8-1928

Studies in life history of Murgantia histronics in Tennessee

Paul Carson Avery

To the Graduate Council:

I am submitting herewith a thesis written by Paul Carson Avery entitled "Studies in life history of Murgantia histronics in Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Extension.

, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

UNIVERSITY OF TENNESSEE

Upon the request of the Committee on Graduate Study

the under-signed have examined a thesis entitled

Studies In the Life History of the Mesogastria Histrionica in Tennessee

presented by Paul Carson Askew

candidate for the degree of Master of Science in College of Agriculture and hereby certify that it is worthy of acceptance.

Ira Bentley)
Edwin B. Forbes) Examiners.

THESIS

STUDIES IN THE LIFE HISTORY

OF THE

MURGANTIA HISTRIONICA IN TENNESSEE

A Part of the Requirement for the Degree of

Master of Science in Agriculture

UNIVERSITY OF TENNESSEE

KNOXVILLE, TENNESSEE

PAUL CARSON AVERY

1928

PLATE 1.

Adult, water colored

CONTENTS

LIST OF ILLUSTRATIONS

Plates:

LIST OF TABLES

INTRODUCTION

This thesis consists of the results of a number of studies in the life history of the Murgantia histrionica, Hahn. This insect was chosen first, because of its great economic importance in Tennessee and secondly, because of a lack of knowledge of control methods. It was believed that if more were known about the life history of the insect, better control methods could be worked out. The experiments were all carried on, in glass cages and vials, in room 400 Morrill Hall. The work was started in September 1927, and ended July 25, 1928. It was originally intended that the work cover only eight months, but on account of the poor results obtained in the winter, it was decided to continue the work through June of 1928.

The experiments are not as scientific as they should be, on account of not having any way of controlling temperature and humidity in the room where the experiments were conducted. I had no way of telling the daily maximum and minimum temperature, and the humidity of the room. Neither did I have a way of recording the hourly temperature of the room. In the winter the temperature of the room fluctuated a great deal. Sometimes there was practically no heat at all in the room; at other times the temperature was ninety. After the beginning of warm weather in the spring, I used temperature and humidity data furnished me by the Knoxville Weather Bureau.

HISTORY

The Murgantia histrionica was first described by Hahn, a German, in 1834 from material collected in Mexico, which material at that time was in his private library in Germany. Although this species was taken in Mexico, there seems to be no doubt that that country is the original home of this insect, as it was not at that time widely distributed in that country. Later investigators found other species of this genus well distributed in Central and South America. It was concluded by these investigators that Central America was the original home of the Murgantia histrionica, Hahn.

The second mention of this insect was by Dallas, in 1851, in his "List of Hemiptera", in the British Museum. He reported four species, three of which were found in Mexico; the location of the fourth was not given.

The year 1864 is assumed as the date of the introduction of this insect into the United States. In this year Dr. Gideon Lincecum, of Washington County, Texas, noticed this insect in his garden and gave an account which is produced below:

> "The year before last they got into my garden, and utterly destroyed my cabbage, radishes, mustard, seed turnips, and every other cruciform plant. Last year I did not set out any of that order of plants in my garden. But the present year, thinking the bugs had probably left the premises, I planted my garden with radishes, mustard, and a variety of cabbage. By the first of April the mustard and radishes were large enough for use, and I discovered that the insects had commenced on them. I began picking them off by hand

and trampling them under foot. By that means I have preserved my 434 cabbages, but I have visited every one of them daily now for four months, finding on them from thirty-five to sixty full grown insects every day, some coupled and some in the act of depositing eggs. Although many have been hatched in the garden the present season, I have suffered none to come to maturity; and the daily supplies of the grown insects that I have been blessed with are imigrants from some other garden.

"The perfect insects live through the winter, and are ready to deposit its eggs as early as 15th of March, or sooner, if it finds any cruciform plant large enough. They set their eggs on the ends in two rows, cemented together, mostly on the underside of the leaf and generally from eleven to twelve in number. In about six days in April -- four days in July -- there hatches out from these eggs a brood of larvae resembling the perfect insect, except in having no perfect wings. This brood immediately begins the work of destruction by piercing and sucking the life-sap from the leaves; and in twelve days they have matured. They are timid, and will run off and hide behind the first leaf stem, or any part of the plant that will answer the purpose. The leaf that they puncture wilts, like the effect of poison and soon withers. Half a dozen grown insects will kill a cabbage in a day. They continue through the summer, and sufficient perfect insects survive the winter to insure a full crop of them for the coming year.

"This tribe of insects do not seem liable to the at-

tack of any of the cannibal races, either in the egg state or at any other stage. Our birds pay no attention to them, neither will the domestic fowls touch them. I have as yet found no way to get clear of them, but to pick them off by hand."

The above account, was included by Benj. D. Walsh, in 1866, in an article in "The Practical Entomoligist". This is the first account of the presence of this insect in the United States. Rather than let the reader be misled, I feel that I should make one correction to the above account. The statement that the insects mature in twelve days is an erroneous one; twenty-three days is the shortest time recorded for the maturity of this insect.

Washington County, Texas, is approximately 200 miles from the Mexican line. Judging from the spread of the cotton boll weevil and other insects, it is supposed that under ordinary conditions the insects spread at the rate of approximately twenty miles per year. If the above statement is correct, then the insect had been in this country some six or eight years before mention was made of it.

In January, 1879, issue of "The American Entomologist", C. V. Riley records the presence of this insect at Salisbury, N. C. In March, 1870, J. S. Steele, of Tennessee, in the above publication records the occurrence of this insect in Georgia, Mississippi, and Alabama.

In 1872 Riley again wrote on this insect in his "Fourth Missouri Report". He said that a specimen of this insect had been found in some of the southern counties in Missouri in 1870, and in Kansas as far north as the latitude of St. Louis.

In 1880, Godman and Salvan described this species rather carefully, giving distribution, synonyms, and life history. Their distribution of this insect included Arizonia, California, Colorado, Delaware, Florida, Indian Territory, Louisiana and Texas; Oaxaca, Mexico; Capetillo, Duenas, Purula, San Geronime, Guatemala; and Costa Rica.[1] In the same year Linter reported the presence of this insect in Virginia.

DESCRIPTION OF SPECIES

Adult

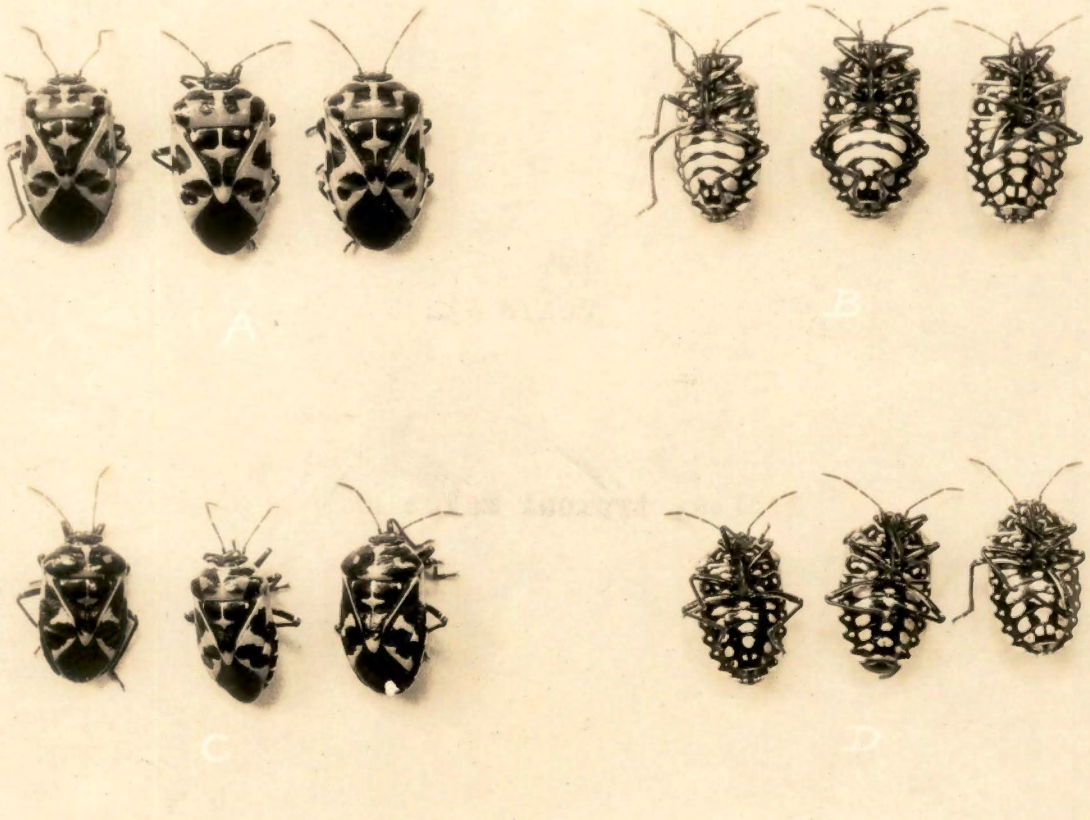
The adult is three-eights to seven-sixteenths of an inch long, black or metallic blue with bright red or orange markings, arranged more or less transversely and alternating. In shape the insect resembles a terrapin but is more oblong. The metasternal orifices are conspicuously located near the coxae, and without a prolonged canal, juga not longer than tylus, frena long, and tibia sulcate above. The scutellum is about three-fifths as long as the abdomen. In each corner of the scutellum, near the pronotum, there is a white spot. The apex is yellow. The pronotum is yellow or red. There is an inverted-black "u" on each side of the pronotum of the typical female; and an "o" on each side of the pronotum of the typical male. In the typical male there are three rows of dots, running longitudionally on the ventral side of the abdomen. The middle row is white, the other two white and orange. In the typical female the first two, sometimes three rows of these dots posterior of the Metathoracic legs are united, forming three solid white transverse bands across the ventral side of the abdomen.

