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H.C. Severin

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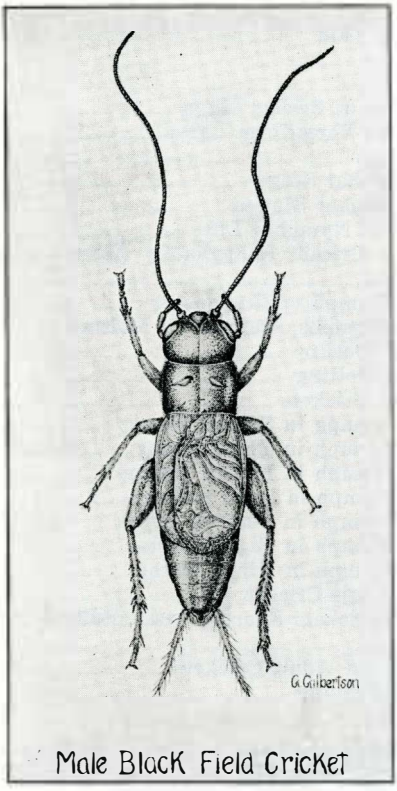

Male Black Field Cricket

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Summary

The common black field cricket is an important insect pest in South Dakota. The injury done is caused entirely by the feeding habits of the insect, the greatest amount of damage being done by the later nymphal stages and by the adults. Crickets are especially fond of certain seeds in the milk and early dough stages; also of certain ripe or ripening fruits. Alfalfa seed in the milk or early dough stage is a preferred food, and it is not uncommon to have crickets, through their feeding activities, ruin an excellent set of alfalfa seed in seven to ten days. The developing seed of wheat, oats, barley, rye, emmer, flax, sweet clover and corn may also be eaten. Frequently, crickets cut off the individual seeds or heads of small grain plants and drop them to the ground. This may take place before the grain is cut or after, and it may continue even after it is shocked or stacked. Such fruits as tomatoes, cantaloupes, watermelons, squash, pumpkins, cucumbers, peas, beans and strawberries are often damaged by feeding crickets. The roots of beets, carrots and parsnips may be attacked, as may also the tubers of potatoes.

Frequently, crickets feed upon and ruin materials made of cloth or paper. This may occur not only to clothing and other materials left lying on the ground out of doors, but also to articles kept indoors. Cotton, linen or silk, all may be attacked, as may also furs. Clothing or articles made of paper are more subject to injury if they are stained with greasy food, syrup or perspiration.

In South Dakota we have but one species of black field cricket, but apparently there are two biological races, one that hibernates in the egg stage, and the other that passes the winter as an immature cricket usually in the fifth or sixth instar. The first-mentioned biological race becomes much more abundant than the second, and is also much more destructive. Each race produces only one generation per year. The eggs of this pest are laid singly in the soil to a depth of usually less than an inch beneath the surface, and are not protected by an abundance of secretion. While the number of eggs laid by a cricket varies from 1 to 488, the average number is approximately 270. Cricket eggs that have passed through the winter unharmed usually hatch during late May or during the first half of June. These eggs do not all hatch at one time, but the great bulk of them ordinarily hatch within a period of two weeks.

Most of the crickets pass through eight or nine nymphal stages before becoming adult although an occasional specimen may pass through an additional instar. The great majority of the crickets that pass the winter in the egg state complete their nymphal development and become adult crickets in 65 to 90 days, which means that the adults of this race will make their appearance during the latter half of July and during August. Egg-laying begins usually 7 to 14 days after the female crickets have made their adult appearance and is continued off and on throughout the life of the females. Many of the adult crickets have outlived their normal span of life by September fifteenth and have died; others, on the other hand, live until heavy freezes destroy them. None of the adult crickets hibernates.

The black field cricket has a host of parasitic and predaceous enemies but in spite of this, the insect flourishes and is a serious pest year after year in certain areas in South Dakota. The most important parasite is *Ceratoteleia marlatti* Ashmead, a small wasp-like insect which destroys from 20 to 50 per cent of the cricket eggs each year.

Crickets may be brought and kept under control by destroying the eggs, by destroying the young and adult crickets, or by using both methods. To destroy the eggs, cultivating, disking or plowing is resorted to. Cultivating and disking have for their main purpose exposing the eggs to the drying action of sun and wind, so that the eggs will dry out and die. Plowing and packing, on the other hand bury the eggs so deeply that few of the young, even though they hatch, will be able to burrow their way through the soil to freedom.

The most effective method of destroying crickets in fields or gardens when the crickets are either in their nymphal or adult stages is by poisoning them with a sodium fluosilicate poison bran bait. Dusting with arsenicals or other insecticides is not recommended. Poultry may be used to advantage in reducing the number of crickets over a small acreage, but over a large acreage, little may be expected of them. Well planned burning may be resorted to in attempting to hold crickets in check, but this method of control has its limitations.

In homes, apartment buildings, stores, hotels, or other buildings, crickets may be destroyed by the use of poisoned baits, or through dusting with certain insecticides such as fresh pyrethrum powder, sodium fluosilicate or sodium fluoride.

The Common Black Field Cricket
A Serious Pest in South Dakota

By
H. C. Severin

INTRODUCTION

The common black field cricket, *Gryllus assimilis* (Fabr.)* is not only a serious insect pest of certain field and garden crops in South Dakota, but in addition it is an important household pest because of the damage it does to fabrics such as wearing apparel, curtains, bedding, etc. While this species of cricket is omnivorous, the greater portion of its diet consists of vegetable matter. Many of our field and garden crops may be injured through the feeding activities of this cricket, but usually the damage done is most severe in alfalfa fields devoted to seed production.

It is the purpose of this bulletin to discuss the economic importance and distribution of the common black field cricket in South Dakota, to consider its systematic status, to discuss the life history and seasonal histories of the cricket, to describe briefly the various stages through which the insect passes in completing its life cycle, to discuss the behavior or habits of the immature and adult crickets, to present an account of the damage done, and last, to present facts regarding control and repression of the insect through natural enemies and through methods worked out by the writer during the course of this investigation.

HISTORICAL

Economic literature contains comparatively few references to damage done to farm, garden or orchard crops through the common black field cricket. Likewise, there are comparatively few references to the damage these insects may do clothing, curtains or other fabrics. Such references as one does find in economic literature are, with three exceptions, extremely short accounts of injury done to certain crops or manufactured products. The first lengthy paper[1] discussing the economics of the black field cricket is also the most exhaustive published to date, so far as life history studies, behavior observations and control experiments are concerned. This paper was prepared by H. C. Severin and published in 1926. The second lengthy paper[2] was prepared by E. A. McGregor and is of interest chiefly because of the account of the nature of the damage done by the crickets to cotton.

* Whenever the word cricket is used in this bulletin, the author refers to the common black field cricket, *Gryllus assimilis* (Fabr.) unless otherwise stated.

[1] Severin, H. C. The Common Black Field Cricket, *Gryllus assimilis* (Fabr.) and its Control Journ. Ec. Ent., Vol. 19, pp. 218-227, 1926.

[2] McGregor, E. A. The True Cricket—A Serious Cotton Pest in California. Cir. 75, U. S. Dept. of Agr., pp. 1-8, 1929.

The third lengthy paper[3] was a joint publication by J. A. Munro and L. A. Carruth and was limited to a discussion of some insecticidal control experiments by the authors on the black field crickets. This paper may be divided into two sections, the first dealing with a discussion of the use of poisoned baits in an attempt to control crickets under field conditions, and the second dealing with the use of insecticides in dust form to control crickets within buildings.

Economic Importance

The damage that is done by the common black field cricket is caused entirely by its feeding habits, the greatest amount of harm being done by the later immature or nymphal stages of the crickets and the adults. The crickets under discussion have chewing mouth parts very similar to those of a grasshopper, and with these mouth parts they cut off bit after bit of the material upon which they are feeding. The particles bitten off are usually swallowed as food, but, at times, the particles are simply dropped.

A large variety of vegetable food is eaten by crickets, but this may be supplemented by animal food whenever such is available. While crickets may eat any and all parts of certain plants, including roots, stems, leaves, flowers, fruits and seeds, a marked preference is shown for the flowers, fruit and developing seeds of many plants. When the seeds become hard and mature, however, they are no longer desired as food.

Alfalfa fields are more heavily infested with crickets in South Dakota than are any other cultivated or uncultivated crops. While crickets will use any part of an alfalfa plant as food, they prefer the flowers and the developing seeds, especially when the seed is in the milk and early dough stage. To obtain such seed, the crickets gnaw off the edge or side of the seed pod and then reach in with their mouth parts and pull out the seed (Fig. 1). So abundant have crickets become in some of our alfalfa fields and so great their damage that it is not an uncommon experience for a farmer to lose his entire seed crop in 7 to 10 days because of the feeding activity of crickets. While most of the damage to the alfalfa seed crop is done to the uncut crop, the damage may continue even after the alfalfa has been cut and either stacked or shocked. At times, considerable damage is done because crickets cut off the seed pods from either the uncut or cut alfalfa and drop them to the ground.

The flowers of alfalfa in all their stages of development may be attacked, and any and all parts of them may be devoured. The young stems of alfalfa plants may be completely or partially severed, or only the epidermis may be gnawed away. The stem injury may occur any place along its length, from a position very close to the ground to its very tip. In our experience the leaf and stem injuries, however, are usually not severe, while the flower, seed pod and seed damage may be enormous.

[3] Munro, J. A., and Carruth, L. A. Insecticidal Control of the Common Black Field Cricket, *Gryllus assimilis* (Fabr.) Journ. Ec. Ent., Vol. 25, pp. 896-902, 1932.

The crickets will also feed upon the developing seed of wheat, oats, barley, rye, emmer, flax, sweet clover and corn. Further, the injury may continue even though the small grain crops have been cut and shocked. At times, crickets cut off the entire heads or individual seeds of our small grain crops and instead of devouring them, drop them to the ground. This may be done to the uncut grain or it may be done after the grain has been cut and shocked.

The fruits of tomato plants, cantaloupe, watermelon, squash, pumpkin, cucumber, ground cherry, pea, bean, and strawberry are often used as food by crickets and either totally ruined or seriously damaged. The roots of beets, carrots and parsnips may be attacked, as may also the tubers of potatoes.

The flowers and young seeds of many weeds are also eaten by crickets, the most important of these being the following:

Russian thistle = *Salsola kali tenuifolia* Meyer
Green foxtail = *Setaria viridis* (L.)
Yellow foxtail = *Setaria glauca* (L.)
Giant ragweed = *Ambrosia trifida* (L.)
Little ragweed = *Ambrosia artemisiifolia* L.
Rough pigweed = *Amaranthus retroflexus* L.
Tumbling pigweed = *Amaranthus graecizans* L.
Lambs quarter = *Chenopodium album* L.
Switch grass = *Panicum virgatum* L.
Old-witch grass = *Panicum capillare* L.
Barnyard grass = *Echinochloa crusgalli* (L.)
Dropseed = *Sporobolus cryptandrus* (Torr.)
Small false indigo = *Amorpha microphylla* Pursh.
Common sunflower = *Helianthus annuus* L.
Slender wheat grass = *Agropyron tenerum* Vasey
Western wheat grass = *Agropyron smithii* Rhyb.

Russian thistle is one of the preferred food plants of crickets during the latter half of July and during August. Not only are the flowers and developing seeds of the Russian thistle eaten, but the succulent soft leaves are also taken. It is not unusual to find a dozen or more crickets feeding on a single plant at this time of year.

While it is true that crickets do not usually have the opportunity of feeding upon the flesh, viscera, etc. of dead mammals, birds, reptiles and amphibians, they will do so whenever they have the opportunity. Members of the insect world are included in their diet more often and, consequently, it is very common to see crickets feeding upon a dead or weakened fellow cricket, grasshopper, fly, caterpillar, etc. If a number of crickets are enclosed in a receptacle provided with plant food only, the crickets will attack and devour one another, until only one or a few remain. This cannibalistic reaction can be avoided by adding meat scraps, meat meal or bone meal to the cage or receptacle, a plan we were forced to adopt when we attempted to study crickets that were confined in cages.

Frequently crickets feed upon and utterly ruin materials made of cloth or paper. This may occur not only to clothing and other materials left lying on the ground out of doors, but also to that kept indoors. Cotton, linen, woolen or silk cloth, all may be attacked, as may also furs. Clothing

or articles made of paper are more subject to injury if they are stained with greasy food, milk, syrup or similar materials. Clothing permeated with perspiration seems to be especially relished as an article in their menu.

The field cricket has been accused of cutting binder twine. This seems to be the prevalent opinion among farmers, but the writer has not observed such injury, nor has he been able to get crickets to work upon binder twine even though he confined the crickets together with binder twine in cages.

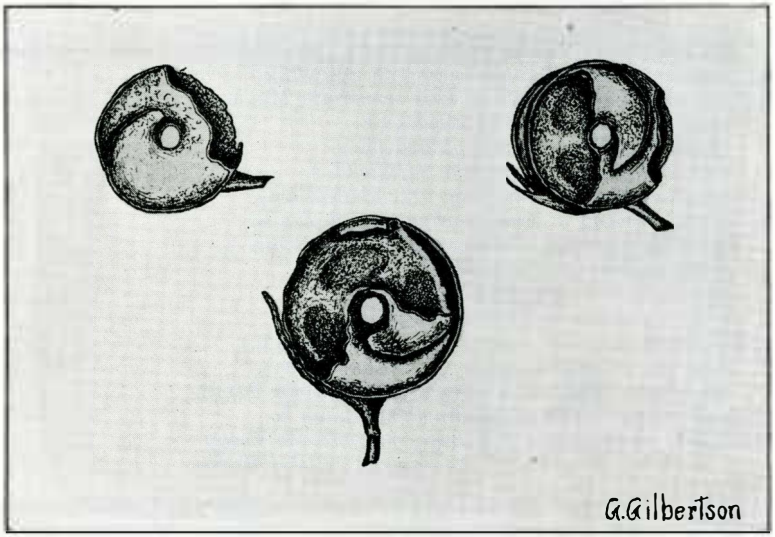


FIG. 1.—Alfalfa seed pods with edge or side chewed away by crickets and seeds removed.

Distribution and Abundance Over South Dakota

In the United States, the common black field cricket has been reported from nearly every state, and undoubtedly it is nation-wide in its distribution. It occurs in southern Canada, and to the south it is found as far as central Argentina and Chile. It has also been reported as occurring on many of the islands off the mainland of both North and South America.

