THE LIFE HISTORY, MORPHOLOGY AND CONTROL

OF DAIHINIA BREVIPES HALDEMAN.

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By

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PREFACE

The possible economic importance of *Daihinia brevipes* Haldeman (Gryllacrididae, Orthoptera), a nocturnal insect living in burrows in sandy soil, was first brought to the attention of the Oklahoma Agricultural Experiment Station in the spring of 1935. At that time letters were received by the Department of Entomology from farmers and a vocational agriculture teacher asking for information on the insect, and stating that it was doing extensive damage to tomato, cotton, melon, and cowpea seedlings. A review of literature indicated that the life history and control were unknown.

Since the insect was observed to thrive in sandy regions, and since sandy soil is found over approximately one-fifth of the western half of the State of Oklahoma, it was thought that the insect merited study as a potential menace to thousands of acres of crops.

In addition to the possible economic importance of the species, it was apparent from the previously published work on the subfamily Rhaphidophorinae, of which this species is a member, that there was a definite need for more life history and morphological information. Blatchley (2) in 1920 observed of the members of this subfamily, "Their food habits and life histories are as yet practically unknown and offer an interesting and virgin field of research......." Hubbell (8) in 1936 states, "No detailed treatment of the morphology of any species of this genus (*Ceuthophilus*), or indeed of any native American Rhaphidophorid, has yet been published". Concerning life histories and habits the same author states, "The following observations, though fragmentary, appear worthy of record in view of the paucity of information upon the subjects treated".

A project could not be set up at the time for the purpose of investigating the species, so from 1935 to 1938 only occasional observations and collections were made. Relatively little was learned during this period. In 1939 the Department employed a full-time assistant on the project at Crescent, Oklahoma, during which time studies on the life history and control were made.

The author studied the problem during 1940, and it is primarily upon information obtained during this time that this thesis is based, although the notes of the previous workers have been used and referred to extensively.

Gratitude is expressed to Dr. F. E. Whitehead, under whose direction the work was conducted; to Mr. John Standish and Mr. Howard Eckley for the use of unpublished notes concerning the problem; to Professor G. A. Bieberdorf for photographical assistance; to Mr. H. E. Arnett for cooperative provision of laboratory and plot space; to Dr. F. M. Baumgartner and Professor George Moore for determination of the species of the predators collected; and to Dr. D. E. Howell for permission to use morphological drawings made in connection with work under his direction.

TABLE OF CONTENTS

INTRODUCTION

Daihinia brevipes Haldeman is a member of the subfamily Raphidophorinae, commonly known as the cave-crickets or camel-crickets. Many students refer this subfamily to the Tettigoniidae, but Hubbell (8) places it in the Gryllacrididae. The insect is dark brown, mottled with lighter shades, and about 24 mm. in length. The body is thick and robust, and roundly humped dorsally.

Research was conducted principally in a sandy farming region near Crescent, Oklahoma, under the sponsorship of the Department of Entomology, of Oklahoma A. and M. College. The author was stationed in this area for intensive study of the cricket from February to July, 1940. Due to the nocturnal habits of the species, much of the work was done at night with the aid of a flashlight.

Laboratory and storage space was obtained in a concrete-walled building in Crescent. A weather station was set up near the laboratory, including three thermographs (two for taking soil temperatures and one for air temperatures), a thermometer, a psychrometer, and a rain gauge.

This work was planned to give information on the general life history, the relation of temperature to activity, food habits, extent and intensity of population, control methods, and various incidental problems. Work on the morphology of the species was later undertaken.

Throughout this paper the term "emergence" has been used to mean the exit of a cricket from its burrow for feeding or other purposes on the surface of the ground, and should not be confused with the more common entomological usage indicating the emergence of the imago from the pupa.

The term "worked" as here applied to a cricket burrow refers to the disturbance of soil or presence of fresh soil about the burrow entrance, indicating that the occupant has been active, either in leaving the burrow or in further digging.

Although this insect belongs to the group commonly known as "camel-crickets", it has been referred to in this paper simply as "the cricket", no common name for the insect being in usage.

Daihinia brevipes is the only species of this subfamily of numerical or other known importance in the area studied, although an occasional specimen of what was determined by the writer to be *Udeopsylla robusta* Haldeman is found in the same environment as is *D. brevipes*. On one occasion specimens of both species were trapped from the same burrow.

REVIEW OF LITERATURE

A review of the literature pertaining to the subfamily Rhaphidophorinae shows a dearth of published work on the taxonomy of D. brevipes, and a virtual absence of life history or morphological information.

Haldeman (5) in 1850 described the species under the genus Phalangopsis, creating at the time a new subgenus Daihinia for the new species. Daihinia was raised to generic rank by Scudder (11) in 1862. Caudell (3) in 1916 reviewed the genera of the insects in this group, giving descriptions of the two species assigned to Daihinia. In 1927 Hubbell and Ortenburger (9) list D. brevipes as occurring in Oklahoma with no further discussion. A note is found by Hyslop (10) in 1934 that the species had been reported as injurious from Hollis, Oklahoma. Hebard (6) in 1936 listed the species as occurring in southwestern North Dakota. In 1936 Hubbell (8) published his revision of the genus Ceuthophilus in which a number of taxonomic and biologic references were made to Daihinia incidental to his discussion of the genus Ceuthophilus. Blair and Hubbell (1) and Hebard (7) in 1938 list the species as occurring in Oklahoma.

It is apparent that the life history has been entirely unknown with the exception of the very general features assumed from its relationship to other better known species.

GEOGRAPHIC DISTRIBUTION

According to Caudell (3) this species occurs from Louisiana, the type locality, north to Wyoming and North Dakota. Hebard (6) records it as present in southwestern North Dakota, and states that the eastern limital records extend southeastward from that area through Martin, South Dakota; Stratton, Nebraska; Winfield, Kansas; and Perkins, Oklahoma. Hubbell (8) states that the genus Daihinia occurs in the Great Plains states from North Dakota to northern Texas, and in areas of similar environment in Colorado and Wyoming. Being present at Boise City, Oklahoma, in the extreme western part of the State, it probably also occurs in at least eastern New Mexico.

In Oklahoma the species is found in small numbers almost throughout the State wherever sandy soil predominates, but one of the highest populations known to the writer is in westcentral Logan County and the northeast quarter of Kingfisher County. This area is a general farming region characterized by very sandy soil. Of this area, two or three square miles immediately southwest of Crescent had the heaviest infestation during the period of study. Another heavy infestation was found five miles southeast of Hennessey.

It is worthy of note that while the cricket population is exceedingly limited outside of sandy areas, the species does not occur in all sandy environments. Apparently there are factors other than type of soil affecting its distribution.

DESCRIPTION OF *D. BREVIPES*

The body is thick and robust, and roundly humped dorsally. (Plate V, Figures 1 and 2) The color varies moderately from brownish-red to dark brown, generally a little darker on the dorsum of the thorax except for a narrow median line of clay yellow. A mottling of lighter shades occurs on nearly all parts of the body. All the tibiae are shorter than the femora, and well provided with spines. The anterior tibiae are semi-fossorial. (Plate VI, Figure 2) The posterior femora of the male are remarkably heavy, and as broad or broader than the pronotal length (Plate VI, Figure 2); a moderate tapering occurs at either end and from five to seven heavy spines are present on the apical half of the outer carina. On the inner carina is a long row of small, closely-spaced tubercles. The anterior and posterior tarsi are three-segmented, the medial ones four-segmented. Measurements of the male are: body 24 mm., ranging from 20 to 28 mm.; pronotum 6 mm., ranging from 5 to 7 mm.; posterior femora 16 mm., ranging from 13 to 20 mm.; posterior tibiae 13 mm., ranging from 11 to 16 mm. Measurements of the female are: body 24 mm., ranging from 22 to 26 mm.; pronotum 6 mm., ranging from 5 to 7 mm.; posterior femora 14 mm., ranging from 13 to 15 mm.; posterior tibiae 11 mm., ranging from 10 to 12 mm.; ovipositor 10 mm., an occasional one as long as 11 mm. (Plate VII, Figure 1)

LIFE HISTORY AND HABITS

Life History

In assembling data for life history information, periodic observations were made throughout the 1939-1940 season. During the winter months these observations were made at approximately two-week intervals, while during the summer the observations were made daily in connection with other work in progress. In obtaining seasonal records for the eggs present in the soil, old burrows were dug out by means of a shovel, and the sand from around the burrow was sifted through 18-mesh copper screen on wooden frames. Dates of hatching of the eggs were secured by observations made while digging. The records of the number of crickets in each instar throughout the season were obtained by making frequent collections. During the winter these collections were made by digging out burrows; during the summer they were made by counting the number of each instar caught in traps set in connection with the study of daily cricket activity in the field. Dates of dying of the adults were approximated from general observations and from records obtained from crickets confined in life history cages.

Records previous to September, 1939, were taken from notes by Standish (12).

Table 1 is a summary of the collection records, showing the number of crickets in each instar from January, 1939, to February, 1941. Figure 1 is a graphic presentation of life history records, based on the data given in Table 1 and on egg deposition records. The lines limiting the space occupied by each stage have been curved to indicate the relative abundance of each throughout the year.

It will be seen from the graph that the life history varies appreciably from year to year. During the 1938-1939 season the overwintering stages included the third, fourth, and fifth instars, while in the 1939-1940 season only thirds and fourths were present during the winter months, the first fifths not appearing until the early part of March. During the 1940-1941 season the overwintering stages again included the fifth, these having appeared the latter part of November, or more than a month earlier than during the first season studied. Included also in the overwintering stages in the 1940-1941 season were a few individuals in the second instar, a condition not met with in the two previous seasons.

The explanation for the rapid development during the 1940-1941 season probably lies in the fact that warm weather persisted for an unusually long time in the fall, hastening hatching of the eggs and shortening the length of time spent in the first instar. The reason for the carry-over of the second instar into winter, considering the general acceleration of development, is not apparent. It is thought that sufficient collections were made during the previous two seasons that any such second instar nymphs present during the winter would have been discovered.

Another interesting situation disclosed by the graph is the fact that although in the 1938-1939 season the crickets matured about two weeks earlier than in 1939-1940, oviposition and death of adults occurred at about the same time.

Collection of early first instar nymphs, and consequent determination of the exact date of hatching, was difficult because of the difficulty experienced in locating burrows at this stage of the life cycle. Immediately after hatching, the nymphs dig upward from the point in the

Table 1.--Cricket Collection Records, Tabulated by Instars Present on Each Date at Crescent, Oklahoma, from January, 1939, to February, 1941.

Date Collected	Number Collected	No. 1st	% 1st	No. 2nd	% 2nd	No. 3rd	% 3rd	No. 4th	% 4th	No. 5th	% 5th	No. 6th	% 6th	No. Adult	% Adult
1939															
Jan. 11	25					10	40	14	56	1	4				
Feb. 1	34					17	50	16	47	1	3				
Feb. 14	17					4	24	7	41	6	35				
Mar. 6	30					5	17	19	63	6	20				
Apr. 3	68							3	4	30	44	35	52		
Apr. 14	60									7	12	53	88		
Apr. 25	74									4	5	57	77	13	18
May 5	53											8	15	45	85
May 15	62													62	100
Sept. 29	4	4	100												
Oct. 5	5	5	100												
Oct. 12	9	9	100												
Oct. 26	7	1	14	6	86										
Nov. 9	7			4	57	3	43								
Nov. 22	20			3	15	17	85								
Dec. 6	12					11	92	1	8						
1940															
Feb. 23	3							3	100						
Feb. 27	26					11	42	15	58						
Feb. 28	26					17	65	9	35						
Feb. 29	13					4	31	9	69						
Mar. 8	2					1	50	1	50						
Mar. 11	49					1	2	46	94	2	4				
Mar. 20	49							36	73	13	27				
Mar. 27	14							4	29	10	71				
Mar. 28	21							5	24	16	76				
Mar. 30	58							2	3	56	97				

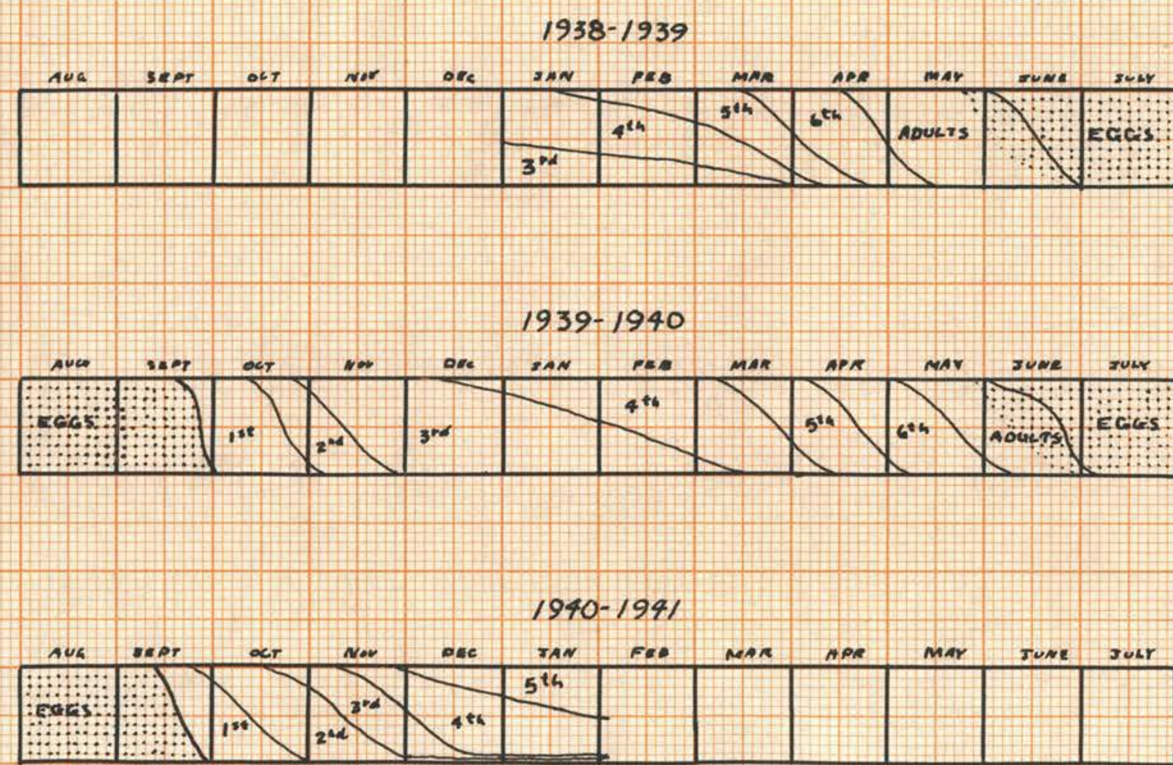
Table 1 (Cont'd)--Cricket Collection Records, Tabulated by Instars Present on Each Date at Crescent, Oklahoma, from January, 1939, to February, 1941.

