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Grasshoppers and their Control

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Grasshoppers and Their Control

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GRASSHOPPERS AND THEIR CONTROL

By

H. C. Severin and G. I. Gilbertson

Summary.

1. Injury to farm crops may be caused by grasshoppers in every part of South Dakota, but the damage is ordinarily done in alfalfa fields and in areas bordering such fields.

2. The locusts which are responsible for the damage are reared usually in alfalfa fields or along the borders of these fields and are not of the migratory kinds.

3. Locusts are held in check ordinarily by various natural agencies, but when these are lacking, the grasshoppers tend to increase in large numbers. If an outbreak of hoppers is to be prevented under these circumstances, artificial methods of control must be adopted.

4. In the fall of the year, after October 15, such areas as contain grasshopper eggs should be plowed, and in the spring the soil should be disked, harrowed and rolled, so as to pulverize and pack the ground. If the ground cannot be plowed in the fall and if spring plowing is possible, then this should be done before May 15. The plow should be followed by the disk, harrow and roller. If the ground is not to be plowed, then it should be disked, harrowed or cultivated in the fall, and in the spring it should be thoroughly harrowed. If in the spring, there are numerous grass clumps in the field, and if these clumps contain uninjured grasshopper egg masses, the field must be thoroughly worked with a brush harrow or plank drag.

5. As soon as the grasshopper eggs have hatched

in the spring, the young hoppers should be killed with poisoned bait. Poisoning should not be delayed until the hoppers are mature or almost mature, for considerable injury will have been done by the immature locusts by that time.

6. The use of the hopper catching machine and the hopperdozer are two effective methods of reducing a plague of locusts, and these machines, if they are employed at all, should be put in operation while the locusts are still small.

7. Other methods of locust control, such as burning the young hoppers, destroying them with poultry, etc., are aids in reducing the number of insects rather than very effective means of destruction.

8. Cooperation is usually an essential factor in grasshopper control.

Introduction.

Every year farmers and gardeners of one locality or another in South Dakota suffer serious losses to their crops through the ravages of grasshoppers.[1] Practically all of the farm and garden produce grown in this state is liable to locust injury, but usually the greatest amount of damage is done in alfalfa fields.

Corn, oats, wheat, barley, rye, timothy, alfalfa, potatoes and garden truck, all were damaged more or less through the work of grasshoppers in 1909, 1910 and 1916, and almost invariably the troublesome insects were bred in alfalfa fields. The hoppers, which were responsible for this injury were not of the migratory kind and usually spent their entire lives in the field where they hatched or in neighboring areas. The grasshopper problem, therefore, is usually a personal one with most of our farmers and gardeners, although cooperation between neighboring individuals in fighting locusts is, at times, an urgent necessity.

It is no longer necessary to be helpless in the face

of grasshopper attacks, for we now know how to successfully combat a plague of this kind. We have demonstrated time and again that such plagues can be wiped out at a reasonable expenditure of money and labor and a consequent saving of the crop. Not only is it possible to control a serious outbreak of hoppers,[1] but through proper farm methods the possibility of a plague may actually be removed. During most years, locusts are held in check by various natural agencies, but whenever these checks are absent, the hoppers tend to increase in large numbers. A farmer usually does not watch his insect pests carefully enough, and consequently does not discover the danger until his crops are largely destroyed. Were this not true, measures would have been adopted which would have destroyed the eggs or the young locusts before any damage had been done.

Injury Caused By Grasshoppers.

Grasshoppers were unusually abundant in 1916 over the greater portion of South Dakota, but it was in the western two-thirds of the state where the ravages of the pest were most severe. The feeding organs of locusts are of the chewing type and, consequently, the parts of the plants which are attacked, disappear entirely.

An alfalfa field, which has been badly damaged by these insects, will have the general appearance of a field of high stubble, for not a leaf or flower is to be seen and even the bark of the alfalfa stems has been chewed away. Likewise, if a potato or corn field is invaded by a swarm of hoppers, all the softer parts of the plants may be eaten away and only the harder parts remain. Fields of small grain may be destroyed entirely. This is true not only of the spring planted grain but also of that planted in the fall. It is only after such a severe loss that many persons ask for help but, of course, a large amount of injury has already been done and now steps can be taken only to prevent further damage and a recurrence of the

1 In this bulletin we use the words locust, grasshopper and hopper interchangeably.

destruction the next year. In other instances, the injury is not so severe and then usually no attention is paid to the hoppers or their work. The yearly loss, which results from grasshopper injury in South Dakota when the locusts are not especially abundant, is considerable, for these insects are with us every year and the food material which they devour may be of the choicest and most succulent character.

The Principal Injurious Grasshoppers.

The grasshoppers which do the greatest amount of damage in South Dakota are the differential locust (*Melanoplus differentialis* Thom.), the red-legged locust (*Melanoplus femur-rubrum* De G.), the lesser migratory locust (*Melanoplus atlanis* Riley) and the two-lined locust (*Melanoplus bivittatus* Say). These four insects may be distinguished from one another by means of the following key:

A. Body robust, 1 to 2 inches in length.
  1—Two light stripes on back..... ..... *Melanoplus bivittatus*
  2—Back not striped..... ..... *Melanoplus differentialis*
B. Body slender, ¾ to 1¼ inches in length.
  1—End of body notched..*Melanoplus atlanis*
  2—End of body not notched..... ..... *Melanoplus femur-rubrum*

The differential locust (Fig. 1) occurs in two forms, a bright yellowish green type and a black one. These two forms occur together in the same fields, the dark

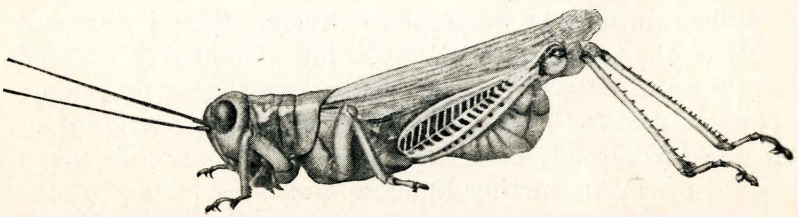


Fig. 1. Differential grasshopper (*Melanoplus differentialis*). Enlarged.

specimens, however, forming but a small percentage of the total number of this species. The differential locust, or the yellow grasshopper as it is sometimes called, was present in greater numbers in the grasshopper outbreak of the year 1916 than any of the other species; in fact, seven out of every ten hoppers examined were insects of this kind.

The two-lined grasshopper (Fig. 2) may be recognized from the fact that two yellow stripes pass over the back of the insect from a position behind the eye to the tip of the first pair of wings. This species was pres-

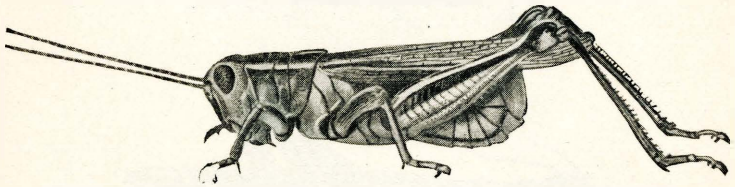


Fig. 2. Two-lined grasshopper (*Melanoplus bivittatus.*) Enlarged.

ent in 1916 only in scattering numbers wherever a grasshopper outbreak occurred, but in past years it has been very abundant at times.

