THE BIOLOGY AND CONTROL OF RED CLOVER INSECTS IN MICHIGAN

Thesis for the Degree of M. S.

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Willet Theodore Van Velzen

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RED CLOVER INSECTS IN MICHIGAN

by

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AN ABSTRACT

Submitted to the College of Science and Arts of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
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MASTER OF SCIENCE

Department of Entomology

1960

Approved Ray Hutson

ABSTRACT

An investigation was conducted in 1959 to study the biology and evaluate the chemical control of the major red clover insects. This study was conducted on the Farm Crops Experimental Farm at Michigan State University, East Lansing, Michigan.

The clover root borer and the clover root curculio were found to be the most important soil insects. Of the head infesting pests the clover seed midge, the clover seed chalcid and the clover head weevil were the insects most commonly found. Aphids, spittlebugs, plant bugs and leaf-hoppers comprised the most numerous foliage pests.

Heptachlor, thiodan, thimet and DDT were applied and an attempt was made to determine the effectiveness of these insecticides in controlling insect pests. Insect sweepings, head analyses, stand measurements, seed yield and other observations were taken throughout the growing season.

Heptachlor proved to be effective in controlling the clover root borer, clover root curculio and spittlebug and in addition improved plant vigor and increased seed yield. The application of thiodan sprays substantially reduced

populations of spittlebugs and aphids. Thimet granules were effective in controlling leafhoppers, plant bugs and aphids as a systemic insecticide. A reduction in insect populations immediately following the thimet application indicated that this insecticide may have acted as a fumigant. The DDT sprays were effective in reducing populations of plant bugs, leafhoppers and spittlebugs. Various interactions were found between the heptachlor soil application and the foliar sprays.

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INTRODUCTION

There has been a consistent decline in red clover seed production in Michigan. Research undertaken because of this decline has placed increased emphasis on insect problems associated with the growing of red clover. Published reports of red clover insect problems in other areas, as well as limited observations in Michigan, indicated that pest insects often have been important factors in the decline of this crop.

Many insects have been found to attack red clover at different stages of its development. Some of these insects damage the roots, some feed upon the foliage and others destroy the developing seed. These insects cause direct damage to the plants and in addition act as vectors of important red clover diseases. Several insect species aid the entrance of disease-producing organisms through the damage they inflict upon the plants. On the other hand insects serve as the major pollinators for this crop and their presence is a primary factor in the production of clover seed. A difficult situation arises in attempting to control the destructive insects while not eliminating those necessary for fertilization.

The purpose of this investigation was to study the biology of some of the major red clover infesting insects and to evaluate the use of chemicals for their control.

LITERATURE REVIEW

The difficulties encountered in the growing of red clover, both on this continent and in Europe, have been recorded for over two centuries (Fergus and Valleau, 1926). In evaluating the various factors contributing to clover failure, particular attention has been given to the important part that insects have played in both seed and forage production. Pieters and Hollowell (1924) and Heusinkveld (1948) stressed the damage wrought by insects to red clover. These workers also listed disease, unadapted and poor seed, unsuitable soil conditions and seedbed preparation as limiting factors in the growing of red clover for seed. In most cases the studies of red clover failure have been associated with specific problems, such as the effect of a particular insect or disease upon the crop. General studies have been few and in most cases very brief, yet the cause of clover failure in many areas has been attributed to a complex of factors and not to any single factor. The literature indicated that the "complex" varies with various geographic areas and therefore the solution for one area cannot necessarily be applied to another.

In addition to insect pests, beneficial insects such as those revealed by the studies of Megee and Kelty (1932) have shown that the amount of seed set is often proportional to the number of pollinators present. This immediately revealed the need for applying insecticides which satisfactorily controlled the injurious insects while not affecting the pollinators. Packard (1952) mentions that cultural control measures still continue to be the best if not the only method of control for some forage insects. This is well illustrated by the practice of cutting red clover early to destroy the clover seed midge larvae present in the heads.

Studies on the biology of many of the important forage pests have been carried on by various workers. A great deal of attention has been given to the complex of soil insects. Workers such as Koehler and Gyrisco (1959) have made substantial contributions in their study of soil and plant conditions which affect clover root borer incidence. Gustafson and Morrison (1957), in their study of the above ground activity of the clover root borer, have added much to our knowledge of this insect. In Michigan, Niemczyk (1958) studied the distribution and magnitude of the clover root borer and clover root curculio infestations.

Numerous publications have appeared dealing with the biology of forage pests in general. Outstanding among these papers is that of Elliott (1952) in which the importance of not only the insects but also plant diseases was explored in West Virginia. Metcalf _et al_ (1951) presented a listing of the important legume insects with notes on their importance, type of injury, plants attacked, distribution, life history and recommended control measures. Dickason and Every (1955) studied the life histories of some of the more important Western pests. Detailed contributions on the biology of specific foliar pests have been made by Weaver and King (1954) in their paper on the biology, ecology and control of the meadow spittlebug, and Markkula and Tinnilä (1956) in their study of the lesser clover leaf weevil Peters and Painter (1958) studied the biology of legume aphids in relation to their host plants. Sorenson (1930) conducted similar studies on the seed chalcis-fly in Utah.

Considerable attention has been given to the use of insecticides both in an attempt to increase forage yield and seed production Stitt (1948) and Gyrisco (1958) attempted to increase the amount and quality of forage through the application of various chemicals. Medler and Scholl (1947) also directed their work along this line, using DDT and sabadilla, Chamberlain and Medler (1949) and Wilson (1[illegible]) used DDT to determine the length of the effective control of injurious insects.

In reviewing the voluminous amount of literature that has been published during the past few years it became readily apparent that much work is being conducted regarding the ecology, distribution and control of red clover insect pests. The literature indicates that many problems still exist and each investigation unveils new problems.

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PROCEDURE

A field of Penscott variety red clover (*Trifolium pratense* L.), seeded in the spring of 1958, was used for this investigation. This field consisted of approximately 2.5 acres and was located on the Farm Crops Experimental Farms of Michigan State University at East Lansing, Michigan. An area 480 by 180 feet was chosen divided into four replications 120 by 180 feet and each replication sub-divided into five plots 24 by 180 feet (Figure 1). Each plot was marked with two border stakes and, in addition, by a taller center stake to facilitate sweepings and other plot investigations.

The five plots in each replication were then randomly assigned numbers, from 1 to 5, which corresponded to the insecticide application that each plot was scheduled to receive (Figure 1).

The field in general presented a level surface however plots 2 and 5 in replication IV sloped slightly downhill.

