BIOLOGY AND FEEDING HABITS OF THE SMALLER EUROPEAN ELM BARK BEETLE, *SCOLYTUS MULTISTRIATUS* (MARSHAM), ON AMERICAN ELM, *ULMUS AMERICANA* LINNAEUS, TREES INJECTED WITH BIDRIN IN OKLAHOMA

By

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PREFACE

At the time of these studies very little research work had been done on the biology and feeding habits of the smaller European elm bark beetle in Oklahoma. Researchers in several states recommended the use of Bidrin as a systemic insecticide in reducing the spread of the disease by curtailing the feeding depth of the beetle thus preventing fungus inoculation. Substantial thought and research to the contrary has pointed out the weaknesses of using Bidrin alone in a control program.

Attempting to establish our own opinion for or against the use of Bidrin as the solution to halting the spread of the Dutch elm disease became the primary objective of this research. Biology studies were run concurrently and in conjunction with the tree injection and feeding program.

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INTRODUCTION

The smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.), was first discovered in this country in Massachusetts by Chapman (1909) and is well-known as the major vector of the Dutch elm disease, *Ceratocystis ulmi* (Buisman) Moreau. Exhaustive studies of this insect have been made in other states since the first diagnosis of the disease in the Cleveland, Ohio area by Irish (1930) and May (1930). Since its initial detection in central Oklahoma (Coppock 1955), the smaller European elm bark beetle has become distributed quite thoroughly over the eastern two-thirds of the state. Its exact distribution in Oklahoma is not known at this writing.

Adults of the smaller European elm bark beetle feed on living elm trees throughout the entire growing season of the elm (Russell and Swingle 1964). The injuries produced by *S. multistriatus* in the crotches of elm twigs are usually made as short holes or burrows. The beetles generally bore into the center of the crotch or slightly to one side (Wolfenbarger and Buchanan 1939). Collins (1938) found extreme variation in the range and extent of feeding by *S. multistriatus*. American elm (*Ulmus americana*) trees which had suitable brood wood in or around them were more subject to feeding attacks by possibly contaminated beetles.

No attempts at control of elm bark beetles by systemic chemicals had been reported prior to 1958 (Al-Azawi and Casida 1958). In August 1958, Bidrin was implanted into slippery elm (*U. rubra*) trees by placing the dosage in 0.5 inch drilled holes on the main trunk (Norris 1960). This technique was further advanced by the development of J. J. Mauget injecting tools and prefilled sealed plastic capsules containing various amounts of technical grade Bidrin (Shell Chemical Company 1964). Conflicting reports as to the effectiveness of Bidrin (Hansel 1966) in preventing elm bark beetle feeding and lack of knowledge about the pest in Oklahoma brought about these studies.

The objectives of this research were to study the smaller European elm bark beetle on American elms to determine:

1. the depth of feeding in treated and untreated American elms.
2. if Bidrin is repellent.
3. the length of time for the beetle to feed into the cambium layer.
4. the time and number of generations per year in Oklahoma.
5. the variation of gallery length by generation.
6. the density of each generation.
7. the problems associated with injecting Bidrin into trees.
8. to determine the sex ratio for each generation of S. multistriatus.

The primary concern of this study was to evaluate the effectiveness of Bidrin as a systemic insecticide in preventing the smaller European elm bark beetle from feeding to the cambium layer of the tree, thus inoculating the tree with C. ulmi. Other research, although considered important facets of the over-all problem, were secondary to the initial objective.

METHODS AND MATERIALS

During 1967 studies were conducted on American elm (U. americana) trees situated along a north-south fence row, 6 miles east and 1 mile south of Stillwater, Oklahoma. The tree injector, plastic capsules, and hollow aluminum tubes used in the treatment of the elms were developed by the J. J. Mauget Company of California. The capsules were left on the trees from 30 to 45 minutes to allow for complete removal of the insecticide. Records were kept on the performance of the capsules during the injection process. A total of 18 trees were treated with Bidrin and an additional 10 trees served as controls. Tree injection began in May and continued throughout August (Table I). As Table I indicates, the American elm trees used in the tests were heavily injected with the systemic insecticide throughout the study period. The smaller European elm bark beetles were reared from infested American elm logs. Trap wood was made available by cutting 3 to 5 inch DBH (diameter breast height) untreated elm trees into 3 ft. sections. These logs were placed upright in the ground in locations where beetle-infested trees were noted. Cages made from nylon tulle nets, 124 gauge, 12 by 18 inches, were placed over the trap logs caging the beetles as they emerged. Identical cages were placed over second year growth elm branches for feeding studies. The trap wood offered a steady supply of beetles for research purposes. A battery-powered hand vacuum aspirator similar to one devised by Fox (1958) was used to collect the beetles from the cage. Data on gallery length and density numbers per generation were taken from the trap logs at the end of each complete emergence. Smaller European elm bark beetles which were not used in the feeding studies were collected and checked later for sex ratio.