1. Paddock, F. B. 1918. Studies on the Harlequin Bug. p. 10

PLATE II.

Adults, typical males and females.

A and B females, C and D males.


A
B
C
D

See plate two. Neither of these taxomic characters can be relied upon for determining the sex of the species, for males have the "u" shaped pronotum, and white bands across the ventral side of the abdomen. The head is about one-half as long as the pronotum and one-third as wide, and carinate above the insertion of the antennae. The head is well set into the pronotum and practically immovable. The antennae, which are located even with the bottom of the eyes, are filiform, and five jointed, the first joint being shorter and thicker than the rest. The compound eyes, which are white, are dichoptic, and are located about one-third of the distance down the head from the edge of the pronotum. There are no simple eyes. The proboscis is practically as long as the first four joints of the antennae; when not in use it is folded in the groove between the pro and mesothoracic legs. The front wing is yellow with black or red markings. About one third of the tip end of the wings are black, tectiform, and marked with fine furrows. When at rest, the wings cross just behind and fit under the apex of the scutellum. The hind wing, which is thin and veined, is thick and yellow at the base. The subcosta vein is yellow for nearly its entire length. There is a fold in the wing passing from the anal angle to the base. From the anal angle to the apex the wing is bluish black. About one-third of the distance from the apex to the base, along the costal margin, there is a light spot. On the ventral side of the legs between the tibia and femur joints, there is a mottled-white line. The tarsal claws are all apical, and the last tarsal segment entire.

Without looking at the genital organs it is almost impossible to distinguish the sexes. Usually the female is the larger, but there are small females and large males, so size cannot

PLATE III.

Abdicr, variation in size and color

be relied upon for the distinction. The wide white bands on the ventral side of the abdomen and the markings on the pronotum cannot be used as a guide, for there are many exceptions to these. The tip of the abdomen of the male is slightly "v" shaped, and the penis, which is large and flattened, is clearly visible. The first white spot on the ventral side and in the middle of the abdomen of the female next to the genitalia, is, almost without exception, narrow and cut into in the middle by a small black line, making the one spot look as if there were two. Looking at the genital organs is the easiest, quickest, and safest way to distinguish the sexes.

Old adults, especially those that have passed the winter, are smaller than young adults, and redder in color. Adults kept for an unusually long time in cages turn very dark, sometimes almost black. Plate two shows typical males and females; plate three shows variation in size and color of old and young adults; and plate five shows ginitatia of male and female.

Nymphs

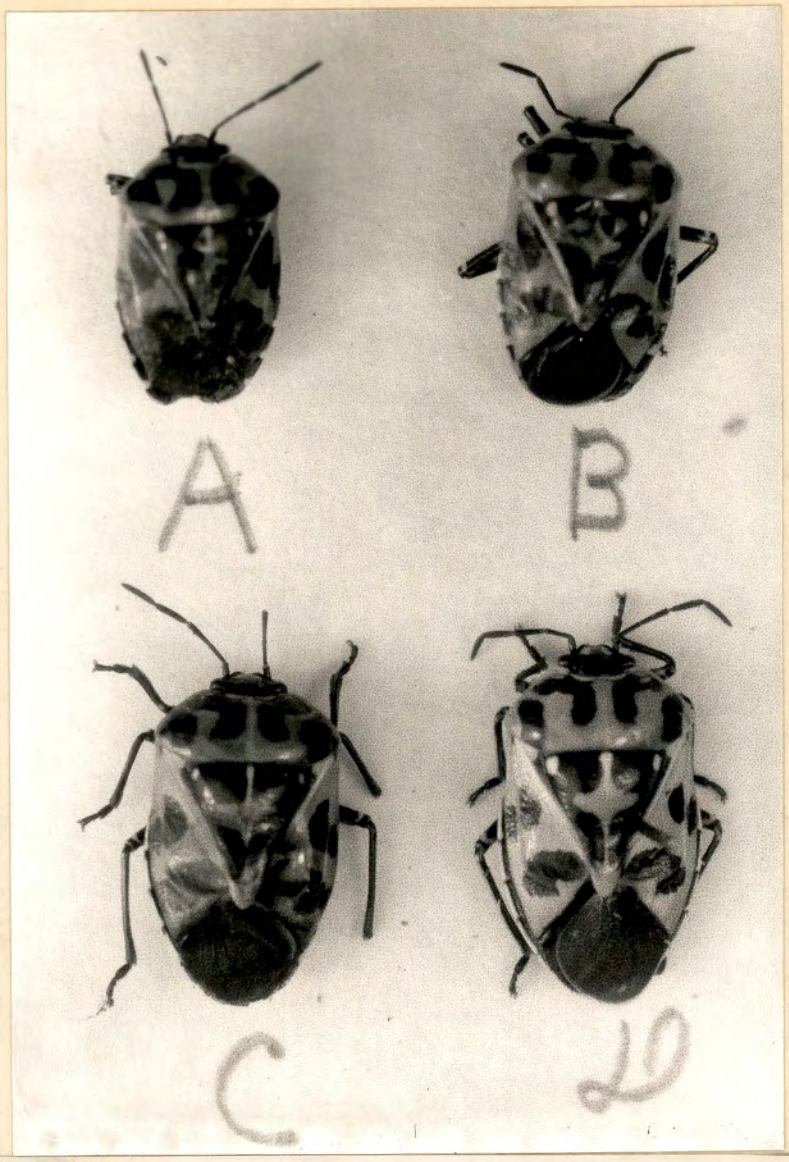
In the first and second instars the pronotum is solid black. Four black lines extend about half way across the ventral side of the abdomen. After the first instar these black lines all but the posterior one, become broken and the ends point posteriorly. The posterior line is rounded behind in all stages. In the second instar, truncated-black marks appear along the edge of the abdomen. In the third instar a yellow, diamond-shaped spot appears in the middle of the pronotum. Along the dextral and sinistral side of the pronotum is a yellow mark about one-eight inch long. There are three, more or less diamond-

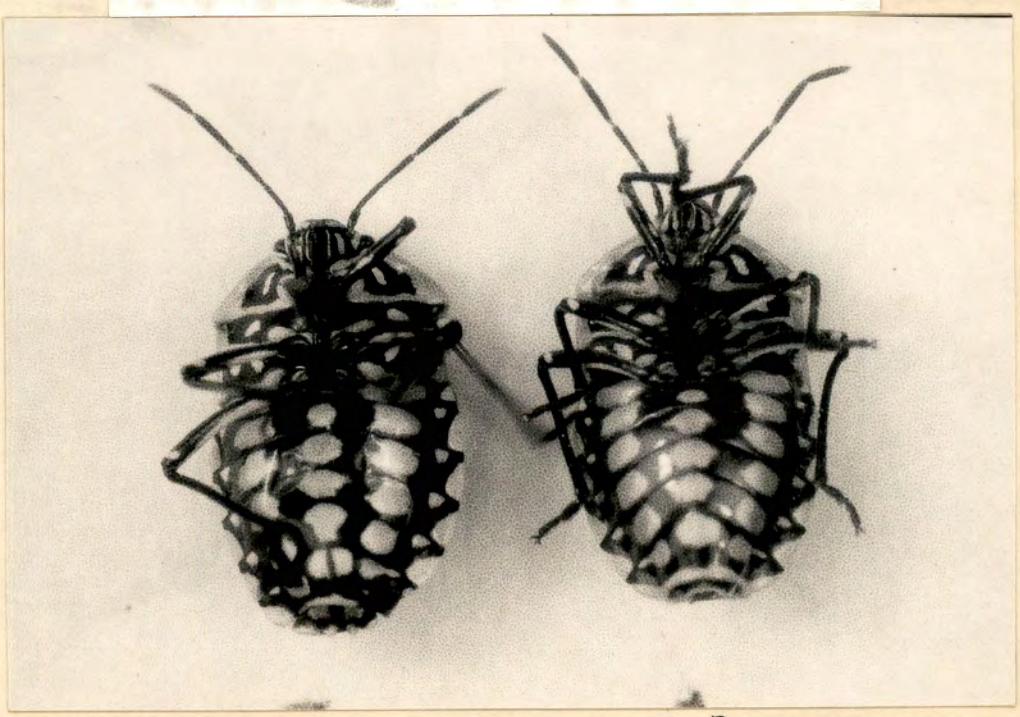
PLATE IV. TOP

Adults, old and young; variation in size and color.
A and B male. C and D female.

PLATE V. BOTTOM

Adults, genitalia of male and female.
A female. B male.


A
B
C
D


A
B

shaped, white spots on the cephalic part of the pronotum. The wing buds begin to appear in the third instar. The fourth instar is just like the third, all markings becoming larger and more prominent, the wing buds becoming very noticeable. The insects in all stages have black marks on the ventral side of the abdomen corresponding very closely to those on the dorsal side. The first instar is a glossy yellow, subsequent instars becoming darker and white and black markings on the abdomen more prominent.

When the insect molts the fifth time it becomes an adult. Wings appear and white markings on the dorsal side disappear save one inconspicuous white spot in each corner of the scutellum.

The nymphs in all stages are semi-xerophilous and phytophagus, sucking the juices from the leaves of the host plants.

Plate six shows eggs, and insect in all stages.

DISTRIBUTION

As previously stated, the Murg antia histrionica is a native of Central America and Mexico. It was first recorded in the United States in Washington County, Texas, in 1864. Within four years the insect had invaded Alabama, Louisiana, Georgia, South and North Carolina. The spread of the insect was most noticeable along the Atlantic seaboard and up the Mississippi River Valley. Mr. F. H. Chittenden reports the spread of this insect as follows:

"This species has been diffused from a central point of dispersal, Mexico, chiefly in the following directions: (1) From Texas eastward through the gulf states and northward along

the Atlantic seaboard to Long Island; (2) from Texas northward through the Mississippi Valley and thence through the Ohio River region into Ohio; (3) from northern Mexico into neighboring states, and from Lower California into southern California and Nevada."[2]

In 1869, Stelle recorded the occurrance of this insect at Humboldt and Nashville, Tennessee. At the present time, the insect is found in practically every, if not every, county in West and Middle Tennessee. The insect is well distributed in Knox County, also in all the bordering counties. A few of the most mountainous counties of East Tennessee are thought to be free from this insect.