In South Dakota, the cricket is generally distributed over the State. It occurs in our lowest altitudes (979 to 1500 feet above sea level), as well as on the sides and tops of the mountains of the Black Hills (3200 to 7236 feet above sea level). It may be found in practically all environments where there is no standing water. It is found in the most humid sections of the state, as well as in the driest portions. It occurs in the sand areas, including the extensive Sand Hills in the south central and southwestern

portions of South Dakota, in the Badlands, on the plains of the central and western portions of the state, on the prairies of the east and in the natural timbered areas in all sections. It may be found in cultivated as well as in uncultivated fields, on virgin sod of the prairies and plains, on the driest of hill sides, and in coulees and river bottoms. Strange to say, the species is found in greatest numbers on the dry plains, and especially in the areas of the plains that are devoted to the growing of alfalfa, either under a system of dryland farming or under irrigation. It is in these sections also where the largest amount of damage is being done by crickets. Here it is not unusual to be able to count from 50 to 200 crickets in a square yard of ground near or about hay-stacks or hay-cocks, but throughout a badly infested alfalfa field the numbers of the crickets usually do not run over 50 per square yard on the surface of the soil.

In the drier sections of South Dakota, which roughly include the western two-thirds of the state, the ground may crack badly, the cracks at times extending from a few inches to six feet or more in depth. Such cracks serve as excellent refuges for the crickets, for they not only protect the insects from their natural enemies, such as birds and parasitic and predaceous insects, but they also offer protection from the intense heat that is to be encountered on the surface of the ground. The writer frequently has been able to force more than 100 crickets from cracks measuring not more than 18 inches in depth and 18 inches in length. Because of these facts, it is exceedingly difficult, in fact impossible, to estimate the average number of crickets per square yard in any field whose soil is badly cracked.

The conditions which evidently favor the enormous increase of field crickets are the following:

1. An abundance of favorable food for the young and adult crickets.

2. Undisturbed and not too dry soil for egg-laying and in which the eggs may pass through the winter unharmed.

3. An abundance of cracks in the soil in which the crickets may seek protection from the intense heat, and shelter from birds and predaceous and parasitic enemies.

4. An abundance or fair amount of vegetation laying on the ground and under which the crickets may seek shelter.

5. Rainfall in such amounts as to produce sufficient food and still not enough to keep the ground from cracking in the summer or from closing up the cracks too rapidly and over a long period of time.

6. A scarcity of parasitic and predaceous enemies.

Systematic Status

The common black field cricket is the most variable of all our North American crickets. Consequently it is not surprising to learn that it is described and discussed in literature under many different specific names. Rehn and Hebard[4] list 45 different scientific names or synonyms of this insect. After a thorough study of 1504 specimens taken from numerous areas in North and South America they conclude: "The different manifes-

tations of the only native American species, *Gryllus assimilis*, are in no case sufficiently differentiated or constant to be considered geographic races. They constitute mere variations, the adaptation of this exceedingly plastic species to local environmental conditions . . . In order to place properly the material of this species examined, we have found it quite impossible to group the specimens under any number of varietal units, and in consequence we have devised a system of symbols . . . by which the coloration, color pattern, tegminal and wing development and size of each specimen recorded . . . is defined. We have found that in general certain types do predominate over certain regions. These constitute the bases of many of the supposed species, but in our opinion should be characterized by symbols rather than varietal names . . ."

Blatchley[5] after calling attention to the great variability in structure, coloration and color pattern of *Gryllus assimilis* reluctantly retains six trinomial names for six "forms" of this insect, with the suggestion that "the student may use them as such and call them variants, varieties or forms of *assimilis* or discard them altogether and lump them as native field crickets under the name of *Gryllus assimilis* . . ."

The writer agrees in the main with the conclusions of Rehn and Hebard regarding the systematic status of the black field cricket, but he believes that there may be two biologic races in South Dakota, one that hibernates in the egg state, the other as nymphs of usually the fifth and sixth instars.

LIFE CYCLE AND SEASONAL CYCLE

Only one generation of the common black field cricket is produced during a year in South Dakota. The vast majority of these crickets hibernate in the egg stage but a small per cent, probably less than five, pass the winter as nymphs of usually the fifth or sixth instars (Figs. 2 and 3). Under normal conditions, the crickets that hibernate in the egg stage begin to appear as adults during the fourth week in July and the first week in August. Within two or three weeks most of the remainder of the crickets have become adult. Many of these adult crickets have outlived their normal span of life by September fifteenth and have reproduced and died; others, however, live until heavy freezes destroy them. The crickets that pass the winter as nymphs usually become adult during the latter part of May and during June, reproduce and die during July. Thus it is seen that there is very little overlapping of living adult crickets of these two biologic races or of any identical stages in the life cycle of the two races.

Since the race that hibernates in the egg stage is of the greatest economic importance, further discussion of the life history as well as discussion of the habits and control of these crickets will be limited to this race.

[4] Rehn, James A. G., and Hebard, Morgan. The Genus *Gryllus* (Orthoptera) as Found in America. Proc. Acad. Nat. Sci. of Phil., pp. 293-322, 1915.

[5] Blatchley, W. S. Orthoptera of Northeastern America, American Nature Pub. Co., Indianapolis, Ind., pp. 696-709, 1920.

Preoviposition

Egg-laying does not begin immediately after the female crickets take on their adult appearance, but usually 7 to 14 days elapse before oviposition begins. The eggs develop gradually within the body of the cricket, and as they increase in size, the abdomen becomes swollen and elongated and finally pear-shaped. Egg-laying is continued off and on during the life of the crickets and, at times, is continued for two months or longer (Fig. 2). In our experimental rearing cages a few crickets began to lay eggs six days after becoming adult, some did not begin to oviposit until they had been adult for 30 days, while the bulk of the crickets began to lay 8 to 11 days after they had molted for the last time.

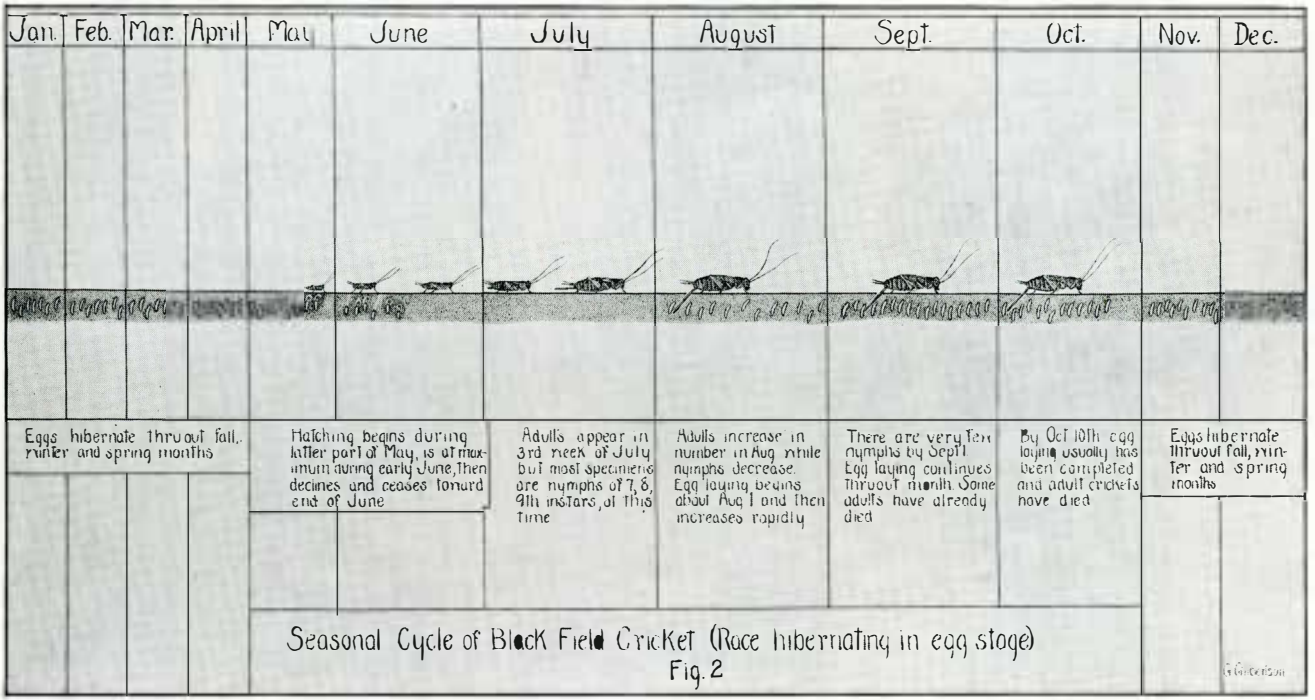
Oviposition

Under average weather conditions in South Dakota, adult crickets of the race hibernating in the egg stage begin to make their appearance during the fourth week in July and increase rapidly in numbers in August. Very few nymphs of this race are to be found alive by September first. Egg-laying usually begins about August first and increases rapidly during August and the early part of September. During the latter part of September many of the adult crickets have died and consequently egg-laying is letting up. By October tenth in normal years most of the adult crickets have died and egg-laying has practically ceased (Fig. 2). The time of day when egg-laying begins is usually in the latter part of the afternoon and early evening, but occasionally a cricket may oviposit or begin to oviposit in the morning, especially if the weather is cool.

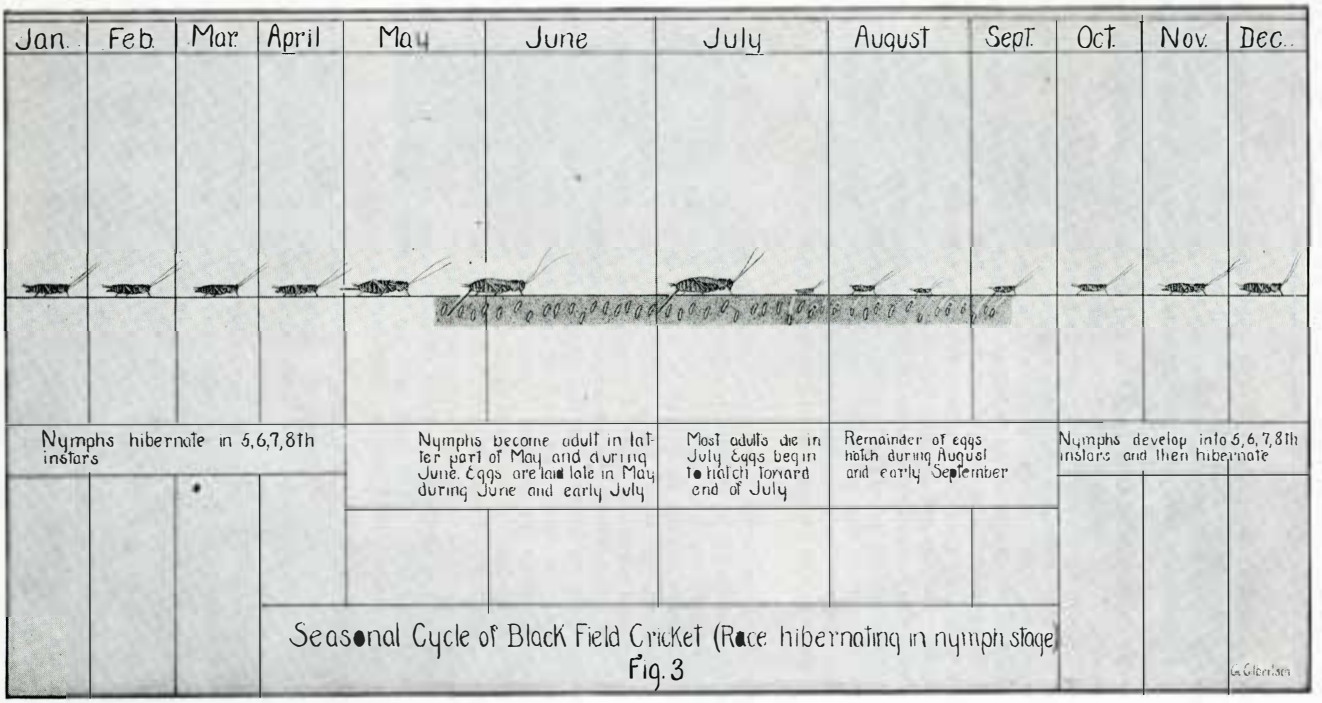
Firm, damp soil is preferred for egg-laying purposes, but the ground must be soft enough to permit the ovipositor to enter readily. Soils filled with grass roots are not desirable, nor is loose soil. If the top soil becomes baked and crusted and thus made unfit for oviposition purposes, a female cricket may use her mouth parts and all her legs in digging away a few square inches of the hard crust and thus expose the more favorable soil beneath. In some sections of the state, the crust of baked soil breaks up into irregular cakes measuring about 6x6 inches more or less and leaving cracks of one-half inch or thereabouts between them. Such cakes may or may not slough loose from the underlying soil. Under these conditions the crickets prefer to oviposit in the comparatively loose soil between the cakes, or they may burrow beneath the cakes to reach favorable soil. If the soil is too loose for oviposition, the crickets may scratch or kick away the loose soil until the more compact ground is reached.

In alfalfa fields, the bare ground between plants, the bare edges around certain ant hills, bare areas in the borders of the fields, the tops and sides of irrigation ditches and other areas with similar qualifications are attractive for egg-laying purposes. The same is true for all other cultivated or uncultivated fields whether in crop or grass.

As a preliminary to ovipositing, the female arches up the middle of her abdomen and presses down the free end. This brings the tip of the ovi-



Seasonal Cycle of Black Field Cricket (Race hibernating in egg stage)
Fig. 2



Seasonal Cycle of Black Field Cricket (Race hibernating in nymph stage)

Fig. 3

positor in contact with the soil. The angle at which the ovipositor is held when it comes in contact with the soil will depend upon many circumstances, such as the degree with which the abdomen is arched, the position the insect has assumed with reference to the surface of the ground, the smoothness of the soil surface, etc. The insect now attempts to force her spear-shaped ovipositor into the soil by slowly moving backward and at the same time rapidly sliding the right and left upper and lower quarters of the ovipositor alternately forward and backward. The right and left upper quarters alternate with one another as do also the lower right and left quarters. Further, the upper and lower quarters of both right and left sides alternate with each other in their movements. Each quarter moves forward and backward about four or five times per second. The ovipositor naturally assumes a different angle with reference to the body as it is pushed farther and farther into the soil and it may even make a right angle with the body. The process of forcing the ovipositor into the ground normally consumes but a few seconds but occasionally a longer time is required. Sometimes the ovipositor strikes an obstruction and then the insect may remove the ovipositor from the ground or it may tilt the ovipositor or abdomen to one side or the other in an attempt to work around the object.