TABLE I

INJECTION DATA ON AMERICAN ELM TREES TREATED WITH BIDRIN DURING 1967

Tree No.	Width	Date of Injection and Amount (ml)	ml Tree
1	14"	5-11(18)6-11(18)7-19(21)8-19(21)	78
2	5"	5-11(9)6-11(15)7-19(15)8-19(6)	39
3	8"	5-11(15)6-11(25)7-19(15)8-19(8)	63
4	14"	5-11(21)6-11(12)7-19(21)8-19(10)	64
5	8"	5-11(15)6-11(10)6-26(21)	46
6	7"	7-19(15)8-19(8)	23
7	5"	6-11(12)7-19(12)8-19(6)	30
8	8"	6-11(8)7-7(18)7-13(5)	31
9	10"	6-11(10)7-7(15)7-13(8)8-13(10)	43
10	4"	6-11(3)7-13(3)8-13(30)	12
11	8"	6-11(8)7-13(5)8-13(30)	43
12	7"	6-11(8)7-13(18)8-13(8)	34
13	9"	6-11(12)7-13(21)8-13(8)	41
14	12"	6-11(10)7-13(18)8-13(10)	38
15	6"	6-11(3)7-13(12)8-13(6)	21
16	4"	6-11(3)7-13(12)8-13(6)	21
17	7"	6-11(8)7-13(12)8-13(6)	26
18	5"	6-11(4)7-13(12)8-13(6)	22

RESULTS

Feeding Depth in Treated and Untreated American Elm Trees

Commencing May 18, 1967 and continuing at weekly intervals throughout August, newly emerged *S. multistriatus* beetles were enclosed in tulle net cages placed randomly on terminal branches of treated and untreated American elm trees. The cages enclosed approximately a 3 ft. section of the branch. The elm bark beetles were caged on the trees for a 24-hour period after which feeding data were recorded. A total of 353 beetles fed on treated twigs and 376 fed on untreated twigs. The average feeding depth from 50 separate cagings, 10 beetles per cage, was 1.87 mm on treated twigs and 1.91 mm on untreated trees. The most frequent depth recorded was 2.0 mm (Figure 1). The average depth to the cambium layer was found to be .5 mm.

Repellent Action of Trees Injected with Bidrin to *S. multistriatus*

Tests were initiated June 15, 1967 with the heavy emergence of the first generation of the beetles. Trees used in these experiments were located so that the branches of test and check trees could be placed in the same feeding cage. A total of 20 separate cagings, 20 beetles per cage, were made in the 3-week period ending July 6, 1967. These beetles had a choice of feeding on treated or untreated twigs. A total of 183 feeding niches were recorded, 90 on the treated and 93 on the untreated twigs.

Rate of Feeding of S. multistriatus to the Cambium Region

Tests were run on untreated American elm trees in May and June 1967. Adult beetles were obtained by confining infested logs in tulle net cages. As the beetles emerged they were collected easily from the cages by a hand vacuum aspirator. Feeding to the depth of .5 mm or greater would indicate the possible inoculation of the tree if the C. ulmi spores were present on the vector. After placing the beetles on second year elm branches, the depth of feeding in the twig was measured at 15-minute intervals for the 3-hour test period (Figure 2). Data indicated that the cambium layer was reached by all S. multistriatus after 30 minutes of feeding.

Emergence Patterns in Oklahoma During 1967

The first reported emergence of the overwintering beetles occurred in mid-April (Arnold 1966). This emergence was similar to Thompson's findings in Kansas in 1958.

To determine the time of emergence in early March, infested American elm trees 3 to 5 inches in diameter were sawed into three foot lengths and placed upright in holes 6 inches deep in a field which offered partial shade. Tulle net cages were placed over the infested logs. Emerging beetles were removed from the cages, counted, and stored for other possible use.

