansas (12) it was found that 97 out of 100 one-year-old apple replants wrapped with newspapers in early April were free from injury, whereas unwrapped checks were all infested. Johnson and Fenton (13), working with American and Asiatic elms, found that wraps materially reduced the number of trees killed by borers but that the beetles tended to concentrate their attack on those parts of the tree above the wrap.

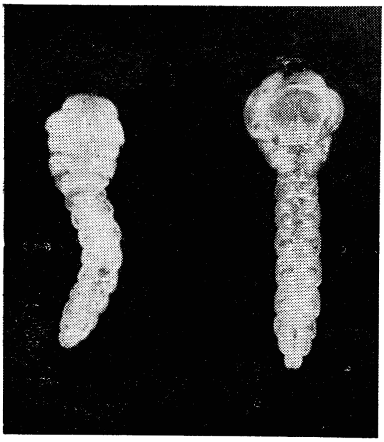

**Figure 3.—Flatheaded apple tree borers.**

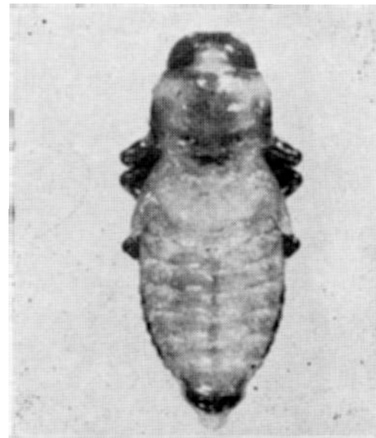

**Figure 4.—Pupa of flatheaded apple tree borer.**

Spraying to control the beetles was recommended by the Nebraska Agricultural Experiment Station (15). It was stated that petiole leaf cutting by the beetles, which in severe cases resulted in a loss of most of the foliage from the trees, could be checked by the application of arsenical sprays used alone or in combination with pyrethrum and a 2 percent summer oil, or with sprays made from pyrethrum extract or cube resin powder. Dusting with sodium fluosilicate was also recommended. Johnson and Fenton (13) reported that in cage tests heavy applications of arsenical sprays were necessary to obtain good kills and that, owing to the strong migratory habits of the beetle, spraying a small area would probably not give good control. Best kills were obtained by a spray equivalent to 6 pounds of lead arsenate per 50 gallons of water. Lead arsenate in heavier dosages showed a repellent effect. Observations in a sprayed orchard in which 2 pounds of lead arsenate per 50 gallons of spray were used indicated that such a spray did not result in a reduction in the beetle population over that in unsprayed orchards.

Because of the beetles' attraction to sunny situations, shading tree trunks has been recommended by Brooks (2), Boillot (1), and others.

Injecting carbon bisulphide into the burrow was recommended by Pettit and Hutson (19). Injecting kerosene into the burrows has also been recommended by several writers. However, Maxwell (unpublished thesis)* tried the latter method in 25 burrows with no success.

Killing the borer in its cell by probing with a wire has also been frequently recommended. To be successful this must be done while the borers are just under the bark and before they enter the wood. Maxwell (unpublished thesis) reports that only in about three percent of the trials was he successful in killing the borer in this way.

* Maxwell, J. M., 1935. Studies on *Chrysobothris femorata* in Oklahoma, Master's thesis, Oklahoma A. and M. College Library, Stillwater.

The use of posts set up in infested orchards and coated with a sticky material has been recommended by Brooks (2), Gill (9), and Boillot (1).

Many writers have noted that the beetle attacks trees in a devitalized condition. Brooks (2) states that trees of almost any size after they are one or two years old may be attacked, and that attacks by the borer are invited by newly transplanted trees, those which have assumed a leaning postion, those deficient in vigor from starving or overbearing, those which have been subjected to injury of the trunk or branches by sun scald, or those which have been injured by tools, rodents, or other insects. Burke (3) states that most attacks in California, by both **C. femorata** and **C. mali,** start from what appear to be sunburns.

## MATERIALS AND METHODS

Most of the work on biology was done by Fenton and Maxwell and the technique has been published (5). The period and rate of emergence of the beetles and their parasites and predators was determined by caging infested branches and logs which were obtained from various sources. This material was observed during the spring and summer of successive years for emergence of beetles. The occurrence of the beetles in the field was checked periodically by jarring trees in the early morning just before sunrise. At this time they were easily shaken from the tree and fell onto a tarpaulin below, from which they were collected. Data on the beetle activity in the field were also obtained by exposing branches of host trees as previously described (13).

The effect of various tree washes in repelling the beetles was determined by exposure of treated branches or by the application of the washes to living trees (13). The effect of tree wraps in protecting trees from attacks by **C. femorata** was studied in cooperation with the state highway department on state highway 40 from Stillwater to Perkins Corner, a distance of 7.8 miles.

## BIOLOGY

### Period of Spring Emergence of Beetles.

The period and rate of emergence of the beetles from infested wood was studied for four years. (Table I.) The earliest emergence was recorded May 3, 1939 and the latest August 3, 1938. The curves representing cumulative emergence are shown in Fig. 5. Ninety percent of the emergence had taken place June 7, 1936, June 21, 1937, July 7, 1938, and June 21, 1939.

### Delayed Emergence of Beetles.

Records were taken of beetles emerged from wood infested for one, two and three years. In all cases where beetles were recovered from cages containing wood infested several seasons previously, the wood had been caged continuously since the trees were cut down. It is very unlikely that this wood was reinfested each year by females before removal from the cages. This is because the female beetle deposits eggs either in fresh or recently cut wood and, moreover, the females were removed from the cages before the end of the preoviposition period and were not supplied with food. Females will not lay eggs unless provided wth their natural food, namely bark from living or recently cut wood (page 15). That laggard larvae occur has been demonstrated by finding them in the caged cuttings of seasoned wood after the emergence of beetles had ceased. The occurrence of laggard larvae is also a fairly common phenomenon with many insects.

**Table I.—Summary of Cumulative Emergence of** Chrysobothris femorata; **Stillwater, Oklahoma, 1936-1939.**

| Year | Date of first emergence | CUMULATIVE EMERGENCE* | | | | | | | Total number of beetles emerged |
|---|---|---|---|---|---|---|---|---|---|
| | | 10% | 25% | 50% | 75% | 90% | 95% | 100% | |
| 1936 | May 4 | May 16 | May 20 | May 25 | May 31 | June 7 | June 9 | June 29 | 669 |
| 1937 | May 21 | May 29 | June 2 | June 8 | June 14 | June 21 | June 26 | Aug. 2 | 1604 |
| 1938 | May 16 | June 4 | June 10 | June 16 | June 28 | July 7 | July 12 | Aug. 3 | 874 |
| 1939 | May 3 | May 22 | May 26 | June 5 | June 14 | June 21 | June 28 | July 9 | 209 |

* Dates upon which the accumulated emergence of beetles had reached the specified percentages of the total emergence.