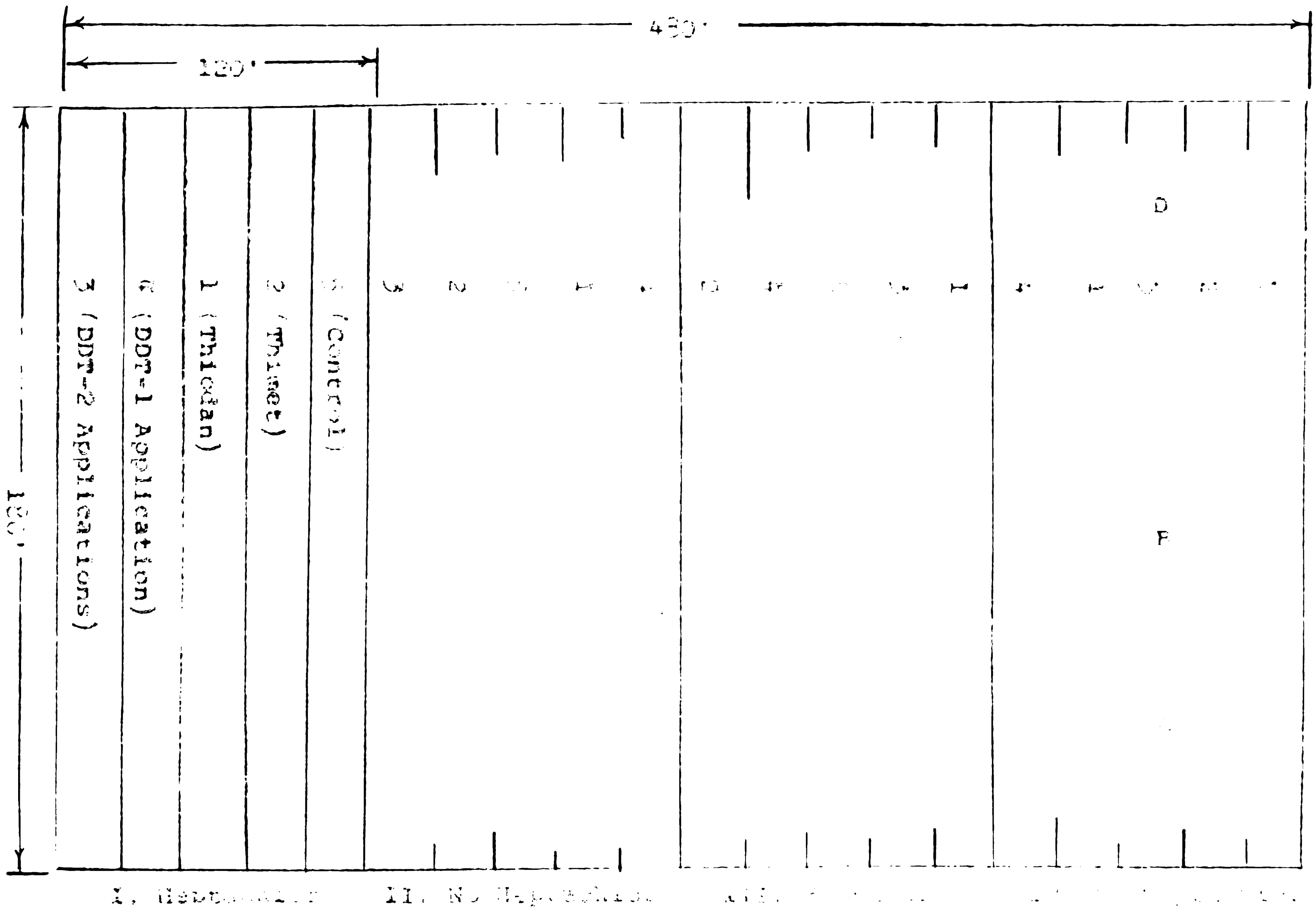
Soil Insecticides. On April 13, 1959, replications I and III were treated with an application of granular heptachlor at the rate of 2 pounds actual insecticide per acre (80 pounds of 2.5 percent 30-60 atta-clay granules). The application was made using a Spred-N-Till Gandy

Applicator, with a gauge setting of 14, pulled by a Farmall Cub tractor driven at 2.5 miles per hour. The insecticide was applied in six foot swaths covering the entire replication. Replications II and IV were retained as untreated "controls" and are referred to as "untreated replications" regardless of the fact that certain plots within them received foliar sprays.

On July 20, 5 percent thimet granules were applied to plot 2 in each replication at the rate of 2 pounds actual insecticide per acre. The same apparatus described above for applying heptachlor was used, with the exception that the gauge on the Gandy Applicator was set at 9.

<u>Foliar Sprays</u>. An application of thiodan was made to plot 1 in each replication on May 15 using a Farmall Cub tractor equipped with a 12 foot, 8 nozzle boom sprayer designed by the Farm Crops Department. This apparatus applied 36 gallons of spray per acre when traveling at a speed of 4 miles per hour. The thiodan was applied at the rate of one-half pound of insecticide per acre (2 pounds per gallon emulsion).

A DDT spray was applied to plots 3 and 4 in each replication on July 20 at a rate of 1 pound actual insecticide



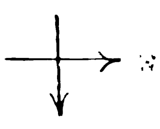


Figure 1. Diagram of red clover field at Michigan State University, East Lansing, Michigan, used for chemical control [illegible] in 1959.

per acre (3 pounds per gallon emulsion). The spray was applied with the same equipment discussed above for the application of thiodan. A second application of DDT at the same rate and formulation was applied to plot 3 on July 28.

In referring to the foliar sprays all number 5 plots are considered as "controls" regardless of the fact that those in replications I and III received a soil treatment of heptachlor.

Sampling and Methods of Analysis. In order to sample the insect complex of each plot, weekly sweepings were taken until the first cutting on June 16. After the growth of the second cutting had started, the number of sweep samples was increased to two per week to more adequately record changes in insect populations. The total period of sweeping extended from May 19 to August 13.

A standard type, short-handled, 12 inch diameter beating net was used for sampling. On each collection date ten 180 degree sweeps were taken at 18 foot intervals along the length of each plot. The insects thus obtained were separated from the debris by the use of a modified Berlese funnel in which methyl-iso-butyl ketone was used as a repellent. This funnel is a modification of the one used by Gray and Schuh (1941) for sampling pea aphid populations. When the insects had accumulated in the collecting bottle at the bottom of the funnel, they were immersed in KAAD for a short time and then preserved in 95 percent ethyl alcohol. Such a process allowed the preservation of all soft-bodied insects for later identification.

Actual counts were made of all insects in each sample except for those samples collected at the time of the greatest spittlebug and pea aphid concentrations. In such cases the sample was evenly distributed in a petri dish marked off into four pie-shaped sections. The number of insects on one section was then counted and this number multiplied by four to determine the total number of insects collected.

A standard form (Figure 2) was used for recording the insects from each sample. The fact that the insect samples were preserved in alcohol made possible accurate counts of immature forms as well as adults. Identification of the insects was confirmed through comparison with a synoptic collection previously identified by competent authorities.

In an attempt to determine the factors affecting seed production, a series of ten heads was collected weekly from each plot from July 16 through August 20. Heads of approximately the same light tan shade were selected to assure

Plot No. ______

Date Taken ______________

Time ______________

REMARKS ____

	ADULTS	IMMATURES
Misc. Grasshoppers		
Adelphocoris lineolatus		
Adelphocoris rapidus		
Lygus lineolaris		
Misc. Miridae		
Macrosiphum pisi		
Theriaphis trifolii		
Philaenus leucophthalmus		
Empoasca fabae		
Macrosteles fascifrons		
Aceratagallia sanguinolenta		
Paraphlepsius irroratus		
Cloanthus frontalis		
Draeculacephala antica		
Endria inimica		
Misc. Leafhoppers		
Grapholitha interstinctana		
Hypera nigrirostris		
Hypera meles		
Hypera punctata		
Sitona hispidula		
Sitona flavescens		
Tychius stephensi		
Misc. Nitidulids		
Misc. Phalacrids		
Misc. Flea beetles		
Pentatomids		
Bruchophagus gibbus		
Dasyneura leguminicola		

Figure 2. Example of Form used for recording insects taken in sweep samples from red clover field at East Lansing Michigan. 1950.

that all heads were the same age. The heads were then placed in pint jars with cheese-cloth covers and allowed to dry.

After drying at room temperature, six of the ten heads were randomly selected from each bottle. The florets from two of the six heads were placed in a metal dish marked off into four equal sections and one-quarter of the florets counted. The remaining four heads were treated similarly. The first ten florets counted from each pair of heads were retained for further analysis. These ten florets were examined under a binocular microscope to determine the percent of fertilization and the number of seeds destroyed by insects.

On September 18 ten plants were randomly dug from each plot and the roots examined in the field for clover root borer and clover root curculio damage.

At the time of the first cutting, on June 16, a swath of hay 6 by 30 feet was cut and weighed from the thiodan and control plots. These swaths were cut to the right of the center stake in each plot to avoid the area trampled by the weekly insect collecting. A smaller sub-sample was retained from each of these plots, weighed, dried and reweighed to determine moisture content.

In order to gather information on variations which might occur in the clover stand, four square yard areas were staked out in each plot (symbols A-D, Figure 1). A count was made of the total number of living plants in each of these areas on July 8 and October 2.

An attempt was made to record differences in bloom on July 30 and August 18. A thin 12 by 12 inch wooden frame, supported by 8 inch legs, was randomly placed at ten locations along the length of the plots and the number of clover heads falling within its margin was recorded. All heads that showed a sign of bloom were counted.

In preparation for seed harvest dinitro (3 pints in 10 gallons of fuel oil per acre) was applied to the field as a dessicant. On September 21 two swaths 7 feet wide were combined from each plot. The seed from each plot was bagged, weighed and then cleaned and reweighed.

PRESENTATION AND DISCUSSION OF DATA

Notes on the Biology of Red Clover Insects

The failure of red clover, Trifolium pratense L., often has been attributed to the complex of soil insects infesting the roots of the clover plants. Of this complex, the clover root borer and the clover root curculio are the most important pests. Both insects do appreciable damage directly to the plants and in addition weaken them and allow the entrance of disease causing organisms. Detailed studies of the biology of the clover root borer and the clover root curculio were not made during this study, however observations associated with the collection of control data were recorded.

