THE DISTRIBUTION AND MAGNITUDE OF INJURY BY THE CLOVER ROOT BORER, HYLASTINUS OBSCURUS MARSHAM, AND CLOVER ROOT CURCULIO, SITONA SPP., TO RED AND MAMMOTH CLOVER IN THE LOWER PENINSULA OF MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

Harry Donald Niemczyk

1958

THE DISTRIBUTION AND MAGNITUDE OF INJURY BY THE CLOVER ROOT BORER, *Hylastinus obscurus* MARSHAM, AND CLOVER ROOT CURCULIO, *Sitona* spp., TO RED AND MAMMOTH CLOVER IN THE LOWER PENINSULA OF MICHIGAN

by

HARRY DONALD NIEMCZYK

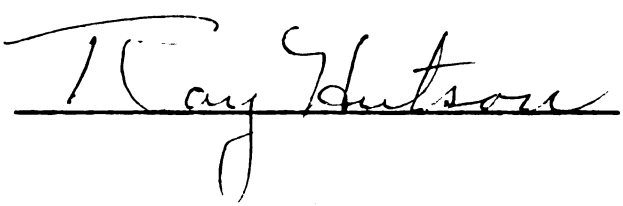
AN ABSTRACT

Submitted to the College of Science and Arts
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Entomology

Year 1958

Approved 

ABSTRACT

During August and September of 1957 a survey was made for the purpose of determining the distribution and magnitude of the clover root borer (Hylastinus obscurus Marsham) infestation in red and mammoth clover in Michigan, and at the same time gather similar information on the occurrence of clover root curculio (Sitona spp.) larval feeding injury to these plants. A total of 1,593 roots were dug from 8 counties in the northern half, and 38 counties in the southern half of the Lower Peninsula. Eighty of these roots were from fields at least in their first crop year. An average of 3.4 samples consisting of 10 randomly selected roots was collected from each county surveyed.

The results from examination of the roots collected are outlined as follows:

1. The 1,513 roots collected from fields at least in their first crop year showed 33.3 percent were infested with an average of 4.8 root borers per root.

2. Root borer infestations ranged from zero to 100 percent and varied considerably from one county to the next. The northernmost counties showed a zero percent infestation.

3. Examination of the 80 roots dug from fields less than one year old showed that none were infested with the clover root borer.

4. Of the roots dug from fields at least in their first crop year, 1,405 were examined for Sitona spp. larval feeding injury. The results showed that 57.8 percent had light damage, 27.7 had moderate damage, and 14.5 percent had heavy damage.

5. Examination of the 80 roots from fields less than one year old showed that 77.7 percent had no Sitona spp. injury, and 12.5, 7.5, and 2.5 were respectively light, moderate and heavily injured.

THE DISTRIBUTION AND MAGNITUDE OF INJURY BY THE CLOVER ROOT BORER, *Hylastinus obscurus* MARSHAM, AND CLOVER ROOT CURCULIO *Sitona* spp., TO RED AND MAMMOTH CLOVER IN THE LOWER PENINSULA OF MICHIGAN

by

HARRY DONALD NIEMCZYK

A THESIS

Submitted to the College of Science and Arts
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Entomology

1958

ACKNOWLEDGEMENTS

My grateful acknowledgement is extended to Professor Ray Hutson, head of the Entomology Department, for making this study possible.

To Dr. Gordon Guyer, under whose direction this study was made, goes my sincere thanks and appreciation for his constant encouragement and enthusiastic interest.

I wish to extend my appreciation to Doctors Herman King and Richard Kiesling for their critical reading of the manuscript, and graduate students Jagat P. Singh, Hari Charan Agarwal, Arthur Wells, and Jack Eichmeier for their able assistance on the survey trips.

My sincere appreciation and gratitude is extended to my wife Dolores for typing the manuscript and for her patience and understanding throughout my years of study. This manuscript is herewith dedicated to her.

Deo Gratias.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Each year many acres of red clover, Trifolium partense Linnaeus, and mammoth clover, Trifolium pratense var. perenne Host, are planted in Michigan. These crops serve as forage for domestic animals and are an important source of income to the farmer when the seed is harvested and sold. Michigan has maintained an average rank of fourth among the red clover seed producing states in this country. In 1956, 115,000 acres of red clover were harvested for seed. This crop was valued at over two million dollars.

The clover root borer, Hylastinus obscurus Marsham, has been a menace to red and mammoth clovers in Michigan for over half a century. This insect has been blamed for causing reductions in seed and forage yields by its burrowing within the clover root. Upon its discovery in this state, the root borer attracted a great deal of attention because it threatened the clover crop. Since then, however, little attention has been given to this pest.

The control of the clover root borer is complicated by the fact that the insect spends all but a few hours of its life protected in the roots of the clover plant. Early efforts to control this pest were largely repressive in nature. Recommendations were made to plow under badly infested fields immediately after the first harvest.

Experiments conducted during the past 15 years on insecticidal control of this pest have indicated that control by this means is quite successful.

There are two insects commonly referred to as the clover root curculios, Sitona hispidula Fabricius, and Sitona flavescens Marsham. These two insects are not considered serious pests on red and mammoth clover, and their net effect upon the clover plant is uncertain. However, the feeding scars left by the larvae do expose the root to many pathogenic organisms, which alone or in combination with poor growing conditions, can contribute to the mortality of the clover plant.

The purpose of this survey was to determine the distribution and magnitude of the clover root borer infestation as it occurs on red and mammoth clovers throughout the southern half and ten northern counties in the Lower Peninsula of Michigan and to gather similar distributional data on the occurrence of feeding injury to these plants caused by the larvae of the clover root curculio.

LITERATURE REVIEW, CLOVER ROOT BORER

Distribution

Foreign. The clover root borer, Hylastinus obscurus Marsham, has been known in Europe for at least a century and a half. Information relative to the distribution of the insect in that part of the world was best summarized by Rockwood (1926). He stated, "According to information compiled from various sources, the clover root borer is now found in Russia (Kief); Germany; Austria; France; Czechoslovakia; England; Canary Islands; Denmark, and Italy (Tuscany)." He further reported that the insect occurred in Canada (southern Quebec and Ontario).

National. Most American authors agree that the clover root borer was introduced into this country from Europe. The means by which this was accomplished is not known. The root borer was first reported as occurring in the United States by Riley (1879), who indicated that it was causing damage to red clover in Branchport, New York, in 1878. Rockwood (1926) indicated that in all probability the root borer was present for many years prior to its first discovery. Henry (1880) stated that the root borer had taken over all the clover fields in

portions of Genessee county, New York. In 1888, extensive damage to clover in Ontario, Canada, was mentioned by Folsom (1909). By 1890, Webster (1896) found serious infestations in the northwest part of Ohio. Davis (1894) considered the clover root borer as one of the most serious insect pests in Michigan at the time of his writing. In 1909, Folsom stated that the root borer had reached Indiana, Illinois, Pennsylvania, West Virginia, North Carolina, and also Oregon. Using information compiled from unpublished records taken from the files of the Bureau of Entomology, Rockwood (1926) found the root borer to be present in Murry, Utah, in 1911, and also in western Maryland in 1915 and 1916.

