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Utah Agricultural College
EXPERIMENT STATION

Bulletin No. 138



How to Control the
Grasshoppers

By

E. D. BALL

Logan, Utah, February, 1915

PRESS OF
THE F. W. GARDINER CO.
SALT LAKE

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HOW TO CONTROL THE GRASSHOPPERS

By E. D. Ball.

INTRODUCTION.

There is no longer any reason why a farmer or a community of farmers should allow their crops and meadows to be destroyed by swarms of grasshoppers. Our knowledge of their habits has increased and better methods of destruction are known, so that at the present time the grasshopper takes its place in the list of crop pests that can be controlled by those who desire to do so.

In the old days when countless numbers of the Rocky Mountain locusts (*M. spretus*) settled down on the crops of the few scattering settlers of the plains or Intermountain region, there was rarely any possibility of successfully coping with them. The grasshoppers were too numerous and the settlers too few. The breeding grounds were hundreds of miles away and almost unknown. Grasshoppers were at that time rightfully considered a public calamity against which no provision could be made.

Grasshopper Injury Is Today a Sign of Laziness.

The Rocky Mountain locust, with its long wings and wonderful power of flight, is a thing of the past. Like the buffalo, another inhabitant of the same region, his millions have dwindled almost to extinction. We still see the buffalo in our parks and museums, but a Rocky Mountain locust would be a greater curiosity today than a buffalo.*

Unfortunately, the old idea that grasshopper damage is unpreventable still persists in many places, and as a result some farmers still allow this pest to destroy the crops unchallenged, when a little foresight and pains would entirely eliminate the loss. The fact that grasshoppers ordinarily appear in injurious numbers only in irregular cycles of a considerable number of

*The writer has kept a sharp lookout for this species in all his travels in the West for the last seventeen years and has not seen one. To anyone who went through the old "grasshopper days," the peculiar flight of this species will never be forgotten, and even a single specimen on the wing will be recognized.

years is another reason why their control is neglected. Often no watch is kept and danger is not recognized until the swarm is at work in the field.

Grasshoppers Are of Two Kinds.

For the purpose of discussing remedies, it is necessary to recognize that the injurious grasshoppers are of two distinct kinds with reference to habits, and that these two kinds rarely occur together, so that a given injury will usually be caused by only one of these. The two kinds are the **migratory** grasshoppers and the **non-migratory** ones. The non-migratory grasshoppers, of which there are three or four injurious species in the Intermountain region, usually spend their entire lives within the radius of a single field, or at the most within a very restricted area. The migratory ones, of which we have only one species now that the old Rocky Mountain locust has gone, are quite different in habit and usually do their greatest damage at long distances from the place where they hatched out. These two kinds will be discussed separately and methods given for the destruction of each.

One Is a Community or County Problem and the Other Is an Individual Problem.

It is necessary to sharply distinguish between these two groups, because in the one case the careless or indifferent individual that raises the hoppers is responsible for them, and if they damage him he should suffer, and if they stray to a nearby neighbor and damage his crops, the individual that raised them should be held responsible.

On the other hand, the migratory grasshoppers, or "warriors," can only be handled by a community, a county or some similar organization. They oftentimes breed in countless thousands on wild land far from any settlement and later migrate to the cultivated lands. In Sanpete Valley their worst damage has usually been done miles from their breeding grounds, and it is impossible to tell in advance when they will appear at a given spot. Under such conditions the only satisfactory method of handling them is to get everyone to contribute his share of labor under organized leadership, either by counties or communities, and this labor should be used to prevent their appearance.

Prevention Is Better Than Any Cure.

Fighting the hoppers themselves must, of course, be resorted to when for any reason they have been allowed to appear, but the cheapest and most efficient method of destruction for both communities and individuals consists of destroying the eggs before time to hatch, and following this up by prompt destruction of the few that escape the previous treatment. Destroying the adults in the field is more costly than the destruction of the eggs, and by that time most of the damage to the crop has occurred. The injury done by the grasshoppers on one or two acres would often be greater than the cost of destroying the entire swarm in the egg stage.