Clover Root Borer Hylastinus obscurus (Marsh.).

In this study an effort was made to roughly ascertain the period of adult migration. On May 12 four 10 by 15 inch "Tree Tanglefoot" coated pieces of aluminum were randomly placed in the experimental area. The traps were placed perpendicular to and about 12 inches above the ground. Except for the use of aluminum the method was the same as that used by Newsom (1948). The traps were examined twice weekly to note the number of adult root borers present. Between May 13 and May 26 a total of 11 specimens were removed from the traps. The last beetle was removed on May 25. Because the number of clover root borers removed was so small it was postulated that the principal part of the migration had occurred before May 12. During similar studies employing the same method, at Mason, Michigan, Niemczyk and Guyer (1968) observed that on May 13 clover root borers were leaving old clover fields in considerable numbers, however traps placed in a one year old field one-half mile away revealed relatively few of these insects. These workers suggest that the peak period of migration took place between May 10 and 15.

The only adult clover root borers taken in the sweep samples in this study were four specimens collected on May 10.

In a random sample of plants taken from the untreated plots on July 1, a 100 percent infestation of roots by the borer was recorded. This infestation consisted of 27 percent larvae and 73 percent adults. No pupae were observed during the examination.

When the plots were sampled for the evaluation of chemical control on September 18, 79 percent of the plants taken from replications II and IV were infested. These plants had roots heavily damaged and averaged from 5 to 6 root borers per plant. This infestation was composed primarily of fully developed larvae and adults. On September 13, 1957, in a survey of 45 southern Michigan counties, Niemczyk (1962) found infestations averaging 15.8 percent larvae, 14.1 percent pupae and 70.0 percent adults.

Clover Root Curculio Sitona hispidula (F.)

Very little information was recorded on the biology of the clover root curculio other than the abundance of adults in the regular sweep samples throughout the sampling period. Metcalf et al (1951) stated that the adults are very active during the spring months. This is then followed by a period of decreased activity during the summer and increased activity in the early fall. Sweep samples in this study substantiate this trend for numerous beetles were taken in May, a steadily decreasing number during June and very few during July. An increase was again noticed after the first week in August.

Clover Seed Midge Dasyneura leguminicola (Lint.).

In this study the first adult midges were collected when sweep sampling began on May 19, approximately six days before the first bloom appeared. The first head collection, taken on July 22, showed that the florets were infested with larvae (Figure 3). The infestation continued throughout July and the first week of August. The lop-sided appearance of the clover heads, caused by the activity of the seed midge larvae, was evident during the entire blooming period. On August 13, ten days after a large increase in the number of adult midges had appeared in the sweep samples, a similar increase was observed in the incidence of larvae in the heads examined. Metcalf _et al_ (1951) state that the first of the summer generation of adults appear during the first part of July. In this study a considerable increase in the numbers of adult midges collected early in August probably indicated this second generation of the seed midge (Figure 3).

Clover Head Weevil _Tychius stephensi_ Schönh.

Adult weevils were taken in this study as soon as sweepings were initiated on May 19 as shown by Figure 4. A concentration of five weevils per sweep was found on June 12. As soon as the clover began forming buds these insects became extremely numerous and could easily be found on the blossoms and buds. It was not at all unusual to find as many as 5 or 6 weevils per blossom during May and early June. After June 18 a rapid decline of beetles occurred, reaching a low of approximately one per sweep by the middle of August.

Heads collected on July 22 averaged 2.3 larvae per head

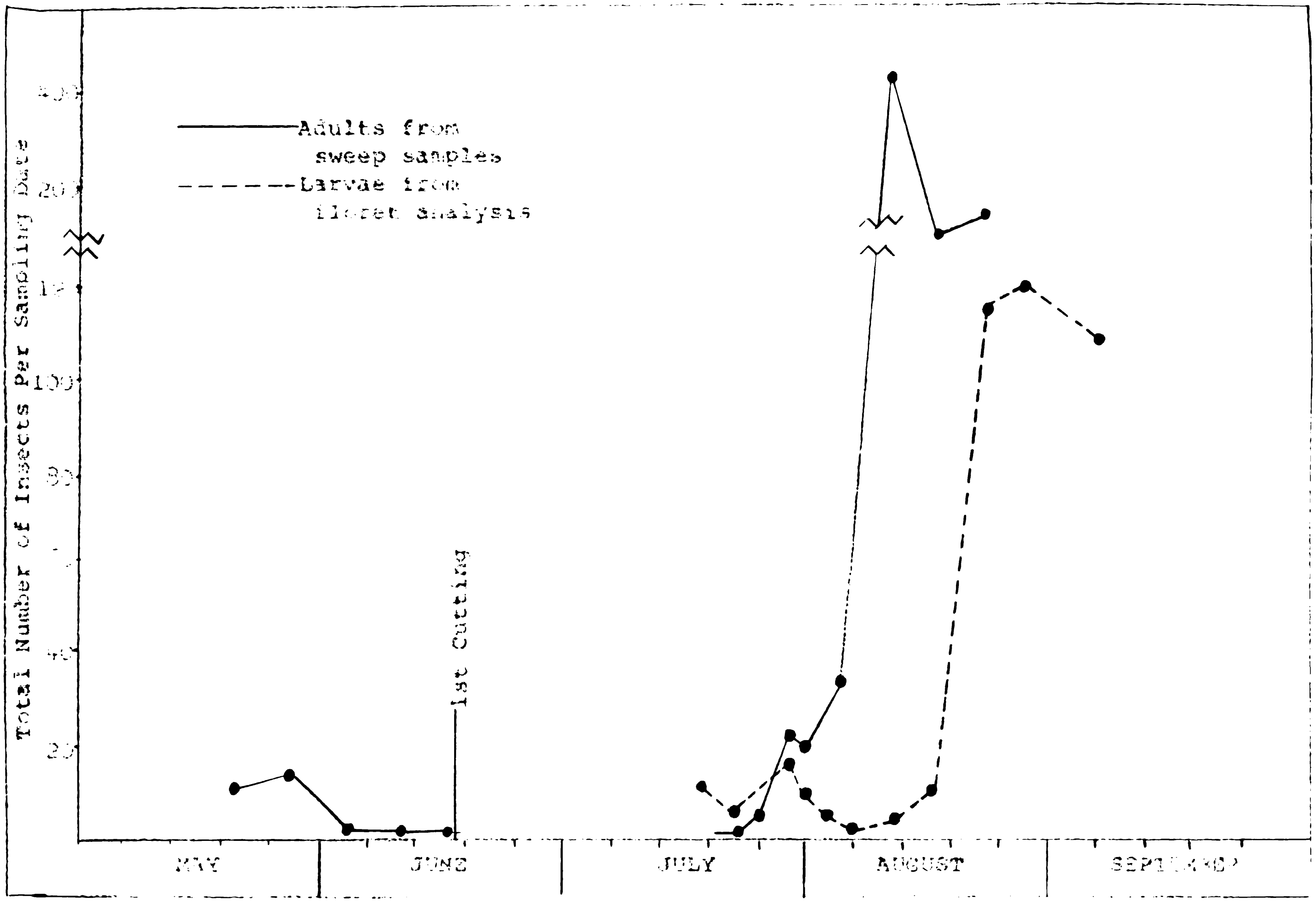


Figure 5 [illegible]undance and Distribution [illegible] the clover seed midge at East Lansing [illegible]igan [illegible].

with a high of 7.4 larvae per head in some samples. Floret examination (Figure 4) showed that the concentration of larvae was highest during the middle of July but tapered off sharply by the first of August. A small number of larvae were evident throughout August and a few during the first week in September.

Clover Seed Chalcid <u>Bruchophagus gibbus</u> (Boh.).

The clover seed chalcid has been reported to be one of the most important pests of red clover. Elliott (1952) and Dickason and Every (19[illegible]) recorded two, or in some cases three generations of the chalcid per year. The insect over-winters as a larvae in the clover seed and the adults emerge with the advent of warm weather.

The July 22 head collection showed the highest infestation of chalcid larvae found in this study with 100 larvae found in 120 heads examined. A rapid decrease in the numbers of larvae was recorded throughout the last week in July and the first week in August as shown by Figure 5. An increase in the number of larvae was again recorded during the middle of August but this tapered off during the last week in the month.