The depth to which the ovipositor is forced into the ground and consequently the depth at which the eggs are deposited, depends upon many factors. Sometimes the ovipositor is worked into the soil its entire length, and then again it may be forced in only a third or half of its length. If the ovipositing cricket should be clinging to a piece of vegetation or to the top of a small elevated piece of ground, or if a small depression should exist at the point where the ovipositor is penetrating, then the ovipositor cannot possibly be driven into the ground its entire length, with the consequence that any eggs that may be laid under these conditions must be relatively closer to the surface. Again, if the ovipositor is driven obliquely into the soil instead of at right angles with the body, the eggs deposited must be relatively closer to the surface of the ground. It is apparent, therefore, that while crickets cannot lay their eggs at a depth greater than the length of the ovipositor, which in most cases is slightly less than an inch, large numbers of the eggs may be laid only three-quarters, one-half or even one-quarter inch beneath the surface of the ground.

When the ovipositor has been pushed into the ground to the desired depth, a period of a few seconds of apparent rest follows, but during this time an egg is forced out of the internal reproductive organs into the base of the ovipositor. The egg is altogether too large in diameter to travel through the small egg canal between the right and left halves of the ovipositor, and consequently these halves are pressed apart as the egg moves downward. The egg appears suddenly in the base of the ovipositor and then travels rapidly, but in jerky fashion, downward to the tip of the egg-laying instrument. The jerky passage of the egg through the ovipositor is explained partly through the alternating forward and backward movements of the four quarters of the ovipositor, movements which are performed not only while the ovipositor is being forced into the soil, but also while the egg passes through this structure.

The inner face of each quarter or valve of the ovipositor over which

the egg passes resembles the face of a wood rasp, the teeth of which all point toward the tip of the ovipositor. As a valve is moved outward, the teeth on its inner face push the egg along, but when the valve is moved in the opposite direction, the teeth slide over the egg, while the teeth of the other three valves hold the egg in position.

After an egg has left the ovipositor, the egg-laying instrument may be withdrawn from the ground or it may be withdrawn only partially and then it is pushed back in again and another egg laid. Usually an ovipositing cricket continues to lay a considerable number of eggs before moving from her chosen area, with the consequence that 50 or more eggs may be laid in an area measuring not more than two inches square over its surface (Fig. 4). These eggs are laid singly and not in egg pods and have no special covering over them as do the grasshopper egg masses.

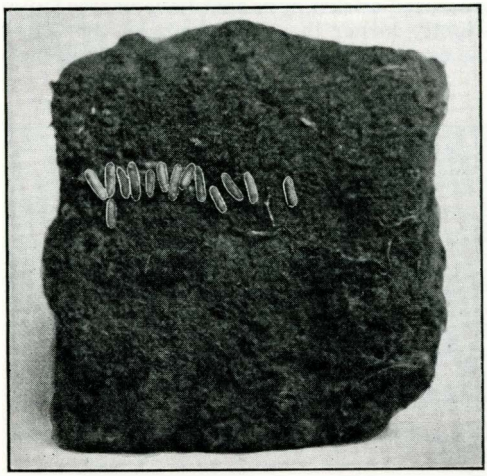


FIG. 4—Section of soil showing cricket eggs in natural position. None of the top soil was removed from the sample. The sample was obtained from an alfalfa field on April 15, 1933.—Original.

Number of Eggs Laid

The number of eggs laid by a cricket varies considerably, the usual number deposited varying from 150 to 400. In a few of our cage experiments only one or two eggs were laid by a cricket and, at the other extreme, a few of the insects laid as high as 400 to 448 eggs. An average of 10 normal ovipositions gave us 271 eggs per cricket. Through dissections, however, it was learned that not a single cricket had emptied its reproductive organs (ovarian tubules) of all of its eggs before it died, for we found from one to many well developed eggs in the ovaries of each specimen. Through cage experiments and through dissections it was further learned that a cricket keeps on developing eggs during her life and that

she lays eggs not on one, two, or three days only but on a half dozen or more days with intervals of rest between successive ovipositions.

The Eggs

Eggs that have been recently deposited are somewhat variable in shape, although not nearly so variable as are the eggs that are about to hatch. When first laid, the eggs are cylindrical in general outline, slightly curved and with ends rounded, although frequently one or both ends may be somewhat pointed. The eggs are of a light honey-yellow color, the yolk globules being readily discernible through the egg shell and membrane. No distinctive markings are to be found on the egg-shell or chorion. In size, the eggs vary from 2.8 to 3.2 mm. in length and from 0.6 to 0.7 mm. in diameter, the average being 3 mm. by 0.65 mm.

Fertile, unparasitized cricket eggs that have passed through the winter unharmed are slightly larger than they were in the fall. They are now cream-colored, the egg shell being more or less translucent. (Fig. 5.)

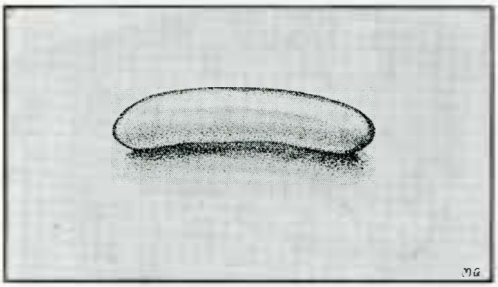


FIG. 5.—A fertile cricket egg early in spring.—Magnified.

A week or two before the eggs are ready to hatch, two pinkish eye spots make their appearance near one end of the egg. Later these spots turn brownish. In the meantime, two light salmon colored streaks appear on the opposite end of the egg. These are the cerci of the developing young cricket, and they measure about one fourth the length of the egg. The cerci later become darker and about this time, the head, thorax, and abdomen of the young cricket become visible. The divisions of the body become more and more distinct as development proceeds and gradually these take on the coloration they will have when the insects emerge from the egg-shell. Finally the legs and the antennae of the baby cricket become visible and now the young is ready to leave the egg.

As the embryo develops, the egg enlarges and it may also change its shape. While some of the eggs remain cylindrical and curved, others become barrel-shaped with the ends rounded. In size the eggs vary now from 3 to 4 mm. in length and from 0.7 to 1 mm. in diameter. An average of 10 eggs measured 3.5 mm. in length and 0.85 mm. in diameter.

Infertile Eggs

Crickets may deposit infertile eggs. Such eggs do not differ at first from the fertile eggs, for both are yellow in appearance. However, the infertile eggs do not develop, and while they may remain plump for several months they finally shrivel up and become dry and hard or they may become covered with a mold. In the spring the infertile eggs are readily distinguished from the fertile through color alone, the fertile eggs being cream-yellow, while the infertile are a light yellow. Unfortunately, the infertile eggs constitute less than one per cent of the total number laid under normal outdoor conditions.

Time of Hatching of Cricket Eggs

In South Dakota, cricket eggs that have passed through the winter unharmed usually hatch during late May or during the first half of June. The time of hatching is largely dependent upon the soil temperature and the soil moisture, but other factors, such as the texture and the color of the soil, slope of the land, cover and winds, and depth of the eggs beneath the surface of the ground are all influential in determining when the egg shall hatch. Because of these facts, the eggs do not all hatch at the same time. The great bulk of the eggs ordinarily hatch within a period of two weeks, but the remainder of the eggs may require another two weeks or even longer. In a late spring the time of hatching is delayed, while during an early spring, it begins correspondingly earlier.

Hatching and the Vermiform Larva

Before a young cricket hatches from the egg, it breaks off completly or in part a small circular portion of the egg shell immediately above its head. In addition, the egg shell is usually torn lengthwise from the circular opening to a point at or near the middle of the egg. Through the opening thus made, the young cricket makes its way out of the egg shell.

The young insect that emerges from the egg shell does not look like a young cricket, for its body and all the appendages are encased in a transparent membrane in such a way as to fold and bind the appendages more or less loosely against the distorted body. The head is flexed so that the mouth parts are directed backward and the face downward. Each antenna, leg and cercus is encased in a separate sleeve. The legs are held along the under surface of the thorax and abdomen. Each leg is folded somewhat and has its free end directed backward. The antennae are also directed backward and are situated between the legs. The cerci are directed backward and are held somewhat separated. In this stage of its existence, the cricket is known as the vermiform larva.

At the forward end of the head of the vermiform larva is a small whitish or colorless pointed protuberance. This structure is probably of some assistance in breaking the egg shell at the time of hatching and it may aid in opening up a pathway when the larva is making its way through the soil to the surface of the ground. In the neck region immediately back of the upper part of the head is the cervical ampulla. This structure con-

sists of a membrane which can be made to pulsate, first becoming inflated like two small bladders, then collapsing entirely. This structure probably assists in breaking the egg shell and undoubtedly aids the recently hatched larva in making its way through the soil.

How the Vermiform Larva Burrows Through the Soil

As soon as the vermiform larva has made its way out of the shell, it begins the slow laborious process of burrowing upward through the soil. This is accomplished principally through peristaltic contractions of the body and through the action of the cervical ampulla. The cervical ampulla alternately inflates and collapses, while the peristaltic action begins at the back end of the body and passes forward. The result of this activity is a slow burrowing movement upward through the soil. Probably the burrowing process is made easier by the presence of the conical or wedge-like protuberance on the fore part of the head. When the cervical ampulla collapses, the fore part of the body is worked forward, and when the structure is inflated it not only tends to open up a passageway but tends to hold the body and thus keep it from slipping backward. The membrane covering the body of the larva is scaley, and when examined with a microscope, resembles a portion of a shingled roof, with the difference that the shingles are shorter and not so numerous. Undoubtedly the structure of this membrane aids the larva in burrowing through the soil. Usually a series of successive peristaltic actions take place and then a period of rest follows. This is repeated again and again until the head and thorax of the larva are worked out of the soil. With the abdomen still in the ground, the cricket undergoes its first molt.

The path followed by the cricket in burrowing through the soil is not always a straight line, but it may be zigzag or even circular at times. When the larva meets a small stone or other obstruction it usually turns to one side or the other and passes around it. It may, however, burrow downward first, then to one side and then upward, and it may even burrow in a circle. Through the last mentioned method, the cricket, of course, never reaches the surface of the soil, and unless it changes its tactics, it ultimately dies somewhere in its circular burrow.

Vermiform larvae hatching in soil that has become caked on the surface may find it impossible to burrow to the surface of the soil. Should the crust become broken into flakes, some of the larvae may be fortunate enough to burrow up between the cracks of the flakes, and thus reach the surface of the ground. At times, the flakes may slough loose from the underlying soil, and should the burrowing larvae work their way under such flakes, they or the nymphs into which the larvae will transform, may make their way to one side or the other to the open air.

Should a field be plowed, the cricket eggs in the field may be buried to a depth of six inches, more or less. Air pockets may be found in such soil and should any vermiform larvae make their way into any such pockets, the larvae behave as if they reached the surface of the ground, in other words they molt and transform into the first stage nymphs. If the soil is loose above the air pocket, the nymphs may burrow through the soil and reach the surface of the ground, but if the soil is compact the nymphs may be imprisoned in the pocket and die.

Cricket eggs were buried at various depths in gumbo soil to determine how far the vermiform larvae could burrow. For this purpose a series of two quart Mason fruit jars were used. A layer of gumbo soil one inch in depth was placed on the bottom of each jar, and after this soil was shaken down and watered, it was well tamped. Two hundred eggs were placed on the surface of the soil. Varying amounts of gumbo soid were then placed over the eggs, and after this soil was well shaken down, it was watered. As the soil in the jars dried out, water was added to keep the soil damp but not wet. The top of each cover of the fruit jars was cut out and in its place was soldered a piece of fine copper wire screen having 24 mesh per inch. The depth of the soil over the eggs in the different jars measured 1, 2, 3, 4, 5, and 6 inches.

The jars were prepared in late fall as described and stored in an unheated attic over the winter. On May 1 of the following year the jars were transferred to a warm laboratory, where the eggs were permitted to hatch out and the vermiform larvae to burrow through the soil. A record was kept of the number of young crickets that appeared on the surface of the soil in each jar and in addition on July 1 a careful count was made of the unhatched eggs in each jar. Following are the data obtained from this experiment:

Table 1.—Two hundred cricket eggs buried in soil at 1, 2, 3, 4, 5 and 6 inch levels, number of eggs remaining unhatched, and number of nymphs that appeared on the surface of the soil.

At 1 inch level—	84 eggs unhatched—	96 nymphs	reached soil surface.
At 2 inch level—	76 eggs unhatched—	109 nymphs	reached soil surface.
At 3 inch level—	96 eggs unhatched—	77 nymphs	reached soil surface.
At 4 inch level—	85 eggs unhatched—	52 nymphs	reached soil surface.
At 5 inch level—	105 eggs unhatched—	37 nymphs	reached soil surface.
At 6 inch level—	102 eggs unhatched—	22 nymphs	reached soil surface.

Since parasitism of cricket eggs run, at times, as high as 50 per cent or even higher, and since the difference in figures of unhatched eggs at the different levels in our experiment are not large, we must conclude that burial of eggs at different levels indicated in our experiment has no important effect upon the percentage of eggs that will hatch. In general, the deeper the eggs are buried, the smaller will be the percentage of young crickets that are able to burrow through the soil to the open air.

It should be stated that in the experiment described, some of the crickets worked their way through the soil to the sides of the glass jars and then followed the glass upward until they reached the surface of the soil. None of the crickets that hatched at a two inch or deeper level burrowed through the soil in a straight line, or even in an approximate straight line, but, in general, the direction traveled was upward.

Intermediate Molt

After the vermiform larva has worked its way to the surface of the ground it is ready to molt. Sometimes only the head and thorax of the larva are pushed above the ground before the actual process of molting begins, but, at times, the anterior abdominal segments are worked out in addition. Occasionally the entire body is worked out of the ground and then the larva usually falls on its side on the surface of the soil. A period of rest varying from a few seconds to several minutes may now take place. Soon varying movements are begun, chief of which are a peristaltic contraction of the body beginning at the posterior end and passing forward and an inflation followed by a contraction of the cervical ampulla. These movements are repeated again and again with the result that the membrane covering the body becomes loosened.

The thorax now swells, and then after another peristaltic contraction of the body, a rent suddenly occurs in the body covering along the middle of the back and extending from the prothorax to the first abdominal segment. This rent is made so suddenly and the covering is so thin, that the formation of the rent may be overlooked. Through the rent, the back of the thorax is immediately protruded. Peristaltic contractions of the body follow and through these the thorax is pushed up still more. Since the head is held within the membrane as the thorax is arched up, the head is bent upon the body more and more. More peristalitc contractions follow, with the result that the body is arched still more and as a result the membrane covering the head begins to slip off. However, the molting insect attempts to straighten out its body now and then and this action undoubtedly assists in removing the membrane from the head. Through a continuation of the actions described, the thorax is freed from the membrane as is also the abdomen. The legs and antennae are also partly freed in this fashion, but to withdraw the legs and antennae entirely from the skin, the insect sways its body from side to side and bends it forward and backward. The entire process of molting may occupy only a fraction of a minute or it may require ten or more minutes. The membrane, after being shed, usually remains in the opening of the ground through which the insect emerged and appears as a small whitish crumpled skin smaller in size than the head of an ordinary pin.