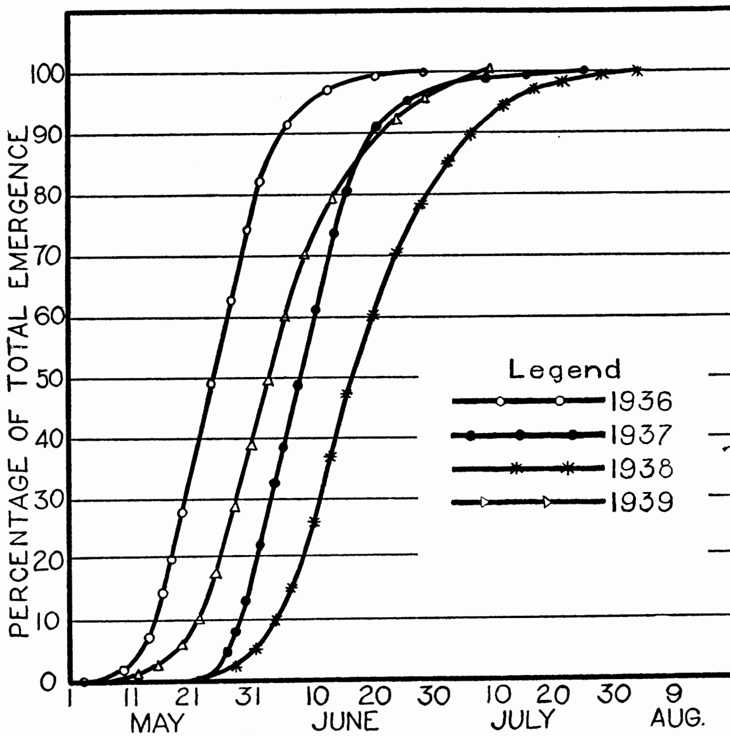


**Figure 5.—Cumulative emergence of** C. femorata **from infested logs; Stillwater, Oklahoma, 1936 to 1939.**

Table II shows the number of beetles emerging the second and third years after infestation. The percentage of beetles emerging the second year from wood infested during 1935 and 1936 was 8.9 and 12.1 respectively. Only parasites were recovered the second year from wood infested during 1937. A few beetles and parasites have emerged the third year after infestation, but none the fourth year. Table III gives further proof of the presence of laggard larvae. In this table are presented the results of examinations at intervals during 1938 of wood that was infested during 1937. The fact that one beetle was found alive August 13 extends the time of emergence for 1938 ten days beyond that recorded by cage emergence records. Since no beetles were found in later examinations, all larvae recovered must have been those which failed to pupate and were destined to emerge as beetles during 1939 or 1940.

**Period of Occurrence of Beetles in the Field.**

The period during which beetles were present in the field as determined by jarring infested trees during the early morning before sunrise is shown in Fig. 6. In 1937, jarring was not started until June 21. It is quite likely that the beetles were active for at least a month before that date, as the first emergence in the cages was recorded May 21. In 1938, the first jarring was done May 25 when 115 beetles were collected; but this year also they

**Table II.—Summary of Emergence of** Chrysobothris femorata **from Wood Infested for 1, 2 and 3 Years; Stillwater, Oklahoma.***

| Year wood was infested | 1936 | | 1937 | | 1938 | | 1939 | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. | Percent | No. | Percent | No. | Percent | No. | Percent | Totals |
| 1935 | 669 | 89.9 | 66 | 8.9 | 9 | 1.2 | 0 | | 774 |
| 1936 | --- | --- | 1582 | 87.2 | 220 | 12.1 | 12 | 0.7 | 1814 |
| 1937 | --- | --- | --- | --- | 816 | 100.0 | 0 | --- | 816 |
| 1938 | --- | --- | --- | --- | --- | --- | 206 | --- | 206 |
| Totals | 669 | | 1648 | | 1045 | | 218 | | 3610 |

* Since there were fewer cages the second and third years after the wood was caged, figures on delayed emergence of beetles from infested branches have been corrected so that they are comparable with the first year's records.

**Table III.—Laggard and Parasitized Larvae Recovered from Material Caged in 1937; Stillwater, Oklahoma, 1938.**

| Date of examination | NUMBER OF STAGES RECOVERED | | | |
|---|---|---|---|---|
| | Larvae | Adults | Pupae | Parasitized Larvae |
| June 18 | 13 | 2 | 0 | 7 |
| June 25 | 18 | 1 | 0 | 3 |
| July 2 | 9 | 0 | 0 | 6 |
| July 9 | 23 | 1 | 0 | 7 |
| July 16 | 13 | 0 | 0 | 8 |
| July 23 | 15 | 0 | 0 | 2 |
| Aug. 6 | 15 | 0 | 0 | 0 |
| Aug. 13 | 6 | 1 | 0 | 2 |
| Aug. 20 | 16 | 0 | 0 | 0 |
| Aug. 27 | 7 | 0 | 0 | 0 |
| Sept. 3 | 7 | 0 | 0 | 0 |

must have been present somewhat earlier. During the latter year, comparatively few beetles were collected after June 19. Since they had been very abundant during July the previous year, it is believed some unknown factor operated to kill most of them long before they would have normally completed their life span. The orchard where jarring records were being obtained had been sprayed with lead arsenate to control the walnut datana (**Dantana integerrima** G. and R.), but it is believed this had little if any influence on controlling the beetles because: (1) the decline in population had been noticed before the treatment; (2) the amount of lead arsenate used, namely, 2 pounds to 50 gallons of water, had been previously found not to be particularly toxic (13) and; (3) extensive collections made in several other vicinities where the trees had not been sprayed showed the same very small beetle population. The jarring records were continued in 1939, but so few beetles were collected that the data have not been plotted. Both the jarring tests and the cage emergence records show that beetles are present in the fields from early May to early October, a period of five months, and that the population is heaviest in the earlier part of the season; namely, during May and June. A summary of all tree jarring records is given in Table IV.

As a further check on the beetle population, freshly cut branches were placed in trees known to be frequented by the beetles. The females readily oviposited on these branches, which were kept fresh by having one end submerged in water. The branches were exposed for three days during the early part of the season and for five to seven days later in the season when the beetles were less numerous. Following exposure, the branches were