Great fluctuations in the numbers of adult chalcids were recorded throughout August. Sorenson (1930) found the

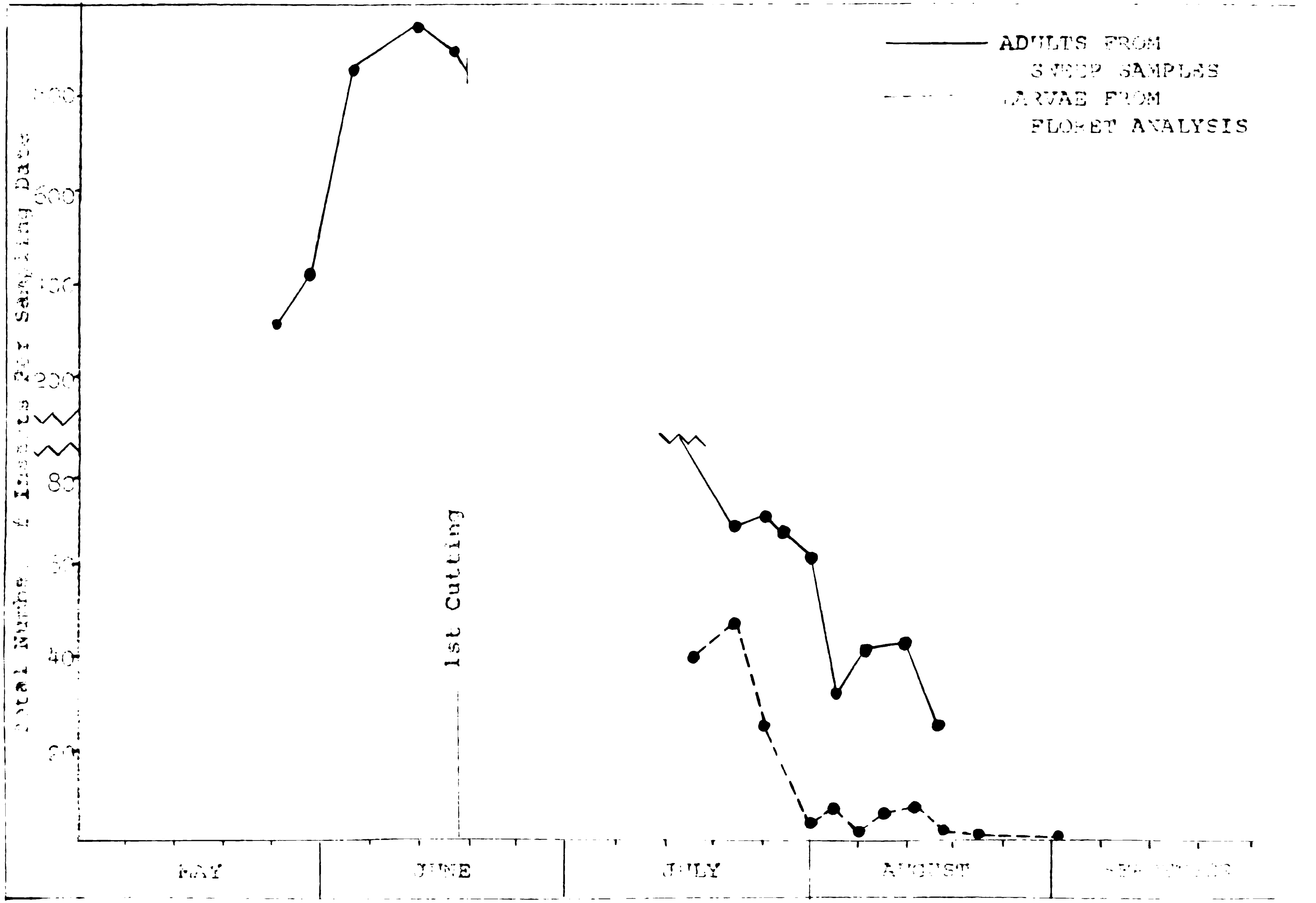


Figure . Abundance and distribution of the clover head weevil at East Lansing, Michigan.

activity of the seed chalcid to be particularly sensitive to temperature changes. The fluctuation in numbers of chalcids collected in this investigation may have been caused by this factor. The highest concentration of adult chalcids occurred during the middle of August.

Meadow Spittlebug *Philaenus leucophthalmus* (L.).

In this study the first nymphs were observed on May 11. This hatching date falls within the range listed by Weaver and King (1954) for states at approximately the same latitude. The first nymphs observed were hidden behind the leaf stipules, without spittle formation, or were just beginning to form spittle masses in the unfolded leaves.

Sweep samples from May 19 to May 27 contained relatively few spittlebug nymphs, but by June 3 a considerable increase in numbers had taken place. The largest number of nymphs were collected on June 10. On June 2 spittlebug counts were conducted in which 50 stems from the check plots were selected randomly and examined for spittle masses. Replication II and IV (untreated) had 0.44 and 0.38 masses per stem, respectively. Elliott (1952) stated that each spittle mass enclosed from one to a dozen or more nymphs. In this investigation the spittlebugs per mass ranged from 1 to 6.

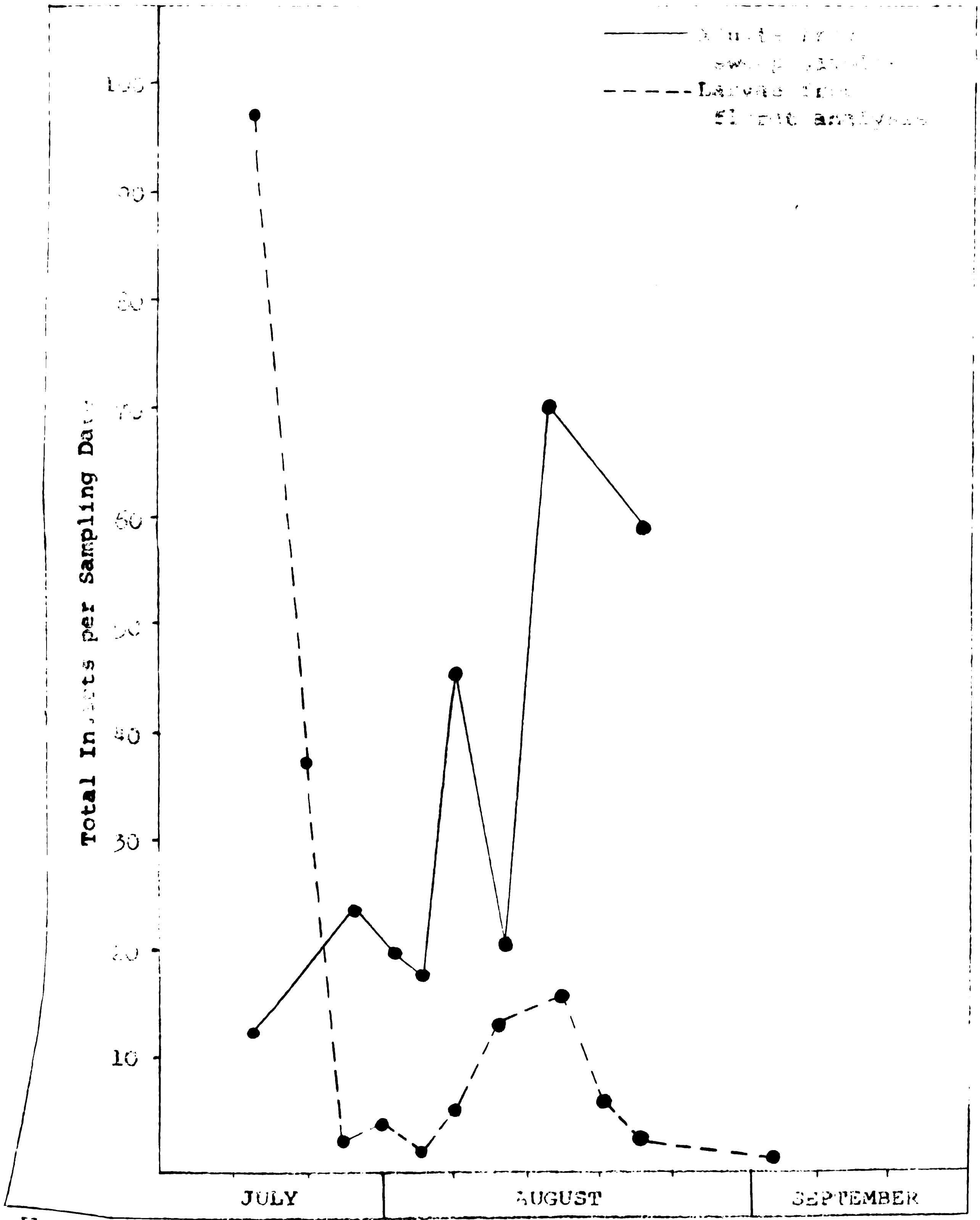


Figure [illegible]. Abundance and distribution of the clover seed chalcid at East Lansing, Michigan. 195[illegible].

