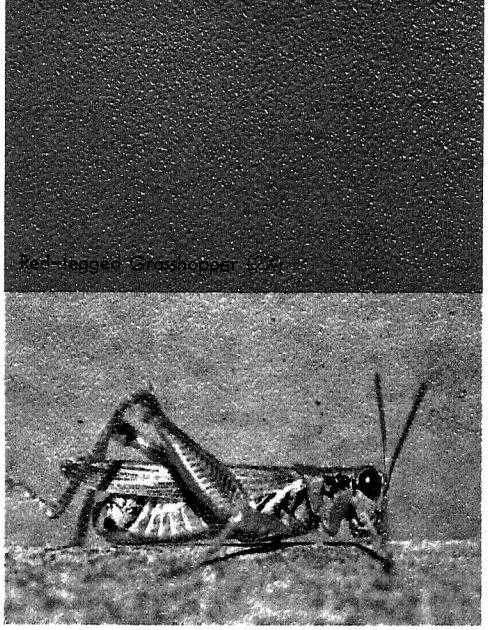
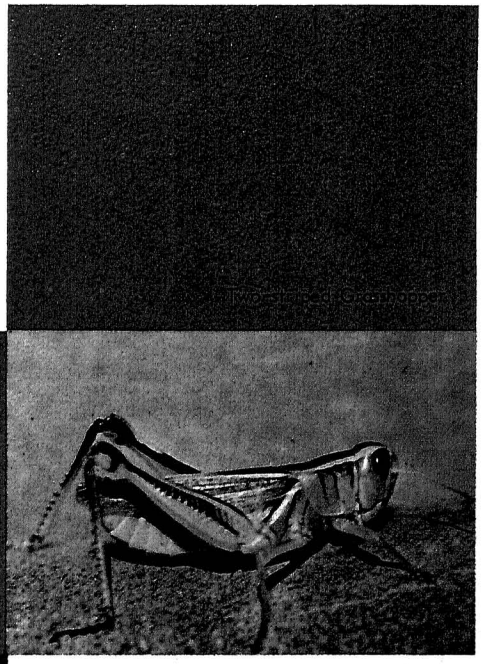


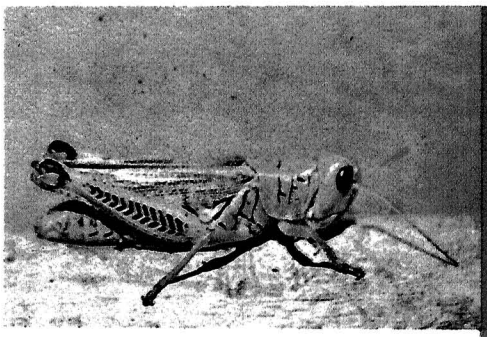
Red-legged Grasshopper (2X)

The GRASSHOPPER

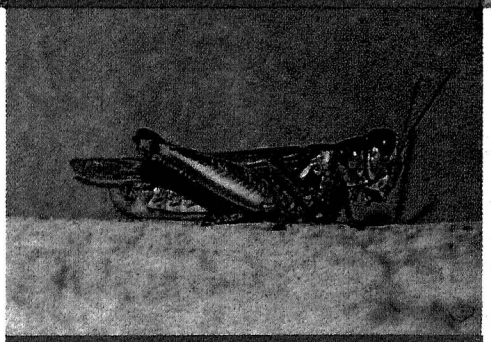
Your SHARECROPPER



Two-striped Grasshopper



Differential Grasshopper



Migratory Grasshopper (2X)

R. L. Shotwell
Entomologist

BULLETIN 714
OCTOBER, 1958
UNIVERSITY OF MISSOURI
AGRICULTURAL EXPERIMENT STATION

Cover photographs courtesy Dr. Robert E. Pfadt, Entomology Dept., University of Wyoming.

CONTENTS

This bulletin reports on Department of Entomology research project 286, Corn Grasshoppers. The author, R. L. Shotwell, Entomologist with the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, worked in cooperation with the University of Missouri Agricultural Experiment Station and Agricultural Extension Service.

Nymphs of the differential grasshopper attacking corn plants.

The GRASSHOPPER... Your SHARECROPPER

R. L. Shotwell,
Entomologist

"The land is as a garden of Eden before them, and behind them a desolate wilderness; yea and nothing shall escape them." Joel II:3.

GRASSHOPPERS IN MISSOURI HISTORY

Grasshoppers have periodically shared large portions of our crops since Missouri became a state in 1821. Some 45 of Missouri's 137 years of statehood could be called grasshopper years—years in which grasshopper damage to crops was either locally or generally severe.

Early Outbreaks

The earliest outbreaks in Missouri were caused by the famed Rocky Mountain grasshopper.[1] The permanent breeding grounds of this grasshopper were in the prairies just east of the Rockies in north-central Wyoming, central and northern Montana, and southern Alberta and Saskatchewan. History records that in some years great swarms flew out of their breeding grounds into Minnesota, Iowa, and Missouri and south through Texas as far as the Gulf of Mexico. Between 1818 and 1876 swarms migrated into western Missouri during four periods, 1818-20, 1855-57, 1866-68, and 1873-76.

The State entomologist for Missouri, C. V. Riley, writing in 1877, said:[2]

> "The voracity of these insects can hardly be imagined by those who have not witnessed them in solid phalanx falling upon a cornfield and converting in a few hours the green and promising acres into a desolate stretch of bare, spindling stalks and stubs. Covering each hill by hundreds; scrambling from row to row like a lot of young famished pigs let out to their trough; insignificant individually but mighty collectively—they sweep clean a field quicker than a whole herd of hungry steers. Imagine hundreds of square miles covered with such a ravenous horde and one can get some realization of the picture presented in many parts of the country."

[1] *Melanoplus spretus.*

[2] Riley, C. V., *The Locust Plague in the United States.* Rand, McNally Co., Chicago Publishers, 1877.

A Governor's Proclamation

At one time the people believed these plagues to be "an expression of Divine wrath for the sin and corruption of the people, a chastisement of the Lord." The peak of destruction by the Rocky Mountain grasshopper came in 1874, when crop damage reached such a proportion as to be considered a national calamity. On May 17, 1875, Missouri's governor, C. H. Hardin, issued a proclamation setting aside the third day of June as a day of fasting and prayer "that Almighty God may be invoked to remove from our midst those impending calamities," meaning the threatened grasshopper outbreaks.