Date Collected	Number Collected	No. 1st	% 1st	No. 2nd	% 2nd	No. 3rd	% 3rd	No. 4th	% 4th	No. 5th	% 5th	No. 6th	% 6th	No. Adult	% Adult
1940															
Apr. 1	55							6	11	49	89				
Apr. 3	46							3	7	43	93				
Apr. 5	4							1	25	3	75				
Apr. 7	46							2	4	44	96				
Apr. 9	6									6	100				
Apr. 11	12									10	83	2	17		
Apr. 13	4									3	75	1	25		
Apr. 15	28									21	75	7	25		
Apr. 17	62							1	2	56	90	5	8		
Apr. 19	70									45	64	25	36		
Apr. 21	66									26	39	40	61		
Apr. 23	21									13	41	19	59		
Apr. 25	65									20	31	45	69		
Apr. 27	46									2	4	44	96		
Apr. 30	21									1	5	20	95		
May 2	67									8	12	59	88		
May 4	71									8	11	63	89		
May 6	31											31	100		
May 8	25											19	76	6	24
May 10	30											23	77	7	23
May 12	20											13	65	7	35
May 14	16											3	19	13	81
May 16	25											1	4	24	96
May 18	65													65	100
May 21	43											4	9	39	91
May 23	10													10	100
May 25	50											2	4	48	96
May 27	25													25	100

Table 1 (Cont'd)--Cricket Collection Records, Tabulated by Instars Present on Each Date at Crescent, Oklahoma, from January, 1939, to February, 1941.

Date Collected	Number Collected	No. 1st	% 1st	No. 2nd	% 2nd	No. 3rd	% 3rd	No. 4th	% 4th	No. 5th	% 5th	No. 6th	% 6th	No. Adult	% Adult
1940															
May 30	32													32	100
Sept.14	1	1	100												
Sept.18	3	3	100												
Sept.21	61	61	100												
Sept.28	2	2	100												
Oct. 5	32	10	31	22	69										
Oct. 12	100	24	24	76	76										
Oct. 30	100			92	92	91	91								
Nov. 28	50					17	34	32	64	1	2				
1941															
Feb. 4	22			2	9	2	9	8	36	10	46				

FIG. I. LIFE HISTORY OVER A PERIOD OF THREE YEARS



soil where they hatch, which is frequently as deep as five feet, until the surface of the soil is reached. They then wander about nearby, finally digging individual burrows, preferably in spots not covered with dense vegetation. These burrows, especially during the first few days in the first instar, are very shallow and the amount of sand thrown out at the surface is small. After a day or two even this small amount of sand may be almost entirely leveled by wind, leaving very little evidence to indicate the presence of a burrow. It was suspected that hatching had occurred when small pieces of egg shells were found in the sand dug from about the burrows. An extended search was necessary before the new individual burrows were found.

The fact that the first instar crickets must dig to the surface from the point of hatching, frequently as deep as five feet in the ground, is unique. At that time of the year the soil is often quite hard due to drouth, and great difficulty is experienced in the tighter soils in digging out the burrows with shovels. Aside from the singular feat accomplished by these small insects in being able to reach the surface under such conditions, it appears that the energy expended and the subsequent food requirements must be great during this time. Roots generally are present on which they may feed, and ants are often to be found in ramifications of nearby dens. It is supposed that material similar to the above is utilized as food during the journey upward, although no cricket definitely known to be effecting this emergence was ever collected and consequently no stomach examinations could be made to clear up the point. Such examinations were made, however, of nymphs in the first instar which possibly had not reached the surface. The stomach contents were found to contain small quantities of insect remains, (probably ants) small amounts of sand, and large amounts of brown, unidentifiable material probably of plant origin. It is thought that this material could easily have been roots of plants growing nearby.

It might also be noted that young crickets are able to exist over long periods of time without known food of any sort. One first instar nymph confined in the laboratory in a can of moist, sifted sand lived for two weeks in apparent good health without food, finally dying during a period of a few days when the sand was not kept moistened as before.

All through the winter months it was possible, if recent heavy rains had not occurred, to find the characteristic mounds of soil which mark the entrance to a burrow. Apparently digging and surface feeding continue to some extent throughout the cold months, crickets having been observed out and feeding, occasionally in large numbers, during February. Certainly there is little if any true hibernation during the winter, as crickets dug from burrows at all times were active although somewhat sluggish if the weather was extremely cold.

The crickets live singly in their burrows until the adult stage is reached, after which several crickets of both sexes ordinarily occupy a single burrow. At one time seven males were trapped from one burrow, no females being taken although possibly some were present but failed to emerge. More commonly, one or two males are found in a burrow with three or four females.

The generalized life history may be summarized as follows: The winter is passed in burrows in sandy soil as partly-grown nymphs, which remain comparatively active all winter, emerging occasionally for feeding and enlargement of their burrows. Fresh work can be seen all winter long in favorable weather. With the advent of cold weather in late November, the crickets are in the third, fourth, and occasionally the fifth instars, with the largest percentage in the fourth. They develop but slowly during the remainder of the winter, even though remaining somewhat active. Moulting into the fifth, then into the sixth or final nymphal instar proceeds as soon as the temperature rises in the spring, and the first adults appear about May 1.

About the first of June egg deposition begins. The eggs are deposited in the sand forming the walls of the burrow, apparently being placed there by the insertion of the ovipositor into the walls. About the middle of June a high mortality becomes noticeable and by July 1 there are practically no crickets alive. About the middle of September the first eggs hatch and by the first of October hatching is completed. After hatching, the nymphs make their way to the top of the soil and disperse over the immediate vicinity, digging new holes for themselves in the sand. Development is relatively rapid until cold weather comes.

There is one generation per year.

Population Studies

To obtain information on the trend of the cricket population from early spring until mid-summer, a number of types of records were kept.

One method employed consisted of a series of surveys of the field population at five selected points from one to two miles apart; data were taken five times during the period from January 28 to June 25. The five points were selected on the basis of the following conditions thought to represent a suitable environment for cricket development: prevalence of loose, sandy soil; available cultivated land or idle land not covered with dense vegetation; and nearby roadside in which the crickets could find refuge in case farming operations in the fields made these unsuitable as a habitat.

In making surveys and infestation counts the basis used was the number of fresh holes per square yard. A fresh hole was considered to be one which apparently had been worked by the occupant during the preceding three or four days. The manner of taking these data varied somewhat as necessity demanded, but ordinarily the method consisted of stepping off 50 steps of one yard each in a straight line and counting the fresh holes appearing within an estimated one and one-half feet on each side of the line of advance. This gave the total number of holes in an area one yard wide by 50 yards long. In cases of extremely high infestations, the distances were actually measured with a tape; otherwise the length of step and the estimation of the one-yard width were considered sufficiently accurate.

In making this particular survey, counts were made at each of the five selected points in each type of nearby environment suited to cricket activity, such as roadside, barley stubble, growing cotton, idle land, etc. The figures for each environment were averaged to give the count for the point. Although the number of environments differed between points, they were kept constant throughout the season for each point.

Table 2 shows the trend of the population through the spring and summer of 1940 as indicated by data taken in this manner. Although earlier counts were not made on a comparable basis, in October of 1940, or in the following generation, there were many places in this area which had as many as two or three holes per square yard. Thus it is evident that only a small percentage of the crickets reach maturity, the survey figure for the last of May being only .07 burrow per square yard.

The figures shown in the table, while indicating the general trend of the population, are not to be considered as representing the infestation in terms of number of crickets present. The number of fresh burrows in evidence is always much less than the number of crickets because of several factors to be discussed later.

TABLE 2.--Field Survey Records from February to June, Crescent, Oklahoma, 1940.

Date	Point Number	Average Burrow per Square Yard	The Average Burrow per Square Yard, All Points for Each Date
2-28-40	1	.37	.21
2-28-40	2	.07	
2-28-40	3	.01	
2-28-40	4	.35	
2-28-40	5	.25	
3-11-40	1	.27	.23
3-11-40	2	.20	
3-11-40	3	.25	
3-11-40	4	.23	
3-11-40	5	.19	
3-19-40	1	.19	.12
3-19-40	2	.07	
3-19-40	3	.05	
3-19-40	4	.18	
3-19-40	5	.12	
5-27-40	1	.14	.07
5-27-40	2	.07	
5-27-40	3	.06	
5-27-40	4	.03	
5-27-40	5	.06	
6-25-40	1	.03	.01
6-25-40	2	.01	
6-25-40	3	.00	
6-25-40	4	.01	
6-25-40	5	.00	

An experiment was set up for detailed study of the population trend in a limited area. Two circular plots 30 feet in diameter were laid out in a heavily infested alfalfa field. Each hole was staked and numbered as it appeared, and a daily inspection was made to determine if the burrow had been worked the previous night. If so, the fresh soil was smoothed off by sliding the sole of a shoe across the entrance to the burrow, so that fresh work could be detected again the following morning. One of these circles was in a rather sandy spot quite favorable for cricket activity. The other was in somewhat heavier soil and showed less cricket activity at all times than the former.

Figure 2 shows the results of this test, the data from the two circles being combined. It will be noted that the test was started rather late in the season. Had it been started earlier the peaks toward the left of the graph supposedly would have extended even higher. It can be seen, however, that the number of burrows in use in the plots undergoes a persistent, although erratic, drop from mid-April until the first of June, at which time practically no burrows are being worked. The number of new burrows being opened roughly follows the number of holes worked daily, although at a lower level, until these new holes cease appearing May 5. At this time the soil was becoming hard, and further digging probably was difficult. In this area as well as in any infested area when the soil began hardening, numerous extremely shallow burrows, only an inch or two in depth, could be found. These frequently surpassed the established burrows in number, evidently representing futile attempts to dig new burrows.

No correlation with weather conditions is evident in the table. In contradiction to this lack of correlation, however, general observation convincingly indicated that following rains the number of burrows in

FIG. 2 RELATION OF TEMPERATURE AND RAINFALL TO BURROWING ACTIVITY IN A SMALL AREA CRESCENT, OKLA., 1940

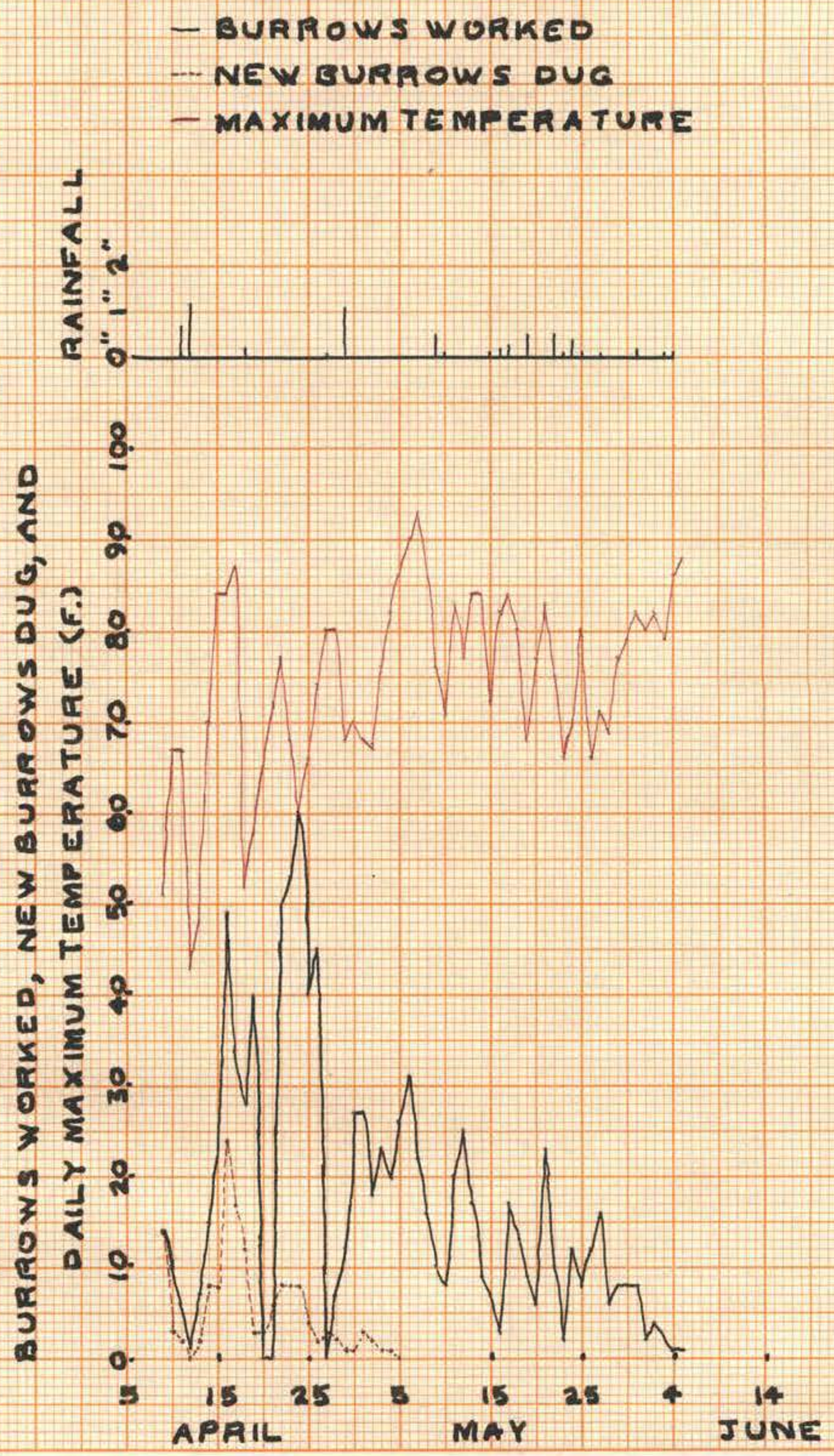
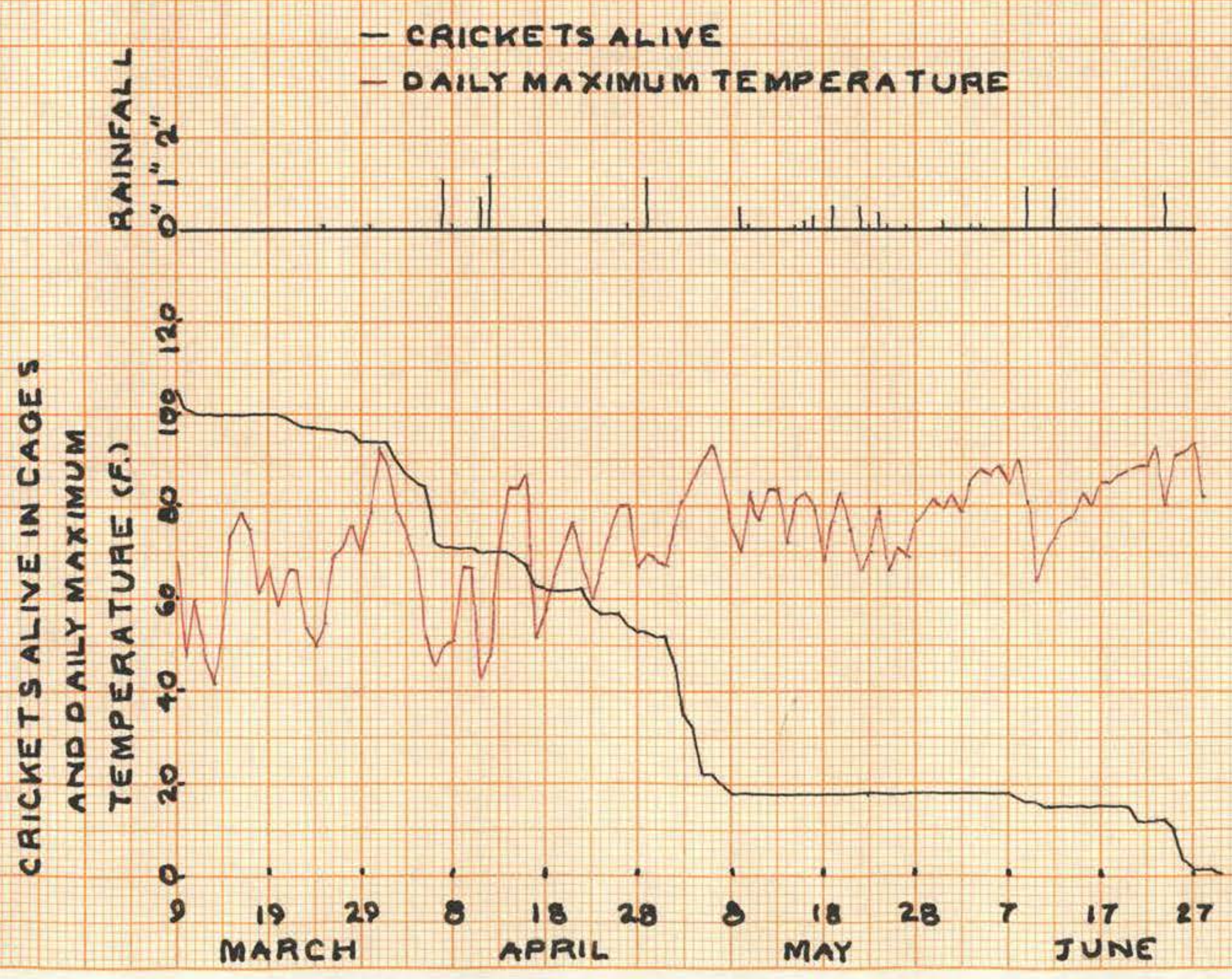