The per cent daily emergence by each generation in Oklahoma in 1967 is shown in Figure 3. To help insure getting data on the succeeding generations, healthy American elm trees were sawed down and their logs placed in wooded locations and the resulting infestation and beetle emergence recorded. Griswold (1948) pointed out the effectiveness of using host wood which was neither freshly cut nor wood with very dry bark for successful reproduction. All emergence data other than the overwintering generation were obtained in this manner.

Main Gallery Length by Generation of *S. multistriatus*

As in Fox's studies (1958), we wanted to see what variation in gallery length per generation occurred in Oklahoma with the changing weather conditions. With the completion of each generations emergence, the bark from trap logs was removed and the galleries measured. To obtain a reliable sample, only the galleries within a 4-inch area around the circumference of the logs were recorded. The lengths of 50 galleries were obtained for each generation. The average lengths per generation were recorded as follows: overwintering generation 20.9 mm, first generation 36.8 mm, and the second generation 22.5 mm.

Density Determination by Generation of Smaller European Elm Bark Beetle

After all *S. multistriatus* emergence had taken place, their exit holes were counted on each of six trap logs. Knowing the diameters of these logs facilitated computation of the number of adult beetles per square foot of the bark surface. The average number of adult beetle exit holes per square foot of bark by generations was as follows: overwintering generation, 384; first generation, 496; and second generation, 341. According to Collins (1935), Wadley found the most favorable wood in outdoor rearing cages yielded about 400 beetles per square foot.

Problems Associated with Injecting Bidrin into American Elm Trees

Throughout the research program a record was kept on the number of injected sites which did not absorb the full amount of Bidrin present in the capsules. A total of 427 capsules containing either 1 ml, 2 ml, or 3 ml of insecticide were placed on American elm trees during 1967. Of this number, 71 capsules or 16.3 per cent leaked Bidrin out the side of the capsule along the tube or it ran out around the inject hole on the tree. All capsules were left on the tree from 30 to 45 minutes to allow adequate time for the insecticide to drain out. Upon removal from the elms, 80 capsules or 18.7 per cent caused the Bidrin to be expelled towards the applicator. Where Bidrin drained onto the bark, later signs of decay were observed.

The Determination of Seasonal Sex Ratios

These studies were conducted to determine whether sex ratios of adults of the smaller European elm bark beetle varied significantly during each generation emergence period. Inasmuch as field evidence has shown this to be a monogamic species (Fox 1958), the ratio of females to males should be approximately equal. Prior to this study, such information was not available for Oklahoma populations, but if a variation were present, it should be considered an important factor in the reproductive potential of the insect at different times of the season or for different broods. Table II shows the sex ratio for each generation in Oklahoma during 1967.

TABLE II

SEX RATIO OF *S. MULTISTRIATUS* BY GENERATIONS IN OKLAHOMA

Generation	No. Males	No. Females	Total	♀/♂ Sex Ratio
Overwintering	363	483	846	.5709
First	432	436	868	.5023
Second	397	374	771	.4850

DISCUSSION

Based on data taken in the field, Bidrin could not be considered effective either as a systemic insecticide or as a repellent in preventing *S. multistriatus* beetles from feeding to the cambium layer of elm branches. Most of the beetles fed into the cambium region and indicated no preference for the untreated or the treated twigs. Important consideration must be given to the fact that the treated trees were subjected to heavier than recommended dosages of the systemic insecticide. Cages containing beetles were attached to different branches on the same tree with the most common feeding depth being 2 mm. The chance of *C. ulmi* inoculation at this depth would be considered great.

As no materials were available to measure Bidrin accumulation in the foliage, one could not assume that uniform translocation of the chemical was obtained throughout the crown of the tree. On June 17, 1967 marginal leaf burn appeared on the terminals of the lower branches of two treated trees. As the summer progressed, evidence of foliar burning became more apparent in the lower branches first, then scattered throughout the tree crown. Lush, green foliage could be seen beside wilted, yellow, black-brown leaves on another branch. Before the end of August, partial defoliation had occurred in some treated trees. Obtaining uniform translocation of the insecticide throughout the tree crown will probably continue as a limiting factor in systemic control of the beetle.