Early in April of that year, Riley in his report to the governor foretold that the grasshoppers would begin to leave the state early in June, and they did. According to Riley, his prediction may have had something to do "with the date fixed upon in the proclamation," because it turned out to be most opportune. In early June the Rocky Mountain grasshoppers matured to winged adults and took off to the northwest in the direction of the prevailing winds.

A month before the 1874 invasion of Missouri, Riley had made this prediction:

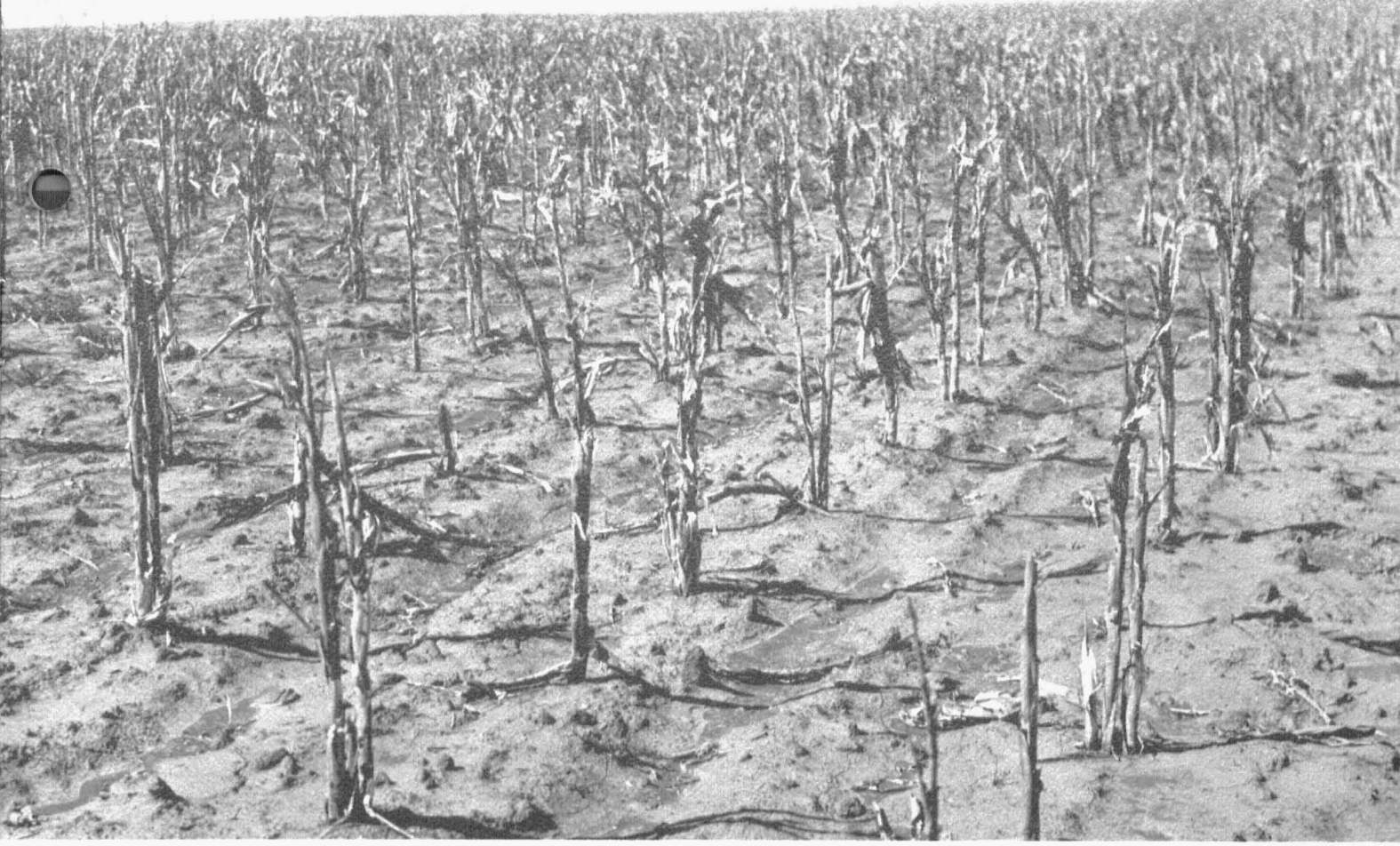
> "Judging of the future by the past, the farmers of Missouri east of the extreme western tier of counties need fear nothing from locust [grasshopper] invasions. They may plant their fall grain without hesitation and console themselves with the reflection that they are secure from the unwelcome visitants which occasionally make their way into the counties mentioned, especially those of the northwest corner of the state. The same holds true of the farmers in Illinois and of all the country east of a line drawn at a rough estimate along longitude 17° west from Washington, D. C. (94th Meridan)."

Today, this would include about all of the state east of Highway 65 from Springfield through Chillicothe.

Riley gave two reasons for his prediction which are important today in the geographical distribution and development of grasshopper infestations. First, this eastern limit of flight was approximately on a line north and south from Canada to the Gulf of Mexico. It roughly separates the natural timberland regions of the United States on the east from the more open plains and prairie regions on the west. The former is wetter and normally unfavorable for grasshopper development. A second reason was that the Rocky Mountain grasshopper had reached the limits of flight in a single year when it approached the 94th Meridian. Then the following year, according to historical records, the offspring of these migrants "do not reach an average of ten miles east of any point where they hatched and that upon acquiring wings they fly in the main northwestwardly."

Outbreaks Since 1876

Grasshopper outbreaks in Missouri since 1876 have been attributed to native grasshoppers. At first it was believed that with the end of the great migratory swarms, the Rocky Mountain grasshopper had disappeared from the face of the earth. There is



The riddled, leafless cornfield is a common sight during bad grasshopper years.

now evidence that this grasshopper was a migratory phase of the species now known as the migratory grasshopper. This species is common over most of the inhabitable North American continent, but conditions for the development of such great migratory swarms have changed. Since 1876 large portions of the great plains region, including the breeding grounds, have been divided into farms and the native sodland has been broken up into cultivated fields. The grasshoppers no longer need leave home in search of food.

There were a number of years between 1876 and 1957 when native grasshoppers reached outbreak proportions in Missouri. Severe infestations occurred in the western half and the most severe ones in the northwestern quarter of the state. In other words, the worst infestations were limited to that part of the state beyond which Riley said the Rocky Mountain grasshopper would not spread because conditions were not favorable for its development. In the United States, grasshoppers become more and more of an annual problem as one leaves the regions of a 30-inch or greater annual rainfall and progresses west through regions having 20 to 10 inches.

