ECOLOGICAL STUDIES OF

TOXOPTERA GRAMINUM (RONDANI)

By

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Bachelor of Science

East Central State Teacher's College

Ada, Oklahoma

1934

A THESIS

Submitted to the Department of Entomology

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

For the Degree

MASTER of SCIENCE

1939

ECOLOGICAL STUDIES

OF

TOXOPTERA GRAMINUM (RONDANI)

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PREFACE

Reports of green bug infestations began coming to the Department of Entomology of the Oklahoma Agricultural and Mechanical College during the latter part of March. Observations revealed a sure epidemic in certain areas, and presented chances for ecological studies.

At the suggestion of Dr. F. A. Fenton, Head of the Entomology Department, the writer began ecological studies concerning the green bug, in small-grain fields situated between Perkins and Ripley, Oklahoma, on March 31, 1939. Termination of the infestations, and consequently of the studies, was May 8, 1939.

This thesis presents data collected by the writer and L. G. Duck who made the field studies when the writer was incapacitated. Since numerical relations between green bugs, their parasites, and predators have not been reported in literature, this type of study was made.

Appreciation of aid in preparing this thesis is accorded the following individuals:

1. Dr. F. A. Fenton, in charge of thesis, who supervised the field studies and writing of the thesis, making numerous valuable suggestions.

2. Dr. F. E. Whitehead gave information concerning the infestation in other counties, and suggested essential changes in presentation of data.

3. Professor C. E. Sanborn afforded the writer assistance concerning the history of infestations in Oklahoma.

4. L. G. Duck made field studies on days when the writer was not able to do so.

5. J. M. Maxwell provided the writer with data concerning specific counties in which infestations occurred, and the extent of damage.

6. Mrs. Elsie Hovey typed the approval copies of the thesis.

7. Mrs. Marie Fisher assisted in making graphs.

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INTRODUCTION

Toxoptera graminum (Rondani), of the order Homoptera and family Aphididae, is most commonly known as the "green bug of wheat". C. Rondani, in 1852 in Italy, described this insect, giving it the name Aphis graminum. Besides the previously mentioned common nomenclature, we also find "spring grain-aphis", "spring grain-louse", and "wheat louse" used in literature.

This pest, which feeds almost exclusively on members of the grass family, especially the small-grains, is commonly considered much more injurious in proportion to numbers than other grain aphids. Secretion of a chlorophyll-destroying enzyme is said possibly to contribute largely to the economic importance of Toxoptera graminum. Estimated loss to grains in the year 1907, the worst green bug epidemic on record, was $15,000,000. In particular areas during years of infestations, there are heavy losses; such was the case of the 1939 spring infestation in Kay County, Oklahoma where oats, wheat, and barley crops were destroyed to the extent of an estimated 19,350 acres, according to Kay County Agent, Hutchinson. Reports showed that 33 other counties in Oklahoma had green bug outbreaks, destroying an estimated total of 96,095 acres of oats, barley, and wheat in the State.

GEOGRAPHIC DISTRIBUTION

Recorded distribution of the green bug includes large parts of North America, Europe, Asia, Africa, and Argentina in South America, greatest injury generally occurring in southern United States, Italy, Hungary, southern Russia, and South Africa.

General distribution in North America includes practically all of

the United States, the grain-growing regions of South Canada, and parts of Mexico. Greatest damage has always been in the states of the Great Plains Biome west of the Mississippi River.

OBJECTS AND PLAN

Purposes of this work are to make scientific observations in the field regarding interrelations of the green bug (Toxoptera graminum), its chief parasite (Lysiphlebus testaceipes), and the chief predator (Hippodamia convergens). Further information is gathered concerning these interrelations as correlated with weather conditions, chiefly temperature, rainfall, and wind.

Small-grain fields with the characteristic more or less circular spots showing green bug infestations were picked for these studies.

New features of these data are that there will be shown a definite numerical relationship during an infestation of the pests, parasites, and predators, correlated with weather. Heretofore there have merely been generalized statements concerning the prevalence of the pests, parasites, predators, and the weather conditions.

REVIEW OF LITERATURE

History of Toxoptera graminum Outbreaks in Oklahoma

Distribution of infestations in 1890, 1901, and 1907 are discussed by Webster and Phillips (17):

1. In 1890 and again in 1901, the green bug did considerable damage to oats and wheat, occurring, during 1890, in the regions of the present Jackson, Tillman, Cotton, Jefferson, Stephens, Comanche, Kiowa, Creek, Payne, Lincoln, and Okfuskee counties.

2. Areas constituting the present Ottawa, Craig, Major, Garfield, Kingfisher, and Logan counties had an outbreak in 1901.

3. The worst green bug epidemic in history occurred in 1907, during which the pest was epidemic in practically the entire state of Oklahoma, not being epidemic in all or parts of Cimarron, Harmon, Jackson, Greer, Beckham, Roger Mills, Ellis, and Texas counties.

Kelly (9) gives a more or less generalized account of this pest during the spring of 1916, giving the information that would suggest its occurrence in numbers in Kay, Grant, Garfield, Kingfisher, and possibly other bordering counties. C. E. Sanborn, Professor Emeritus of Entomology at Oklahoma A. and M., verifies the statement of counties showing infestations in 1916 and adds Noble and Payne counties to the list. Sanborn further stated that the infestation apparently began from eggs hatching in Alfalfa County, a northwest wind carrying winged forms toward the southeast.

A heavy infestation during 1921 in Oklahoma, Logan, Noble, and Tulsa counties was reported by Hyslop (8).

Very minor outbreaks must have occurred in small sections of Oklahoma in 1926, because literature makes reference to such as occurring in the northern part of the state, but no definite data have been found as to counties in which infestations occurred. Presumedly these were such as Kay, Grant, Garfield, and Noble, but this is not definite, therefore is not shown in Fig. 1.

Hixson (6) reported Noble, Kay, Kingfisher, Major, Logan, Caddo, and Nowata counties as areas of outbreaks in 1934.

Fenton (4) reported infestations in Caddo, Kiowa, Comanche, Tillman, and Cotton counties in 1937.

FIGURE 1. YEARLY DISTRIBUTION OF GREEN BUG OUTBREAKS

During the spring of 1939, possibly the most complete check on green bug infestation areas in the history of Oklahoma was made. This check included an aerial survey by Dr. F. E. Whitehead and questionnaires to County Agents. The total number of counties in which green bugs did damage was 34, heaviest being in Kay, Noble, Tulsa, Rogers, Creek, Osage, and Garfield. Other counties are indicated in Fig. 1 which shows the counties in which there have been rather epidemic green bug infestations, and the years of occurring.

Temperature Effects

General. According to Sanborn (12), "If, when winter weather breaks, we have a spring with temperatures ranging not lower than 50 degrees F., mean, the prospects will be in our favor because the parasite will control the green bug before it can become serious." "If, when cold weather breaks, the temperature fluctuates above and below 50 degrees F., mean, the green bug will do severe damage because the parasite will be more or less inactive and unable to multiply rapidly. The green bug, under such conditions, will be able to develop and multiply rapidly."

Green Bugs Specifically. English (3) observed green bugs in Oklahoma giving birth to young when the temperature was below freezing.

Sanderson (13) states that green bug development takes place at 1.65 degrees C. (34.97 degrees F.), mean, the critical point (death) for the pest is -8.33 degrees C. (17 degrees F.), and reproduction may actually take place at a daily mean of -7.8 degrees C., being frequent at a daily mean of 0 degrees C.

Wadley (14) found that green bug development occurred from 7 degrees C. (44.6 degrees F.) to 33 degrees C. (91.4 degrees F.), being most rapid at about 30 degrees C. (86 degrees F.), and maximum reproduction was at approximately 22 degrees C. (71.6 degrees F.). Green bugs are quickly killed at 15 degrees C. (5 degrees F.) or as high as 42 degrees C. (107.6 degrees F.). At temperatures less extreme yet still above or

below the range of development, death was slower. Wheat and oats were observed to be unsatisfactory food after the heading stages.

Observations by Wadley (14), in a greenhouse compartment heated accidentally over 100 degrees F., were that some green bugs on oats growing in a flower pot standing on soil, left the plants and clustered on soil under the pot. In another case, in a cage kept at 40 degrees C., the aphids left the plants for the soil; when the soil became dry, they returned to the plants. Heat avoidance is suggested as a feature of their behavior, and may possibly be related to their root-inhabiting noted in hot climates.

It was found by Webster and Phillips (17) that the maximum number of young produced by a single alate green bug was 44 and the minimum was 10, with an average of 28. The maximum number of young produced by a single apterous green bug was 61 and the minimum was 4, an average of 34.25.

To understand the rapid increase in numbers of green bugs, the following observations of Wadley (14) together with previously mentioned reports give valuable information:

1. Wingless females occur most abundantly and constantly.

2. Winged females produce nearly all wingless, while wingless produce both winged and wingless.

3. Nymphs go through 4 instars in about 1 week of summer temperatures. Advanced embryos occur in late fourth instar nymphs.

4. Apterous parthenogenetic females may begin reproduction within a few hours after the last molt; winged females usually do not reproduce until 24 to 48 hours after the molt.

A Parasite (Lysiphlebus testaceipes) Cresson. Sanderson (13) stated that development takes place in this parasite at 4 degrees C. (39.2

degrees to 41 degrees F.). Although development may take place at such a low temperature, evidence shows that it is not active at such a low temperature, that is, it has little or no effect in control of the green bug.

> Webster and Phillips (17): "Probably the whole secret of these disastrous outbreaks of Toxoptera lies in the fact that this parasite is not active in a temperature much below 56 degrees F., while, as has already been shown, the aphis begins to reproduce in a temperature at or slightly below 40 degrees F., a probable difference of at least 16 degrees."

Phillips (10) reports that this parasite reproduces parthenogenetically, which fact furthers its ability as a parasite.

Rainfall and Humidity Effects

Wadley (14) stated that in Texas, Oklahoma, and Kansas, winter and spring rainfall in the four most serious green bug years have been about normal or a little below, never much above. During fall and winter of 1926, green bugs were widely distributed over Oklahoma, southern Kansas, and northern Texas, but heavy rains fell in January and again in April in northern Texas and southern Oklahoma, damage not developing there. In southern Kansas, northern Oklahoma, and New Mexico, it remained dry, and injury was severe.

Equal rains probably have stronger controlling action in cool than in warm weather, because losses are replaced by reproduction more slowly when cool, (Wadley (14)).

Headlee (5) found that Toxoptera graminum was little affected by relative humidities ranging from 37 to 100 per cent. Wadley (14) furthers this belief with the statement that sap-feeding insects evidently are not affected directly by the amount of humidity; the indirect results of such are in connection with precipitation and food supply.

Field Preparation and Time of Planting

Bilsing (1) suggests that early sown wheat affords good protection for green bugs and therefore should be avoided whenever possible.

According to Webster (16), self sown grain should be destroyed by grazing in late autumn or early winter, as this measure will destroy the primary breeding grounds of green bugs and Hessian flies.

Good farming, suggests English (2), is the best method known to lessen the ravages of this pest; such would include rotation, manure, legumes, early deep-plowing, and good seeds. Also he observed that the green bugs were as plentiful on rank wheat as other, but thrifty rank wheat did not succumb.

ENVIRONMENT

Time

This study began March 31, 1939 and continued at designated intervals through May 8, 1939. The observations were made and recorded on the designated dates between 1:00 and 5:00 P. M.

Place

Small-grain fields, infested with the green bug, situated near the highway between Perkins and Ripley were chosen as study fields. Fields occurring near these were investigated as to variety of grains and times of planting.

Weather Conditions During the 1939 Infestation

Near Stillwater, Oklahoma

Weather data were obtained from the United States Weather Bureau, Wahlgren (15). Figs. 6 to 12 inclusive each show daily maximum and

minimum temperatures during infestation studies. Departures in °F. from monthly mean temperature normals are shown in Fig. 2. Departures in inches from monthly normal rainfall are shown in Fig. 3.