No adult spittlebugs were taken in the sweep samples on June 3 however sweepings taken on June 10 produced nearly equal proportions of adults and nymphs. On June 15 no nymphs were taken in the sweep samples and the adult spittlebug population had attained its highest peak (Figure 6).

Leafhoppers.

The Potato Leafhopper, Empoasca fabae (Harr.), was the predominant leafhopper encountered in this study. On May 10, when the sweepings were started, a small population of the adult insect was present. A gradual increase was noted throughout the season until by the middle of August nearly 20 times the original number was present.

Smaller numbers of Cloanthus frontalis (VanD.), Aceratagallia sanguinolenta (Prov.), Macrosteles fascifrons (Stal.), Endria inimica (Say) and Paraphlepsius irroratus (Say), in their respective order of abundance, were also noted throughout the season.

Various species of immature leafhoppers were numerous in the samples and attained their highest numbers during the first week of June (Figure 6).

Aphids.

Elliott (1952) stated that injurious infestations of aphids had not been observed on red clover and that the greatest numbers appeared in the spring soon after the plants started new growth. This seemed to hold true in this study since the highest populations of aphids, predominately the pea aphid, Macrosiphum pisi (Harris), were recorded during the last week of May. A gradual tapering off occurred in June, and during July and August comparitively few aphids appeared in the sweepings. Two other aphids, Therioaphis trifolii (Mon.) and Anuraphis bakeri (Cowen), were also noted in the sweep samples.

Although Hottes and Frison (1931) stated that the English grain aphid, Macrosiphum granarium (Kirby), has been collected from red clover, the literature on red clover insects contains little mention of this aphid. On August 10 approximately 60 percent of the stems examined had infestations of from 1 to 40 English grain aphids. These aphids were found between the leaf stipules and the plant stem.

Plant Bugs.

An abundance of plant bugs, especially the tarnished plant bug, Lygus lineolaris (P. de B.), were observed in the

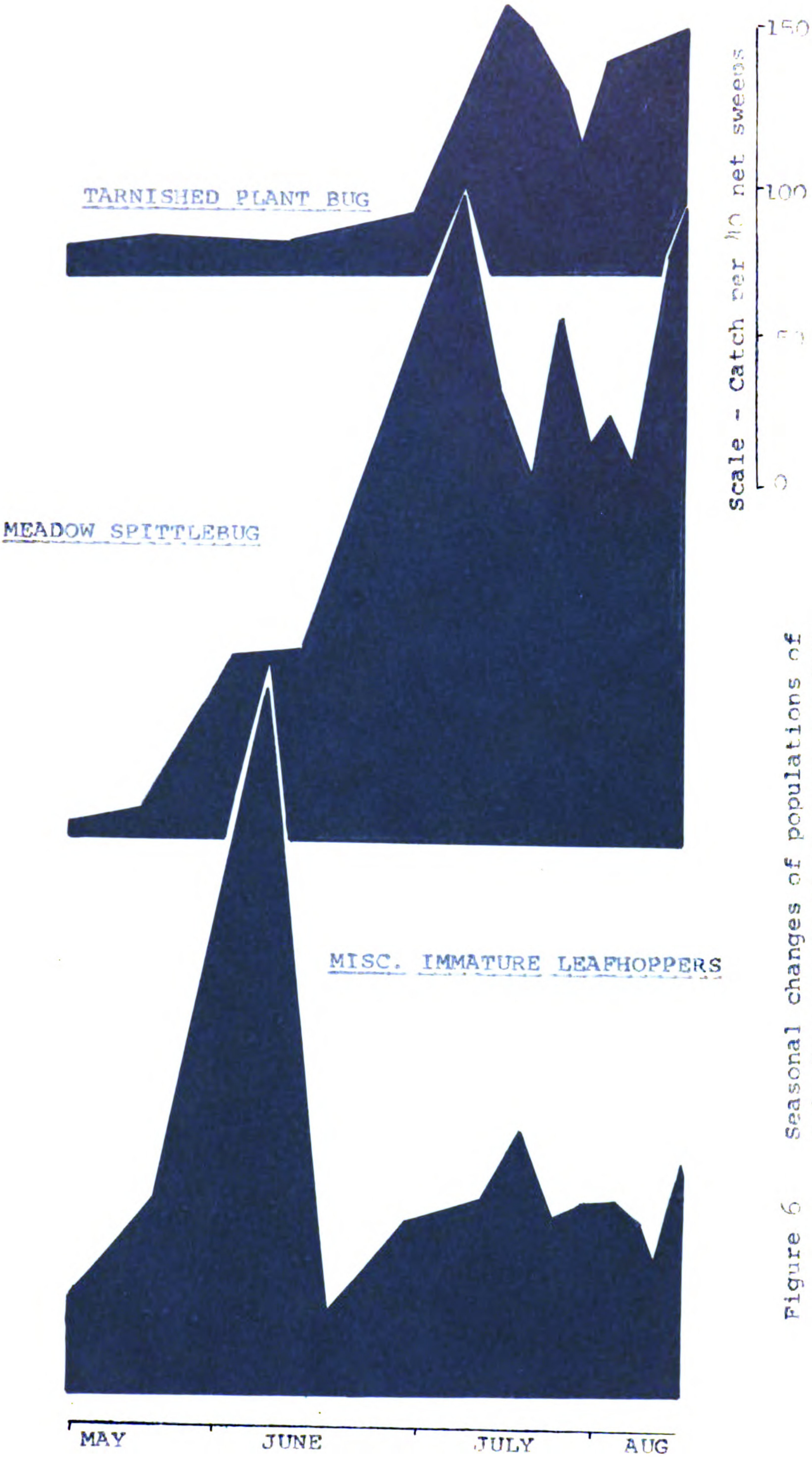


Figure 6 Seasonal changes of populations of red clover insects at East Lansing, Michigan. 1959.

field during the study. By the first week of August approximately 20 tarnished plant bugs were present in each sample and remained at this level for the remainder of the collecting period (Figure 6). Smaller numbers of Adelphocoris lineolatus Goeze and a few Adelphocoris rapidus Say were also collected throughout the season.

Immature plant bugs became numerous in the sweep samples as early as June 10 and by the second week in August 75 to 100 of these insects per sample was not unusual.

Evaluation of Chemical Control

Heptachlor Soil Treatment.

Meadow Spittlebug Control. The first difference observed resulting from the heptachlor application was the effect on the meadow spittlebug population. As early as May 21 it was possible to delineate the boundaries between the heptachlor and untreated replications simply by parting the clover plants and observing the numbers of spittle masses. In the untreated replications there were numerous masses in comparison with the heptachlor plots.

On June 2 a count was made of the numbers of spittle masses on a random sample of fifty stems collected from each replication. No spittle masses were recorded from the heptachlor treated areas. In the untreated areas 34 percent of the stems in replication II and 64 percent of the stems in replication IV contained from one to two spittle masses. An average of [illegible] spittle masses per stem was found in the untreated replications. Niemczyk and Guyer (1958) applied heptachlor at the same rate and achieved similar spittlebug control. Only one spittle mass (0.004 masses per stem) was found in an examination of 225 red clover stems collected from their heptachlor plots.

In the sweep samples taken between May 10 and June 10 a significant difference was found between the number of nymphs taken from the two replications. Not more than 5 nymphs per 20 sweeps were collected on a single sample date in the heptachlor replications while in the untreated replications as many as 60 nymphs per 20 sweeps were recorded. On June 15, approximately 6 days after the first adult spittlebug had been noted, 1114 adults were taken from 40 sweeps in the untreated replications and only 23 in an equal number of sweeps from the heptachlor treated areas.

<u>Clover Root Borer Control</u>. In July a preliminary check was made of plant roots to ascertain the effect of heptachlor on the root borer. A total of 20 plants were dug from each replication on July 1 and 3 and the roots examined for evidence of this insect. Only one of the 20 plants sampled from the heptachlor replications showed root borer damage, whereas every plant from the untreated replications was either infested with adult and larval root borers or showed considerable damage resulting from feeding and egg laying activities.