The last two severe outbreaks in Missouri occurred in the 1930's and the 1950's. It is significant that seven of the ten years beginning in 1931 were dry years and five of the six years beginning in 1951 were also much below normal in rainfall.

GRASSHOPPERS AS FOOD FOR HUMANS

During the severe grasshopper plagues in the 1870's, grasshoppers were tested for their palatability and value as food for humans in a country ravaged of its normal food supply by these same insects. For centuries grasshoppers have been used as food by people in many parts of the world. Within the

last few years in the United States canned grasshoppers have been on the shelves of grocery stores selling exotic foods.

In Missouri in 1875 Riley investigated the possibility of using grasshoppers for food. He went so far as to go on a strict grasshopper diet. He gave this as his reason:

> "I was governed by weightier reasons than mere curiosity, for many a family in Kansas and Nebraska were brought to the brink of the grave by sheer lack of food while the St. Louis papers reported cases of actual death from starvation in some sections of Missouri where the insects abounded and ate up every green thing in the spring of 1875."
>
> "Whenever the occasion presented I partook of locusts [grasshoppers] prepared in different ways and one day ate of no other kind of food, and must have consumed, in one way and another the substance of several thousand half grown locusts."

He was agreeably surprised after some misgivings that they were quite palatable. "Fried or roasted in nothing but their own oil with the addition of a little salt and they were by no means unpleasant eating and have quite a nutty flavor."

At one hotel he finally succeeded in getting the cook to let him prepare a complete meal using grasshoppers.

> "It was most amusing to note how, as the rather savory and pleasant odor went up from the cooking dishes, the expression of horror and disgust gradually vanished from the faces of the curious lookers on and how at last the head cook took part in the operations; how when the different dishes were neatly served upon the tables and were freely partaken of with evident relish and many expressions of surprise and satisfaction by the ladies and gentlemen interested, this same cook was actually induced to try them and soon grew eloquent in their favor; how finally a prominent banker as also one of the editors in town joined in the meal. The soup soon vanished and banished silly prejudice; then cakes with batter enough to hold the locusts together disappeared and were pronounced good; then baked locusts with or without condiments; and when the meal was completed with dessert of baked locusts and honey a la John the Baptist, the opinion was unanimous that that distinguished prophet no longer deserved our sympathy and that he had not fared badly in the wilderness."

Several others at Riley's suggestion experimented in preparing grasshoppers for their own consumption and said they were excellent. Evidently the idea did not catch on, because there are no recipes in our cookbooks for preparing grasshoppers baked, fried or stewed.

KINDS OF GRASSHOPPERS

Four Important in Missouri

Grasshoppers belong to the family Acrididae of the order of insects called the Orthoptera. Other members of this order are the crickets, cockroaches, and katydids. In Missouri one could easily collect 30 to 40 different kinds of grasshoppers, all of which cause some damage to our native and cultivated plants, but from an economic standpoint there are only four kinds considered important. They are the migratory grasshopper,[3] the differential or big yellow grasshopper,[4] the two-striped grasshopper,[5] and the red-legged grasshopper.[6] All four belong to the subfamily Cyrtacanthacridinae, or spine-breasted grasshopper. Beneath the body between the front pair of legs is a distinct spine.

The Less Important Species

In our pastures and sometimes in our crops we have two other groups which we could call the musical or noise making grasshoppers. The males alone have the musical organs. This caused some-

[3] *Melanoplus bilituratus.*
[4] *M. differentialis.*
[5] *M. bivittatus.*
[6] *M. femur-rubrum.*

one to say:

"Happy the grasshopper lives
Since they all have noiseless wives."

One of these musical groups is the subfamily Acridinae, or slantfaced grasshoppers. From the top of the head the face is slanted backwards, often making the head cone-shaped. They are the grasshoppers you often hear making stridulating sounds or a shrill buzz. They do this by rubbing the inner part of the hind legs against the fore wing. Quite often one or two species of this family will occur in sufficient numbers to do severe damage to our pasture grasses.

The subfamily name of the other musical group is Oedipodinae or band-winged grasshoppers. Most of these make a harsh, crackling or rattling sound in flight which is as characteristic of a summer day as the flight of a butterfly. They make this noise by rubbing their wings together. Most of the species of Oedipodinae have inner wings colored mostly yellow or red with some black. In flight they can be mistaken for butterflies. Some of the species of band-winged grasshoppers are of great economic importance in the rangelands of the West. There the conditions, drier than those found in Missouri, favor their development.

Our most common band-winged form is the Carolina grasshopper.[7] It is a rather large, long-winged grasshopper, whose general color is a dull ashy-brown sprinkled with numerous small dusky spots. It is the most noticeable because it congregates along roadways and paths rather than in fields or pastures. This gives an exaggerated impression of their numbers. You may think there is a damaging infestation of grasshoppers when that is not so. Because of its conspicuous black wings and habit of frequenting roadsides, this is one of the best known of our Missouri grasshoppers although it is not of much economic importance.

[7] *Dissosteira carolina.*

THE IMPORTANT MISSOURI GRASSHOPPERS

The migratory grasshopper is about one inch long. The body is grayish or reddish brown with irregular black markings just back of the head. Its favored breeding places are pastures, grain stubble, and poor stands of alfalfa and clover. Of the four species important in Missouri it is the first to appear in the spring. It is a strong flier and has been known to migrate 200 to 300 miles in a single season. In the country as a whole it has caused more crop damage than any of the other grasshoppers.

The differential, or big yellow, grasshopper is a robust insect about 1½ inches long, the females larger than the males. The body is a dark brownish-green or olive-brown above to a dull or bright yellow beneath. The hind thigh is dull to bright yellow in color, and bears narrow black bars arranged in herring-bone fashion, resembling chevrons. This species appears about the middle of May, three weeks later than the migratory grasshopper.

Before the midwestern and plains states were settled, the differential grasshopper lived in the weedy creek and river bottoms. After such crops as small grains, corn, and alfalfa covered the prairies, it moved into the croplands. There it found ideal breeding places in field margins, closely grazed pastures, and poor alfalfa stands, together with an abundant food supply in the nearest crops. In the Corn Belt where it became a number-one threat to the corn, in many places it has rightly earned the name of "corn hopper." It is also a strong flier, but not the long-distance flier that the migratory grasshopper is. During the recent outbreaks in Missouri, the differential and migratory grasshoppers were by far the most important species.