The insect made its appearance in Nevada, Arizona, Colorado, and Virginia in 1875; Kentucky in 1879; Indiana 1890, Pennsylvania 1896; and Ohio and New York in 1910. Since 1920 the insect has spread into Nebraska, South Dakota, and Iowa.

Murgantia histrionica is destructive over the entire South to tidewater Virginia, which appears to be its northern limit as a permanent pest. Sometimes the insect does considerable damage northward of the District of Columbia, for example, in 1908 it did considerable damage in New Jersey. However, the occasional severe winters in the northern states prevents this insect from becoming established in these states. Plate seven shows a map of distribution of Margantia histrionica in the United States, June 1, 1928.

2. Chittenden, F. H. 1925. Harlequin Cabbage Bug. p. 5. U. S. Dept. Agr. F. B. 1061.

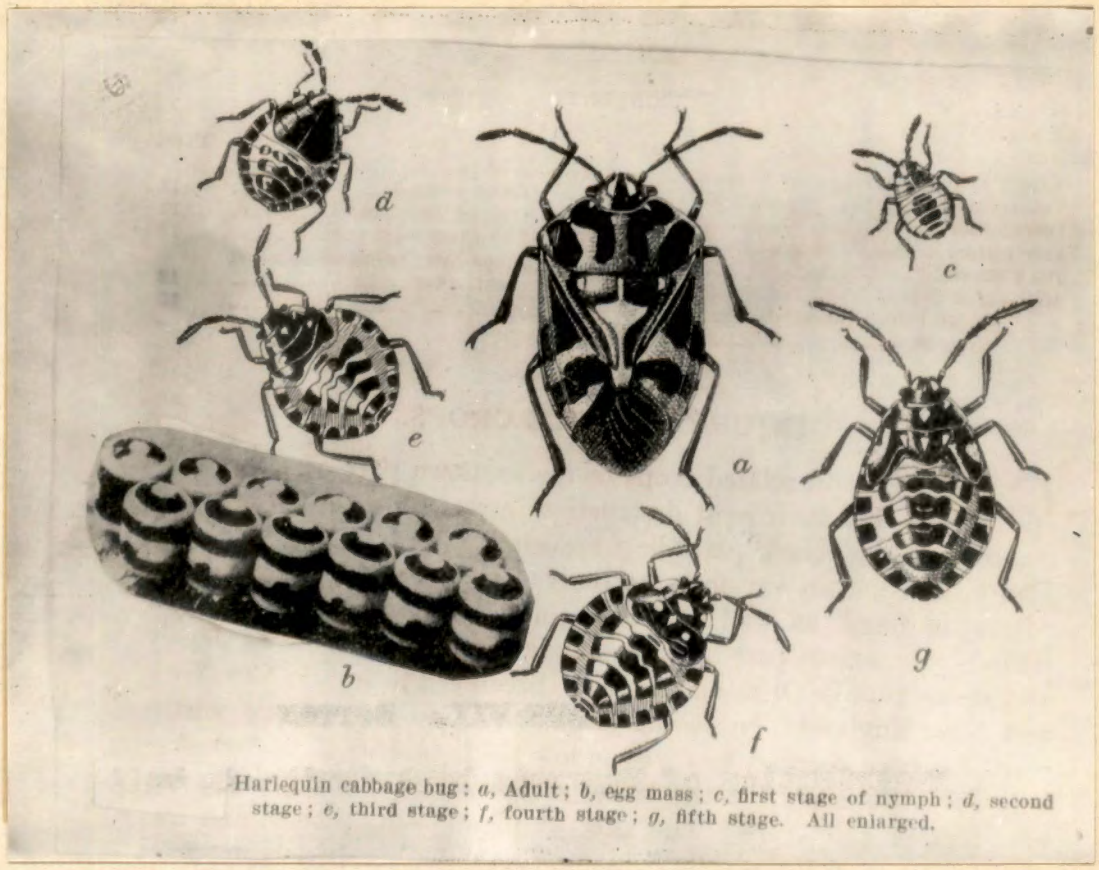
PLATE VI. TOP

Eggs, and imago in all stages

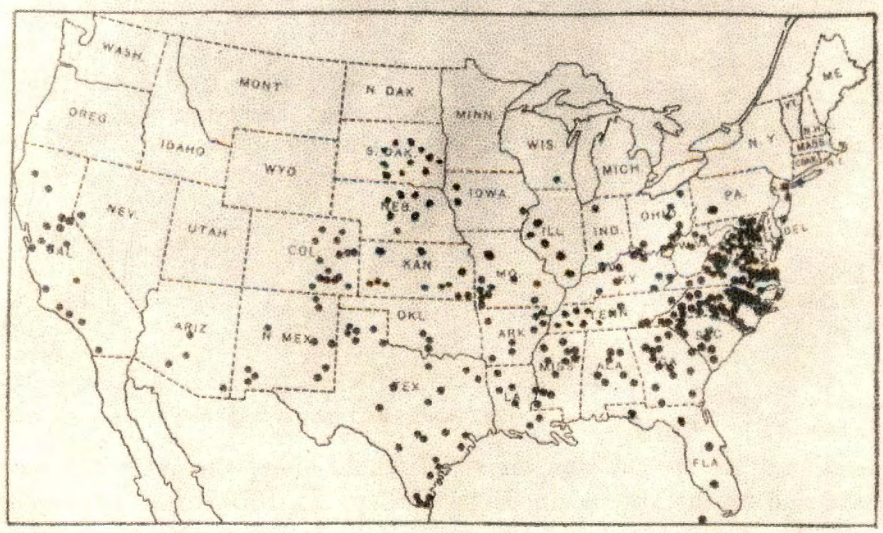
PLATE VII. BOTTOM

Distribution of Hypoderma diffusum in United States

June 1, 1938. (After Cobbenhem)



Harlequin cabbage bug: *a*, Adult; *b*, egg mass; *c*, first stage of nymph; *d*, second stage; *e*, third stage; *f*, fourth stage; *g*, fifth stage. All enlarged.



Map showing distribution of Murgantia histrionica, June 1928.

CLASSIFICATION

Murgantia histrionica is a true bug, and belongs to the order of Hemiptera. The name of this order -- Hemiptera -- comes from the Greek, "hemi", meaning half, and "pteron", a wing, on account of the basal half of the wing being thickened, in many species, with the terminal half transparent and membranous. The Murgantia histrionica belongs to the stink bug family, Pentatomidae; subfamily Pentatominae; and tribe Pentatomini.

Hahn in 1834 described the Harlequin bug as Stracha histrionica. Stall in 1867 erected the genum Murgantia in his work, and placed "histrionica", Hahn, as the only division of the genus. It seems that the work of Stall was received promptly in the United States, for Riley in 1872 gave the scientific name as Strachia (Murgantia) histrionica, Hahn. The name Murgantia histrionca has been accepted by all writers since that time.

COMMON NAMES

The Murgantia histrionica is spoken of in American Literature as the Harlequin Cabbage Bug. Cokerall called this insect harlequin because its black and orange markings are arranged somewhat like the pattern on a harlequin's clothes.[1]

In North Carolina this bug has been called: "Lincolnite", "A-Bug", "Collard Bug", "Terrapin Bug", "Fire Bug", and "Sherman Bug". This insect made its appearance in North Carolina about the time that Lincoln was President, and Sherman's Army

1. Cockerall, T. D. A. Observations on Insects. N. Mex. Sta. Bul. No. 35, p. 23.

was operating most actively; thus the names: "Lincolnite", and "Sherman Bug".

Howard says that this bug was called the "Abe Lincoln Bug" in Georgia for many years, and in Texas the "Third Party Bug". This bug has also been called "Yankee Bug", "Calico Bug", and "Calico Back".

In Tennessee this insect is commonly called by truckers the Cabbage Bug, Terrapin Bug, and Fire Bug. Plants upon which these bugs feed soon turn white or yellowish as if scorched by fire; hence the name "fire bug".

ECONOMIC IMPORTANCE

The early writers did not fail to impress on their readers the great destruction done by this insect. Dr. Linceum, one of the first writers, mentions the "utter destruction of cabbage, radish, mustard and turnip, finding from thirty-five to sixty full grown insects on every plant". Riley in 1870 said that the insect was a great pest in North Carolina. In the same year, B. R. Townens, Austin, Texas, gathered, by hand, 47,000 bugs. Stelle in 1870 said: "Last year it worked wholesale destruction". In 1881 the insect entirely destroyed the cabbage crop in some sections of Virginia. In 1892 and 1893 this insect was a very serious pest in the cabbage fields of Delaware. In 1908 it did considerable damage to the cabbage fields in New Jersey.

This insect is, more or less, a serious pest in the southern states every year. This insect has been a pest in Tennessee since 1869, and is getting worse every year. On the afternoon of

PLATE VIII

A. Injury caused to cabbage leaf by bug.

B. Field of cabbage in Delaware ruined by Imported bug.

(After Sanderson & Peairs).

Field of cabbage in Delaware ruined by the harlequin bug.

July 16, in three and one-half hours, I collected 1964 insects in a small rape patch. On one rape plant I caught forty-seven insects. Thirty of these were copulating. On April 23, I found fifty-one adults on a single cabbage plant. On June 7, I found 208 eggs on a single cabbage plant.

The amount of injury done to plants by these insects varies from a small per cent to complete destruction. Young plants are damaged much more than old plants. The insect prefers the outer green leaves of cabbage; and after the plant has begun to head, very little damage is done by the presence of the insects.

Plants upon which the insects feed soon turn white as if scorched by fire. Plate Eight A & B shows the nature and amount of injury done by the insect.