In the review of the literature from 1927 to 1950 the author found no reference to infestations in states which previously had not reported the root borer's presence. With this in mind the author surveyed the Cooperative Economic Insect Report (1952-1957), published by the United States Department of Agriculture, in an effort to obtain a more current distributional picture. According to information compiled, the root borer has been reported as a pest on clover in the following states: Michigan, Illinois, Indiana, Ohio, Pennsylvania, Virgina, West Virginia, New York, Washington, Oregon, and Idaho.

Michigan. According to Davis (1894), the earliest record of the root borer in Michigan was 1889, in the southern part of Monroe county. Webster (1899) ascribed the insect's entry into this state to a continuation of the Ohio invasion, but Davis (1894) indicated that "in all probability specimens were brought across Lake Erie by wind, from farther east, and lodged on the lake shore." Davis further stated that in 1890 specimens were found near Lansing and that by 1894 the root borer was present throughout the southern two-thirds of the Lower Peninsula, except for four counties in the extreme southwest corner of the state. No mention was made of how this distribution was ascertained.

Until completion of the present survey by the author, there has been no further information gathered on the distribution of the root borer in this state.

Plants Attacked

As early as 1807, various German workers came to the conclusion that the root borer's natural food was common red clover, Trifolium pratense Linnaeus. Most authors agreed that mammoth clover, Trifolium pratense var. perenne Host, is an equally susceptible host plant. Davis (1894) indicated that mammoth clover suffered most from the root borer.

Schmitt (1844) disagreed with other German authors of his time in stating that the root borer occurred on alfalfa, Medicago sativa Linnaeus. Folsom (1909) stated that in Illinois the root borer fed on alfalfa, "but not enough to have done any damage up to the present time." From observations made in Ontario, Canada, Gibson (1913) stated, "In some fields of alfalfa this borer was working freely, causing noticable loss." Rockwood (1926) recorded some instances of damage to alfalfa by the root borer, but stated, that "It seems improbable that the clover root borer will become a serious pest of alfalfa, as the rapidly growing, tough roots of alfalfa do not appear well adapted to the successful propagation of the species."

In Abergavenny, England, Chapman (1869) noted the root borer attacking furze, Ulex europaeus Linnaeus, and Scotch broom, Cytisus scoparius Linnaeus.

Rockwood (1926) mentioned two examples brought to his attention of damage to garden peas by the clover root borer.

In 1940 Lincoln (1941) conducted studies on host resistance to the clover root borer and found that alsike clover, Trifolium hybridum Linnaeus, was only lightly infested, and ladino, Trifolium repens Linnaeus, not at all. Rockwood (1926) pointed out that alsike clover might be severely injured in sections where recent changes from red to alsike clover had been made.

Damage

The literature on the damage done to red clover by the clover root borer contains some disagreement. Schmitt (1844), while agreeing with other early German workers that Trifolium pratense Linnaeus was the primary food of the borer, disagreed with their theory that the insect was the principal cause of the death of red clover in its third year. He said that the cause of death was due to the agricultural practice of cutting clover for seed late in the fall, which weakened the plant and exposed it to frost and disease.

In reporting the first occurrence of the root borer in the United States, Riley (1879) stated that, "in Seneca, Ontario, and Yates counties in New York, the insect was prevalent enough to prevent the cutting of clover, the roots being entirely devoured and the plants pulling out with the greatest of ease and gathering in windrows before the mower." White (1888) reported that in Edmonton, Ontario, the borer was doing incalculable damage to clover fields. Similar reports were made by Davis (1894) and Webster (1899).

Folsom (1909) presented perhaps the best description of the injury inflicted by the root borer. He stated, "An affected plant finally wilts and dies; when pulled by hand it breaks off at the surface of the ground. The roots of such a plant are burrowed out longitudinally. The amount

and rapidity of injury depends not only upon the number of insects present but also upon the amount of moisture received by the plant. Injured plants are liable to die late in June or early July." There is general agreement in the literature that clover in its first growth year with roots being small in the spring, is not subject to attack. Rockwood (1926) noted one unusual instance where clover of less than one year's growth was noticeably damaged.

The publications written by Hunter (1909) and Folsom (1909), refer to the lowering of seed yields due to the ravages of the root borer. Practically all of these are observational in nature, showing little or no experimental evidence for such claims.

Pieters and Hollowell (1924) stated that insects rarely caused clover failure; the only insect known to be serious was the clover root borer. They further stated that, with but rare exceptions it damaged clover only in the late summer of its second year. Hudson (1925) stated, "The root borer is not regarded as an important pest because it attacks plants in the second year of growth, and clover, being a biennial, is usually ploughed under after the second season." Mills (1941) pointed out that intense injury to clover was not common and further stated that the insect "does not usually injure stands which are one or two years old, doing the most of its damage to older fields."

Pieters and Hollowell (1937) believed that one of the principal causes of the dying out of red clover during the second winter was the injury produced by the clover root borer.

Newsom (1948) summarized his findings on damage to red clover by the root borer as follows: "The amount of injury produced may be measured quantitatively by reduction in number of leaves produced, reduction in carbohydrate root reserve, and differences in shoot-root ratio between infested and uninfested plants. Infestation by the root borer reduced the number of leaves produced 23 percent, total sugars as much as 60 percent in heavily infested plants, and the shoot-root ratio about 30 percent." He further indicated that the borer might cause outright death of 10 percent of plants in their first crop year and might be responsible for about 40 percent of the remaining plants entering the winter low in carbohydrate reserves.

Elliott (1952) conducted an extensive study of the diseases, insects, and other factors in relation to clover failure in West Virginia. He found that a species of Fusarium which caused root rot was generally associated with injury by the root borer. Studies made at Pensylvania State College (Anonymous 1948) indicated that unless the clover root was injured, the fungus could not enter. During July and August Fusarium spp. were found to have entered the plant following initial injury by the root borer.

Life History and Seasonal Activities

Overwintering. In the review of literature on the life history of the clover root borer, the author found general agreement that there is but one generation per year and that the adult beetles represent the primary overwintering stage. Riley (1879) and Webster (1899) pointed out that the insect might overwinter in all three stages. The latter author reported larvae present in clover roots at Wooster, Ohio, on January 14, 1899. Similar observations were made by Davis (1894), Rockwood (1926), and Lincoln (1941). Upon examination of second crop year fields at Ithaca, New York, on April 13, 1947, Newsom (1948) found that larvae comprised about 20 percent, pupae less than 1 percent, and adults about 80 percent of the total population.

Rockwood (1926) stated, "Adults which for any reason have become separated from the clover roots, may pass the winter in the soil or, rarely, under trash on the surface of the ground."

Activity before dispersal flight. The literature contains comparatively little detailed information on the seasonal activity of the clover root borer. One of the earliest and most extensive American investigations concerning the bionomics of this insect was conducted by

Rockwood (1926), at Forest Grove, Oregon. It was found that resumption of feeding by the adults and overwintered larvae took place when the soil reached a temperature of about 45 degrees Fahrenheit. During March and April, the adults worked their way to the crown of the plant where they fed on the root tissues. Feeding activity increased as the soil temperature reached 50 degrees Fahrenheit and, when the air temperature at ground level was between 55 and 60 degrees Farhenheit, the borers left the roots and walked about. This form of activity took place in March or early April and rarely during warm days in February. Rockwood stated that "in case of a cool, backward spring, this movement of the beetles on foot is the only method of migration to new host plants until late in the season." In studies of clover fields coming into their second crop year, Newsom (1948) found that the number of infested plants had increased 32 percent prior to spring flight. This increase was shown to have been due to movement of the beetles on foot to these plants.