The two-striped grasshopper is about 1¼ inches long. The females are larger than the males. You may easily recognize this species by the two yellowish stripes, which gave it its name, extending from

the eyes on the sides of the head back almost to the tips of the wings. The body is olive-brown above to a pale to dull greenish yellow beneath. It breeds in pastures, field margins, and wherever there is open, weedy or soddy ground. Like the migratory grasshopper, it hatches early, and often occurs in damaging numbers. In Missouri, however, it has not equaled the migratory or differential grasshoppers in economic importance.

The red-legged grasshopper gets its name from its reddish hind legs. The body is reddish brown above and a dull greenish to sulfur-yellow beneath. It is about the size of the migratory grasshopper. The females of the two species can hardly be distinguished. It is found in various habitats, but particularly in pastures and alfalfa fields. In some sections of the country where alfalfa is the important crop, it is the number one grasshopper.

LIFE STORY OF THE GRASSHOPPER

Egg Laying

Of the four important species in Missouri, only the migratory grasshopper is known to have two generations in a single season, with eggs for the second generation deposited in June and early July. All four species lay eggs in the late summer and fall. These overwinter in the soil and hatch the following spring.

Different species select different places for egg laying, but the method for depositing eggs is similar for all. The female presses the tip of her abdomen against the soil surface and digs her way down by means of a horned process at the end of her body (Fig. 1, Fig. 2), and then deposits one egg at a time until for most species 15 to 100 of them are placed in regular order.

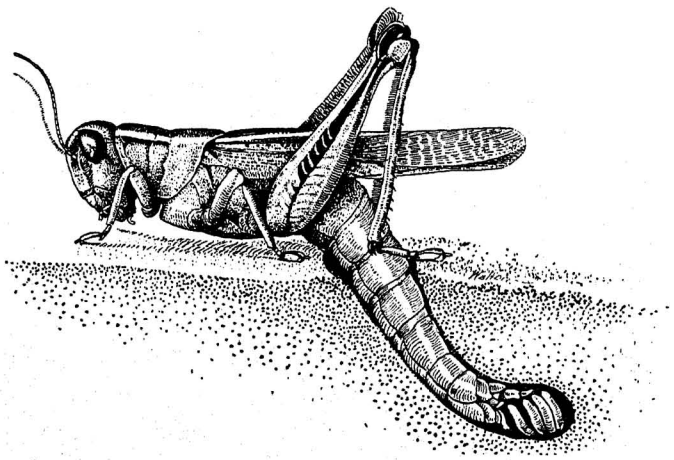


Fig. 1—Female two-striped grasshopper laying eggs.

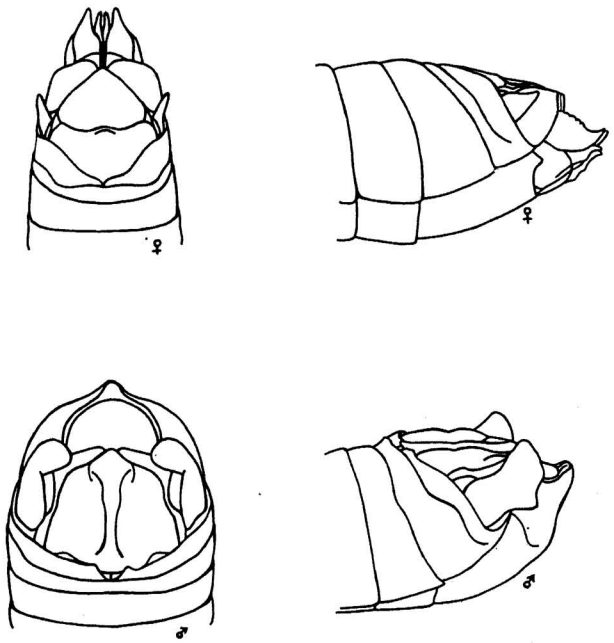


Fig. 2—Last abdominal segments showing the difference between male and female grasshoppers. Adult two striped grasshoppers used to illustrate. Top and side views of female above, top and side views of male below.

Migratory and red-legged grasshoppers will deposit about 20 eggs in a mass while the differential and two-striped grasshoppers will place 50 to 100 eggs in a single mass. The migratory grasshopper, although laying fewer eggs per mass, can lay up to 15 to 20 masses. The differential and two-striped grasshoppers lay three to four pods. Studies of mass egg laying have shown that each female lays about 300 eggs.

Fig. 3—Egg pods of two-striped grasshopper, natural size.

A gluey fluid is discharged along with the eggs, mixing with the surrounding soil. The hole is also capped with this fluid and the whole mass hardens into a pod (Fig. 3). This cementing process protects the egg from the elements. The size and shape of the pods vary with the species and may be from ½ to 1½ inches long and ¼ inch or less wide. They look like small pellets of hardened mud (Fig. 4).

Description and Location of the Eggs

Eggs of the differential and two-striped grasshoppers are olive color and about $^1/_5$ inch in length. Those of the migratory and red-legged grasshoppers are cream-colored or whitish and $^1/_6$ inch in length. The eggs of all four species are banana-like in shape.

Fig. 4—Eggs of the differential or big yellow grasshopper in clump of sod.

All of these species avoid loose soil when laying eggs, preferring firmly packed ground. The egg pods of the two-striped and differential grasshoppers are concentrated among the roots of scattered grass clumps and weeds along roadsides, in field margins, in pastures, poorer stands of alfalfa and clover, corn and sorghum fields, and sometimes among the roots of the corn plants themselves. Eggs of the migratory grasshopper are more scattered and are found throughout pastures, in bare spots in poorer stands of alfalfa, or in small-grain stubble fields clinging to the roots of the stubble or nearby in spots where the dirt is firmly packed. Pods of the red-legged grasshopper are found scattered in all of the locations selected by the other three species. Sometimes a female may be forced to deposit eggs in less desirable places.

In bulletins on grasshopper control, we are urged to kill the grasshoppers while they are still concentrated on their "egg beds" and before they spread to adjoining crops. This calls for early action soon after they hatch. This advice applies to those localities where the egg-laying grounds are well defined and limited in size. When entomologists make egg surveys to predict infestation the following year, these are the places they examine, because egg pods are easy to find.