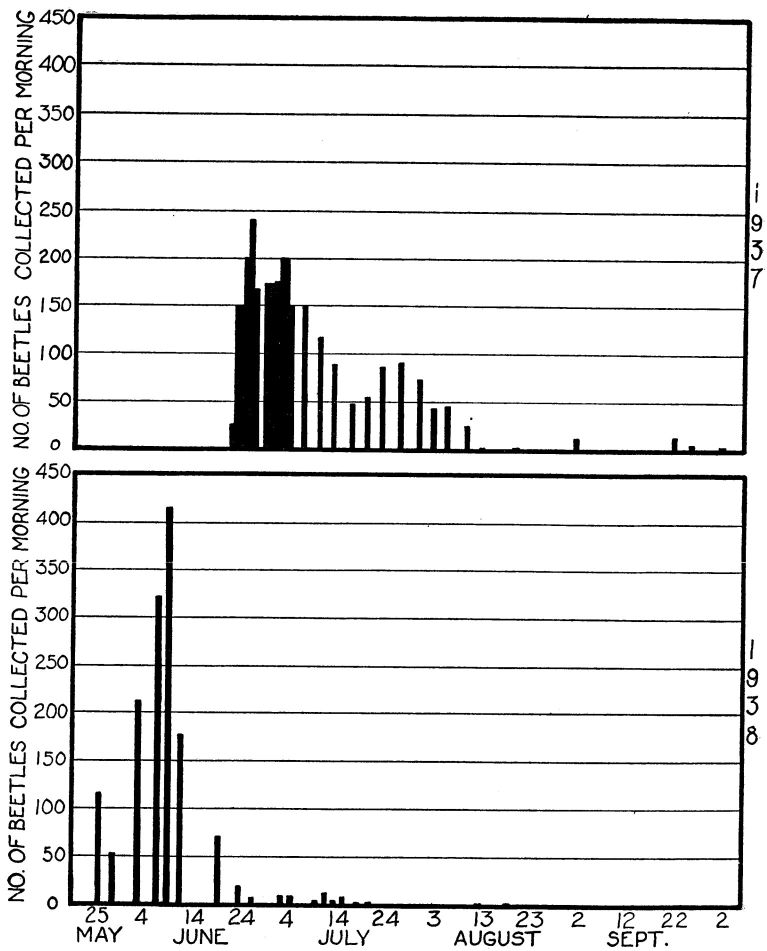


**Figure 6.—Field collections of** Chrysobothris femorata; **Stillwater, 1937 and 1938.**

**Table IV.—Summary of Field Collections of** Chrysobothris femorata; **Stillwater, Oklahoma, 1937-1939.**

| Year | Number of observations | Date of first collection | Date of last collection | Total number collected | Average number per date of collection |
|---|---|---|---|---|---|
| 1937 | 30 | June 21 | Oct. 1 | 2886 | 96.2 |
| 1938 | 21 | May 25 | Aug. 15 | 1456 | 69.3 |
| 1939 | 7 | May 18 | July 7 | 10 | 1.4 |

kept as nearly fresh as possible by the same method as previously mentioned. At the end of 25 or more days they were examined for borers. This experiment was started July 3 in 1937, and June 24 in 1938. In 1939, so few beetles were present that this work was discontinued. The records (Table VI, page 16) show that infestations occurred in branches exposed July 3, 1937, and as late as August 11, that year. They also show that the rate of egg deposition was much lower beginning with August 9, 1937.

**Comparative Abundance in Different Years.**

The comparative abundance of the flatheaded apple tree borer from 1936 to 1939 is shown in Table V. Emergence records show 1937 to be the year when most beetles issued from branches infested the previous year. This is also reflected in the field collections that year when 2,886 beetles were collected or an average of 96.2 per day form two trees. In 1938 the emergence per hibernation cage was fairly heavy but less than the two preceding years. Likewise the field collection was smaller, averaging 69.3 beetles per day from two trees. As shown in Fig. 6, most of the beetles were collected earlier in 1938 than in 1937; and, as already noted, there was a sudden unexplained disappearance of the beetles after mid-June. In 1939 an average of only 34.3 beetles per hibernation cage emerged during the season, and only 10 were jarred from the trees or an average of 1.4 beetles per day from two trees. Total and comparable infestation data on exposed branches during 1937 and 1938 show the latter year to have had a much lower beetle population, while there were so few beetles present in 1939 that no branches were exposed. The three types of records,

**Table V.—Comparative Abundance of** Chrysobothris femorata; **Stillwater, Oklahoma, 1936-1939.**

| | Number of beetles emerged from preceding year's infested wood | | Number of beetles jarred from 2 trees | | Number of borers recovered from branches of— | | |
|---|---|---|---|---|---|---|---|
| Year | Total | Average per cage | Total | Average per day | Apple | Walnut | Elm |
| 1936 | 669 | 223 | --- | --- | --- | --- | --- |
| 1937 | 1582 | 395.5 | 2886 | 96.2 | 345 (4.4)* | 1504 (20.9)* | --- |
| 1938 | 816 | 204 | 1456 | 69.3 | 8 | --- | 11 |
| 1939 | 206 | 34.3 | 10 | 1.4 | --- | --- | --- |

* Figures in parenthesis are average per branch.

therefore, show that the peak of the beetle population during the period of the study was reached during 1937, that it was lower during 1938, and that it reached a very low point in 1939.

**Food.**

The beetles feed on the bark of new growth (Fig. 7.) In cage tests they fed readily on the bark of one-year-old apple and elm branches, especially in crotches and around bud scars. Although the branches very often had twigs with leaves attached, no evidence of feeding on the leaves was obtained. However, in some cases the beetles cut through the leaf petiole and caused shedding. In a letter to the author, Professor Raymond

**Figure 7.—Feeding scars on tender bark caused by** C. femorata **beetles.**

Roberts of the Department of Entomology at the University of Nebraska states that defoliation in Nebraska was caused in this way and that he has observed the ground under the trees green with newly fallen leaves.

Maxwell (unpublished thesis)* supplied the beetles with pollen obtained from a bee hive but observed no feeding on this material. The beetles fed readily on tender bark, especially in crotches and around bud scars. He also observed them to feed on the older bark.

**Habits and Longevity of the Beetles.**

Male beetles vibrate the abdomen in a vertical motion against the surface on which they are resting. This drumming habit is developed on the second or third day after emergence and is apparently a mating call as the female beetles are attracted by the action or sound. When the beetles were confined in glass chimney cages the drumming sound was audible, the glass chimney apparently acting as a sounding board. Female beetles approach the male in the act of drumming, stopping about one-half inch or three-fourth inch from him. This is followed very shortly by pairing.

During the night many beetles apparently seek shelter in trees with more dense foliage than selected for oviposition, especially those with limbs extending more or less at right angles from the main trunk. Experience in a walnut grove showed that certain trees invariably produced the most beetles upon jarring. Two trees were repeatedly jarred until all beetles had apparently been dislodged, but despite this an equally large number could be collected from these same trees the next morning or a few days later. These records and the fact that isolated trees which have been recently transplanted are attacked show the insect to be very active and that there is considerable movement from infested trees to those within easy flight range of the beetles. Under caged conditions in a greenhouse, 18 females lived for an average of $26.3 \pm .36$ days, the range being from 11 to 43 days.

**Oviposition.**

Beetles provided with food began oviposition in four to eight days, averaging 5.8 days. No eggs were laid by females which had not fed. The lower or main trunk and larger branches are preferred for oviposition. Devitalized trees or those with sparse foliage are favored. On hot, sunny days, the beetles may be observed rapidly running up and down the larger branches, with the females ovipositing in cracks in the bark or in wounds or broken places in smooth-barked trees such as apple. The female has no difficulty in ovipositing on upright trunks and branches with rough bark; but on smooth-barked trees, such as young apple, most oviposition may be on branches in a more or less horizontal position. The eggs are laid on the sunny side of the tree, hence flatheaded borer infestations usually develop on the south or west sides of the trunks. The beetles oviposited freely on freshly cut branches exposed in a heavily infested walnut and pecan grove. The female apparently uses her extensile ovipositor in locating a spot for egg deposition. This may be a crack in the rough bark, or a wound of some sort. The female beetles preferred cuttings at least ¾ inch in diameter to smaller ones. In laboratory tests when they had a choice between ¾-inch cuttings and twigs of less than ½ inch in diameter, practically every egg was found in the larger cutting. The female requires about 10 to 30 seconds for the act of egg laying. The maximum number deposited in any 24-hour period per female was 24. The average number of eggs deposited per female ranged from 22 to 173, with a mean of 69 for the experiment.

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* *Op. cit.*

Comparative oviposition data in 1937 show walnut to be much more favored by the beetles than apple. An average of 44 borers was removed per apple branch as compared with 20.9 per walnut branch (Table V). These branches were as nearly the same size as could be obtained for the tests and were exposed for three to seven days in a pecan grove (13). The comparative attraction to the female beetles for egg deposition was determined 20 to 25 days later by removing the bark from these branches and counting the borers.

