EXPERIMENTS ON THE CONTROL OF CHRYSOBOTHRIS FEMORATA

IN OKLAHOMA

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By

George V. Johnson

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PREFACE

The first consideration in a control problem is to determine when control measures must be practiced and what forms they might take. This paper deals with a study of the emergence of Chrysobothris femorata Fab. from overwintering larvae, its period of activity during the summer, and experiments on its control under Oklahoma conditions.

The control experiments are somewhat preliminary in nature and should be so recognized. They should be considered as a basis for further work and not as a completed project.

The work is discussed under several sections into which it easily divides; such as, biological considerations, toxicity studies on adult borers, studies on repellent paints, studies on fumigant paints, and wrapped trees.

Indebtedness is acknowledged to Dr. F. A. Fenton of the Oklahoma A. & M. College, Department of Entomology, who assigned the writer this problem and gave valuable suggestions and criticisms; to the Department of Horticulture for the use of their pecan grove; to the Department of Highways of the State of Oklahoma for the use of a planting of trees; to Mr. J. N. Knull, curator of the museum of the Department of Zoology and Entomology of Ohio State University who determined several species of beetles; and to Messrs. Lawrence Bewick, Abbott Kagan, Martin Kagan, Albert Crain, and Robert Kaiser for their assistance in the experimental work.

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INTRODUCTION

The flat-headed apple tree borer, Chrysobothris femorata Fab., which has become of increasing importance as an insect pest of trees in Oklahoma, presents a rather difficult problem in control. The facts that the larva is concealed and feeds under the bark of trees, and the adult is very active tend to favor the maintenance of the borer in a pestiferous position. The common name, flat-headed apple tree borer, might be somewhat misleading since the larvae attack a great number of fruit and forest trees. Some of the most favored are elm, pecan, walnut and apple.

Two of the first controls recommended were given by Hopkins (6) in 1890. He stated that fresh wood ashes spread around the roots of the trees and rags saturated with soft soap and placed in the crotches acted as repellents in preventing oviposition by the females.

In 1923 Lovett (8) recommended several washes for the control of the flat-headed borer. The first one consisted of rock lime, rock salt, rice paste, powdered casein, naphthalene flakes and water. Crude carbolic acid could be substituted for the naphthalene flakes in the above preparation if desired. Another paint was given as containing quick lime, casein, copper sulfate, flake naphthalene and water.

Pettit (13) also in 1923 listed a borer repellent composed of potash soap, naphthalene, flour and water.

In 1935 Mote (12) restated Lovett's washes as given in 1923.

Bissell (1) in 1935 reported that repellent washes of soap and naphthalene painted on several times during the season gave no control of borers on larger trees, but that wraps of cloth or paper applied to the trunks of the trees gave good control.

Farrar and Flint (3) concluded in 1937 that whitewash and soap repellents containing naphthalene failed to protect the tree trunks but wrappings of light proof paper, wrapping paper, newspaper, muslin, and burlap all proved satisfactory for protecting the trunks of newly transplanted trees.

In 1937 Houser (7) decided that wrapping gave good control but repellent preparations were in general ineffective. One material of a liquid grafting wax still showed a little repellence the second season after application.

The following experiments were carried on at Stillwater during the summer of 1937 in an effort to devise some means of control of the flat-headed apple tree borer under Oklahoma conditions. Investigations were divided into several phases as follows:

A continuation of the biological considerations of Maxwell (10) included records of adult and parasite emergence from caged infested material, field collections for population and life history notes, and cage observations to determine the effect of repellents on oviposition of and repellence to the adults.

Toxicity studies under cage conditions were undertaken to determine the effect of poison sprays on both field collected and cage emerged beetles.

Field exposure of walnut and apple cuttings painted with repellent paints were made in an effort to find a paint that would prevent oviposition by the females.

Several fumigant paint preparations were tried on infested cuttings as a means of ascertaining the effectiveness of the preparations in killing the borer in the larval stage.

Various kinds of paper wraps were applied to newly transplanted trees to determine the value of wrapping to prevent injury from borers.

BIOLOGICAL

Methods. Infested branches and trunks were gathered in the spring of 1937 and put in 16-mesh screen cages 2 feet by 2 feet by 4 feet in dimension. Four cages were filled with this material and one cage of material from the previous winter's collection was kept to check on the possibility of a two-year life cycle. These cages were kept outside where they would be exposed to as nearly natural weather conditions as possible. When emergence began in the spring, beetles and parasites were removed and recorded daily.

Beginning June 22 field collections were made several times weekly for the remainder of the summer to determine the field population and to obtain adults for cage tests. These collections were made in a grove of pecan and black walnut trees from 15 to 25 feet tall. A white canvas was spread under the tree and the limbs were then jarred smartly with a pole. The beetles were thus knocked down on the canvas where they could be gathered up in individual vials. Collections were made between daylight and sunrise since soon after sunrise the beetles became active and would fly off the canvas or take flight before dropping to the canvas.

Emergence Records. The emergence record from infested wood collected in the spring of 1937 is presented in Table 1 and graphically in Figure 1. The first beetle emerged May 21, 17 days later than the previous season, and the last August 2, 34 days later than the year before, with the bulk of emergence occurring between May 26 and June 29. The peak of emergence

Table 1. Daily Emergence of C. femorata from Infested Wood. 1937.

Date	No. of Beetles Emerged	Cumulative Emergence	Per Cent of Total Emerged	Date	No. of Beetles Emerged	Cumulative Emergence	Per Cent of Total Emerged
May 21	2	2	0.1	June 19	17	1364	86.2
24	5	7	0.4	20	36	1400	88.5
25	4	11	0.7	21	28	1428	90.3
26	35	46	2.9	22	18	1446	91.4
27	23	69	4.4	23	10	1456	92.0
28	61	130	8.2	24	20	1476	93.3
29	47	177	11.2	25	11	1487	94.0
30	39	216	13.6	26	18	1505	95.1
31	63	279	17.6	27	13	1518	95.9
June 1	80	359	22.7	28	12	1530	96.7
2	65	424	26.8	29	12	1542	97.5
3	93	517	32.7	30	2	1544	97.6
4	52	569	36.0	July 1	4	1548	97.8
5	50	619	39.1	2	1	1549	97.9
6	70	689	43.5	4	1	1550	98.0
7	84	773	48.9	5	2	1552	98.1
8	36	809	51.1	6	6	1558	98.5
9	44	853	53.9	7	3	1561	98.7
10	34	887	56.1	9	2	1563	98.8
11	78	965	61.0	11	3	1566	99.0
12	115	1080	68.3	12	3	1569	99.2
13	85	1165	73.6	13	1	1570	99.2
14	41	1206	76.2	14	3	1573	99.4
15	18	1224	77.4	16	6	1579	99.8
16	31	1255	79.3	17	1	1580	99.9
17	46	1301	82.2	20	1	1581	99.9
18	46	1347	85.1	August 2	1	1582	100.0