In Missouri, however, the term "grasshopper egg bed" has little meaning either in control programs or for making egg surveys, because the egg bed usually includes all the pastureland as well as field margins, alfalfa fields, and grain stubble on a farm. It may also include the marginal portions of wood lots and some waste areas. To tell a farmer to spray his grasshopper egg beds early is to tell him to spray from half to most of his farm. It is impossible to make an accurate grasshopper survey in Missouri because of the type and extent of breeding places.

Hatching

In the spring when the soil temperature has reached 60° F for a number of days, the hoppers begin

hatching. The cap in the top of the egg pod serves as an escape for the young grasshoppers. They break through the outer egg shell and worm their way to the top of the ground while covered completely by a skin. The young hoppers appear to be sprouting as they come up out of the soil. At the surface, the sheath splits and the grasshopper frees himself. You see the remains of these first cast skins as small white pellets on the ground.

Often the hoppers do not have the use of the egg cap as an escape hatch, because during the winter soil covers the pods and the hoppers have to work their way out through it. In normally packed dirt, if this distance is much greater than 1½ inches, they die in their tunnels. At depths of four inches or in hard-baked ground, hatching grasshoppers fail to reach the surface. A light rain can free them from hard ground, and you may notice greatly increased hatching after a rain. Deep fall or spring plowing, which buries the eggs four inches or more, can prevent hatching, if the soil is not lumpy but loose enough to pack and form a firm cover over the buried eggs.

Many eggs of the migratory and two-striped grasshoppers go into the winter with the embryos partly developed. When soil temperatures rise above 60° F in the spring development resumes. Eggs of the differential grasshopper show no development at the beginning of winter. This is probably the reason why this species and the red-legged grasshopper hatch about three weeks later than the migratory and two-striped grasshoppers.

The young hopper will not develop in the egg at temperatures below 60° F. Above this point and within a normal range, the rate of development is related to temperature. The higher the temperature the sooner the hatch. A warm, dry spring brings on an early hatch, while a cold, wet spring causes a late hatch.

The effect of temperature on egg development is cumulative. Each period of temperatures above 60° F helps growth until hatching takes place. This is an adaptation to the changing temperatures of spring. If grasshopper eggs were like chicken eggs, this heating and cooling would kill the embryo.

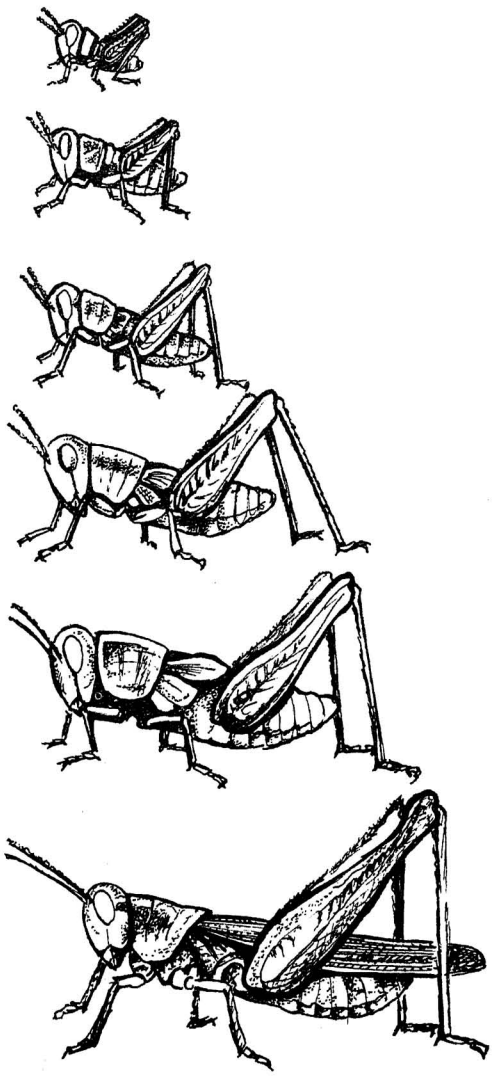


Fig. 5—Five nymph stages and adult in the development of the grasshopper. About three times natural size.

The spring and early-summer hatching period for any of these four species lasts four to six weeks.

Altogether, hatching may extend over 10 to 12 weeks. For the second-generation migratory species, this period is a month to six weeks in July and August. In Missouri, as observant farmers have reported, there are grasshoppers hatching all summer.

How a Young Grasshopper Develops

A newly hatched grasshopper looks like a miniature of its parents, less than ¼-inch long. It is covered with a hard shell stronger than bone. Be-

cause this tough shell is not elastic, the grasshopper casts its skin five to seven times in growing up. Each time the skin is cast, we see changes other than increased size. (Figure 5). During the last two stages, the immature wings are padlike structures pointed upward at the shoulders, where before they are pointed downward and less noticeable.

Temperature plays an important part in the rate that young grasshoppers develop. Below 70° and above 95° F. they show very little growth or activity. Within this range the higher the temperature, the faster they grow and more active they are.

Generally, from hatching to adulthood takes three months, between April 10 and July 10. For the second-generation migratory grasshopper this period is July 1 to September 20.

Adult Stage

After the last molting of the skin, the fully developed wings emerge from the pads. The grasshopper has come of age and reached full size. Adult migratory grasshoppers may appear as early as May 15, while the grown differential grasshopper may not show up until after July 1.

There are some short-winged, sometimes incorrectly called wingless, grasshoppers, but in Missouri all the important species are long-winged. Having wings is a mark of adulthood, and there are two pairs of them. When the grasshopper is not in flight, the forward pair of narrow wings lie alongside and over the body, covering the hind pair, which are broad, fanlike, and folded up underneath. In flight, both pairs unfold and spread out to the side.

About two weeks after reaching the adult stage, the males and females start mating. In another week the females commence laying eggs. Mating occurs between the times eggs are deposited. This ends only with death.

The old grasshoppers disappear gradually in the fall, slowly dying off a few at a time. Even after we think that the cold weather may have killed them all, we may find a few old ragged females still laying eggs during a warm spell in late October or early November.

There is a group of overwintering grasshoppers that reverses this whole process. They hatch in the late summer and early fall and go through the winter as nymphs. You may see them moving around on a warm day in the middle of winter. Even in our northern plains states they have often been seen hopping about among patches of snow on a warm sunny hillside. Hardly a winter passes that some one, seeing them, does not report an early hatch of grasshoppers taking place. These hoppers reach the adult stage early in April and May. They are not of economic importance.