**Egg Deposition Period.**

Data on the period when the females are laying eggs were obtained by exposing fresh branches of elm, walnut, and apple trees in an orchard. In 1937 the first cutings were put out July 3. Thereafter, until oviposition began to decline, each group of cuttings was left out for three days (later this was increased to five or seven days). The records show that the very first cut branches were infested and that oviposition continued until at least as late as August 11 (Table VI). Fluctuations occurred in the number of borers recovered, but there was no marked decrease until August 9. Unusually heavy egg depositions occurred in three-day exposures on walnut

**Table VI.—Oviposition by** C. femorata **in Cut Branches of Apple and Walnut, Stillwater, Oklahoma, 1937.**

| Date of exposure* | WALNUT No. of borers recovered | | APPLE No. of borers recovered | |
|---|---|---|---|---|
| | Total | Average | Total | Average |
| July 3 | 42 | 21 | 4 | 4 |
| July 4 | 64 | 32 | 20 | 6.7 |
| July 5 | -- | -- | 3 | 0.8 |
| July 6 | 128 | 42.7 | 9 | 3 |
| July 7 | 56 | 18.7 | 7 | 2.3 |
| July 8 | -- | -- | 19 | 6.3 |
| July 9 | 30 | 10 | 24 | 8 |
| July 10 | 61 | 8.6 | 102 | 14.6 |
| July 11 | 0 | 0 | -- | -- |
| July 12 | 110 | 36.7 | 14 | 4.7 |
| July 13 | 70 | 23.3 | 14 | 4.7 |
| July 14 | 1 | 0.3 | 29 | 7.3 |
| July 15 | 180 | 45 | 23 | 7.7 |
| July 19 | 61 | 12.2 | 2 | 0.7 |
| July 20 | 188 | 62.7 | 22 | 3.7 |
| July 21 | 22 | 7.3 | -- | -- |
| July 26 | 230 | 38.3 | 18 | 3 |
| July 27 | 92 | 23 | 9 | 1.5 |
| Aug. 1 | 61 | 20.3 | -- | -- |
| Aug. 2 | -- | -- | 13 | 4.3 |
| Aug. 3 | 30 | 10 | 5 | 1.7 |
| Aug. 4 | 69 | 23 | 1 | 0.3 |
| Aug. 9 | 0 | 0 | 0 | 0 |
| Aug. 10 | 3 | 1 | 3 | 1 |
| Aug. 11 | 6 | 2 | 4 | 1.3 |
| Totals | 1504 | 20.9 | 345 | 4.4 |

* Total period of exposure varied from three to five days.

for the periods of exposure beginning July 6, 15, and 20, respectively, and for apple for the period starting July 10. In 1938, apple and elm cuttings were used and the exposures were started earler, namely, on June 24. Some oviposition occurred on the first date of exposure. The latest oviposition that year was recorded on apple for the seven-day period August 5-11, inclusive. During both years, egg-laying had started at least as early as the dates when the first cuttings were exposed and had undoubtedly been taking place much earlier. As compared with 1937, the year 1938 was one of comparative freedom from the insect, only 19 borers being recovered from apple and elm cut branches (Table V). From these records it appears that egg deposition begins early in May and continues until early September in most years.

**Incubation Period.**

The incubation period in a laboratory where temperatures approximated those outside ranged from six to eight days with a mean of seven days as determined from 25 eggs.

**Larval Development.**

The larva cuts its way through that side of the egg which is in direct contact with the wood, filling the egg shell with tiny bits of sawdust from the entrance tunnel. The one-day old larvae measure 1.3 to 2 mm in length and are of the same characteristic shape as the mature larva. The larvae live in the tissue in and surrounding the cambium layer until nearly full grown. As most of the eggs are laid in cracks on the south and west exposures of the larger branches, most of the larvae are found in these situations. Except in the case of smooth, thin-barked trees, as young apple trees, there is little external evidence of their work. Little or no sawdust is forced out and the entrance hole is so small that it cannot be detected. As several borers may excavate a sizable chamber just beneath the bark, a slight pressure applied directly over this area may cause the bark to give slightly. When the bark over the borer galleries is removed, the dead tissue beneath is colored dark brown and the tortuous galleries are packed full of the sawdust cuttings made by the borers. Observations made at intervals throughout the growing season show the presence of the larvae in the cambium area from late May to September. As soon as the larva is fully developed it leaves the cambium area, and tunnels radially into the xylem. At this point it tunnels either upwards or downwards a short distance from the entering gallery and prepares the pupal chamber. The tunnel is packed with sawdust, with a more compact plug at the opening of the pupal chamber. This habit makes it virtually impossible to reach it by probing with a wire. Within this cell, in a crowded U-shaped position (Fig. 8), the larva passes the winter. Occasionally, as shown (page 8 and Table II), larvae sometimes pass more than one season in this cell without change.

**Pupation and Emergence.**

In a great majority of cases, pupation takes place the following spring. Maxwell removed several larvae from their cells in March and placed them in a constant temperature room where they were held at 80° F. Under these conditions the pupal stage lasted for eight days to two weeks.

The beetle emerges from the tree by following the old sawdust packed tunnel to the bark, through which it then cuts. These small, circular emergence holes are not only signs of flatheaded borer infestation. They are also signs that the beetles have already emerged; and injecting chemicals into these holes is, therefore, useless.

**Total Life Cycle.**

As shown by the emergence of beetles from wood infested on a known date, it is evident that the majority complete their life cycle in one year. Of the 3,356 records obtained by caging infested wood, only 83 required longer than 1 year to complete their life cycle. Seventy-seven of these matured in 2 years and 6 in 3 years. Adjusting these figures to a percentage basis (because there were fewer cages of old infested wood than that caged the previous fall), from 87.2 to 89.9 percent of the borers emerging in 1936 and 1937 completed their life cycle in one year.

## INJURY

One or two larvae working on the trunk of a young tree will kill it by girdling. Where trees are insufficiently wrapped the larvae may girdle them at the crown or at the top of the trunk. When larger trees are attacked, several larvae will kill large areas of cambium on the main trunk, usually on the south or west sides (Fig. 9). This undoubtedly checks growth and favors reinfestation in subsequent years; and finally, under the combined effects of the borers, disease, or other insects, the tree is killed. This is clearly shown in records of elm trees planted along route 40 by the Oklahoma Highway Department, as shown later (page 25). Trees may recover from severe flathead infestation, especially if they have become well established and taken care of. In such cases the new growth develops over the dead area, finally completely enclosing it (Fig. 10). Large, well established trees may be severely attacked by flatheads when suffering from lack of water, as in a drought. In such cases it is difficult to determine which killed the tree, the borers or drought; but unquestionably the borers hasten its death, and it is conceivable that without this added injury many trees might survive. Trees defoliated by leaf-feeding caterpillars may be severely injured or even killed by these borers. This was the case in 1934-36 when many pecan trees in Oklahoma were defoliated by the walnut datana (**Datana integerrima** G. and R.) at a time when the borer population was unusually high.