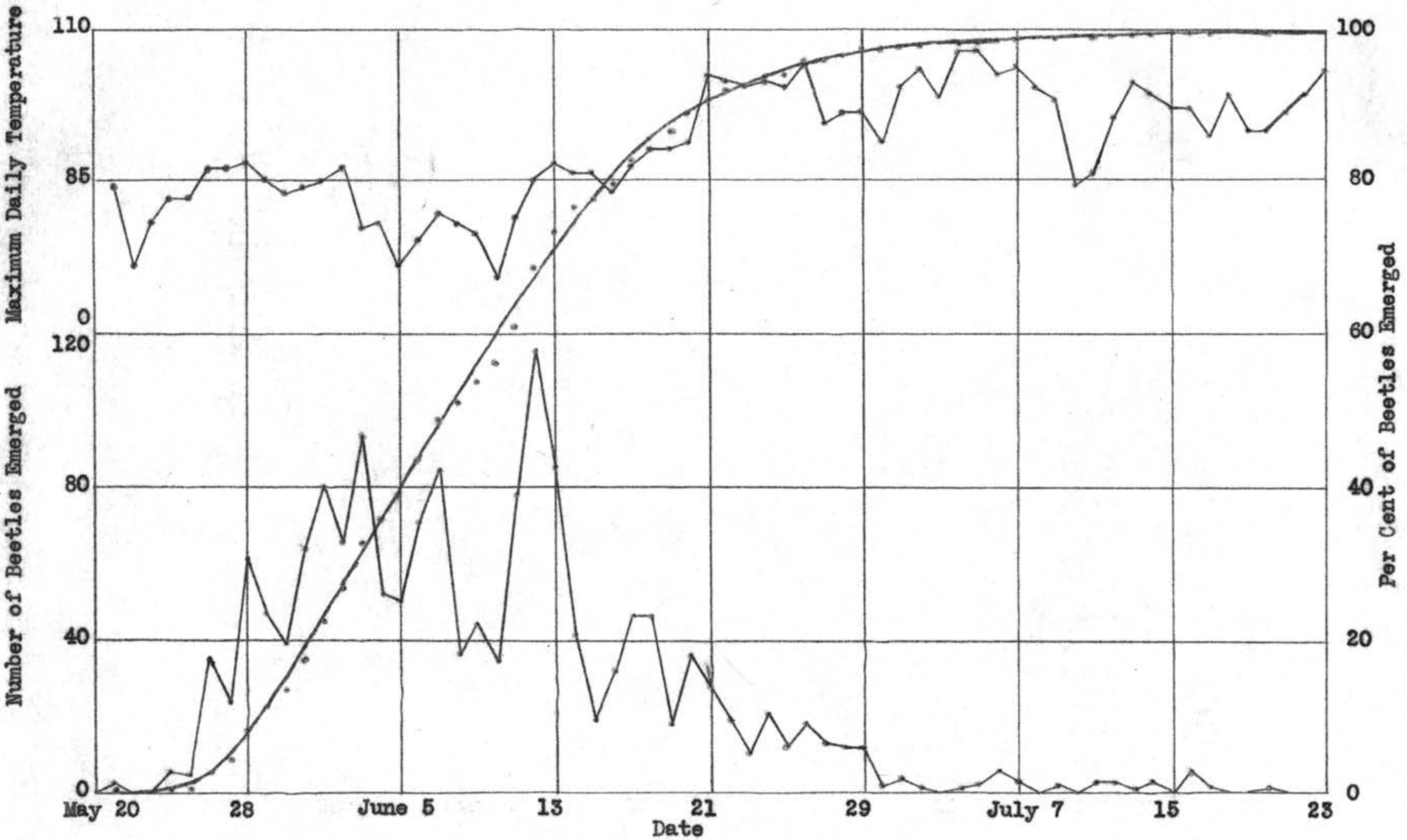

Fig. 1. C. femorata Emergence from Caged Material, 1937.

occurred June 12 at which time 115 adults emerged making 1080 beetles or 68 per cent of the total number of beetles emerged. Maxwell (10) found the peak to occur on May 21 in 1936. While the first 50 per cent of the beetles emerged in the 18-day period from May 21 to June 8, the last 50 per cent took the 55-day period from June 9 to August 2, thus showing again that the heaviest emergence occurred early in the emergence period. A total of 1582 beetles were removed from the four cages.

Here too as found by Maxwell (10) in his work there is a positive correlation between temperature and emergence. The correlation in this instance holds in general until 97 per cent of the individuals had emerged.

It was noted that toward the last of the emergence period a higher percentage of those emerged were females.

Parasitism was greater for 1937 than the year previous. Maxwell (10) in 1936 noted that 6.9 per cent of the individuals taken from the cages represented at least seven species of hymenopterous parasites. The writer in 1937 found that 13.8 per cent of the individuals removed were two species of hymenopterous parasites. Nearly all of these were Phasgonophora sulcata Westwood and a few were Atanycolus rugosiventris Ashm., both of which were of lesser importance in the previous season's work.

A few specimens of four other species of beetles were removed from the cages. These were Chrysobothris purpureovittata (Buprestidae), Achmaeodera pulchella (Buprestidae), Bostrichus bicornis (Bostrichidae), and Elaphidion macronatum (Cerambycidae).

From the cage of material held over for the second year 22 C. femorata adults and two parasites were removed indicating a two-year life cycle in some cases. There is a possibility that the cage had a piece of newly collected wood accidentally added to it in the spring but this is not very likely.

Field Collections. On and after July 3, collection was limited to two trees that had proved to harbor the beetles consistently so that comparison of population from day to day might be made. Prior to July 3, collections had not been limited to a certain number of trees but about the same length of time was spent each morning so that at least an indication of the comparative population was obtained.

Table 2. Field Collections of *C. femorata.* 1937.

Date	Number of Beetles	Date	Number of Beetles	Date	Number of Beetles
June 22	150 (approx.)	July 6	150	August 12	2
23	150 (")	9	119	15	0
24	200 (")	12	88	19	2
25	240	16	46	September 1	12
26	166	19	56	21	14
28	172	22	88	25	5
29	172	26	92	October 1	3
30	175	30	74	9	0
July 1	200	August 2	42	19	0
2	200	5	44		
3	150	9	28	Total Beetles	2840

Table 2 presents the collection records, while Figure 2 gives a comparison of field collected and cage emerged beetles. Field collecting was begun at or shortly after the peak of the field population it is believed. The first two collections are smaller than those immediately following mainly because the collecting technic was still in an