Why Grasshoppers Appear Periodically.

Nearly all insect pests fluctuate in numbers from year to year. One year they may be very numerous, while the next year few will appear. Some insects are only slightly variable in numbers and have to be fought each season, while others are usually periodic and only occur in numbers sufficient to be considered injurious once in several years. The tent caterpillar, the alfalfa worm and the grasshopper are examples of the latter class. Such insects occur in small numbers for a year or two, gradually increasing, and then when a favorable season for their increase occurs they appear in enormous numbers and cause great damage, only to disappear again for several years.

The reason for this fluctuation is that while grasshoppers are capable of increasing twenty to sixty times in one year, their enemies and diseases are capable of increasing several hundreds up to thousands of times in a season. Thus, while the hoppers are scarce, their parasites have a hard time to find them and the parasites nearly all perish, then the hoppers increase in numbers, the few parasites left have no trouble in finding them and they increase enormously. The year that grasshoppers are "worst" is often the year in which the parasites increase to such an extent that practically no hoppers or eggs are left to produce a brood the following year.

In the case of the grasshoppers the weather often plays an important part. Cold wet weather in the spring will destroy a large number of young grasshoppers. Hot dry weather, on

the other hand, allows every egg to hatch and every young hopper to thrive. The same hot dry weather burns up the vegetation so that there is less for the grasshoppers to feed on. Drought and grasshoppers often go together, especially if the drought extends through several years.

The Scope of This Study.

The writer's first experience with grasshoppers was in helping in an unsuccessful fight against the Rocky Mountain locust in the prairies of Iowa in the seventies. Although only a small boy at this time, the experiences will never be forgotten. Straggling swarms of these insects were seen passing overhead, with an occasional lighting, for a number of years afterward. The last ones seen were a few stragglers that came down in Northwestern Iowa in July, 1894. The writer was at that time, and as occasion permitted until 1897, studying the life histories and distribution of the grasshoppers of Iowa.* From 1898 until 1902, and especially during the last three years of this period, the writer studied the life histories, food, habits and distribution of the grasshoppers in Colorado.** During the year 1902 several outbreaks in Western Kansas and Nebraska and Eastern Colorado were studied. One of the most serious and destructive outbreaks of the injurious species ever known in the Poudre Valley occurred the same year, and much time was spent in the application of remedial measures. Coming to Utah just at the close of the destructive season of 1902, when Sanpete County alone suffered thousands of dollars in damage from the Warrior grasshoppers, the writer at once took up the study of this pest and in 1903 and up to the end of 1905, when they were exterminated, was on these meadows much of the time in the summer. A severe outbreak of native hoppers in 1907 occurred on the west side of Cache Valley and in certain sections of Bear River Valley, and considerable time was spent in assisting the communities to get rid of them and in studying methods of control. Local swarms of grasshoppers have traveled down from the lower slopes of the west side of the Wasatch range on to orchard and farm lands all the way from

*See Notes on Orthoptera of Iowa. Proc. Ia. Aca. of Sci. Vol. IV—1897.

**See Annotated List of Colorado Orthoptera. Colo. Exp. Sta., Bull. 94—1904.

Brigham City on the north to Nephi on the south, causing much damage. The movement of these swarms has been studied at Spanish Fork, Salt Lake, Centerville, Layton and Brigham City. Other serious swarms occurred north of Ogden and at Bountiful. The Warrior hoppers started to increase in numbers in Sanpete Valley in 1912, and by 1913 were quite threatening. Another year's increase would have brought back the condition of 1902. Instead, the breeding grounds were located and the eggs destroyed, and consequently very few appeared in 1914 and these were promptly destroyed before any damage was done.

When Will They Come Again?

The swarm of Warriors that threatened Sanpete County has been reduced to a negligible quantity and no other swarms are known at present. It usually takes two or three favorable years for these swarms to increase to destructive proportions, so there does not seem to be any serious danger from them for the next year. The Native grasshopper practically disappeared following the outbreak of 1907 and 1908 and have not been seriously injurious since that time until last year (1914). They were quite injurious in some parts of Davis County last year and occurred in unusual numbers in Box Elder and Cache Valleys again. With the number of hoppers that laid eggs last fall all that will be necessary to bring on another outbreak next season or the year after will be favorable weather conditions.