HOST PLANTS

Probably there is no insect, out of the 600,000 that have been classified and named, that have a greater range and number of host plants than the Murgantia histrionica. Truck crops, especially vegetables, and particularly those that belong to the cruciferous group, are the ones most likely to be attacked. However field crops, vineyards, flowers, and wild plants and trees are subject to attack by this insect.

Among the more common host plants are : Brussel's sprouts, cabbage, cauliflower, collards, kale, kohlrabi, radish, horseradish, mustard, rape, streotanthus, and turnip. The above named plants, at all seasons, are the ones most likely to be attacked and constitute the first choice of the insect. If these plants

are not available the insects will feed on any of the following: Cress (Lepidium sativum), asparagus, bean, beet, citrus (orange, grapefruit, and loquat), cherry, chrysanthemum, corn, cowpeas, eggplant, grape, lambquarters, wild and cultivated lettuce, potatoes, tomatoes, locust, okra, pigweed, (Amaranthus spinosus), ragweed (Ambrosia artemisiifolia), rose, squash, and sunflower.

Prof. F. B. Paddock, State Entomologist of Texas, says that this insect during March prefers pepper grass to all other vegetables, including cabbage, grown in gardens of that state. During the month of July in Texas, eggs are laid on the leaves of the corn plant, and the insect, in all stages, is found in great numbers on the corn plant. Cotton in Texas is attacked during August and September, at which time, there are, usually, few succulent vegetables.[3]

Along the Pacific Coast citrus fruits are subject to attack, especially very ripe fruits if the skin is broken.

Mr. Ollie Bean, trucker and gardener for the East Tennessee Hospital for the Insane at Bearden, Tennessee, told the author that he had observed this insect feeding on pokeweed (phytolacca decandra). He says that this insect almost completely strips the pokeweed plants on the hospital farm nearly every spring.

This insect does not attack the same host plants in different states; for example, there is no record of it ever attacking corn or cotton in Tennessee. This is true, no doubt, due to the fact that when the insect would most likely attack these plants, there are other available plants more desirable.

3. Paddock, F. B. Studies on the Harlequin Cabbage Bug. Texas Agr. Exp. Sta. Bul. No. 227, p. 17

In various states and at different seasons this species feeds on the following wild host plants: Pepper grass (Lepidium sativum), rock cress (Arabis virginica), water cress (Radicula Nasturtium-aquaticum), bitter cress (Cardamine Clematis Shuttlw), shepherd's purse (Capsella Bursa-Pastoris), Colorado honey plant, ragweed (Ambrosia artemisiifolia), grape (Vitis labrusca, V. vulpina, and V. rotundifolia), plumb (Prunus hortula, and P. americana et. al.) cherry (Prunus pennsylvanica, et. al.), pokeweed (Phytolacca decandra), and mustard (brassica, nigra). With the exception of the Colorado honey plant, all the above named plants are found in Tennessee.

Early in the spring the emerging adults feed and breed upon any nearby wild host plants until the more desirable cultivated plants are available. Eggs are laid upon the leaves of the wild host plants, and usually the first brood in the spring feeds entirely upon the wild plants. Especially is this true in Tennessee and states farther north. In states farther south, during mild winters, this insect may feed the entire winter on cabbage, collards, cauliflower, radishes, and other green winter crops. This is true in California and Florida, and in the southern part of Texas, Georgia, Louisiana, Mississippi, Alabama, and South Carolina.

METHOD OF STUDY

For the purpose of observing the details of the life history of this insect, specimens were isolated in glass cages. The types of cages used in this work are shown in plate nine. The cages used were made from photographic plates. The edges of the

PLATE IX.

cages were bound with adhesive tape to hold them in the desired position and to keep the cages from coming apart. To prevent the insects from escaping, tops were made from window screening to fit tightly over the tops of the rectangular cages. These tops have the advantage of admitting plenty of fresh air, and under certain conditions preventing excessive moisture in the cages; but they have the disadvantage of allowing the food material in the cages to become dry in a few hours. On account of the rapid drying of the food in the wire top cages, some were made with glass tops, adhesive tape being used for hinges. These cages have the distinct advantage of keeping the food material fresh longer. Fresh food was placed in the cages daily, which usually consisted of leaves of cabbage, kale, rape, mustard, and turnip, taken from the growing plants in the field when possible. In the winter when the above plants could not be secured, leaves from fresh lettuce were used. Two sizes of cages were used. When specimens were first collected from the field, they were placed in cages 5 x 7 x 5 inches, from one to three dozen being placed in a cage. As fast as the insects mated, single pairs were placed in cages $3\frac{1}{2}$ x 5 x $3\frac{1}{2}$ inches. By daily observation it was very easy to determine the number of copulations and the daily egg deposition of the mature bugs. For sanitary reasons a little sand was placed in the bottom of all cages. The sand was dampened with water as often as necessary to provide mositure in the cages and help keep the food material fresh.

For the purpose of determining the length of copulation, glass-shell vials, 1 x 4 inches were used. The vials bore the

same number as the cage from which the copulating insects were taken so that no mistake would be made. The insects were observed every two or three hours during the day and night. If a pair of copulating insects were observed at 2:30 A. M. and found "tied", and again at 4:30 A. M. and found "separated", the time of separation was recorded at 3:30 A. M., or half the time between the last two observations. No such allowance was made at the beginning of copulation. It is believed that the length of time the bugs copulated before being observed would, on the average, more than make up for any error in the allowance made when last observed.

Small glass vials, lined inside with adhesive tape to help prevent excessive mositure, were used for determining the length of the instars. Covers for the vials were made of cheese cloth and adhesive tape. This type of cover allows for circulation of fresh air and is a further preventive against excessive moisture in the vials.

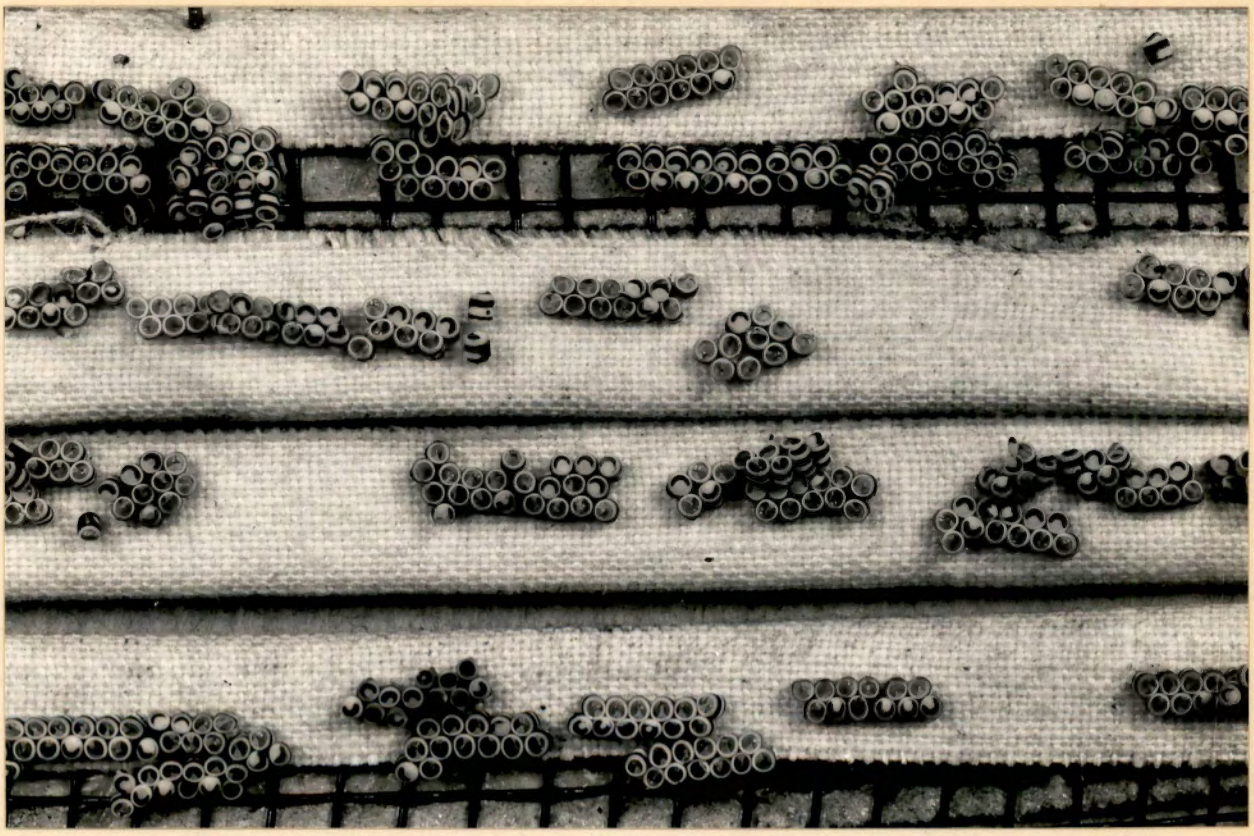
Several field trips were made, and quite a number of observations were made in the field, the results of which are given in this investigation.