After the insect has molted, it rests usually for a few seconds, arranges its legs and antennae in a walking position and then walks away. It is now able to run and even jump.

Sometimes a nymph may be unable to rid itself of the skin it is trying to shed. If the skin clings to one leg only, the life of the cricket is not immediately endangered, but if it remains clinging to the head or body, the nymphs do not as a rule survive. The principal cause for the inability of the young cricket to shed its skin properly and entirely is a lack of sufficient relative humidity.

Number of Nymphal Stages

Fifty-one male and fifty-four female crickets were reared from egg to maturity in cage experiments. Since a cricket eats its molted skin, each

insect was marked with a small amount of Sanford's white ink in order that one might be certain when a molt had taken place. Only one cricket was confined to a cage. Approximately 50 per cent of the crickets were reared indoors, while the other 50 per cent were brought to maturity out-of-doors. The crickets were fed tankage and the tips of alfalfa stems bearing leaves, flowers, and occasionally seed pods. The indoor cages consisted of glass cylinders 5½ by 11 inches while the outdoor cages consisted of wooden boxes measuring 6x6x12 inches. The tops of both types of cages were covered with cheese cloth held in place by four rubber bands. In the bottom of each cage was placed about two inches of fine sterilized moist sand. The food was changed daily and the alfalfa was watered twice per day with an atomizer. The rearing work carried on under the conditions described was highly successful. No appreciable difference was noted in the data obtained in the rearing work carried on in the two sets of cages. Table 2 shows the number of nymphal stages that each cricket passed through in our rearing cages.

Table 2.—Number of nymphal stages that each male and female cricket passed through in rearing experiments:

Number of Nymphal stages	8	9	10
Number of male crickets	29	21	1
Number of female crickets	13	41	0

Duration of Nymphal Stages

The duration of the same nymphal instar of a group of male or female crickets varies considerably even though the insects are reared under as nearly the same conditions as possible. The variations ordinarily are one or two days and usually do not exceed four days. The average duration in days of each instar of 20 male and 20 female crickets is shown in Table 3.

Table 3.—Average duration in days of each instar of 20 male and 20 female crickets.

Instars	1	2	3	4	5	6	7	8	9
Average duration in days of instars of male crickets	8.4	8.4	8.2	8.7	8.8	10.8	11.7	11.3	13.7
Average duration in days of instars of female crickets	8.9	8	7.6	8.9	10.4	10.7	12	12.8	15.5

From a study of Table 3 it is apparent that there is no material difference between the average duration of an instar of a male cricket and a corresponding instar of a female. It is also apparent that the average

duration of the first four instars is shorter than the last four instars of both sexes. Crickets of either sex that require seven or eight instars before becoming adult complete their development in a shorter time than do those that pass through nine nymphal stages.

The male cricket which passed through 10 nymphal stages was abnormal, for it required a much longer period of time for it to become adult than any of the other crickets. The rearing experiments indicate that the female crickets have a tendency to pass through one more nymphal stage than do the males.

J. W. Folsom[6], after rearing 131 crickets from egg to adult, concluded that the number of molts which each cricket must undergo before becoming adult is surprisingly large. He found that 102 specimens required 10 molts, 14 required 9 molts, 13 had 11 molts and 2 had 12. Folsom's work was carried on at Tallulah, Louisiana.

Duration of the Total Nymphal Life

Through cage experiments it was determined that newly hatched crickets required from 65 to 102 days to reach the adult stage. Seventy-one out of 105 crickets or 67.6 per cent required from 78 to 90 days to complete this development (Table 4).

Description of a Cricket Immediately After the Intermediate Molt

A cricket that has just completed its intermediate molt has its body considerably elongated and has a coloration peculiar to this stage. Following is a description of such a cricket:

Head and greater portion of pronotum salmon colored; color of head deeper than that of pronotum. Posterior and lateral edges of pronotum yellowish. Posterior end of dorsum of abdomen salmon colored, deepest on last two segments. The remainder of the abdomen and metathorax transparent but with a slight salmon shade. Dorsum of mesothorax light yellow, sometimes tinted with salmon. Legs and palps transparent but with slight salmon tint. Antennae transparent gray except the two basal segments, which are more or less salmon colored. Cerci deep salmon in color except at tips where they are transparent and colorless. Compound eyes dark brown. Ocelli whitish, surrounded by a dark brown salmon colored ring. Hair-like setae on dorsal and lateral sides of thorax and abdomen black.

Membrane connecting the head and prothroax conspicuous and salmon colored. On each side of the median line of the pronotum is a depressed shiny area. The two areas together roughly form a crescent but this is interrupted in the middle. A dark line, narrow in front but broader posteriorly, extends from the anterior end of the prothorax to near the posterior end of the abdomen on the median dorsal side. On each side of this line on abdominal segments 1 to 8 is a more or less depressed oval area.

[6] Folsom, J. W. Insectary Notes on the Field Cricket. Journ. Ec. Ent. Vol. 27, pp 744-745, 1934.

These spots may be partly covered should the anterior edges of these segments be partially overlapped by the segments immediately anterior to them.

Description of Nymph of First Instar

Five or six hours after a cricket has passed through its intermediate molt, the body has shrunk to normal and hardened, and the coloration typical of the first instar has been acquired. This coloration is maintained until the time for molting approaches, but the body form is slightly altered

Table 4.—Days required by newly emerged male and female crickets to become adult.

Male Crickets		Female Crickets	
Days	Number of crickets	Days	Number of crickets
65	1	68	1
68	1	70	1
71	1	71	2
76	1	72	1
77	1	74	1
78	2	76	2
80	3	77	1
81	2	78	2
83	3	79	1
84	5	80	1
85	2	81	3
86	4	82	4
87	5	83	6
88	3	84	5
89	2	85	3
90	2	86	3
91	2	87	2
92	1	88	3
93	2	89	2
94	1	90	3
95	1	91	1
96	2	92	1
97	1	93	2
98	1	96	1
101	1	97	1
102	1	102	1

as soon as food has been consumed, and again when molting time draws near. A description of a typical or average specimen of unfed cricket of the first instar, 12 hours old, follows (Fig. 6).

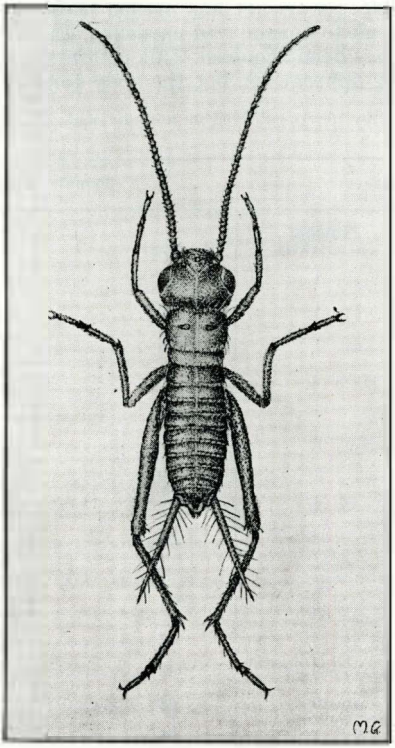


FIG. 6.—Nymph of first instar.

Length of body (excluding antennae and cerci) 3 mm.; width of head 0.8 mm.; with of abdomen 0.75 mm. Head viewed from in front, circular; from the side hemispherical. Color of head shining blackish-brown, of compound eyes dark brown with lighter brown periphery. Ocelli white. Maxillary and labial palps gray. Antennae 3.2 mm. long, with 34 segments, each segment brownish-black except at distal end, where it is grayish-white and not heavily chitinized.

Pronotum slightly narrower than head, brown suffused with black, darkest on anterior margin and yellowish or brownish on posterior border. A series of long black hair-like setae (22 - 26) extending forward from the anterior margin of the pronotum forms a fringe protecting the union between head and thorax. On the posterior border of the pronotum is an-

other fringe of similar setae (10 - 14) but these are directed backward. A pair of distinct, slightly depressed areas on dorsum of pronotum. The two areas together roughly form a crescent, but this is interrupted in the middle. Mesonotum lemon-yellow in color, narrower than pronotum and provided with fringe of long, backwardly pointing, black setae (10 - 14) along posterior margin. Metanotum black with fringe of backwardly pointing setae along posterior margin.

Abdominal terga, 1 to 8 inclusive, brownish-black with fringe of backwardly directed setae along posterior margins. Each of these terga with a large reticulated slightly depressed spot in the anterior lateral areas. Abdominal terga 9 and 10 lighter brown than the preceding eight. The lateral edges of tergum 10 and most of border of epiproct yellowish. A light yellowish line running lengthwise over the median dorsal part of abdomen, thorax and head. On the head, this line bifurcuates, each arm of the fork passing to one of the lateral ocelli.

Two conspicuous cerci 1.25 mm. long attached to tenth abdominal segment. Cerci light brown in color at base, darker toward the middle and gray at the distal end. Cerci sparsely provided with long sensitive yellowish hair, some fully two-fifths as long as cerci. Numerous short hairs clothe the entire length of the cerci and in addition there are present on the base of the cerci many elongated bulbous sensilla.

Thoracic sterna not heavily chitinized and usually colorless, yellow or gray. Nine abdominal sterna visible, grayish or blackish in color and not so heavily chitinized as the abdominal terga. Two fleshy lobes, the periprocts, guard the anus on the sides and beneath. Tergo-pleural membranes of the abdomen often colorless, but usually with tinge of yellow or purple. Abdominal spiracles black; situated in tergal membranes. No external morphological indication of sex.

Coxae and trochanters usually colorless; femora and tibiae black or gray-black; tarsi gray. Length of hind femora 1.5 mm.; of hind tibiae 1.1 mm. A variation of 0.1 mm. above or below these measurements may occur in different specimens.

Appearance of Nymphs Previous to Molting

Two or three days before a cricket is to molt, the body exhibits certain unmistakable signs of the approaching event. The thorax and abdomen begin to elongate and swell, processes which become more intensified as the actual time of molting draws near. The old integument or body covering becomes glossy and a fluid, the molting fluid, makes its appearance between the old covering and a new one that is forming underneath. The result of this activity is that the old integument becomes stretched and lighter in color.

Where Molting Occurs

Molting takes place almost anywhere. We have found crickets molting while clinging to the stems or leaves of low growing plants, or while clinging to the walls of cracks in the ground. We have also found molting crickets in the open on the surface of the ground, and again we have

found such specimens under the protection of hay, boards and other materials.

The Process of Molting

The molting processes, as the crickets pass from one instar to the next, are very much alike and are so similar, except in minor details, to the intermediate molt already described, that it will not be necessary to describe the process again.

Ordinarily a nymph completes the task of molting as soon as a rent has occurred in the integument that is to be shed, but sometimes a nymph may defer shedding the integument for an hour or more after the rent has formed. During this interval of time the nymph may walk, run or jump in an apparently normal fashion.

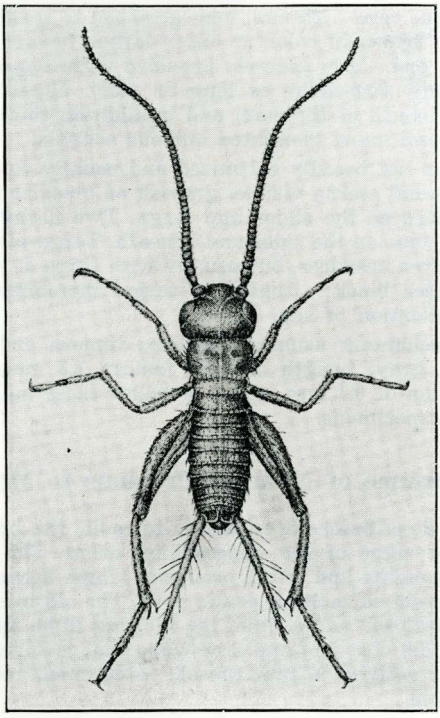


FIG. 7.—Nymph of second instar.

Recently Molted Crickets

Recently molted crickets of all instars can be readily distinguished from all others through their coloration and body form. In the newly

molted specimens, very little if any black color is present, a light chocolate brown being found over areas that later are black. Lighter shades of brown or yellow color such body parts as are a deep brown or yellow in the fully hardened specimens, while salmon color precedes the gray.

The body of a recently molted cricket is considerably longer than it will be later on, and the integument is much softer. Within two hours after molting the insect has become considerably darker and usually within another two it has acquired all of its normal coloration. Its body has now shortened and taken on the normal size and the integument has hardened.

Description of Nymph of Second Instar

Same as first instar except as noted hereafter. Length of body (excluding antennae and cerci) 3.25 to 3.9 mm.; width of head 1 to 1.1 mm.; width of prothroax 0.9 to 1 mm. Color of head, metanotum and abdominal terga shining black or dark brownish-black. Maxillary and labial palps darker than in preceding instar. Compound eyes dark reddish-brown. Antennal segments shiny black except at their distal ends where they are unchitinized and grayish-white. Antennae 4.5 to 5.5 mm. long and composed of 46 to 50 segments.

Pronotum darker brown than in first instar and with variable amount of black pigment, the black being more abundant on the anterior half. The posterior border of pronotum sometimes yellowish. Mesonotum yellow throughout or yellow only along posterior border and brownish over the remainder.

Sterna of thorax yellowish or dirty yellowish-brown. Sterna of abdomen gray or blackish or blackish mottled with black and gray or black and green. Coxae and trochanters yellowish or brownish or greenish-yellow; femora and tibiae black or brownish-black; tarsi gray. The oval depressions on abdominal terga only faintly indicated. Cerci 1.5 to 2 mm. long, darker than in first instar. Length of hind femora 1.8 to 1.9 mm.; of hind tibiae 1.3 to 1.4 mm. No external evidence of sex (Fig. 7)

Description of Nymph of Third Instar

Same as nymph of second instar except as noted hereafter.

Length of body (excluding antennae and cerci, 4.2 to 5 mm.; width of head 1.25 to 1.4 mm., width of prothorax 1.1 to 1.25 mm.; width of abdomen 1.25 to 1.4 mm.

Pronotum darker than in second instar with a variable amount of brown in different specimens. Color of the mesonotum variable, but predominately yellow or brown suffused with black. The line running over the median dorsal part of the body brown to yellow and conspicuous chiefly on the thorax. Abdominal sterna brownish to blackish; of thorax dirty-gray, brown or yellow. Palps black except at distal end where they are reddish brown or rose color. Coxae and trochanters dirty-gray; femora and tibiae brownish-black or black; tarsi grayish-brown or black. Cerci variable in color, usually reddish-brown over proximal half, suffused with black over distal half and lighter at extreme tip. The long sensitive hair-like setae on cerci yellow, brown or brownish-black.