The red-legged locust and the lesser migratory (Fig. 3) are very similar in general appearance and size, but the latter may be distinguished readily from the former by the fact that the end of its body is notched. In the grasshopper outbreaks of 1916, the red-legged species was present in far greater numbers than the lesser migratory and consequently was more injurious.

It is still the common opinion in South Dakota, that the grasshoppers which are destroying our crops at the present time, are Rocky Mountain locusts (*Melanoplus spretus* Uhl.). The older inhabitants of South Dakota and neighboring states well remember the visits of the dreadful scourge of these insects of the sixties and seventies and the vast amount of injury which was done by the hoppers at that time. Frequently the writers were

asked, "Is it possible for us to control the grasshoppers working in our fields and gardens and are these insects Rocky Mountain locusts?" Our replies were to the effect that the hoppers were not Rocky Mountain locusts, and that the troublesome pest could be controlled at a reasonable expenditure of money and labor.

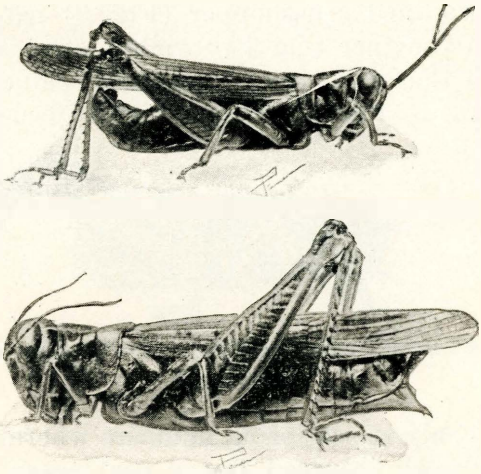


Fig. 3 Lesser migratory grasshopper (*Melanoplus atlanis*): Above, adult male; beneath, adult female. About twice natural size.

From Where Do Our Injurious Grasshoppers Come?

The grasshoppers which ordinarily damage our crops are not of the migratory kind, and usually spend their entire lives in the field where they hatched and in this same field they lay their eggs. When there is a shortage of food, however, the hoppers migrate, but the distance that they cover is small and normally the migration stops in a neighboring field. Migration is accomplished by walking and jumping when the insects are not yet fully winged, but when the wings are fully developed, the hoppers may resort also to short flights

as a means of travel. It is seldom that any of the four species discussed in this bulletin are seen flying in swarms through the air, and if such a swarm is witnessed, the members constituting it are usually the lesser migratory locusts.

Life Cycle of the Injurious Grasshoppers.

The four species of locusts, which we have been discussing, lay their eggs in the ground during the fall of the year, and after egg laying has been completed, the insects die. The eggs remain unhatched over winter, and in the spring usually during May and early June,

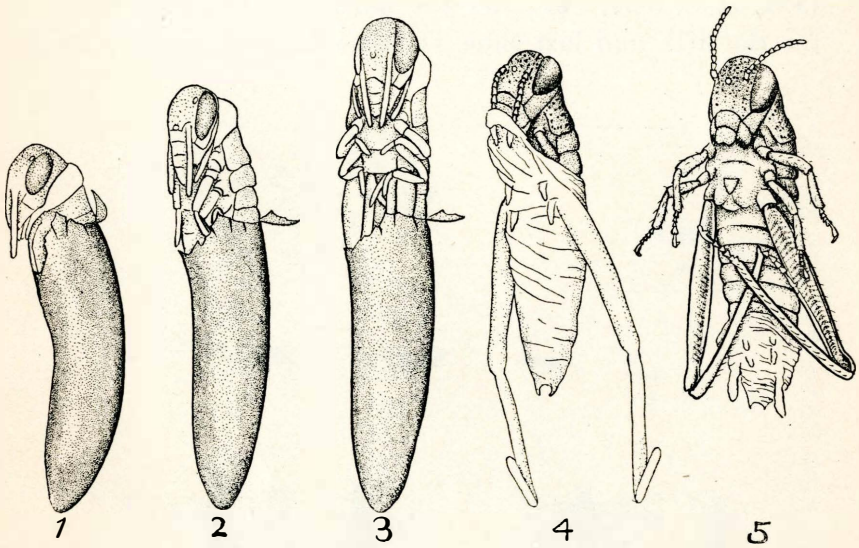


Fig. 4.—Successive stages in the hatching of a grasshopper.

they give rise to young hoppers (Fig. 4). Grasshoppers, which have just hatched, are very light in color and vary from ⅛ to 3-16 of an inch in length, but after the young have been exposed to light and air for a time, their color gradually darkens, and they become less conspicuous (Fig. 5, C-1). The young insects feed upon any succulent material which is at hand, but they can

increase in size only after they molt or shed their hard body covering. Molting takes place on five different occasions during the life of a grasshopper, and after each molt, the skin of the insect remains soft and pliable for a short time. Immediately after a molt, the hopper increases in size, but later the body becomes protected again with a hard covering. When a locust is very young, no wings can be found on its body, but after the first molt has taken place, traces of wings appear. The wing traces become slightly larger after each molt (Fig. 5, C, 3-5), but after the hard skin has been shed for the fifth and last time, the grasshopper acquires its

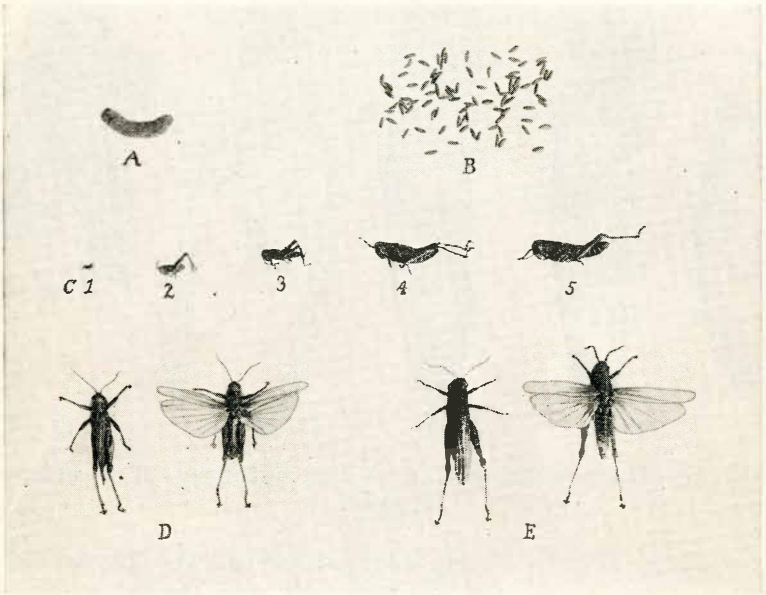


Fig. 5.—Life history of differential grasshopper. A, Egg pod; B, eggs taken from one egg mass; C-1, 2, 3, 4, 5, stages of immature grasshoppers; D, male grasshoppers; E, female grasshoppers. (Original).

full sized wings (Fig. 5, D, E). Not all of the locusts of a particular species infesting a field become winged at the same time, for, weeks after the majority of the hoppers have acquired their wings, there may be found in that same field, grasshoppers which have not yet become adult. This condition is to be accounted for in one of two ways; 1st, not all eggs hatch at the same time; and 2nd, some hoppers require a longer period to become adult than do others. The fact that not all eggs hatch at the same time is to be explained, in part at least, through the fact that a certain amount of moisture and a certain degree of temperature over a definite period of time hastens hatching, while less of the favorable temperature and moisture retards hatching.