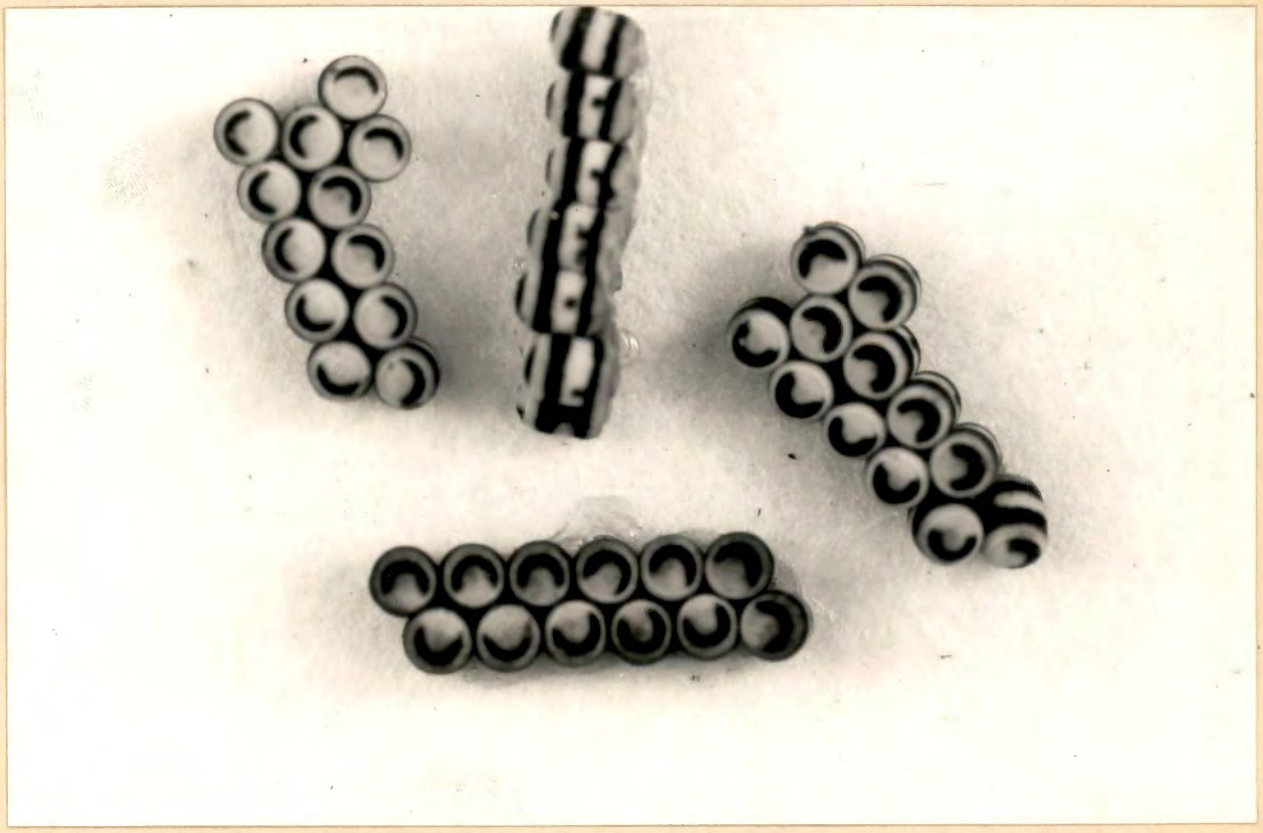
LIFE HISTORY

Eggs

The eggs, which resemble "minature white barrels bound with black hoops and with black spots set in for bung holes," are cylindrical and rounded at the ends. The eggs are deposited on the end in batches, which usually consist of two straight

PLATE X.





apparently has to "squeeze" out of the opening. While emerging the insect is held in an erect position by the shell. When all but the tip of the abdomen has emerged the insect stops for several minutes, allowing its parts to harden. This enables it to crawl off. The batch of eggs hatches irregularly over a period of from six to ten house, which allows freedom to the young insects in drying. From the time the shell is cut until the insect is dry there is a period of thirty to fifty minutes, depending somewhat on temperature. On dry hot days the whole process is completed in thirty or thirty-five minutes. After hatching the young remain clining to the sides of the shells from twenty-four to forty-eight hours, depending on temperature.

Incubation Period

The period of incubation varies, even under the same conditions. Eggs laid on the same date and placed in the life history room, basement of Morrill Hall, varied from one to three days hatching. Eggs laid on the same date and placed in an incubator, and kept at a constant temperature of 96 degrees F., would sometimes vary two days in hatching.

At a constant temperature of 80 degrees F. eggs hatch in five to eight days; at a temperature of 90 degrees F. they hatch in five to six days; and at a temperature ranging from 90 degrees to 100 degrees F. the eggs hatch in three to five days. Eggs kept in an incubator at a constant temperature of 96 degrees F. usually hatch on the fourth day.

NYMPHS

Number of Molts

From the observations made on Murgantia histrionica, the number of molts was always the same, five in number. On account of the delicacy and small size of the first and second instars, the insects were tedious to work with. Scores of experiments were started, but only six insects were reared to maturity with complete records of all the instars. The record for the instars is shown in the table that follows:

Table 1. Length of Instars

Hatched	First molt	Second molt	Third molt	Fourth molt	Fifth molt	Total Days
Apr. 22	Apr. 25	Apr. 30	May 7- 8	May 17-20	June 8-12	48-51
Apr. 25	Apr. 28	May 3-4	May 13-14	May 31 June 3	June 15-18	51-54

Duration of Period of Maturity

The duration of the period of maturity depends on food supply and climatic conditions. F. B. Paddock made a three year study of the life of this insect in Texas. He found the period of maturity to vary from twenty-three to sixty-six days. He records two insects that hatched on the same day, July 22, one matured August 27, the other September 10, a difference of thirteen days. Mr. Paddock found the insect to mature, on an average as follows: at a mean temperature of 68 degrees F., 52 days;

75 degrees F., 41 days; 80 degrees F., 32 days; 85 degrees F., 27 days; and 86 degrees F., 23 days.[4]

Ecdysis

The ecdysis is the most critical period in the life of the insect. No record was kept of the fatalities in ecdysis, but from my observations, I would judge there is at least twenty per cent. There is possibly ten per cent more fatalities in cool weather than in warm weather. Nymphs are about equally apt to die in any one of the five ecdysis.

The period of duration of any single ecdysis averages approximately seventeen minutes. The skin first splits transversely across the pronotum, then down the dorsal side of the abdomen forming a "T". When the insect first crawls out of the old skin it is solid white tinged with orange. In about one hour the insect changes to its normal color and markings. Plate eleven shows a nymph in the fourth instar just before, during, and after ecdysis.

ADULTS

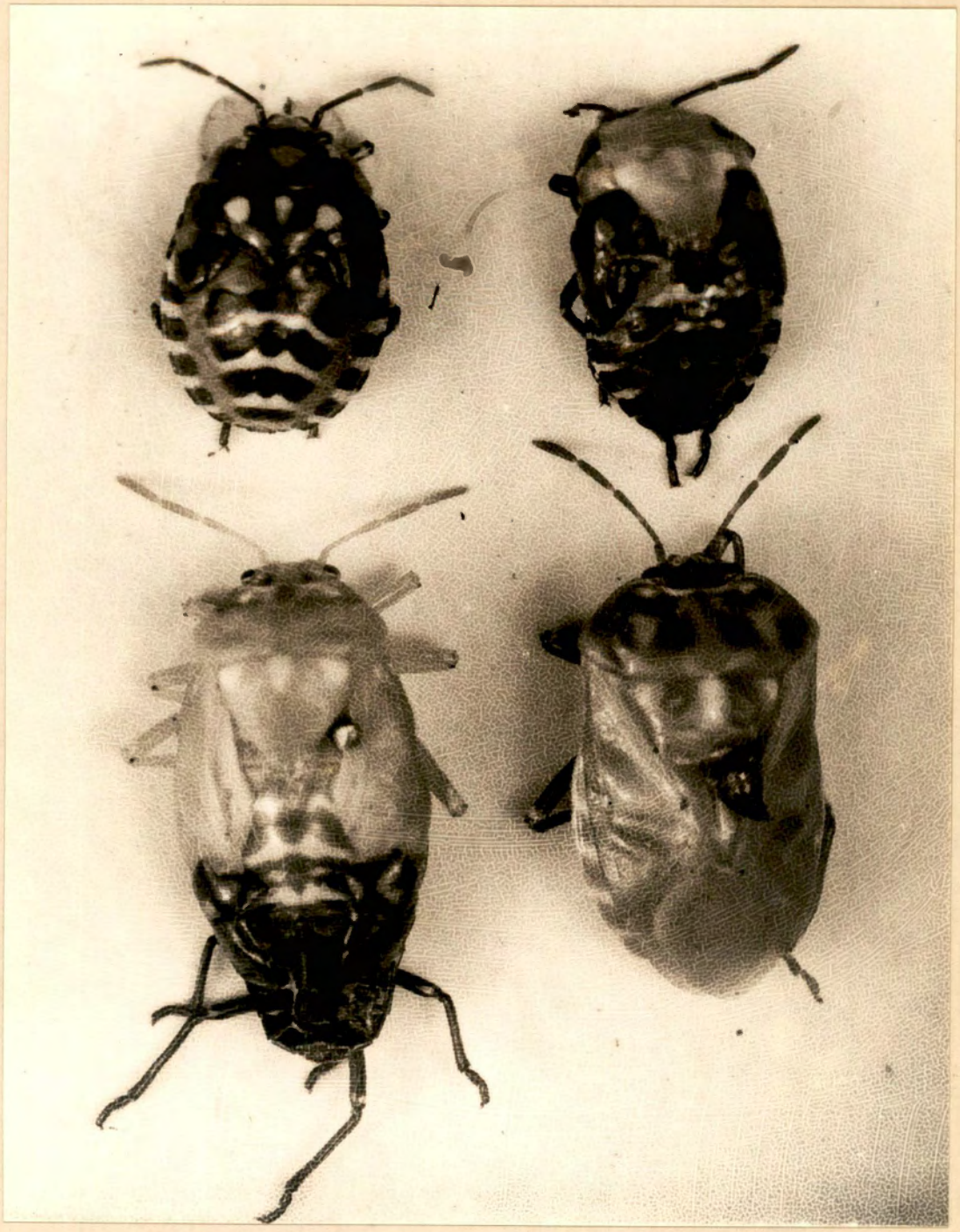
Duration of Life

Generally the male dies before the female, the exception being for the female to die first. When the male dies first, the difference is very little, whereas the female may live forty

4. Paddock, F. B. Studies on the Harlequin Cabbage Bug. 1918, Texas Agr. Exp. Sta. Bul. No. 227, pp. 30-34

PLATE XI.