**Figure 8.—Overwintering larvae in wood.**

Occasionally when the beetles are unusually abundant they may defoliate trees by cutting through the leaf petioles. In a letter to the writer, Professor Raymond Roberts of the University of Nebraska states that a small orchard in South Lincoln, Nebraska, was practically stripped of

**Figure 9.—Tunnels in sapwood made by the flatheaded apple tree borer.**

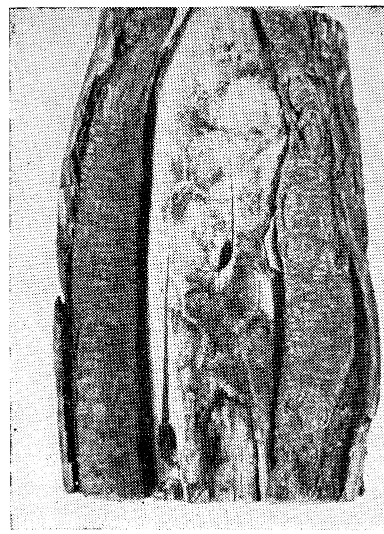

**Figure 10.—Scars in tree trunk made by the flatheaded apple tree borer. Note hole through which the beetle emerged and the bark growing over the wound.**

foliage and that "the beetles were flying from tree to tree almost like bees visiting blossoms." A large elm growing by the highway was so severely defoliated in two weeks by the beetles that a person could easily count the leaves left on the tree, while the highway under the tree was green with newly fallen leaves.

## TESTS WITH TREE PAINTS

The use of repellent washes or tree paints to protect trees from borers has been recommended for many years. These materials may (1) repel the beetles so that no egg deposition occurs; (2) destroy eggs through contact for those species that oviposit on the bark of the tree or in such places as cracks in the bark or in wounds; or they may (3) kill the borers while in the larval stage under the bark by penetration or fumigation. The literature on the flatheaded apple tree borer is replete with directions for repelling the beetles by the use of tree paints, and many formulae have been recommended. The value of several tree paint formulae in protecting trees from attacks of this insect was studied for three years. During 1937, the first year of these tests, the borer infestation was very heavy, but in the remaining two years there were so few present that it was only possible to study the effects on the tree of the washes tested.

Three methods were used to evaluate the effectiveness of the paints: (1) beetles were placed in cages and observed to study their reactions to treated branches; (2) freshly cut branches were painted with the repellent and exposed for short periods in a heavily infested grove, and (3) the trunks of growing trees were painted. The comparative effectiveness of the washes on the cut branches in cages was determined by observing whether or not they repelled the beetles. On the cut branches exposed in the grove, it was ascertained by later examinations to locate borers which had developed from eggs laid when the branches were exposed; and on the living trees it was determined by careful inspection.

**Cage Tests.**

The cage tests have been reported by Johnson and Fenton (13). While it is apparent that the beetle is not suited to cage testing or else that proper technique was not developed, several interesting observations were made. Repellent formula No. 1, which contained potash fish-oil soap, water, flour and napthalene flakes, and which as shown later gave a fairly high degree of protection to cut branches, did not repel the beetles. Of a total of 1,170 observations, 49.1 percent of the beetles were observed resting on the wood coated with this preparation as compared to 50.9 on the checks. This would indicate a possibility that this formula acts by preventing or decreasing oviposition or that it may be toxic to the eggs. Repellent formula No. 9, composed of one part of liquid lime sulphur and seven parts of water to which sufficient hydrated lime was added to make a thick whitish wash, was actually attractive to the beetles. The addition of the hydrated lime to this paint colored it white and the attraction of the beetles to this color agrees with field observations that these insects are rather strongly attracted to white objects. Two other repellent paints, both containing carbolineum, were decidedly repellent to the beetles.

**Repellent Paints on Cut Branches.**

The technique used and results obtained in testing repellent paints in 1937 on cut branches have been reported by Johnson and Fenton (13). It was concluded that three and possibly four formulae merited further investigation. Four fumigant paints were also tested with negative results. In 1938, similar tests were made except that elm and apple cut branches were used. Despite somewhat longer periods of exposure, the percentage of borer infestation was so low that no data were obtained.

**Repellent Paints on Living Trees.**

In cooperation with the Department of Horticulture, land was made available for planting nursery stock (apple and elm) for a study of the value of several tree paint formulae. In 1937, there were 84 young apple trees in a block which were used in these tests. The first paints were applied June 23, and the remainder on July 2. A total of 49 trees were treated. The results of this experiment have been given by Johnson and Fenton (13). The paints were applied too late to prevent borer infestation even if some of them had been effective. Four formulae were used. The most interesting development was the fact that the paints seemed to repel parasites of the borers, for 13 of the 35 untreated trees, or 37 percent, contained from one to four parasitized larvae each, and only two of the 49 treated trees, or 4 percent, contained one parasitized larva each.

In 1938, 500 young American elms were set out in one block. The trees were set out six feet apart in 30 rows of 20 trees each, and the experimental unit consisted of 10 trees. Each plot was replicated five times. Because of a very favorable location and growing season and extremely low borer infestation, no data were obtained except on the effect of the paints on the trees. In 1939, 90 American elms and 80 Asiatic elms from the 1938 plantings were dug up and replanted on a terraced field with a south slope and where the soil was rather poor. It was intended that the size of the trees when transplanted, together with the poor location, would make them susceptible to attack by the flathead. However, again due to an extremely low borer infestation, no data were obtained.

**Summary of Two Years' Tests on Three Formulae.**

As a result of the 1937 tests, Johnson and Fenton (13) recommended further trials with the following formulae:

Repellent Formula No. 1.—Prepared by heating 50 pounds of potash fish-oil soap and 3 gallons of water to 180 degrees F. and mixing well. Two pounds of flour are then stirred in slowly. The flour mixes better if first stirred up separately with part of the water. Twenty-five pounds of naphthalene are added while holding the mixture at 180 degrees F. Following solution of the napthalene, the mixture is chilled as quickly as possible while stirring occasionally.

Repellent Formula No. 4.—One pound of potash fish-oil soap and 1 pint of carbolineum avenarius are thoroughly mixed, following which 1 quart of water is added.

Repellent Formula No. 5.—One pound of sodium carbonate is dissolved in 1 quart of hot water, then 1 quart of carbolineum avenarius is added and the mixture is stirred vigorously until emulsified. A bucket spray pump aids in the emulsification. This is a stock solution and is diluted with 2 quarts of water when used.

Repellent Formula No. 13.—Paraffin applied while liquified.

Further tests were made with the first three of these formulae, and the results of the two years' tests were as follows:

**Tests with Repellent Formula No. 1.**—Although the 1937 cage tests showed that this paint did not repel beetles, in 26 cut branches of apple exposed for three to five days to beetle oviposition there was a reduction of 40 percent in the number of borers over the check; and in 20 cut branches of walnut the reduction over the check was 81.6 percent. In tests on living apple trees in 1937, no protection was given over the check trees, but the formula repelled the parasites of the borer. Lack of borer protection was undoubtely partly due to the fact that the paint was applied too late that year. In 1938, tests were made with this formula on 50 American elm trees. The first application was made May 23, and on July 8 one half or 25 of the trees were given a second treatment. As previously stated, lack of any infestation prevented a field evaluation of the effectiveness of this formula. However, the paint was found to be harmless to the trees.

**Tests with Repellent Formula No. 4.**—There were 56.9 percent fewer borers recovered in 25 cut apple branches treated with this mixture than in the check, and 97.6 percent fewer in 22 cut walnut branches. No injury was observed on apple trees in 1937 and none noticed on the cut branches. However, in tests on American elm in 1938 definite injury was observed. The most extreme form was a bending over of the tree (Fig. 11). All injured trees had been treated twice. No cage tests were made.