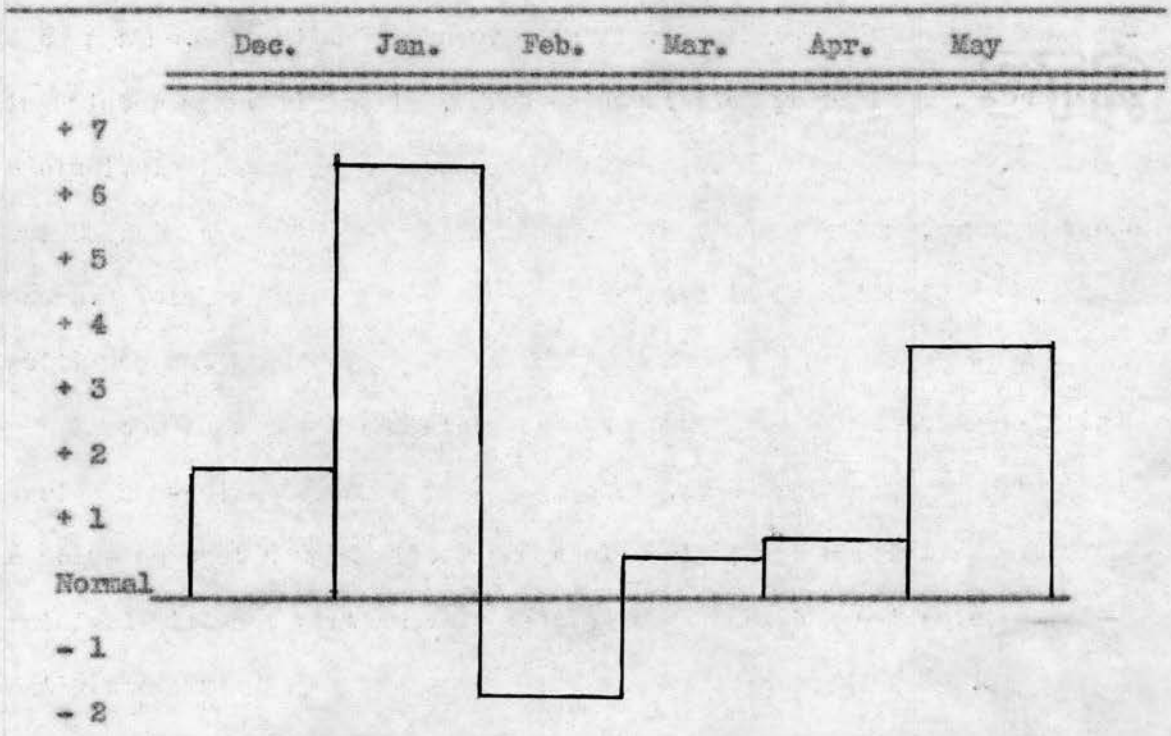


FIGURE 2. MEAN TEMPERATURE DEPARTURES FROM NORMAL NEAR STILLWATER, OKLAHOMA; DECEMBER, 1938 TO JUNE, 1939

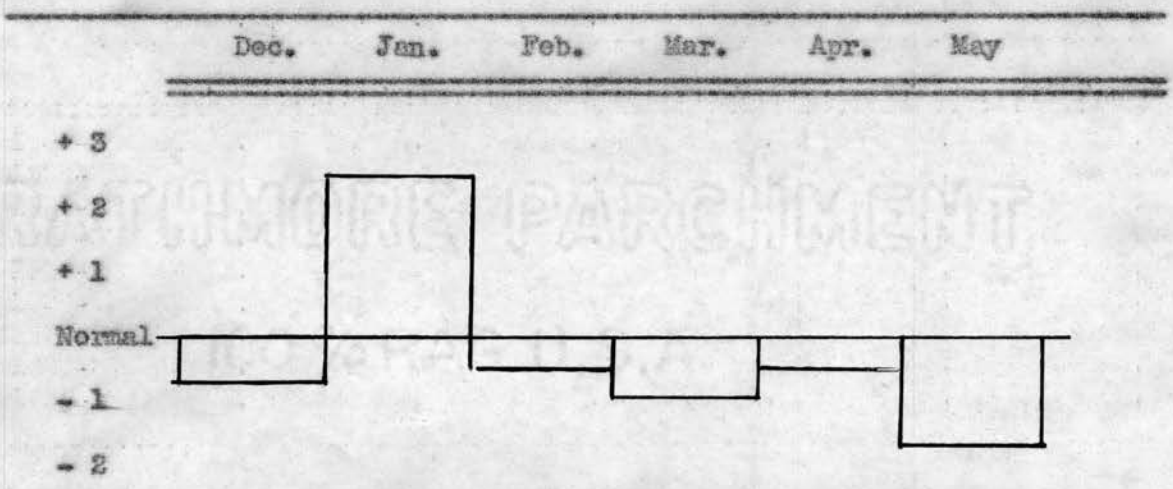


FIGURE 3. MEAN RAINFALL DEPARTURES FROM NORMAL NEAR STILLWATER, OKLAHOMA; DECEMBER 1938 TO JUNE 1939

December of 1938 was warmer than average and was abnormally dry, only 0.42 inch of rain. There were only a few days with mean temperatures below seasonal normal. Subsoil moisture was reported deficient over the state as the month closed. Only 1.75 inches of snow fell, this total being deposited on two separated days.

January was very warm compared to the normal and also had above average rainfall, 3.42 inches. Snow fell on three scattered days, giving a total of 2.25 inches for the month. Prevailing wind was from the southwest.

February was a little below normal temperature, and rainfall was at a minimum, 0.61 inch, as well as was snow, 0.5 inch in one day. Southwest wind prevailed.

March temperature was slightly above normal and rainfall was considerably below normal, 1.09 inches. Southwest wind prevailed.

April was cool, being only slightly above normal temperature. Rain total of 3.64 inches was slightly below normal, but occurred on three consecutive days. Rain occurring on April 4, 5, and 6 was 1.44, 1.70, and 0.50 inches respectively. Important is the fact that these rains were particularly heavy, not slow showers. Southwest wind prevailed.

The first eight days of May were consistently warm, no rain fell until the night of the 8th. Southwest wind prevailed during these days.

Progress of Infestation

Reports of green bug infestations in small-grain fields were being made during the latter part of March. Infestations were said to be present in Pontotoc, Murray, Payne, Logan, and Kay counties, heaviest

being in the latter county. Final check in Oklahoma disclosed 34 counties had infestations (Fig. 1), according to J. M. Maxwell, Assistant Extension Entomologist, Oklahoma A. and M. College.

The infestations between Perkins and Ripley, that were studied, were rather heavy March 31 when the writer's studies began, gradually increasing until about the middle of April, at which time the parasites and predators, aided by favorable temperatures, effected considerable decrease in the numbers of green bugs. This decrease continued until May 8, at which time no green bugs could be found in any of the fields studied.

There were, however, small-grain fields which were nearly completely destroyed before May 3, one of these being plowed under and planted in corn on May 6. This particular barley field would not have made decent pasture at the time it was plowed under. The three other small-grain fields known to be plowed under early were all in barley, no fields of wheat or oats being so infested that such be necessary. A general consensus of opinion of farmers in the area of the study fields reveals that a great deal more injury was done to barley this year than to wheat or oats.

TECHNIQUE

In the six green bug-infested small-grain fields between Perkins and Ripley, Oklahoma, which were chosen for study, more or less circular areas of green bug infestation were located; five such areas were staked off in each field except Field No. 1, where only three such areas were located. These stakes were placed at points between the plants which had already succumbed to the attack and those which were heavily

infested, but upright and alive. Each field was numbered, facilitating the keeping of data by field number instead of extensive description of location. Each point (circular area of infestation) staked off in each field was also numbered.

From each point in each field, random samples of green bugs were taken by placing samples of infestation (on leaves) in vials of alcohol. These were brought to the laboratory and observed under a binocular, making counts of the relative numbers of alate and apterous (whether parasitized or unparasitized), and parasitized green bugs. Percentages of these forms were calculated from these data.

Numbers of lady beetle (Hippodamia convergens Guer.) larvae, pupae, and adults were recorded at two locations in each of the infested points studied. These data were later compiled for each field to arrive at an average number of particular forms per three feet of plants.

An additional type of study was not begun until April 13, 1939, at which time an attempt to determine the percentage of green bug-infested leaves was made. These estimates were made by taking 50 random host plant leaves and counting the number of leaves with green bug colonies on them. Such counts were made at each infested point studied as to per cent infested in inner, middle, and outer rows. Inner rows consisted of those three rows which might be next to succumb to the green bug attack (those which were still upright, but most heavily infested). Middle rows were the next three out from the inner rows, and the outer rows were the next three from the middle. A diagrammatic sketch (Fig. 4) may better show these regions.

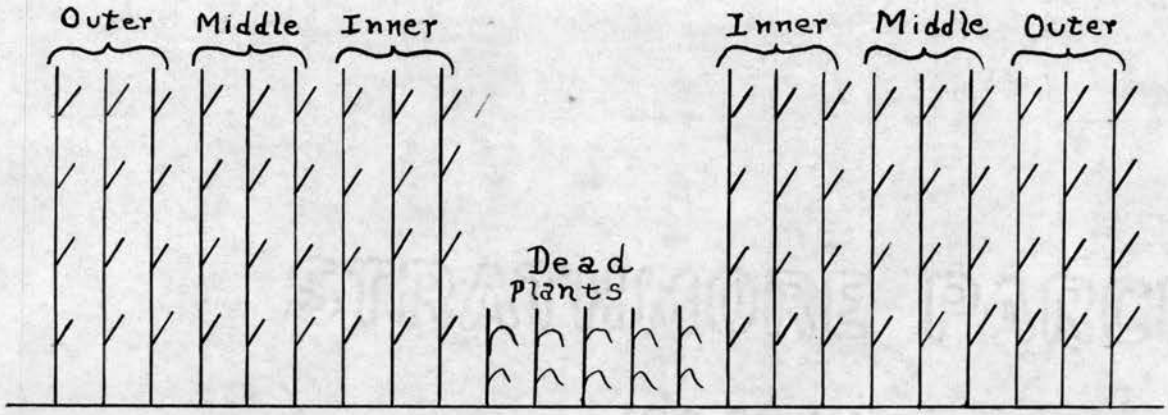


FIGURE 4. DESIGNATION OF ROWS FOR DATA CONCERNING PERCENTAGE OF LEAVES INFESTED.

DATA

Tables of Field Data

Data on the proportion of alate green bugs (Toxoptera graminum), percentage of parasitization of green bugs by Lysiphlebus testaceipes, comparative populations of the larval, pupal, and adult stages of lady beetles (Hippodamia convergens), and the percentage of infested leaves are shown in Tables I to V inclusive. These same data are later presented graphically in Figs. 6 to 10 inclusive. Following the tables, separate discussions of field preparations, infestations, parasitization, predators, and weather phenomena are evaluated.

An explanation concerning percentage of alate green bugs, listed in Tables I to V inclusive, is needed. The figures given for percentage of the winged forms includes both parasitized and unparasitized aphids.