FIG. 3. CRICKETS ALIVE IN LIFE HISTORY CAGES
THROUGHOUT SEASON
CRESCENT, OKLA., 1940



operation declined sharply for several days. The failure of the above test to show this may be due to the small sample employed, undoubtedly leading to a high variation from day to day. In studying the graph it is evident that rainfall in many cases coincides with decreases in the number of burrows worked, but these are insignificant in view of the numerous other decreases on days of no rainfall.

After activity had nearly ceased in these circular plots early in June, another similar plot was staked off in an extremely sandy area where activity still was rather great. Here again the number of occupied burrows declined rapidly through the remainder of June until only one or two burrows were active by June 27.

In the life history cages to be discussed later, in which crickets were confined to individual cages for observation, records were kept of the number of crickets dead on each day. In the majority of cases death occurred beneath the surface of the soil so no evidence was obtainable as to the exact date of its occurrence. In these cases the cricket was considered as having died the day after the last time it was observed out of the burrow. Figure 3 shows the typical rapid drop in population, with no correlation with temperature or rainfall.

A high mortality also was encountered in attempting to rear the crickets to the adult stage during the winter in artificial quarters. The cage used consisted of a glass tube one foot long and two inches in diameter, set on end and filled three-fourths full of moist sand. Thirty-two crickets in the first and second instars were collected in the field and caged on October 1, 1940. Of these only three were alive on January 31, 1941, four months later, representing a 9.4 percent survival. One of these was an adult male, one an adult female, and one a sixth instar male. This work was done at room temperatures.

As previously stated, soil type has much to do with distribution of the crickets. This factor likewise influences fluctuations of the population from the viewpoint of individual small areas. The species prefers soil which is sufficiently sandy to afford ease in burrowing. This condition varies with the season, and as the weather becomes hot and dry and soil which earlier was loose enough for digging becomes hard, the crickets apparently leave such places and migrate to the sandier spots. By the last of June few can be found except in the sandiest places. It is possible that the drying of the soil might shorten the lives of the individuals living in the heavier soils, but due to the known habit of the insects of migrating at least short distances for digging new holes, it is probable that as the soil hardens they wander about until a sandier location is found. It was noted that extremely fine sand was not desired by the crickets; a sandy loam tending to the sandy side seemed to be preferred.

Knowing that many more burrows were to be found in sandy soil than in heavier soil during the dry part of the season, a seriesof 25 traps were set daily for five days on sandy soil and an equal number on heavy soil to determine if a higher emergence from a given number of holes also could be expected in the sand. The results are shown in Table 3.

Table 3.--Comparative Catches of Crickets on Different Types of Soil.

Date	No. Crickets Trapped on Heavy Soil	No. Crickets Trapped on Sandy Soil
June 4	1	38
5	1	25
6	9	39
7	12	10
8	1	66
TOTALS	24	178

This great difference in catch indicates that not only are burrows more numerous in sandy soil during the dry months, but that more crickets occupy each burrow. Before dry weather appeared, this difference undoubtedly would not have been found.

<u>Daily Activity of Crickets in the Field</u>

In order to obtain records as to the number of crickets which could be expected to emerge each night from a given number of holes under various conditions of weather, a trap was used which could be set over a burrow so as to secure the cricket as it emerged. This device (Plate III, Figure 1) was made of a one-pound coffee can having a circular hole three inches in diameter cut in the bottom, into which fitted one end of a screen-lined metal cylinder extending upward to just below the top of the coffee can. The trap was placed over a hole in the evening; the cricket upon coming out was able to crawl up the inside of the cylinder by means of the screen and fall into the outer part of the can, but was then unable to ascend either the smooth outer wall of the cylinder or the side of the can. These traps, when placed in high vegetation, were marked by driving sharpened laths into the ground beside them as stakes. One side of the tip of each lath was painted red and the other side left unpainted, so that in checking a large number of traps close together the stakes could be faced in a certain direction to indicate which had been inspected.

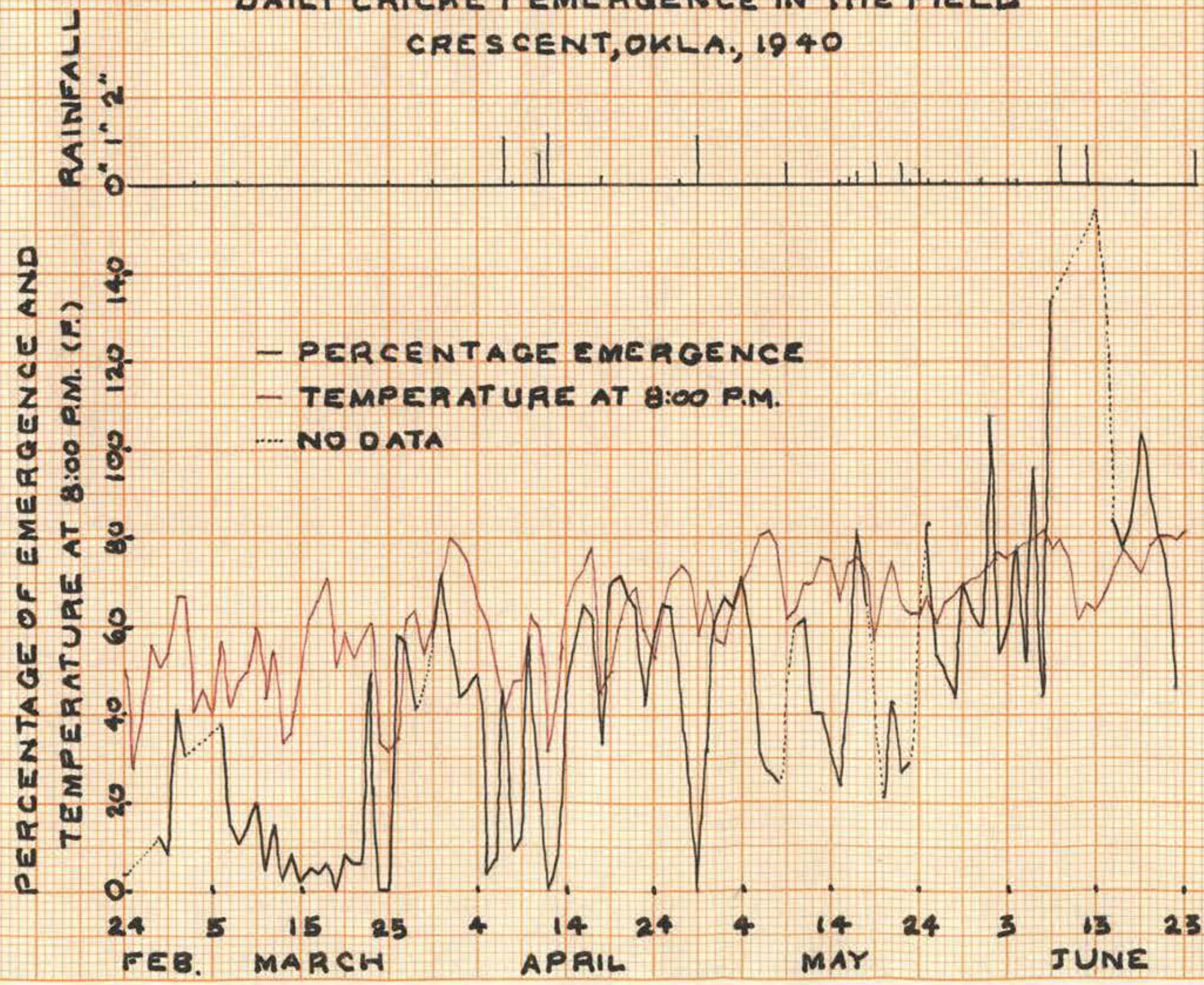
Each day 50 of these field traps were set over freshly worked burrows in an alfalfa field and the night's catch recorded the next morning, the crickets being replaced in the holes and the traps moved to another set of 50 fresh holes for the next night's records. The number of crickets trapped was divided by the number of traps set to give the percentage of emergence for the night.

The data representing the daily catches are shown graphically in Figure 4. In interpreting this graph it must be kept in mind that the data here treated do not represent the population as a whole, but only those crickets actively working as indicated by fresh soil at the burrow entrance. During periods of extremely cold or rainy weather the number of such freshly-worked burrows was much less than during more favorable weather, difficulty often being experienced in finding 50 fresh holes for trapping. This use of only fresh holes conceivably may have biased the sample sufficiently to obscure possible correlation of emergence with weather.

Temperature apparently affects emergence as taken in this experiment only in a general way. In places, temperature and emergence appear to be closely correlated, but this correlation is not consistent on a day-by-day basis. This is possibly to be expected, as the optimum temperatures for the species are much lower than for the majority of insects, and apparently cover a wide range. Crickets were trapped on nights when a freeze occurred, others were observed out feeding in large numbers on cold nights in late winter, and in one case several were seen digging within a few inches of a snow-drift in late February. Nightly temperatures were not known to have gone sufficiently high during 1940 to retard activity but individuals exposed to daytime temperatures during the summer died within an hour or two. Lesser variations in the relatively low temperatures to be expected during the night hours, however, appear to affect the species but little.

Rainfall has no consistent effect on the percentage of emergence from worked holes as can be seen from the graph. During some periods of rainfall the percentage of emergence drops, while during others it rises. For several days following rains, however, it was always difficult

FIG. 4. RELATION OF TEMPERATURE AND RAINFALL TO DAILY CRICKET EMERGENCE IN THE FIELD CRESCENT, OKLA., 1940



if not impossible to locate burrows for trapping, as the rain washed away all signs of fresh work. A period of several days ordinarily elapsed before the crickets resumed digging to any great extent.

Some of the periods of low emergence possibly are to be attributed to the fact that the crickets were undergoing a moult. During ecdysis the crickets habitually stay in the burrow for a varying length of time, usually about seven to ten days. Due to the method of selecting only freshly worked holes for trapping, however, this factor cannot be indicated on the graph.

The sharp rise in percentage of emergence after the latter part of May is due principally to two factors. First, the crickets tend to emerge with greater frequency after becoming adult; secondly, after maturity is reached several crickets commonly occupy the same hole, so that more crickets will be caught with any given number of traps. The sharp drop after June 13 undoubtedly is due to the high death rate of the crickets at this time; this shows up even on a percentage basis since fewer crickets would be alive in each burrow and since during a few days time the holes would retain their appearance of being worked and the trap would be set, although the occupants may have died.

On four occasions catches of over 100 percent were recorded. Since several crickets frequently were trapped from the same burrow, this condition is not necessarily unusual. It merely means that the total number of crickets caught was greater than the number of traps set.

Over the entire season the average nightly emergence was 44.3 percent.

In connection with the habits of emergence of the field population, observations were made to determine the time of day at which emergence occurred and the period during which activity was greatest. One method of obtaining this information consisted of setting field traps over a number of burrows in the afternoon and then visiting these traps hourly during the fore part of the night to check the number of crickets caught during each hourly period. Another method consisted merely in walking after dark with a flashlight about fields known to be heavily infested and counting the number of crickets observed during periods of five minutes at various hours.

A summary of the hours of emergence as indicated by the trapping method above described appears in Table 4.

Table 4.--Crickets Trapped at Various Hours, Crescent, Oklahoma, 1940.

Date	Number Traps	Number Trapped in Hour Preceding 6 p.m.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	Later
3-14	50	1	1	0	0	0	1
3-15	50	0	0	1	0	0	1
4-9	25	0	0	9	4	0	4
4-24	25	0	0	10	0	0	5

On May 31 the hours from dusk to 12:00 midnight were spent in the field noting the numbers of crickets abroad by the method of hourly counting the number of crickets to be seen in five minutes. On June 18 the entire night was devoted to taking notes in this manner. These observations are tabulated in Table 5.

Table 5.--Crickets Seen Abroad during Five-Minute Searches at Various Hours of the Night, Crescent, Oklahoma, 1940.

	Number Crickets Seen During 5-Min. Search at Each Hour											
	p.m.						a.m.					
Date	7	8	9	10	11	12	1	2	3	4	5	6
5-31	0	1	3	6	4	6	-	-	-	-	-	-
6-18	0	3	9	12	13	9	4	2	0	1	1	0

In summary it may be stated that as a rule at least 50 percent of the crickets will emerge between 7:00 p.m. and 9:00 p.m. After this heavy early emergence the remainder come out in small numbers almost throughout the night, although the greatest activity occurs during the hours from sunset to midnight. The time of first emergence varies with the time of the year. Early in the season, in February and March, emergence may start as early as 6:00 p.m., probably because darkness comes earlier at that time than later in the year. In May and June the usual time of first emergence is near 8:00 p.m.