Rockwood (1926) stated that "in clover fields plowed during the preceding summer and fall, soil conditions and the disturbed, abnormal state of residues of the clover root borer's host plant induce premature activity of the adult borers, which attempt migration in response to the stimulus of the first warm days of late March." This fact was evidenced by root borers being swept from winter wheat

seeded on clover sod, three weeks prior to spring flight.

Based on the predominance of fertilized females in the first flights, Rockwood (1926) indicated that a general mating occurred previous to the first spring flights, and that mating probably occurred in the roots, on the clover crown, and on the ground. Schmitt (1844) observed the beetles in copula on the clover plant during April and May at Mainz, Germany.

Dispersal flight. According to flight studies made by Rockwood (1926) and Newsom (1948), dispersal of adults by flight may take place when the air temperature is about 65 degrees Fahrenheit. Their findings showed that little flight occurred until the air temperature reached 70 degrees Fahrenheit; however, the latter author observed that once flight had begun the beetles might fly at lower temperatures. Both workers agreed that the time of first spring flight was governed primarily by soil temperature and consequently would vary from year to year. At Ithaca, New York, Newsom (1948) observed first flight in late April of 1942; however, in 1947 flight did not begin until the latter part of May, because of an unusually cool and late spring.

First flights have been recorded by Rockwood (1926) at Forest Grove, Oregon, on April 7, 1916. Davis (1894) reported capture of the first beetle in flight on May 3,

1893, presumably near Lansing, Michigan. Late first flights have been recorded by Rockwood (1926) at Forest Grove, Oregon, on May 8, 1917, April 26, 1920, and May 5, 1917, at Wapato, Washington.

Rockwood (1926) found 85 to 90 percent of the borers in first flight were females and that 90 percent of these were fertilized before flight. Additional studies indicated that the root borer might fly as high as 50 feet and travel a distance of two miles.

Flight studies on the comparative number of borers flying in fields in the first crop year fields and those in the second crop year fields were made by Newsom (1948). Using seven-by-nine inch board traps with upper and lower surfaces coated with "Tree Tanglefoot" and placed fifteen inches above the plants, Newsom showed that over four times as many beetles at one location and over twice as many at another flew into each square foot of second crop year field as in first crop year fields. According to Newsom, these data indicated that the beetles made numerous short flights in second crop year fields.

Oviposition. Webster (1910) found that upon reaching a suitable clover plant the female root borer gouged out a small cavity or burrow in the clover plant, sometimes in the sides of the root two or three inches below the crown. Into the sides of the burrow she deposited, singly, about

six small, white elliptical eggs. According to Rockwood (1926), the female burrowed to a depth of 6mm. before beginning to oviposit. The egg galleries varied in character from simple grooves starting at the crown, to those consisting of spiral grooves almost girdling smaller roots. The construction of egg galleries required nearly a month. Males and females were common in the egg galleries during the whole reproductive period, and it was believed that females mated more than once during their reproductive period. Toward the end of May these egg galleries were abandoned by the adults, which then probably died outside the plant. Rockwood was first to observe that the female root borer might oviposit in as many as four clover plants in one season.

Davis (1894), who studied the life history and distribution of the clover root borer in Michigan, made the following statements regarding oviposition: "As soon as warmer weather comes in spring, the beetles revive and begin burrowing and feeding. This year, by the 20th of May, the females had commenced depositing eggs along the galleries made in boring....They (the eggs) are not left in the gallery with the beetle, but are pushed into the dead part of the stem at one side, securely packed and covered from view with refuse from the burrow." These statements seem to indicate that oviposition took place before dispersal flight; however, in the description of

the root borer's life history, no mention was made of a spring flight.

Webster (1910) stated that in Ohio oviposition occurred between the middle of May and June 20. Hudson (1925) reported that during breeding studies carried on in Ontario, Canada, egg laying continued throughout the summer. The beetles started to lay during the latter part of May and continued up to August 3. Rockwood (1926) stated that the number of eggs were at maximum toward the end of May. In studies made in New York during 1940, Lincoln (1941) observed that eggs were most abundant from middle June until the middle of August.

Schmitt (1844) stated that the female root borer laid four to six eggs. Riley (1879), Webster (1899) (1910) and others agreed with Schmitt and seemed to indicate that these were all the eggs the female laid in one season. Hudson (1925) found that the largest number of eggs secured from a single female was sixteen. Rockwood (1926) stated that the total number of eggs laid by a single female seldom exceeded twenty. In laboratory studies on oviposition, Newsom (1948) found that females laid an average of thirty-three eggs in one season and fifty-eight during two seasons.

Incubation. From observations made near Mainz, Germany, Schmitt (1844) stated that eight days were required for first larvae to appear. The writings of early

American workers such as Riley (1879) and Webster (1896, 1899, 1905, 1910) indicate that they accepted the incubation period of eight days as given by Schmitt. Hudson (1925) found from a close study of thirty-four eggs, that the maximum length of the egg stage was seventeen days; the minimum nine days; the average, 12.67 days. Using as incubation chambers salve boxes containing moistened plaster of Paris cells, Rockwood (1926) concluded that at effective temperatures the incubation period varied from 32 days in May to 16 days in June. Under a controlled laboratory temperature of 65 degrees Fahrenheit, Newsom (1948) found that the incubation period required about two weeks.

Larvae. Rockwood (1926) described the newly hatched larvae as "helpless, inactive creatures" which apparently found the leverage made possible by the small egg cells "absolutely necessary for the successful attack of clover roots." While conducting studies of the larvae, Newsom (1948) transferred newly hatched larvae to freshly cut root sections by lifting a small flap of bark and placing therein a single larva. The larva soon died but, when five or six larvae were introduced at the same time, survival was high.

Rockwood (1926) stated that at first the larvae made small tunnels at right angles to the egg gallery, but as the larvae increased in size the burrow generally conformed

to the longitudinal axis of the root.

Webster (1910) described the larva as being an eighth of an inch long, dingy white, with a honey-yellow head and brown jaws.

The literature contains relatively little information based on experimental evidence relative to the duration of the larval period. After extensive studies, Rockwood demonstrated that the larval period varied from 32 to 65 days and that at least 50 days were required under natural conditions. Newsom (1948) found it varied from 40 to 77 days when studed at a controlled temperature of 65 degrees Fahrenheit.

Pupae. In New York, according to Riley (1879), pupal formation took place at the end of the larval mine and pupae could be found as early as September. However, Newsom (1948) found that pupae usually appeared in August and were most abundant during September in the same state. At Fair Grove, Oregon, Rockwood (1926) determined the pupal period as 10 days, from August 17 to August 27, 1917, and 12 to 13 days during September and early October. He also reported that Webster and Mally had recorded pupal periods of 7 to 11 days at Wooster, Ohio, during July 1896. In the summary of his work, Rockwood stated that the pupal period lasted from 8 to 13 days.

Webster (1910) described the pupa as smaller than

the larva, dingy white, and with two minute spines on top of the head and two larger spinous projections at the anal extremity. The description given by Rockwood (1926) generally agreed with the above but was much more detailed.