TABLE I. ECOLOGICAL STUDY OF THE GREEN BUG, ITS PARASITE (*LYSIPHLEBUS TESTACEIPES*), AND ITS PREDATOR (*HIPPODAMIA CONVERGENS*) IN FIELD NO. 1, PAYNE COUNTY, OKLAHOMA, 1939

	Percentage Green Bugs		Av. No. Lady Beetles per 3 Feet of Plants			Percentage Leaves Infested		
Date	Alate	Parasitized	Larvae	Pupae	Adults	Inner rows	Middle rows	Outer rows
3-31	2.6	1.1	15.0	0.0	0.5			
4-3	3.9	7.7	24.0	0.8	1.0			
4-6	8.1	10.3	14.0	1.3	1.0			
4-7	8.6	8.5	37.0	8.1	1.3			
4-8	11.4	10.6	22.0	8.0	0.7			
4-10	10.8	9.5	19.0	23.0	0.5			
4-11	8.3	2.7	11.0	23.0	0.3			
4-12	14.8	3.9	16.0	35.0	0.5			
4-13	10.0	2.4	8.0	26.0	0.3	78.0	32.0	3.3
4-14	9.5	3.1	6.0	21.0	0.7	75.3	30.0	4.7
4-15	6.4	6.4	2.3	15.0	1.8	66.0	30.7	3.3
4-18	7.1	7.4	3.1	16.0	7.0	20.7	13.3	2.0
4-19	9.5	10.1	1.3	12.0	3.0	26.7	8.7	1.3
4-20	8.7	10.9	1.7	12.7	3.5	31.3	12.7	2.7
4-21	8.0	10.4	0.7	8.8	3.7	22.7	6.0	0.7
4-23	9.8	10.8	2.1	5.7	14.1	19.3	6.7	1.3
4-24	10.2	10.6	3.5	16.5	4.5	26.0	9.3	4.0
4-25	10.3	10.8	2.7	6.7	22.8	25.3	10.0	0.7
4-26	12.3	18.7	2.7	5.2	22.8	24.0	7.3	1.3
4-27	11.2	24.8	2.2	8.7	15.0	24.7	7.3	2.7
4-28	11.8	31.2	1.7	5.8	11.6	15.3	10.0	4.7
4-30	11.3	43.2	2.2	2.8	11.0	11.3	6.7	2.7
5-1	13.1	60.0	0.8	2.2	7.3	5.3	2.7	0.0
5-2	10.7	59.5	1.2	2.0	6.0	2.7	0.7	0.0
5-3	9.1	56.4	0.3	1.0	3.0	2.7	0.7	0.0
5-5	5.5	38.3	0.3	0.7	2.5	1.3	0.0	0.0
5-8	?	100	0.2	0.2	1.3	0.0	0.0	0.0

TABLE II. ECOLOGICAL STUDY OF THE GREEN BUG, ITS PARASITE (LYSIPHLEBUS TESTACEIPES), AND ITS PREDATOR (HIPPODAMIA CONVERGENS) IN FIELD NO. 2, PAYNE COUNTY, OKLAHOMA, 1939

	Percentage Green Bugs		Av. No. Lady Beetles per 3 Feet of Plants			Percentage Leaves Infested		
Date	Alate	Parasitized	Larvae	Pupae	Adults	Inner rows	Middle rows	Outer rows
3-31	3.3	10.3	6.6	0.0	0.0			
4-3	11.1	20.9	17.7	6.8	0.0			
4-6	11.3	23.4	8.0	3.2	0.0			
4-7	8.0	25.7	18.7	6.4	0.2			
4-8	9.4	25.3	16.4	5.8	0.1			
4-10	9.5	31.8	18.6	20.1	0.2			
4-11	8.6	24.4	14.6	20.6	0.6			
4-12	7.4	29.6	6.3	15.8	0.1			
4-13	3.4	28.9	3.3	23.6	0.1	87.2	55.2	11.2
4-14	4.3	27.7	3.0	22.4	0.6	87.2	56.4	16.0
4-15	4.7	33.4	1.8	20.7	0.6	33.8	20.4	5.0
4-18	3.0	62.0	2.2	14.1	2.2	13.6	9.2	3.6
4-19	2.3	69.8	2.1	14.9	1.4	16.0	12.0	4.4
4-20	3.4	57.5	1.7	13.0	2.5	19.6	10.4	2.0
4-21	3.9	61.5	0.7	9.0	3.6	14.0	9.6	2.0
4-23	5.3	57.3	1.5	5.0	5.1	13.6	7.2	0.4
4-24	5.1	50.5	2.7	13.6	3.0	12.8	5.6	1.6
4-25	5.3	66.9	2.0	5.4	6.1	14.4	4.0	0.4
4-26	7.4	66.1	2.3	5.3	6.7	14.0	4.0	0.0
4-27	7.4	62.9	2.4	6.7	12.8	12.0	5.6	0.8
4-28	8.9	67.7	1.3	3.7	10.4	7.2	2.8	0.0
4-30	7.0	68.1	1.2	2.7	8.9	6.4	2.4	0.0
5-1	11.3	71.6	0.6	0.9	3.3	2.0	0.0	0.0
5-2	9.4	64.5	0.4	1.4	3.9	0.4	0.0	0.0
5-3	?	100	0.2	0.8	2.8	0.0	0.0	0.0
5-5	-	100	0.2	0.6	1.9	0.0	0.0	0.0
5-8	-	100	0.0	0.2	1.0	0.0	0.0	0.0

TABLE III. ECOLOGICAL STUDY OF THE GREEN BUG, ITS PARASITE (*LYSIPHLEBUS TESTACEIPES*), AND ITS PREDATOR (*HIPPODAMIA CONVERGENS*) IN FIELD NO. 4, PAYNE COUNTY, OKLAHOMA, 1939

	Percentage Green Bugs		Av. No. Lady Beetles per 3 Feet of Plants			Percentage Leaves Infested		
Date	Alate	Parasitized	Larvae	Pupae	Adults	Inner rows	Middle rows	Outer rows
4-3	5.2	0.0	12.5	0.5	0.0			
4-6	6.2	1.8	3.5	0.5	0.0			
4-7	7.0	2.1	1.4	1.2	0.0			
4-8	4.5	2.5	3.4	2.1	0.1			
4-10	3.9	3.8	2.7	3.6	0.2			
4-11	5.3	2.2	2.9	5.4	0.5			
4-12	17.1	4.5	2.3	8.7	0.1			
4-13	3.3	4.5	1.2	9.2	0.0	46.0	26.4	11.2
4-14	3.4	2.7	0.9	9.6	0.4	48.4	25.6	6.8
4-15	3.3	9.0	0.9	9.5	0.7	40.0	21.6	6.4
4-18	4.5	12.7	1.1	8.8	0.7	28.0	18.8	8.0
4-19	10.2	9.6	1.5	5.5	1.2	30.4	18.8	10.0
4-20	10.3	11.8	1.5	6.6	1.4	33.2	17.2	6.0
4-21	9.5	19.0	1.0	4.7	1.6	28.8	16.0	6.4
4-23	6.9	16.0	0.8	3.0	5.3	30.0	16.8	7.2
4-24	5.7	11.8	0.8	3.7	8.0	32.0	16.8	6.0
4-25	7.0	22.1	2.9	5.1	10.2	31.6	16.0	8.0
4-26	8.3	26.1	2.7	4.8	10.0	32.4	15.6	6.4
4-27	7.9	29.5	2.5	4.8	9.9	32.8	17.2	3.6
4-28	9.8	37.1	1.3	3.7	7.5	31.6	18.4	4.0
4-30	10.8	47.4	1.5	2.5	5.8	22.8	14.8	4.0
5-1	10.8	58.3	1.0	3.2	5.0	14.4	9.2	2.8
5-2	8.8	54.0	0.9	2.3	4.3	6.8	4.4	1.2
5-3	8.2	60.5	0.6	1.7	3.4	2.8	1.6	0.0
5-5	6.2	37.5	0.3	1.2	3.0	2.0	0.4	0.0
5-8	2.6	68.3	0.1	0.8	2.2	1.0	0.0	0.0

TABLE IV. ECOLOGICAL STUDY OF THE GREEN BUG, ITS PARASITE (*LYSIPHLEBUS TESTACEIPES*), AND ITS PREDATOR (*HIPPODAMIA CONVERGENS*) IN FIELD NO. 5, PAYNE COUNTY, OKLAHOMA, 1939

	Percentage Green Bugs		Av. No. Lady Beetles per 3 Feet of Plants			Percentage Leaves Infested		
Date	Alate	Parasitized	Larvae	Pupae	Adults	Inner rows	Middle rows	Outer rows
4-3	4.3	9.6	11.1	12.9	0.0			
4-6	4.4	10.3	7.5	2.2	0.1			
4-7	3.9	8.8	5.6	5.4	0.2			
4-8	5.7	3.1	6.2	8.7	0.2			
4-10	10.0	6.3	6.1	9.1	1.1			
4-11	7.4	3.7	14.6	20.6	0.6			
4-12	10.2	2.4	2.3	21.2	1.1			
4-13	11.3	10.6	0.8	18.1	1.0	60.4	31.2	7.2
4-14	8.0	15.9	1.1	14.4	1.8	56.8	34.4	9.2
4-15	5.7	19.5	1.2	9.8	3.6	49.2	29.6	12.4
4-18	4.5	46.5	0.9	7.2	4.7	38.0	15.6	5.6
4-19	11.3	30.7	1.1	8.1	2.3	38.0	17.6	8.4
4-20	8.4	47.6	1.0	6.8	3.2	36.4	19.2	4.8
4-21	8.7	41.0	1.1	6.5	3.4	32.8	20.0	3.2
4-23	7.4	46.9	1.3	4.2	5.5	29.6	15.6	3.2
4-24	7.5	45.1	2.0	4.4	6.2	25.6	15.2	2.4
4-25	7.4	50.0	2.2	4.9	6.4	24.4	12.8	1.2
4-26	8.9	52.6	2.7	5.7	7.3	24.0	15.2	1.6
4-27	10.3	52.9	2.1	4.9	7.9	29.2	14.8	3.6
4-28	10.8	58.9	0.7	2.3	5.4	13.2	7.6	1.6
4-30	11.8	64.1	1.1	2.1	5.2	11.2	7.6	1.6
5-1	10.7	69.3	0.5	1.2	2.8	5.6	2.4	0.0
5-2	9.1	65.4	0.5	0.9	2.8	3.6	0.4	0.0
5-3	7.4	58.0	0.0	0.4	1.6	1.2	0.0	0.0
5-5	5.5	41.5	0.1	0.3	1.2	0.4	0.0	0.0
5-8	?	100	0.0	0.1	0.5	0.0	0.0	0.0

TABLE V. ECOLOGICAL STUDY OF THE GREEN BUG, ITS PARASITE (*LYSIPHLEBUS TESTACEIPES*), AND ITS PREDATOR (*HIPPODAMIA CONVERGENS*) IN FIELD NO. 6, PAYNE COUNTY, OKLAHOMA, 1939

	Percentage Green Bugs		Av. No. Lady Beetles per 3 Feet of Plants			Percentage Leaves Infested		
Date	Alate	Parasitized	Larvae	Pupae	Adults	Inner rows	Middle rows	Outer rows
4-7	3.4	1.0	7.6	2.5	0.2			
4-8	3.9	1.4	12.9	2.8	0.3			
4-10	3.9	1.6	8.9	10.3	0.1			
4-11	3.4	1.6	6.8	13.0	0.3			
4-12	7.9	3.6	6.0	16.0	0.2			
4-13	9.7	3.0	1.5	13.4	0.0	65.2	29.6	5.6
4-14	10.3	4.1	1.2	14.7	0.3	64.0	35.6	8.0
4-15	9.7	6.6	1.5	13.8	0.8	49.2	30.0	6.4
4-18	5.7	4.4	3.0	10.0	1.5	31.2	15.2	2.4
4-19	11.4	4.2	1.9	6.8	1.5	30.4	16.0	4.4
4-20	13.8	4.2	2.6	5.8	2.1	28.0	16.4	3.2
4-21	14.2	7.8	1.0	6.4	2.2	25.6	12.8	2.4
4-23	11.2	11.8	1.9	7.0	4.9	20.0	8.8	1.6
4-24	11.8	10.6	2.4	6.0	6.4	17.6	8.1	0.8
4-25	10.7	11.3	1.5	6.7	4.7	23.2	9.2	
4-26	7.0	18.9	1.9	4.1	6.3	21.6	12.4	0.8
4-27	7.0	25.9	3.2	6.1	7.3	20.0	12.4	1.2
4-28	8.6	35.3	0.7	2.6	6.3	5.6	1.2	0.0
4-30	10.7	46.4	1.0	2.7	4.5	3.2	0.4	0.0
5-1	9.9	63.0	0.7	1.4	3.2	1.2	0.0	0.0
5-2	9.7	57.8	0.4	1.0	3.2	0.8	0.0	0.0
5-3	6.2	50.0	0.3	0.5	2.5	0.4	0.0	0.0
5-5	3.9	36.5	0.2	0.4	1.7	0.4	0.0	0.0
5-8	?	100	0.0	0.2	1.4	0.0	0.0	0.0