Under ordinary circumstances, from 40 to 70 days are required by a recently hatched locust to reach its full growth. Female hoppers do not lay eggs immediately after they acquire wings, but first feed for 10 days or more, mate, and then feed for another interval of 10 days or more. At the end of the second feeding period, a batch of eggs is laid and then the locust either dies shortly after or passes through still another feeding interval, when a second cluster of eggs is deposited. The large species of locusts which we have been discussing, lay one, two and rarely three masses of eggs, while the small species deposit two, three and even four, but the number of eggs in a batch will be considerably smaller when two or more clusters are deposited, than when only one is laid. In South Dakota, egg-laying has been completed usually by the middle of October. From this discussion of the life cycle it is seen that there is but one generation of grasshoppers per year.

How the Eggs Are Laid.

When a grasshopper is about to lay eggs, she makes a hole in the ground or among the stems or roots of plants with her abdomen. For this purpose, the end of the body of each female locust is provided with four

curved, hard, horny, pointed processes, the ovipositor. The hole is made by pressing the tips of these processes against the ground and then alternately opening and closing the ovipositor. The abdomen is worked in this manner gradually downward and backward into the ground or among the stems or roots of plants (Fig. 6). When the abdomen has been forced into the ground as far as it will go, the body is greatly elongated and, if it be a differential locust that we are watching, it may reach 1½ inches beneath the surface. A frothy liquid

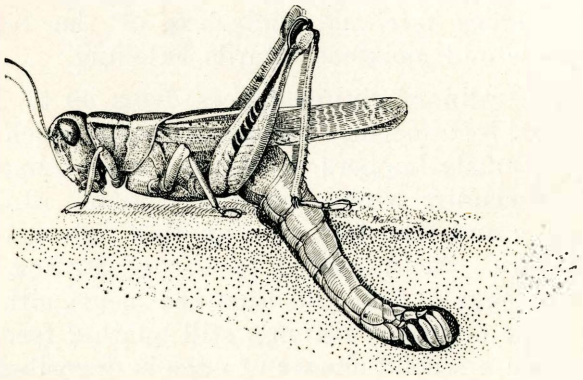


Fig. 6. Two-striped grasshopper laying eggs.

is now poured into the hole, and into this fluid, eggs are placed one at a time. The abdomen is gradually withdrawn from the hole as more liquid and eggs are added, and finally after egg laying has been completed, a mass of frothy material is secreted as a plug to the hole. The dried liquid not only binds the eggs together, but forms an envelope around the egg mass, and to this envelope numerous dirt particles adhere. An egg mass or pod of a differential locust is cylindrical in shape, curved and may be 1½ inches long and ¾ of an inch in diameter (Fig. 7, A). The egg pods of the smaller species of locusts are correspondingly smaller.

Appearance of Grasshopper Eggs.

If an egg mass be broken open carefully, the small yellowish eggs are to be seen. At times, the eggs may be brown or pink in color, but this is usually due to a stain resulting from the frothlike liquid which the locust

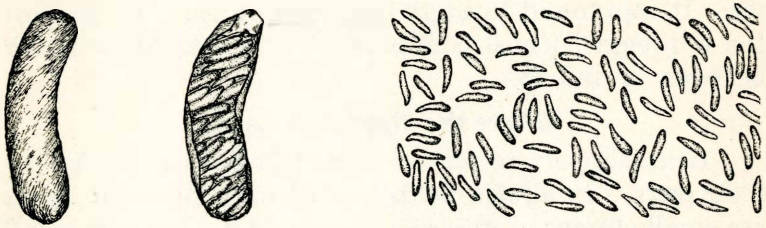


Fig. 7. Egg masses and eggs of differential grasshopper. Natural size. (Original.)
(A) Egg pod with envelope unbroken; (B) Egg capsule with portion of envelope removed to show arrangement of eggs; (C) Eggs taken from one egg mass.

poured over the eggs at the time of egg laying. Each egg of the differential and two-lined locusts is more or less oval in shape, slightly curved, about 3-16 of an inch in length and 1-16 of an inch in diameter (Fig. 7, C), but the eggs of the red-legged locust and the lesser migratory are slightly smaller. If the envelope surrounding an egg pod be removed carefully, it will be seen that the eggs are neatly packed together, and that none of the eggs lie at right angles to their neighbors (Fig. 7, B).

Number of Eggs Laid By One Grasshopper.

The total number of eggs laid by a grasshopper depends upon the number of clusters which are deposited and upon the number of eggs in each mass. The writers examined 30 pods laid by differential locusts and found that the number of eggs in these masses ranged between

50 and 127 and averaged 91. It is possible that some of these clusters were produced by a locust which deposited two batches of eggs, and if this were the case, the average number of eggs laid by one female differential grasshopper would considerably exceed 91. The egg masses of the smaller species of hoppers contain a far smaller number of eggs than do those of the larger species. It was found through examination that the pods of the red-legged locust contained eggs ranging in number between 14 and 28.

Where the Eggs Are Laid.

Grasshoppers select suitable regions in which to lay their eggs. In alfalfa fields, the favorite breeding areas are small clumps of grass surrounded by a large or small spot of bare ground, or clumps of grasses fringing a bare area such as an ant hill. Oftentimes, alfalfa plants in thin stands serve as attractive places for egg laying, and in such cases the egg masses are placed among the stems near the crown of the plants. The areas mentioned are chosen, 1st, because they warm up rapidly in the morning, 2nd, because here the insect can get a firm footing while boring a hole in the ground, and, 3rd, because the ground elsewhere may be too hard. Sometimes a spot of ground entirely free from plant growth is chosen for egg laying, but this is not the usual state of affairs with the four species of locusts which we have been discussing.

If the alfalfa grower who has been troubled with grasshoppers, dig up in his alfalfa field, grass growing in small clumps and carefully break apart the clumps dug, he will almost invariably find egg clusters of locusts among the roots and lower portions of the stems. Grama, young buffalo, and false buffalo grass seem to be the preferred grasses for egg laying.

The writers, on a number of occasions, marked off areas a foot square on the outskirts of ant hills and counted all the egg pods and eggs in these areas. In several instances 55 or more masses were obtained from

such areas and these included a total of 5,000 eggs or more. Circular clumps of grass measuring 2 inches in diameter were taken from these same areas and were found frequently to contain over a thousand eggs (Fig. 8).

Fig. 8. Clump of grama grass, showing grasshopper egg masses among the stems and roots. (Original).

Principal Plant and Animal Enemies of Grasshoppers.

The natural enemies of grasshoppers may be grouped into two divisions, first an animal and second, a plant group. The animal enemies are far more numerous in species than are the plant foes and they are also more important.

Animal Enemies of Young and Adult Grasshoppers.