Adults. According to Rockwood (1926), newly transformed adults were pale, creamy white and seven days elapsed before there was sufficient sclerotization to allow feeding. In the summary of his extensive studies, Rockwood stated that the developmental period from egg to adult covered not less than 60 days but might be 90 or more. Thus the total life span of an individual root borer might be a year or more. Corroborative evidence for Rockwood's findings was gathered by Newsom (1948). He found that development from egg to adult required about three months. In the spring of 1946 Newsom collected 92 pairs of adults for oviposition studies. Under the conditions of a screened insectary, a total of 31 adults were still alive in April 1947 and on October 26, 1947, one pair of the beetles was still alive.

Folsom (1909) described the adult beetle as follows: "The beetle is small.... at most only 2.5 mm. in length... dark brown or blackish, cylindrical, hard-bodied and hairy. The elytra, or wing-covers, often have a reddish tinge, and are coarsely punctate; the head and pronotum are more finely punctate, the latter bearing sparse long hairs.

The tibia have large teeth near the outer end."

During the course of Newsom's (1948) studies, he found it necessary to separate adult male beetles from females. No reliable characters were known for distinguishing living males and females. Newsom was the first to discover a method for such differentiation. If the female was held by forceps, on her side, in the struggle to escape the sixth and seventh tergites were extruded, exposing the secondary sexual characters. When a male beetle was held the same way only the seventh tergite was exposed but this is much larger and more heavily sclerotized than in the female. In addition, the aedeagus of the male, a heavily sclerotized tubular structure, is not found in the female.

Control

Natural Enemies. The literature indicates that the clover root borer has very few natural enemies. Riley (1879) found the larva of a soldier beetle, (Telephorus) Cantharis bilineatus Say, preying on the clover root borer. Rockwood (1926) reported that H. L. Parker reared larvae of the soldier beetle, Chauliognathus pennsylvanicus DeGeer, on the larvae of the clover root borer. During his investigations concerning the life history of the clover root borer in Canada, Hudson (1925) stated that he found no

parasites or predacious enemies of the root borer.

Rockwood (1926) observed the entomogenous fungus, (Sporotrichum) Beauveria globulifera (Spegazzini) Picard, attacking clover root borer adults. He indicated that infection of adults probably took place during their movement from plant to plant. However, occasionally larvae and pupae were attacked within the clover root. This pathogen was most prevalent in the fall and spring on low, wet, poorly drained land.

During April and May 1920, Rockwood (1926) attempted to find bird enemies of the clover root borer. Twenty-two species of birds were collected during the height of the root borer's dispersal flight. Examination of stomach contents indicated that eight species of birds had eaten a total of thirty-nine root borers. The cliff swallow, Petrochelidon lunifrons Say, had consumed twenty-seven of the thirty-nine insects found.

Resistance. Very few investigations have been conducted on the resistance of red clover to root borer attack. Preliminary results from studies on host resistance conducted by Lincoln (1941) showed a variation in infestation of the different red clovers ranging from 13 to 50 percent, the variation being entirely due to root size. Further investigations by Lincoln et al. (1942) showed that the variation in infestation due to root size, found

during the 1941 investigations, completely disappeared and all strains of red clover were infested.

During experiments on chemical control of the clover root borer on twenty different varieties of red clover, Gyrisco and Marshall (1950) observed little or no difference in root borer infestation among the varieties in the check plots.

Cultural. Early efforts to control the clover root borer were largely repressive in nature. Experiments conducted by Webster (1899) at Wooster, Ohio, showed that plowing down badly infested clover fields immediately after removal of the first hay crop (July 8) resulted in killing nearly all borers present in the roots. Examination of decayed roots in the plowed fields, three months later, showed a total of four live adult borers. Similar examination of decayed roots in neighboring unplowed fields showed that larvae, pupae and adults were present. Webster (1910) further stated that if plowing was delayed for a few weeks the larvae would have transformed into pupae, which require no food, and then plowing would have little or no effect on the borers.

Hudson (1925) stated, "The control of this insect is simple. Ploughing under clover after the second crop is taken off, and the destruction of volunteer clover is all that is necessary."

After considerable experimentation and observation, Rockwood (1926) made the following conclusions regarding cultural control of the clover root borer: (1) Plowing and harrowing clover fields soon after the seed crop was removed resulted in killing many of the borers; (2) The practice of green manuring and late fall and winter plowing had little or no effect on the root borers; (3) Early spring plowing of heavily infested fields was completely ineffective as a control measure; (4) Serious injury to red clover might be avoided by cooperative community farm practices, such as not allowing clover to stand undisturbed for two or more years.

Chemical. Davis (1894) used large quantities of nitrate of soda, murite of potash, and kainit as possible repellents for the clover root borer. He found that these applications had no effect on root borer infestation, and in fact, caused serious injury to the clover.

Application of phosphatic fertilizers to clover fields in order to induce more rapid growth was tried by Rockwood (1926). The results of these experiments indicated that no definite conclusions could be drawn regarding any difference in root borer infestation among plots tested.

Early experiments on chemical control of the clover root borer were conducted in New York by Lincoln et al. (1942) during the 1941 growing season. Paradichlorobenzene

at 1,000 pounds per acre showed repellent and fumigant action, reducing the number of roots infested and also the number of root borers developing within the roots. Naphthalene at 2,000 pounds per acre was effective as a repellent but not as a fumigant. Dichloroethylether, applied as a fumigant after the clover roots became infected, showed some promise.

Schwardt et al. (1947) applied one percent DDT dust and one percent benzene hexachloride to an even stand of red clover and timothy, in its first crop year. The results showed that neither material gave significant control of the clover root borer. Tests conducted by Newsom (1948) during 1946 and 1947 indicated that 5 percent dusts of benzene hexachloride and chlordane showed great promise for clover root borer control.

During the period 1946 to 1948, Marshall et al. (1949) conducted tests to determine the comparative efficiency of benzene hexachloride, chlordane, parathion, and DDT in control of the clover root borer, when applied as dusts or sprays to red clover in its first crop year. Insecticide applications were made before the spring dispersal flight. Benzene hexachloride, as a dust at 1.5 pounds of actual gamma isomer per acre, showed no phytotoxicity and gave excellent control. Parathion, chlordane, and DDT also gave good control, but results were not as consistant as those obtained with benzene hexachloride.

When used as sprays at the rate of one pound actual toxicant per acre, all materials gave unsatisfactory control.

In 1949 Gyrisco and Marshall (1950) tested the materials mentioned by Marshall et al. (1949) as well as toxaphene, methoxychlor, aldrin and dieldrin for control of the clover root borer. All materials were applied as dusts. Aldrin and dieldrin applied at two pounds of actual toxicant per acre and benzene hexachloride at one pound of gamma isomer per acre were most effective, followed by chlordane, parathion, toxaphene and methoxychlor, respectively. App and Everly (1950) also reported that benzene hexachloride at 1.25 pounds gamma isomer and aldrin at 2.0 pounds actual toxicant per acre, gave good control as surface applications.

From 1950 to 1954 Gyrisco et al. (1954) used aldrin, dieldrin, heptachlor, isodrin, endrin, chlordane, toxaphene, methoxychlor, TDE, parathion, NPD (Tetra-n-propyl-dithionopyrophosphate), lindane and benzene hexachloride in eleven different tests for control of the clover root borer in New York. Test results indicated that a pound of actual toxicant of aldrin, dieldrin, and heptachlor dusts gave consistantly good control. Dust applications of lindane, isodrin, chlordane, and benzene hexachloride at one pound actual toxicant per acre gave good control, but parathion, endrin, toxaphene, TDE, and NPD at one pound and higher dosages gave unsatisfactory control.