Treating *U. americana* trees three and four times during the study period may have had a girdling effect on the elms. Thompson (1966) indicated that this was also a problem in his research and had not been entirely eliminated by using hollow tubes. Bark discoloration, splitting, and bleeding could be seen around most injected sites during the research program.

In the study of the length of time for individual beetles to feed to the cambium area as described above, the niche depths appeared greater than in the feeding times for 24 hours. This was due to the fact that the elm bark beetles placed on the trees for a 24-hour period were not observed individually as they fed on the twigs. Often on both treated and untreated trees, the beetles would cling to the cage as though unaware of the host wood.

Other possible factors which may have influenced the feeding habits of S. multistriatus should be mentioned. The number of beetles per cage may have had a psychological and crowding effect, reducing the number and length of the feeding niches. Other factors including the length of time between emergence and testing of the beetles, their handling, and temperature, moisture and humidity conditions at the time of use, may have affected feeding results.

There were three complete generations and a partial fourth emergence in Oklahoma during 1967. The light emergence occurring in mid-October was thought to be part of that generation which normally overwinters. Its presence can be attributed to the mild temperatures during September and October. Beetle activity came to a halt with cold temperatures returning October 25, 1967. The extended emergence periods of the first, second, and third generations may be partially attributed to prolonged oviposition of individual females and differential rates of larval development. Temperature and moisture conditions helped to lengthen the third generation in August and September.

The longer gallery lengths and higher egg numbers of the first generation in June and July correspond to the higher number of adults emerging from this same generation. Larval galleries extend off the main gallery at an average spacing of 0.5 mm. In favorable brood wood the distance between main galleries will range from 15 mm to 25 mm. A tremendous adult emergence potential exists, but is seldom reached due to natural mortality factors.

The systemic insecticide Bidrin was implanted into the cambium layer of American elm trees in Oklahoma during 1967 to determine what effect this chemical would have in preventing or reducing feeding by the smaller European elm bark beetle. The elm bark beetles must feed into the cambium region of the twig to inoculate the tree with the Dutch elm disease fungus. Biology studies of the bark beetles were conducted simultaneously with the tree injection and feeding tests.

The feeding of the smaller European elm bark beetles on the terminal branches of American elm trees that were injected with Bidrin was not significantly different as compared with that on untreated trees. Evidence of nonuniform translocation of the chemical throughout the tree crown, the girdling effect of Bidrin on the tree at the injection site, and the scattered phytotoxicity to the foliage, all were considered negative aspects of this control method. Three complete generations and a partial fourth emergence of the beetles occurred in Oklahoma during 1967.

LITERATURE CITED

Al-Azawi, A. F. and J. E. Casida. 1958. The efficiency of systemic insecticides in the control of the smaller European elm bark beetle. J. Econ. Entomol. 51(6): 789-790.

Arnold, D. C. 1966. Oklahoma Cooperative Economic Insect Survey and Detection Report. April 16, 1966.

Chapman, J. W. 1910. The introduction of the European scolytid, the smaller European elm bark beetle, Scolytus multistriatus (Marsh.) in Massachusetts. Psyche 17: 63-68.

Collins, C. W. et al. 1935. Bark beetles and other possible insect vectors of the Dutch elm disease Ceratostomella Ulmi (Schwarz) Buisman. J. Econ. Entomol. 29(1): 169-177.

Collins, D. L. 1938. Feeding habits of Scolytus multistriatus Marsham with reference to the Dutch elm disease. J. Econ. Entomol. 31(2): 196-200.

Coppock, S. 1955. Oklahoma Cooperative Economic Insect Survey and Detection Report. Annual Summary.

Fox, R. C. 1958. Bionomics of the smaller European elm bark beetle, Scolytus multistriatus (Marsham) in Michigan. Ph.D. Thesis. Michigan State University. 63 pp.

Griswold, C. L. 1948. Bulk rearing of Scolytus multistriatus (Marsh.) and Hylurgopinus rufipes (Eich.). U. S. Dept. Agr. Bur. Entomol. and Plant Quarantine. ET-252.

Hansel, John P., Ed. 1966. Bidrin: Pro and Con. Elm Bulletin 2: No. 1, 1-3. Elms Unlimited Incorporated, 60 West Prospect St., Waldwick, N.J.

Irish, C. F. 1930. Our elms are endangered by the European elm disease. (Poster) Chas. F. Irish Co. of Ohio. 1 p.