Many of our large well known animals prey upon grasshoppers, but of these, it is the birds that usually act as the most efficient destroyers of young and adult locusts. Practically all birds which feed in fields infested with grasshoppers, include these insects in their bill of fare, but the following are probably the most useful in this respect: prairie chickens, quails or bob whites, meadow larks, Franklin gulls, all species of plovers, sparrow hawks, marsh hawks, red-winged blackbirds, yellow-headed blackbirds, purple grackles, crows, screech owls, burrowing owls, robins and several kinds of sparrows. Chickens and turkeys when present in sufficient numbers, also aid in checking an outbreak of hoppers.

Toads, lizards, some snakes, ground squirrels, mice, hogs and skunks, all feed upon locusts and destroy large numbers of young and adult.

Small red or orange colored mites, smaller or slightly larger than an ordinary pinhead, may be found attached to the wing pads of young locusts or to the wings of fully developed hoppers. The mites in this stage do little, if any, harm to the grasshoppers, for some may have as many as 75 to 125 or more mites attached to them and still be as active and apparently as vigorous as uninfested grasshoppers. Occasionally a locust may be destroyed by these mites, but this, if done at all, is rather uncommon.

Large spiders and certain species of beetles and flies capture locusts and feed upon them, but these animals are usually not numerous enough to act as very efficient checks upon a grasshopper plague. The same may also be said of hair worms which are parasitic within locusts, and of such wasps which sting and paralyze hoppers in order that they may serve as food for the young of the wasps.

At times, several species of flies may destroy locusts

by the hundreds of thousands. These flies deposit either eggs or maggots upon the body or wings of the hoppers. The eggs hatch shortly into maggots, and these then make their way into the body of the grasshopper, and, after feeding and acquiring their complete growth, bore their way out again, a process which usually ends in the death of the hopper.

Plant Enemies of Young and Adult Grasshoppers.

Occasionally, during or after a warm moist summer, numerous dead or dying grasshoppers may be found clinging tightly to the tops of alfalfa plants, grass plants, weeds, etc. (Fig. 9). These locusts have been attacked by a fungous disease, an enemy, which gains access to and develops within the body not only of adult hoppers but also of immature forms. A grasshopper, which has been attacked by this disease, crawls away from the ground as far as it can and then firmly clasps the object upon which it is resting. The bodies of the diseased locusts swell and finally break open, thus liberating thousands of spores, which, in turn, communicate the disease to other hoppers. At least two fungous diseases attack locusts in South Dakota.

Considerable misunderstanding regarding the value of fungous diseases as a means of grasshopper control seems to be found among the farmers of South Dakota It seems to be the prevalent opinion among many that to rid a field of hoppers, one need only scatter through it a few diseased locusts. It should be borne in mind, however, that these fungous diseases develop with great rapidity only under the most favorable conditions, two of which are a high temperature and high humidity, and when these factors are absent, diseased locusts become uncommon or rare. Further, the diseases occur naturally over the state and await only ideal conditions to develop.

Fig. 9. Grasshoppers that have been killed by a fungous disease.

Chief Enemies of Grasshopper Eggs.

The eggs of grasshoppers may be destroyed by numerous enemies, chief among which are the larvae or grubs of blister beetles. So abundant may these grubs become, at times, that they destroy almost every locust egg mass in a field. Not all larvae of blister beetles feed upon grasshopper eggs, however, but the grubs of the common troublesome blister beetles which devour our alfalfa fol-

iage and flowers, potato foliage, etc., do destroy locust eggs. The beetles under discussion lay their eggs in the ground. The eggs number several hundred and soon hatch into small active larvae that are well provided with legs and eyes (Fig. 10, A). Each grub runs about actively, all the while seeking a grasshopper egg mass, and when one is found, the larva burrows into the same and begins to devour the eggs. After feeding for a time, the grub molts and now its legs are reduced in size and its body is curved and fleshy. The larva then feeds for

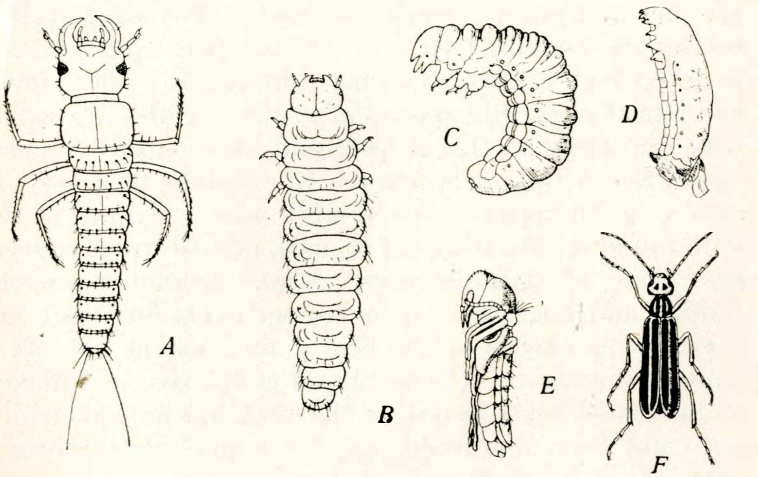


Fig. 10. Life cycle of blister beetle. (A) first larval stage; (B), (C), other larval stages preceding pseudo-pupa; (D) pseudo-pupa; (E) pupa; (F) blister beetle. All enlarged except F. After Riley.

another period and, after molting, assumes the appearance of the grub shown at B, Fig. 10. Another feeding interval and molt follows and then the insect resembles the form represented at C, Fig. 10. The larva now usually leaves the grasshopper egg pod, burrows into the ground a short distance and transforms into a yellow or orange colored body, the pseudo-pupa (Fig. 10, D). It is in this stage wherein the blister beetles pass the winter. In the following spring the pseudo-pupa gives rise

to an active form of grub, which soon changes to a pupa (Fig. 10, E). The pupa, in turn, gives rise to a beetle (Fig. 10, F).

A grasshopper egg mass which has been attacked by a blister beetle larva, usually has the greater share of its eggs destroyed, but remains of the destroyed eggs may be found in the pod. If the egg mass be a large one, some of the eggs will be unharmed, but if the pod be small, all of the eggs will be destroyed.

Besides blister beetle grubs, the larvae of certain bee flies and ground beetles, as well as the adult ground beetles themselves, feed upon grasshopper eggs and act as important checks to locust outbreaks. The larvae and adults of certain species of ground beetles are especially important in this respect and become quite numerous in South Dakota whenever an outbreak of grasshoppers tends to appear. A red silky mite, the adult of the mite found on the wings of locusts, also destroys numerous eggs of grasshoppers. Mice, ground squirrels, skunks and hogs feed upon hopper eggs, but their importance as checks is not nearly as great as the other animals discussed. Certain birds which frequent disked or cultivated fields feed upon the eggs, but in fields which have not been disturbed, the birds play no important part in egg destruction.

Reasons for Grasshopper Outbreaks.

Grasshoppers fluctuate in numbers from year to year and this is explained through the fact that conditions favorable or unfavorable to locust development vary from year to year. There are many reasons why hoppers increase in numbers to such an extent in South Dakota where they become a plague, the chief causes being:

1. The soil in which the eggs are laid is left undisturbed from the time the eggs were deposited until they hatched.

2. There is a sufficient food supply for the young hoppers immediately after they have hatched.

3. There may be a lack of plant and animal enemies.

4. Favorable weather may be prevalent during the time the eggs are hatching and immediately following this period.

5. Favorable weather may prevail during the life of the grasshopper.

6. The above mentioned conditions may recur two or more years in succession.

7. Locusts multiply rather rapidly, the rate of increase per year varying from 20 to 85 or more.

Methods of Grasshopper Control.