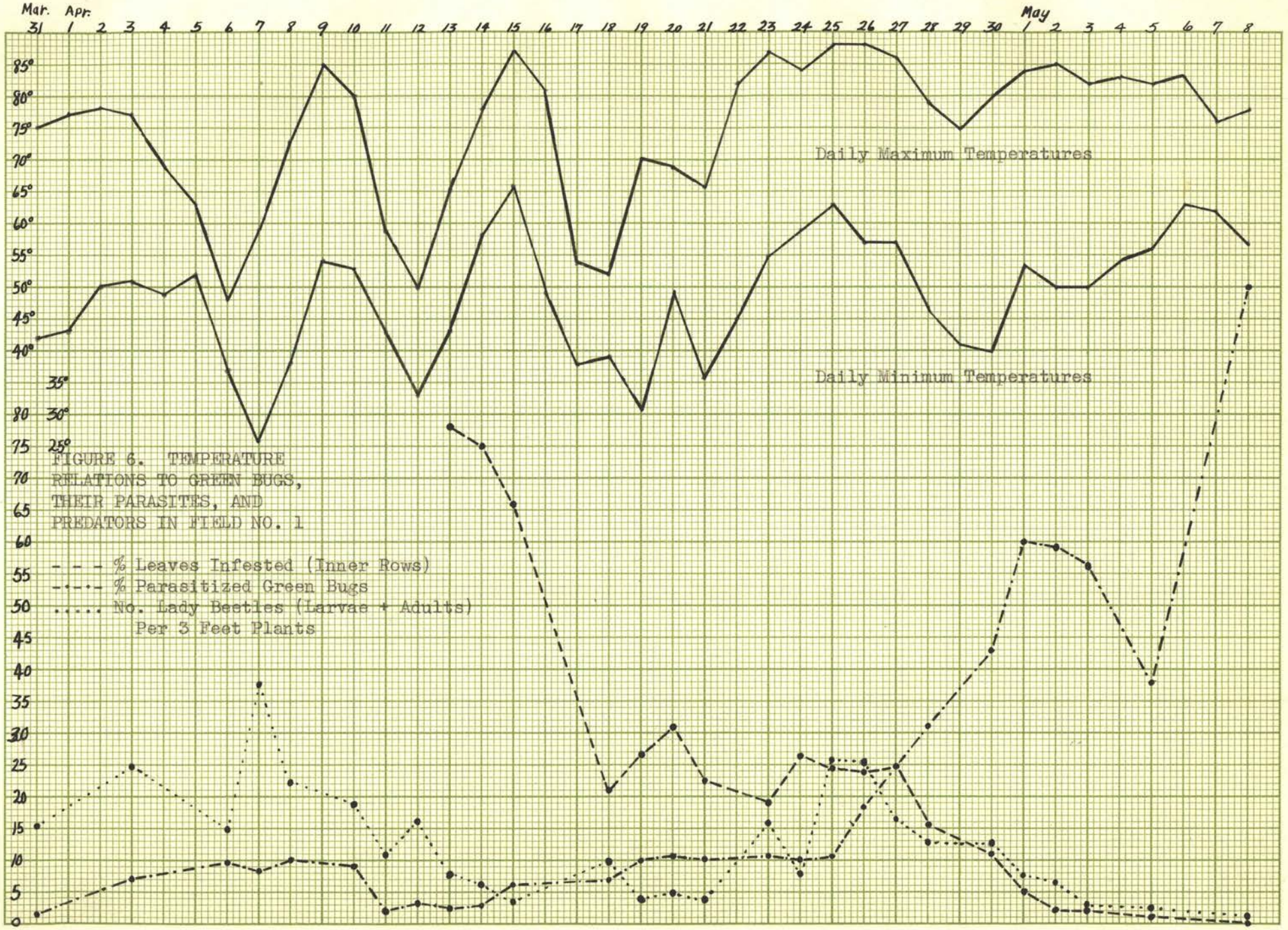
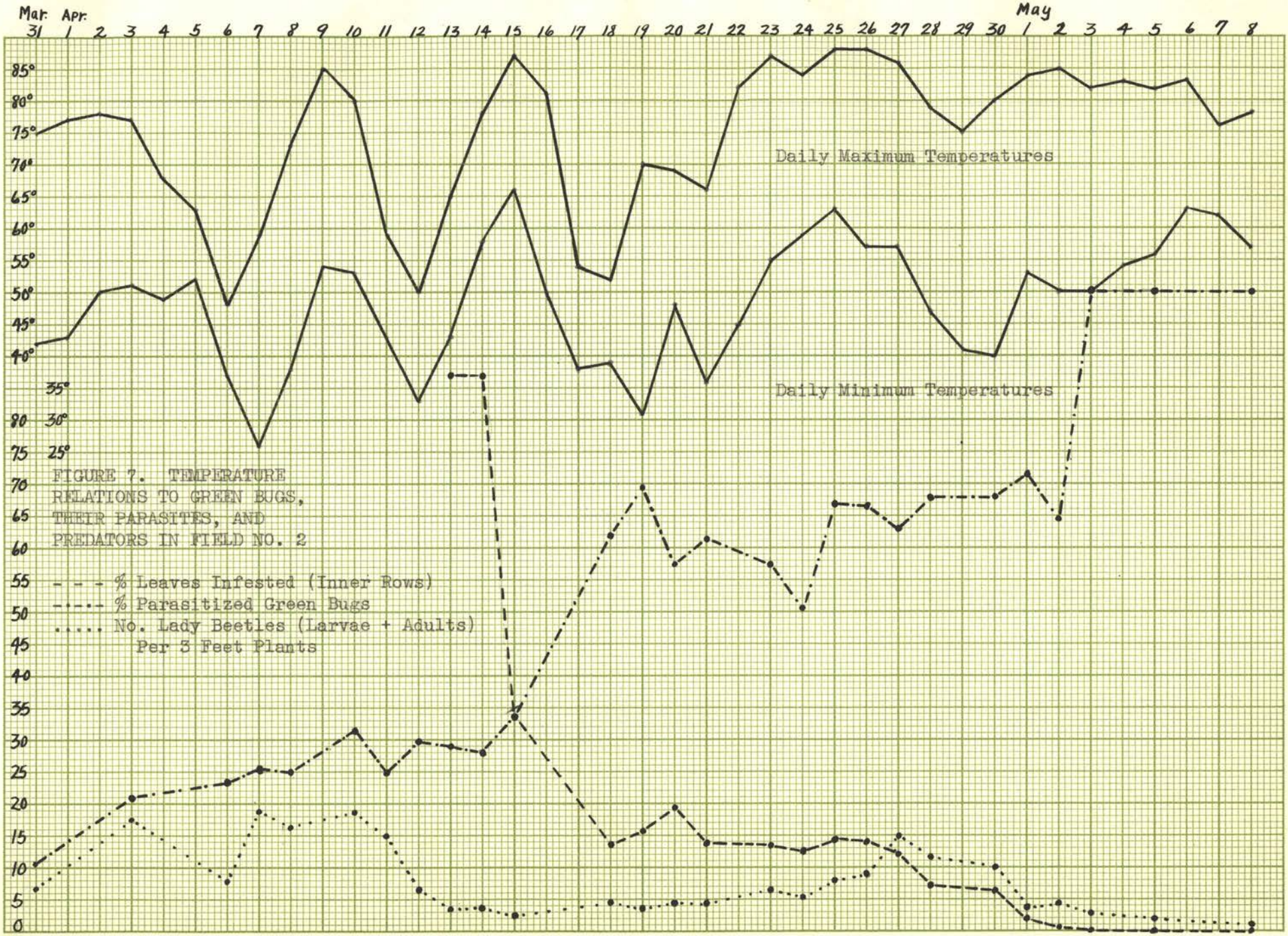


FIGURE 6. TEMPERATURE RELATIONS TO GREEN BUGS, THEIR PARASITES, AND PREDATORS IN FIELD NO. 1


Mar. Apr. May
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8
85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25°
80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
Daily Maximum Temperatures
Daily Minimum Temperatures
FIGURE 7. TEMPERATURE RELATIONS TO GREEN BUGS, THEIR PARASITES, AND PREDATORS IN FIELD NO. 2
- - - % Leaves Infested (Inner Rows)
-·-·- % Parasitized Green Bugs
····· No. Lady Beetles (Larvae + Adults) Per 3 Feet Plants