Insect before, during, and after ecdysis.



or fifty days longer than the male. Table 2 shows period between death of male and female. In a count of the proportion of sexes, from bugs which I kept over winter in the laboratory, there were 27.272 per cent more females than males. In a similar count made on July 9, from young adults, there were 20.624 per cent more females than males. Two other counts were made, July 16, and July 20; the proportion of females in these counts was 0.356 and 3.654 per cent, respectively, greater than the males. From these counts it seems that at least twenty or twenty-five per cent more females than males live through the winter. The period between the death of the male and female in eight cages is shown in table two.

Table 2. Period between death of male and female

Male died	Female died	Period, days
May 5	July 11	37
June 11	June 17	6
June 1	July 19	48
June 18	July 16	28
June 9	June 11	5
June 2	July 23	52
June 4	June 11	7
May 13	May 26	13
		Av. 23.2

Only adult insects are able to withstand a killing frost. October 29 is the average date for the first killing frost around Knoxville. From my observations in the field I would judge that over fifty per cent of the old adults are dead by June first. Assuming that the insects are forty-five days old at the first

killing frost, October 29, and that the insects that live over winter are dead by June first, the average life of the fall brood would be about 260 days. It is claimed that the spring brood dies before fall, or during hibernation.

In a starvation test made with fifteen males and fifteen females, the females lived about two days longer; however this test is not conclusive. Table three shows the results of this test.

Table 3. Starvation test. Bugs taken from field and caged July 10.

Caged 4, P.M. July 10	Temperature			Observed	Dead		Period, days
	Max.	Min.	Mean		Male	Female	
July 10	91	80	77				
July 11	90	69	80				1
July 12	91	67	79				2
July 13	81	67	74				3
July 14	83	65	74				4
July 15	86	64	25	9:00 A.M.	2	1	5
July 16	90	68	79	7:00 P.M.	2	2	6
July 17	88	67	78	8:00 A.M.	2	1	7
				1:00 P.M.	5	3	
				5:00 P.M.	3	2	
				9:00 P.M.	2	1	
July 18	92	70	81	8:00 A.M.	1	2	8
				12:30 P.M.		2	
				7:00 P.M.		1	
					15	15	

Period Beteen Oviposition and Death

The period between the last deposition of eggs and death is short. The average for the eleven cases observed being 4.27 days. Only one of the eleven females lived over six days after the last deposition of eggs. The observations are given in the following table, number four:

Table 4. Period between oviposition and death.

Cage	Last eggs laid	Female died	Period days
1	May 1	May 3	2
2	July 18	July 20	2
20	July 5	July 11	6
21	June 14	June 17	3
22	July 13	July 19	6
23	July 10	July 16	6
24	*		
25	July 8	July 10	2
26	June 9	June 11	2
27	July 15	July 25	10
28	June 8	June 11	3
29	May 21	May 26	5
			Av. 4.27

* Female lost May 10.

Proportion of Sexes

Four counts were made to determine the proportion of the sexes. The first count was made June 28, on specimens of the fall brood, which I had kept alive in the laboratory over winter. The proportion of females in this count was 27.272 per cent greater than the males. The second count was made July 9, on young adults, many of which had molted on this date. These bugs were of the first to become adult in the spring. The proportion of the females in this count was 6.648 per cent less than in the first count, but greater than in either of the last two. The third count was made July 16, from specimens collected from the field on this date. The proportion of the females in this count was only 0.356 per cent greater than the males. The last count was made July 20, from insects collected in the field on this date. From the specimens collected on this date, 410 pairs were copulating. Had I not collected any

that were copulating, I believe the proportion of the females would have been greater in this count. The last count was on forms taken from a rape field approximately 20 feet wide and 400 feet long, on a farm about one mile southeast of the end of the Sevierville street car line. The insects in the two previous counts were taken from a cabbage field located about 150 yards south of the rape field. In all 2804 bugs were counted; of these 1473 were females and 1331 were males. The per cent of the females for the total count was 5.064 more than the males. The results of these counts are given in the tables that follow:

Table 5. Proportion of Sexes. Fall brood which hibernated.

Count made	No. females	No. males	Per Cent		Difference per cent
			Females	Males	
June 28	98	56	63.636	36.364	27.272

Table 6. Proportion of Sexes. First spring brood.

Count made	No. females	No. males	Per Cent		Difference per cent
			Females	Males	
July 9	76	50	60.317	39.624	20.624

Table 7. Proportion of sexes. First and Second spring broods.

Count made	No. females	No. males	Per cent		Difference per cent
			Females	Males	
July 16	281	279	50.178	49.822	0.356

Table 8 Proportion of sexes. First three spring boards.

Count made	No. females	No. males	Per Cent		Difference per cent
			Females	Males	
July 20	1018	946	51.872	48.173	3.654

Number of Generations per Year

Around Knoxville, the average date, over a period of fifty-six years for the first killing frost in the fall and the last in the spring, is October 29, and April 3. The difference between and including these two dates is 156 days. This leaves 209 days for the activity of the insect. Forty days under field conditions, would be a fair average for the maturity of the bug. In mid-summer the insect would mature a week or two sooner, but in the spring and fall they would be a week or two longer. On the average it would take the eggs about seven days to hatch. If the females started laying eggs eight days after maturity, the life cycle at the above allowance would be fifty-five days; and there could be only four generations a year at the most. My observations covered only one year: September 1927 to July 1928.

REPRODUCTION

Copulation

The insects are rather "long" on copulation, both in frequency and time. While on a field trip on April 23, I collected several pairs of insects copulating. Two of these pairs copulated thirty-six hours after I had collected them. On

December 14 and 15, I had a pair of bugs to copulate twenty-four hours and fifty minutes. Table nine shows a complete record of the copulation on thirty-three pairs of insects. The insects copulated a total of 141 times, and the average time of copulation was nine hours, fourteen and six tenths minutes. The average for the first, second, third, etc. up to the eleventh copulation is shown in the table. The average number of times copulated was 4.27. Copulation is usually started in the afternoon or early evening. Of the 141 cases of copulation recorded, only fourteen were begun in the morning.

In warm weather it seems that, typically, the insects copulate every day or every other day; that is once or twice between each deposition of eggs.

Copulation is begun by the male "backing-up" to the female. Plate twelve A shows copulating position. Owing to the large size of the penis of the male (See plate twelve C & D), it is with much difficulty that the "union" is made. Possibly the large size of the penis is the cause of the insects remaining "tied" so long. Plate twelve C shows the penis of the male extended. During my observations on copulation, I found, on three occasions, a male "tied" to a dead female. Plate twelve B shows one of the couples; the female had been dead three hours (I do not know how much longer) when this picture was taken. On several occasions I saw a male try to copulate another male. This phenomena is not so very uncommon even among some of the higher animals. I cite one example:

PLATE XII.

A. Gaze accentuating.

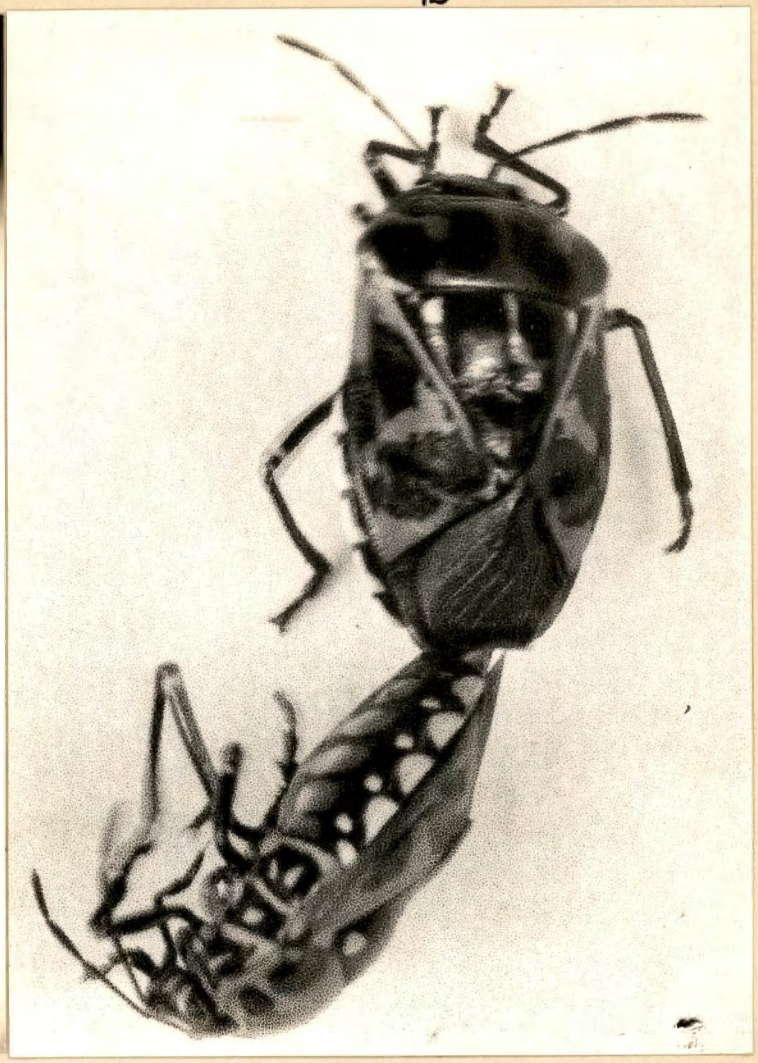
B. Male "lean" to a deaf female.

C. Male, facial-extended.

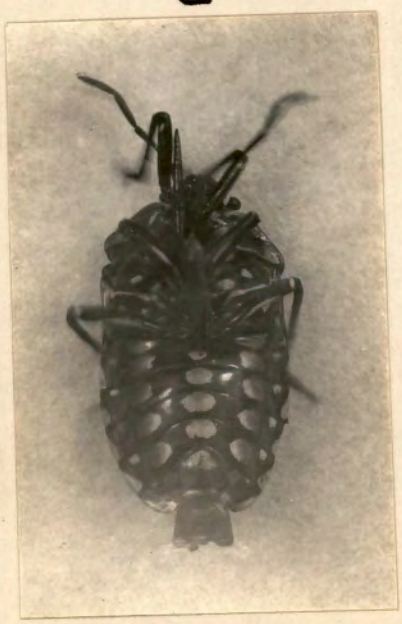
D. Female.