Antennae 6 to 7.75 mm. long and composed of 57 to 66 segments. The length of the antennae and the number of antennal segments vary with different individuals, and even in the same specimen there are marked differences between the right and left antenna. Some of these differences, but not all, may be due to the fact that some crickets through accident lost a portion of the distal end of one or both antennae.

Hind femora 2.2 to 2.6 mm. long; hind tibiae 1.7 to 2 mm. long; cerci 2 to 2.5 mm. in length (Fig. 8).

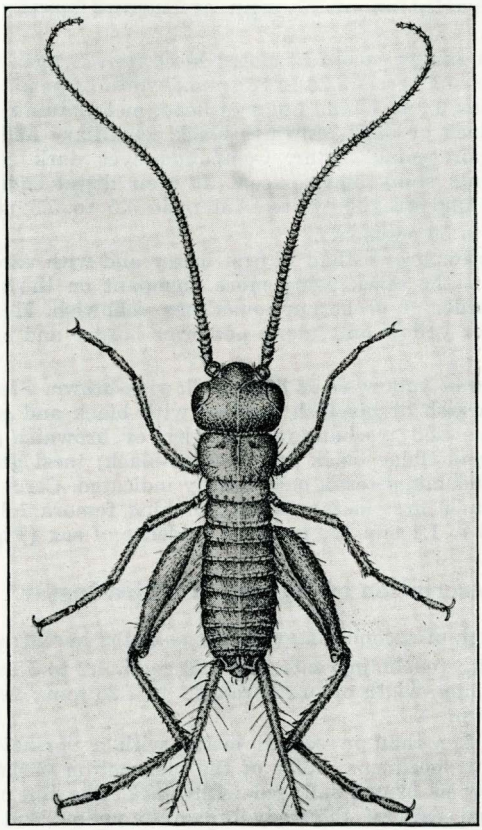


FIG. 8.—Nymph of third instar.

A distinction between the sexes may or may not be apparent. In some female nymphs a pair of small widely separated appendages are attached to the posterior edge of the eighth abdominal sternum, while to the following sternum are attached two pairs of such appendages. The appendages

are known as valvulae. The appendages vary considerably in size, for they may be barely perceptible knobs or they may be elongated and fairly conspicuous (Fig. 9, A). The distance between the members of each pair of valvulae is also quite variable. The appendages discussed are the structures which later develop into the blades of the ovipositor.

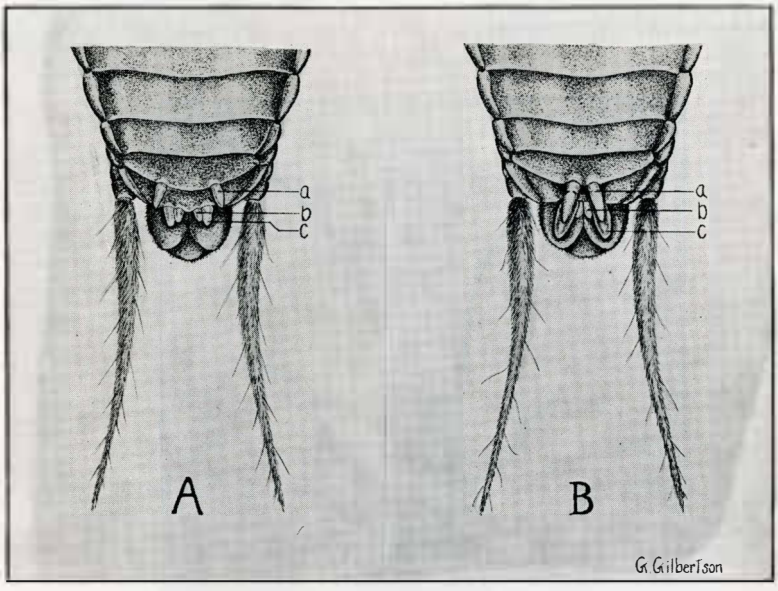


FIG. 9.—Posterior end of abdomen of two cricket nymphs showing early stages in the development of the ovipositor. A, nymph in third instar; B, nymph in fourth instar. a, valvulae attached to posterior edge of eighth sternite; b, c, valvulae attached to posterior edge of ninth sternite.

Description of Nymph of Fourth Instar

Same as third instar except as noted hereafter. Length of body (excluding antennae and cerci) 5 to 6 mm.; width of head 1.6 to 1.7 mm.; width of prothorax 1.4 to 1.5 mm. Antennae black; maxillary and labial palps black except at distal end where they are reddish-brown. Pronotum usually black; in some crickets, brown on sides and sometimes along posterior border. Mesonotum variable in coloration, in some specimens entirely black, in others black suffused with dark brown, in others yellow suffused with a variable amount of brown or black. Frequently a row of black dots borders the posterior edge of the mesonotum. Metanotum and abdominal terga usually black, occasionally brownish-black. Sterna of thorax dirty-gray, brown or yellow; of abdomen black or brownish-black. Coxae and trochanters colored like thoracic sterna. Femora black except on prox-

imal inner surface where they are usually brown; tarsi black or greyish. Cerci usually a trifle darker than in third instar and measuring 2.8 to 3 mm. in length. Length of antennae 8.2 to 10.5 mm.; number of antennal segments 79 to 86 (Fig. 10).

The rudimentary ovipositor may make its appearance for the first time with crickets either in the third or fourth instar. If in the third, then the valvulae have increased considerably in size in the fourth (Fig. 8, B), but if in the fourth, then the structures may be minute protuberances as described in the preceding instar.

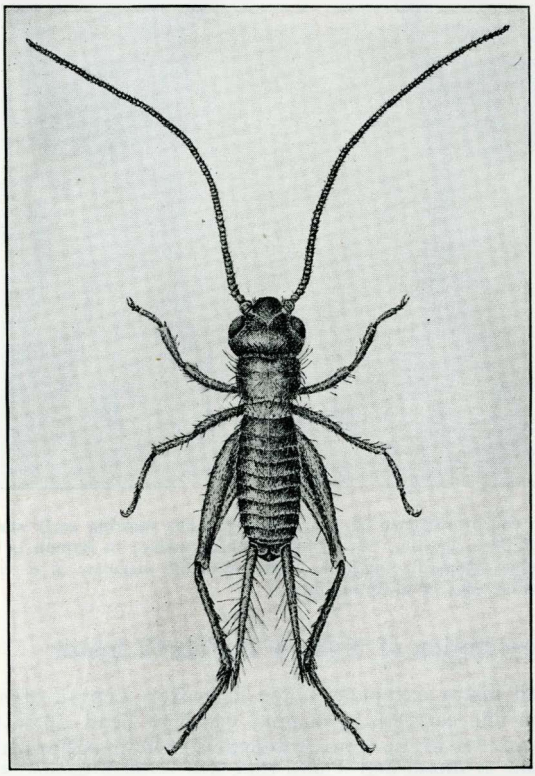


FIG. 10.—Nymph of fourth instar.

Description of Nymph of Fifth Instar

Same as fourth instar except as noted hereafter. Coloration in general darker than in preceding instar. Length of body (excluding antennae and cerci) 7 to 8 mm.; width of head 1.95 to 2.3 mm.; length of antennae 11 to 13.5 mm.; number of antennal segments 101 to 124; length of hind

femora 2.5 to 3 mm.; length of hind tibiae 3.8 to 4.5 mm.; length of cerci 4 to 4.25 mm. Ovipositor longer than in preceding instar but measuring about 0.5 mm. in length. The valves now usually held closer together and directed straight backward but not always so. The inner pair of valves attached to the ninth segment small and covered by valves of eighth segment (Fig. 11).

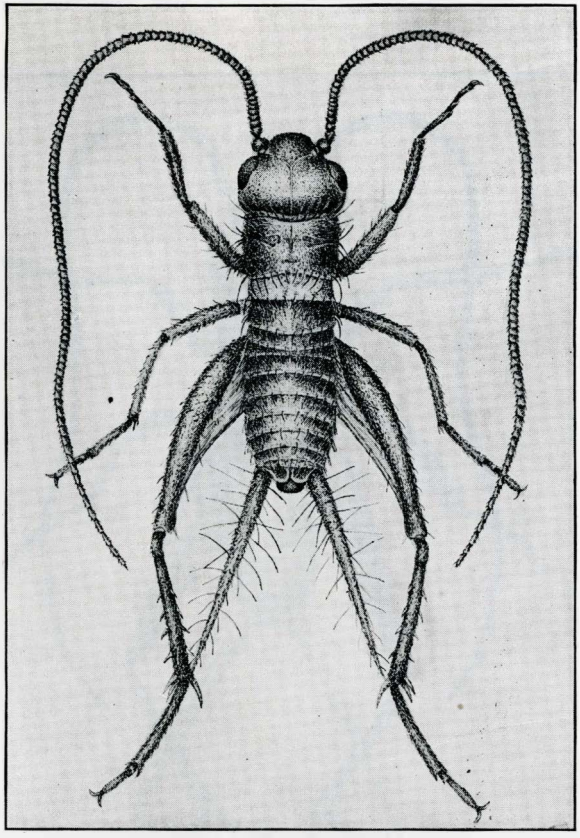


FIG. 11.—Nymph of fifth instar.

Description of Cricket in Sixth Instar

In general, a cricket in the sixth instar is similar except for size to one in the fifth. There is considerable variation in coloration in this instar, some specimens being black with a large portion of the body and append-

ages brown, while other individuals are almost totally black. The head black, although in some specimens the lateral sides are brown. The inner basal surface of the hind femora varying shades of brown, the remainder of the hind femora usually black, although occasionally some shade of brown. The middle and front femora usually black although frequently colored at least in part with brown. On the body, if brown pigment is present, it is most frequently found on the mesonotum, but even here it is usually mottled with black. The metanotum and the abdominal terga and occasionally the pronotum may also be colored more or less with brown pigment, the

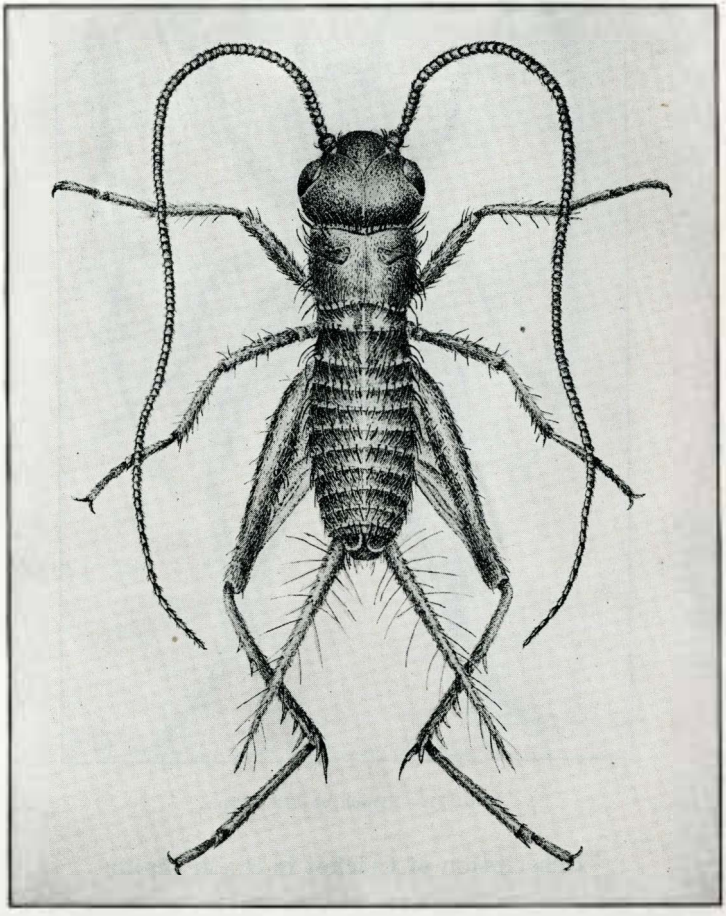


FIG. 12.—Nymph of sixth instar.

prothorax and the metathorax usually having the pigment on their posterior lateral surfaces, while the abdominal terga have the brown on their anterior lateral surfaces. The cerci are darker than in the preceding instar. Ventral surface of thorax black, brown or gray, of abdomen usually black. (Fig. 12.)

Length of body (excluding antennae and cerci) 7.3 to 8.5 mm.; width of head 2.2 to 2.5 mm. Length of antennae 14 to 16 mm., number of antennal segments 120 to 149, averaging 132. Length of cerci 4.5 to 5.5 mm. Length of hind femora 4 to 5.5 mm.; length of hind tibiae 3.25 to 4 mm. Ovipositor

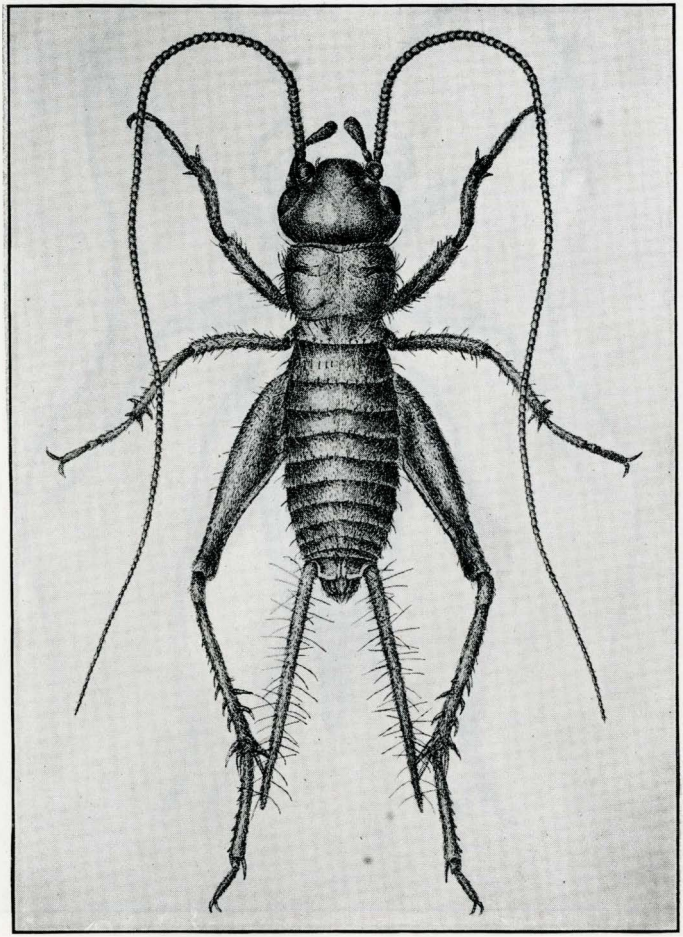


FIG. 13.—Male Nymph of seventh instar.

longer than in preceding instar, measuring 0.5 to 1mm. and usually extending to tip of abdomen. The upper and outer lower valves long, equal in length, and covering the smaller inner pair. In approximately 40 per cent of the nymphs, minute lateral wing pads are present. The anterior pair of wing pads are entirely or almost entirely covered by the pronotum, the posterior pair are fully exposed but visible only from the side.