In only a few instances were crickets seen out of their burrows before dusk. In one case a cricket was seen out of its burrow at 2:30 p.m., on a partly-cloudy day, and in another case a cricket was seen at the surface enlarging its burrow at 1:30 p.m. Despite this small number observed working during the day in this particular season, members of the Entomology Department of Oklahoma A. and M. College report that it has been common in past years to see crickets out in the evening before sundown and early in the morning.

It is the habit of the crickets to spend some time near sundown at work within their burrows. At this time nearly all of the active holes will be open and will have fresh, moist soil thrown out at the entrance. If such a hole is watched for several minutes, the occupant will be seen to appear at the entrance, pulling soil up from the bottom of the burrow to the mound at the entrance. Shortly thereafter the cricket will discontinue this work and leave the burrow in search of food.

<u>Daily Activity of Confined Crickets</u>

For more intensive study of life history and habits cages were devised and a number of these placed close together next to the weather station. (Plate III, Figure 2) In 1940 there were 105 of these, placed in rows in a rectangular plot and spaced one and one-half feet apart. The cage, which was very similar to the field trap, consisted of a number 10 (approximately one gallon) tin can, open at the top end and with a three-inch circular hole cut in the bottom. The can was sunk in the soil to half its height, with the open end up, after which a cricket was placed in the can. Not being able to climb the smooth sides, the cricket eventually found the hole in the bottom opening downward to the soil, and dug a burrow. Food was kept in the cage, consisting of moistened wheat bran and green plant material, upon which the cricket could come out and feed during the night. To determine on what nights the cricket emerged from its burrow, and also to keep development records, a tin cylinder was placed over the hole in the bottom of the cage as a trap. This cylinder was of slightly larger diameter than the hole, four inches tall, and open at both ends. The inside of the cylinder was lined with window screen. Coming out of the burrow, the cricket easily ascended the screen lining, fell out into the cage, and fed. It could not get back to its burrow because of the cylinder.

Each morning the cages were inspected, notes taken, and the trapped crickets returned to their burrows.

Crickets put in these life history cages were each marked with red fingernail polish on a hind tibia. This mark persisted until ecdysis occurred, at which time the cricket was measured, re-marked, and replaced in the cage.

In only two or three instances were crickets suspected of getting into each other's burrows through ramification of their holes. Their habit of digging at a sharp downward angle made this only a slight possibility.

During the 1939 season Standish (12) suspected cats of catching the crickets after they were trapped in the cages, so thereafter wooden frames covered with window screen were placed over the cages at night to prevent this.

A mate of the opposite sex was given each cricket within a few days after it reached maturity.

From March 1 to March 6, 1940, 105 of these cages were stocked with third and fourth instar individuals as fast as they were collected from the field. Fifteen were in the third instar when caged, and 90 were in the fourth instar. Trapping was commenced on March 9, this lapse of time being allowed to permit the crickets to establish their burrows before being disturbed. Records were taken until June 29, on which date the last individual died.

By rearing these crickets to maturity it was hoped that essential life history data would be obtained. One type of information desired was the habits of the crickets with regard to daily emergence from the burrows. Figure 5 is a graph showing the relationship between number of crickets emerging daily and the temperature and rainfall. The emergence figures are expressed in terms of percentage of the live crickets which were not staying underground due to moulting. Moulting crickets were eliminated from the calculations for each day, since, otherwise this would be an uncontrolled factor of considerable importance. Their habit is to pass a number of consecutive days without emerging prior to emerging in the succeeding instar, and during this time weather conditions likely have no influence with regard to emergence.

The exact date of death of most of the individuals confined in these cages could not be determined as the majority died beneath the surface. A cricket was arbitrarily considered dead the day following its last emergence.

In a general way there is a great deal of correlation with temperature and rainfall, but on a day-by-day basis it is not strong. As temperatures become consistently higher during the latter part of the season, it is true that a higher emergence occurs, but this is probably not a result primarily of temperature. Adultshabitually emerge oftener than nymphs, and probably would do so even at lower temperatures.

The habits of the individual cricket in leaving its burrow varied with the different instars. Data on the frequency of emergence in each instar studied are presented in Table 6.

Table 6.--Frequency of Emergence from Burrows of *D. brevipes* under Cage Conditions, Crescent, Oklahoma, 1940.

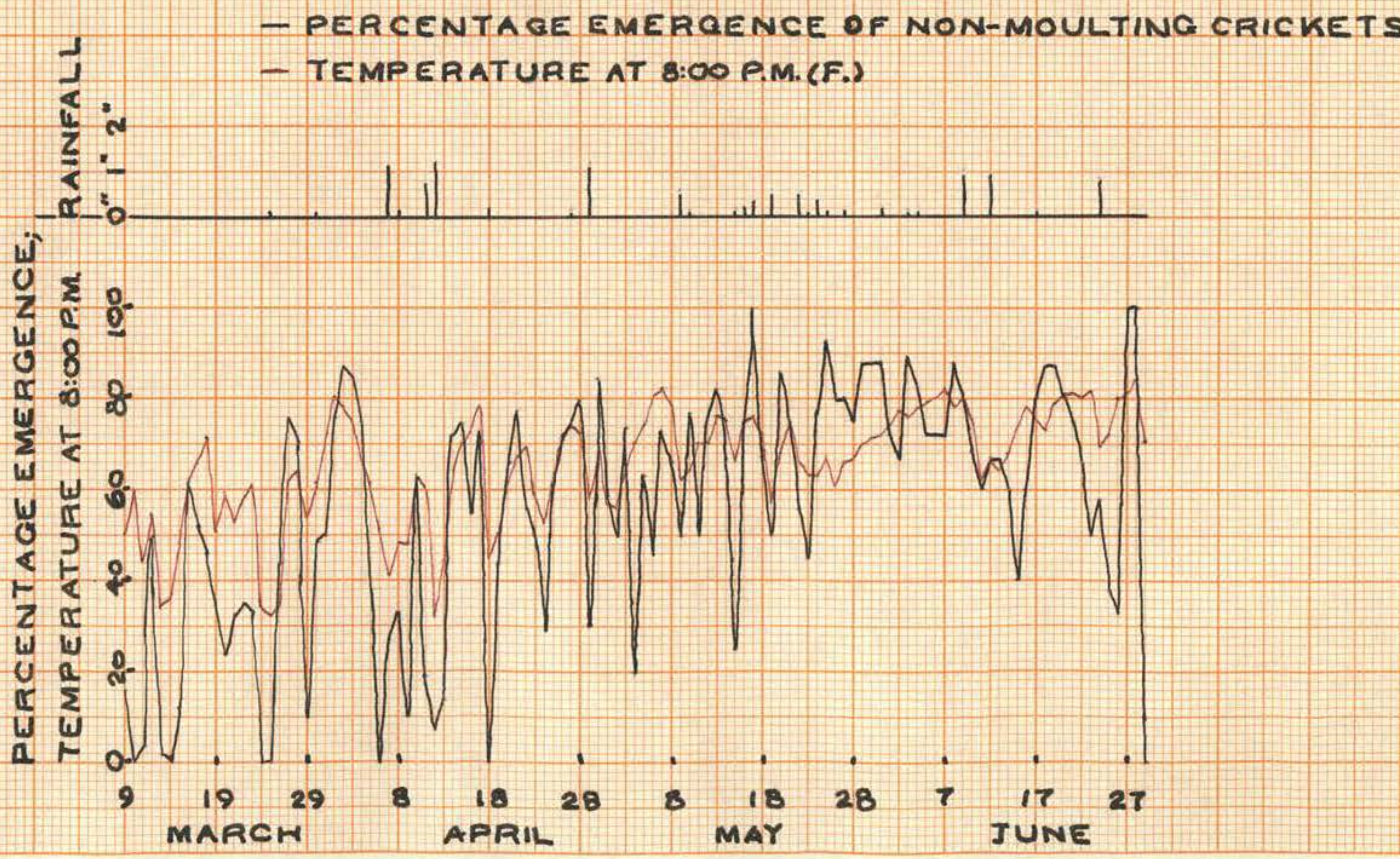
Instar	No. Crickets Studied	Av. Length of Stadium	Av. Times Emerged	Percentage of Days Emerged
3	15	20.7 days	---	---
4	88	24.3 days	1.8	7.4
5	50	25.1 days	7.2	28.6
6	18	19.2 days	5.6	29.1
Adult	18	30.2 days	22.4	74.1

It is seen that the earlier instars leave the burrow comparatively few times, emergence becoming more frequent as each instar is passed until in the adult stage they may be expected to emerge on about three nights out of four.

Although no emergence of a third instar was recorded, this in all probability was an unnatural condition brought on by caging. The third instars were caged during the latter part of the stadium and did not emerge until they appeared as fourth instar nymphs.

Emergence nights were well scattered among nonemergence nights, no particular sequence being followed in this respect. There was, however, some tendency to come out several nights consecutively once an

FIG. 5. RELATION OF TEMPERATURE AND RAINFALL TO DAILY EMERGENCE OF CONFINED CRICKETS CRESCENT, OKLA., 1940



emergence had occurred.

In the case of the adult it was noted that while a single male or female might leave the burrow only occasionally, the addition of a mate almost invariably caused it to emerge nearly every night.

Figure 6 is a second graphical presentation of the same data from which Figure 5 was drawn, but in this case the emergence line is drawn to represent the daily percentage of emergence based on the total live crickets in the experiment, regardless of whether they were remaining below ground for a moult or not. The former graph was corrected for this factor, excluding from calculations all crickets known to be moulting. It is apparent almost at once that this second method shows even less correlation of emergence with the temperature curve than the former, indicating that the number of crickets in ecdysis definitely affects the percentage of emergence.

Figure 7 shows emergence records in 1939 obtained by Standish (12) under a similar setup of caged crickets, the figures being based only on live crickets as in Figure 6. It will be seen that a condition similar to that in Figure 6 exists. In general some correlation can be seen, but there are many specific exceptions.

Life History Studies of Confined Crickets

Observations on points in the life history based on the crickets confined in the cages just described probably does not give quite the true picture of crickets in the field, but is thought to be reasonably close.

The average length of time spent in each instar has previously been in Table 6. Data for the third instar are entirely incomplete, as the crickets were caged while in the third and fourth instars. This instar, however, and any others in which the winter is passed, is of much longer

FIG. 6. RELATION OF TEMPERATURE AND RAINFALL TO DAILY EMERGENCE OF CONFINED CRICKETS CRESCENT, OKLA., 1940

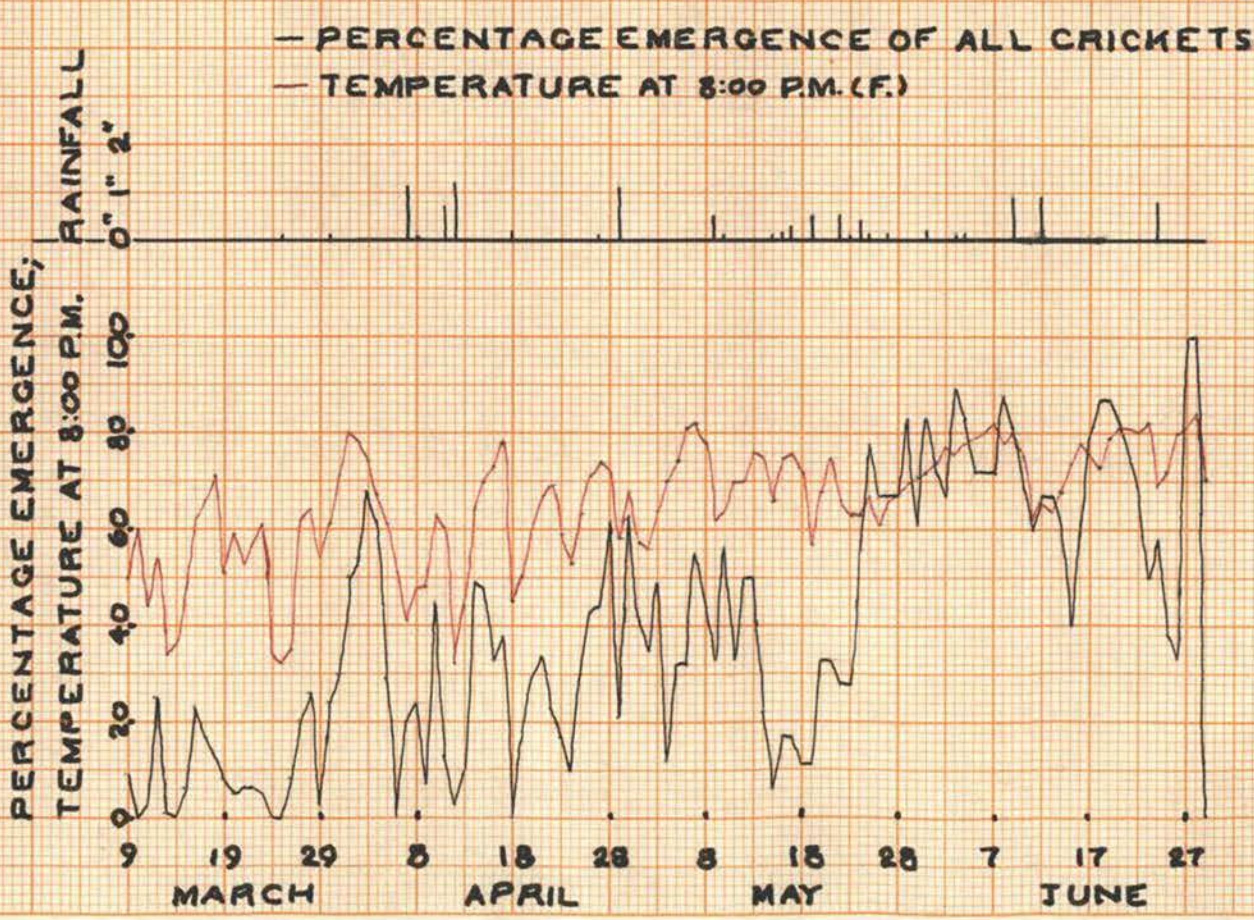
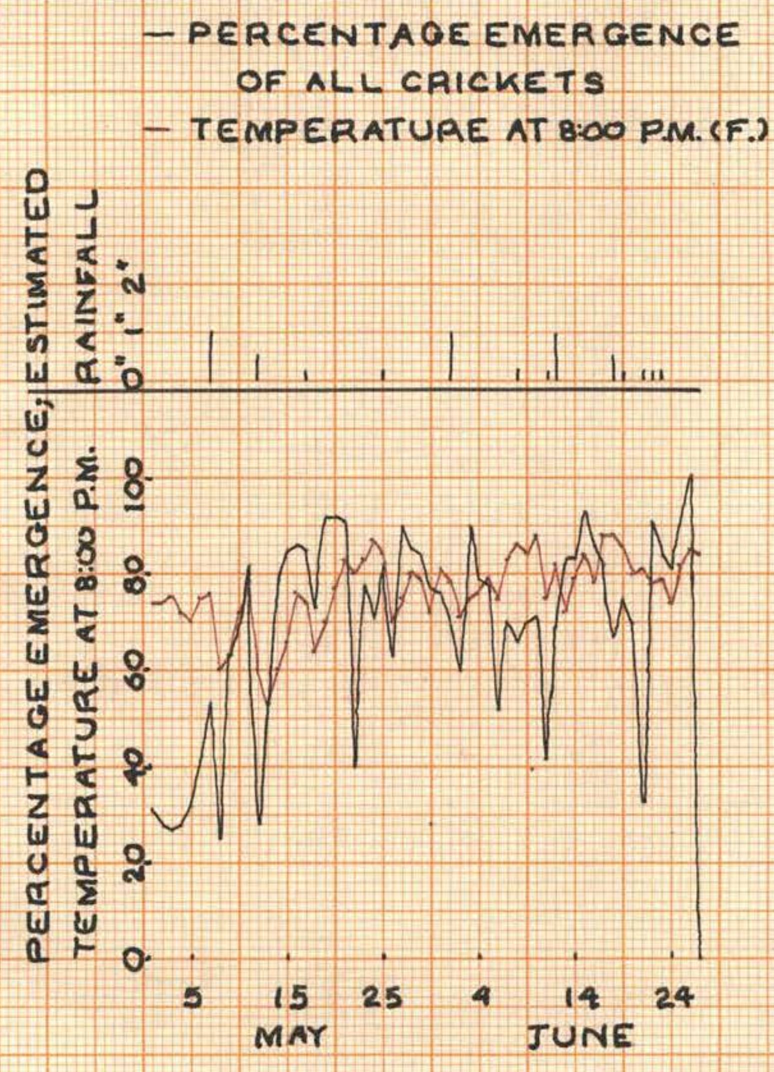


FIG. 7. RELATION OF TEMPERATURE AND RAINFALL TO DAILY EMERGENCE OF CONFINED CRICKETS CRESCENT, OKLA., 1939



duration than those passed after March.