May, C. 1930. Dutch elm disease in Ohio. Science 72: 142-143.

Norris, D. M. 1960. Systemic insecticidal action in the cortical tissues of elm twigs. J. Econ. Entomol. 53(6): 1034-1036.

Thompson, H. E., S. M. Pady, R. A. Keen. 1961. Dutch elm disease and its control in Kansas. Kan. Agr. Exp. Sta. Bull. No. 434. 11 pp.

Thompson, H. E. 1966. Dutch elm disease control. Elm Bull. 2(1): 11-14.

Shell Chemical Company. 1964. Instructional Manual: Implantation of Bidrin insecticide into elm trees. Agr. Chem. Div., 110 W. 51 St., New York 20, New York.

Wadley, F. M. 1936. Bark Beetles and other possible insect vectors of the Dutch elm disease Ceratosomella Ulmi (Schwarz) Buisman. J. Econ. Entomol. 29(1): 171.

Whitten, Russell R. and Roger U. Swingle. 1964. The Dutch elm disease and its control. U. S. Dep. Agr. Information Bull. No. 193. 12 pp.

Wolfenbarger, D. O. and W. D. Buchanan. 1939. Notes on elm twig crotch injuries produced by Scolytus multistriatus (Marsham). J. Econ. Entomol. 32(3): 377-381.