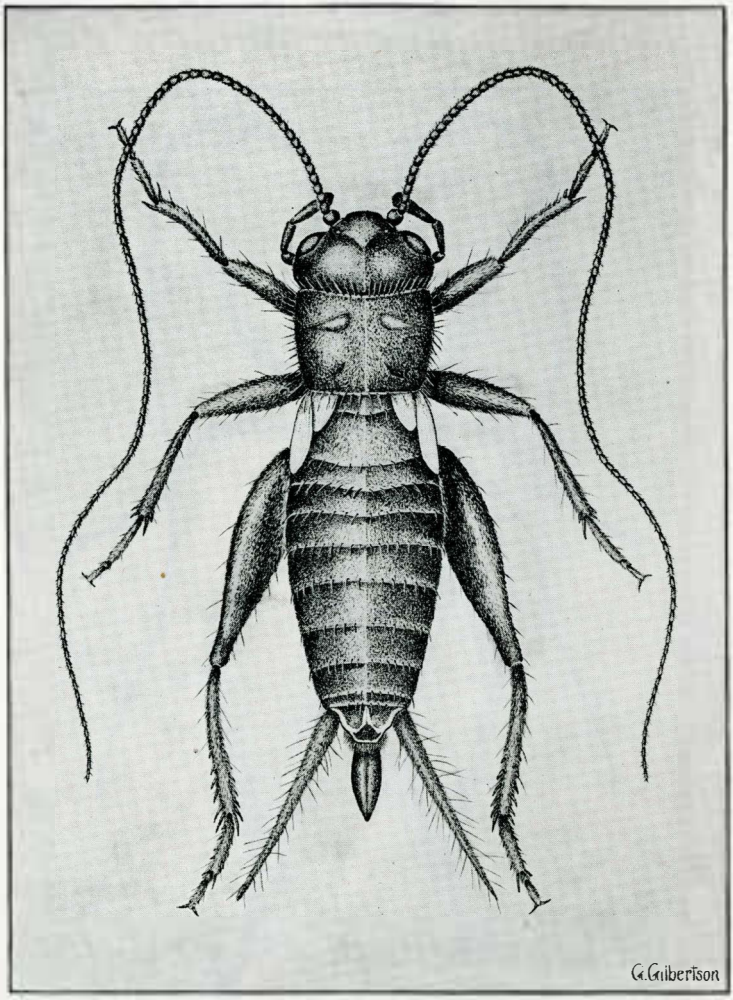


FIG. 14.—Female Nymph of eighth instar.

Description of Nymph of Seventh Instar

Coloration like that of preceding instar except usually darker. In approximately 60 per cent of the nymphs, minute wing pads are present, similar in size and position to those already described for those nymphs possessing wing pads in the sixth instar. In 40 per cent of the nymphs in the seventh instar, larger wing pads are present. These are visible from above and are designated dorsal wing pads by us. The position of these wing pads is now reversed, the metathoracic pads being outside of and partially covering the mesothoracic pads.

Lenth of body (excluding antennae, cerci and ovipositor) 9 to 12 mm.; width of head 2.8 to 3.75 mm. Length of antennae 17 to 22.5 mm.; number of antennal segements 150 to 181. Length of cerci 5 to 6.75 mm. Length of hind femora 6 to 7.75 mm.; length of hind tibiae 4 to 5 mm. Length of dorsal mesothoracic wing pads 1.3 to 2 mm.; of metathoracic wing pads 1.5 to 2 mm. Length of ovipositor 1 to 2.3 mm. (Fig. 13).

Description of Nympth of Eighth Instar

Coloration like that of preceding instar except usually darker. Some specimens almost entirely black, others marked with varying amounts of brown. Ovipositor brownish or black. Cerci much darker at distal end than at base.

Length of body (excluding antennae, cerci and ovipositor) 12 to 18 mm. Width of head 3.5 to 4.2 mm. Length of antennae 20 to 30 mm.; number of antennal segments 143 to 200. As the number of molts increased, it became increasingly more difficult to find specimens that had not suffered a loss of a portion of one or both antennae. Length of cerci 6 to 8 mm. Length of hind femora 7 to 8 mm.; length of hind tibiae 5 to 6.5 mm. Dorsal wing pads present. Forty per cent of the crickets with wing pads measuring 1.3 to 2 mm. in length; 60 per cent with wing pads measuring 2.5 to 4 mm. The group of crickets with the larger wing pads will become adult crickets after another molt. Length of ovipositor 3 to 5.5 mm. (Fig. 14).

Description of Nympth of Ninth Instar

Approximately 40 per cent of the crickets are adult in the ninth instar, while 60 per cent are in the last nymphal instar. Coloration like that of preceding instar except somewhat darker. Length of body (excluding antennae, cerci and ovipositor) 13.5 to 20.5 mm. Width of head 4 to 6.5 mm. Length of antennae 27 to 38 mm.; number of antennal segments 179 to 222 segments. Length of cerci 7 to 11.5 mm. Length of hind femora 7 to 13 mm.; length of hind tibiae 6 to 10 mm. Wing pads, both fore and hind, each measuring 2.5 to 4.5 mm. in length. Length of ovipositor 6 to 7.5 mm. (Fig. 15).

Description of Adult Cricket

Approximately 40 per cent of the crickets that we reared became adult after passing through eight nymphal instars, while practically the remainder or 60 per cent became adult only after passing through an ad-

ditional instar. Those crickets that required the additional instar did not differ greatly from those that required one instar less. In general, the former crickets were slightly larger on an average than were the latter, although both groups were somewhat smaller on an average than are those

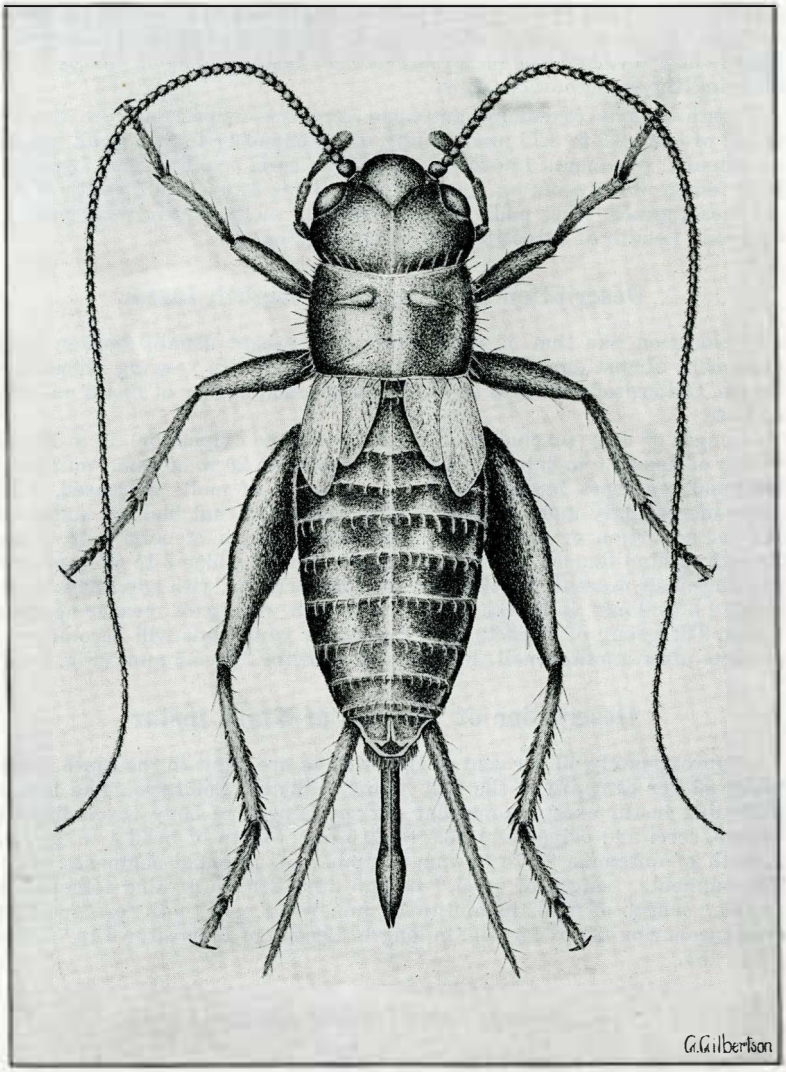


FIG. 15.—Nymph of ninth instar.

crickets that reach their adult state in the open under normal field conditions.

The measurements of 105 crickets that were reared to maturity under control conditions were taken three to five hours after they had become adult. The ovaries of the females were developing eggs at this time, but the eggs were still small and immature, with the consequence that the ab-

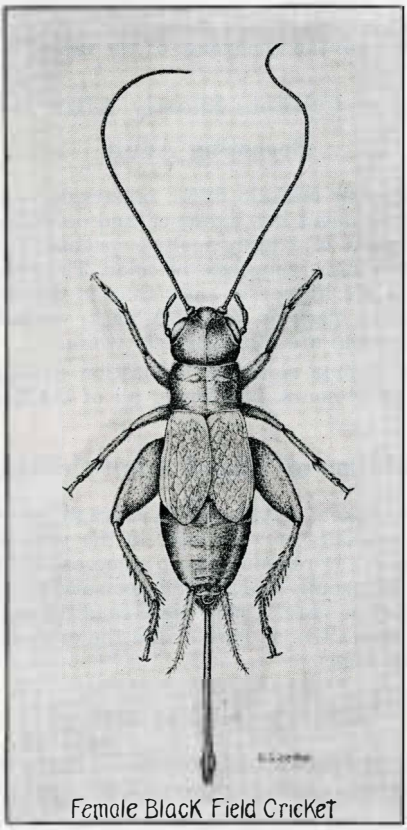


FIG. 16.—Adult female cricket.

domen of these crickets was neither swollen nor elongated. Body measurements of these crickets gave us the following data: length of body (excluding antennae, cerci and ovipositor) 15 to 26 mm. Width of head 4.8 to 7.5 mm. Length of antennae 25 to 40 mm.; number of antennal segments 178 to 250 segments. Length of cerci 7 to 12 mm. Length of hind femora 8 to 14 mm.; length of hind tibiae 7 to 11 mm. Tegmina 7.5 to 13 mm.

in length. Second pair of wings usually not well developed and measuring 5 to 8 mm. in length; when well developed, extending beyond tip of abdomen and measuring 15 to 27 mm. in length. Length of ovipositor 14 to 22 mm. An excellent drawing of a male cricket as seen from above may be found depicted on the cover of this bulletin, while Figure 16 shows a female cricket as seen from above.

For an excellent description of the adult crickets the reader is referred to the following work by Rehn and Hebard: "The Genus *Gryllus* (Orthoptera) as Found in America."[7] In this work not only is a scientific description given of the species, but the many variations in body structure are discussed and in addition the synonomy of the insect is published.

Description of Crickets Shortly After Molting and Becoming Adult

Recently molted adult crickets differ remarkably in appearance from specimens whose integument has hardened and developed the normal coloration. The integument of freshly molted specimens is soft and on the whole is more or less light chocolate in color. The head, legs, antennae, palps and ovipositor are lighter in color than is the thorax or abdomen, the compound eyes are black or brownish-black, while the wings are decidedly whitish. The ocelli are conspicuously white.

As the crickets become older the coloration gradually darkens, and after the lapse of three hours, practically all of the adult coloration has been acquired.

Duration of Life of Adult Crickets

In general, male crickets mature, on an average, somewhat earlier than do females, but the females survive later in the year than do the males. In our outdoor cages, we were able to keep an occasional adult cricket alive for 65 to 70 days, but usually they would not survive more than 50 to 60 days despite the best of care. Under field conditions, the average adult cricket probably does not live as long as did the crickets which were kept in confinement in our cages.

Mating and Egg-laying

It is necessary that crickets mate and that sperms be transferred into the body of the female in order that she may lay fertile eggs. The sperms are transferred from male to female by means of spermatophores. Each spermatophore consists of a spermatophore sac, a long fine duct leading off from the sac and a peculiarly shaped plate possessing a number of hooks. The plate has the function of fastening the spermatophore sac and duct in place. The sac contains the sperms, while the duct leads from the sac and is directed into the body of the female to an organ called the spermatheca, where the sperms are stored. The duct is hollow and through

[7] Rehn, James A. G., and Hebard, Morgan. The Genus *Gryllus* (Orthoptera) as Found in America. Proc. Acad. Nat. Sci. of Phil., pp. 293-322. 1915.

the duct the sperms make their way out of the spermatophore sac into the spermatheca.

A female cricket that has recently been mated can be readily distinguished from unmated specimens through the presence of the spermatophore sac, a small pear-shaped body fastened to the under surface of the abdomen immediately beneath the ovipositor (Fig. 17). The length of time that a female cricket will carry about a spermatophore sac varies.

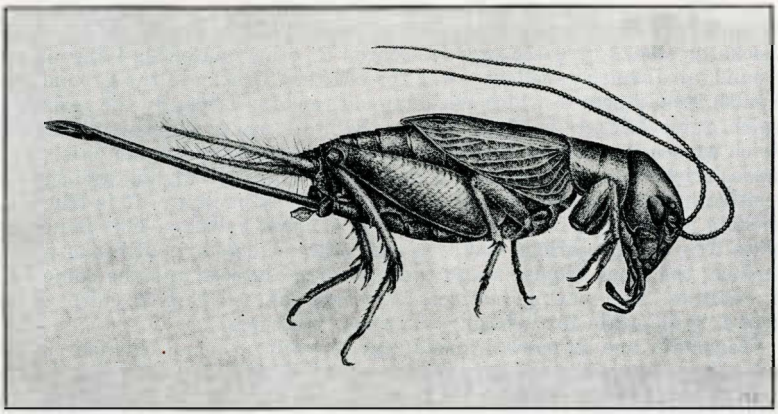


FIG. 17.—Female cricket viewed from the side and showing the spermatophore sac fastened to the under surface of the abdomen immediately beneath the ovipositor.

Sometimes the same sac may be retained attached to the abdomen for 24 hours or longer, and at the other extreme the sac may be retained for only ten minutes. Ordinarily the sac is removed within one-half hour. When the sac is to be removed, the female cricket bends the abdomen downward and forward and her head downward and backward between the legs, and then the sac is seized between the jaws, removed from the abdomen and devoured.

Unmated crickets as a general rule lay eggs, though occasionally a specimen does not. Such unmated specimens as do lay eggs may lay fully as many as do crickets that are permitted to mate once or twice or as many times as they desire. Apparently the fertilizing fluid of the male is not needed to stimulate egg production. In no instance in our experience have the infertile eggs developed and given rise to young crickets.