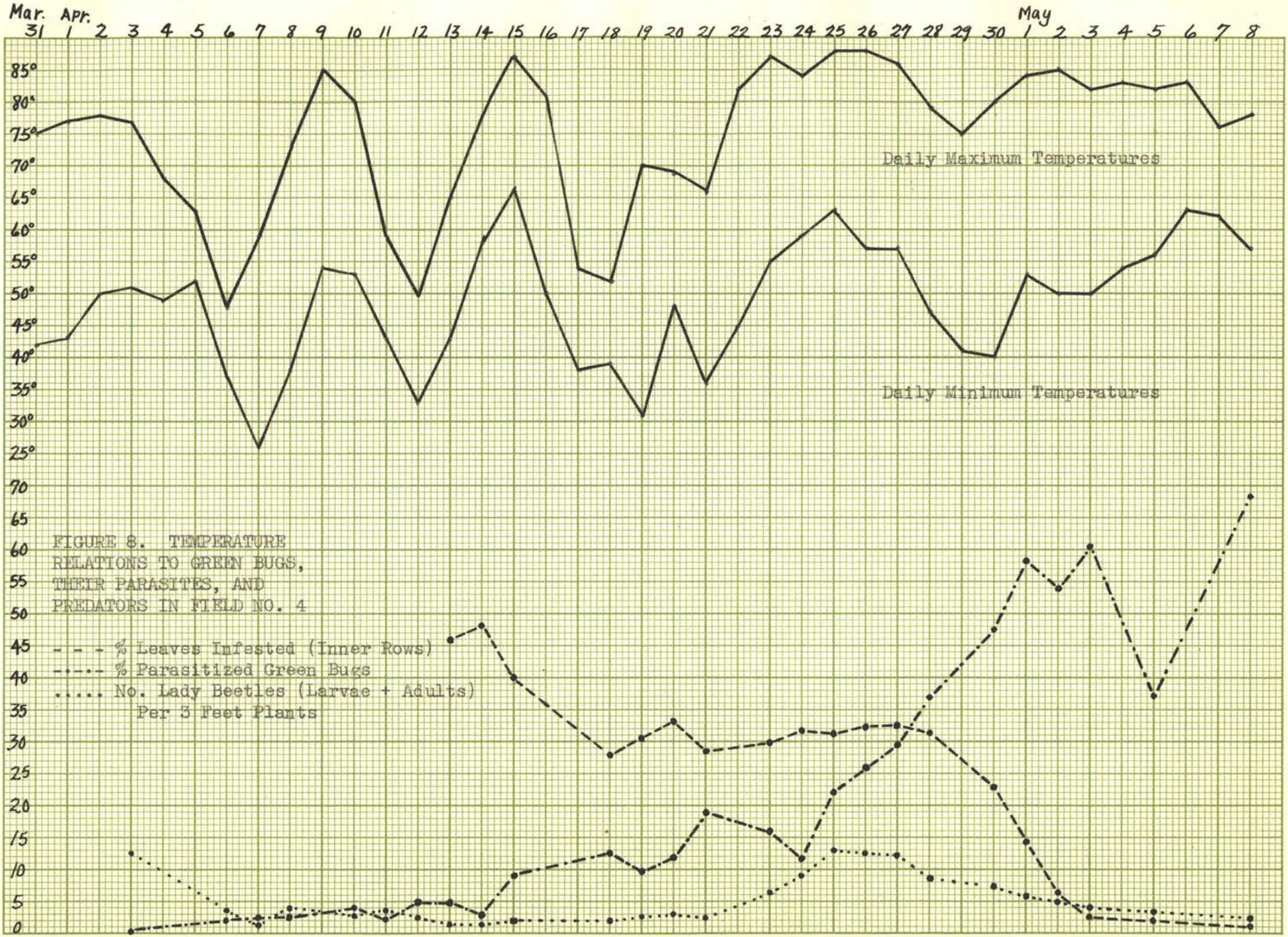
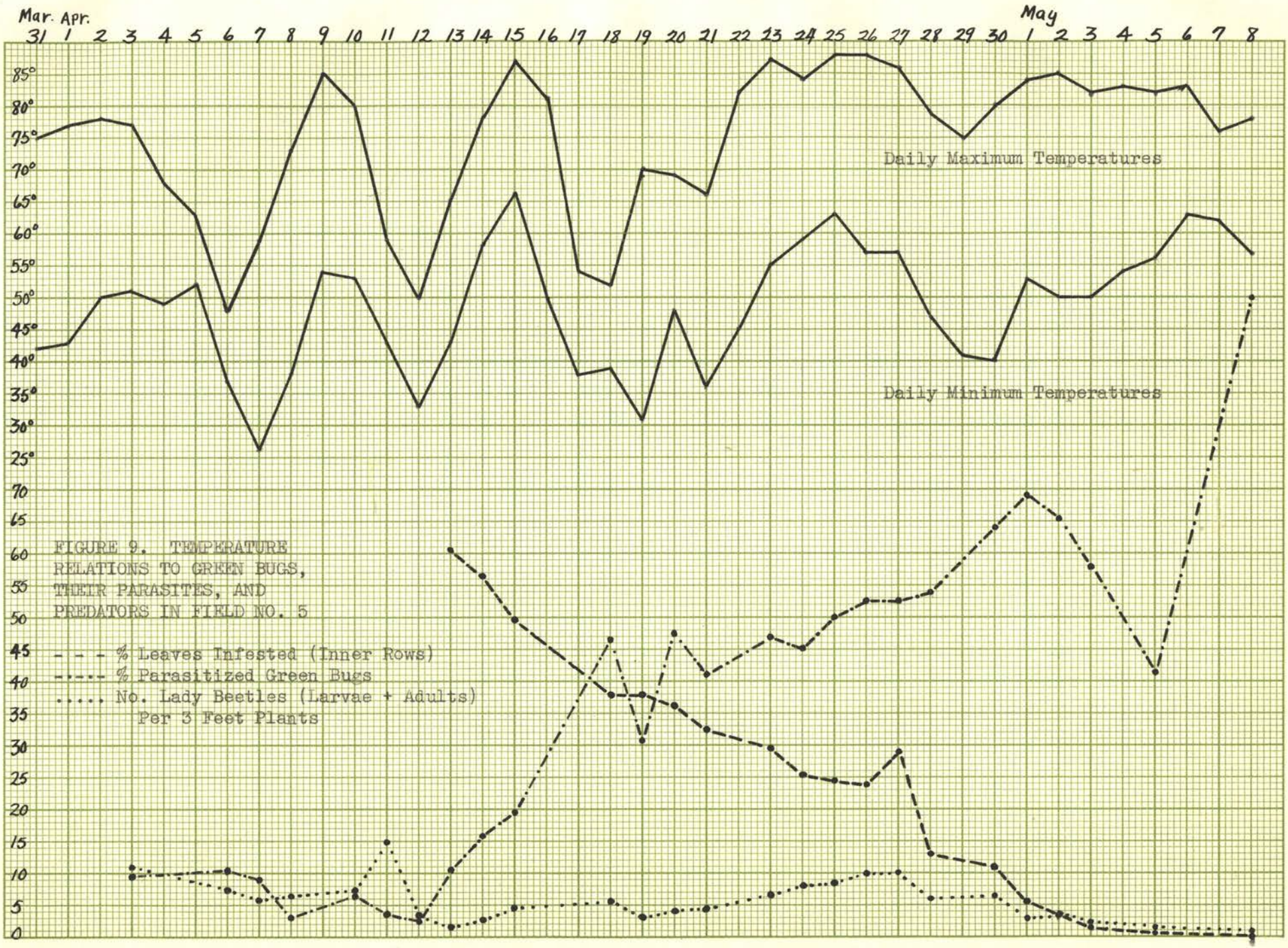


FIGURE 8. TEMPERATURE RELATIONS TO GREEN BUGS, THEIR PARASITES, AND PREDATORS IN FIELD NO. 4


Mar. Apr.
May
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8
85°
80°
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70°
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55°
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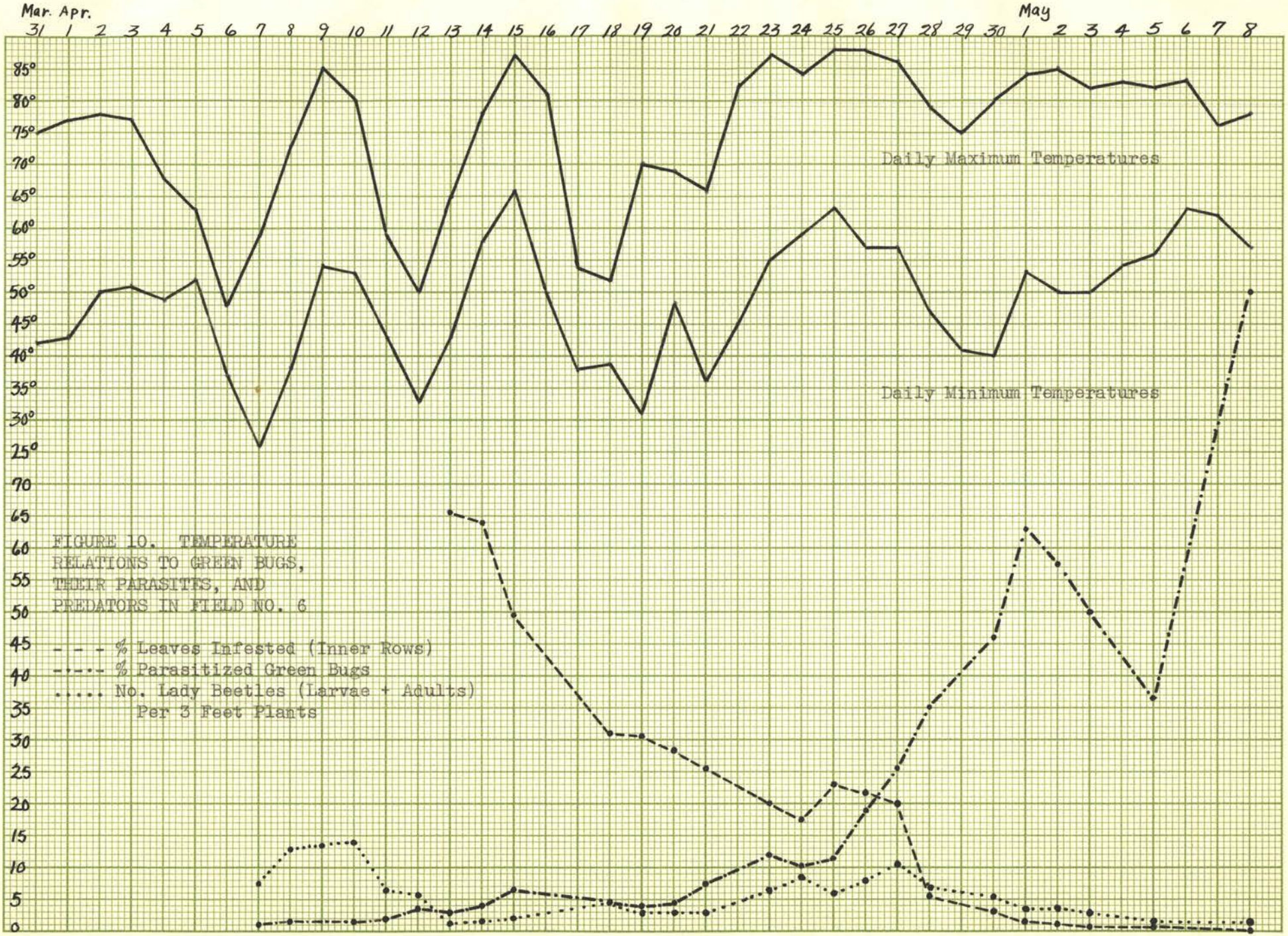
40°
35°
30°
25°
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Daily Maximum Temperatures
Daily Minimum Temperatures
FIGURE 9. TEMPERATURE RELATIONS TO GREEN BUGS, THEIR PARASITES, AND PREDATORS IN FIELD NO. 5
- - - % Leaves Infested (Inner Rows)
-·-·- % Parasitized Green Bugs
..... No. Lady Beetles (Larvae + Adults) Per 3 Feet Plants


Mar. Apr.
May
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8
85°
80°
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70°
65°
60°
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45°
40°
35°
30°
25°
90
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Daily Maximum Temperatures
Daily Minimum Temperatures
FIGURE 10. TEMPERATURE RELATIONS TO GREEN BUGS, THEIR PARASITES, AND PREDATORS IN FIELD NO. 6
- - - % Leaves Infested (Inner Rows)
-·-·- % Parasitized Green Bugs
..... No. Lady Beetles (Larvae + Adults) Per 3 Feet Plants

Preparation of Fields; Time and Kinds of Grain Planted

Preparation for sowing winter barley and wheat includes early plowing to allow complete settling of soil and consequent improvement of its water-holding capacity. Failures many times occur when either of these grains be planted on new plowed ground, especially when a dry season followed. Plowing again and double disking are advised just before planting.

Field No. 1 was plowed in August, disked and harrowed once, and planted with smooth-head (beardless) barley during the first week of October. This crop was approximately 5 per cent destroyed by green bugs, no more damage occurring chiefly because of a very good stand of healthy plants.

In direct contrast to Field No. 1 and Field No. 2, was a field of wheat (Red Currell) directly across the highway east of Field No. 1. This field was plowed in July and again in October. Disking and harrowing preceded the planting which occurred the first week of November. Frequent observations in this field disclosed no damage at all, only a very few green bugs ever being found on any of the plants.

Field No. 2 was plowed in August, but crab grass and oats were prevalent around the edges, leaving suitable hosts for the green bugs during the summer. During the first week of October, the field was disked and harrowed and the wheat (Red Currell), obtained from the same shipment as the Red Currell previously mentioned, was planted shortly after. This wheat was about 20 per cent destroyed by the infestation.

Field No. 3 was not plowed until late September and disked and harrowed shortly after. Smooth head (beardless) barley was planted the first week of October. This field was readily succumbing to the green

bug attack during the month of March, finally being practically destroyed by April 3, at which time it was plowed under, being planted in corn on April 6. Loss in this field, of course, was 100 per cent.