**Tests with Repellent Formula No. 5.**—Cage tests showed this mixture to be repellent to the beetles, there being 87.9 percent fewer of them on the treated branches than on the check. There were 60 percent fewer borers recovered in 25 cut apple branches painted with this preparation than in the check, and 74.4 percent fewer in 20 cut walnut branches. No injury was

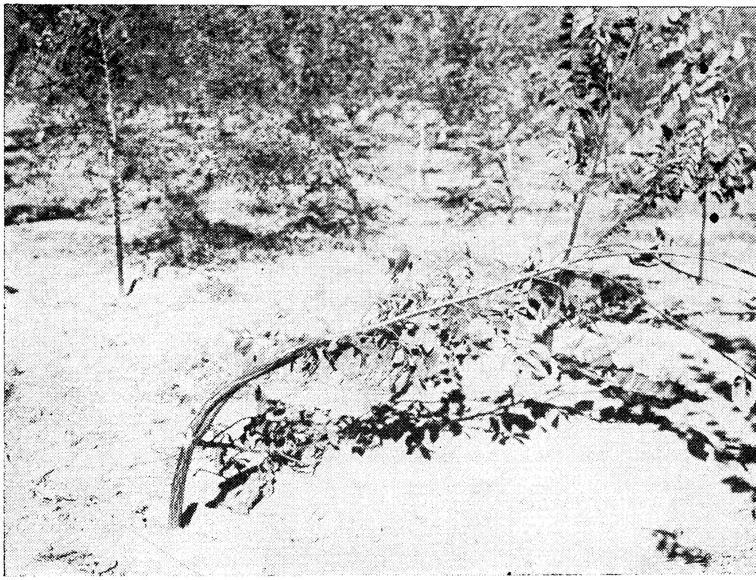

**Figure 11.—Young elm injured by tree paint.**

observed on living apple trees painted with this mixture in 1937, but on elm in 1938 some injury was observed. The same type of injury was noted to be caused by this preparation as on trees the trunks of which were painted with formula No. 4, namely, a bending over of the tree. Likewise this injury was observed only in trees painted a second time with this preparation.

**Summary of Results with Tree Paints.**

Most of the tree paint formulae tested had been previously recommended for the control of borers, either the flatheaded apple tree borer or other species. Many of them were very injurious to apple and elm. One mixture attracted the beetles under caged conditions. In short exposures of not over nine days, some of the paints decreased the number of borers; but in only two tests was 100 percent protection afforded.

## TESTS WITH PAPER WRAPS

A report of the results of one year has already been made (13). However, since then these trees have been carefully studied and more information on this point is available. This test was begun in 1937 when permission was obtained from the state highway department to test several types of wraps on several hundred American and Asiatic elm trees set out along state highway 40 between Stillwater and Perkins Corner, a distance of 7.8 miles. The trees were planted in March. There were 352 trees in the project, 168 of which were not wrapped as checks. The trees were planted for the most part in small groups at intervals along the highway. Many of them were set out in very unfavorable soil situations. The different types of wraps were tested at intervals along the entire route so that each was tried out under a variety of soil and other environmental conditions. Five types of wraps were tested, as shown in Table VII. These wraps have been previously described by Johnson and Fenton (13). The wide (12-inch) single crinkle paper was tested on only 11 trees because it was soon found that the long longitudinal type of wrap was very unsatisfactory. It was impossible to tie the paper around the tree trunk sufficently tight to prevent the wind from blowing it open and exposing parts of the trunk. Each of the other wraps was used on 45 trees, except that 38 trees were wrapped with ordinary wrapping paper. On each tree, except the 11 already mentioned, the wrap was started around the base of the trunk which was wrapped upwards as far as the crotch with a 50 percent spiral overlap. In 1938, to compare methods of wrapping, some trees were wrapped downward, starting just below the lowest branches (Fig. 12). These wraps were four inches wide. The wrap was tied around the base of the tree and at the top. The first trees were wrapped April 15, another group between April 28 and 29, while others were wrapped between May 8, and 24. While some beetles must have been present on the later dates, an analysis of the data shows no increase in the borer infestation. Six observations to determine the condition of the trees were made on the following dates: July 16-17, August 5-6, 16-17, 26, Sept. 9-15, and October 19-26. The state highway department cut down all dead or nearly dead trees Sept. 30 and October 1, so a special observation was made on these trees Oct. 2-3. On July 18, wraps were repaired on 25 trees in the first treatment, 24 in the second treatment, 5 in the third, 24 in the fourth, and 32 in the fifth. In all cases except the wide single crinkle, the same type of wrapping paper was used as originally placed on the tree. In this case the narrow width single crinkle paper was used in a spiral wrap to replace the length-wise wrap of the same paper. In September the trees were attacked by caterpillars and many were defoliated. The rest were sprayed with lead arsenate in water with casein as a sticker. The lower few inches of the trunks of many trees were exposed by the soil settling after rains and watering, but part of these were soon repaired. The data are shown in Table VII. From 89.5 to 100 percent of the wrapped trees in the different plots had their lower trunks so exposed. The trunk at this point was attacked by borers in from 8.9 to 28.9 percent of the trees, in the different plots, showing that this contributed to the borer infestaton of the wrapped trees. However, a much larger proportion, from 31.1 to 55.6 percent, were attacked above the wrap. **From 6.7 to 15.6 percent of** the wrapped trees were killed by borers during the summer as compared with 44 percent of the unwrapped trees. In many cases trees died due to cause other than borer infestation.

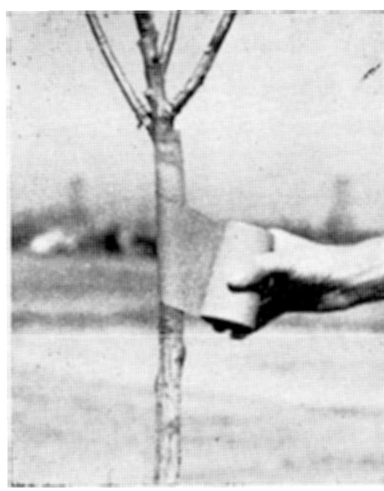

**Figure 12.—Close-up of crotch of young tree, showing method of starting wrap at this point.**

**Table VII.—Results of Wrapping Trees to Control** C. femorata; **Stillwater, Oklahoma, 1937.**

| Type wrapping paper* | No. of trees | Trees killed by flat-heads | | Trees with dead tops | | Dead tops caused by flat-heads | | Trees infested | | Trees with flatheads above wrap only | | Trees with flatheads below wrap | | Trees with bottom exposed | | Trees with wrap badly torn or gone or side open | Trees removed by highway department | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | | No. | % |
| No. 1 | 45 | 7 | 15.6 | 14 | 31.1 | 8 | 17.8 | 27 | 60 | 14 | 31.1 | 13 | 28.9 | 42 | 93.3 | | 13 | 28.9 |
| No. 2 | 45 | 3 | 6.7 | 8 | 17.8 | 4 | 8.9 | 26 | 57.8 | 18 | 40.0 | 8 | 17.8 | 41 | 91.1 | | 19 | 42.2 |
| No. 3 | 11 | 2 | | 1 | | 1 | | 4 | | 2 | | 2 | | 9 | | | 5 | |
| No. 4 | 45 | 3 | 6.7 | 9 | 20 | 5 | 11.1 | 29 | 64.4 | 25 | 55.6 | 4 | 8.9 | 45 | 100 | | 16 | 35.6 |
| No. 5 | 38 | 3 | 7.9 | 8 | 21.1 | 3 | 7.9 | 21 | 55.3 | 15 | 39.5 | 6 | 15.8 | 34 | 89.5 | 15 | 15 | 39.5 |
| No. | 168 | 74 | 44.0 | 19 | 11.3 | 4 | 2.4 | 113 | 67.3 | | | | | | | | 86 | 51.2 |

* The types of wrapping were as follows:

No. 1—Slightly creped, 2 sheets of creped Kraft laminated with heavy coating of asphalt, having a stretch of approximately 15 to 20% 4 inches wide.