Locust control measures may be grouped into two divisions: 1st, those which deal with the destruction of the eggs; and 2nd, those employed in destroying the hoppers, both young and adult. The methods which are followed in destroying the eggs are preventive in nature, and are so called because through them an outbreak of locusts may be avoided. The measures which are employed in destroying the young and adult locusts are remedial in character, for it is by these measures that swarms of young and adult hoppers are brought under control.

Destroying Grasshopper Eggs.

A farmer or gardener who has been troubled with locusts during the year should examine his fields at the end of October for grasshopper eggs. Such fields as were badly overrun with hoppers during the summer, and over which are scattered numerous dead grasshoppers in the middle of October usually will contain a large number of egg masses. Not only should an examination be made of such fields, as are likely to contain eggs, but the borders of these fields, ditch banks, roadsides, etc., also must be investigated.

Soil that contains eggs should be plowed, disked, harrowed or cultivated. Which of these methods will be used, depends upon the farmer and his tools, the area

that is infested, the crop that is now on the field and the crop that is to follow.

Plowing has for its object, the burial of the eggs to such a depth where the young, should they hatch, will not be able to make their way through the soil to freedom. The ground should be plowed at least 6 inches deep between the time the eggs were deposited and before they have hatched in the spring, usually between October 15 and April 30. The plowed soil should then be pulverized and packed as much as possible, and this may be done by disking or harrowing and, whenever necessary, rolling the land. The degree of success which is obtained through plowing will depend upon the following conditions:

1. The depth at which the eggs are buried.
2. The thoroughness with which the packing of the soil has been accomplished.
3. The character of the soil.

As a rule, recently hatched locusts are not able to tunnel through compact soil for a distance of 5 inches or more, and such hoppers as have hatched at this depth, either die before gaining freedom or make their way through the soil to the open air by following cracks or other channels. It should be borne in mind while the farmer or gardener is plowing and compacting the soil, that young hoppers are able to tunnel through a light sandy soil for a greater distance than through a heavy clay soil, and whenever possible, therefore, deeper plowing of the lighter soil is advisable.

Such areas as are infested with grasshopper eggs and which are not to be plowed, should be disked, harrowed or cultivated in the fall after the eggs have been laid. Since the egg pods are to be found in the first two inches of surface soil, it will not be necessary to stir the ground to a depth greater than two inches. The object of disturbing the soil as recommended, is to crush as many of the egg masses as possible and expose the re-

mainder in a broken condition to the drying action of wind and sun or to the attacks of animals and plant diseases. Eggs, which have been exposed in dry weather to the effects of wind and sun for several weeks, will be shriveled and dead. Usually before the eggs shrink, however, the egg shell (chorion) cracks and in many instances peels away from small areas over the egg. Success with this method of control will depend upon the thoroughness with which the locust egg masses are crushed, broken and exposed.

A field, which is being disked, should be worked not only lengthwise, but also crosswise and even cornerwise whenever possible. Further, the land should be left in as rough a state as can be, in order that the largest number of eggs may be exposed, and early the next spring such a field should be well harrowed. If in the field at this time, there are numerous grass clumps which contain uninjured egg masses, the clumps may be broken up with a brush harrow or plank drag.

A brush harrow may be made by fastening together brush, young trees, or other flexible material with heavy wire or heavy woven wire such as hog fencing. The brush harrow, before it is used, should be weighted down with bags of earth, sand or other material.

A plank drag may be made by bolting together three or four planks. These planks should be 12 or 10 inches broad, 2 inches thick and 8 or 10 feet long and they should be fastened together lengthwise so that one plank will overlap the one behind it by 2½ inches. Strips of strap iron should be fastened to the forward edge of each plank in order to prevent the rapid wearing away of this edge of the planks. The drag must be weighted down to do effective work and should not be longer than 8 or 10 feet where the ground tends to be uneven.

The use of a brush harrow or a plank drag will break up clumps of grass, and will crush many of the egg masses enclosed in the clumps. Such eggs as are not crushed

but exposed, will dry out in a few weeks of sunshine and wind.

Alfalfa fields, which are badly infested with locust eggs, should be thoroughly disked in the fall. Heretofore, the disk-harrow, set straight and weighted down so that it would disturb the soil to a depth of two or three inches, was used to work alfalfa fields in the spring. Such machines injured alfalfa seriously in some sections and consequently a new harrow, known as the alfalfa renovator or spike tooth disk, has come into use. The renovator tears up the soil, but does not injure the crowns of the alfalfa plants nearly as much as does the ordinary disk harrow. Early during the next spring, the alfalfa field should be worked with a straight-tooth harrow, but if, at this time, there are numerous grass clumps in the field and if these contain uninjured egg clusters, then the brush harrow or plank drag should be brought into use.

Whenever it is possible to destroy a large number of exposed eggs through the use of poultry, wild birds, hogs or other animals, this should be done.

How to Destroy Young and Adult Grasshoppers.

If the grasshopper eggs have not been destroyed by one of the methods mentioned, and the eggs have hatched into young hoppers in large numbers, then one of the following remedial measures should be adopted. Which of the methods is chosen, will depend upon the size of the area that is infested with locusts, the crop which is to be protected, the materials which are at hand, and the time and help that are available.

Poisoned Bran Bait Method of Control.

The use of the poisoned bran bait offers a simple, cheap and effective method of destroying young and adult locusts. The bait is prepared according to the following formula:

[1]Bran, coarse flaked if possible....	25 pounds
White arsenic or Paris green.....	1 pound
Lemons or oranges	6
Cheap molasses, such as sorghum, black strap or glucose sirup....	2 quarts
Water	4 gallons

The dry bran and poison are placed in a large tub or box and mixed with a hoe, wooden stick or other implement. The bare hands and arms should not come in contact with the poison more than is necessary, for the skin of the arms and back of the hands may absorb enough of te poison to cause serious trouble. The bran and poison should not be mixed out in the open air where a strong wind is blowing, and it is advisable for the person preparing the bait, to keep tied over his nostrils a sponge moistened with water. The sirup or molasses should be dissolved in three gallons of water, and to this is added the lemon or orange juice, followed by the finely graded pulp and peel of the fruit. The resulting mixture is poured slowly over the poisoned bran, and at the same time the entire mixture should be stirred so that every particle of bran is thoroly dampened. If the bait will hold another gallon of water, then this amount should be added, for the efficiency of the poisoned material depends upon the length of time that it remains damp. The bait may be prepared, in part, the day before it is applied to the field, but the poisoned bran should not be moistened more than 12 hours before it is to be scattered.

The proper time to apply the bait is late in the afternoon just before the hoppers climb up to their roosting places. During the heat of the day, the locusts remain in the shade, but towards evening they climb up the stems of plants, fence posts or other objects. Here the hoppers remain over night and during the early portion of the following morning until the sun begins to warm up the atmosphere. The poisoned bait is attractive and efficient

[1] Alfalfa meal or shorts may be substituted if bran cannot be obtained.

when it is fresh and moist, and when it is in this condition, the locusts prefer to feed upon it rather than upon their natural food plants. When, however, the bait becomes dry, and this is usually the case after the material has been exposed for a day, it looses its attractiveness and consequently little of the poisoned material is eaten. The efficiency of the bait is also destroyed by rains and showers, and for this reason the poisoned bran should not be applied on a day when there is liable to be a rainfall.