Preliminary tests with aldrin and dieldrin indicated that spray applications were less reliable than dusts.

Experiments were conducted at Wooster, Ohio, by Weaver and Haynes (1955) to test the effectiveness of band-placed insecticides for clover root borer control. Band placement of aldrin and benzene hexachloride at 0.75 pound toxicant per acre gave good control. Further tests by Weaver et al. (1957) showed that aldrin, lindane, and heptachlor, at the concentration mentioned above, gave an average of 83.9 percent control.

Of ten insecticides tested by App (1956) for control of the meadow spittlebug and clover root borer, heptachlor and aldrin dusts at 1.5 to 1.75 pounds actual toxicant per acre reduced clover root borer populations 97 to 100 percent, respectively, the former being applied in the spring; the latter, in the fall. "Fall applications of benzene hexachloride at 1.0 and 1.25 pounds gamma isomer per acre reduced clover root borer populations 37 and 72 percent, respectively, and spring applications of 0.75 to 2.0 pounds from 13 percent to 89 percent."

Woodside and Turner (1956) reported effective control of the clover root borer with applications of benzene hexachloride at one pound gamma isomer per acre in granular, spray, and dust formulations. Tests with dieldrin, aldrin, isodrin, endrin, and heptachlor, at one pound actual toxicant per acre, and chlordane at 5 pounds gave good control.

LITERATURE REVIEW, CLOVER ROOT CURCULIO

There are several species of insects belonging to the family Curculionidae that are often referred to as the clover root curculios. The literature on these insects indicates that Sitona hispidula Fabricius, is the most common species, and the one usually associated with injury to red and mammoth clover. However, Elliott (1952) found that the majority of clover root curculios collected in west Virginia were identified as Sitona flavescens Marsham.

The adult clover root curculio feeds at the edges of the leaves chewing out characteristic crescent-shaped patches. Bigger (1930), and others have agreed that this injury has relatively little effect on the clover plant. The most damage is caused by the larvae, which first feed on the nodules and small fibrous roots, later attacking the large roots. Sizeable cavities and grooves are excavated along the tap root, the latter sometimes encircling the entire root. Examination of a heavily infected field by Bigger (1930) in Illinois on May 18, 1927, showed from 36 to 41 larvae per square foot. Jewet (1934) examined a two year old clover field in Kentucky in September 1932 and found 71 percent of the clover roots showed curculio injury. Studies by Elliott (1952) in West Virginia indicated that injury caused by the clover root curculio facilitated entry of root rot organisms. Most authors agreed that this

insect feeds on all common clovers, alfalfa, soybeans, cowpeas and other legumes.

According to Metcalf et al. (1951), most of the insects pass the winter as young larvae. In the spring these larvae develop by feeding on the crown and roots of the clover plant. During May and June the adult beetles emerge. These beetles feed for about six weeks on the leaves of the clover plant. After a summer period of lesser activity the adults again become active in early fall. During this time maturation takes place and the females deposit their eggs about the crowns of the plants. Most of the eggs hatch in the fall, but some hatch the following spring. A considerable number of the adults survive the winter.

PROCEDURE

The survey area included all counties south of a line extending from Whitehall, in Muskegon county, to the tip of Huron county, and the following counties north of this line: Mecosta, Osceola, Missaukee, Kalkaska, Antrim, Otsego, Montmorency, Oscoda, Ogemaw. The approximate location of each sample site is shown in Figure 1. In each of the counties south of the line mentioned above, an average of 3.8 samples, consisting of ten clover roots each was collected. The number of samples collected from a given county depended upon the availability of sample sites, amount of clover grown, and the size of the county. In the survey area north of the above mentioned line an average of 1.9 samples per county was collected. Except for one sample collected in Wayne county on March 29, 1958, the survey covered the period from August 8, 1957 thru October 4, 1957.

Of the 159 samples collected during the survey, 151 were from clover fields which were at least in their first crop year[1], and 8 from fields less than one year old. Fields of either red clover Trifolium pratense Linnaeus,

---

[1]The term "first crop year" as used in this paper refers to the first calendar year following the year which a clover field was seeded.

Figure 1. Approximate locations of sample sites during 1957 clover root borer survey.

or mammoth clover Trifolium pratense var. perenne Host, were indiscriminately selected for sampling. Samples were taken by walking approximately 100 yards into each field and digging a randomly selected clover plant every 10 yards. Both living and dead clover plants were accepted as sample plants. In order to assure removal of the entire root a tile shovel with a blade 16 inches long was used to remove plants from the ground. The tops of the clover plants were removed about 3 inches above the crown and the roots placed in poultry size polyethylene plastic bags. A rubber band was placed about the open end of each plastic bag in order to prevent the roots from drying out. The location of the sample site and observational notes on the general condition of the field was recorded on a specially prepared survey form (Figure 2). Upon completion of a survey trip, the plastic bags containing the clover roots were placed in a cooler at 39 degrees Fahrenheit until dissection took place.

In the laboratory, examination and dissection of the roots was completed without the use of magnification, since larvae, pupae, and adults were large enough to be seen with the naked eye. The diameter of each root was measured at the crown and recorded on the survey form. Each root was examined for Sitona spp. larval feeding scars. This was recorded as none, light, moderate, or heavy. Each root was then carefully dissected over a

Figure 2. Example of survey form used during 1957 clover root borer survey.

RED CLOVER ROOT SURVEY - 1957

SAMPLE NO._____
DATE TAKEN_____
COUNTY_____
TOWNSHIP_____
T____,R____,Sec.____

TIME _____
WEATHER_____
TAKEN BY_____

H. Niemczyk
Dept. of Ent.
M.S.U.

REMARKS _____

PLANT NO.	Sitona DAMAGE	BORER ADULTS	LARVAE	PUPAE	NO. BORERS IN ROOT	DIAM. OF ROOT(mm)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

TOTAL NO. BORERS.....
% PLANTS INFESTED.....
NO. BORERS PER PLANT.....
% PLANTS WITH Sitona DAMAGE.....
AVG. DEGREE OF Sitona DAMAGE....
AVG. DIAM. OF ROOTS.....

white porcelain pan 19 inches long and 13 inches wide, and the number of clover root borer larvae, pupae, and adults present was recorded. The porcelain pan was emptied before dissection of another root began in order to avoid recounting root borers already counted. Whenever possible, roots were examined and dissected as soon as they were brought from the field, but because of the large number of clover roots collected during the survey, laboratory work was not completed until November 1, 1957.

PRESENTATION AND DISCUSSION OF DATA

Clover Root Borer

A total of 1,593 clover roots were examined during the survey. Of these, 1,513 were from clover fields at least in their first crop year, and 80 were from fields less than one year old. The results from examination of these roots are shown in Table I and Table II respectively.

Of the 1,513 roots collected from fields at least in their first crop year, 33.3 percent (504 roots) were infested with an average of 4.8 clover root borers per plant. The percent of root borer infestation among the sites from which these roots were collected ranged from zero to 100 percent. Table III shows the percentage distribution of larvae, pupae, and adults according to the date collected. The distribution of the average percent of root borer infestation among the counties from which the 1,513 roots were collected is shown in Figure 3.

The results of examination of all clover roots collected during this survey showed that the clover root borer was present in each county south of a line extending from Whitehall, in Muskegon county to the tip of Huron county, and also in the following counties north of this line:Mecosta, Osceola, Missaukee, Ogemaw (Figure 3).