Acknowledgement.

Most of the methods of handling the adult and young hoppers have been found in use at one time or another. Many of these were somewhat crude and have been improved or simplified. The Hopper Catcher was in use near Greeley, Colorado, when first seen.* The straight fronts used then "leaked" hoppers badly and the curved front, introduced for the first time in Utah in 1907, was a great improvement. The false front suggested will probably still further increase its efficiency. The "Balloons" have been in use in Utah for a long time, but are

*The photographs taken by the writer at this time were used by Gillette in the Annual Report of the Entomologist for 1902.

only used against the Warrior hoppers.** The addition of a semi-circle in front will probably improve them for most conditions. Trenching and fencing have both been used many times previously, but, not understanding the movements of the swarm with reference to the sun, much of this labor has previously been lost.

Dr. E. G. Titus assisted on several occasions in Cache Valley in 1907 and made one trip to Bear River and one to Davis County and has in other ways been very helpful. Mr. John K. Olson of Kesko Farm, a graduate of the College, represented the Station in the organizing for the destruction of the eggs in Sanpete Valley in the fall of 1913 and the spring of 1914. Much of the striking success of this work was due to his efforts and enthusiasm.

THE "WARRIOR" GRASSHOPPER.

This species (*Camnula pellucida*) has been known ever since the settlement of the West, and its swarms have caused widespread destruction from time to time in the valleys of the Mountain region. It has frequently been confused by the farmers with their old enemy the Rocky Mountain grasshopper, and for a time all the damage was referred to that species.* Even yet many people think that an outbreak of grasshoppers means a return of the old "Ironclads" of the sixties and seventies. The control of this species is, however, a very much simpler problem than that of the "Ironclads" and they should not be confused. They differ widely in appearance. The Warrior adults being pale, dirty straw color varying to bright yellow with pale yellow hind wings, while the Ironclads had bright red hind legs and pale hind wings

Distribution.

The Warrior grasshopper occurs throughout the mountain region of the West and extends across the continent to the North. Injurious outbreaks have been reported from Idaho,

**The writer showed photographs of these "balloons" to a representative of the U. S. Dept. of Agriculture some years ago, who reported their use to the Amer. Assoc. Econ. Ent. See Bur. of Ent. U. S. D. A. Bull. 46 NS., p. 78.

*Part of the grasshopper trouble of the sixties and seventies was probably caused by this species.