HOW GRASSHOPPERS LIVE

Feeding

A grasshopper has a pair of strong, broad jaws, which work sideways, in and out, like a pair of scissors. The hopper is chiefly occupied with only one thing—its appetite. It prefers green succulent plant food, but can subsist on dry organic matter. During some past severe outbreaks of the differential grasshopper, all the green plant food was practically gone by July. Then the grasshoppers entered houses and chewed holes in the curtains and upholstery. Clothes in a washing hung outdoors to dry soon had holes chewed in them. Even the rubber tread on the running boards of early model automobiles was roughed up by the pests. A person standing in a field was soon attacked by them. They would climb up on him and bite hard enough to draw blood. They stripped trees of their leaves, and in many places, the limbs of bark. At such times they displayed a restless savagery in their actions.

Grasshoppers prefer small grains to corn or alfalfa, but alfalfa is especially susceptible right after

the first or second cutting, when grasshoppers will feed on the new shoots. This feeding checks the growth and if continued will eventually kill the plants. Corn will be eaten into the ground at any time when there are enough grasshoppers. Damage to corn when there are fewer grasshoppers usually comes later, when it is silking and tasseling. They will eat down into the cob, blasting 25 to 60 percent of the kernels even when the leaves show little damage. They sometimes chew leaves to the midrib or cut them off at the axil. The riddled leafless cornfield is a common sight during bad grasshopper years.

Grasshoppers seem to have some aversion to most varieties of sorgo, except for the heads when they first appear. They will attack sorgo leaves as a last resort. Cutting off of the heads of wheat and barley and the bolls of flax, the shattering of oats, and the chewing of the leaves, blossoms, and seed pods of alfalfa are typical forms of grasshopper damage. They will also eat weeds, such as sunflowers, ragweed, and wild lettuce, especially when the plants are young and tender.

As a grasshopper grows it naturally eats more. In the last two stages of nymphal development and the first two weeks of adulthood it reaches its peak of destructiveness. In a season this may mean a month to six weeks. After this, the feeding becomes more desultory, as the grasshoppers become occupied with reproduction.

Migrations

One of the chief characteristics of the economic species of grasshoppers is their urge to be on the move. We notice this migratory habit when they reach the third and fourth nymphal stages, particularly under crowded conditions. In late June and July the differential grasshopper is often seen crossing the road on foot. Where hatching takes place along the margin of a crop, the newly hatched hoppers soon start sifting into the crop, but this is not a typical migration. The migratory movement is one of concerted action in one direction by the entire population. In some parts of the country where crops are scattered, young grasshoppers have been known to disperse on foot up to ten miles from their hatching place. More often this dispersal is less than five miles. Some may never leave the pasture where they hatched. Missouri grasshoppers for the most part do not wander far on foot.

Nymphal migrations have been closely watched. One of these was from a destroyed alfalfa field across a field of corn half a foot high, and into a green barley field across a road. As they passed through the corn, the young hoppers would deviate two to four feet from the line of march to clamber up on the young plants. There they would take a few nibbles, climb down, and pass on again with the migrating horde. Apparently they knew where they were going and why.

More than 2500 years ago, the prophet Joel wrote about a locust plague symbolic of the mystic forces of destruction. Of migrations he said:

> "They shall run like mighty men; they shall climb the wall like men of war; and they shall march every one on his ways, and they shall not break their ranks. Neither shall one thrust another; they shall walk everyone in his path; and when they fall upon the sword, they shall not be wounded." He also went on to say: "They shall climb up upon the houses; they shall enter in at the windows like a thief." (Joel II:7-9).

Many a housewife on the farm has experienced the same thing much to her disgust and anguish. All through history man has had to share some part, large or small, of his food and comfort with the grasshoppers, and their ways are eternal.

Adult migrations are accomplished on the wing. Usually these flights are local, from a destroyed field upwind toward a standing crop which offers more succulent food. The movement consists of low flying jumps until the crop is reached. A typical swarming flight begins with a restless milling in a field, which increases with the temperature until the air is full of circling grasshoppers. If there is any wind, the whole swarm takes off in the direction the wind is blowing. A strong wind will carry them several miles. Such flights usually commence about 11:00 a.m. and end about 4:00 p.m. on sunshiny days. By shading your eyes against the edge of the sun you can recog-

nize flashes of silvery reflected light coming from the wings of flying grasshoppers.

Weather Affects Grasshoppers

The weather plays an important part in what a grasshopper does and whether it will live to do it. Its body temperature goes up and down with the surrounding air temperature. It cannot protect itself from temperature changes like a human. All its activity is geared to the existing temperature.

Between 70° and 90° F. activity increases with the temperature. Above or below these points the grasshopper slows down. It is likely to move to seek more favorable temperatures. In cold weather hoppers will hide in weeds and under trash seeking warmth. In hot weather they will roost as high off the ground as possible; if adult they will take to the air.

When grasshoppers hatch, they must have food within a short time or die. If the temperature is below 70° F. for three or more days, the hoppers would be inactive, not eat, and die. Continued cold weather following a general hatch has frequently killed off whole infestations. If the young hopper can survive the first week or ten days of development, he stands a chance of reaching maturity.

Since grasshoppers do most of their feeding between 70° and 90° F., an insecticide used on plants the grasshopper eats should be applied when the temperature is in this range.

Heavy rains or even hailstorms do not often drown or beat the life out of grasshoppers. Usually when the weather clears off they emerge from their hiding places. Egg pods in the sod buried under water for months have hatched at the water line as the water receded. However, eggs may rot under wet conditions. Extremely hot, dry weather in late August and September has been known to cook eggs that were loosely laid in exposed clumps of short grass.

There is usually enough moisture in the soil in the spring to permit eggs to hatch. However, the ground has sometimes been too dry and hard. Then hatching was delayed until late rains came to wet and loosen the soil.

Over the years, grasshopper outbreaks have been linked with drouth conditions, and rightly so. During wet years grasshoppers are not nearly the problem they are during dry years. On the other hand, weather is not the sudden destroyer we might think. Whenever there is a spell of unusually hot, cold, or wet weather, the common notion arises that "this should kill off all the grasshoppers." According to scientists, grasshoppers have been around for some 200 million years. They have had to put up with weather conditions such as we have never seen and they have survived.