The records for the fourth instar are partially incomplete, as 90 out of the 105 crickets studied were caged in the fourth instar. Records for the fifth, sixth, and adult stages are complete.

The length of life of crickets eventually reaching maturity in the cages, computed from the time they were caged until death occurred is indicated in Table 7.

Table 7.--Length of Life of Confined Crickets Reaching Maturity, Crescent, Oklahoma, 1940.

	Number of Individuals	Average Days Life	Range
Males	3	106.6	103-109
Females	15	104.6	90-112
Both sexes	18	104.5	90-112

Assuming the average cricket hatched on September 21 of the previous year, making 170 days before caging was effected, the average life of the species is about 274 days, or roughly nine months.

It was seen throughout the season that development in these cages was lagging about a week or 10 days behind that in the field. Therefore the length of life in the adult stage in the field undoubtedly is a few days longer, since they matured earlier and apparently died at about the same time.

With regard to mortality, there is some indication that the death rate of males is higher than that of females. Of the 46 males caged, three reached maturity, representing a 6.5 percent survival. Of the 59 females caged, 15 or 25.4 percent survived. Standish (12) in a similar experiment in 1939 had approximately equal percentages of survival of the two sexes, although his work was started much later.

Field records show that many more females than males were present in the natural population (Table 8), but indicated that if a high mortality occurs among the males, it comes earlier than the date on which the life history cages were started.

Table 8.--Number of Crickets of Each Sex Trapped in Field over a Period of Three Months, Crescent, Oklahoma, 1940.

Month	Total Crickets Trapped	Total Males	Total Females	Percent Males	Percent Females
April	1,036	336	700	32.4	67.6
May	932	290	642	31.1	68.9
June	709	283	426	39.9	60.1

The possibility exists that the initial sex ratio is not 50-50. Sex determinations of first instar individuals were not made in numbers sufficient to draw a conclusion in this respect.

It is characteristic of the crickets to remain in the burrow for some time during ecdysis. The average length of time thus spent continuously in the burrow while moulting into each of the instars was:

Moulting into 4th instar ----- 19.6 days
Moulting into 5th instar ----- 16.7 days
Moulting into 6th instar ----- 10.8 days
Moulting into Adult instar --- 10.0 days

As the actual act of moulting was observed in the laboratory to cover only from 45 minutes to an hour, this time in the burrow apparently is spent either in a quiescent period before moulting, or is spent following moulting as an insurance that the cuticula will be completely hardened before emergence and exposure to possible natural enemies. With regard to the first possibility, a quiescent premoulting period is common in insects; it is possible that this period is merely prolonged in this species. An attempt to determine during what portion of the stay in the burrow moulting actually occurred resulted in failure.

The number of individuals dying while in each of the instars observed in the cages is shown in Table 9.

Table 9.--Deaths Occurring in Each Instar, Crescent, Oklahoma, 1940.

Instar	Number Starting Each Instar	Number Died	Percentage Mortality
3rd	15	--	--
4th	105	16	15
5th	89	38	43
6th	51	33	65
Adult	18	18	100

Daily temperatures were gradually rising as development proceeded from the third instar to the adult stage, which fact may at least partially explain the increase in percentage of mortality in the later instars.

Migration and Burrow Retention

A system of marking holes in a small area and trapping previously-marked crickets was used to determine habits of movement in this area during the period studied. Each hole in a circular plot 90 feet in diameter (Plate II, Figure 2) was marked by pushing a numbered garden stake into the ground beside it. As more holes appeared they were marked in the same way. Each of these holes was trapped with the field trap when staked; the crickets when caught were marked and returned to the same hole, and the trap removed for a few days. Later the hole was trapped again to see if the same cricket still occupied the hole, or if another had moved in. For marking the crickets a pair of dissecting forceps were made into clippers, capable of removing individual spines from the hind tibiae of the cricket, by bending the tips of the forceps inward and grinding each to a sharp edge. These two edges met and made an effective instrument. For the numbering system, use was made of the four rows of spines on the two hind tibiae. (Two rows occur on each tibia.) Viewing the cricket posteriorly, the extreme left row was the thousands "column", the next the hundreds, the next the tens, and the extreme right the units. Mentally numbering the first five spines in each row in order from the proximal to the distal end of the tibia, the proper spines were clipped to indicate the cricket's number. When a number over five was desired in one of the rows, two spines totaling the desired number were clipped. Only the first five spines were used because the distal spines are not as exposed and therefore more difficult to clip.

Confusion occasionally arose in the numbers because of the accidental loss of spines by marked crickets. Most of these errors could be corrected by reference to the sex and instar records of the cricket in question. Moulting did not affect the numbers.

In this experiment it was intended to clear up several important questions regarding habits of the species. These questions were: (1) Do the crickets always keep the same hole? (2) If not, do they use one previously dug by another cricket, or dig a new one? (3) If they use one previously dug, how far do they travel to this hole? (4) If they dig a new hole, how far do they travel before doing so?

Table 10 is a summary of the results obtained in this experiment. It was established that the crickets do not retain the same hole at all times, although there was a definite tendency in this direction. Of the total number of times marked crickets were retrapped, 65.7 percent were trapped in the same hole as previously. Of these, the average cricket retained its burrow for 17.4 days, with a range of from 1 to 42 days. These figures are not intended to represent habits of the crickets throughout their lifetime, being drawn only from data taken from March 15 to June 7, 1940.

Table 10.--Trap Records in Investigations of Migration and Habits of Burrow Retention, Crescent, Oklahoma, 1940.

	Previously Untrapped Burrows	Previously Trapped Burrows	Totals for Trapped and Untrapped Burrows
Total Times Traps Set	756	362	1118
Total Times Crickets Caught	502	263	765
Total Times Unmarked Crickets Caught	386	128	514
Total Times Marked Crickets Caught	31	109	140
Total Crickets Discarded (Dead, injured, etc.)	85	26	111

Of the 31 marked crickets caught in previously untrapped burrows, records of distance of travel to the new hole were obtained on 29 individuals.

The average distance traveled from the old hole to the new was 26.5 feet, with a range of from 2 feet 2 inches to 72 feet.

Of the 109 times marked crickets were caught in previously trapped holes, 92 were trapped in the same hole in which they were previously trapped. Seventeen were trapped in a hole different from last time.

Of the above 92 crickets retaining the same hole, records of the exact length of time retained were obtained in 83 cases. The average length of time in the same hole was 17.4 days, with a range of from one to 42 days.

Of the above 17 crickets retrapped in a previously dug burrow other than the one it originally occupied, the average distance traveled from the old hole to the new was 17.3 feet, with a range of from 2 feet to 54 feet 3 inches.

During the winter months when activity is low, the burrows probably are retained much longer than during the period over which the experiment was in operation.

Of the retrapped crickets which changed holes between trappings, 64.5 percent dug a new hole upon leaving the old one, and 35.5 percent used a hole previously dug by another cricket. Those digging a new burrow traveled an average distance of 26.5 feet to the new site; those using another cricket's burrow traveled an average of 17.3 feet. This difference, if significant, is unexplained.

These conclusions were not verified when the problem was analyzed from the standpoint of the number of new and old holes trapped and the marked and unmarked crickets caught in each. There are so many complicating factors involved here, however, that the records from the standpoint of retrapped crickets are considered more dependable. The high mortality rate of the crickets, for instance, would decrease the number of marked crickets subject to being caught, and affect the records from the standpoint of the hole records. Likewise the constant shifting of crickets in and out of the trapped area would decrease the proportion of marked crickets. It is also likely that many times apparently new holes which appeared in the plot were there all the time but were closed and not being worked by the occupant. This situation is known to occur. Still another factor is the fact that the first 302 holes were trapped before any marking of crickets was done, these, therefore, having no chance of containing marked crickets.

One brief experiment was conducted to indicate the rate at which holes are abandoned. Fifty freshly-worked holes were staked and observations made daily as to the number still in use as indicated by fresh work. In two weeks the percentage of worked holes declined from 50 to 16 percent showing that in any given group of holes there is a steady, rapid rate of abandonment.

Probably the only valid conclusions which can be drawn from the above experiments are that there is more or less of a tendency for the crickets to retain their own burrows, with an appreciable number leaving and either digging new burrows or using those already dug; and that in changing burrows the majority travel from 20 to 25 feet although some may travel several times that far.

The method by which the crickets find their own burrows after leaving them for some distance remains somewhat of a puzzle. The compound eyes are but poorly developed. Blatchley (2) speculates that the antennae are used by the crickets to an important degree, with which the writer agrees, but how these could be used to locate a burrow perhaps 50 feet away is not apparent. Caged crickets seemed to have difficulty finding their burrows only a few inches distant. Invariably it was necessary for the tips of the antennae accidentally to encounter the opening to the burrow, after which the cricket quickly extended the antennae into the burrow and descended.

Several experiments were set up to determine the distance traveled by the crickets while out foraging, disregarding the use of burrows, but no results were obtained. In these experiments pitfalls were used to trap previously-marked crickets as they wandered about the fields. These were one-pound coffee cans, unmodified, sunk in the ground until the open top of the can was level with the surface of the soil. Crickets fell into these unbaited traps in surprising numbers, but very few marked crickets were thus caught. This could not be explained as many unmarked crickets were caught in the traps, and the marked crickets were inside an area surrounded by several ranks of the sunken traps.

It is interesting to note that in the above experiment the same problem presented itself as in the former work to determine the retention of burrows; namely, the fact that only a small percentage of marked crickets were retrapped. Some possible solutions of this peculiar situation have been offered earlier in this discussion.

The only indication of distances traveled while foraging were gained from observations made in connection with the control experiments to be discussed later. Within the plots where poison bran mash had been spread, it was common to find many crickets dead just inside the entrance to burrows. Some of these poisoned crickets were to be found in the unbaited area immediately surrounding the baited plots. Frequently they were found within a distance of 25 feet from the baited plots, but almost never were dead crickets found as far as 50 feet from the baited plot. Considering the tendency of the crickets to return to their own burrows after feeding on the surface of the ground, it appears that few crickets leave their burrows for more than 50 feet.

Burrowing Habits, Mating, and Oviposition

In 1940, records were made of burrow depths throughout the season. From October to February they were from three inches to six inches deep; in March they ranged from three inches to a foot in depth; in April the depth ran from one to one and one-half feet; the same depth prevailed in May; in June most of the holes ranged from one to three feet, but some were as deep as five feet. In most cases this late in the season the limiting factor was the depth at which clay subsoil was encountered.

Through the winter and until June the burrows are single shafts sunk downward into the soil. (Plate IV, Figure 1) From the surface downward for two or three inches the burrow ordinarily drops at about a 30-degree angle, or rather slowly; from there the burrow drops suddenly, at about a 60 or 70-degree angle. Occasionally it may go straight down for some distance. The tunnel typically curves several times in various directions before the bottom in reached, and if digging is stopped by hard clay subsoil, the burrow may turn sharply to the horizontal and follow the plane of the subsoil for a few inches. The diameter of the hole varies with the size of the cricket, the hole being slightly larger than the occupant and being enlarged as development takes place.

After approximately the first of June the general habit of burrowing is about the same, but at this time lateral galleries appear. These are branches off the main shaft at approximately right angles and at various depths in the burrow. They are generally more nearly horizontal than the main shaft. The diameter is slightly but noticeably smaller than that of the main tunnel, and they may extend for a foot or slightly more away from it. Occasionally tertiary branches, or tunnels leading a few inches off from these lateral branches, were found.

The entrance to the hole is kept plugged with soil while the cricket is inside as long as the soil is damp enough to permit this. (Plate I, Figures 1 and 2) Later when the soil is dry it seems that there is difficulty in making the soil hold together sufficiently to form a plug, after which the plugging is done farther down in the burrow where there is more moisture. (Plate II, Figure 1) At any rate the holes will be found sealed at one point or another in the majority of cases except when the cricket is digging or is out feeding.

It was observed a number of times while the crickets were in the adult stage that at the bottom of the burrow a mass of plant stems and leaves, cut into short lengths, could be found. Immediately after a rain these masses of plant material could be seen at the entrances to many burrows, having been removed by the crickets during the customary acceleration of digging following rainfall. Crickets were never observed carrying this material into burrows, so it may have been accidental. The fact that each piece had been cut into a length about equal to the diameter of the burrow, however, indicated that the material was to be used as food during a stay beneath the surface.

The manipulation of the body in digging was observed in detail in glass containers filled with sand in the laboratory. At the bottom of the burrow the cricket loosens a small mass of soil by using alternating strokes of the fore legs, similar to the method of a dog. In the meantime the middle legs are held at a wide angle from the body against the sides of the burrow, serving as braces. Having dislodged a mass of soil, the cricket backs upward, pulling the pile of soil along underneath the body by means of short backward strokes of the fore legs, these being now worked simultaneously and held close together. When the top of the burrow is reached, the pile of soil is dropped while the cricket walks forward over it until the hind legs are below the pile. These hind legs, with their long, closely-spaced spines, are then used alternately to catapult the soil out on the surface by means of short, quick flips. An adult cricket can kick soil as far as 18 inches.