TABLE I

OCCURRENCE OF THE CLOVER ROOT BORER IN RED AND MAMMOTH CLOVER ROOTS COLLECTED FROM FIELDS AT LEAST IN THEIR FIRST CROP YEAR.

County	Number of Roots Examined	Percent of Roots Infested	Average Number of Borers Per Root	Percent		
				Larvae	Pupae	Adults
Alcona	10	0	0.0	0.0	0.0	0.0
Allegan	40	35	1.0	22.5	12.5	65.0
Antrim	10	0	0.0	0.0	0.0	0.0
Barry	40	40	2.0	29.1	25.3	45.6
Berrien	30	43	2.0	44.3	32.7	22.9
Branch	40	45	2.3	44.4	21.1	34.4
Calhoun	40	30	1.8	28.5	11.0	60.3
Cass	40	30	1.9	38.7	40.0	21.3
Clinton	40	73	4.3	27.2	26.6	46.2
Eaton	49	49	2.1	23.1	22.1	54.8
Genesee	39	13	0.7	46.1	23.1	30.8
Gratiot	49	35	1.6	45.1	26.8	28.1
Hillsdale	30	67	3.4	39.8	22.3	37.9
Huron	30	27	8.3	13.8	31.0	55.2
Ingham	50	41	1.7	71.8	15.4	12.8
Ionia	40	38	1.5	31.7	30.0	38.3
Jackson	30	57	2.5	9.2	5.3	85.5
Kalamazoo	29	27	0.9	11.1	11.1	77.8
Kalkaska	20	0	0.0	0.0	0.0	0.0
Kent	40	58	3.6	48.9	29.4	21.7
Lapeer	40	13	0.7	48.1	33.3	18.5
Lenawee	40	75	4.2	30.8	18.9	50.3
Livingston	40	30	1.8	31.0	23.9	45.1
Macomb	30	23	0.7	57.1	14.3	28.6

TABLE I (Continued)

County	Number of Roots Examined	Percent of Roots Infested	Average Number of Borers Per Root	Percent		
				Larvae	Pupae	Adults
Mecosta	40	25	0.5	21.0	21.0	57.9
Missaukee	30	10	0.3	77.8	22.2	0.0
Monroe	30	50	3.0	21.1	24.4	54.4
Montcalm	40	28	1.1	36.4	29.5	34.1
Montmorency	10	0	0.0	0.0	0.0	0.0
Muskegon	30	30	1.2	45.7	0.0	54.3
Newago	20	60	3.5	58.0	10.0	31.9
Oakland	40	8	0.1	25.0	25.0	50.0
Ogemaw	10	10	0.5	80.0	20.0	0.0
Osceola	30	13	1.1	75.0	21.9	3.1
Oscoda	10	0	0.0	0.0	0.0	0.0
Otsego	10	0	0.0	0.0	0.0	0.0
Ottawa	30	30	1.8	41.8	41.8	16.4
Saginaw	40	5	0.3	60.0	20.0	20.0
Sanilac	60	48	2.3	35.8	23.3	40.8
Shiawassee	40	25	1.2	30.4	39.1	30.4
St. Clair	49	14	0.4	53.8	0.0	46.2
St. Joseph	29	31	2.3	36.2	15.9	42.8
Tuscola	50	38	1.7	24.1	12.6	63.2
Van Buren	40	30	1.4	16.4	16.4	67.3
Washtenaw	19	62	2.7	55.6	13.0	31.5
Wayne	10	30	0.3	33.3	0.0	66.7

TABLE II

OCCURRENCE OF THE CLOVER ROOT BORER IN RED AND MAMMOTH CLOVER ROOTS COLLECTED FROM FIELDS LESS THAN ONE YEAR OLD.

County	Number of Roots Examined	Percent of Roots Infested	Average Number Borers Per Root	Percent		
				Larvae	Pupae	Adults
Huron	10	0.0	0	0.0	0.0	0.0
Ingham	10	0.0	0	0.0	0.0	0.0
Kalamazoo	10	0.0	0	0.0	0.0	0.0
Muskegon	10	0.0	0	0.0	0.0	0.0
Newago	10	0.0	0	0.0	0.0	0.0
Oakland	10	0.0	0	0.0	0.0	0.0
St. Joseph	10	0.0	0	0.0	0.0	0.0
Washtenaw	10	0.0	0	0.0	0.0	0.0

TABLE III

PERCENTAGE DISTRIBUTION OF CLOVER ROOT BORER LARVAE, PUPAE, AND ADULTS ACCORDING TO DATA COLLECTED FROM FIELDS AT LEAST IN THEIR FIRST CROP YEAR.

Date Collected	Number of Roots	Number of			Average Percent of		
		Larvae	Pupae	Adults	Larvae	Pupae	Adults
1957							
August 8,	30	0	0	0	0.0	0.0	0.0
August 9,	30	6	9	7	50.0	28.9	21.9
August 15,	60	119	55	51	52.9	24.4	22.7
August 16,	100	123	73	56	48.8	28.9	22.2
August 17,	80	53	21	13	60.9	24.1	14.9
August 28,	40	47	46	80	27.2	26.6	46.2
September 4,	120	108	91	107	35.3	29.7	34.9
September 5,	80	63	30	69	38.9	18.5	42.6
September 10,	70	46	32	26	44.2	30.8	25.0
September 11,	80	26	6	20	50.0	11.5	38.5
September 12,	120	60	42	86	31.9	22.3	45.7
September 13,	70	27	15	44	31.2	17.4	51.2
September 17,	40	20	25	30	26.7	33.3	40.0
September 18,	110	47	42	208	15.8	14.1	70.0
September 23,	180	36	33	188	14.0	12.8	73.2
October 4,	60	38	10	11	64.4	16.9	18.6
1958							
March 28,	10	1	0	2	33.3	0.0	66.6

Figure 3. Distribution of percent clover root borer infestation in fields at least in their first crop year.

In the northern survey area it was found that infestations became smaller the farther north the survey area extended. The northernmost counties surveyed showed no infestation. The resons for this phenomenon were not investigated.

In the southern survey area considerable variation was evident in the average percent of clover root borer infestation (Figure 3). These percentages ranged from a low of 5 percent in Saginaw county to a high of 75 percent in Lenawee county. Rockwood (1926) indicated that temperature (soil and air), moisture, condition of the host plant, and topography are largely responsible for the distribution of the clover root borers and the damage done by them. Although these factors were not a part of the present study, the author feels that it is reasonable to assume that they were partially responsible for the variations in root borer infestations found.

During the course of the survey it became obvious that the acreage of red and mammoth clover grown varied considerably throughout the state. It was felt that this fact also might be partially responsible for the variations in root borer infestation found. Assuming that the acres of red clover harvested for seed in 1954, as given in the 1954 Census of Agriculture, was indicative of the amount grown in a given county in 1957, a comparison of this information and the percent of root borer infestation in the counties surveyed was made. It was found that Antrim county

harvested 1,007 acres and showed a zero percent infestation, Monroe county harvested 967 acres and showed a 50 percent infestation, Ionia county harvested 7,521 acres (the highest in the state) had an infestation of 38 percent and Lenawee county harvesting 5,605 acres had a 75 percent infestation. On the basis of this information it was therefore concluded that little or no relationship existed between the amount of clover grown in a county and the percent of root borer infestation.