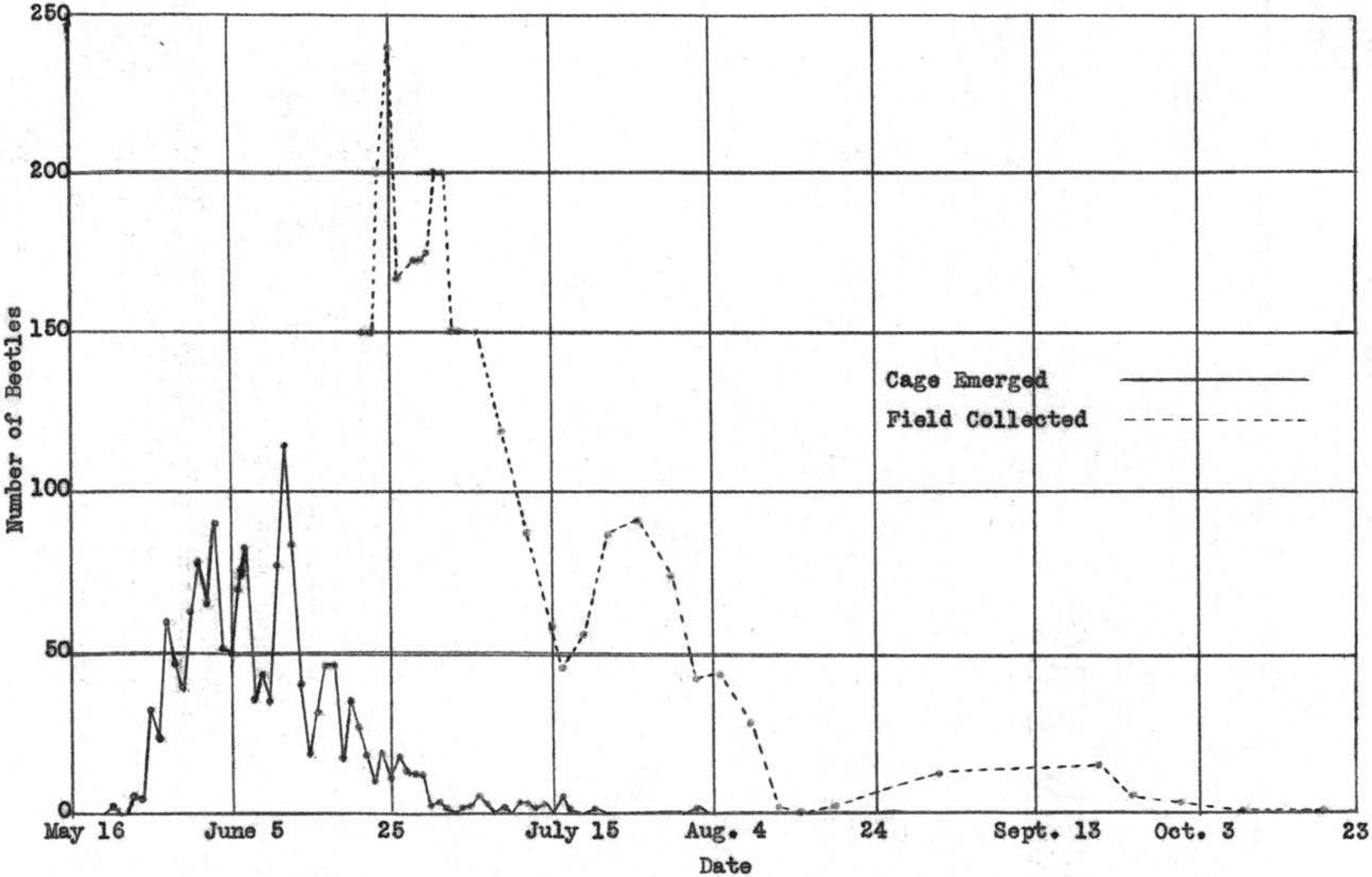

Fig. 2. C. femorata Emergence from Cages Compared to Field Collections, 1937.

experimental state. The collection for June 25 is high because special effort was made to obtain a large number of adults for cage tests. It is believed that the records for July 16 and 19 are too low because of the effect of unfavorable weather. The July 16 collection had been preceded during the early morning with rain and wind, and the morning of July 19 was quite windy. Two possibilities suggest themselves. The wind and rain might have knocked some beetles to the ground so that fewer beetles were present in the tree, or the adult borers might have crawled in on the larger limbs and trunk making it more difficult to jar them from the tree.

It will be noted that a general trend downward started about July 2 and continued until no adults were collected on August 15. Then four days later two beetles were taken and an increase in population was noted until September 21 when 14 adults were collected. A decline was then observed until October 1 after which no beetles were found. It is felt that this indicates the possibility of a partial second generation of borers. Further evidence pointing to the possibility of a second generation are the facts that on September 2 an adult was found in a borer mine in a walnut cutting, and on September 11 one was observed emerging from a young elm tree. It is possible that they were late emergents from the previous summer's infestation. However, the walnut cutting was taken from a group of seedlings with heavy foliage and of vigorous growth and exposed to borers in the field during the summer, while the elm tree had been planted early in the spring from nursery stock so that chances of previous infestation are reduced but not eliminated. It should be noted that these beetles were observed 31 days and 40 days after the last cage emerged beetle was recorded.

If it can be assumed that the peak of field emergence occurred at about the same time as the peak of cage emergence, one can get a rough idea of the length of adult by a comparison of field collection and cage emergence records in Figure 2. By rounding off these curves it appears that the average adult life would be from 40 to 50 days.

Trees with a fairly rough bark as black walnut and trees with spreading tops so that the limbs were more slanting were favored as overnight resting places of the beetles. The adults are very active during the day and at temperatures as high as 105° F. they could be observed running rapidly about and stopping frequently on the limbs and trunk of weak or poorly foliated trees.

TOXICITY STUDIES

Methods. The following group of tests were undertaken to determine the effectiveness of various stomach poisons at different concentrations in controlling adult borers. Cylindrical 16-mesh wire screen cages about 12 inches in diameter and 24 inches high were constructed. Each cage was placed over two or three apple branches contained in a four-ounce wide mouth bottle set in the ground so that it would not tip over. The bottles were kept full of water to maintain the material in a fresher condition. Since the adults feed on bark and phloem tissue from the spurs and crotches of one or two-year old wood, this type of branch was used in the cages. The poisons were applied in liquid form with a paint brush. The branches were changed when a new cage of adults was started. Beetles were placed in the tests the same day they were taken from the emergence cages. Observations were made and recorded daily. Cages were run for a period of eight days unless the beetles in the treated cages were all dead before that time.

All of the tests discussed herein were conducted under greenhouse conditions except a few cages as noted later but otherwise the technic was the same in both cases.

Lead arsenate was tried at concentrations of two pounds per 50 gallons of water, 4-50, 6-50, 8-50, 10-50 and 12-50. Derris at two pounds per 100 gallons of water was used with casein as a sticker. Two and one half pounds sodium arsenate and five quarts of summer spray oil (Verdol) per 50 gallons of water, and five pounds of sodium arsenate and five quarts of Verdol per 50 gallons of water were also tested.

Cage Emerged Beetles. Table 3 presents the results obtained from cage emerged beetles. While it is felt that the results are inconclusive because of the small number of beetles used, the figures for lead arsenate are especially interesting. Lead arsenate at two pounds per 50 gallons did not give 100 per cent mortality in eight days while all other treatments gave 100 per cent mortality in five days or less. At 6-50, 100 per cent mortality was reached the third day, while at 8-50 and 10-50 the rate of mortality decreased. A possible explanation is apparent when these data are plotted time against per cent mortality. Note in Figure 4 that at a concentration of 8-50 there is a distinct lag in the mortality the first day and at 10-50 this lag is somewhat greater. This suggests that at concentrations over 6-50, arsenate of lead becomes repellent so that the beetles don't feed readily. At 12-50 (Fig. 4) this lag in the first day's mortality is further accentuated but the kill rapidly increases to 100 per cent on the third day. The repellence, if such is the case, is still acting but at this high concentration of poison only a little feeding is necessary for the beetle to ingest a lethal dose. It is not known how long this insect can live without food, so it can not be said what part starvation might have in this explanation.

Table 3. Toxicity Tests on Cage Emerged *C. femorata* Adults.