On September 13 a more thorough root examination was conducted in which 10 plants were dug at random from each plot. Final analysis showed that [illegible]0 percent of the 100 plants dug from the untreated replications were damaged while not a single plant was damaged in the heptachlor treated areas. In 1958 Niemczyk and Guyer obtained similar clover root borer control using the same rate of heptachlor. Gyrisco (1958) also lists heptachlor among the insecticides consistently giving good results in the control of this insect.

During this phase of the experiment a record was maintained of the number of roots which were neither damaged by the clover root borer nor the clover root curculio. Of the 100 plants dug in the heptachlor treatments 71 percent were entirely free of damage while, of an equal number sampled in the untreated replications, only 9 percent were free of damage.

<u>Clover Head Weevil Control</u>. The first indication of control of the clover head weevil was noticed in the May sweep samples. An average of 3 beetles per sweep were collected in the untreated replications and less than 1 beetle per sweep in the heptachlor replications. Except for the June 3 sample, in which approximately equal numbers of weevils were taken from all replications, this differential

not only remained but increased throughout the collecting period.

Interesting data were also secured on the clover head weevil larvae population at the time of the first clover head collection. On July 22, 400 clover heads were picked and placed in bottles to dry. On July 27, before dissection of the heads had taken place, an examination of the bottles revealed that the weevil larvae had crawled out of the heads and had dropped to the bottom of the jars. A count of these larvae, as presented in Table I, showed a total of 505 per 200 heads for the untreated replications, compared with 20 per 200 heads from the heptachlor replications.

An analysis of data from florets taken from heads collected between July 22 and September 2 showed that there were significantly fewer clover head weevil larvae in the heptachlor than in the untreated replications.

Thiodan Foliage Sprays.

<u>Meadow Spittlebug Control</u>. Sweep samples taken between May 10 and June 10 averaged 3 spittlebug nymphs per sweep in the control plots and 0.04 nymphs per sweep in the thiodan plots. Spittle mass counts conducted on May 2 supported the sweep data. No spittle masses were found on 50 stems selected

Table I. Number of clover head weevil larvae collected from drying red clover heads on July [illegible], 19[illegible], at East Lansing, Michigan.

Treatment	Number of Larvae per 10 Heads		Mean
Heptachlor	I	III	
Thiodan	0	9	
Thimet	0	1	
DDT-2 appl.	0	0	
DDT-1 appl.	1	5	
Control	4	[illegible]	
Total	[illegible]	[illegible]	0.1
No Heptachlor	II	IV	
Thiodan	62	44	
Thimet	-	38	
DDT-2 appl.	[illegible]	32	
DDT-1 appl.	20	29	
Control	56	32	
Total	[illegible]	175	2.5

at random from the thiodan plots while an average of 0.55 masses per stem were recorded from stems picked in the control plots.

From sweep samples taken on June 15, 5.5 adult spittlebugs per sweep were recorded from the thiodan plots as compared to 55 per sweep from the control plots. After June 16, the date of the first cutting, the adult spittlebugs migrated out of the field and thus prevented collection of further data.

Pea Aphid Control. An outstanding difference between the thiodan and control plots was noted in the pea aphid population during May (Table II). The thiodan plots averaged approximately 2 aphids per sweep compared with 26 per sweep in the control plots. As many as 1243 aphids were taken from 10 sweeps in a control plot while never more than 47 were collected from 10 sweeps taken in the thiodan plots.

Leafhopper Control. From May 19 to June 15 the control plots averaged 1.4 immature leafhoppers per sweep, approximately three times the number found in the thiodan plots. Nearly the same ratio existed in the sweep samples taken between July 20 and August 13.

Table 17. [illegible] foliage [illegible] May [illegible] from red clover plots at East Lansing, Michigan. [illegible]

	Control Plots			Thiodan Plots		
	Hept.	NoH	Total	Hept.	NoH.	Total
Tarnished Plant Bug	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Immature Mirids	3	[illegible]	[illegible]	2	[illegible]	[illegible]
Pea Aphid	[illegible]	[illegible]	7006	[illegible]	[illegible]	[illegible]
Spittlebug Adults	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]
Spittlebug Nymphs	12	[illegible]	[illegible]	[illegible]	[illegible]	7
Potato Leafhopper	[illegible]	[illegible]	[illegible]	126	[illegible]	[illegible]
Immature Leafhoppers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Clover Head Weevil	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Clover Seed Midge	4	9	13	[illegible]	[illegible]	[illegible]

Thimet Soil Treatment.

Clover Head Weevil Control. A reduction from 2 beetles per sweep to 0.1 beetles per sweep was recorded in the clover head weevil population immediately following the granulated thimet application. The numbers of clover head weevil adults remained consistently lower (Table III) in the thimet than in the control plots.

An analysis of florets taken from the heads collected between July 22 and September 2 showed an apparent trend towards a reduction in the number of larvae found in the thimet plots as compared to the control plots. This reduction was close to but not significant at the 5 percent level.

Clover Seed Chalcid Control. Only a small variation was recorded in the numbers of adult clover seed chalcids collected from the plots during this investigation (Table II).

An examination of florets during the head analysis showed that there was a significant difference between the thimet and control plots (Table IV).

Plant Bug Control. A decrease in the numbers of adult tarnished plant bugs occurred on the day following the

Table III. Number of foliage insects per 180 sweeps taken from July 20 to August 13 from red clover plots at East Lansing, Michigan. 1959.

	DDT-1 Plots			DDT-2 Plots			Thimet Plots			Control Plots		
	Hept	NoH.	Total	Hept	NoH.	Total	Hept	NoH.	Total	Hept	NoH.	Total
Tarnished Plant Bug	256	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Immature Mirids	15	35	50	4	7	11	48	231	[illegible]	[illegible]	[illegible]	[illegible]
Pea Aphid	53	160	[illegible]	[illegible]	43	[illegible]	17	[illegible]	71	[illegible]	[illegible]	[illegible]
Spittlebug (Adult)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	677	[illegible]
Potato Leafhopper	197	174	[illegible]	221	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Immature Leafhoppers	[illegible]	15	[illegible]	12	[illegible]	[illegible]	[illegible]	31	[illegible]	[illegible]	[illegible]	[illegible]
Clover Head Weevil	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36	[illegible]	[illegible]	[illegible]	214	[illegible]
Clover Seed Midge	61	117	178	111	144	[illegible]	[illegible]	92	187	[illegible]	[illegible]	[illegible]
Clover Seed Chalcid	25	25	50	51	31	[illegible]	[illegible]	33	67	[illegible]	[illegible]	[illegible]

thimet application, however later sweep samples showed little differences in populations between the thimet and control plots. The mobility of this insect and narrow plot width was probably responsible for the repopulation of plant bugs in the thimet plots. A more striking, residual effect was recorded for the less mobile immature forms of plant bugs. A complete absence of immature forms was recorded during the first week following the thimet application. For the remainder of the sweep period the total number of immature plant bugs taken remained consistently low in the thimet plots (Table II). On August 13, at the peak period of populations of these insects, the control plots averaged 9 bugs per sweep. This was approximately three times the average in the thimet plots (Figure 7).

Aphid Control. The rapid decline in the aphid population during June afforded little comparison of control between the various treatments, however at the time of the increase of these insects during the second week in August, the control plots contained eight times as many aphids as the thimet plots.

Complete control was achieved of *Therioaphis trifolii* (Mon.) in the thimet plots immediately following application.

Control plot samples taken during the same period contained from 0.1 to 1 Therioaphis trifolii per sweep.

On September 18 an examination of the stipules of the red clover leaves showed complete control of the English grain aphid, Macrosiphum granarium (Kirby), in the thimet plots. Approximately 60 percent of the stems in the control plots had infestations of from 1 to 40 aphids each.

Leafhopper Control Nearly complete control of potato leafhopper adults was recorded on the day following the thimet application (Figure 8). This sudden reduction in leafhoppers may have been due to the fumigation action of thimet as suggested by Cook (1959). A gradual increase was recorded until August 13, when the numbers of this insect in the control plots were comparable to those recorded in the thimet plots. Other adult leafhoppers (page 24) totaled between 0.1 and 0.2 per sweep in the thimet plots during the sampling period while the control plots averaged 1.6 leafhoppers per sweep.