A very good demonstration of correct soil preparation and clean culture is shown by the contrast in results of Field No. 3 and a barley field directly north of it, only a highway separating the two. This field was prepared and planted by the same man who prepared and planted Field No. 3; the seed used was the same variety and from the same source as that used in Field No. 3. The only difference in preparation of this field was that it was plowed in July; other preparations and planting were done the same days as Field No. 3.

Prevailing winds were from the southwest, which fact gives room for belief that the winged forms of the heavy infestation to the immediate south would migrate with the wind to the field to the north. This fact was somewhat true, but the numbers of green bugs were at a minimum, being able to do no noticeable damage in the more thrifty growing barley. Soil conservation of moisture, producing healthier plants, and clean cultivation to do away with the green bug breeding places are undoubtedly responsible for this phenomenon observed.

Field No. 4 was plowed in July and again during the first week of September, after which it was double disked and harrowed. Wheat (Blue Stem) was planted by about September 10. Apparently this field was prepared well, but closer observation revealed volunteer oats plants at the south edge of the field, directly south of the infested area. These plants may have harbored the green bugs, later going to the younger, more tender wheat. Damage to this field was about 8 per cent.

Field No. 5 was plowed in August, disked and harrowed, and planted

in wheat (Blue Stem) about September 22. Damage in this field was about 5 per cent.

Field No. 6 was plowed in July, disked and harrowed in September, and planted in bearded barley the first week of October. Damage was about 5 per cent.

Some more data were collected from farmers in the vicinity of the study fields. Information concerning these four fields follows:

1. A field was plowed in July, disked twice in latter September and the first of October, and planted in beardless barley October 6 and 7. The point to be observed is that the field was plowed only once, this being early; also it was planted early. The crop was completely lost, the few spots of remaining injured plants afforded a little cattle pasture.

2. Another field nearby was plowed in August, disked once in November, and planted to beardless barley (from the same source as the field just mentioned) about November 15. No damage was observed in this field although there were a few green bugs present.

3. Wheat was planted during latter November in a plot immediately south of the heavily infested barley field just mentioned. This field had been plowed in July and again in November, and disked and harrowed in November. No damage was observed.

4. The only case known of a control measure attempted against the pest, during this infestation was reported by one farmer who, upon observing a few heavy infestations in more or less circular areas in his barley field about the first of April, harrowed these areas well and the infestation stopped, no more damage apparently occurring than that already accomplished before the harrowing.

Infestation in Fields Studied

By determining the percentage of leaves infested, the method was discussed under the technique procedures, the amount of infestation in each field was comparatively arrived at (Figs. 6 to 10 inclusive).

Such data were gathered in each field between the dates of March 13 and May 8 inclusive. Figs. 6 to 10 inclusive show the rather uniform percentages of inner leaves infested, and Tables I to V inclusive show percentage of inner, middle and outer leaves infested. Abrupt drops in percentages of inner leaves infested (Figs. 6 to 10 inclusive) during May 15 to 18 may be explained by presence of lady beetles and parasites, as will be discussed later, and sudden drops in temperatures.

Extent of Damage

Measurements were taken on several points of infestation to ascertain the direction of greatest spread from the original more or less circular area. On the days of beginning studies in the particular fields, stakes were placed at four locations in each point of infestation. Positions of these stakes were at the margins between the plants which had succumbed to the attack and were dead, and those plants which were heavily infested, but alive. At the termination of field studies, counts were made to determine the direction of spread of infestation from the original center. Host plants (stools) which had died in lines directly north, east, south, and west of these stakes were counted; this gave a better idea of the actual amount of damage done in particular directions from the initial infestation than to measure the distance, because there is space between rows which would be measured, no infestation occurring there. It was found in the five fields studied that

there were more dead plants north and east of the original dead plants than south and west. Greatest spread was to the north, (Table VI and Fig. 5).

TABLE VI. NUMBERS OF HOST PLANT STOOLS KILLED IN PARTICULAR DIRECTIONS FROM THE ORIGINAL INFESTATION

Field	Point No.	North	East	South	West
1	1	7	3	2	2
	3	5	2	2	2
2	1	6	3	2	2
	3	4	2	2	2
4	1	2	1	1	1
	3	7	3	1	2
5	1	1	0	0	0
	3	8	4	2	2
6	1	6	3	1	1
	3	8	4	3	2

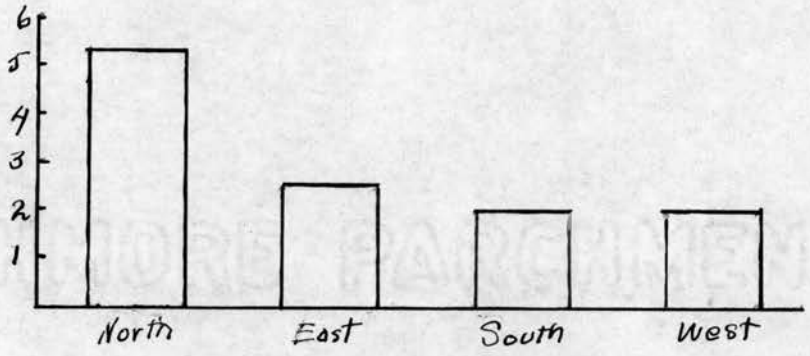


FIGURE 5. AVERAGE NUMBER OF DEAD HOST PLANT STOOLS IN RELATION TO DIRECTION FROM ORIGINAL DEAD AREA.

Prevalence of a southwest wind is undoubtedly responsible for the greater spreads north and east.

Parasitization

A number of parasites collected from green bugs was sent to C. F. W. Muesebeck (in charge of the Division of Insect Identification, U. S. D. A. Bureau of Entomology and Plant Quarantine) who identified them as Lysiphlebus testaceipes Cress., probably the most important parasite of the green bug. This parasite is an insect of the order Hymenoptera and family Braconidae.

As previously mentioned by Webster and Phillips (17), this parasite is not sufficiently active at temperatures below 56 degrees F. to parasitize its host. Green bugs begin increasing their numbers noticeably at 40 degrees F. or a little below; that is to say that at these temperatures the rate of reproduction is sufficient to more than offset the mortality. It can be readily seen by Figs. 6 to 10 inclusive that the percentage of parasitized green bugs increased steadily with the increase in temperature. The sudden drop in percentage of parasitized green bugs during the first part of May was due to the fact that the aphids were mostly down in the leaf sheaths, not giving the parasites much chance to do their beneficial work. Warm weather must have caused this protection-seeking in the leaf sheaths.

The seasonal percentage of parasitization in the five fields studied is shown in Figs. 6 to 10 inclusive where it is compared with temperatures, percentage of leaves infested, and the predatory stages of the lady beetles.

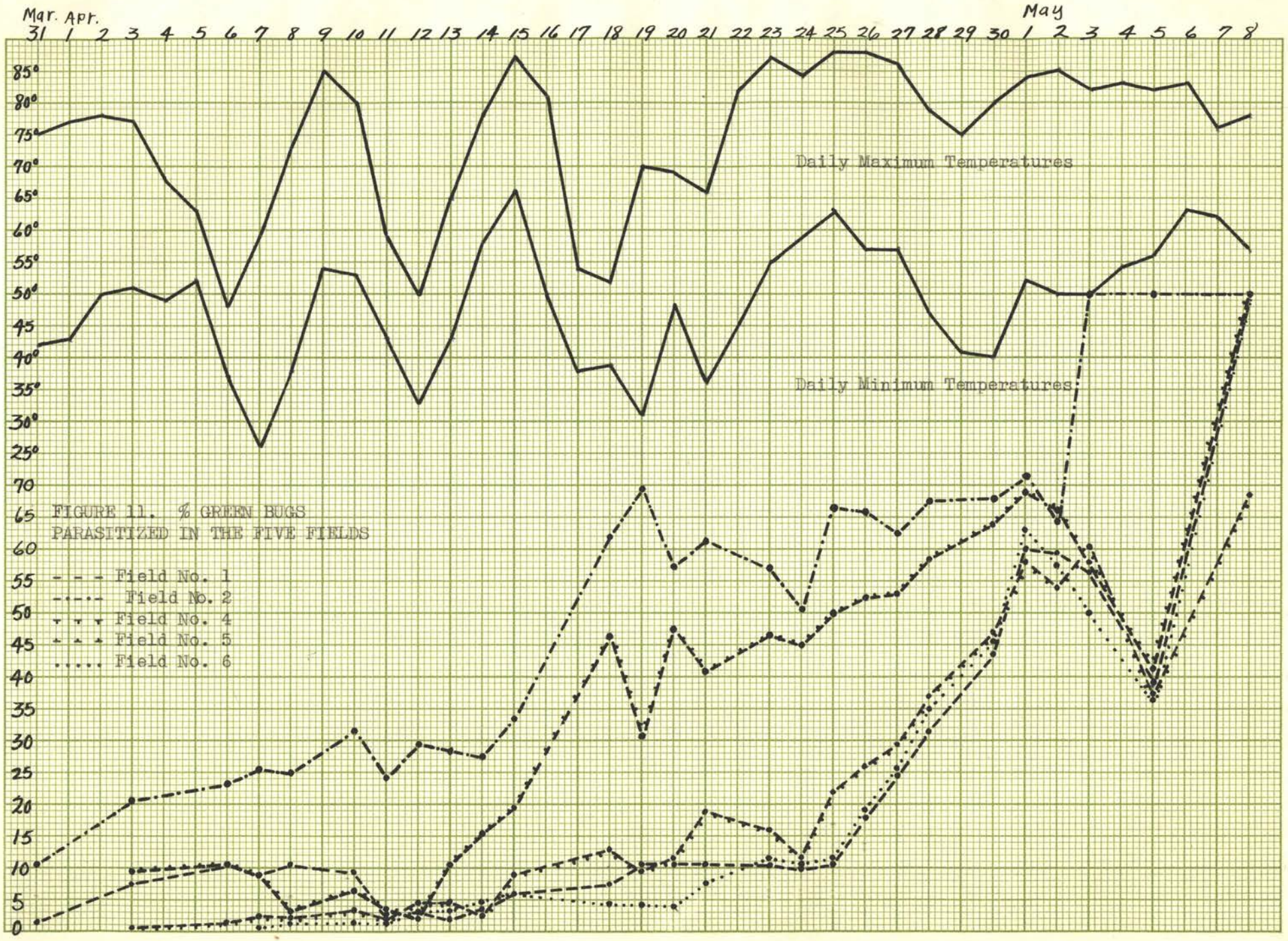
Fig. 11 is shown to make a comparison of green bugs parasitized in the various fields. It has been generally stated by previous workers that the parasites are rather evenly distributed in the various infested fields; this was observed by the writer to be false. For instance,

Field No. 2, Fig. 11, showed a much greater parasitization during the major part of the infestation than any other field, reaching 100 per cent on May 3, five days before such percentage was reached in any of the other fields. Of the five fields in which complete studies were made, Field No. 2 was most heavily infested with green bugs at the beginning of observations, but the evident greater numbers of parasites brought the infestation in this field to a low point as early as April 18. The parasites in this field were actually swarming, whereas no such phenomenon was observed in the other fields.

Further notice of Fig. 11 shows that there were 3 fields (Nos. 1, 4, and 6) in which the percentage of parasitized green bugs was about the same throughout the infestation, being low during the first part of the study and not reaching their peaks until May 1. Undoubtedly the parasites did considerable good in Field No. 2 during the early studies, but none of the other fields, with the possible exception of No. 5, showed much parasitization until the last part of the infestation.

Field No. 3, plowed under April 3, after being nearly completely destroyed by the green bug infestation, was studied twice before being plowed under. These two studies disclosed a lack of parasites, in fact none could be seen flying in this field, whereas they were observed in the others. Actual presence of the parasites, however, was disclosed in the two counts of the green bugs, showing only one parasitized aphid in 325, and 4 parasitized aphids in 275. This was a very small amount of parasitized green bugs as compared to those in other fields.