Number	Date	Treatment	Number Beetles	Per Cent Mortality on Successive Days 1	2	3	4	5	6	7	8	Total Number Dead	Total Per Cent Dead
1	June 7	Lead Arsenate 2-50	37	13.5	37.8	51.4	70.3	83.8	86.5	86.5	91.9	34	91.9
2	9	Lead Arsenate 4-50	20	15.0	35.0	65.0	85.0	100				20	100
3	10	Lead Arsenate 6-50	17	29.4	88.2	100						17	100
4	12	Lead Arsenate 8-50	24	12.5	54.2	87.5	100					24	100
5	13	Lead Arsenate 10-50	25	8.0	32.0	72.0	96.0	100				25	100
6	15	Lead Arsenate 12-50	9	0.0	44.4	100						9	100
7	14	Derris (5% Rot.) 2-100 (Casein Spreader)	14	7.1	28.6	42.9	92.9	100				14	100
8	11	Sodium Arsenate 2½-50 Verdol - 5 qt.	37	10.8	40.5	81.1	94.6	100				37	100
9	14	Sodium Arsenate 5-50 Verdol - 5 qt.	14	21.4	35.7	71.4	100					14	100
		All Checks	185	4.9	17.3	34.6	43.8	48.0	48.6	50.3	50.8	94	50.8

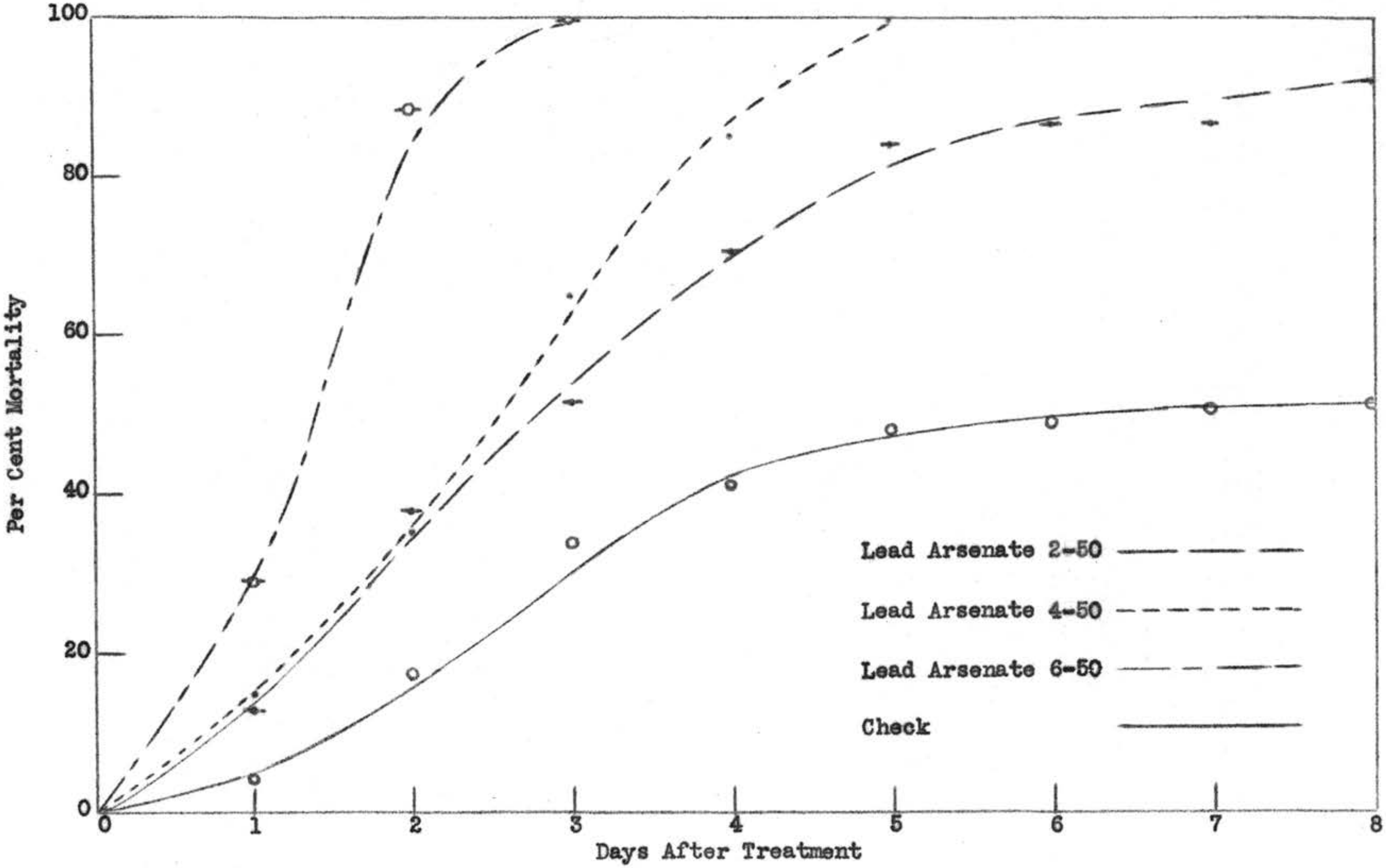

Fig. 3. Time-mortality Comparison of C. femorata Adults with Several Concentrations of Arsenate of Lead, 1937.

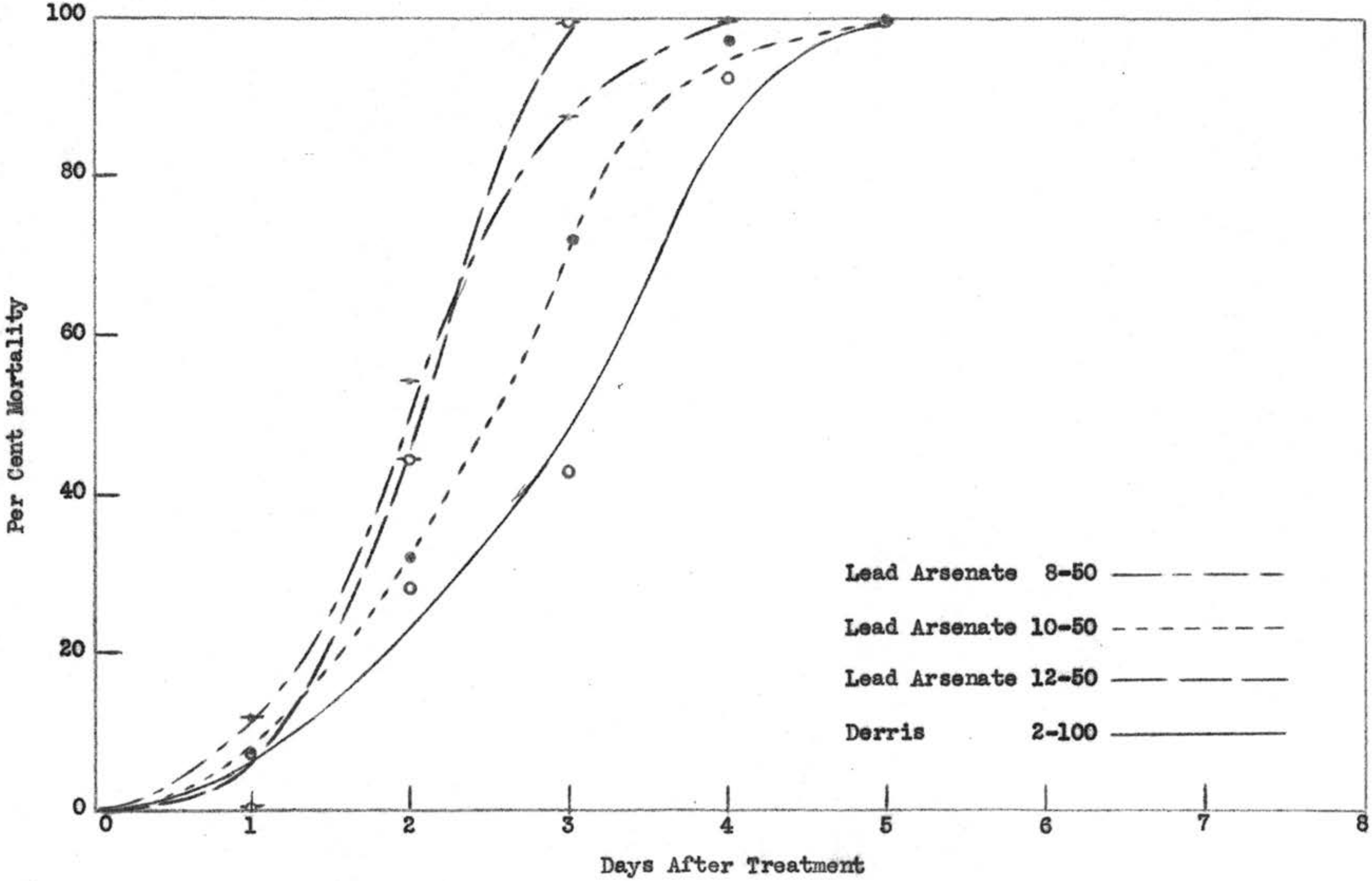

Fig. 4. Time-mortality Comparison of C. femorata Adults with Derris and Several Concentrations of Arsenate of Lead, 1937.