In trying to follow a cricket burrow to determine digging habits and location of the eggs, several difficulties were met. After the female had deposited her eggs in the burrow and had died, the hole would be filled within a few days with sand blown or washed in, after which it was impossible to follow the burrow. In following fresh burrows the difficulty was the tendency of the sand to fall into the hole, obliterating it. The problem was partially solved by pouring Portland cement of a soupy consistency into the hole until it was full, allowing it to harden and then digging out the concrete reproduction of the hole thus cast. (Plate IV, Figure 1) All crickets had to be trapped from the holes before this was done due to their habit of plugging the burrow underground at various places.

As only two eggs were actually seen undisturbed in the soil where they had been laid, discussion of oviposition habits must be largely hypothetical. Evidence indicates, however, that the eggs are deposited by insertion of the ovipositor to its full length into the walls of the burrow at random. The eggs are placed singly. Oviposition occurs at least in the lateral galleries and probably also in the main tunnel, although none were actually seen in the latter place.

In one instance, by following the burrow carefully in rather heavy soil, two eggs were located in the position in which they had been laid. They were two feet deep in the soil, one-half inch from the wall of a gallery which was going nearly straight downward at the time. The two eggs were about one inch from each other. At another time two eggs of what was thought to be a related species of cricket were found eight inches deep, one-fourth inch away from a main tunnel, and a half inch apart. These looked very similar to D. brevipes eggs, but were distinctly shorter and more nearly brown in color.

The method resorted to in collecting eggs in numbers consisted in digging a hole about three feet in diameter straight downward with the burrow as a center, sifting all the soil taken out through 18-mesh window screen sifters. These were wooden frames two feet square covered with the screen, the soil being thrown on the screen and shaken through by hand. In cases where the soil was too lumpy or too wet to go through the sifter, a stream of water was played on the soil to wash it through the screen. During the latter part of the 1940 season a sifter was used consisting of two screens, one coarse for excluding trash (one-fourth-inch-mesh) and one fine for retaining the eggs (18-mesh). The screens were fastened together with the fine screen below, and mounted on four coil springs from a discarded auto cushion. These were strong enough to hold the weight of several shovelsful of sand, and permitted movement for shaking the sand through.

No eggs were ever found at a depth of less than one and one-half feet, the most usual depth for the first eggs being about two feet. From this point scattered eggs were found steadily until clay was reached, in the case of shallow soil. In the case of soil where the sand extended to a depth of five feet, the eggs ordinarily were first found at about two feet, the bulk were found at from three to four feet, and a few scattered eggs were found on down to five feet. In the process of digging out these holes, it was suspected that many of the eggs were being found around the main shaft, as there usually was one area in the bottom of the excavation, presumably the former location of the main shaft, where a shovel full of sand would usually yield a number of eggs. This spot would shift gradually as excavation continued. In addition it might be expected to strike a few eggs in almost any part of the bottom of the hole.

This scattering of the eggs has a possible biological significance. The species being cannibalistic, it is better that the eggs be separated from each other when they hatch and the nymphs begin making their way to the top of the soil. It is also well that the old burrow is entirely obliterated by hatching time; were it still open many of the nymphs might find and use it, therefore encountering each other with fatal results.

About the middle of May, females were observed becoming gravid, and on the 29th of May, 1940, the first eggs were found. There was no great increase in the number of eggs found from this time on. Many times no eggs at all were found in holes. During this time one hole was dug which contained 128 eggs, and another was dug which contained 123, but for the most part from 12 to 15 eggs was the usual number found if any were found at all. This early digging was done almost entirely in rather hard soil. Late in the fall, just prior to hatching time, excavations were made on holes marked during the summer with concrete in a much sandier area; here eggs were found more consistently, although 128 remained the record. Of all digging done throughout the year, eggs were found in a total of 25 holes. The total eggs was 671, an average of 26.8 eggs per burrow for those burrows containing eggs. Thirty-nine holes were dug in which no eggs were found.

Considering the fact that about 30 nearly mature eggs ordinarily were found in dissected females, with several times that number in a less advanced stage of development; and considering the fact that after the crickets mature it is common to find several females occupying the same hole, it is surprising that no more than an average of 26.8 eggs should be found per burrow.

Mature eggs were to be found in the ovaries of the females as late as the last of June, when most of the crickets were dead, indicating that oviposition probably continues over a long period of time.

An attempt was made to secure oviposition in the laboratory by confining females in various sized tin cans filled with moist sand. Food in the form of moist bran was provided. From a total of 75 pairs of crickets thus confined, a total of only 18 eggs was secured. These experiments were started on May 27 and continued until the death of the females. The interior of the laboratory was cool, following almost at all times within one or two degrees of the temperature of the soil outside at a depth of one foot.

Attempts at incubation of the eggs also met with little success. The method followed was to place the recently-secured eggs in salve cans or other containers filled with moist sand. Water was added to the sand as it was observed to dry out. Of several hundred eggs treated in this manner both in 1939 and in 1940, not one hatched until the attempt was made in the fall of 1940. This time 30 eggs in an advanced stage of development were placed in a one-pound coffee can full of sand. The lid was perforated with several small holes and kept on the can. After two weeks three nymphs were found to have hatched and burrowed their way to the top of the sand. Whether these would have hatched had they been collected earlier in their development can never be known. No indication of the reasons for this difficulty was found. Sensitivity to abrupt moisture changes, exposure to daylight, or jarring of the eggs in the sifting process are some possible explanations which might be advanced.

A unique habit of the crickets is mentioned here because of its possible connection with the mating instinct. At many times during the season, but somewhat oftener during the adult stage, it is possible to cause the emergence of a cricket during the daytime by scratching at the entrance of the burrow with the fingers or with a small twig. When this emergence occurs the cricket sometimes comes out rapidly and leaves the entrance of the burrow for a few inches in great excitement. At other times less haste is shown, the cricket merely appearing at the burrow opening for a moment. There are times when nearly every cricket will respond to this scratching, whether male or female, while at other times very few can be induced to emerge. No positive explanation of this phenomenon is offered, but it is possible that the scratching imitates the activities of a cricket at the entrance closely enough that the occupant comes up to investigate.

The only known observation of the act of copulation is recorded by Standish (12). He notes:

> "At 10:25 p.m. (May 19, 1939) a pair of crickets were found mating in a field newly planted to cotton. A female was feeding on a cottonseed lying in a furrow and just as the flashlight was turned on the female a male approached her. The male immediately turned his abdomen toward the female, kicked a few times with his hind legs, and then backed against the female. By telescoping his abdomen in and out and by switching it up and down and from side to side he soon located the tip of the female's abdomen. To form the final contact he found it necessary to turn his abdomen slightly under and to the right, although only a few seconds were required for him to form this contact. The female continued feeding on the seed and seemed very much unconcerned over the activities of the male. The pair remained in contact for exactly four minutes, after which the female simply crawled away, leaving the male in the position he had assumed throughout the intercourse. Neither the female nor the male had moved appreciably during the four minutes of contact except

> that the female continued nibbling at the seed. After the female left, the male remained in the same position, apparently having 'sulled' ".

Thus it is known that copulation does occur above ground, although it is suspected that it also occurs in the burrow during the day, as the males and females in the burrow must be easily accessible to each other.

Injury and Food Studies

The exact importance of this species of insect as an enemy of farm crops remains rather uncertain. Farmers tell of extensive damage by the crickets, yet no experimental work has demonstrated serious injury. There are two possible explanations of this contradiction in evidence: (1) Experimental work was done under conditions of a rather low infestation when damage could be expected to be slight. (2) The injury to plants by crickets is very similar to that done by cut-worms, possibly leading to confusion by the farmer.

During the two years in which experimental work was carried on, the crickets were observed many times at night on the surface. They were observed to feed on such material as dry sticks, dead leaves, both dead and green grass, weed seeds, pecan nuts, carcasses of toads and insects killed by automobiles passing along the road, rabbit pellets, bird droppings, live ants of several species, and upon growing cotton and alfalfa. There seemed to be no pronounced preference for any of these, the writer's impression being that whatever the crickets chanced upon that was at all edible, they ate. In feeding upon growing plants, the individual leaves near the ground may be eaten, or the stem may be gnawed away until the plant falls over of its own weight.

The crickets seem to relish ants as food. One of the best methods found for collecting crickets consisted of visiting ant hills after dark with a flashlight. Often as many as seven or eight crickets could be picked up near the den, apparently lying in wait for the occasional ants which were abroad after dark. Occasionally a cricket could be found in this manner on a red harvester ant den, but they apparently preferred smaller species.

Standish (12) in 1939 notes that an outdoor lighted pen designed to confine a number of crickets for possible observation during the night hours attracted many May beetles, these being quickly snatched and eaten by the crickets in the pen.

It is also the habit of the crickets to eat their exuviae following moulting. This was observed in glass cages in the laboratory and was suspected once by Standish (12) in the field when a newly-moulted cricket was dug from a burrow with only a part of the cast skin remaining.

Eckley (4) in the winter of 1940 conducted experiments under greenhouse conditions to test the injury by crickets to seedlings of various varieties of plants. Each of four groups of individually caged crickets received a different type of food. The summary of this work appears in Table 11.

Table 11.-- Injury by Caged Crickets to Seedlings of Various Plants, Stillwater, Oklahoma, 1940.

Exp. No.	No. of Crickets	Type of Food	No. Plants Cut Off	No. Plants Partly Eaten	Sq. mm. of Surface Eaten
1	5	Watermelons	0	2	39
2	4	Tomatoes	19	1	1,247
3	5	Cowpeas	0	3	129
4	5	Tomatoes and moist bran	55	4	7,829

Individuals of the above test were females with these exceptions: one male was in each of experiments 1 and 4, and two males were in number 3.

The above data are rather surprising. It would seem, for instance, that more damage would be done where tomato plants were available than where they were supplemented with moist bran. Those in the latter group, however, did far the more damage. It is recognized that the above table represents a very small sample, but it nevertheless can be seen that under certain conditions not now recognized the crickets may become destructive to plant growth.

In both 1939 and 1940, experimental gardens were planted in areas infested with crickets for the purpose of determining the extent of their injury. In 1939 the garden took the form of 12 adjacent plots of ground, each measuring 12 by 16 feet and each fenced in with strips of galvanized sheet iron. The plots were planted to various crops and infested with crickets in numbers ranging from a normal population to extremely heavy. Almost no damage to the crops was noted, this development being attributed to the fact that it was impossible to maintain the respective degrees of infestation because of death of the crickets. This latter factor was thought to be due to cannibalism induced when the crickets were confined in a restricted area.

In 1940 the experiment was set up so as to eliminate this factor. A plot 4 feet wide and 200 feet long was divided into six unfenced plots and planted to various garden and field crops, this narrow strip bordering on one of the highest infestations of crickets in the locality. The crops planted were beets, watermelons, Alaska peas, lettuce, spinach, onions, black-eyed peas, Kentucky Wonder beans, carrots, radishes, cantaloupes, okra, sweet corn, cucumbers, and tomatoes. These were planted in short rows lengthwise of the plots, the plots being replicated with different row arrangements so that each crop appeared in the row nearest the cricket infestation, as well as in all other positions, twice. Very few instances of damage of any kind were noted throughout the summer, and in no instance could damage be positively attributed to crickets although some of it undoubtedly was done by them. In some cases it was almost certain that cut-worms had been responsible. No damage which could be termed serious, however, occurred.

With the object of establishing the food habits of the crickets, stomach examinations of field-collected crickets were made at intervals through the summer. The tabulation of the results appears in Table 12. Inspecting the totals, it appears that a majority of the crickets' food consists of dead plant material and insects, including other crickets, with a relatively small amount of green plant material and sand making up the majority of the remainder. Small amounts of white plant material, consisting probably of roots and plant sprouts, are also eaten.

A noticeable decline in amounts of green plant material and roots and sprouts is seen as the crickets progress from the fourth instar to the adult, these foods being replaced by dead plant material and insects as the crickets mature.

Pieces of insects found in the digestive tract included, in part or whole, ants, beetles, lepidopterous larvae, moths, mites, bluebottle flies, and other crickets.

In the nymphal instars a positive identification of cricket remains in the digestive tract was made in only four cases out of the 32 examinations made, but in numerous other cases unidentified insect remains were suspected of being parts of crickets. Of the 25 adults examined, one positive identification of cricket remains in the stomach was made, and one doubtful case recorded. These figures are not sufficient to prove cannibalism a major factor, as even those crickets found in the digestive tract may have been eaten after having died. The assumption is based primarily on the fact that it is impossible to confine a number

Table 12.--Type of Food Found in Digestive Tracts of *D. brevipes*.

		Amount of Each Food in Percent of Whole					
		Green[1] Plant Tissue	Dead[2] Plant Tissue	White[3] Plant Tissue	Insect[4] Remains	Sand	Roots[5]
Sex and Instar	Number Examined	Average Percent	Average Percent	Average Percent	Average Percent	Average Percent	Average Percent
M-4*	2	15	13	28	5	28	13
F-4	2	30	15	18	16	15	7
M-5	3	8	1	.3	83	8	0
F-5	5	30	24	7	4	35	0
M-6	9	6	46	4	21	21	.3
F-6	11	30	28	7	17	13	4
M-A	12	14	40	2	41	3	0
F-A	13	14	27	3	46	7	0
Totals							
All Crickets	57	18	30	5	31	13	1
All Males	26	11	36	5	36	12	1
All Females	31	24	26	6	27	14	2
All 4ths	4	23	14	23	11	21	10
All 5ths	8	22	15	5	34	25	0
All 6ths	20	19	36	6	19	16	2
All Adults	25	14	33	3	43	5	0

1 Any fresh, green-colored plant material.

2 Plant material of brown color; e.g., sticks, dead leaves.

3 White plant material; as sprouts, internal portions of roots.

4 All insects included, both crickets and other species.

5 Roots determined as such. Probably "White Plant Material" also included appreciable root material.

* M indicates male; F indicates female; numbers refer to instars; A indicates adult.

of crickets in a bucket or other small container and recover the full number placed in it. At one time 84 nymphal crickets were placed in a large covered wash tub full of sand for three days, at the end of which time only 62 live crickets were found. Twelve of these had legs or antennae missing. A few scattered remains of crickets were found in the soil

Comparing the food habits of males against females, it is seen that the females eat appreciably more green plant material than the males, and somewhat less of dead plant material and insects. Other foods are consumed in about equal amounts.

In the fall of 1940 three first instar crickets were opened for examination of the stomach contents, these figures having been omitted from the foregoing table and discussion because of being part of another generation and because a large part of the stomach contents could not be identified.

The examinations were made on September 24, 1940. The average contents of the three examined were: sand, 10 percent; insect remains, 8 percent (probably ant legs); unidentified, 82 percent. The unidentified material probably was of plant origin, but could have been additional insect remains.