Literature makes generalized statements that Lysiphlebus testaceipes oviposits in alate as well as apterous green bugs, but in the writer's observations, oviposition in alate forms was more difficult. On


Mar. Apr.
31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
May
1 2 3 4 5 6 7 8
85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25°
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
Daily Maximum Temperatures
Daily Minimum Temperatures
FIGURE 11. % GREEN BUGS
PARASITIZED IN THE FIVE FIELDS
- - - Field No. 1
-·-·- Field No. 2
▾ ▾ ▾ Field No. 4
▲ ▲ ▲ Field No. 5
····· Field No. 6

several occasions the writer has watched this parasite attempt to oviposit in alate green bugs but the roof-like folding of the aphids' wings over the dorsal and lateral parts of their abdomens protects them from this parasite, the parasite passing on to another aphid. The writer's data concerning parasitization in the green bug also show that the ratio between apterous unparasitized and apterous parasitized is greater than the ratio between alate unparasitized and alate parasitized. Such data were taken during three days in all fields, making a total of fifteen ratios to be studied. Table VII gives data concerning this discussion.

TABLE VII. PARASITIZATION OF ALATE AND APTEROUS GREEN BUGS

Date	Field No.	Parasitized and Unparasitized		Parasitized	
		Alate	Apterous	Alate	Apterous
April 20	1	19	200	2	22
	2	7	200	4	115
	4	20	175	3	20
	5	16	175	5	86
	6	36	225	9	2
April 26	1	21	150	3	29
	2	14	175	7	118
	4	18	200	4	53
	5	17	175	7	94
	6	16	150	3	28
April 30	1	16	125	4	57
	2	16	150	9	104
	4	21	175	6	87
	5	20	150	9	100
	6	15	125	3	62

The apterous green bugs which were parasitized may be shown in percentage deviation from the alate green bugs which were parasitized. Such percentage may be derived from the figures in Table VII, using

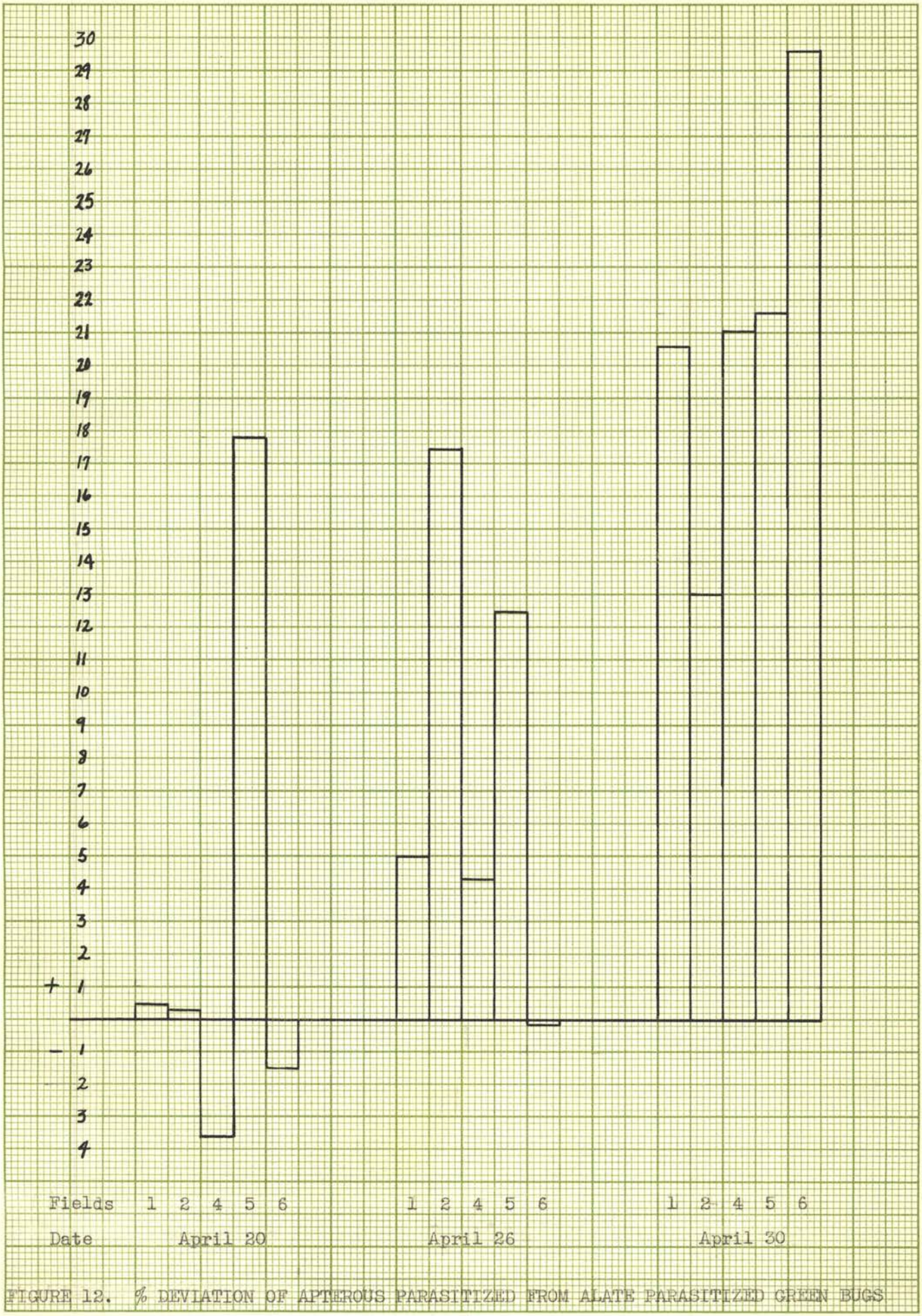


FIGURE 12. % DEVIATION OF APTEROUS PARASITIZED FROM ALATE PARASITIZED GREEN BUGS

this formula: $\frac{\text{apterous unparasitized}}{\text{apterous parasitized}} > \frac{\text{alate unparasitized}}{\text{alate parasitized}}$.

Fig. 12 shows 12 cases out of the 15 studies which conform to the writer's observations concerning parasitization of green bugs.

Insect Predators

Lady beetles, order Coleoptera, family Coccinellidae, are next in importance in control of green bugs. Larvae and adults both consume the aphids and are found abundantly in infested regions. As is true with the previously mentioned parasite, these predators are not active at low temperatures.

Hippodamia convergens Guer. and Megilla maculata De Geer were the only species found in these studies, the former being in greatest abundance, in fact the latter being observed only nine times.

Figs. 6 to 10 inclusive show that the predatory stages of the lady beetles were generally rather numerous during the first 8 to 10 days of April and again during the last week of April. The value of the lady beetles is great, but they alone could not have done much toward controlling this infestation by themselves; the parasites undoubtedly terminated the outbreak with a comparatively minor assistance from the lady beetles.

Fig. 13 shows an average of all fields of larval, pupal and adult stages of the lady beetles. The peaks of abundance of the various stages are shown rather clearly, the life cycle being shown by these peaks and depressions. As the green bugs were killed, lady beetles went to new locations to seek food, as evidenced by the decline in numbers of all stages during the last observations in May.

Although it has been stated that the lady beetles could not have

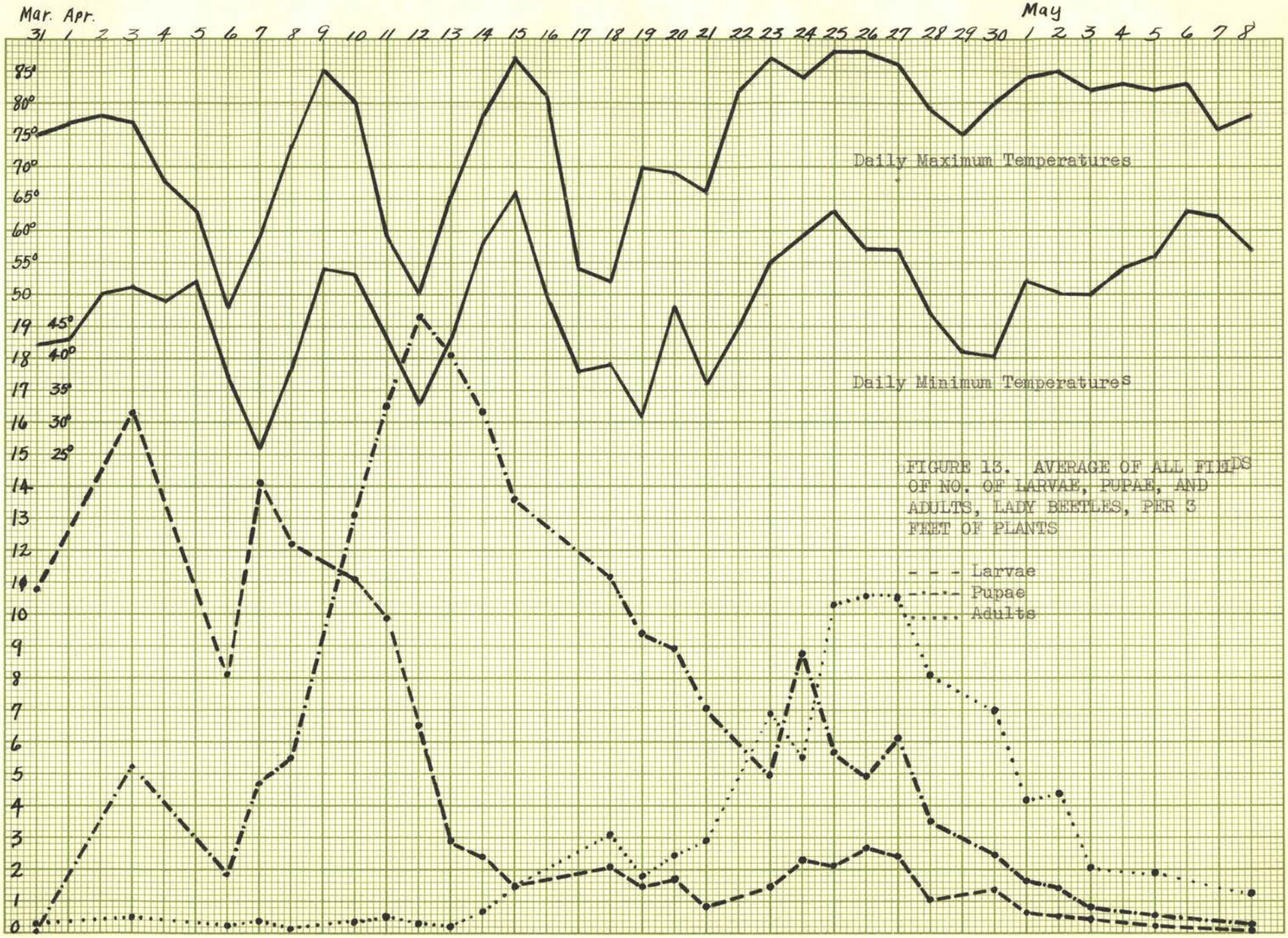


FIGURE 13. AVERAGE OF ALL FIELDS OF NO. OF LARVAE, PUPAE, AND ADULTS, LADY BEETLES, PER 3 FEET OF PLANTS

controlled the infestations in these studies, Fig. 12 indicates a period of abundance of lady beetle larvae from about March 31 to April 11, and an abundance of adults from about April 23 to May 1. This leaves a period of some 12 days between these larval and adult abundances when there were few larvae and adults, although there was an abundance of pupae, but only the larvae and adults are predatory.