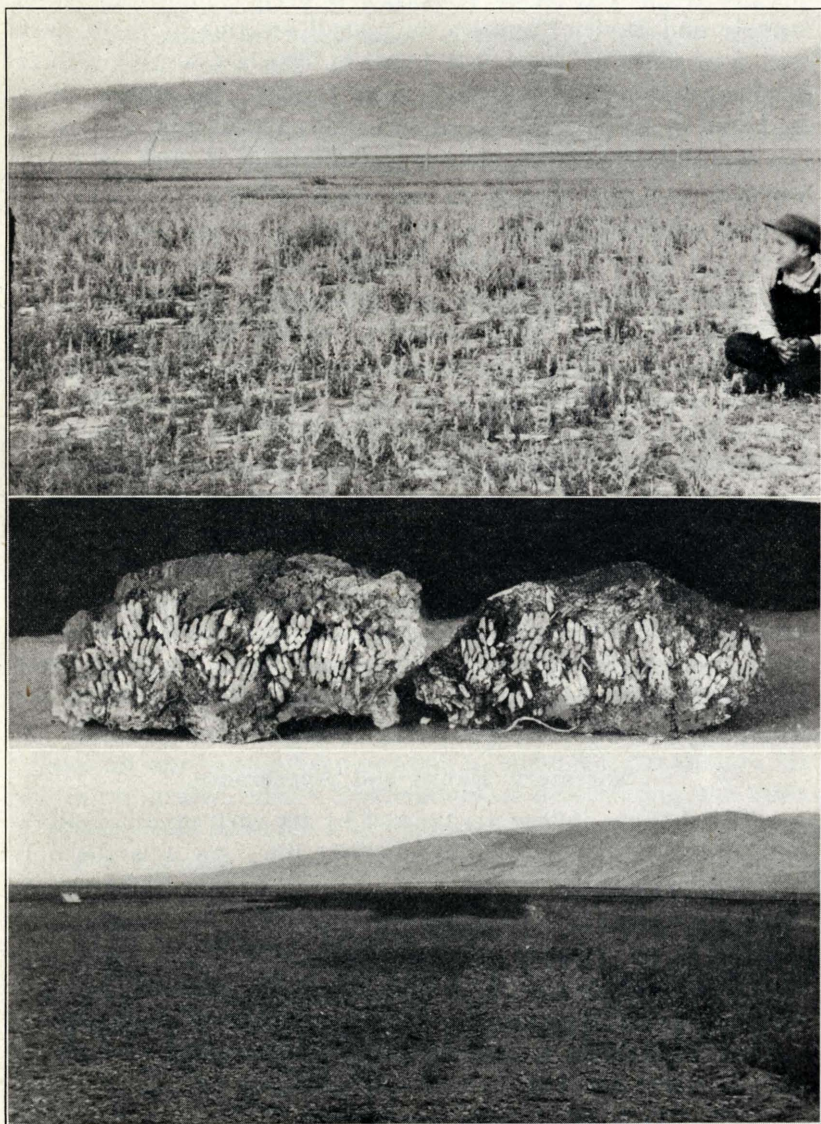


Plate 1—Fig. 1 (Upper)—A typical breeding ground. Fig. 2—Two lumps of dirt from the breeding ground above, to show how thick the eggs were placed. Fig. 3—Showing corner of oat field left by migrating Swarm that passed obliquely across and out onto dry pasture.

Wyoming, Montana and Utah. In Utah serious damage from this species in late years at least has been confined to Utah, Sanpete and Sevier Counties, but small swarms of them have been seen south of Great Salt Lake, in Tooele County, north of Brigham and in Cache Valley, near Logan. In general, they are found in rather high mountain valleys and usually their eggs are deposited in rather strongly alkali land, if such is to be found.

Life History.

Like all other grasshoppers, this species has but a single brood in a season. The young hatch out from May 1st to June 15th, depending on the season and the condition of the ground in which the eggs were laid. The great majority of a swarm hatch out within a few days of the same time, but there will be stragglers appearing for a week or more after the main swarm departs. The greater number hatch about the middle of May in a normal season and begin to get wings the latter part of June and early July, and commence laying eggs in August, continuing into September. Some few in specially dry, hot locations will hatch out the last of April and get wings in early June, while eggs laid in low wet places may not hatch until after the middle of June and not get wings until into August.

Migratory Habits and Appearance.

This hopper is best recognized by its very peculiar migratory and gregarious habits throughout life. As it is the only one with such habits in the Intermountain region, there can be no mistake made if its actions are observed.

The young hoppers are dusky brown to almost black with a small oblique light line on the side of the thorax. Within a few hours after they emerge they begin to travel if the sun is shining, hopping in the direction of the sun as long as it shines and the temperature is high enough. As soon as a cloud passes over the sun the migration ceases and the hoppers gather in clusters on the dryer and more open places, or on the vegetation if it grows in clumps, especially if the ground is wet, often piling up until they form solid masses of young hoppers. If it gets cold or rains they hide under anything and everything available, crawling into the grass clumps down into cracks in

the ground until they practically disappear. Passing over a swarm of them at such a time one would scarcely notice them, while as soon as the sun warms them up the earth is alive with them again and they start off as before, always towards the sun.