No. 2—Double crinkle, 2 sheets of 30 lb. basis paper laminated with 30 lbs. of asphalt, crinkled in one direction and corrugated in the other direction so as to give 25% stretch in both directions.

No. 3—Same as No. 4, but 12 inches wide.

No. 4—Single crinkle, same as No. 2, but with single crinkle so as to give approximately 30% stretch in the longitudinal direction.

No. 5—Wrapping paper, 4 inches wide.

No. 6—Check.

It was noticed that when the trunks of the trees were wrapped the beetles tended to oviposit on the exposed portions of the trees at the crotch just above the wrap. This caused the top of the tree to be killed by borers concentrated at this point. This is shown in Table VII where it is seen that from 7.9 to 17.8 percent of the wrapped trees had dead tops caused by borers as compared with only 2.4 percent of the check trees with dead tops caused by this insect. Wrapping did not greatly reduce the borer infestation; as shown in the table, from 55.3 to 64.4 percent of the wrapped trees were infested with flatheads, as compared with 67.3 percent in the check trees. The chief value of the wrapping was, therefore, in reducing the borer infestation or confining it to less vital parts of the tree. Had the wraps been extended a little deeper in the soil and the crotch of the trees wrapped, much less borer infestation would probably have occurred in the wrapped trees. The number of trees in the check plot removed as dead or dying by the highway department was 86 or 51.2 percent as compared to from 28.9 to 42.2 percent in the wrapped trees. Best protection was given by the commercial or specially prepared papers. Ordinary wrapping paper gave fair protection but did not last long and presented a poor appearance. It had to be repaired frequently and at the end of the experiment the trunks of 15 of the 45 trees in this series were exposed, either by torn paper or by the wrap being blown open by the wind.

In 1938, approximately half of those trees which were wrapped in 1937 were again wrapped and part of the replants were wrapped. As a comparison there were two series of trees which were not wrapped, namely, those set out in 1937 and those set out in 1938 (Table VIII). Wrapping a second year gave no extra protection to the trees. The mortality was 10.5 percent in trees wrapped for two years as compared with 12.1 percent for one year. The percentage of surviving trees with borer infestation in these two blocks was 35.1 and 36.2, indicating no difference. On the other hand only 24 percent of the living trees in the check block had a previous borer infestation, showing that a greater percentage of the trees which were wrapped in 1937 and had become infested had recovered from the borer injury than was the case in trees which were not wrapped but not killed in 1937. Another test showed the lack of borer damage in 1938. Seven out of 50 trees set out that year were dead at the end of the year, giving a survival of 86 percent, as compared to 79 percent survival in a block of 100 trees also set out that year and wrapped. This difference in favor of the 1938 check trees was due to some other factor as shown by the very light percentage of borer infestaton, 6 trees in a block of 50 check trees and 3 in the block of 100 wrapped trees. The percentage of living trees with no previous borer infestation in 1937 was significantly very nearly the same.

Because of the low borer infestation, no more trees were wrapped in 1939 or 1940. However, all trees in the test were carefully watched during this period. The data are shown in Table IX. The percentage of survival in 1939 was better than in previous years, indicating a good year for tree growth. However, a few trees which had not been wrapped in 1937 died, indicating a continuing effect of the heavy borer infestation during that year. Mortality was greater in 1940 but no significant differences occurred in the different treatments.

**Summary of Wrapping Tests.***

A summary of the four years' wrapping tests of American and Asiatic elms is shown in Table X. Of the trees which were not wrapped in 1937 and were therefore severely damaged by the flatheaded apple tree borer,

* For recommendations on methods of wrapping trees to protect them from the flatheaded apple tree borer, see Okla. Agr. Exp. Sta. Cir. 84, pp. 9-11.

**Table VIII.—1938 Tree Wrapping Experiment; Perkins-Stillwater Highway, Oklahoma, 1938.**

| Treatment | Number of trees | Trees dead Sept. 9-Oct. 7 | | Dead trees with previous borer infestation | | Number of trees with callouses | Number of trees with flatheads | Living trees with previous borer infestation | | Living trees with no previous borer infestation | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | | | Number | Percent | Number | Percent |
| Not wrapped in 1937 or 1938 A Series | 75 | 17 | 22.7 | 11 | 14.7 | 21 | 0 | 18 | 24.0 | 40 | 53.3 |
| Wrapped in 1937, not in 1938 B Series | 58 | 7 | 12.1 | 3 | 5.2 | 19 | 4 | 21 | 36.2 | 30 | 51.7 |
| Wrapped in 1937 and in 1938 C Series | 57 | 6 | 10.5 | 4 | 7 | 11 | 0 | 20 | 35.1 | 31 | 54.4 |
| New trees not wrapped in 1938 D Series | 50 | 7 | 14 | | | 7 | 6 | | | % living trees 86 | |
| New trees wrapped in 1938 E Series | 100 | 21 | 21 | | | 3 | 3 | | | 79 | |

**Table IX.—Survival of wrapped and unwrapped elm trees; Perkins-Stillwater Highway, Oklahoma, 1939 and 1940.**

| | | TREES ALIVE SEPTEMBER 1939 | | TREES ALIVE NOVEMBER 1940 | |
|---|---|---|---|---|---|
| Series | Treatment | Number | Percent | Number | Percent |
| A | Not wrapped in 1937 | 56 | 74.7 | 50 | 66.7 |
| B | Wrapped in* 1937 | 51 | 87.9 | 41 | 70.7 |
| C | Wrapped in* 1937-1938 | 50 | 89.3 | 43 | 76.8 |
| D | Set out 1938; never wrapped | 43 | 86 | 31 | 61 |
| E | Set out 1938; wrapped in 1938 | 79 | 79 | 68 | 68 |

* Fifty-eight surviving trees which were wrapped in 1937 were not wrapped in 1938 and 56 others were also wrapped in 1938. The survival figures are therefore only for 1939 and 1940 and do not include mortality data for 1937.

only 29.8 percent were alive at the end of their fourth growing season following transplanting. Trees in the same group which were wrapped showed a survival of 45.7 percent. Had precautions been taken at the time these were wrapped to allow for the soil settling around the bases of the trunks, and especially had the bases of the branches at the crotch of the trees been wrapped, a much greater difference would have occurred. As shown by the survival figures for the 1938 replants, even without a borer infestation and including a year when growing conditions were favorable, the location of the trees in many areas where poor soil conditions occurred and where moisture was frequently insuffcient caused poor growth and a high rate of mortality.

**Table X.—Percentage of survival of wrapped and unwrapped elm trees; Perkins-Stillwater Highway, Oklahoma, 1937-1940.**

| | | PERCENTAGE OF SURVIVAL AT END OF GROWING SEASON OF— | | | |
|---|---|---|---|---|---|
| Date transplanted | Treatment | 1937 | 1938 | 1939 | 1940 |
| 1937 | Wrapped in 1937; approximately half rewrapped in 1938 | 75 | 54.9 | 54.9 | 45.7 |
| 1937 | Check; not wrapped | 51.8 | 34.5 | 33.3 | 29.8 |
| 1938 | Check; not wrapped | | 86 | 86 | 62 |
| 1938 | Wrapped in 1938 | | 79 | 79 | 68 |

## NATURAL CONTROL

During the course of the project several species of parasites were reared from borer infested material. These have been identified by specialists as:

**Labena grallator** Say
**Cryptohelcostizus chrysobothridis** Cushman
**Phasgonophora sulcata** Westwood
**Eusandalum** (2 new species)
**Heterospilus astigmus** Ash.
**Atanycolus rugosiventris** Ash.