The immature leafhopper population in the thimet plots was reduced from 4.5 per sweep on July 20 to 0.05 per sweep on July 22 and remained at the latter level for the remainder of the sampling period.

Table IV. Mean percent of red clover florets damaged by head infesting insects at East Lansing, Michigan. [illegible].

	Clover Seed Chalcid	Clover Head Weevil	Clover Seed Midge
Thiodan	[illegible] a b*	[illegible] a	[illegible] b
Thimet	[illegible] a	1.4 a b	[illegible] a
DDT-2 Applications	[illegible] a b	2.7 a b	7.[illegible] c
DDT-1 Application	2.3 a	1.0 b	5.4 a
Control	3.6 c	2.4 a b	5.2 a

*If two treatments do not have a common letter, then the treatments are significently different at the 5 percent level. If two treatments have a common letter, then they are not significantly different.

DDT Foliage Treatments.

Meadow Spittlebug Control. In spite of the mobility displayed by adult spittlebugs, sweepings taken from July 20 to August 13 had from 1.5 to 2 times as many of these insects in the control plots as in the DDT plots. From 1 to 2 adult spittlebugs per sweep were collected from the DDT plots as compared with 4 per sweep from the control plots.

Plant Bug Control. The population of immature plant bugs was almost eradicated in the plots receiving two applications of DDT. In those plots receiving one application of DDT, only an occasional immature plant bug was taken in the sweeps during July and August. During this same period as many as 9 immature plant bugs per sweep were taken from the control plots.

Clover Seed Midge and Clover Seed Chalcid Control. The examination of clover heads collected between July 22 and September 2 showed that the numbers of clover seed midge larvae present in the florets of the plots with 2 applications of DDT were significantly larger than the numbers collected in the control and other treatment plots.

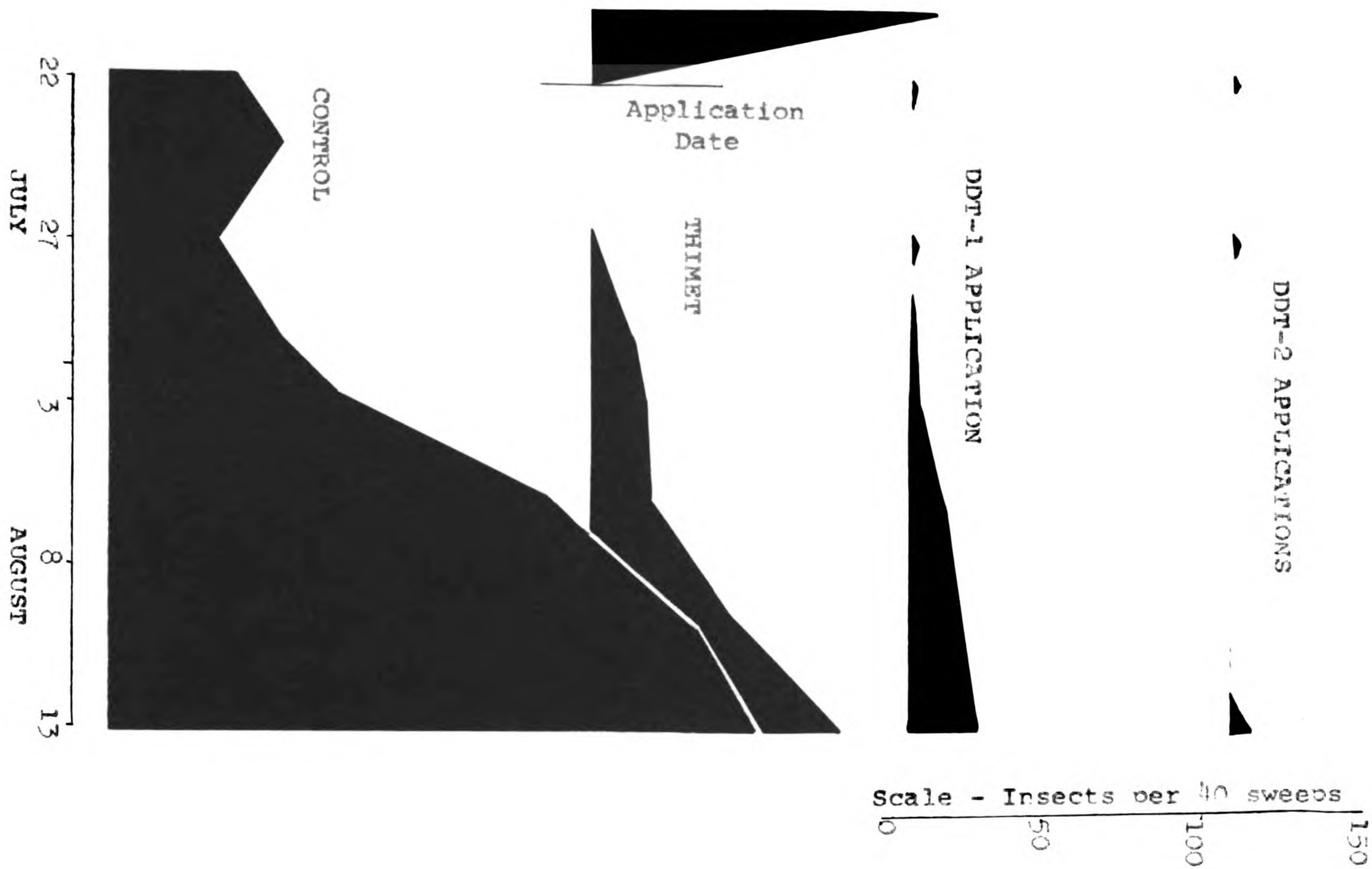


Figure 7. The effect of insecticide application on immature plant bugs at East Lansing, Michigan, 1959.

The numbers of clover seed chalcid larvae were significantly less in both DDT treatments than in the control plots.