The bait should be sown by hand or by a broadcast seeder over such parts of fields and gardens as contain grasshoppers. No very great danger from poisoning is incurred by sowing the material with the naked hands, unless the skin has been cut or broken. A convenient method of scattering the bait over a large area is to sow it from the rear end of a light wagon. Where the locusts are very numerous, the amount of bait prepared by using 25 pounds of bran should be sufficient to cover 5 or 6 acres, but where the hoppers are only moderately numerous, this amount will treat 10 to 12 acres. In the latter case, the poisoned material is scattered so thinly over the ground that it is to be seen only by careful observation. Whether 2 or 4 pounds of the bran are to be applied to an acre, it is advisable to weigh out the amount of bran accurately, make it up into a poisoned bait and then sow it over an acre of land, in order that a proper conception may be obtained as to how thinly the bait is to be used. When the locusts are very abundant, it may be necessary to repeat the application of the bait a second or even a third time at intervals of two or three days. Under no circumstances should the poisoned material be sown thickly or placed in heaps in a field or garden. If these instructions are followed, there will be no danger of poisoning domestic animals or wild birds. However, care should be taken that the receptacles containing the prepared bait be kept away from children and farm animals.

If grasshoppers are scattered thru a field of oats or

other small grain or alfalfa that cannot be cut, the bait must be broadcasted over the entire field. If only a portion of the field is infested, then only that part should be treated. If a grain, potato or alfalfa field is being invaded from a neighboring area, a strip several rods wide and bordering the area from which the locusts are coming, is to receive the poisoned bait. This treatment should be repeated at intervals of two days as often as is necessary. If alfalfa contains a large number of locusts, and if it fits in with the general scheme of farming to cut that alfalfa for hay, then this should be done. After the alfalfa has been cut, the field is to receive one or more applications of the poisoned bait. Or instead of cutting over the entire field, strips of alfalfa 4 to 6 feet wide may be left uncut at intervals of 75 to 100 yards. Within a few days, the grasshoppers collect in these strips and here the insects may be killed with the poisoned material.

If, instead of working in a low-growing crop, the hoppers are destroying a tall-growing one, such as corn, then it is advisable to use a modified poisoned bait. The same ingredients are used in this bait as were employed in the ordinary, but the quantity of molasses should be, according to Milliken, 3 to 4 times the usual amount, and the water should be correspondingly less. This bait "is applied by throwing small quantities among the tops of the plants so that it will stick to the leaves or blades."

The effects of the poisoned bran bait are not immediate; in fact, some hoppers may begin to die 4 hours after the poisoned material was applied, while others will be dying 2 to 5 days later. The full effects should be judged from the number of dead hoppers on the ground 3 to 5 days after the bait was scattered. It should be noticed that many of the poisoned locusts will be found dead among the stems of plants, such as alfalfa, grass clumps etc., and these hoppers must not be overlooked when an estimate of the value of the poisoned bait is being formed. From 40 to 95 per cent of the grasshoppers

may be killed with one application of the bait, but the per cent of hoppers destroyed will depend in large measure upon their original abundance. In very severe outbreaks, from 40 to 60 per cent of the locusts should be destroyed with one application of the poisoned bran bait, while with a second application 70 to 80 per cent should be killed. In some instances, where a badly infested field received two treatments of the poisoned bait, from 50 to 500 dead locusts were counted over a square foot of ground.

The cost of treating a field or garden with the poisoned bran bait varies somewhat with conditions, but the price per acre of one treatment, including labor, will range between 11 and 25 cents. The expense will be increased if Paris green is used instead of white arsenic and if a high grade of molasses or sirup is employed instead of the grades mentioned in the formula. Furthermore, the efficiency of the bait is decreased if the better grades of molasses or sirups are used.

The Criddle Mixture.

The Criddle mixture, in modified form, is another poisoned bait which is very effective as a means of destroying locusts. It may be prepared according to the following formula:

Fresh horse droppings free from straw	one-half barrel or fifty pounds
White arsenic or Paris green	1 pound
Lemons or oranges	6 to 8

This bait, like the poisoned bran bait, must be thoroly mixed before it is used. If fresh horse droppings are not available, older droppings may be substituted, but a pound of salt and sufficient water should then be added to moisten the entire mass. In mixing the bait it is advisable to wear rubber gloves and to observe the precautions discussed under the preparation of the poisoned bran bait.

The modified Criddle mixture should be scattered

broadcast over the fields, gardens etc. wherever locusts are to be found, and such direction and precautions as were discussed under the application of the poisoned bran bait should be followed or observed when the modified Criddle mixture is to be applied. This mixture is not as effective as the poisoned bran bait, but is far cheaper.

The Grasshopper Catching Machine and How To Use It.

Grasshopper catching machines (Fig. 11) have been used very effectively in South Dakota in the control of locust outbreaks. With these devices, no oil or tar is needed, for the hoppers are caught alive. A ma-

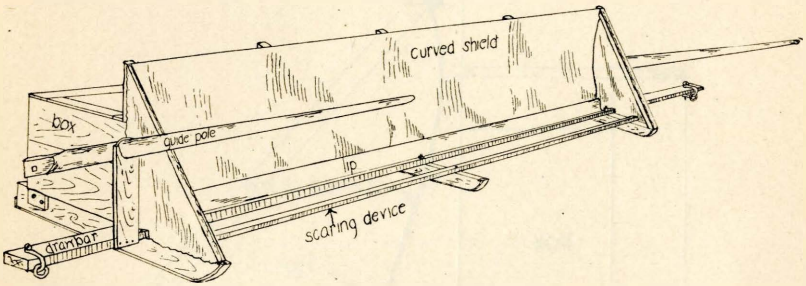
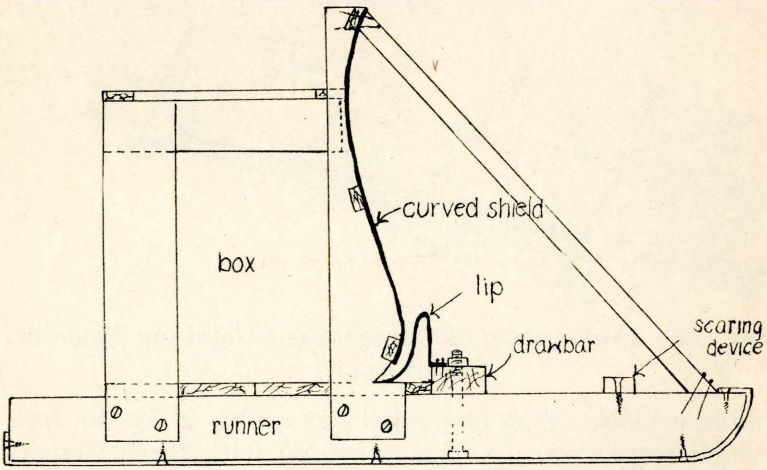


Fig. 11. Perspective of Grasshopper Catching Machine. (Original).