Lace-wing flies, order Neuroptera, family Chrysopidae, have been known to assist in decreasing green bug infestations. These predators were observed to a small extent in all fields studied, the greatest abundance being in Field No. 1. From this field was taken a lace-wing larva which the writer first observed feeding on green bugs and later attempting to consume the juices of a pupa of the lady beetle, Hippodamia convergens Guer. This larva was removed and brought to the laboratory where it was placed in a vial, covered with gauze, with a stem of barley containing three pupae (Hippodamia convergens). As checks, 12 other pupae (of the same species of lady beetles), on stems of barley, were placed in vials. In a few days the 12 checks emerged as adults, but the three pupae in the vial with the lace-wing larva were dead, not having emerged over two weeks later. The lace-wing larva was observed to thrust its mandibles into the three pupae, apparently taking the juices from the body.

Later, from this lace-wing larva which had pupated, an adult lace-wing emerged, the writer determining it to be Chrysopa plorabunda Fitch. Twenty-two other collections of adult lace-wings were made and all were determined to be the same species as above.

A New Predator

Some interesting findings may be mentioned with regard to a predator of the green bug not previously mentioned in literature available to the writer. This predator is a lizard, Sceloporus undulatus consobrinus, which was determined by Dr. John Mizelle. It was collected by the writer in a barley field (No. 3) very abundant with green bugs, and was brought to the laboratory where it ate all the green bugs fed it, consuming approximately 100 in one hour. A green bug-infested barley plant was placed in a cage with the lizard, the lizard consuming green bugs on the barley and those which had fallen from the barley, at the rate of about 100 in one hour.

To prove further that this lizard is a good green bug predator, lady beetle (Hippodamia convergens) eggs, larvae, pupae, and adults were placed in the lizard's cage, the lizard not once making an attempt to eat any of the four forms during one week of such association, in fact the larvae and adults crawled over the lizard with no danger apparent to them.

Two other lizards of this same species were collected in small-grain fields by L. G. Duck and K. C. Emerson. These were also fond of green bugs; however no exact data were kept concerning their feedings.

A. I. Ortenburger of the Zoology Department of Oklahoma University obliged the writer with information concerning distribution of Sceloporus undulatus consobrinus, showing the general location to be in the southwestern part of the state; these records in Payne County may possibly be new for this area of Oklahoma.

Heavy Rains

Although April rainfall was below normal for the area of infestation, there were three successive days (April 4, 5, and 6) which had heavy rains of 1.44, 1.70, and 0.50 inches respectively. When the field counts were made on April 6, it was observed that there were very few live aphids to be found, most of them being dead on the ground, due to the hard rains of the preceding days. When observations were made on April 7, it was noted that the green bugs were confined largely to the lower portions of the plants, not having been able to migrate to the higher leaves since the hard rains.

Unfortunately there were no data being kept of the percentage of leaves infested prior to April 13, but the writer knows that the infestation had to be rebuilt. Records were being kept on abundance of lady beetle larvae and adults, and Figs. 6 to 9 show the sharp drop in numbers of lady beetle larvae and adults on April 6.

Weather Comparisons of Some Epidemic and Non-Epidemic Years

To check the correlation between temperature and rainfall, and green bug infestations, a graph (Fig. 14) has been made showing monthly mean temperatures and monthly total rainfalls in infested areas during some epidemic years. Since the 1907 infestation nearly covered the State, temperature and rainfall data are given for the State as a whole. The 1934 epidemic included specific counties; therefore weather data were taken for each county and averaged for the entire area. 1939 data are for Stillwater.

Lines across the graph at 40 degrees F. and 56 degrees F. represent

a zone of mean temperatures within which the green bug reproduces readily and its chief parasite (Lysiphlebus testaceipes) is not active, at least to the point of parasitizing the pests. Webster and Phillips (17) have made the statement which verifies and gives reason for showing such a zone. It will be observed in Fig. 14 that the temperatures during winter and early spring, of the infestation years shown, lie almost exclusively in the zone between 40 degrees F. and 56 degrees F. Also rainfall is shown to be rather small, with few exceptions, during these years. Total rainfall in spring may be high in an epidemic area, and still may not decrease the infestation unless the rains are heavy.

After checking the monthly mean temperatures and total rainfalls during non-epidemic years in Payne County, the writer has come to the conclusion that a warm winter and cool spring, and a small amount of rainfall will not particularly result in a green bug epidemic; apparently there are other factors which enter into the epidemics.

TABLE VIII. MEAN MONTHLY TEMPERATURES AND TOTAL MONTHLY RAINFALL FOR STILLWATER, OKLAHOMA

Year	Dec.		Jan.		Feb.		Mar.		Apr.		May	
	Temp.	Rain	Temp.	Rain	Temp.	Rain	Temp.	Rain	Temp.	Rain	Temp.	Rain
1907-08	41	2.72	40	1.23	42	5.00	54	2.36	58	6.90	67	11.21
1930-31	40	2.19	42	0.86	48	1.04	45	2.15	56	2.88	65	2.02
1931-32	44	0.49	40	4.17	49	2.41	44	0.09	65	0.49	69	2.28
1932-33	36	4.32	47	0.41	38	1.72	52	4.62	62	2.23	71	1.73
1933-34	46	1.96	41	1.75	43	0.80	49	1.14	62	2.65	69	2.68
1934-35	38	0.82	40	0.60	41	1.38	55	3.15	56	2.45	64	3.59
1935-36	39	1.92	34	0.14	32	0.25	57	0.02	61	1.11	71	4.84
1936-37	43	1.49	31	0.91	41	0.23	46	0.96	61	1.72	71	2.86
1937-38	38	1.49	42	0.57	46	2.25	59	5.63	60	2.51	69	5.71

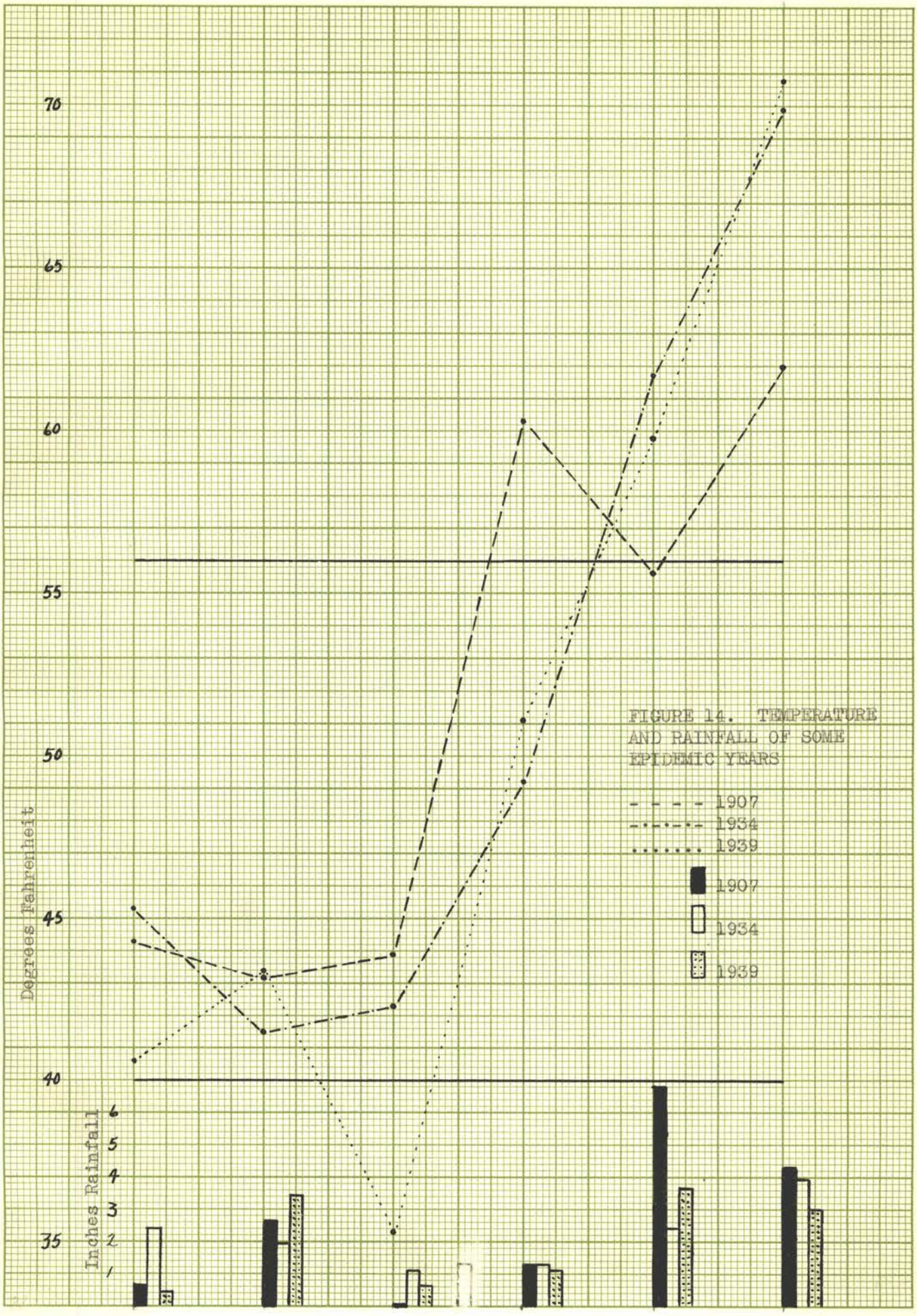


FIGURE 14. TEMPERATURE AND RAINFALL OF SOME EPIDEMIC YEARS

Table VIII presents data showing mean monthly temperatures and total monthly rainfalls for Stillwater, Oklahoma during non-epidemic years. Attention is called to the fact that only during the season of 1936 was there a very cold winter followed by a suddenly warm spring which facts were not conducive to green bug epidemics. Even 1936 did not have abundant rainfall, in fact it was very scarce, which is considered correct for epidemics of the pest.

SUMMARY

Actual field data were taken in the study of the green bug infestations between Perkins and Ripley, Oklahoma, from March 31 to May 8 inclusive. These field data and observations resulted in the following conclusions:

1. In general, fields which are plowed soon after grain is harvested, plowed again and disked in the fall, and the grain drilled late (about middle October to middle November) have little or no green bug infestation.

2. Clean culture, cleaning out volunteer small grains and other host grasses, has been shown to decrease possibilities of infestation.

3. Spread from original circular infestations is greatest north and east, being greatest toward the north.

4. Lysiphlebus testaceipes, the only parasite found, is not present in all infested fields in the same proportions, in fact one field showed many more than any other, the parasite ending the infestation in it 5 days before any other field. One field was observed to have practically no parasites in it on April 3, at which time it was plowed under because of nearly total destruction by the pest.

5. Lysiphlebus testaceipes generally increases in abundance as the temperatures increase, until the infestation is terminated.

6. The ratio of apterous unparasitized green bugs to apterous parasitized is greater than the ratio of alate unparasitized to alate parasitized.

7. Hippodamia convergens, the only lady beetle predator found in abundance, Megilla maculata was observed only 9 times, can be given credit for consuming a great number of green bugs throughout the infestation; larvae and adults are predatory.

8. A lace-wing larva (Chrysopa plorabunda) was observed feeding on and eventually killing Hippodamia convergens pupae.

9. Relatively few lace-wing adults (all captured were determined to be Chrysopa plorabunda) were found in all infested fields.

10. A new predator was found, a lizard (Sceloporus undulatus consobrinus). This lizard was captured in a heavily green bug-infested barley field and brought to the laboratory where it proved itself a good predator on green bugs. The lizard would not eat lady beetle eggs, larvae, pupae, or adults.

Two other lizards of the same species were later collected in small-grain fields and were found to consume green bugs freely.

11. Heavy rains appreciably decrease the numbers of green bugs, killing them outright or burying them in mud and water.

12. Warm winters and cool springs together with a lack of rainfall do not necessarily signify green bug epidemics.

13. Barley was destroyed more in Payne County than were oats and wheat crops.

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