In the Sanpete Valley, where most observations have been made, the mornings are usually clear. About 8:30 or 9 o'clock the temperature is high enough to start them traveling and they therefore start towards the southeast, swinging into the south as the sun does. Much of the time while these swarms are traveling the clouds appear by or before noon and often there is a shower in the afternoon, which stops their migration. As a result their travel is almost always in a southeast to southerly direction.

Rate and Method of Travel.

The distance and direction in which a given swarm of young hoppers will travel can only be roughly estimated, as it depends upon sunshine, temperature and the character of the land over which they are moving. Water will stop them indefinitely; cold weather, and especially cold wet weather, will halt them while it lasts, while during warm dry sunny days their speed is at its maximum. Several swarms have been timed as they moved along under favorable weather conditions and they have shown an average speed of about six feet per minute for one-third grown swarms to eight feet per minute for two-thirds grown ones. The method of determining the rates of movement is to watch a single individual for several minutes, noting a definite starting point and timing him to another definite place, and then measuring the distance traveled in the given time. By doing this on a number of individuals, each time, a close approximation to the speed of the swarm can be obtained. Six feet per minute would be three hundred and sixty feet per hour or one hundred and seventy-five rods in a day of eight hours, or a mile in less than two days. Eight feet per minute would be nearly thirty rods an hour, or two hundred and thirty rods a day, or a mile in a day and a half.

They rarely advance at this rate, however, as there is rarely eight hours of favorable weather for travel, and if there should be the route would be in a semi-circle, starting southeast and winding up in the evening traveling west, so that it

would take several days to make a mile of advance in a given direction by this method.

They never turn aside or stop in their travel on account of feed. Figure (3) shows part of a strip of oats through which a swarm traveled. In the center of their path there is no sign of the oats at all; even the roots were eaten out. Along the edges the damage decreased as the number of hoppers decreased.

There was no widening of the path, however, as they passed through. They apparently went straight ahead right out onto a dry pasture, leaving the oats on either side untouched.

If a swarm comes to a body of water or even an irrigation ditch they will pile up against the bank and stay there for a long time, traveling up and down the bank as the sun swings around, but not turning aside and going back.

As one looks at a swarm advancing the impression is that they progress mainly by hopping, because the air is full of hopping individuals, but there are many more that are walking rapidly along. By watching one individual at a time it will be seen that they travel by rapid walking, interspersed with a hop of six to eight inches every few feet.

Habits of the Adults.

When the larvae are ready to transform to the adult stage they stop migrating and cling to some upright stem for some time, the actual emerging of the adult usually occurring in the morning, and before night the wings are dry and they are ready to fly. In the meantime the swarm has been passing on and unless the individual was one of the leaders of the swarm, or the swarm was very large, they will all have passed by by the time the adult is dry. Thus, in examining a swarm very few adults will ordinarily be found with them. The stragglers in the rear will often be mixed with soft undried adults, while still further in the rear the adults will be flying about in numbers.

The adults are affected by the weather in the same way that the larvae are, flying only during bright, warm sunny days with light winds, remaining quiet during cold wet weather and high winds. At first they fly rather aimlessly around, usually drifting with the light winds, flying from two to six feet above the vegetation and usually from ten to twenty rods at a flight. A little later they gather into rather definite swarms that leave