A

B



C



D

"Sex discrimination in frogs is not very precise. Males are sometimes held by other males for a long time, and copulation is not infrequently known to occur between males of different species. Spallanzoni records a male toad that carried around an individual of his own sex that had died some days previously and was in an advanced state of decay."[5]

Period Between Maturity and Copulation

The period between maturity and copulation in the twelve couples of insects observed varied from five to thirty-one days. Only two couples went over ten days before copulating, and these four insects matured March 20, when the days were cool and the nights chilly. The other ten couples observed, that became mature in July, copulated, on an average, 7.5 days after becoming mature. The average for all cases observed is 10.5 days. The results are shown in the table number ten.

5. Holmes, Samuel J., 1927 The Biology of the Frog, p. 323

Table 10 Period between maturity and copulation.

Box	Matured	Mated	Copulated	Period days
S 1	March 20	March 22	April 11	21
S 2	March 20	March 22	April 28	31
S 3	July 2	July 3	July 9	7
S 4	July 2	July 3	July 10	8
S 5	July 2	July 3	July 12	10
S 6	July 7	July 7	July 12	6
S 7	July 7	July 7	July 14	7
S 8	July 7	July 7	July 16	9
S 9	July 7	July 8	July 15	8
S 10	July 7	July 8	July 16	9
S 11	July 13	July 14	July 19	6
S 12	July 14	July 15	July 19	5
				Av. 10.5

Fertility Period

On May 4, I collected 237 insects in the field. Pairs that were copulating were placed in a cage to themselves, and as soon as copulation was finished the males were permanently separated from the females. In this way twenty-five cages were prepared. No doubt some of the females had copulated before; even so, this would not affect the accuracy of the experiment. The experiment shows that the female can lay eggs for at least two months. One female laid six eggs on July 20, seventy-three days after being separated from the male. Four of the six eggs hatched; the other two were mashed. Table eleven shows the oviposition period, number of eggs laid, and the per cent hatched. The oviposition period averaged 35.7 days; the average number of eggs laid per female was 77.8; 89.5 per cent of the eggs hatched.

Table 11 Showing fertility period after copulation, number of eggs laid, and per cent that hatch.

Cage	Oviposition period	days	No. eggs laid	Per cent of eggs that hatch
1	May 7	1	12	100
2	May 9, to July 17	69	167	85.63
3	May 8, to July 20	73	143	94.40
4	May 7, to June 10	34	42	71.42
5	May 8, to July 6	59	111	84.68
6	May 10, to June 15	36	51	100
7	May 7, to June 21	45	106	52.83
8	May 10, to June 15	36	49	97.95
9	May 8, to June 12	35	84	100
10*				
11	May 8, to June 18	41	143	89.52
12	May 10, to June 24	45	103	88.35
13*				
14*				
15	May 11, to June 12	32	62	85.48
16	May 9, to June 12	34	81	75.31
17	May 12, to June 10	29	35	88.57
18	May 9	1	12	100
19	May 13	1	13	100
20	May 8, to July 30	66	101	99.01
21*				
22	May 10, to May 14	5	24	100
23	May 9, to June 23	45	110	78.18
24	May 7, to June 3	27	107	99.06
25*				
	Total	714	1556	1790.30
	Average	35.7	77.8	89.50

* Never laid.

Oviposition

In the field eggs are laid on the under side of the leaf, occasionally to the midrib. During my observations in the field I found only three batches of the eggs that were laid on the top of the leaf. In glass cages eggs are usually attached to adhesive tape. In all cases the eggs are deposited in a protected place.

I observed several females in the act of oviposition. The period of duration of a deposition of eggs depends upon the number of eggs in the batch. During oviposition a female lays an egg every two or three minutes. I observed the deposition of three batches of eggs, twelve eggs in each batch, the time in each case was between twenty-seven and thirty minutes.

Age at Beginning of Oviposition.

The age of the females when oviposition starts varies greatly with the individuals, and seasons. Table ten shows that females copulate the first time from five to thirty-one days after maturity, the average being 10.5 days. Table twelve shows that the first deposition of eggs is two to four days after the first copulation, the average being 3.3 days. The average age of females at beginning of egg deposition is 13.8 days.

Period Between First copulation and First Deposition of Eggs.

Females begin deposition of eggs in two to four days after the first copulation. The average for the twelve females observed is 3.3 days. The period between the first copulation and the first egg deposition is shown in the following table:

Table 12 Period between first copulation and first deposition of eggs.

Cage	First Copulation	First eggs laid	Period, days
S 1	April 11	April 15	4
S 2	April 28	May 1	2
S 3	July 9	July 9	3
S 4	July 10	July 13	3
S 5	July 12	July 15	3
S 6	July 12	July 16	4
S 7	July 14	July 18	4
S 8	July 15	July 18	3
S 9	July 16	July 20	4
S 10	July 16	July 20	4
S 11	July 19	July 22	3
S 12	July 19	July 22	3
			Av. 3.3

Rate of Oviposition

Some females lay eggs more or less regularly every three days, others every four days. Typically it seems that the female lays every three days until she is about "spent". Sometimes a female just beginning to lay will lay every other day until she has laid four or five batches of eggs. Near the end of the oviposition period a female may go ten or twelve days, sometimes longer, before laying. When females lay over twelve batches of eggs, there may not be over six or eight eggs in each of the last three or four batches laid.

The rate of oviposition for two sets of cages are shown in the two following tables:

Table 13 Rate of Oviposition

Cage	Eggs	Batches	Period, days
1	70	6	16
2	184	17	78
20	193	19	64
21	130	11	46
22	215	19	76
23	159	14	72
24	69	6	14
25	119	10	44
26	102	10	39
27	194	17	79
28	154	13	38
29	96	8	22
Total	1685	150	588
Average	140.41	12.5	49

Table 14 Rate of Oviposition

Cage	Eggs	Batches	Period, days
1	12	1	1
2	167	17	69
3	143	14	73
4	42	4	34
5	111	11	59
6	51	4	36
7	106	10	45
8	49	4	36
9	84	7	35
10 *			
11	143	12	41
12	103	8	45
13 *			
14 *			
15	62	6	32
16	81	7	34
17	35	4	29
18	12	1	1
19	13	1	1
20	101	11	66
21 *			
22	24	2	5
23	110	10	45
24	107	9	27
25 *			
Total	1556	143	714
Average	77.8	7.15	35.7

* Never laid

Relation of Number of Copulations to Number of Eggs Laid

A careful analysis of tables 15 and 16 shows that there is very little relation between the number of copulations and the number of eggs laid. Especially is this true if the female copulates as many as three times after she starts laying eggs. The females in table 15 were allowed to copulate at will, while those in table 16 were allowed to copulate only once after being collected in the field May fourth. The highest number of eggs laid by a

single female was 215; this female copulated nine times. One female copulated twelve times and laid only seventy eggs; another female copulated ten times and laid 102 eggs; another nine times and laid 159 eggs. Two females copulated three times each; one laid 96 eggs; the other 193. Three females copulated seven times each; one laid 119 eggs, another 130 eggs, and the third 184 eggs. In table 15 the three females which copulated the largest number of times (nine, ten, and twelve) laid a total of 331 eggs. The three females that copulated seven times each laid a total of 433 eggs. In table 15 the four females that copulated the largest number of times laid a total of 546 eggs. The four females that copulated the smallest number of times laid a total of 610 eggs, or 64 eggs more than the four that copulated the largest number of times.

The average number of eggs laid per female in table 15 is 140.41, the average in table 16 is 77.8. The five females which laid the highest number of eggs in table 15 copulated a total of thirty-three times, and laid a total of 945 eggs. The five females in table 16 which laid the highest number of eggs copulated a total of only three times and laid a total of 638 eggs. The latter copulated one-eleventh as many times as the former and laid over two-thirds as many eggs. The female in table 16 that copulated only one time, and laid 167 eggs, laid over twice as many eggs as the female in table 15 that copulated twelve times.

Table 15 Relation of number of copulations to number of eggs laid, and per cent that hatch.*

Cage	Oviposition period	No. Cop.	No. eggs laid	Per Cent eggs hatch.
1	April 15, to May 1	12	70	100
2	May 1, to July 18	7	184	98.37
20	May 2, to July 5	3	193	93.21
21	April 29, to July 13	7	130	100
22	April 11, to July 13	8	215	69.30
23	April 30, to July 10	9	159	96.79
24	April 30, to May 13	4	69	75.35
25	April 26, to June 8	7	119	100
26	May 1, to June 9	10	102	89.47
27	April 28, to June 15	6	194	96.39
28	May 1, to June 8	5	154	99.35
29	April 30, to May 21	3	96	98.86
Total		81	1685	1117.20
Average		5.72	140.41	93.10

* Insects allowed to copulate at will.

Table 16 Relation of the number of copulations to the number of eggs laid, and the per cent that hatch.*

Cage	Oviposition Period	No. Cop.	No. eggs laid	Per cent of eggs that hatch
1	May 7	1	12	100
2	May 9, to July 17	1	167	85.63
3	May 8, to July 17	1	143	94.40
4	May 7, to June 10	1	42	71.42
5	May 8, to July 6	1	111	84.68
6	May 10, to June 15	1	51	100
7	May 7, to June 21	1	106	52.83
8	May 10, to June 15	1	49	97.95
9	May 8, to June 12	1	84	100
10**				
11	May 8, to June 18		143	89.52
12	May 10, to June 24	1	103	88.35
13**				
14**				
15	May 11, to June 12	1	62	85.48
16	May 9, to June 12	1	81	75.31
17	May 12, to June 10	1	35	88.57
18	May 9	1	12	100
19	May 13	1	13	100
20	May 8, to July 13	1	101	99.01
21**				
22	May 10, to May 14	1	24	100
23	May 9, to June 23	1	110	78.18
24	May 7, to June 3	1	107	99.06
Total			1556	1790.03
Average			77.80	89.50

* Insects allowed to copulate only once after being caged.