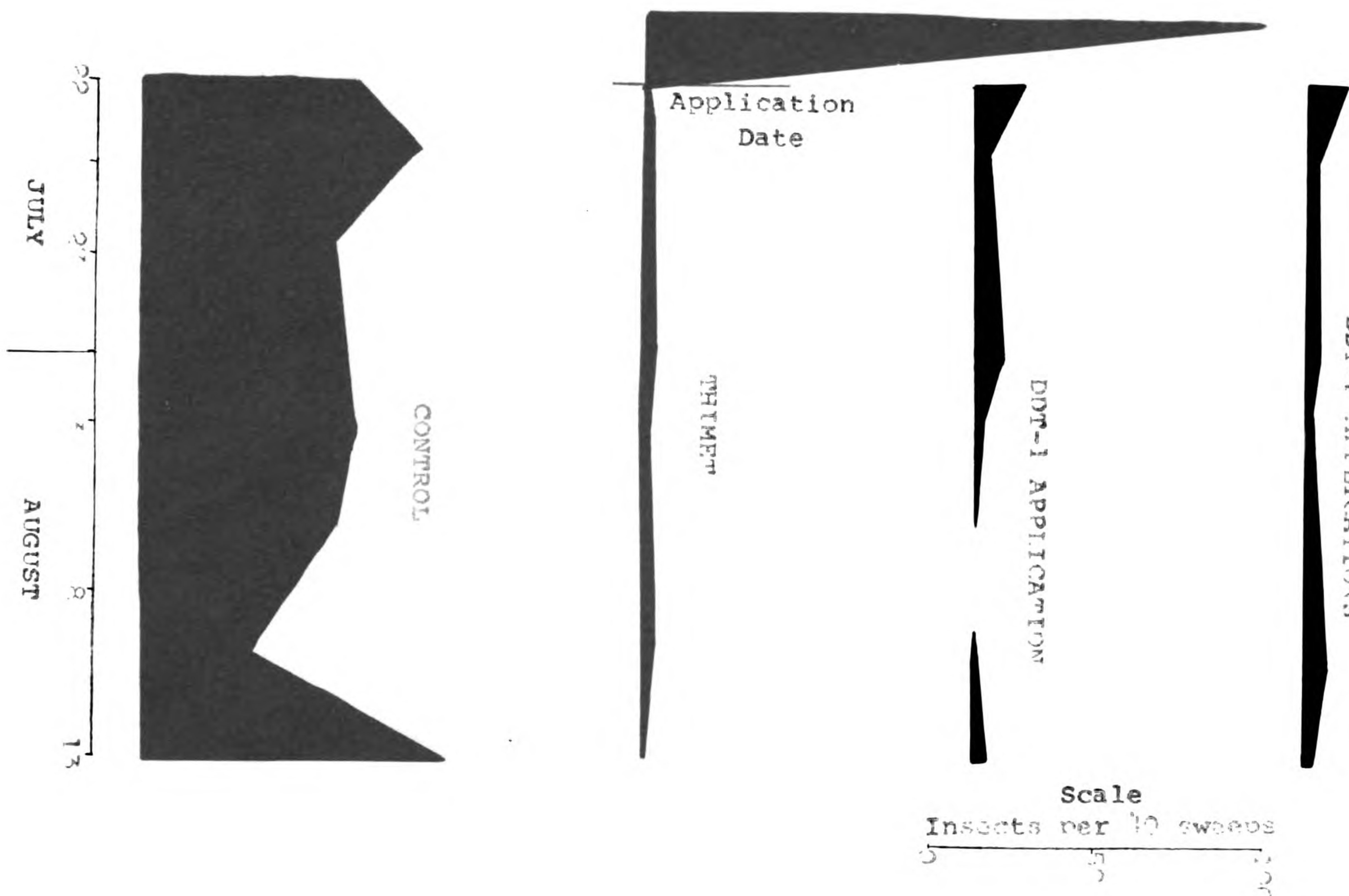


Figure 8. The effect of insecticide application on immature leafhopper populations at East Lansing, Michigan. 1959.

Plant Response to Insecticide Application

Forage yield measurements taken on the June 16 cutting showed that little variation existed between the amount of growth of the heptachlor and untreated replications. A very noticeable difference in plant height and amount of bloom existed between the heptachlor and untreated replications by July 19. At this time it was possible to distinguish the boundaries between the two replications from a considerable distance by the difference in the height of the plants and, at a shorter distance, by the amount of bloom present. By July 27 a difference of 2 to 5 inches existed between the two replications. In the untreated replications the plants averaged 9 to 10 inches while in the heptachlor replications the plants averaged 12 to 14 inches.

Plant stand counts taken on October 2 showed that a similar reduction in the numbers of plants had occurred between the two replications (Table V). A 42 and 41 percent reduction in the number of plants present per square yard, since the July 7 count, was recorded for the heptachlor and untreated replications respectively. A similar reduction in stand counts was recorded by Niemczyk and Guyer (1959). Stand counts taken by these workers the following spring

Table 7. Square yard plant stand counts taken July 9 (Column 1) and October 2 (Column 2) at East Lansing, Michigan. 19[illegible].

	A*		B		C		D		Plot Total		Repl. Total	
	1	2	1	2	1	2	1	2	1	2	1	2
Treatment No.												
I. Heptachlor												
3	73	24	[illegible]	23	72	[illegible]	41	40	196	103		
4	[illegible]	27	[illegible]	43	33	22	33	30	164	131		
1	63	33	41	41	71	34	37	20	212	140		
2	57	54	63	45	61	40	57	27	243	166		
5	62	30	70	52	56	31	41	41	229	163	1034	714
II. No Heptachlor												
3	54	27	70	34	46	28	64	23	234	118		
2	65	40	52	23	51	30	40	24	217	125		
5	76	47	66	[illegible]	67	[illegible]	[illegible]	47	[illegible]	[illegible]		
1	59	13	72	50	63	28	75	44	269	130		
4	47	[illegible]	[illegible]	[illegible]	[illegible]	23	51	34	131	130	[illegible]	702
III. Heptachlor												
2	64	17	32	[illegible]	68	30	40	21	263	103		
4	55	34	68	29	59	35	33	23	215	123		
5	66	24	54	21	73	30	56	33	248	108		
3	53	47	53	15	[illegible]	28	46	41	187	131		
1	67	27	53	19	67	24	60	39	257	106	1160	571
IV. No Heptachlor												
4	48	27	53	17	47	24	51	24	199	92		
1	54	19	47	17	43	21	49	21	193	78		
3	57	32	57	24	62	36	68	30	243	122		
2	50	30	49	12	92	40	63	34	244	127		
5	66	34	[illegible]	20	63	30	53	25	247	100	1123	[illegible]

*A-D indicates predetermined positions of square yard sampling areas (see Figure 1).

showed a significant difference between the heptachlor and control plots, with a 68 and 88 percent reduction respectively.

On August 3 striking differences could be seen between the bloom of the two replications. The heptachlor replications were in full bloom at this time while the untreated replications had an estimated 60 percent bloom. Square foot head counts taken on August 18 substantiated this observation for statistical analysis showed a significant difference at the 5 percent level between the two replications (Table VI). A significant difference at the 1 percent level was also found among the treatments and an interaction was shown between the foliage treatments and the heptachlor soil application. By the first week in July, when both replications were past full bloom and beginning to turn brown, these differences were only slightly noticeable.

From the middle of August until seed harvest an obvious difference was evident in the amount of weed growth present in the treated and untreated replications. Large patches of grass and broad-leaf weeds dominated much of the area in the untreated replications whereas only moderate amounts were scattered through the heptachlor replications. When the clover seed was cleaned in October, the untreated replications averaged 0.6 of a pound more weed seed than the heptachlor

Table VI. Square foot red clover head counts taken at East Lansing, Michigan. 1959.

July 30

	Hept. I	No H. II	Hept. III	No H. IV	Mean
Thiodan	[illegible]	15.3	14.5	11.6	[illegible]
Thimet	21.9	[illegible]	18.3	12.9	[illegible]
DDT-2 appl.	[illegible]	16.7	17.4	15.5	[illegible]
DDT-1 appl.	26.5	14.9	[illegible]	13.4	[illegible]
Control	[illegible]	17.4	[illegible]	13.4	17.7
Mean	[illegible]	15.3	[illegible]	13.3	

August 18

	Hept. I	No H. II	Hept. III	No H. IV	Mean
Thiodan	37.7	30.5	30.1	26.9	33.5
Thimet	34.1	24.0	31.7	34.7	31.1
DDT-2 appl.	27.7	27.2	31.0	23.6	[illegible]
DDT-1 appl.	37.8	31.7	30.2	25.6	31.7
Control	32.5	25.0	40.4	26.6	31.1
Mean	22.4	16.3	17.1	13.3	

replications. This could perhaps be attributed to the fact that the slower growth of the clover in the untreated replications gave less competition to the grass and weeds.

Statistical analysis did not reveal a significant difference between the seed yield in the heptachlor and untreated replications. The difference that existed, however, was close to significance at the 5 percent level. Actually the heptachlor treated plots averaged 5.05 pounds (92 pounds per acre) as compared with 4.00 pounds (74 pounds per acre) in the untreated replications (Table VII).

Table VII. Pounds of cleaned red clover seed harvested per 1/1[illegible] acre plot at East Lansing, Michigan. 1959.

	Heptachlor I.	Heptachlor III.	No Heptachlor II.	No Heptachlor IV.	Treatment Mean
Thiodan	5.63	4.34	3.48	3.45	4.3[illegible]
Thimet	4.8[illegible]	4.74	4.50	4.20	[illegible]
DDT-2 applications	4.11	5.29	4.90	4.41	4.65
DDT-1 applications	5.90	5.61	4.12	4.47	5.00
Control	4.52	5.31	3.74	3.60	4.31
Replication Mean	5.05		4.08		

SUMMARY

In 1959, an investigation was conducted at East Lansing, Michigan, to study the biology of the major red clover insects and evaluate their chemical control. The results indicate that:

1. Both the clover root borer and the clover root curculio were important soil pests associated with the clover roots.

2. Meadow spittlebugs, leafhoppers, plant bugs, aphids and miscellaneous foliage pests were consistently present during the investigation.

3. The clover seed chalcid, clover head weevil and clover seed midge were the important head infesting insects.

4. The application of heptachlor to the soil reduced the damage from the clover root borer and the clover root curculio.

5. Fumigation as well as systemic activity from the application of granular thimet to the soil was suggested by a reduction in the numbers of clover head weevils, plant bugs, aphids and leafhoppers on the day following treatment.

6. Both soil application of heptachlor and foliar

treatments of thiodan eliminated spittlebug populations.

7. DDT reduced the infestation of clover seed chalcid larvae and the populations of plant bugs, spittlebugs and leafhoppers.

8. A reduction in the pea aphid population was obtained by the application of thiodan sprays.

9. Soil application of heptachlor increased the height and bloom of the clover plants as well as seed production.

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