The curve for derris shows a delayed action somewhat similar to that of lead arsenate 10-50, but the cause might not be the same.

On the basis of these tests, if lead arsenate were to be used as a means of killing the adults it should be applied at the rate of six pounds per 50 gallons of water.

The practicability of controlling the adults with a stomach poison is questioned. Field studies showed the beetles to be actively running over the branches of the trees and to be flying from tree to tree. Repeated collections from the same trees also showed that the adults move from tree to tree freely. Even if all the trees in an orchard were sprayed with a poison it would not prevent beetles from flying in and ovipositing on the trees. However, the possibility of being able to poison the young larvae remains. If the limbs and trunks of trees were covered with a poison prior to oviposition, the newly hatched larvae might ingest a lethal dose when it burrows into the bark. It is planned to test this possibility in future work.

Several cages were set up outside the greenhouse between June 22 and 26. The mortality in both treated and check cages was excessive. On the second day over 50 per cent of the checks were dead. A higher temperature at this time might have had an effect, but note also that the checks on the cages inside the greenhouse showed a fairly high death rate the first four days (Fig. 3). Consider further the field collected adults that were tested between June 24 and July 2. In all cases of 33 cages with 20 beetles per cage, 100 per cent mortality resulted in from one to four days in both check and treated cages. In 27 of the 33 cages, 100 per cent mortality occurred in two days. The poison used had no apparent effect on the mortality. That all the field collected adults died a natural death is denied by the fact that the field population from which the samples were taken was not on a rapid decline at that time. It appears that some factor or factors on which no measure is had influenced the kill of beetles. Two possibilities present themselves. Either the beetle is unsuited to cage testing because of its great activity, or other reasons, or a suitable technic was not employed. Further evidence emphasizing these possibilities is presented in the section on studies of repellent paints.

STUDIES ON REPELLENT PAINTS

Formulae. A list of the repellents used is presented here to eliminate repetition since some of them are used in several types of tests. There were 16 preparations tested as repellents to prevent oviposition by the female beetles. Several of these paints were also used in cage tests to determine their effect in preventing the beetles from resting on treated cuttings. All were applied with a brush.

Repellent Number 1. Heat 50 pounds of potash fish-oil soap and three gallons of water to 180° F. and mix well. Slowly stir in two pounds of flour. The flour mixes better if first stirred up separately with part of the water. Add 25 pounds of naphthalene while holding at 180° F. (melting point of naphthalene is 176° F.) and stir thoroughly until dissolved. Chill as quickly as possible while stirring occasionally. Quick cooling tends to make the naphthalene crystals smaller. This formula is the same as that recommended by Pettit (13) except potash fish-oil soap is used here instead of potash soap.

Repellent Number 2. Mix five pounds of washing soda and three quarts of potash fish-oil soap with water to make six gallons. Add hydrated lime to the consistency of thick paint. To this add three teaspoonfuls of Paris green and one ounce of carbolic acid and mix thoroughly. This formula is the same as that used by Fletcher (2) for peach bark borer control except that he used a soft soap and air slaked lime.

Repellent Number 3. Slake one half bushel of rock lime with water and while still hot add three pounds of rice boiled to a thin paste and two quarts of rock salt previously dissolved in a little warm water. Sift two pounds of powdered casein slowly into the cool whitewash. Sift in two pounds of naphthalene flakes and add water to a thick wash. Lovett (8) lists this wash as being particularly effective against the flat-headed borer.

Repellent Number 4. Thoroughly mix one pound of potash fish-oil soap and one pint of carbolineum avenarius, then add one quart of water.

Repellent Number 5. Dissolve one pound of sodium carbonate in one quart of hot water, add one quart of carbolineum avenarius and stir vigorously until emulsified. Dilute with two quarts of water when used. A bucket spray pump aids in the emulsification of the stock. This paint was used by Matheson (9) in his work on the poplar and willow borer.

Repellent Number 6. Liquify four pounds of paraffin in a double boiler, add one pound of paradichlorobenzene, and stir until dissolved. Apply while in a melted state. Gilbertson (4) used this wash against the plum tree borer.

Repellent Number 7. Take nine parts of ethylene dichloride to one part of dilute potash fish-oil soap (30 per cent soap and 70 per cent water) and emulsify by agitation to make a stock emulsion. This was used at a dilution of one part stock to four parts water giving a 20 per cent ethylene dichloride emulsion. Snapp and Tomson (14) found this preparation very effective in the control of the peach tree borer. While it is primarily a fumigant, it was tried both as a repellent and fumigant in this work.

Repellent Number 8. Mix one pint of carbolineum americanus and one pound of potash fish-oil soap, and add one quart of water.

Repellent Number 9. One part of liquid lime sulfur mixed with seven parts of water and made into a thick wash by the addition of hydrated lime. Guyton and Knull (5) used this paint to repel the round-headed apple tree borer.

Repellent Number 10. (8). Dissolve one-fourth pound of copper sulfate crystals in a small amount of water and add to eight pounds of quick lime while it is slaking. Add one-half pound of casein, one pound of naphthalene flakes, and water to form a thick wash as in repellent number three.

Repellent Number 11. (8). Same as repellent number three except substitute crude carbolic acid in place of the naphthalene flakes. Use the carbolic acid at the rate of one-half pint per six gallons of dilute wash.

Repellent Number 12. Full strength creosote. Matheson (9) reported this wash as giving good control of the poplar and willow borer.

Repellent Number 13. Paraffin applied while liquified.

Repellent Number 14. Paraffin and paradichlorobenzene at one-half the strength of repellent number six.

Repellent Number 15. Three gallons of water, one gallon of potash fish-oil soap, and one-half pint of crude carbolic acid mixed thoroughly. Lovett (8) lists this preparation against the shot hole borer.

Repellent Number 18. Same as repellent number five except use without dilution.

Cage Tests of Repellent Paints

Methods. Cages of 16-mesh screen on a wood framework $2\frac{1}{2}$ by $2\frac{1}{2}$ by $2\frac{1}{2}$

feet in dimension were used in these tests. A door was built in the bottom half of one side to facilitate the placing of material in the cage. No bottom was needed since the cages were placed directly on the ground. Apple cuttings from one and one-half to three inches in diameter and about two and one-half feet long were used in the cages. Two painted cuttings, one of larger diameter and one of smaller diameter were placed in jars of water set in the soil for support in opposite corners of the cage, while two similar unpainted ones were placed in the other two corners. Observations on the number of beetles on both painted and unpainted wood were made and recorded at 9 and 11 A.M. and 1, 3, and 5 P.M. daily. The number of adults per cage varied from 30 in most cases, to 73. Beetles from hibernation cages and from field collections were used in separate cages the same day they were removed or collected.