A cricket may mate within 12 hours after it becomes adult, but usually one to four days elapse before the first mating takes place. The largest number of matings per day by any pair of crickets observed by us was eight and the largest number during the life time of any pair of crickets was 138. Undoubtedly these numbers do not represent the total in either case, for we kept the crickets under observation only from 7 a. m. until 7 p.m. daily. Crickets must mate several times during their egg-laying period, otherwise an exceptionally large number of infertile eggs are pro-

duced. Ten caged female crickets were permitted to mate but once, and this occurred from one to four hours immediately after the crickets became adult. The eggs laid in each instance were all infertile, or if some were fertile, then only a small number were, and these were laid early in the life of the cricket.

Behavior of Crickets

Habitats Preferred

Crickets unless actually feeding, foraging, mating or egg-laying, prefer to remain in or under some sort of shelter. Cut hay, alfalfa, or weeds, shocks or stacks of grain or hay, boards or other materials lying on the ground, all furnish excellent cover for crickets. Cracks in the ground also furnish ideal places in which crickets may remain. Evidently the responses which guide crickets to their favored habitats are a negative phototaxis which causes the cricket to seek dark areas, a positive thigmotaxis which causes crickets to seek contact of their body with surrounding areas and a positive hydrotaxis which causes crickets to seek moisture. It is true that crickets are usually found in numbers in favored habitats. This is not because they are gregarious and seek each others company, but because they perform the same tropisms and these lead the insects into the same sort of habitats. The mating instinct, including the sex call or chirp, is, of course, responsible for bringing the sexes together.

Frequently one or more crickets may excavate a small chamber in the soil and remain in it during the inactive part of their day. At times a male and female may occupy such an excavation, but often the individuals are of the same sex. Then again, more than a pair of crickets may be found in the excavated chamber. If a pair of crickets is found in a chamber, it does not mean that the pair is mated for life, but it means that the crickets are occupying the same area only temporarily and during this time matings may or may not take place.

The chambers which the crickets excavate are usually small. Ordinarily they are just large enough to accomodate one insect, but sometimes they are several inches long and wide, and then several crickets may be found in the cell. These chambers are sometimes constructed under a cake of hardened soil, but they may be found around the crowns of plants, under clods of soil, under plant remains, etc.

The cracks in soil occupied by crickets may or may not be improved by the work of crickets. Should a rain close up a crack, the imprisoned crickets may open up the crack again; or, if loose soil is blown into the crack partially blocking the passageways, then the crickets may remove the soil particles and open up the passages. At times, neighboring cracks may be joined by a tunnel constructed by one or more crickets.

The immature crickets are no more gregarious than are the adults. In fact, what was written concerning the adults, applies equally well to the nymphs, except, of course, that the mating instinct is not developed in the young crickets.

Activity of Crickets at Different Times of the Day

During the greater part of hot sunshiny days, both immature and adult crickets ordinarily seek dark protected places in which to hide. Occasion-

ally a few crickets may be found exposing themselves to the hot sunshine, by running over the ground or by clinging or climbing up or down or over plants, but this is not the usual performance, and is done for only a short period by any one cricket. As soon as the heat of the day begins to wane, more and more of the crickets expose themselves. By 4 and 5 o'clock the exposed crickets are fairly numerous, and by this time, of course, the light is not so intense nor is the temperature so high. However it is after sundown, that crickets become most numerous over the surface of the ground or on plants. Many crickets will still be out on the ground or on plants in the morning as late as eight or nine o'clock and then they rapidly disappear as the sunshine becomes more intense and the temperature rises.

On cool days, even though the sun shines brightly there will be more crickets active on the surface of the ground than on hot sunshiny days. The same is true for cloudly days as compared with days that are not cloudy. In the fall of the year, as the days become cooler, more and more crickets may be on the surface of the ground or on plants during the daytime.

While the crickets are above ground, they are usually quite active. They may wander about on the ground, they may forage, feed, carry on courtship, mate, lay eggs etc.

Behavior of Crickets When Approached

Crickets ordinarily walk or run when undisturbed in the field, but when approached they may supplement these methods of progression with that of jumping. When one follows a cricket, it may jump several times in succession and then it attempts to crawl into a tuft of grass or among the stems or leaves of plants, under boards or clods of soil, under rocks, hay or other materials, into cracks etc. When they have reached a favorable place they remain quiet for some time.

Should a person approach a hay stack in an alfalfa field where there are large numbers of crickets around the stack, the crickets make their way hurriedly to the stack and crawl into it. Some will jump, others will run and still others will alternately jump and run. The crickets will nearly all head for the stack even though the person walks between the main body of the crickets and the stack. One must conclude that the crickets are able to see the stack from a distance of 15 feet at least and that the stack offers a more attractive refuge than do the individual alfalfa plants growing in the vicinity.

Time of Feeding

On warm sunhiny days crickets that are above ground feed principally from 4 p. m. through the night and until 8 or 9 a. m. From 8 or 9 a. m. until 4 p. m. they show little feeding activity. On cloudy warm days or on cool days feeding may take place above ground throughout the day. These facts should be taken into consideration when poisoning operations of crickets are conducted.

Behavior of Crickets During Rain or Irrigation

Crickets that are on the surface of the ground may seek shelter during a rain among the stems or leaves of plants or under the materials lying on

the ground. Should the rain continue, the crickets may be forced to climb and cling to the plants or other objects. If the crickets are in cracks in the soil, the insects may be driven out of the cracks by the rain, and then they either seek shelter among the stems or leaves of plants or other objects, or they climb such objects and then remain clinging to them. Should a rain be abundant enough to wash soil into the cracks and close them up at the surface of the ground but not below, the crickets may not be driven out of the cracks, but they may remain in the cracks until they open up again by drying, or the crickets may burrow through the barriers and thus gain the surface of the ground. Should a very severe downpour of rain occur, many crickets may be trapped and destroyed in the water or mud of the cracks. If a field is being irrigated, the crickets react to the irrigating water as they do to rain, and surprisingly few crickets are destroyed.

Behavior of Crickets While Feeding

When two or more crickets attempt to feed upon the same food, they may pay no attention to one another, or they may threaten to bite or they may actually bite each other. When a male or female cricket approaches a feeding male, the latter may elevate his wing covers at an angle of 60 degrees, and at the same time he may elevate his abdomen slightly. The feeding male may chirp and then dart towards the offending male or female and even attempt to bite. Usually, however, a wound is not inflicted, for the approaching male or female backs away before any harm is done. Should a female specimen be feeding, and be approached, she may dart towards the approaching male or female cricket and threaten to bite, but she does not elevate her wings, and of course, cannot chirp. Ordinarily the cricket that has been driven away may move away only a short distance and later again approach the feeding cricket, but now does so more slowly. Often the approaching cricket is tolerated and permitted to feed undisturbed. In this manner groups of crickets often gather about the same particle of food and feed in harmony.

Apparently a diet of alfalfa alone is not sufficient to satisfy the dietary requirements of crickets. In our rearing work, whenever more than one cricket was enclosed in a receptacle, cannibalism took place if we fed the crickets on a plant diet alone, such as flowers, leaves and stems of alfalfa, but if the plant diet was supplemented with a small amount of bone meal or meat meal, all cannibalistic tendencies disappeared.

How Crickets May Be Forced Out of Cracks

Crickets that have sought shelter in cracks may be forced out of the cracks by dropping finely pulverized soil or dust into them or by running water into them. Whenever soil is irrigated, and if such soil is cracked at the time of irrigation, the crickets in the cracks are forced to come to the surface of the ground. This is an important fact to remember whenever crickets are to be poisoned on land than may be irrigated.

Natural Enemies

The common black field cricket has a number of important parasitic and predaceous enemies, but in spite of these, the crickets maintain their

numbers fairly well. Usually the crickets are abundant in the same areas year after year despite the presence of their enemies. The most important parasitic and predaceous enemies of this pest are the following:

Ceratotelia marlatti Ashmead, an hymenopterous parasite of the eggs.

Paridris brevipennis Fouts, an hymenopterous parasite of the eggs.

Exoristoides johnsoni Coq, a tachinid parasite of the nymph and adult crickets.

Cephalobium microbivorum Cobb, a nema parasite of the intestine of the nymph and adult cricket.

Paragordius varius (Leidy), a tread or hairworm parasite of the nymphs or adults.

Gregarina oviceps Diesing, a protozoan parasite in the food tube of nymphs and adults.

Euthrombidium (sp?) a mite parasite externally upon the adults.

Chlorion cyanium Dahlborn, a predaceous wasp which uses the nymphs and adults as food for its offspring.

Spiders (several species) which catch and feed upon crickets that are principally in the nymph stage. More nymphs in earlier instars are caught and used as food by spiders than are nymphs in the later instars.

Birds of many species feed upon the immature stages of the field crickets, but adult crickets may also be taken. The adults, however, are not taken in as large numbers as are the nymphs except late in the year. Nearly all birds that feed upon the surface of the ground will feed upon crickets. In passing it may be of interest to know that crows and ring-necked pheasants eat considerable numbers of crickets.

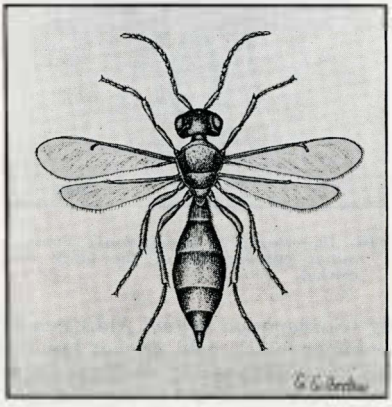


FIG. 18.—*Ceratoteleia marlatti* Ashmead, an important egg parasite of the black field cricket.

Chicken and turkeys also consume quite a large number of crickets.

Many species of snakes, lizards, toads, frogs, gophers and other mammals feed to some extent upon crickets but their importance as a control factor is not great.

Of the two egg parasites listed, *Ceratoteleia marlatti* Ashmead (Fig. 18) is the more important. From 20 to 50 per cent of the cricket eggs are destroyed each year through this parasite alone. *Paridris brevipennis* Fouts is also an egg-parasite of the black field cricket but ordinarily it parasitizes only from one to five per cent of the cricket eggs yearly. Only one specimen of either *Ceratoteleia* or *Paridris* can be reared from a single cricket egg. Adult specimens of *Paridris* were reared from cricket eggs only during the month of June, but adult *Ceratoteleia* were obtained during May, June, July, August, and September, with August furnishing us with the largest number of specimens. Under field conditions where crickets are abundant, one frequently finds speciments of *Ceratoteleia* running over the surface of the ground. It is not unusual to find five specimens of this parasite in a space six inches square during August and September.

Only one species of tachinid parasite was reared from the nymph and adult crickets. This fly, *Euxoristoides johnsoni* Coq was encountered rarely, however, and must be regared as negligible from a control standpoint.

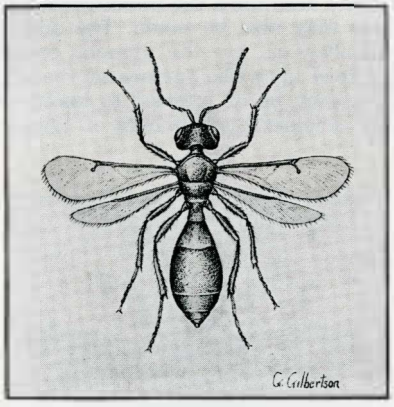


FIG. 19.—*Paridris brevipennis* Fouts, a minor egg-parasite of the black field cricket.

A sarcophagid fly (*Sarcophaga kelleyi* Ald.) is a slightly more important enemy of the common black field cricket but in no instance did we ever find it attacking this cricket in any such number as it frequently does our grasshoppers.

At least two species of mites were found to parasitize our crickets. These were found to attack the later nymphal stages and the adult crickets. Usually the mites were found attached to the body under the wings or wing pads. The economic importance of these mites cannot be very great, for frequently as many as 20 mites were found attached to the body of a cricket and yet this cricket was apparently as vigorous as uninfested specimens.

Hairworms were found quite commonly in the body cavity of crickets.

From one to five worms were taken from single specimens of crickets, and while the worms may kill the crickets which they infest, or at least destroy the reproductive organs, they cannot be regarded as an important control agency, because of lack of abundance.

Cephalobium microbivorum Cobb, a small nema parasite in the intestine of crickets was found in 29 out of 159 adult crickets examined. Each infested cricket contained from one to fifty nemas, although usually only one or two nemas were found in a cricket. Infested crickets were collected from alfalfa fields, grain fields, grasslands, groves and from beneath boards in barnyards. All our infested specimens were taken from Eastern South Dakota. Fully a third of the crickets examined for the presence of nemas were taken from Western South Dakota, but strange to say, none of these were infested with nemas. Sixteen specimens out of 65 that were reared in captivity at Brookings, were infested with the nemas. These specimens were reared in cylindrical glass containers measuring 10 inches high and five or six inches in diameter. About two inches of fine moist sand was kept in each jar and usually one, or at the most two, crickets were reared in each jar. Alfalfa leaves, stems and flowers and bone or meat meal was fed the crickets. The old food was removed daily and a new supply was added. Crickets, whose intestines contain one or a few nema parasites of the species under discussion are apparently as healthy and vigorous as are uninfested crickets. In fact, it is believed that the nemas if present in small numbers may be even beneficial to the cricket, because they appear to feed on the microbe fauna of the cricket's intestine.

Gregarina oviceps Diesing is a very common protozoan parasite in the food tube of both nymphal and adult crickets. Of 159 crickets examined for the presence of this parasite, 101 were infested. The severity of infestation ranged from one parasite to more than 200 per cricket. Numerous cysts were also present in many crickets. The effect of the parasites upon the crickets is very difficult to determine through general observations. Undoubtedly mild infestations have little effect upon the health and vigor of the crickets, but heavy infestations, although they do not kill the crickets outright, undoubtedly have a deleterious effect.

Cblorion cyanium Dahlborn is a species of wasp, the females of which use the older nymphs and adult crickets as food for their offspring. The wasps, however, occur in such small numbers that they may be looked upon as a negligible control factor of crickets.

Spiders of many species have been observed feeding upon crickets. In most cases, the crickets caught were specimens that were in the first or second instar, but occasionally even adult crickets were used as food. Spiders that were found most often feeding upon crickets were the wandering species, or those that run about in search of their prey and pounce upon it when they find it. Species of wolf spiders (Lycosidae), species of the jumping spiders (Attidae) and an occasional crab spider (Thomisidae) were found to feed upon crickets. An occasional ambush spider (Thomisidae) was also found feeding upon crickets. These spiders lie in ambush in the heads of flowers and capture insects as they come to the flowers to feed. While there are many species of spiders that may feed upon crickets, still spiders do not serve as an important check to cricket propagation and increase.