The first three are the most important in Oklahoma. The percentage of parasitization as determined by emergence of the parasites from infested wood was 6.9 in 1936, 13.8 in 1937 and 58.6 in 1938. **P. sulcata,** while not very important in the early stages of the infestation, was by far the most numerous in 1937 and 1938. During the latter year, 1,213 were recovered from the hibernation cages, emerging over a period from April 5 to August 25, the peak of the emergence occurring June 18.

The borers were also attacked by several species of insect predators. As previously reported by Maxwell, two species of Corynetidae were important in 1936, namely, **Chariessa pilosa** Forst. and **C. pilosa onusta** Say. In 1938 a species of robber fly, **Andrenosoma fulvicauda** Say, was reared in moderate numbers from infested wood.

## VARIETAL SUSCEPTIBILITY

Asiatic elm (**Ulmus pumila** Linn.) was much more resistant to the borer than American elm (**U. americana** Linn.). A year after the heavy borer infestation in 1937, 51.9 percent of the unwrapped American elms were killed by borers as compared with 11.8 percent of the unwrapped Asiatic elms. In the 1938 replants, 85.8 percent of the American elm survived as compared to 71.7 percent of the Asiatic elms in the absence of any borer infestation.

## SUMMARY

The flatheaded apple tree borer completes its life cycle in most instances in one year. Corrected data on the emergence of beetles from wood infested in 1935 and 1936 show that 87.2 and 89.9 percent respectively completed their life cycles in one year, 8.9 percent and 12.1 percent required two years, and 0.7 to 1.2 percent three years. The beetles start emerging from infested wood early in May and continue to emerge until early August in some years. Under laboratory conditions they live for an average period of 26 days, the maximum record being 43 days. As a result of the prolonged period of emergence and comparatively long life, they are present in the field until early October. They feed on the tender bark, especially in crotches and around bud scars, and they may bite through leaf petioles, causing shedding. The females begin egg laying in from four to eight days after feeding and prefer sickly, dying, or recently transplanted trees for oviposition. Eggs are inserted in cracks in the bark or in wounds, in sunny areas on the tree trunks and larger branches. The eggs hatch in six to eight days and the larvae burrow into the bark, immediately beneath the egg shell. Development takes place in the cambium region immediately beneath the bark. Late in the summer, the larvae leave this region and tunnel into the xylem where they remain in a quiescent state until the next spring at which time a majority pupate. Under favorable conditions the duration of the pupal stage ranges from eight days to two weeks.

The borer kills recently transplanted trees by girdling them or it may cause the tops of the trees to die by girdling them at the crotch. Surviving trees may be so severely injured that they may die a year or so later. If the injury is not in any vital part of the tree, it may recover, especially if the tree is located in a favorable situation. Older, well established trees are not immune to attack during dry years due to their devitalized condition and to the enormous number of beetles which may be developed in dry cycles.

The flatheaded apple tree borer reached its peak of abundance in Oklahoma during 1936 and 1937. The next two years, it was relatively scarce due to control by natural agencies. Insect parasites and predators greatly reduced borer infestation. Cage records show a steady increase in the percentage of parasitization from 6.9 in 1937 to 58.6 in 1938.

Walnut was favored by the beetles over apple in one year's records. Asiatic elm (U. pumila Linn.) was injured far less than American elm (U. americana Linn.), 11.8 percent being killed as compared with 51.9 percent.

Evidence is not sufficient to recommend protection by the use of tree paints. In fact, in one test they seemed to protect the borer from its parasites and in another attracted the beetles. A considerable degree of protection was given by two formulae for a short period of time but lack of borer infestation in later years prevented further investigations on these paints.

Best protection was obtained by spiral tree wraps. To give most protection, these must be in place by early May and should remain on the tree for the first growing season or until about October 1. The wrap should extend a few inches below ground level and extend beyond the point in the crown where the first branches originate. The bases of these should be wrapped also. The best paper to use is a medium heavy, specially treated water resistant material with a certain amount of resilience to allow for expansion due to increase in diameter of the trunk.

## LITERATURE CITED

(1) Boillot, B. F.
1933. Worming apple trees. Mo. State Bd. Agri. Monthly Bul. 28: 30.

(2) Brooks, F. E.
1919. The flatheaded apple tree borer. U. S. Dept. Agr. Farmers' Bul. 1065.

(3) Burke, H. E.
1917. Notes on some western Buprestidae. Jour. Econ. Ent. 10: 328.

(4) ———
1919. Biological notes on the flatheaded apple tree borer (**Chrysobothris femorata** Fab.) and the Pacific flatheaded apple tree borer (**Chrysobothris mali** Horn). Jour. Econ. Ent. 12: 326-330.

(5) Fenton, F. A., and Maxwell, J. M.
1937. Fatheaded apple tree borer in Oklahoma. Jour. Econ. Ent. 30: 748-750.

(6) Georgia Agricultural Experiment Station.
1934. Flatheaded borers in pecan. Ga. Agr. Exp. Sta. Ann. Rept. (1933-34) 46: 38-39.

(7) ———
1935. Flatheaded borers in pecan. Ga. Agr. Exp. Sta. Ann. Rept. (1934-35) 47: 36-28.

(8) ———
1936. Flatheaded borers in pecan. Ga. Agr. Exp. Sta. Ann. Rept. (1935-36) 48: 26-27.

(9) Gill, J. B.
1924. Important pecan insects and their control. U. S. Dept. Agr. Farmers' Bul. 1364: 38-41.

(10) Houser, J. S.
1937. Borer control experiments. Nat. Shade Tree Conf. Proc. 13: 159-168.

(11) Hutson, Ray.
1931. Borers severely injure fruit trees. Mich. Agr. Exp. Sta. Quar. Bul. 14: 28-29.

(12) Isely, D.
1938. Flatheaded apple-tree borer. Ark. Agr. Exp. Sta. Ann. Rept. (1936-37) 49: 45. (Bulletin 351.)

(13) Johnson, G. V., and Fenton, F. A.
1939. Control of the flatheaded apple tree borer in Oklahoma. Jour. Econ. Ent. 32: 134-142.

(14) Minnesota Agricultural Experiment Station.
1899. Beetles injurious to fruit producing plants. Minn. Agr. Exp Sta. Bul. 66: 137-141.

(15) Nebraska Agricultural Experiment Station.
1938. Neb. Agr. Exp. Sta. Ann. Rept. (1936-37) 51: 36.

(16) Pettit, R. H.
1900. Insect and animal life on the Upper Peninsula Experiment Station. Mich. Agr. Exp. Sta. Bul. 186: 36-37.

(17) ----------
1923. A repellent for flatheaded borers. Mich. Agr. Exp. Sta. Quar. Bul. 5: 170-171.

(18) ----------
1932. Flatheaded apple tree borer. Mich. St. Bd. Agr. Rept. (1932) 71: 236-237.

(19) ---------- and Hutson, Ray.
1931. Pests of apple and pear in Michigan. Mich. Agr. Exp. Sta. Cir. Bul. 137: 52-54.

(20) Saunders, W.
1883. Insects injurious to fruits. pp. 20-22.

(21) Smith, J. B.
1896. Economic entomology. pp. 188-190. (J. B. Lippincott Co.)

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