** Never laid.

Relation of Number of Copulations to Number of Eggs that Hatch.

In all cases the per cent of eggs that hatch is either high or low, usually less than ninety or more than ninety-eight. There seems to be a relation between the number of copulations and the per cent of eggs that hatch. In table 16 the average per cent of hatch is 89.5; in table 15 the average is 93.1 per cent. In

table 16 the per cent of hatch of eggs of six females is 100; in each of these cases the number of eggs laid is less than eighty-five. In three of the six cases, the female laid only one batch of eggs, thus making the per cent of hatch unusually high. The hatch of eggs of over one-half of the females in table 16 is less than ninety-six per cent while three-fourths of the females in cage 15 has a hatch of over ninety-six per cent. In table 15 in each of the three cases of 100 per cent hatch, the females copulated seven times each. This is, I think, a mere incident, for one of the females that copulated only three times, and laid ninety-six eggs, has a hatch of 98.96 per cent. Another female that copulated seven times, and laid 184 eggs, has a hatch of 98.37 per cent. The average per cent of hatch of the five lowest cases in table 16 is 72.42; the average for the five lowest in table 16 is 84.74 per cent, or 12.48 per cent more.

SUMMARY

1 Average period between maturity and copulation was 10.5 days.

2 Average period between first copulation and first deposition of eggs was 3.3 days.

3 Average number of eggs deposited per female was 109.1.

4 Largest number of eggs deposited by single female was 215.

5 Largest number of eggs laid in single batch was 19.

6 The eggs deposited by ten females hatched 100 per cent.

7 Average per cent of eggs that hatched was 91.3.

8 Average period of egg deposition was 42.3 days.

9 One female laid fertile eggs 79 days after being mated with male.

10 Largest number of eggs found on single plant in field, (June 18) was 208.

11 Date of first eggs found in the field in the spring was May 5.

12 First adult found in the field was April 23.

13 First young adult found in the field was July 2.

14 Largest number of adults found on a single plant in the field was 51.

15 Average period of copulation was 16 days.

16 Longest length of single copulation observed was 36 hours.

17 Average length of single copulation, 141 cases, was 9 hours, 14.6 minutes.

18 Average number of copulations per mated pair was 4.27.

19 On average females live about 23 days longer than males.

20 There are about 5 per cent more females than males.

21 There is little relation between the number of copulations and the number of eggs laid.

22 There is more relation between the number of copulations and the number of eggs that hatch, than between the number of copulations and the number of eggs laid.

23 The insect molts 5 times in becoming adult.

24 Duration of maturity varied from 48 to 54 days.

25 During deposition, the female lays an egg every two to three minutes.

26 Average duration of ecdysis was about 17 minutes.

27 There cannot be over four generations of Murgantia histrionica.

BIBLIOGRAPHY

Atkinson, J. F. 1888. The Harlequin Cabbage Bug. S. Car. Bul. No. 2, part 1, page 76.

Barre & Conradi. 1909. Treatment of Plant Diseases and Injurious Insects in South Carolina. S. Car. Bul. 141, p. 28, 1909.

Beckwith, H. M. 1891. Injurious Insects and Insecticides. Del. Bul. 12, p. 11, 1891.

Bennett, E. R. 1909. Cabbage-Growing on the Irrigated Land of Colorado. Col. Bul. 143, p. 7.

Bentley, G. M. 1910. Sixth An. Rept. Tenn. State Board of Ent., pp. 55-58.

Britton, W. E. Miscellaneous Insects and Notes. Conn. State Report, 1914, p. 193.

Campbell, J. P. 1889. The Harlequin Cabbage Bug. Ga. Bul. No. 3, p. 47.

Chandler, W. H. 1912. Spraying Cabbage, Cauliflower, Kale, etc. Mo. Bul. No. 102, p. 69.

Close, C. P., and White, T. U. 1909. Cabbage Experiments and Culture. Md. Bul. No. 133, p. 195.

Cockerall, T. D. A. 1900. Observations on Insects. N. Mex. Sta. Bul. No. 35, p. 23.

Conradi, A. F. 1907. Insects of the Garden. Texas Bul. No. 89, p. 9.

Crosby, C. H. & Leonard, M. D. 1918. Manual of Vegetable-Garden Insects. Pp. 38-42.

Essig, E. O. 1926. Insects of Western North America. Pp 340-342.

Felt, E. P. 1910. Garden and Grain Insects. N. Y. Bul. No. 409, p. 53.

Fernald, H. T. Applied Entomology. P. 172.

Fulton, R. H., Wright, W. J. Gregg, I. W. 1911. The Control of Insects and Diseases Affecting Horticultural Crops. Pa. Bul. No. 110, p. 21.

German, H. 1895. The Harlequin Cabbage Bug. Ky. Rpt. 1895, p. 44.

1904. Insects Injurious to Cabbage. Ky. Bul. No. 114, 1904. p. 40.

Garcia, Fabian, 1890. Injurious Insects. N. Mex. Bul. No. 68, p. 10.

Glover, Townsen. 1867. Report Commissioner of Agriculture, 1867, p. 71.

1870. Report Commissioner of Agriculture, 1870, p. 90.

1871. " " " " 1871, p. 84.

1875 " " " " 1875, p. 16.

Howard, L. O. 1897. Some Miscellaneous Results of the Work of the Division of Entomology. U. S. D. A. Bul. 7, Bur. of Ent., p. 80, also Bur. Circ. No. 10.

1912. The Insect Book. P. 313.

Kellogg, U. L. 1908. American Insects. Pp. 214-215.

Linter, J. A. 1882. Murgantia histrionica (Hahn), N. Y. First An. Rpt. of Nox. Insects, 1882, p. 264.

1893. Murgantia histrionica (Hahn), N. Y. Ninth An. Rpt. of Nox. Insects, 1893, p. 315.

1895. N. Y. 11th. Rpt. (An.) of Nox. Insects, p. 280.

Lockhead, William. 1919. Economic Entomology. P. 166.

Lutz, Frank E. 1921. Fieldbook of Insects. P. 114.

Morgan, H. A. 1897. Entomological Report. La. Bul. No. 48, pp. 139-141.

Morrill. 1910. Plant-Bugs Injurious to Cotton Bolls. Bur. Ent. Bul. 86, p. 38,110.

Newell, W., & Rosenfield, A. 1909. Some Common Insects Injurious to Truck Crops. La. Crop. Pest. Circ. 27, p. 97.

O'Kane, Walter. 1912. Injurious Insects. P. 191.

Paddock, F. B. 1915. The Harlequin Cabbage Bug. Texas Bul. 179, 1915.

1918. Studies on the Harlequin Cabbage Bug. Texas Agr. Exp. Sta. Bul. No. 227.

Parrott, P. J. 1894. Insects Affecting Late Cabbage. Geneva Bul. 83, p. 683.

Quaintance, A. L. 1899. Insect Notes for 1899. Ga. Sta. Rpt., 1899, pp. 141-145.

Riley, C. V. 1893. Injurious Insects of Maryland. Md. Bul. 23, 1893, p. 85.

Sanborn, 1914. Garden and Truck-crop Pests. Okla. Bul. 100, p. 24.

Sanderson, E. D. 1900. Report of the Entomologist. Del. Rpts., 1899-1900, pp. 210-211.

1902. The Harlequin Cabbage Bug. Del. Rpt., 1902, p. 139.

1907. Insects of the Garden. Texas Bul. 89, pp. 9-11.

1908. The Influence of Minimum Temperatures in Limiting the Northern Distribution of Insects. Jr. Eco. Ent., 1, 4, p. 245.

1912. Insect Pests of the Farm, Garden, and Orchard. P. 268.

Sherman, F., Jr. 1904. The Harlequin Cabbage Bug. N. Car. State Dept. of Agr., Ent. Cir. 8.

Smith, J. B. 1896. The Harlequin Cabbage Bug. N. J. Rpt., 1896, pp. 458-461.

Smith, J. B. 1897. The Harlequin Cabbage Bug and the Plant Louse. N. J. Bul. 121. 1897. E. S. R., Vol. 9, p. 68. 1917. Control of Some Garden Insects. Va. Truck Exp. Sta. Bul. 23, p. 497.

Smith, R. I. 1908. Some Insect Enemies of Garden Crops. N. Car. Bul. 197, p. 18. 1908.

1909. Biological Notes on Murgantia histrionica (Hahn). Jr. Eco. Ent., Apr. 1909, p. 108.

Stedman, J. M. 1893. Injurious and Beneficial Insects. Ala. Bul. 45, p. 28, 1893.

Stinson, J. T. 1895. Injurious Insects to Fruit and Vegetables and Remedies for Destroying Them. Ark. Sta. Rpt., 1895, p. 83.

Symonds, T. B. 1905. The Common Injurious and Beneficial Insects of Maryland. Md. Bul. 101, p. 187. 1905.

U. S. Y. B. 1905. Insects Injurious to Truck and Vegetable Crops. P. 629.

1906. Insects Injurious to Truck and Vegetable Crops. P. 511.

1907. " " " " " " " P. 514.

1908. " " " " " " " P. 571.

Washburn, F. L. 1918. Injurious Insects and Useful Birds. P. 235.

Watts, R. I. 1892. Fruit Trees and Experiments with Vegetables. Tenn. Bul., Vol. V., No. 1, p. 16.

Webster, F. M. 1896. Some Destructive Insects. Ohio Bul. 68, 1896, p. 35.

Weed, H. E. 1892. Insects Injurious to the Cabbage. Miss. Bul. 21, p. 12.