The only conclusion which can be drawn from this part of the work is that the crickets possibly may become injurious under certain conditions; in the meantime they must be considered as scavengers with little economic importance.

Natural Enemies

The rapid decrease in the population of the crickets from fall to summer would indicate that some potent biological factor is at work, yet none of importance sufficient to explain this drop have thus far been uncovered. Since the larger parasites and predators would certainly have been observed had they been of great importance, it is possible that a disease is principally responsible for lowering the infestation. No pathological work has been attempted. Hubbell (8) has recorded several species of pathogens known to attack other members of this group of insects.

During the spring and summer of 1940 collections of various potential predators were made and the stomach contents inspected for evidences of cricket remains. A list of these appears in Table 13.

Table 13.--Remains of Crickets Found in Stomach Examinations of Possible Predators, Crescent, Oklahoma, 1940.

Common Name	Scientific Name	Total Number Collected	Total Crickets Found
Sand swift	*Cnemidophorus sexlineatus*	29	6
Ground squirrel	*Citellus tridecimlineatus*	5	4
Pocket gopher	*Geomys breviceps llanensis*	10	0
Scissor-tailed flycatcher	*Muscivora forficata*	1	0
King-bird	*Tyrannus tyrannus*	1	0
Bull snake	*Pituophis sayi*	1	0

In addition to the above, toads and the larger animals known to be insectivorous, such asskunks and opossums, may account for a few of the crickets but were never seen in any numbers in the area under study. Standish (12) observed a toad eating a cricket, but records only the one observation. Droppings of some larger animal twice were found containing large pieces of crickets, mostly hind femora, but the animal responsible was not seen. Many times the soil plugging the entrance to cricket burrows was seen marked by some instrument such as a bird's beak.

Some of these disturbed holes were trapped, however, and crickets found in the holes. Evidently if a species of bird had been attempting to catch crickets, it was having little success.

From the foregoing table it is seen that sand swifts and ground squirrels were the most important predators indicated by the 1940 work.

The method followed by the ground squirrels in capturing crickets was to dig a burrow into the ground following the cricket's burrow. In a number of instances the location of a cricket burrow was definitely known by reason of having been staked, and was later found to have been followed downward by a ground squirrel burrow. Because of this rather slow process in effecting the capture, and because of the rather low number of these animals, however, it is difficult to see how they could be responsible for a very large part of the population drop.

The method of the sand swifts was more interesting and seemingly more efficient, notwithstanding the fact that a small number of crickets was found upon examination of their stomach contents. They were observed to scamper rapidly across the ground, entering briefly every cricket burrow encountered. If the hole was securely plugged beneath the surface they withdrew immediately. If the hole was open to them, however, they apparently went down and got the cricket. In only one instance was the actual capture of a cricket in this manner observed, but because of the large numbers of these little animals found in the locality, and their industrious habits throughout a large part of the day, they could easily account for many crickets. This would be especially true late in the season, when the crickets find it difficult to maintain the plug in their burrow because of dryness of the soil.

As to parasitism, but one instance has been observed. Standish (12) in 1939 found a female cricket dead in her burrow in a cage, and found the pupa of a Dipteron lying in the burrow. Further identification was not made. In 1940, 30 adult crickets were forced to burrow under lamp globes covered with muslin, in an attempt to collect whatever parasites might kill the crickets and emerge. No such parasites were observed to emerge.

A mite collected from a preserved adult male was identified by Dr. H. E. Ewing as a species of Macrocheles, his suggestion being that it was certainly a symbiont, and not injurious.

It might be noted that work attempting to establish important biological enemies has one large obstacle; namely, the fact that dead or dying crickets are very seldom seen on the surface. Death in nearly all cases occurs in the burrow, except when it occurs as a result of feeding on poison bait, in which case many of the poisoned crickets will be found dead at the burrow entrance.

With regard to enemies of the egg stage, it was noted in the fall of 1940 that the soil surrounding one burrow in which eggs were being found contained ramifications of an ant den nearby. It was obvious that the ants could destroy many of the eggs if they so desired, so two eggs were placed on the soil about six inches from the entrance to the den. The eggs were carried into the den by the ants almost immediately. There is a possibility that ants have some importance in this respect.

CONTROL

Results of Experimental Work

Control by means of spreading poison bran mash seemed the most likely to meet with success, so in 1939 experiments of a preliminary nature were conducted by Standish (12) to give an indication of the best bait to use for further tests. A summary of the formulae used and the percentage of kill obtained by their use appears in Table 14. Although highly variable results were obtained due probably to the small number of replications, a basis for the following year's work was provided.

In 1940 the formula chosen was slightly different from any tried in 1939, no outstanding difference in kill due to slight variations in the amounts of the various ingredients having developed in the preliminary work.

The bait used was composed of the following:

Wheat bran....................	100 lbs.
Sodium arsenite (4-lb. material)............	2 qts.
Blackstrap molasses..........	1 gal.
Water........................	12 gal.

Molasses was omitted from the above formula in half of the tests.

All bait was scattered at the rate of 15 pounds of dry bait per acre, the 1939 work having shown no particular advantage in heavier applications.

The 1940 baiting experiments were set up primarily to determine two things: (1) whether this type of bait could be depended upon to give consistent good kills and (2) whether the molasses in the bait was essential. Therefore each experiment was made a comparison of bait containing molasses with bait containing no molasses.

Table 14.--Summary of Preliminary Baiting Experiments, Crescent, Oklahoma, 1939.

Experiment Number	Formula*	Rate per Acre (Lbs.)	Percent Kill
1	1	15	46
	2	15	60
2	3	30	63
3	3	20	90
	4	20	58
4	3	20	82
	3	10	74
5	3	20	90
	3	10	86
6	3	20	89
	3	10	87
	4	20	92
	5	20	56

* Numbers under this heading refer to the following numbered formulae:

Formula 1. Wheat bran..................100 lbs.
White arsenic.............. 4 lbs.
Molasses.................... 2 gal.
Water...................... 12 gal.

Formula 2. Wheat bran..................100 lbs.
White arsenic.............. 4 lbs.
Water...................... 12 gal.

Formula 3. Wheat bran..................100 lbs.
Sodium arsenite............ 1 gal.
Molasses.................... 2 gal.
Water...................... 12 gal.

Formula 4. Wheat bran..................100 lbs.
Sodium arsenite............ 2 qts.
Molasses.................... 2 gal.
Water...................... 12 gal.

Formula 5. Wheat bran..................100 lbs.
Sodium fluoride............ 4 lbs.
Molasses.................... 2 gal.
Water...................... 12 gal.

Several methods of conducting the tests were tried. The one finally decided upon as best consisted in laying off three one-tenth acre plots, 100 feet by 43.5 feet each, with 50 feet separating the side of each plot from the neighboring one. The size of plot was selected for convenience, and the 50-foot distance between plots was decided upon as a distance over which relatively few of the crickets appeared to travel in any short period of time. As often as possible 50 holes were staked out in each plot, although in some cases a smaller number were available. The bait was spread in the evening on two of the three plots, these being selected by lot just previous to baiting. The crickets were allowed to feed on the bait for two evenings. The following two evenings all staked holes in the three plots were trapped with the field trap, the number of trapped crickets in the unbaited plot being considered as the normal or check plot. This number was compared with the catches in the baited plots to determine the kill. For instance, if half as many crickets were caught on a baited plot as were caught on the check plot, the kill was considered to be 50 percent.

Tabulation of all experiments conducted by the above method in 1940 appears in Table 15.

Table 15.--Summary of Baiting Experiments, Crescent, Oklahoma, 1940.

Experiment Number	Date	Check: Number Holes	Check: Number Crickets	Molasses Bait: Number Holes	Molasses Bait: Number Crickets	No-Molasses Bait: Number Holes	No-Molasses Bait: Number Crickets	Percentage of Kill: Molasses Bait	Percentage of Kill: No-Molasses Bait
1	5-13	17	10	9	0	15	1	100	88.6
2	5-13	19	8	5	0	15	3	100	52.5
3	5-13	8	8	22	1	19	0	95.5	100
4	5-17	40	20	40	8	40	5	60.0	75.0
5	5-24	22	35	20	2	20	3	93.7	90.6
6	5-24	22	18	19	2	26	3	87.2	85.9
7	5-24	20	9	17	0	23	4	100	61.3
8	5-27	50	24	50	8	50	3	66.7	87.5
9	5-27	50	31	50	1	50	4	96.8	87.1
10	5-29	50	27	50	4	50	5	85.2	81.5
11	5-31	50	17	50	20	50	10	0.0	41.2
12	5-31	50	25	50	4	50	18	84.0	28.0
13	5-31	50	54	50	5	50	16	90.7	70.4
14	6-4	50	40	50	8	50	21	80.0	47.5
15	6-5	50	98	50	10	50	29	89.8	70.4
							Average kill*	82.3	71.1

* Computed from original data - not individual percentages of kill.

The average kill resulting from use of bait containing molasses was 82.3 percent, while the average kill of bait containing no molasses was 71.1 percent. The statistical tests were applied to these results to determine if there was a significant difference between plots baited and plots not baited. Analysis of variance was used on the group of experiments from number 8 to 15, inclusive, as these all had 50 traps set on each plot. A highly significant difference was obtained.

The method of covariance was used on experiments 1 to 15, inclusive, these including several experiments where a uniform number of traps on each plot was not maintained. Again a highly significant value resulted, indicating that definite kills were being obtained, even with the discrepancy in number of traps set.

The difference in the average kills between molasses and no-molasses bait seems upon inspection to be rather striking, but statistical analysis did not bear this out. The standard deviation method was applied, the result indicating that there was no significant difference between these two baits. It appeared that roughly three to four times as much data were needed at this existing difference between the means to give significance.

With regard to experiment number 11, some uncontrolled condition obviously crept in. No certain knowledge being had as to what this might have been, the figures were included. A possible explanation is the fact that the supply of sodium arsenite was low at the time this experiment was made, and a noticeable amount of sediment was seen to be present. A new supply was obtained for the next test.

Standish (12) in 1939 conducted experiments to determine the value of molasses as an attrahent. One-pound coffee cans were sunk in the soil until the open tops were flush with the level of the soil, and in the bottoms of the cans were placed variously blackstrap molasses, corn syrup, and nothing at all. Ten traps were used for each treatment. The total crickets caught by each treatment in three weeks was as follows:

Blackstrap molasses..........145
Corn syrup.................... 44
No bait....................... 62

In 1940 similar experiments were run, the comparison being made between traps baited with bran moistened with water and traps baited with bran moistened with molasses and water. Ten traps of each treatment were baited daily and the nightly catch noted for nine days. The total crickets caught by each type of bait was:

Molasses, water, bran......231

Water, bran................186

Both the 1939 and the 1940 totals show a big difference between treatments in favor of blackstrap molasses. Statistical methods could be applied, however, to only a part of the data and did not give a significant difference between treatments for the portion used in the analysis. Totals for each trap for the last four days of the 1940 experiment, which constituted the data analyzed statistically, are given in Table 16.

Table 16.--Crickets Trapped by Means of Different Baits, Crescent, Oklahoma, 1940.

Trap Number	Molasses Bait	No-Molasses Bait
1	18	13
2	11	12
3	5	7
4	22	0
5	18	6
6	8	7
7	7	9
8	11	10
9	15	7
10	24	13
Totals	139	84
Means	13.9	8.4

Four tests using sawdust and bran in a three to one proportion as the carrier were made, the kills ranging from 22 percent to 69 percent with an average kill of 50.5 percent. These data are considered inconclusive because of the small number of experiments.

Concerning the length of time required by the bait to cause death of the cricket after feeding had occurred, it was observed that early in the morning following spreading of bait the night before, many crickets were to be seen dead or dying at the entrance of the burrows. On the morning following the second night's feeding, no noticeable increase in numbers of these poisoned crickets was apparent. It seems, therefore, that the bait requires about 12 hours or less to act. Presuming that most of the poisoned crickets die or become helpless in this length of time, it would not be expected that many such dying crickets would be found after the second night of feeding, as the heavier emergence will almost always occur the first night from any given group of holes whether the area has been baited or not.

Considering the control problem from the standpoint of the farmer, that of effecting economic control on a particular piece of ground, there are a number of complicating factors which much be considered other than mere percentage of kill per baiting. There will be, of course, no 100 percent kills, leaving some for subsequent baitings. Migration may affect control at least around margins of the baited area, but should not be a great problem as it is thought the crickets ordinarily do not travel far. Of more importance is the fact that not nearly all of the cricket population is active at any one time. This is due not only to moulting and the accompanying stay underground, but also to the fact that individuals may stay for long periods in their burrows for no apparent reason at all.

In an experiment designed to indicate what percentage of the population might be expected to emerge over a given period of time, traps were set and maintained continuously on 10 holes during the time when the crickets were in the adult stage and comparatively active. Of the total number of crickets caught from these holes in 11 days of trapping, the number and percentage emerging each day was calculated and set down in Table 17.

Table 17.--Crickets Trapped Daily from 10 Selected Burrows, Crescent, Oklahoma, 1940.

Date	Number Emerging	Percent of Entire Catch Emerging Each Day
June 13	16	44.4
14	8	22.2
15	2	5.6
16	3	8.3
17	0	0
18	0	0
19	0	0
20	1	2.8
21	3	8.3
22	1	2.8
23	2	5.6
Total	36	

Without a doubt others would have emerged had the experiment run longer. It can be seen, however, that by allowing the crickets to feed on the bait for only two days, as in the case of the previously described control experiments, only about 66 percent of the total population is affected.

Controlled experiments were not run specifically to determine how often and over what period of time baiting should be conducted to effect economical control. It is estimated, however, that in ordinary cases if the bait is kept on the ground available to the crickets for a period of 12 to 15 days, somewhere near 75 to 80 percent control should be effected at the end of that time. If unfavorable weather does not occur, spreading of bait every three or four days should be frequent enough, as the food preferences of the insects do not lead them to avoid food in a somewhat dry state. If rain dilutes the poison, however, or if high winds cover the bait with soil, an additional spreading of bait should be undertaken soon. The above estimate of the total kill to be expected must also be qualified by the fact that during periods when moulting is under way, or when a low emergence is occurring for other reasons, the kill will necessarily be less unless the baiting period is prolonged. It must be kept in mind by the operator, however, that he cannot wait for an "ideal" time for baiting, hoping to economize on labor and bait expense. It is extremely likely that such a time will never come, or that the operator will fail to recognize the opportunity until it has passed. The only safe plan is to put the bait on the ground and keep it there until the desired control has been effected.