Cage Emerged Beetles. Table 4 presents the data secured by using beetles from hibernation cages. The test on repellent number one showed practically as many on the treated cuttings as on the checks. Repellent number nine, a white colored paint, seemed to attract the beetles and this agrees with the field observation that the adults were apparently attracted to white objects such as clothing and would alight on them more often than on darker things. Treatments 5 and 18, both carbolineum preparations, show a marked repellence to the beetle and agree well in results. However, it is felt that care should be taken in drawing conclusions from these data. It was noted in these tests as in those with stomach poisons that the beetles were very restive in the cages. They would run rapidly around over the cage or fly across it and seemed to be trying to get away. Field collected adults were tested in the same way but no results were obtained. They would behave in a manner similar

Table 4. Effect of Repellent Paints on C. femorata Adults in Cages.

Repell-ent Number	Date of Test	Number of Beetles Used in Test	Number of Readings	Number of Beetles Observed		Per Cent of Beetles Observed	
				On Treat-ed Wood	On Check	On Treat-ed Wood	On Check
1	June 3 to 23	?	95	574	596	49.1	50.9
5	June 7 to 12	?	25	7	51	12.1	87.9
9	June 14 to 19	30	26	120	85	58.5	41.5
18	June 12 to 19	73	33	31	165	15.8	84.2

to the beetles emerged from the cages but in addition they died rapidly and were all dead by the end of the second day after being started. Thus, the same possibilities are encountered as under the toxicity test setup.

Repellent Paint on Growing Trees

Part of a group of 84 young apple trees which had been set out the spring of 1937 were treated with several repellent paints. Some of the trees were treated June 23 and the remainder July 2. There were 35 trees left untreated. All were examined for borers late in July at which time it was found that the treated trees varied somewhat from an average of five borers per tree while the checks averaged four borers per tree. Since the treatments were applied after oviposition had probably been going on for some time*, it is felt that the results do not give a picture of the effect of the paints on repellénce.

One point brought out by this test deserves note. Of the 35 trees

* Maxwell (10) found a preoviposition period of about 6 days in cage studies. Since the peak of cage emergence was June 12 and assuming that field emergence roughly corresponded, it is believed a reasonable conclusion that oviposition had been in progress some time before the trees were painted.

untreated, 13 had from one to four borers that were parasitized, or 37 per cent of the check trees contained from one to four parasitized larvae. Only two of the 49 treated trees had one parasitized borer each, or four per cent of the treated trees contained one parasitized larva. These preparations, namely numbers 1, 3, 4, and 5 of the repellent paints, appear to protect the borers from being parasitized, an observation that may or may not but probably does hold true for most preparations.

Repellent Paints on Cuttings

Methods. After it was found that cage tests were not giving satisfactory results, a plan for testing repellent preparations under field conditions was devised. Several trees about 20 feet tall and poorly foliated or weakened by previous borer attack were located in the horticultural pecan grove. These trees were observed to be sure they were being frequented by the adult borers. Quart oil cans with the tops cut out were washed and fastened to exposed limbs of the selected trees. Black walnut and apple cuttings about 30 inches long and one to three inches in diameter were selected from borer free material. Several cuttings of both kinds were painted with each of the repellent mixtures to be tested and fastened in the cans in the trees with pieces of twine. The cans were filled with water to help keep the wood from drying out. Exposure was for three days during the first part of July when the borer population was high and from five to seven days when the population had fallen off later in the season.

After being exposed in the trees, the cuttings were taken in and those treated with the same preparation were put together in five quart tin cans kept filled with water. After 20 to 25 days, the exposed material was examined for borers by cutting off the bark with a knife.

Any borers present were large enough at this time to be easily seen.

Data and discussion. At the time of examining the cuttings for borers it was noted that several of the preparations were injurious to the bark. Repellent number twelve, full strength creosote, was quite injurious. Number six, containing paradichlorobenzene, was somewhat injurious, while number fourteen, containing one-half as much paradichlorobenzene as number six, was less harmful. Material number two which contained carbolic acid and Paris green was a little injurious to the bark, while preparations number eleven and fifteen which contained more carbolic acid than number two but no Paris green only very slightly affected the bark.

The results of cutting examinations for borers is presented in Table 5.

It should be noted that the untreated walnut cuttings were much more heavily infested than the untreated apples. The walnut bark is probably more attractive to the female beetles as a place for oviposition due to its rougher character.

The effectiveness of the materials used is measured by the per cent fewer borers per cutting than in comparable checks. It is seen that in most cases the same paint differs considerably in per cent reduction of borers in apple and walnut. This difference is probably caused by the fairly small number of cuttings treated with each preparation. However, it might be possible that one repellent would be more effective on apple than on some other kind of wood while the reverse could be true of some other preparation. Since this study was more or less of a preliminary nature as a basis for further work it was thought wise to test as many preparations as possible in an effort to eliminate ineffective or injurious materials.

Table 5. Infestation by C. femorata of Treated Apple and Walnut Cuttings Exposed to Field Conditions.

Formula Number	Date Series Began	Date Series Closed	Apple Cuttings: Number of Cuttings	Apple: Total Number of Borers	Apple: Number Borers per Cutting	Apple: Number Less Than Check	Apple: Per Cent Less Than Check	Walnut Cuttings: Number of Cuttings	Walnut: Total Number of Borers	Walnut: Number Borers per Cutting	Walnut: Number Less Than Check	Walnut: Per Cent Less Than Check
1	July 3	July 15	26	102	3.9	2.6	40.0	20	76	3.8	16.9	81.6
2.	"	"	25	142	5.7	0.8	12.3	23	433	19.7	1.0	4.8
3	"	"	25	142	5.7	0.8	12.3	22	41	1.9	18.8	90.8
4	"	"	25	71	2.8	3.7	56.9	22	11	0.5	20.2	97.6
5	"	"	25	66	2.6	3.9	60.0	20	105	5.3	15.4	74.4
Checks Comparable to 1, 2, 3, 4, 5.			42	272	6.5			36	745	20.7		
6	July 3	July 19	23	8	0.3	5.8	95.1	20	81	4.0	15.7	79.7
Checks Comparable to 6.			45	274	6.1			41	806	19.7		
7	July 5 Aug. 9	July 10 Aug. 11	19	40	2.1	3.3	61.1	16	122	7.6	2.8	26.9
Checks Comparable to 7.			32	172	5.4			28	291	10.4		
8	July 12	Aug. 4	26	76	2.9	0.6	17.1	26	29	1.1	24.2	95.6
Checks Comparable to 8.			43	151	3.5			44	1112	25.3		
9	July 19	Aug. 11	24	39	1.6	0.4	20.0	24	67	2.8	17.2	90.5
10	"	"	24	27	1.1	0.9	45.0	24	162	6.7	12.3	64.7
11	"	"	24	44	1.8	0.2	10.0	24	181	7.5	11.5	60.5
13	"	"	24	17	0.7	1.3	65.0	24	56	2.3	16.7	87.9
Checks Comparable to 9, 10, 11, 13.			39	78	2.0			40	759	19.0		
12	July 19	July 26	10	6	0.6	2.2	78.6	10	0	0.0	29.5	100.0
Checks Comparable to 12.			15	42	2.8			17	501	29.5		
14	Aug. 2	Aug. 11	12	0	0.0	1.5	100.0	12	12	1.0	8.2	89.1
15	"	"	12	21	1.7	-0.2	-13.3	12	15	1.2	8.0	86.9
Checks Comparable to 14, 15.			18	27	1.5			18	166	9.2		

It is seen that in general the repellents gave a greater reduction in borers in the walnut than in the apple. It is felt that this is due to the paint causing a greater change in the physical character of the surface in the case of walnut. The paints applied to the walnut bark make it smoother compared to the untreated cuttings and less attractive comparatively than in the case of apple.