CONTROL OF GRASSHOPPERS

Natural Control

When grasshoppers appear in great numbers, one of the questions asked is "Where did they all come from?" The answer is that, for species having one generation annually, they came from the grasshoppers that were present the year before, unless they have just arrived by air. A grasshopper population is made up of half males and half females. Each female will lay 200 to 300 eggs. The following year, if all these eggs hatched and the hoppers all survived, we would have 100 to 150 times as many grasshoppers. This never happens, or we would be buried by the pests in one year's time.

Fortunately nature maintains a balance by cutting down on the enormous numbers of young. With grasshoppers the natural balances are weather, parasites, predators, and disease, which annually take care of at least 90 percent of this "100 to 150 times" potential.

There are two common beetles and one fly whose larvae feed on grasshopper eggs in the pod. These are blister beetles, ground beetles, and bee fly larvae. In some places they may destroy from 25 to 75 percent of all the eggs in one season. There is also a mite that sucks the juice from the eggs. Various birds, ground squirrels, field mice, and skunks will feed on the eggs, especially where the pods are congregated in great numbers and easily reached. There is a wasp that parasitizes the eggs soon after they are laid. It works its way down into the pod

and lays its eggs in the grasshopper's eggs, and in the spring a wasp emerges instead of a grasshopper.

Flesh flies and others deposit eggs or living larvae on the grasshopper. Eventually the larvae of these flies enter the body of the grasshopper and eat it up from the inside.

In Missouri whitish balls of tightly coiled threadlike worms are often dug up out of the soil. These are the round worms *(Nematodes)* which parasitize grasshoppers. Inside the grasshopper these worms sometimes reach the great length of 17 inches and are tightly coiled, filling the whole of the body cavity. There may be up to 40 worms in one grasshopper, but one is sufficient to kill it. Up to 30 percent of grasshoppers may be parasitized by these worms.

Fungus and bacterial diseases destroy grasshoppers when conditions are right. Grasshoppers attacked by a fungus disease will assume a characteristic position on the stem of a plant, clasping it with the front and middle legs. The head is always up, and the grasshopper dies and remains in this clinging position. Local grasshopper infestations are often wiped out by fungus diseases which show up during warm muggy weather.

Weather as a factor in destroying grasshoppers has already been discussed in its effect on hatching and the development of the young. Some newly hatched nymphs no doubt are destroyed each year by inclement weather.

These are the more common natural enemies of the grasshopper. There are others. One wonders how we could have any grasshoppers left, but as with many other animals, nature has made grasshoppers prolific in order that they can survive all these hazards.

Effect of Tillage

Breaking up the original sod of our native prairies and seeding it with crops has had a tremendous influence on the life and numbers of our grasshoppers. In Missouri it has produced conditions for cyclic outbreaks of the so-called native species.

Grazing pastureland makes a short-grass sod condition favorable for those grasshoppers which choose grass clumps for egg laying. Growing corn, alfalfa, and other crops insures an abundant late food supply after the small grains and hay are cut.

Since grasshoppers will not breed in well-tilled fields, the pastures, margins, and fields of alfalfa and clover are the chief sources of infestation. Where stubble fields are thoroughly worked either in the fall or early in the spring before the eggs hatch, the infestations in these fields are usually destroyed. In the wheat states where clean summer fallow is practiced, proper tillage becomes an important control measure.

Control with Insecticides

For 75 years poisoned bran or bran-sawdust mash was used to control grasshoppers. At first arsenic in various forms and then sodium fluosilicate were the poisons used in the mash. The mixture was broadcast by hand or machine at the rate of 20 pounds per acre. The effectiveness of the bait depended upon how many of the grasshoppers ate it. In order to draw them to the bait, scientists tried a number of attractants. They tested banana oil, citrus fruits, molasses, melons, and about 30 other substances in the mash. After thousands of tests they realized that the wet bran or bran-sawdust as a carrier of the poison was all they needed. They got best results in dry weather when there was not much green vegetation. However, poisoned bait was far from being a sure method of control.

In the 1940's the chlorinated hydrocarbon compounds appeared. They soon proved to be excellent grasshopper killers when used in sprays. Toxaphene and chlordane were the first of these compounds. They were soon followed by aldrin, dieldrin, and heptachlor. Very small amounts, such as one or two pounds of the first two, and one or two ounces of the last three insecticides per acre, often gave 100 percent kills.

To be effective against grasshoppers, an insecticide must have a lasting effect, to kill off any late comers from hatching or migration. The chlorinated hydrocarbon sprays do this. They are effective one to three weeks, depending upon the compound and dosage used.

The long residual effect of these compounds poses a serious problem in pasturing or feeding live-