As indicated by Rockwood (1926), Newsom (1948), and other workers, clover in its first growth year is seldom attacked by the clover root borer, primarily because the roots are small in the spring. Evidence derived from examination of 80 clover roots collected from fields less than one year old lends support to this information. As shown in Table II, none of the roots examined contained clover root borers. These roots averaged 5.26 mm. in diameter at the crown.

The average percent of larvae, pupae, and adults, when considered with respect to the date collected (Table III), showed considerable variation. The most outstanding variation was that from roots collected on October 4, 1957. These roots contained an average of 64.4 percent larvae, 16.9 percent pupae and 18.6 percent adults. One of the roots collected in Osceola county contained 20 root borer larvae. By way of comparison, Newsom (1948) examined first

crop year fields on October 6, 1946 and found 35 percent larvae, 7 percent pupae and 58 percent adults. Similar findings were reported by Folsom (1909) and Rockwood (1926). It must however be emphasized that the findings of the above workers were based on the examination of relatively few fields in a comparatively small area. Therefore, variations in percent of the different stages at a given time, (as demonstrated in this study) would be less likely to appear. Variations in environmental factors such as temperature, soil type, moisture, topography, and condition of host plant can not be naturally encountered unless an extensive area is studied. The author therefore feels that a plausible explanation for the variations in percent of larvae, pupae and adults shown in Table III, is the variation in the environmental conditions encountered during this survey. However, before any definite conclusions can be drawn, further study will be necessary.

Clover Root Curculio

Until completion of the present survey by the author there was no information available relative to the occurrence of clover root curculio feeding injury on red and mammoth clover in Michigan. This study was made in conjunction with the survey of the clover root borer. Before the clover roots were examined for clover root borer content, they

were first examined for Sitona spp. feeding injury. In order for the injury to be specifically attributed to the Sitona spp. it would have been necessary to collect the roots at a time when the larvae were actually in the process of feeding on the root. This however, was impossible because of the time of year that the survey was conducted. The description of the Sitona spp. larvae feeding scars as given by Bigger (1930), Jewet (1934), Metcalf et al. (1951) and Dickason and Every (1955) were used as criteria for injury identification. No attention was given to the particular species inflicting the injury.

The injury to clover roots was classified as none, light, moderate and heavy. None meant that the roots were free of any feeding scars; light, from one to approximately 10 feeding scars; heavy, the roots were badly gouged and scarred; moderate was approximated as that between 10 feeding scars and heavy injury. Roots which were broken or damaged, such that the feeding scars were unidentifiable, were not counted as part of the roots examined.

A total of 1,485 roots were examined. Of these 1,405 were from fields at least in their first crop year, and 80 from fields less than one year old. Of the 1,405 roots examined, 72 percent (1,012 roots) showed varying signs of clover root curculio injury. Of these 1,012 roots, 57.8 percent showed light damage, 27.7 percent moderate damage and 14.5 percent were heavily damaged.

Table IV shows a complete breakdown of the percent of damage found on clover roots collected from fields at least in their first crop year, according to the county from which the roots were collected. The location of the individual sample sites is the same as that shown on Figure 1. Figure 4 shows the occurrence of clover root curculio injury varying from light to heavy as determined by the survey. An examination of Figure 4 and Table IV readily shows that injury to red and mammoth clover by the clover root curculio is very common in Michigan.

The literature examined by the author contained no information relative to the question of whether or not the clover root curculio damages the roots of clover less than one year old. In order to determine whether such damage occurs, 80 roots from fields less than one year old were examined. The results of these examinations is shown in Table V. These data show that although feeding injury is less severe than that in older fields, it nevertheless does occur on young plants.

Figure 4. The percent distribution of clover root curculio (Sitona spp.) larval feeding injury on red and mammoth clover roots collected from fields at least in their first crop year.

TABLE IV

THE OCCURRENCE OF CLOVER ROOT CURCULIO (*Sitona* spp.) LARVAL FEEDING INJURY ON RED AND MAMMOTH CLOVER ROOTS COLLECTED FROM FIELDS AT LEAST IN THEIR FIRST CROP YEAR.

County	Number of Roots Examined	Percent Feeding Injury			
		None	Light	Moderate	Heavy
Alcona	10	100.0	0.0	0.0	0.0
Allegan	39	23.1	59.0	12.8	5.1
Antrim	10	80.0	0.0	20.0	0.0
Barry	38	18.4	39.5	28.9	13.2
Berrien	29	13.8	37.9	34.5	13.8
Branch	35	14.3	40.0	8.6	37.1
Calhoun	29	17.2	31.0	24.2	27.6
Cass	40	40.0	45.0	10.0	5.0
Clinton	39	46.2	48.7	5.1	0.0
Eaton	46	32.6	39.1	13.1	15.2
Genesee	29	24.1	58.6	13.8	3.5
Gratiot	44	36.4	25.0	20.5	18.1
Hillsdale	28	0.0	35.7	42.9	21.4
Huron	39	35.9	30.8	20.5	12.8
Ingham	58	19.0	56.9	20.7	3.4
Ionia	31	38.7	41.9	12.9	6.5
Jackson	24	29.2	54.2	12.5	4.1
Kalamazoo	35	57.1	20.0	22.9	0.0
Kalkaska	20	5.0	65.0	15.0	15.0
Kent	34	5.9	61.8	17.7	14.7
Lapeer	32	12.4	31.3	31.3	25.0
Lenawee	33	3.0	42.4	39.4	15.2
Livingston	38	23.7	42.1	26.3	7.9
Macomb	26	15.4	42.3	23.1	19.2

TABLE IV (Continued)

County	Number of Roots Examined	Percent Feeding Injury			
		None	Light	Moderate	Heavy
Mecosta	37	51.4	24.3	24.3	0.0
Missaukee	28	35.7	57.1	7.2	0.0
Monroe	20	35.0	35.0	20.0	10.0
Montcalm	28	57.1	28.6	14.3	0.0
Montmorency	10	40.0	0.0	60.0	0.0
Muskegon	38	44.7	47.4	5.3	2.6
Newago	22	63.6	22.7	9.1	4.6
Oakland	44	25.0	29.5	29.5	15.9
Ogemaw	10	50.0	40.0	0.0	10.0
Osceola	29	27.6	51.8	10.3	10.3
Oscoda	8	37.5	50.0	0.0	12.5
Otsego	10	0.0	0.0	100.0	0.0
Ottawa	29	31.0	51.7	13.8	3.5
Saginaw	32	9.4	53.1	31.3	6.2
Sanilac	51	19.6	31.4	25.5	23.5
Shiawassee	35	17.1	45.7	22.9	14.3
St. Clair	40	15.0	50.0	22.5	12.5
St. Joseph	36	25.0	52.8	16.7	5.5
Tuscola	39	23.1	43.6	20.5	12.8
Van Buren	38	26.3	63.2	10.5	0.0
Washtenaw	27	40.8	29.6	14.8	14.8
Wayne	8	12.5	75.0	12.5	0.0

TABLE V

THE OCCURRENCE OF CLOVER ROOT CURCULIO (*Sitona* spp.) LARVAL FEEDING INJURY ON RED AND MAMMOTH CLOVER ROOTS COLLECTED FROM FIELDS LESS THAN ONE YEAR OLD.