APPENDIX

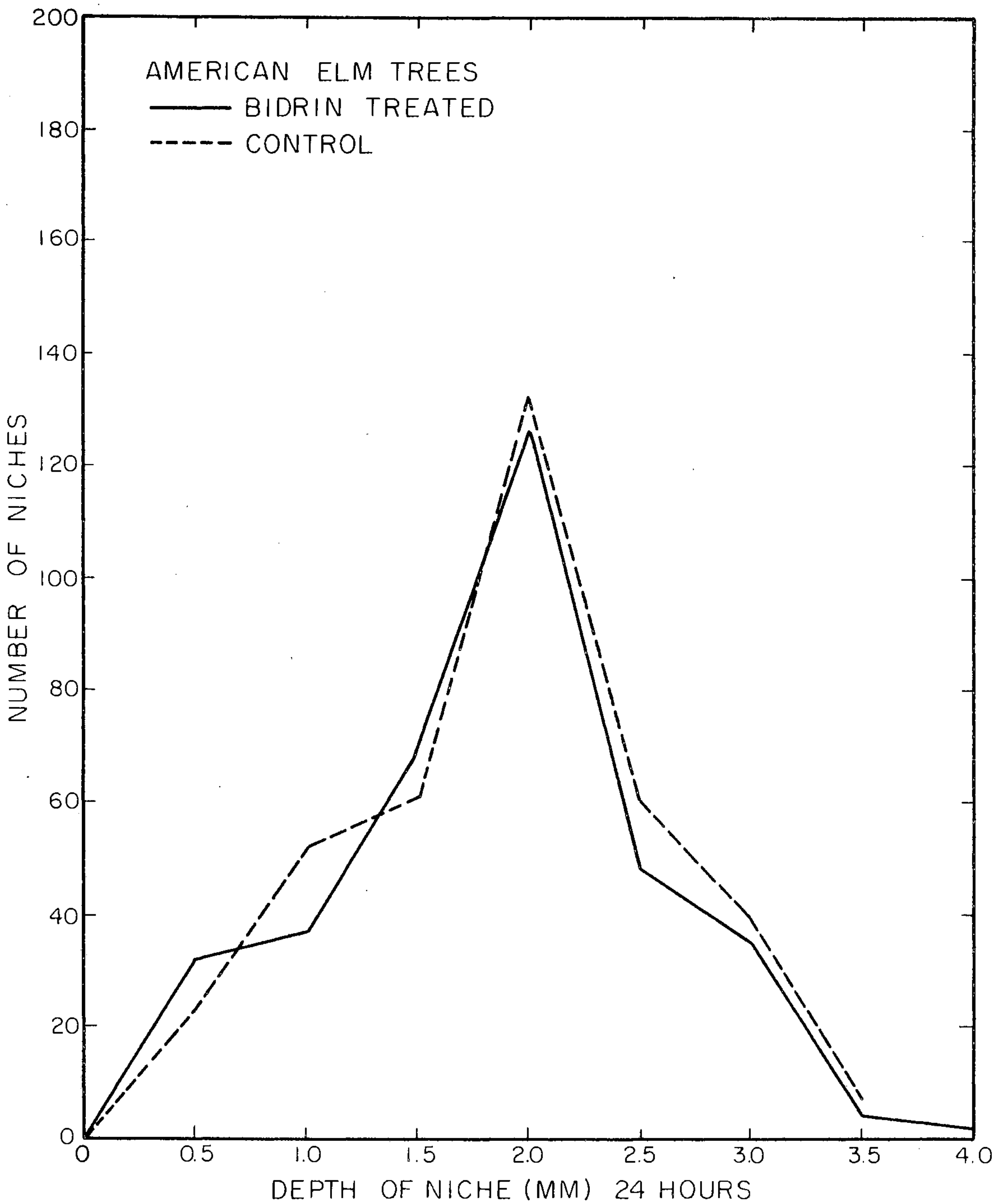

Figure 1. Depth of Beetle Feeding Niches in Bidrin Treated and Control Trees.

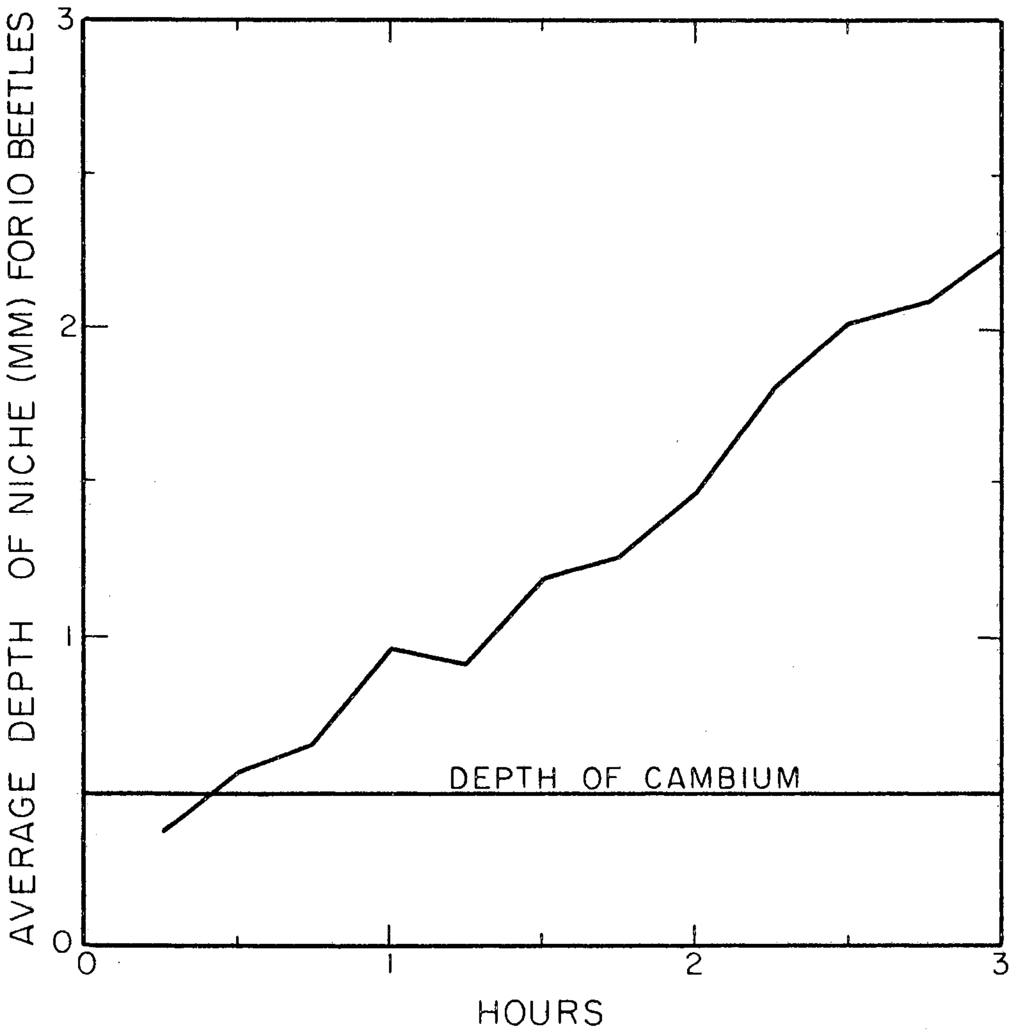

Figure 2. Time for S. multistriatus Adults to Feed to Various Depths in Twigs of Untreated American Elm Trees.