chine consists of an elongated box 2 by 2 by 16 feet, which rests upon a sledge provided with three runners or skids that have been shod, and which measure 2 inches by 4 inches by 5 feet. The upper and rear sides of the box are made of wire mosquito netting, the base is formed by the floor of the sledge, and the front is constructed of a curved shield of tin or galvanized iron. This shield closes the entire front of the box except two inches at the bottom, and extends about six inches above the box (Fig. 12). In front of the shield is a tin or galvanized iron lip, four inches high. One edge of this lip is bent under the large shield and nailed to the floor of the box, while the other edge is nailed to a long draw

bar two inches by four inches by twenty-four feet. The drawbar is bolted to the runners as shown in Fig. 11. The lip should be bent and nailed to the machine so that there is a space of two inches between the lip and the lower edge of the shield, and a space of 4 inches between the shield and upper edge of the lip. The machine is drawn over the field by horses, one horse being hitched to each end of the drawbar. To keep the horses an equal distance apart, two poles twelve feet long may be fastened to the machine, as indicated in Fig. 11, and the horses are then tied to the outer side of these poles. As the machine is drawn over the field, the hoppers jump when the catcher approaches them, and before they can



fall to the ground, they strike the shield, slide down its curved surface, and fall upon the inner face of the lip. The lip then throws the grasshoppers back into the box. In order that the hoppers may be made to jump at the proper time, a rope or wooden strip is fastened to the catcher so that it will drag over the ground or disturb the plants about a foot ahead of the machine (Fig. 11).

The grasshopper catcher may be used upon practically all low-growing crops, such as grain, flax, hay, potatoes, etc. It cannot be used on ripening grain, on corn or on seed alfalfa on which the seed pods have be-

come well developed. The catcher should be run first over such parts of fields where the locusts are most abundant, for it is in such areas where the greatest amount of damage is being done and where the greatest number of locusts are to be caught in a given time. Where the locusts are abundant and winged, it should not be necessary to run the machine longer than 10 to 15 minutes, in order that the catcher may be loaded to its capacity. Two to three bushels of grasshoppers should be in the machine at this time and these must now be removed. If the locusts are not taken out of the catcher, they pile up and clog the entrance to the box. As soon as the machine has been brought to a standstill, the entrance should be closed with sacks, a long roll of canvas or other material. The box is opened by raising one of the doors on the upper side, but before doing this, it is well to strike the wire screen sharply so as to knock off the locusts clinging thereto. The grasshoppers are shoveled out of the box into sacks (Fig. 13), and the bags, after being tied, may be left out in the field until the locusts

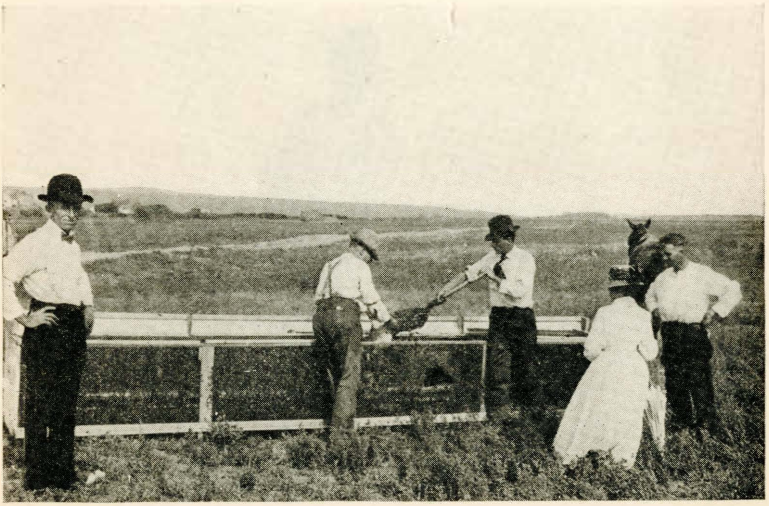


Fig. 13. Shoveling grasshoppers out of a hopper catching machine into a sack. (Original).

are dead. Usually the hoppers die in these sacks within three days, and then the bags may be emptied and used over again. The locusts may be sun-dried, ground and later fed to poultry or they may be used as fertilizer.

The hopper machine does not catch all the locusts from such areas over which it passes but once, and, consequently, it will be necessary to run over badly infested fields several times. Some idea of the efficiency of the machine may be formed when it is realized that a bushel of adult yellow hoppers, *M. differentialis*, weighs about 25 pounds and contains about 20,000 specimens. Further, if slightly over two bushels of adult locusts are caught from one acre every 15 minutes (Fig. 14), then one hopper is taken from every square foot in that acre every 15 minutes. If an alfalfa field is infested with grasshoppers, and if it is planned to use a hopper catcher to bring the locusts under control, the field should be cut if pos-

Fig. 14. Bag of grasshoppers caught with hopper catching machine in 15 minutes. (Original).

sible, but strips of alfalfa 6 to 8 feet wide should be left uncut every 75 to 100 yards. The locusts will collect in the uncut alfalfa and then the machine may be run back and forth over the narrow strips.

In making a hopper catcher, it will be well to pursue the following plan. First cut and shoe the skids; then fasten the draw bar to them, and nail to the skids the boards which form the floor of the box; cut the upright pieces which form the framework of the hopper catcher and fasten these in place; next nail the shield to the machine and then bend and nail the lip in its proper position; the box should be completed now, and finally the wings, guide poles and scarer should be added.

The cost of building a hopper catcher will vary between 8 and 15 dollars, depending upon the size of the machine and the material which is used in constructing the catcher. If tin cannot be obtained for making the shield, lip and wings, then galvanized iron or even oil cloth may be substituted. If possible, however, tin, galvanized iron or stove pipe iron should be used to make the lip. When locusts are able to cling to the shield, a small amount of kerosene should be applied to it with a rag.

The Hopperdozer and How to Use It.

A hopperdozer (Fig. 15) is a devise for destroying young or adult locusts by means of a trap containing a low grade of kerosene, crude oil or other cheap oil. Hopperdozers may be of various sizes, but the general scheme of construction is the same in all machines. Whether a hopperdozer be large or small, it consists of the following parts: one or more sledges; one or more pans, each of which contains water and oil; upright screens on the sides and rear but not in front of the pans; and a device by means of which the dozers are drawn over the field by one or more horses.

Each pan is made of a long piece of galvanized sheet iron and should be 4 inches deep, about 18 to 24 inches wide and 7 to 8 feet long. The top of each pan should

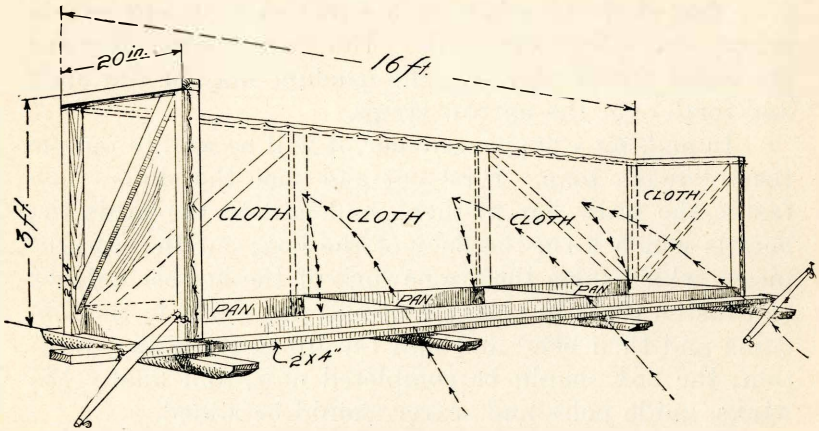


Fig. 15. Hopperdozer with cloth back.

be turned inward 2 inches as a flange in order to keep the liquid in the pan from slopping over. If the pan is 7 or 8 feet long, two partitions, 4 inches high, are to be fastened an equal distance apart across the pan. These cross pieces will keep the water and oil from flowing to and over one end of the pan when the dozer is used on uneven ground.