Just how important non-domesticated birds may become in the control

of crickets in an area or on a particular farm, we have no way of estimating. It is a fact, however, that we may have an abundance of crickets year after year in the same locality despite the presence and activities of birds, or for that matter, despite all the parasitic and predacious animals that feed upon crickets and their eggs.

When chickens and turkeys are given the run of a field where crickets are abundant but where the poultry cannot do any damage, they certainly feed upon crickets. In a field of a few acres this influence may be considerable, but in a large field, the controlling effect is usually negligible.

Control

Crickets may be brought and kept under control by destroying the eggs or by destroying the young and adult crickets, or by using both procedures which are employed to destroy the eggs and the young and adult crickets. In areas where crickets are very numerous and where they do considerable damage year after year, it would be well to destroy as many eggs as possible, and later, after the eggs have hatched, to destroy the young as well as adult crickets.

Destruction of Eggs

Exposure of cricket eggs to the drying effect of air, sun and wind, destroys the eggs. On a hot, windy day an exposure of the eggs lying upon the ground will cause the eggs gradually to lose their moisture. In three to five hours, such eggs will be so dry that they may be powdered by rubbing them between thumb and fingers. Eggs that have become as dry as this are dead, and regardless of weather conditions, will not absorb water and hatch. During cooler weather and when the soil is moist, the eggs either do not dry out or they dry out very slowly. Cricket eggs may lose considerable moisture without dying, and later may take up moisture again.

Since cricket eggs are not laid deeper than an inch beneath the surface of the ground, and since they are laid singly and not in pods, and therefore are not protected by any large amount of secretion, any practice that will disturb the soil to a depth of an inch or slightly more, so as to bring the eggs to the surface of the ground and expose them, will subject the eggs to the danger of drying out. Whatever treatment is given the ground containing the cricket eggs, it should take place late in the fall after the majority of the adult crickets have died, and again early in the spring, if possible and practicable, before the eggs have hatched. In alfalfa fields a large number of eggs may be exposed to the elements if a spring tooth harrow is run over the field, first lengthwise and then crosswise a few days later. The edges of such fields as well as the sides and tops of irrigation ditches should also be gone over. Whenever grain fields and gardens become overrun with crickets, these too, should be worked.

Plowing may also be quite effective in holding crickets in check. The effectiveness of plowing will depend, however, upon the type of soil that contains the eggs, the depth to which the eggs are turned under, and the degree of packing that the soil undergoes before the eggs hatch in the spring. Sandy soil is more readily penetrated by the newly hatched

burrowing vermiform larvae than is soil that is not sandy, and consequently, plowing under cricket eggs in sandy soil will be less effective than if the soil were not sandy. The deeper the eggs are buried through plowing the more effective will be the control. Few nymphs in the vermiform stage are unable to burrow through two inches of firmly packed, damp gumbo soil, but the opposite is true of eggs buried underneath five to six inches of such soil. Loose soil is much more easily penetrated by the recently hatched young crickets than is firmly packed soil. However, cavities in soil frequently trap the burrowing vermiform larvae where they shed their membrane that enswathes them, and where they sometimes die because they make no further attempt to reach the surface of the ground or because they are unable to burrow further. A soil that has developed a hard crust may also prevent the burrowing crickets to reach the surface of the ground.

With the afore-mentioned points in mind, it can be readily understood that soil that contains numerous cricket eggs and that can be plowed should be plowed deeply, and if possible in late fall, in order that the soil may become compacted before the eggs are ready to hatch in the following May or early June. If spring plowing is practiced, then the plowed soil should be pulverized in order that it may pack more readily.

Destruction of Nymphs and Adults Under Field Conditions

Destroying the Crickets Through a Poisoned Bait

The most effective method of destroying the black field cricket in any of its nymphal stages or in its adult form is through a poisoned bait. In our experimental work we tried out more than 50 different baits which differed from one another in the ingredients used or in the proportions of the ingredients. Despite the most strenuous efforts on our part, we never found it possible to obtain an accurate count of the number of crickets that were killed under actual field tests, first, because the crickets may crawl into cracks to die and the cracks may be many feet in depth; second, because we have no way of knowing how many dead or perfectly healthy crickets are in these cracks; and third, because many of the dead and dying crickets are carried away or eaten by other insects, such as ants, grasshoppers, unpoisoned crickets, etc.

The most effective bait that we used, from the standpoint of percentage of crickets killed or rapidity with which the bait killed, was a mixture of ingredients made up according to the following formula:

Coarse bran	100 pounds
Sodium fluosilicate	5 pounds
Cane molasses (low grade known as black strap)	1½ gallons
Water	10 to 12 gallons

Mixing the Bait

The bait may be mixed by hand, or by the use of machinery. If the bait is mixed by hand, the following procedure may be followed, or a modification of it may be used. A known amount of bran should be spread out

on a tight floor, or in a tight wagon box, or in an old water tank, to a depth of about 8 to 10 inches. Now mix the required amount of water, molasses and sodium fluosilicate in a large can, tub or barrel. After the mixture has been thoroughly made, pour about 3 gallons of it over the bran and begin working it into a mash by turning the mash over and over with a scoop, rake or potato fork. Stir up the poisoned liquid thoroughly and then add another 3 gallons of it to the poisoned bran mash, and again work it over and over. Continue this process until all the poisoned liquid has been added to the bran mash. Thoroughly mix the poisoned bran by shoveling it over and over at least 8 to 10 times. A thorough job of shoveling over the poisoned bran is essential, for each flake of bran must receive a coating of molasses and poison in order that it may be effective as a killing agent of crickets. The prepared bait should not contain lumps of bran, nor should it be sloppy, but it should be well moistened so that it falls in flakes when it is scattered over the ground. Do not attempt to prepare too large a quantity of poisoned bran mash at one time, for a good mix cannot be obtained by trying to prepare too much of the poisoned mash in a minimum of time or in a small receptacle or on a small floor. In a wagon box about 200 pounds of the bran may be treated satisfactorily at one time.

Bran.—Coarse wheat bran is preferred over all other materials as a base for the bait. However, if good, clean, screened sawdust is available, 50 per cent by weight of the bran may be replaced by an equal quantity of the sawdust. The sawdust, however, should be well screened so that it does not contain chips of wood; nor should the sawdust be rotted.

Sodium Fluosilicate Substitutes.—Munro and Carruth[3] after using sodium fluosilicate, sodium fluoride, sodium arsenite, white arsenic, Paris green, and thallium sulfate, as killing agents in their poisoned cricket baits, concluded that sodium fluosilicate gave the best results in control. They also found that sodium fluoride was only slightly less efficient as a killing agent of the crickets, but when the price differential of the two poisons was considered, that the sodium fluosilicate was to be preferred. These authors also concluded that the baits which included white arsenic, sodium arsenite or Paris green as the killing agent produced only poor results in their experiments.

Our experiments in South Dakota corroborate those of Munro and Carruth. However, sodium fluosilicate is not so readily available as is crude white arsenic, nor is it as cheap. Consequently, if it becomes necessary to use a killing agent which is more readily available than is sodium fluosilicate, it is recommended that crude white arsenic be employed. The bait should then be prepared according to the following formula:

Coarse bran	100 pounds
Crude white arsenic	5 pounds
Cane molasses (low grade known as black strap)	1½ gallons
Water	10 to 12 gallons

As a substitute for 5 pounds of crude white arsenic, 2 quarts of the liquid sodium arsenite (4 pounds material), or 2½ pounds of dry sodium

[3] Munro, J. A., and Carruth, L. A. Insecticidal Control of the Common Black Field Cricket, *Gryllus assimilis* (Fabr.). Jour. Ec. Ent., Vol. 25, pp. 896-902, 1932.

arsenite, may be used. Paris green is out of the question because of its high cost.

Molasses.—Only a cheap cane molasses such as black strap should be used in the poisoned cricket bait. Ordinarily, molasses that may be purchased from a grocery store is too costly for our purpose. It is not recommended that beet molasses be substituted for black strap.

Method of Distribution of the Bait

The poisoned bran mash should be broadcast thinly over the cricket infested fields at the rate of about 20 pounds of the prepared bait per acre. The bait may be applied by a person on foot who carries the bait in a pail, but this is hard work and a slow procedure. A much faster method is to spread the bait from the rear end of a wagon or truck. The bait in this case is placed in a large tub and then one or two persons sitting on either side of the tub and facing to the rear, distribute the bait. If a strong wind is blowing, a better distribution of the bait will be obtained by casting the bait in the direction of the wind rather than against it.

During the past few years, quite a number of different devices have been constructed by farmers to distribute grasshopper baits. Such devices, if satisfactory, can of course be used to distribute the cricket bait. Endgate seeders have been used extensively for this purpose, but these must not be fed too rapidly for fear of clogging them.

Time of Day to Distribute the Bait

Since the black field cricket feeds chiefly from 4 p. m. until 8 or 9 a. m. on warm days, the bait should be distributed late in the afternoon on days when the following night temperature will not drop below 70 degrees F., and when there is little probability of rain. In areas where irrigation may be practiced, the fields should first be irrigated and two days later the bait should be spread. The object of this procedure is to drive the crickets to the surface of the ground, and to close the cracks in the soil so that more of the crickets will find and eat the bait. In areas that are not irrigated it would be advisable to bait after a rain. Alfalfa fields that are heavily infested with crickets should be baited after the first cutting of hay has been made, and after the hay has been stacked or removed from the field, provided of course, this procedure fits in with the farming plan. In no case should one wait until fall or very late summer to bait a field, for by that time much of the injury will already have been done by the crickets and, besides, a large number of eggs will also have been laid by the already mature crickets.

Results to be Expected From Baiting

Destroying crickets with a poisoned bran mash is the most effective method that we know of to use against crickets. However, if a 70 per cent kill is obtained in a field through one application of the bait, the results should be considered satisfactory. The maximum killing effect of the bait will be noted at the end of the third day, but even later, additional crickets will die, not only because they feed upon the poisoned bran mash, but also because they feed upon dead or dying poisoned crickets or grasshoppers. In passing, it should be noted that the bait used to destroy crickets will also destroy grasshoppers.

Since many of the crickets crawl into cracks to die or among the stems of plants close to the ground or under hay, etc., and since many of the

dead or dying crickets are either eaten or carried away by other insects, it becomes impossible to estimate the effectiveness of the bait by counting the dead crickets lying on the surface of the ground and comparing this number with those still alive and healthy.

Migration of the common black field cricket because of flight is a negligible factor, but migration of crickets through walking, running and hopping is important. In other words, since crickets may migrate through walking, running and hopping from one field to another, across roads, etc., it is desirable that neighboring farmers cooperate in poisoning their crickets.

Caution

Poisoned bran mash may be prepared and distributed for the destruction of crickets, without danger of poisoning human beings, livestock or birds, but to do this, certain percautions must be observed. When stored, the poison should be kept in containers labeled with the word "Poison" in large letters and preferably the label should be red in color and should have the familiar skull and cross bones printed upon it. As an additional precaution, the poison should not be kept in the house, but in a building away from the house, and under no circumstances should children have access to it.

When the poisoned bait is being prepared, care should be exercised by the workers not to breathe in any more of the poison in the form of dust than is absolutely necessary. Care should also be exercised not to slop any of the poisoned molasses and water over one's clothing or shoes. The workers shoveling over the bait should not walk about in the bait and thus get their shoes and socks wet with poison. At night, the individuals preparing the bait should change all their clothing and take a thorough bath. Clothing worn one day should be washed before being used again.

After the bait has been prepared it should be kept in barrels, tubs, bags, wagon box or elsewhere, until it is used. Preferably it should be used within a day or two after it was prepared; otherwise it is likely to dry out or mold. Bait that has become dry may be moistened again by adding water and is not harmed during the process. All bait must be kept away from livestock and poultry, for the bait is very attractive to such animals.

Care should also be exercised to clean up thoroughly all left-over or scattered bait at the mixing plant. No receptacle which once contained the poison or the poison bran mash should be permitted to be within reach of farm animals, for the animals may lick such receptacles and become poisoned.

Men scattering bait by hand should first grease their hands with axle grease. While distributing the bait, it should be remembered that the bait must be scattered thinly over the ground and that it must under no circumstances be put out in lumps. If the bait is put out in piles or lumps, farm animals may find and eat it and die.

Unused bait should not be buried in soil, put in an old hay or straw stack, thrown into a creek or river, or be similarly disposed of, but should be scattered as if it were being used for poisoning crickets or grasshoppers. If the bait is burned, the ashes should be gathered up carefully and scattered thinly over a wide area, for burning in all probability did not destroy the poison. Wooden tubs, barrels and bags that once contained the poison or mash should be burned and the ashes distributed as already discussed.

Dusting

Dusting cricket-infested fields with various insecticides was found to be neither practicable nor effective. Many different dusts were used in attempts to control the crickets in alfalfa fields but none proved as effective nor as cheap as the use of the sodium fluosilicate poisoned bran mash. Further, there is considerable danger of poisoning the operator of the dusting equipment, a condition which should not exist when a reasonable amount of care is exercised in mixing and spreading the poisoned bran mash.

The Use of Poultry in Cricket Control

Chickens and turkeys are very fond of crickets and eat large numbers of them whenever they have the opportunity. Consequently, a flock of such poultry may be used to advantage in reducing an outbreak of crickets over a small acreage, but over a large acreage little can be expected from them.

Burning As a Control

Weeds cut, raked into windrows or piles and allowed to lie on the ground for some time, will attract many crickets as places of refuge during the day time. If fire could be set to such piles or windrows between the hours of 10 a. m. and 3 p. m., many of the crickets would be destroyed. Straw scattered in heaps or in windrows where crickets tend to become abundant, can be similarly burned.

Destruction of Nymphs and Adults in Homes, Apartment Houses, Stores and Other Buildings

Crickets that have made their way into houses, apartment houses, hotels, stores or other buildings may do considerable damage unless they are destroyed. In basements it may be practicable and not undesirable to destroy crickets by putting out small amounts of poisoned bait in corners, under boards, boxes, etc. However, if children are in the house, this procedure may be considered unsafe.

Another method of destroying the crickets in buildings is by means of certain dusts. These dusts may be blown by means of a hand duster into corners, under boxes, boards, cupboards—in fact any hiding place where crickets may congregate. Fresh pyrethrum powder, when it comes in contact with crickets, usually kills the crickets within 3 or 4 hours. However, the powder loses its effectiveness upon exposure to air and then becomes harmless as an insecticide. Sodium fluosilicate and sodium fluoride may also be used in dust form to kill crickets, but these are not quite as effective as is pyrethrum powder. A more serious objection to the use of sodium fluosilicate or sodium flouride in the home is their toxicity to man, but if care is exercised not to get any of these materials in food, or if children are not in the home, there is little danger in using these dusts in the home for the control of crickets.

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