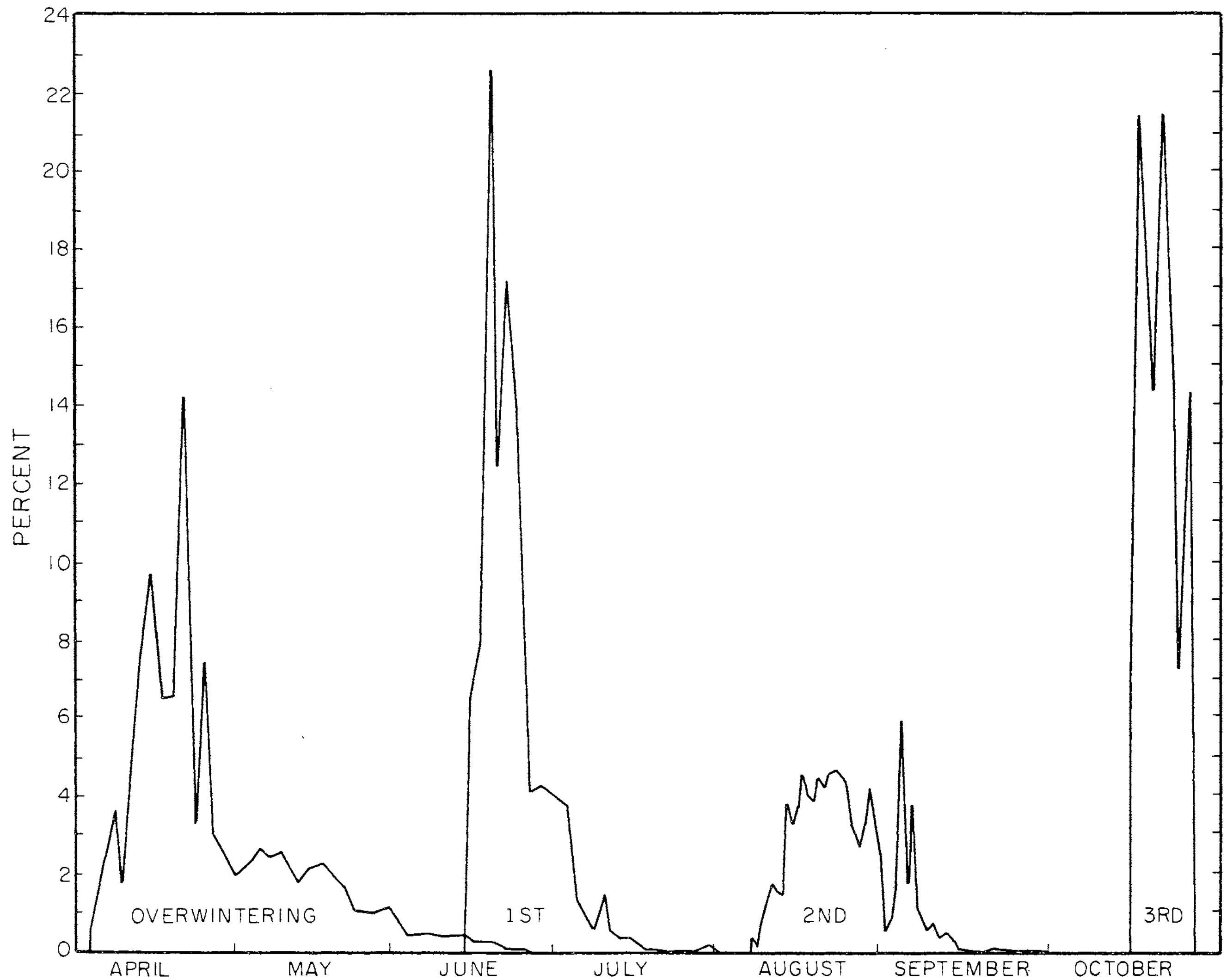

Figure 3. Per Cent Emergence of S. multistriatus Adults by Generations During 1967.

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