Control Recommendations

In planning a control program, the first item to consider is the degree of infestation. Since intensive work was not done on the crickets when a high infestation was present, and since the amount of injury to be expected from any given infestation will necessarily depend a great deal upon what crops are grown and the stage of the crops when the infestation becomes active, no definite figure can be given as to what represents a potentially injurious population. The operator should inspect his fields early in the spring, about two to four weeks before seedlings are to be in the soil, and if, considering the value per plant in the seedling stage of the crop to be grown, he believes the number of cricket burrows present indicate a threat to his crop, he should begin baiting at once and continue for approximately two weeks or until the population has decreased to the point where fear of injury is no longer felt. It is well to bear in mind the fact that almost all of the damage will be done while the plants are tiny seedlings.

The bait recommended consists of the following:

Wheat bran............	100 lbs.
Sodium arsenite (4-lb. material).....	2 qts.
Water.................	12 gal.

One gallon of blackstrap molasses may be added to the above formula if desired. It probably will give a slightly greater kill.

In mixing, all the liquid materials should be poured together and thoroughly stirred. Then the bran should be spread thinly onto a smooth concrete floor or similar surface, and the mixed liquid distributed upon it evenly. The mix should then be turned with a shovel until every particle of bran is uniformly wet.

The bait should be spread uniformly at the rate of 15 to 20 pounds dry weight per acre over the area to be protected and over a strip about 50 feet wide immediately outside each margin. Spreading should be done in the evening just before sundown. Great care should be used in ascertaining that the bait is well broken up as it falls to the ground, so that birds or poultry will be unable to pick up any great amount of it. Likewise the poison bait should not be allowed to remain in sacks where livestock may get to it. The bait is always potentially dangerous while quantities of it are in one place; once thinly scattered it is harmless to larger animals.

Determining the kill after baiting is very difficult by inspection of the area baited, for reasons previously mentioned. By watching the baited area and noting the number of fresh holes for a period of a week or more, however, the operator should be able to form an opinion as to whether a dangerous population still is active.

In the case of small gardens, lawns, or other small areas being damaged by crickets, it may be more practical in some cases to eliminate them by methods other than baiting. Traps similar to those used in this research may easily and economically be constructed. With only a few traps a small area may be cleaned of crickets by shifting the trap to a new hole every time a cricket is caught. Drowning the crickets out by pouring water in the burrows may be effective at times.

In all cases, however, the possibility of cut-worms being responsible for the damage should be investigated before the conclusion is drawn that crickets are the offenders, although from a control standpoint this matters little. The recommended bait spread as instructed will effect control of cut-worms as effectively as it will control crickets.

It is said that chickens and turkeys will eat many of the crickets coming out before dark and those still abroad in the early morning. Although this is probably true, during the 1940 season it would have affected the population but little, as few crickets emerged before dark and few were to be found in the early hours of the morning. Destruction by birds and poultry of all kinds undoubtedly would be considerable in years when the crickets are out during the daylight hours.

SUMMARY

Daihinia brevipes Haldeman (Gryllacrididae, Orthoptera) occurs in the Great Plains states from North Dakota to northern Texas. In Oklahoma it is found in most sandy environments. It has been reported injurious to various field and garden crops.

The winter is passed in burrows as partly-grown nymphs which remain comparatively active during the winter months. The adult stage is reached about May 1, and oviposition occurs throughout the month of June. The eggs are laid in the sand surrounding the burrows. The eggs hatch during the last two weeks in September and the nymphs make their way to the top of the soil where they dig new individual burrows. There is one generation per year.

From late winter through spring a high mortality occurs in the population. Biological factors of importance sufficient to explain this mortality have not been discovered.

Records of nocturnal emergence from burrows showed no consistently close correlation with weather conditions, although a general correlation was apparent. Over the entire season, crickets emerged from an average of 44.3 percent of the active burrows each night.

Crickets were confined in cages open at the bottom to allow burrowing; emergence records taken on these individuals again gave no striking correlation with weather.

In the above cages it was indicated that the longevity of this species is about nine months. There was some evidence that fewer males than females reach maturity.

By trapping, marking, and releasing crickets in a circular plot and later trapping to recover marked crickets, it was apparent that there is

a strong tendency for the crickets to return to their own burrows after emerging and feeding on the surface. Many dug new burrows or used those previously dug by another cricket, however. Limited evidence indicated that in few cases did a cricket leave itsburrow for more than 50 feet.

The burrows gradually increase in depth from three to six inches in February to one to five feet in June. After the crickets mature the burrows include lateral tunnels entending off from the main shaft. Eggs obtained by sifting soil about the burrow were found from a depth of two feet to the bottom of the burrow. An average of 26.8 eggs per burrow were found.

The act of copulation was observed on the surface of the soil in but one case. It is suspected that copulation also occurs in the burrow.

From observations and stomach examinations it was found that the species is quite general in feeding habits. In addition to green plant material the crickets feed on such material as dry sticks, weed seeds, rabbit pellets, and other insects. Serious injury to growing crops was not demonstrated experimentally.

Of a number of possible predators examined, the sand swift (Cnemidophorus sexlineatus) and the ground squirrel (Citellus tridecimlineatus) were found to be the most important predators. Parasitism was not observed to be an important biological factor.

Control experiments consisted primarily of tests of poison bran mash bait, both with and without molasses. Statistical analysis indicated that significant kills were being effected, but the difference in kill between bait containing molasses and bait without molasses was not significant. The average kill of bait containing molasses was 82.3 percent; the average kill of bait containing no molasses was 71.1 percent.

The control recommended consists of application of poison bran mash mixed according to the following formula:

Wheat bran	100 lbs.
Sodium arsenite (4-lb. material)	2 qts.
Water	12 gal.
Blackstrap molasses (optional)	1 gal.

Baiting should be started two to four weeks before seedlings are to be in the soil, and should be repeated at approximately three-day intervals for about two weeks. Bait should be spread in the evening at the rate of 15 to 20 pounds per acre.

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Plate I

Figure 1.--Mound covering entrance to cricket burrow in left foreground. Ant burrow in right foreground. Photo taken in early April, 1940.

Figure 2.--Beetle burrows, similar in appearance to cricket burrows. An ant burrow can be seen at the immediate lower right of the hat, and a cricket burrow is in the extreme right background.

Plate II

Figure 1.--Cricket burrow in early June. Compared with Plate I, Figure 1, the burrow is of larger diameter and the mound does not completely cover the entrance.

Figure 2.--White stakes indicate burrows used in work to determine retention of burrows and migration. Photo taken in late April. Stakes represent all burrows which had appeared since the work started on March 15, 1940.

Plate III

Figure 1.--Field trap in place over a burrow.

Figure 2.--Sunken cages used in life history work. The screen frames were used to cover cages at night.

Plate IV

Figure 1.--Concrete casts of cricket burrows. No. 1, $2\frac{1}{2}$ feet deep, shows signs of at least two lateral tunnels which probably extended farther but were not filled with the concrete. No. 2, 1 foot 9 inches deep, shows a typical lateral tunnel, with the beginning of a tertiary branch near the end of the lateral tunnel. No. 3, 1 foot 2 inches deep, shows two branches starting upward, an unusual condition. No lateral branches extending upward were ever cast for more than a fraction of an inch. No. 4, 1 foot 1 inch deep, shows horizontal turn of the burrow when hard clay subsoil was reached. No. 5, 1 foot 3 inches deep, shows an unusual division of the main shaft into two equal branches. No. 6, 1 foot 11 inches deep, shows one of the longest lateral tunnels found. Probably none of the above casts reached to the full depth of the burrow.

Plate V

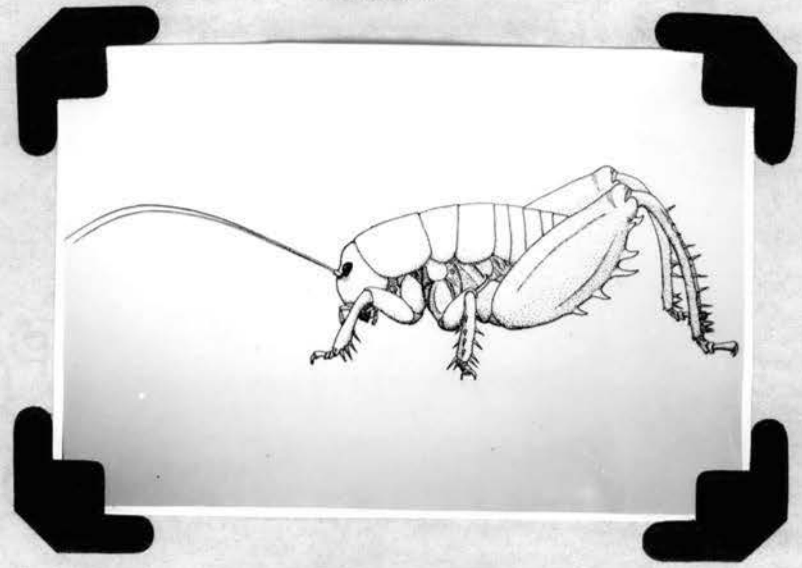

Figure 1.--Male of D. Brevipes. One and one-third times natural size.

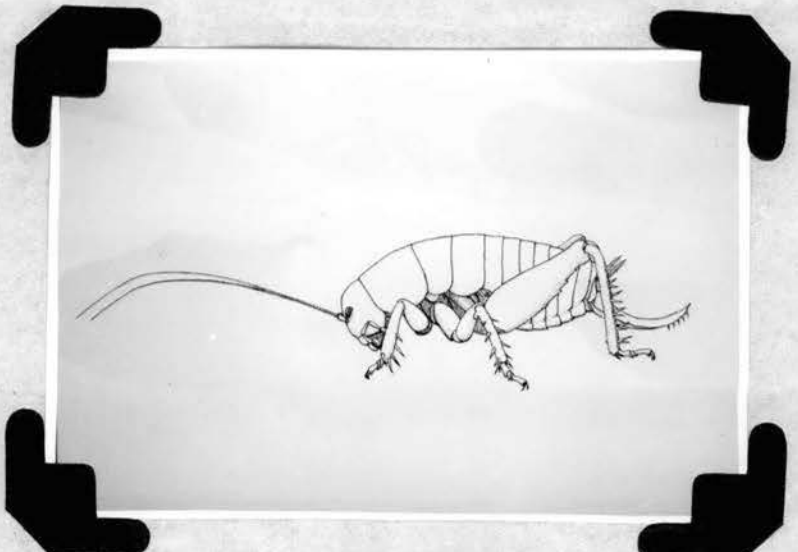

Figure 2.--Female of D. brevipes. One and one-third times natural size.

Plate VI

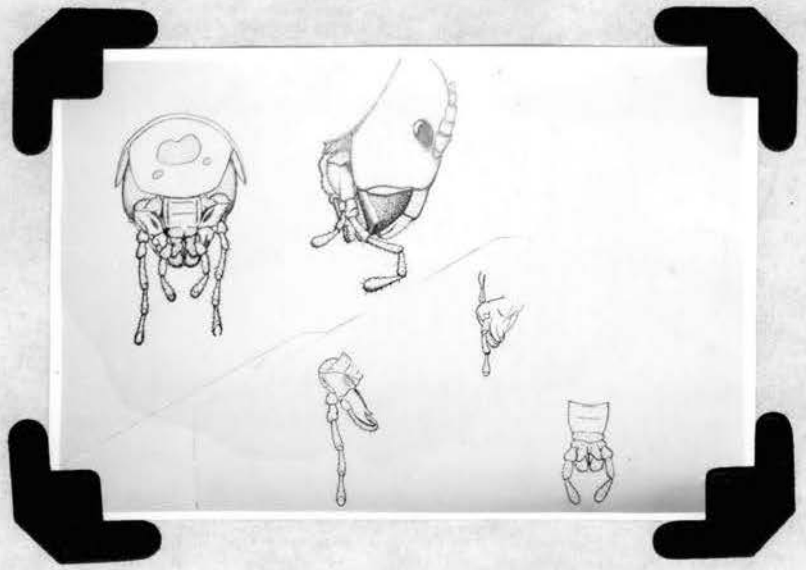

Figure 1.--Head and mouthparts of D. brevipes; 2 2/3 times natural size. Shown are mouthparts in situ, and dissected maxilla, hypopharynx, and labium.

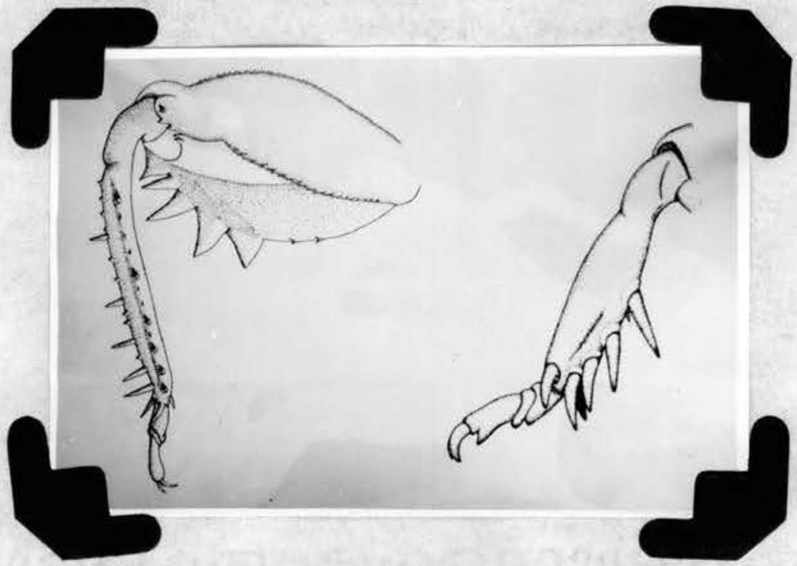

Figure 2.--Posterior leg of male on left, 2 2/3 times natural size, showing adaptation of femur and tibia as prehensile instrument. Anterior tibia and tarsus of female on right, 6 times natural size, showing fossorial adaptation.

Plate VII

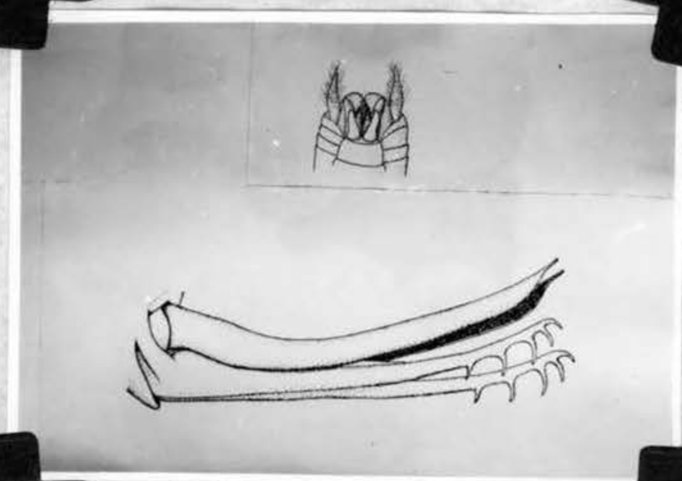

Figure 1.--External genitalia of second instar female at top, viewed ventrally; 10 times natural size. External genitalia of adult female at bottom, viewed laterally; 5 1/3 times natural size.

Typist

Mary Sue Ruark