County	Number of Roots Examined	Percent Feeding Injury			
		None	Light	Moderate	Heavy
Huron	10	100.0	0.0	0.0	0.0
Ingham	10	70.0	20.0	0.0	10.0
Kalamazoo	10	60.0	10.0	30.0	0.0
Muskegon	10	60.0	10.0	20.0	10.0
Newago	10	100.0	0.0	0.0	0.0
Oakland	10	70.0	20.0	10.0	0.0
St. Joseph	10	60.0	40.0	0.0	0.0
Washtenaw	10	100.0	0.0	0.0	0.0

SUMMARY

The primary purpose of this study was to determine the distribution and magnitude of the clover root borer (Hylastinus obscurus Marsham) infestation in red and mammoth clover in Michigan, and at the same time gather similar information on the clover root curculio (Sitona spp.) injury to these plants. A total of 1,593 roots were dug from fields in 46 counties. Eighty of these roots were from fields less than one year old and 1,513 were from fields at least in their first crop year. An average of 3.4 samples consisting of 10 randomly selected roots was collected from each county surveyed.

The results from examination of the roots collected are outlined as follows:

1. The 1,513 roots collected from fields at least in their first crop year showed 33.3 percent were infested with an average of 4.8 root borers per root.

2. Root borer infestations ranged from zero to 100 percent and varied considerably from one county to the next. The northernmost counties showed a zero percent infestation.

3. Examination of the 80 roots dug from fields less than one year old showed that none were infested with the clover root borer.

4. Of the roots dug from fields at least in their first crop year, 1,405 were examined for Sitona spp. larval feeding injury. The results showed that 57.8 percent had light damage, 27.7 had moderate damage, and 14.5 percent had heavy injury.

5. Examination of the 80 roots from fields less than one year old showed that 77.7 percent had no injury, and 12.5, 7.5, and 2.5 were respectively light, moderate and heavily injured.

LITERATURE CITED

Anonymous
1948. Clover injured by borer killed by disease. Ann. Rept. Penn. Agr. Expt. Sta. (1947) 61: 16.

App, B. A.
1956. Control of the clover root borer and the meadow spittlebug on red clover. Jour. Econ. Ent. 49: 161-164.

App, B. A. and R. T. Everly
1950. Insecticide dusts to control the clover root borer and the meadow spittlebug. U. S. Dept. Agr., Bur. Ent. Pl. Quar., Mimeo. E-811.

Bigger, J. H.
1930. Notes on the life history of the clover root curculio, Sitona hispidula Fab., in central Illinois. Jour. Econ. Ent. 23: 334-341.

Chapman, F.
1869. Notes on the habits of Phloeophthorus rhododactylus and Hylastes obscurus. Ent. Mon. Mag. 6: 6-8.

Davis, G. C.
1894. Insect of the clover field. Part I. Insects destructive to clover. Mich. Agr. Expt. Sta. Bul. 116: 41-47.

Dickason, E. A. and R. W. Every
1955. Legume insects of Oregon. Oregon State College Ext. Bul. 749: 14-15.

Elliott, E. S.
1952. Diseases, insects, and other factors in relation to red clover failure in West Virginia. W. Va. Agr. Expt. Sta. Bul. 351T: 1-65.

Folsom, J. W.
1909. The insects pests of clover and alfalfa. Univ. Ill. Agr. Expt. Sta. Bul. 134: 113-197.

Gibson, A.
1913. Clover root borer. Ann. Rept. Ent. Soc. Ontario (1912) 43: 13.

Gyrisco, G. G. and D. S. Marshall
1950. Further investigations on the control of the clover root borer in New York. Jour. Econ. Ent. 43: 82-86.

Gyrisco, G. G., A. A. Muka, L. Hopkins and H. H. Neunzig
1954. Insecticide concentrations and timing of applications for control of the clover root borer. Jour. Econ. Ent. 47: 327-331.

Henry, W. A.
1880. The clover root borer. Amer. Entomol. 3: 227.

Hudson, H. F.
1925. Notes on the life history of the clover root borer, Hylastinus obscurus. Ann. Rept. Ent. Soc. Ontario (1924) 56: 92-93.

Hunter, B.
1909. Clover-seed production in the Willamette Valley, Oregon. U. S. Dept. Agr., Bur. Pl. Indus., Circ. 28: 1-15.

Jewet, H. H.
1934. The clover root curculio. Ky. Agr. Expt. Sta. Circ. 42: 13-23.

Lincoln, C. G.
1941. Studies on the biology and control of the clover root borer Hylastinus obscurus. Ann. Rept. Cornell Univ. Agr. Expt. Sta. (1940) 54: 129-130.

Lincoln, C. G., L. D. Newsom and H. H. Schwardt
1942. Studies on the biology and control of the clover root borer, Hylastinus obscurus. Ann. Rept. Cornell Univ. Agr. Expt. Sta. (1941) 55: 127-128.

Marshall, D. S., L. D. Newsom, G. G. Gyrisco and H. H. Schwardt
1949. Control of the clover root borer. Jour. Econ. Ent. 42: 315-318.

Metcalf, C. L., W. P. Flint and R. L. Metcalf
1951. Destructive and useful insects. McGraw Hill Book Company, New York. 1071 pp.

Mills, H. B.
1941. Montana insect pests 1939 and 1940. Twenty-Eighth Report of the State Entomologist. Mont. Agr. Expt. Sta. Bul. 384: 12.

Newsom, L. D.
1948. The biology and economic importance of the clover root borer, Hylastinus obscurus Marsham. Thesis for degree of Ph.D., Cornell Univ. 129 pp. Unpublished.

Pieters, A. J. and E. A. Hollowell
1924. Clover failure. U. S. Dept. Agr. Farmers Bul. 1936: 1-24.

_____
1937. Clover improvement. U. S. Dept. Agr. Year Book 1937: 1190-1214.

Riley, C. V.
1879. The clover root borer. Rept. U. S. Comm. Agr. 1878: 248-250.

Rockwood, L. P.
1926. The clover root borer. U. S. Dept. Agr. Bul. 1426: 1-28.

Schmitt, P.
1844. Entwicklungsgeschichte des Hylasinus trifolii (Muller). Stettin. Ent. Ztg. 5: 389-397.

Schwardt, H. H., L. D. Newsom and L. B. Norton
1947. Increasing red clover yields by treatment with DDT or hexachlorocyclohexane. Jour. Econ. Ent. 40: 363-365.

Weaver, C. R. and J. L. Haynes
1955. Band placement of insecticides for clover root borer control. Jour. Econ. Ent. 48: 190-191.

Weaver, C. R., K. P. Pruess and J. L. Parsons
1957. Further tests of band placement of insecticides for clover root borer control. Jour. Econ. Ent. 50: 255-256.

Webster, F. M.
1896. The clover root borer. Ohio Agr. Expt. Sta. Bul. 68: 31-33.

1899. The clover root borer. Ohio Agr. Expt. Sta. Bul. 112: 143-149.

1905. The clover root borer. U. S. Dept. Agr., Bur. Ent., Circ. 67: 1-5.

1910. The clover root borer. U. S. Dept. Agr., Bur. Ent., Circ. 119: 1-5.

White, J.
1888. The clover root borer, Hylastes trifolii (Muller). Canad. Ent. 20: 138.

Woodside, A. M. and E. C. Turner
1956. Control of the clover root borer in Virginia. Jour. Econ. Ent. 49: 640-643.

25 Mar 59

 pd. WSC