Paint number twelve, full strength creosote, gave good results, especially on walnut, but could not be used as a control because of its injurious effect on the wood. Possibly it could be prepared in the form of an emulsion which would give good results without injury.

Preparations 2, 11 and 15 all contained carbolic acid and were more or less injurious as noted above but also they were in general ineffective with the exception of number fifteen on walnut. Number fifteen on apple, however, resulted in more borers than the comparable checks.

Numbers six and fourteen, containing paraffin and paradichlorobenzene were effective but also injurious. Compared with number thirteen, paraffin only, it is seen that the effectiveness in these cases is probably due largely to the paraffin and not to the paradichlorobenzene.

Preparations containing naphthalene, namely 1, 3 and 10, were quite effective on walnut but only moderately effective on apple.

Repellents containing lime to make a thick wash tend to scale or shell off easily, especially on the smoother bark of the apple cuttings. This might help account for the fact that paints 2, 3, 9, 10 and 11 showed fairly low repellence on apple. Because of this possibility, of the preparations containing naphthalene, number one would be the most desirable.

It is felt that paint number seven would not be an effective repellent because ethylene dichloride is very volatile and would not have any lasting quality. Further consideration is given this material in fumigant tests in the next section.

Number four, carbolineum avenarius and potash fish-oil soap, gave better results than number five, carbolineum avenarius and sodium carbonate. But number five is a more lasting preparation. It would not wash off by rain so easily as those preparations containing soap as an ingredient.

Material number eight, the same as number four except carbolineum americanus was substituted for carbolineum avenarius, appeared slightly inferior to number four.

From the standpoint of injury to the wood, effectiveness of repellence and lasting quality, it is believed that the carbolineum avenarius and sodium carbonate mixture is superior.

As a result of this study then, preparations that merit further investigation as repellents, excluding those that are more or less injurious, are numbers 1, 5, 13 and possibly 4. The potash fish-oil soap and flour mixture in number one seems to give the preparation a more durable quality than soap alone.

STUDIES ON FUMIGANT PAINTS

Formulae. Four preparations were tried as fumigants to kill the borers while in the larval stage under the bark. These were as follows:

Fumigant Number 7. Same as repellent number 7.

Fumigant Number 14. Same as repellent number 14.

Fumigant Number 16. One pound of paradichlorobenzene dissolved in two quarts of cottonseed oil.

Fumigant Number 17. One pint of Black Leaf "50" (50 per cent free nicotine) mixed with one pint of summer spray oil (Verdol) to make a 25 per cent nicotine stock. This mixture was diluted and used at the rate of two parts of stock to three parts of water giving a 10 per cent nicotine preparation.

Methods. The methods used in this study were quite similar to those used in the study of repellent paints. Untreated black walnut and apple cuttings of a size similar to those used in the repellent tests were infested with borers by the same method of exposure. The exposure varied from 3 to 12 days depending on the field population of adults. Eight groups of material were infested with borers; the first was put up July 8 and the last August 12. All groups consisted of approximately 17 cuttings each of apple and walnut. On August 25, each group of infested cuttings was divided into five units of apple and five of walnut. Each unit consisted of three cuttings. One unit of apple and one of walnut from each group were treated with the same fumigant preparation. Four preparations were tested as shown under the formulae list. These materials were applied with a brush as in the repellent tests. The fifth unit of both the apple and walnut cuttings (three to five of each) was kept untreated as a check. Examination was made one week later by barking the wood with a knife. Numbers of living and dead borers were recorded.

Data and discussion. From the data presented in Table 6, it appears that preparation number sixteen, cottonseed oil and paradichlorobenzene, was the only one that gave any appreciable kill of borers and even in this case the kill was not high enough to be of any great importance in controlling the borer.

Table 6. Results of Fumigant Paints Applied to Apple and Walnut Cuttings Infested with C. femorata.

Fumigant Number	Apple Cuttings: Number of Cuttings	Apple: Number of Borers Total	Apple: Number of Borers Dead	Apple: Per Cent Dead Borers	Walnut Cuttings: Number of Cuttings	Walnut: Number of Borers Total	Walnut: Number of Borers Dead	Walnut: Per Cent Dead Borers
7	24	83	2	2.4	24	124	6	4.8
14	24	109	8	7.3	24	190	21	11.0
16	24	72	11	15.3	24	277	72	26.0
17	24	72	2	2.8	24	240	5	2.1
Checks	37	94	6	6.4	38	307	11	3.6

Fumigants 7 and 17 on apple and number seventeen on walnut show a lower percentage of dead borers than their respective checks but it is doubtful if this is significant.

TREE WRAPS

In the spring of 1937, the State Department of Highways set out elm trees along Highway No. 40 from Stillwater nine miles south. Permission was granted to use these trees in an experiment with wraps.

Wrapping material. Five different kinds of paper were tried in the study as follows:

Wrap Number 1.* A slightly creped paper, two thicknesses cemented together with asphaltum. This was put up in rolls 150 feet long and four inches wide.

Wrap Number 2.** Single crinkle, two thicknesses cemented together

*Manufactured by Weissinger Paper Company, Lansing, Michigan

**Wraps 2, 3 and 4 were manufactured by Arkel Safety Bag Company, 10 East Tenth Street, New York, N. Y.

with asphaltum. Same size rolls as number one. The crinkle across the band permits it to stretch as the tree grows.

Wrap Number 3. Double crinkle, otherwise similar to number two. The double crinkle permits greater stretch.

Wrap Number 4. Single crinkle paper as in number two, but put up in rolls about 12 inches wide.

Wrap Number 5. Medium grade wrapping paper. Rolls four inches wide were cut from an ordinary size bolt.

Methods. The wraps were applied to the trees in the spring before emergence of adults began. The wrap was started slightly below ground level by digging the soil away from the trunk, and wrapped spirally upward with a 50 per cent overlap giving two thicknesses of wrap. A twine string was tied around the top with a slip knot to hold the wrap in place and still allow the tree to grow and slip the string. Wrap number four, the wide roll, was cut into 36-inch strips and applied to the tree the long way of the strip, wrapped around the trunk and tied several places with slip knots. The various wraps were distributed over the entire nine miles of road with the exception of the wrapping paper which was confined to the south five miles. The trees were from one to two inches in diameter with a trunk of from five to seven feet. Observations were made several times during the summer as to conditions of wraps and trees. The last observations and records were taken October 21 to 26 at which time the wraps were removed and the trees closely examined.

Data and discussion. After wrapping 11 trees with the wide strips (number four) it was decided to discontinue this wrap. It was difficult to handle and apply and did not present a neat appearance as the other wraps did. Observations showed that it did not stay in place so well as the narrow wraps and it had to be repaired oftener.

It was found that the populations of adults and infestation of borers appeared quite uniform over the entire nine miles of road so that the south half of the strip, where the wrapping paper was used, is considered comparable to the rest of the experimental layout.