The skids are made of 2 by 4, 2 by 6 or 2 by 8 runners 4 feet long and bevelled at the forward end, and upon these is nailed a floor large enough to accommodate the pans. If the sledge is 8 feet long, only two runners are necessary, but if it is 15 feet long, then three runners should be used. Whether 2 by 4, 2 by 6 or 2 by 8 runners are employed, will depend upon the crop to be protected and the height to which the grasshoppers jump.

The screens consist of upright frameworks 30 to 36 inches high, to which are fastened oilcloth, canvas or strong muslin. If oilcloth is used, then the smooth side is to be placed facing the pans. The framework may be fastened to the sledge by bow irons, and if this is done, then the screens may be removed from the sledge, rolled up and stored away when the dozer is not being used.

The pans are held in place on the sledge on three sides by the framework of the screens, but on the fourth

and front side, they are held by a long 2 by 4 which is bolted to the runners and which extends 3 feet beyond the outer ends of the pans. This 2 by 4 acts as a draw bar, and it is to the ends of this bar that one or more horses are attached. The 2 by 4 should be braced by a board which is nailed on one end to the sledge and on the other to the 2 by 4.

If the hopperdozer is but 8 feet long, one horse draws the device over the field, but if it is 12 to 16 feet, two horses are employed. Before the hopperdozer is put into operation, water should be poured into the pans until they are half filled and then enough kerosene or other oil is to be added to form a film over the water. If the screens are made of canvas or muslin, they should be kept saturated with the oil while the dozer is being used. As the hopperdozer passes over the field, the locusts jump and usually fall either directly into the pans, or first strike the screen and then drop into the pans. If some of the hoppers strike the screen with their bodies and hop away without falling into the pans, these grasshoppers usually die, but, of course, they are not killed as quickly as are those that fall into one of the pans. Whenever the efficiency of the machine is being reduced owing to the presence of large numbers of hoppers in the pans, the locusts should be removed with a scoop through which numerous holes have been made. As much of the water and oil as is practical should be allowed to drain back into the pans and, whenever necessary, more water and oil should be added before the machine is operated again.

A large hopperdozer, that is drawn by four horses and which can be used over uneven ground, may be made by fastening together two ordinary hopperdozers. This may be brought about by placing two sledges end to end and by loosely bolting the end runners of each sledge to a third runner which is placed between them. The third runner should be of the same height as the other two, but is to extend 4 to 5 feet farther back. From the

back end of this middle runner, a stout wire should be fastened as a brace to the free end of each sledge.

The hopperdozer, like the hopper catcher, is to be used when the locusts are still young, for then much of the injury ordinarily done by grasshoppers will be prevented. Directions for using a dozer are very similar to those that pertain when a catcher is employed, and the reader, if he intends using a dozer, should first read what is written regarding the hopper catcher.

When a hopperdozer and a hopper catcher are compared in cost of operation, we find that the hopper catcher has the advantage. Further, the catcher can be used on rougher and more hilly land than can the dozer. On the other hand, the dozer is cheaper and easier to construct, but this is offset by the fact that no oil or water is used in operating the catcher. Again, it is a little more difficult to remove the hoppers from a catcher and to sack them, than it is to remove the locusts from a hopperdozer.

Burning.

Occasionally it is possible to destroy a large number of young locusts by burning. Weed patches, native prairie bordering alfalfa fields, roadsides and the right of way along railroad tracks, all may be swarming with young locusts early in spring, and a large number of these hoppers may be destroyed by burning at practically no expense. During the latter part of May and early in June, farmers and gardeners should watch the areas indicated and whenever the hoppers have hatched, the old hay or weeds should be set on fire. If there is not sufficient dry plant material on the area to be burned, it

may be practicable, at times, to haul and scatter old hay or straw over such areas and set fire to the same.

Driving.

Grasshoppers may be driven for short distances from one area to another, but ordinarily in South Dakota it is advisable to either trap the locusts with a catcher or dozer or to poison them. Occasionally, however, when a swarm of hoppers has invaded a field or garden, injury may be avoided therein by driving them out again. Driving is, at best, only a slow process and should be carried on at a time of day when the grasshoppers are most active. Whenever possible, the insects should be driven with the wind and down hill. One or more individuals armed with a long bushy twig, should begin on one side of the field and drive the hoppers slowly ahead. A locust tires very rapidly, and when the same insect has been forced to jump several times in rapid succession, it will remain quiet for a time, usually hiding in some protective nook. Consequently it becomes necessary for each driver to chase the hoppers out of a narrow strip of the field at a time. The first strip should be located at the extreme edge of the field and should extend at right angles to the direction in which the locusts are moving. When the first strip has been cleared of hoppers, a second and adjacent strip should be worked and so on until the entire field is free. After the locusts have been driven into an adjoining field, they should be trapped or poisoned.

Poultry as a Means of Grasshopper Control.

Frequently poultry are used as a means of reducing a grasshopper outbreak. To be most effective, chickens and turkeys should be turned into locust infested fields

or gardens when the hoppers are still young, for then the fowls are able to devour the largest number of the insects, and the severest damage has not yet been done to the crops. However, poultry cannot be depended upon to free large areas from a heavy infestation of locusts, and on such occasions, other methods of control must be put into operation.

To get the greatest amount of service out of a flock of chickens, one or more portable hen houses should be built and placed along the edges of a grasshopper infested field. The houses should be moved from time to time to new areas which are badly infested with hoppers. As a change of diet, grain should be fed, at times, to the poultry.

Cooperation.

Occasionally it is not necessary that there be cooperation between neighboring farmers and ranchmen in fighting locusts, but this is true only where a cultivated area is surrounded by large tracts of native prairie land. More often cooperation is an absolute necessity, and then such recommendations as are offered in this bulletin and which are adapted to the affected area, should be adopted. It would be well, in some instances, for several neighboring farmers or gardeners to construct a single hopper catcher or dozer and use this jointly, or, after a machine has been built, it might be profitable to hire the same help to free the community of locusts. Again, counties and townships may be organized under competent direction for the purpose of destroying locusts, and the leaders of this work should take it upon themselves to designate a certain day early in June as the day to destroy grasshoppers by the poisoned bait method. This

day should be made known to every farmer or gardener of the area concerned, either by telephone, personal calls, newspapers or otherwise. Further, there should be placed in the hands of each of these persons, printed directions for preparing and applying the bait. Moreover, it may be advisable to furnish at county or township expense, a limited amount of the bait to each farmer and gardener of that area, in order that the persons interested may see the value of this method of locust control.

Acknowledgments.

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114. Digestion Coefficients of Grains and Fodders for South Dakota.
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