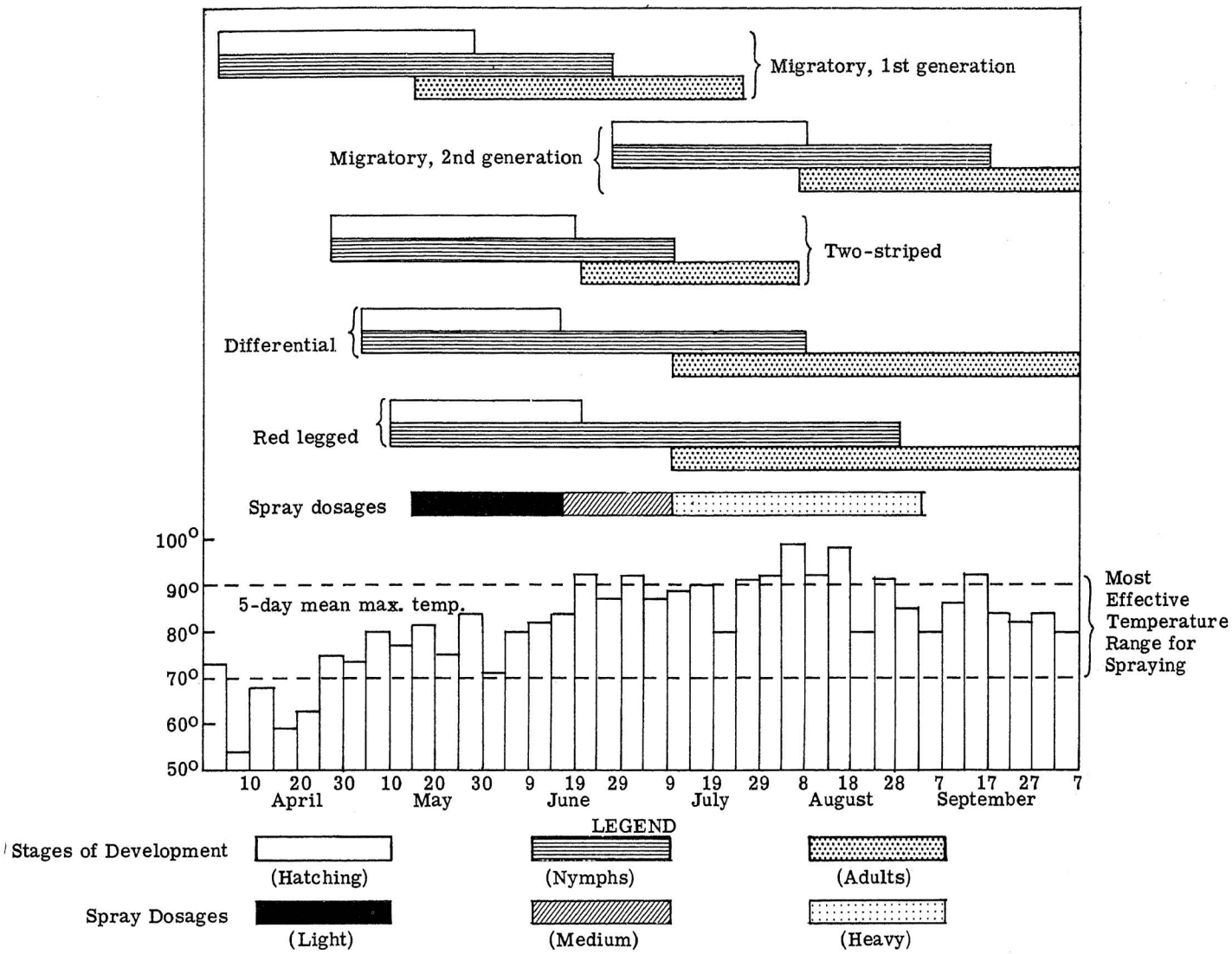


Fig. 6—Spray schedule in relation to seasonal history and temperature, Ash Grove, Missouri, 1956.

stock. Residues may appear in the fat or meat and show up in the milk of animals that have fed on treated forage. There are restrictions on pasturing and feeding livestock to avoid harmful residues from such sprays. These are printed on insecticide labels and in the recommendations for grasshopper control put out by the University of Missouri Extension Service.

You should consider weather conditions in using any insecticide. Apply the sprays when the grasshoppers are active. Below 70° F. the grasshoppers are not feeding and spraying at this time is not immediately effective. If spray is applied under this condition, its residual action will still destroy grasshoppers providing above 70° temperatures return within two or three days. Above 90°, or when grasshopper are full grown, you should double the dosage for best results.

Spraying for Grasshoppers in Missouri

In 1955 a cooperative state and federal research project was conducted to find a grasshopper control method fitted to Missouri conditions. Research workers made large-scale spray tests with aldrin, dieldrin, and heptachlor applied at recommended dosages. They selected a block of farms totaling 2,987 acres in the southwest part of the state for the tests. They sprayed 1,388 acres in 1955 and 2,192 acres in 1956. Their main objective was to see how much spraying it would take to control all the grasshoppers in one season. They checked to see what effect this spraying had on infestations the following years. Several farms outside the treated area were included in the check. The sprays were applied with a turbine-blower sprayer with a side-delivery nozzle at 1 to 2½ gallons per acre in a 2- to 3-rod swath. They kept records of the development and activities of grasshoppers, weather,

and anything else that might influence results.

Conclusions from Spray Tests

Several conclusions were reached from these tests:

1. The main sources of grasshopper infestation in southwestern Missouri are the pasturelands, including marginal wood lots, alfalfa, and field margins. Control on the hatching grounds may require spraying all the pastureland and alfalfa on a farm as well as the field margins. This may include from half to three-fourths of a farm. It is sometimes difficult to cover all the sources of infestation, since areas such as wood lots or waste places are too rocky, woody, or bushy to allow access with spray equipment.

2. The hatching period of the most important species in Missouri begins about April 10 and may last for 10 to 12 weeks. Beginning in mid-July there is another hatching period, for the second-generation migratory grasshopper, which lasts for five or six weeks. Spraying should be timed so that one application will get as many of the young hoppers as possible. This usually means waiting until June 1. By the time the hatching of the differential grasshopper is far enough along for treatment, some adults of the migratory grasshopper will be ready to lay eggs for its second generation. When these two species are in a mixed infestation, it is practically impossible to get all the hoppers in one spraying. A careful check on the infestation in any field will determine when it should be treated.

3. From 95 to 100 percent reduction in numbers can be expected from the use of aldrin or heptachlor at 2 ounces, or dieldrin at 1 ounce, per acre before daily temperatures of 90° F. occur and before the grasshoppers reach the last stage of development. This usually means before June 15. Thereafter dosages must be increased to twice these amounts. (Fig. 6).

4. Grasshopper migrations on foot become noticeable in late June. In years of severe infestations, flights take place after the middle of July. Migrating grasshoppers are probably the major source of reinfestation of treated fields. In July and August a second and sometimes a third treatment of a field is necessary to protect crops. Spraying at this time causes little damage to crops. It was demonstrated that 95 to 100 percent of the grasshoppers in corn six to eight feet high can be destroyed by spraying with ground equipment at this time. About 5 percent of the corn plants were knocked down by the spray truck.

5. Residue tolerances and intervals between the application of the insecticide and the feeding or pasturing of livestock have been established for some insecticides. Ask your county agent for the latest restrictions on the use of grasshopper insecticides.

6. Using insecticides on crops and pastures may or may not affect grasshopper populations in those fields the next year. Reinfestations do occur in treated fields, mostly from second-generation grasshoppers or those moving in from untreated places. These reinfestations limit the effectiveness of control to one year.

In Missouri, **grasshoppers in damaging numbers can be expected periodically along with dry years. They can be controlled with organic insecticidal sprays to protect all crops and pastures from damage.**

The main sources of grasshopper infestation are pastures and hayland, including marginal woodland, alfalfa and clover fields and field margins. Several factors such as migrations and the inability to treat all sources of infestation limit the effectiveness of control to one year. Not all grasshopper infestations can be eradicated feasibly.

The hatching period of the four important species in Missouri extends over a period of ten to twelve weeks, beginning about April 10. For best results spraying should be started about June 1. Dosages of insecticide must be doubled or tripled for best results after daily maximum temperatures reach 90° F or above, around June 15, or when the grasshoppers become full grown.