In tabulating the data for Table 7, it was assumed that the dead trees infested with borers were killed by them. It is recognized that this is probably not quite true since a few of the trees might have been affected by disease or other factors which would have caused death unaided by the borers, or death might not have resulted had only the larvae and no other influence been present. Several of the dead trees were not infested with borers as noted in Table 7. They probably died from the effects of transplanting.

Table 7. Effect of Different Paper Wraps on Infestation of Elm by C. femorata.

Wrap Number	Number of Trees	Number of Trees Dead	Killed by Borers		Live Trees Infested		Total Infested*	
			Number	Per Cent	Number	Per Cent	Number	Per Cent
1	45	13	13	28.9	14	43.7	27	60.0
2	45	16	13	28.9	15	51.7	28	62.2
3	45	19	16	35.5	10	38.5	26	57.8
5	36	14	13	36.1	8	51.7	21	58.3
Check	168	86	80	47.6	34	41.5	114	67.8

* Includes those killed by borers.

It is seen that nearly 48 per cent of the check trees were killed by borers while about 29 to 36 per cent of the various series of wrapped trees were killed. Protecting the trunk by wrapping reduced the number of trees killed by the flat-headed borer. The reduction in trees killed would have been somewhat higher but half of each series of wraps was purposely not repaired as needed during the summer. Since the trees were watered frequently, the wraps tended to rot away from the bottom of the tree. During the latter part of the period when adult borers were active, nearly half of each series of wraps had the bottom of the tree exposed. Examination of the trees showed that these exposed bottoms were attacked by the borers in a number of cases.

While wrapping reduced the kill of trees by borers, it did not reduce the infestation of the remaining living trees as seen in column seven of Table 7. Wraps 1, 2 and 5 had a higher percentage of living trees infested than the checks but it is believed this is because a greater percentage of the infested check trees and a smaller percentage of the wrapped trees were killed by borers.

Column nine of Table 7 shows the percentages of trees killed or infested by borers. These data indicate that wrapping the trunk of the tree up as far as the first branches is not enough to prevent infestation of the tree.. While a reduction of about five and one-half to ten per cent is noted, this is not very great. It was observed that when the trunks were wrapped the beetles oviposited on the limbs above the wraps. To be really effective in preventing attack the branches as well as the trunk should be protected since the trunk was definitely unattacked when wrapped.

There was little difference in the results relative to borers obtained from the various wraps. However, the ordinary wrapping paper was considerably less durable than the prepared wraps, necessitating frequent repairs. In addition, it was hard to apply without tearing. Wrap number one handled very well and presented a neat appearance. Its durability was equal to the other prepared wraps.

The size of these trees when transplanted tended to make them more susceptible to borer attack. They were fairly large so that they were probably weakened more than a smaller tree would have been and were thus in a condition favoring attack. The smaller the tree the better its chances for escaping injury because of its quicker recovery and growth following transplanting.

Houser (7) in his experiments with wraps started from the top of the trunk and wrapped downward. He stated that this kind of spiral caught the rain, directed it inward to the trunk, and helped to maintain a more nearly normal moisture condition. It is felt that this is a good plan but no ill effects were noted in this experiment where the wrap was started at the bottom and wound upward.

SUMMARY

The method of collecting plum curculio by jarring the trees was successfully used in collecting flat-headed borer adults.

Cage emergence of adults began on May 21 and ended August 2 as compared to May 4 and June 29 of the previous year's work.

The bulk of emergence took place fairly early in the emergence period with the peak occurring on June 12 as compared to May 21 for the peak in 1936.

There is a positive correlation between temperature and emergence of adults.

In 1937, 13.8 per cent of the individuals removed from the cages were two species of parasites. This was twice the percentage of parasites in 1936.

Evidence of a two-year life cycle was obtained from a cage of wood held over for the second season.

Field collections indicated the possibility of a partial second generation of beetles in 1937.

The adult flat-head spends the night resting on the branches of the trees. Those with a rough bark and fairly spreading tops seem to be favored.

Observations showed the beetles to be active all day and even the hottest days did not seem to affect them adversely.

Stomach poisons tested indicated that heavy applications of arsenic sprays are necessary to obtain good kills.

Cage tests show that the adult of *C. femorata* is either unsuited to cage testing or that a suitable technic was not employed.

Because of the activity of the adult it is believed that spraying

a small area to kill the beetles would not protect the trees.

Observations showed that the beetle is apparently attracted to white objects.

Repellent paints applied to growing apple trees reduced the number of parasitized borers by 33 per cent.

A method of testing repellent mixtures by exposing cuttings in trees frequented by the adult borers was devised.

Walnut cuttings were more heavily infested with borers than apple cuttings exposed at the same time. This is probably because the walnut is more attractive for oviposition due to its rougher bark.

Creosote, paradichlorobenzene, and carbolic acid were injurious to the bark of apple and walnut in this project.

Paraffin alone gave nearly as good repellence as paraffin and paradichlorobenzene and without injury to the wood.

Possibilities of developing an efficient repellent seem good. Most promising are carbolineum preparations, paraffin and a naphthalene-flour-soap preparation.

Materials tried as fumigants to kill the borer in the larval stage were ineffective.

Protecting the trees with a paper wrap materially reduced the number of trees killed by borers.

When wraps are applied to the trunk, the beetles tend to center their attack on the limbs above the wrap.

Paper wraps tend to rot away near the ground and need attention at this point, especially when the trees are watered frequently.

BIBLIOGRAPHY

(1) Bissell, T. L. Entomology Rept. Ga. Exp. Sta., 47 (1934-35).

(2) Fletcher, James. 26th Rept. Ent. Soc. Ont. (1895).

(3) Flint, W. P. Report of Entomologist. 49th Ann. Rept. of Ill. Agr. Exp. Sta. (1937) 143-71.

(4) Gilbertson, G. I. The Plum Tree Borer. S. Dak. Agr. Exp. Sta. Bul. 288 (June 1934) 22 pages.

(5) Guyton, T. L. and J. N. Knull. The Round-headed Apple Tree Borer. Penn. Dept. Agr. Gen. Bul. 386 (April, 1924) 6 pages.

(6) Hopkins, A. D. Rept. of Entomologist. W. Va. Sta. 3rd Ann. Rept. (1890), 145-80.

(7) Houser, J. S. Borer Control Experiments. Proc. of the Ann. Meet. Thirteenth Nat. Shade Tree Conference (Sept. 1937) 159-67.

(8) Lovett, A. L. Tree Borers and Their Control. Ore. Agr. Exp. Sta. Cir. 39 (1923) 7 pages.

(9) Matheson, R. The Poplar and Willow Borer. Cornell Agr. Exp. Sta. Bul. 288 (April, 1917) 30 pages.

(10) Maxwell, J. M. Studies on Chrysobothris femorata Fab. in Oklahoma. Master's Thesis, Okla. A. & M. Col. 1937.

(11) McDaniel, E. I. Some Wood Borers Attacking the Trunk and Limbs of Deciduous Trees and Shrubs. Mich. Spec. Bul. 238 (1933) 37 pages.

(12) Mote, D. C. Tree Borers and Their Control. Ore. Exp. Sta. Cir. 110 (1935) 6 pages.

(13) Pettit, R. H. A Repellent for Flat-headed Borers. Mich. Agr. Col. Quar. Bul. 5(1923) 170-71.

(14) Snapp, O. I. and J. R. Tomson, Jr. Experiments with New Materials to Control Peach Borer. Jour. Ec. Ent. 29 (1936) 1088-92.

Typist--Verna Wiley Yeats
(Mrs. Parks Yeats)