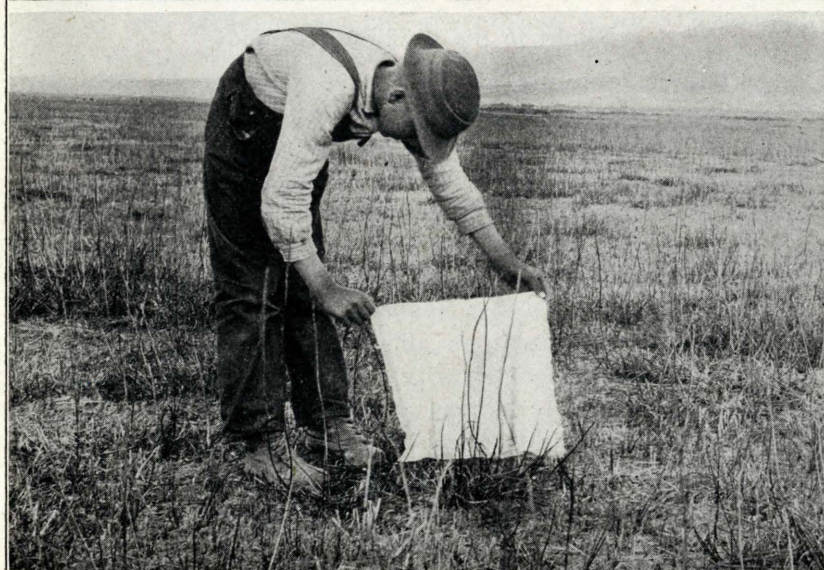
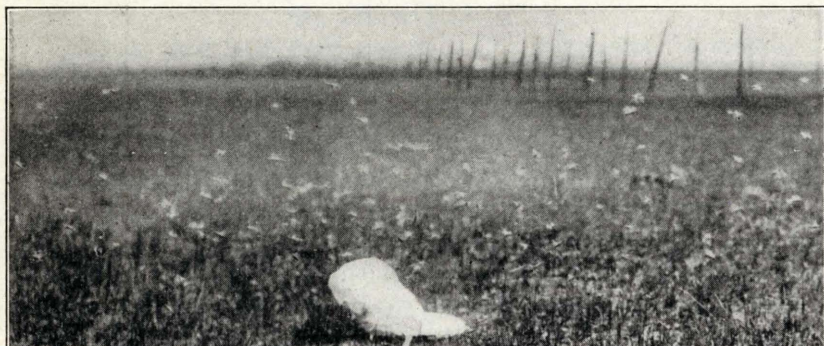


Plate 2—Fig. 4 (Upper)—Snap Shot of Breeding Ground, Showing Hoppers on ground and in the air. Fig. 5—Enlarged view of same. Fig. 6—Meadow stripped by migrating swarm.

the meadows and fly to the crops along the valley slopes. There will always be larger numbers of adults in the meadows at these times, however, and stragglers will be found in many fields besides those infested by the swarms.

Egg Laying Habits.

After the adult females have fed for a few weeks and developed a mass of eggs they fly to the egg-laying grounds. This is one of the most remarkable habits of this species. The adults may be spread over an area of from fifty to one hundred square miles in one valley alone and yet the eggs from all these millions of hoppers will be deposited in a small number of acres of ground. These few acres may be scattered in several different localities, but they will all be similar in nature of soil and vegetation and usually mainly in a long narrow strip along one side of the valley slope just between the damp meadow on one hand and the cultivated fields or sagebrush on the other. Such a strip extends along the west side of Sanpete Valley from a few miles north of Manti up to near Moroni.

In all cases, however, there will be found small groups laying eggs in different parts of the valley, usually on slightly rising ground, edges of knolls, etc.

Flight to the Breeding Grounds.

Along in late July or throughout August and early September any sunny afternoon the females will be seen flying in numbers a few feet above the vegetation; some few may be flying at random, but by carefully watching the direction taken by the great majority of those in the air and following it the breeding grounds will be found. On approaching the place the air will be full of circling hoppers, mostly males, while from every direction other hoppers will be seen approaching. The ground will present an almost solid mass of squirming, struggling grasshoppers, usually from five to seven and sometimes as high as ten or fifteen males, struggling for possession of each female. The females are mostly in the act of boring a hole or depositing the egg mass.

The Breeding Grounds.

The places selected for egg laying are always dry and dusty, usually strongly alkaline with more or less of loose

crystalline dust and deep cracks. The vegetation is mainly a small annual *Atriplex*, which by this time is drying up and losing its leaves, interspersed with Salt Grass (*Distichlis*) or Squirrel Tail Grass (*Hordeum jubatum*) in scattered stalks. Sometimes one plant will predominate, sometimes the other, but the general conditions are always very similar and the vegetation of any kind scarce. After the grounds have been used for a few days there is a very characteristic and decided odor that will materially assist in locating them. After a week or more the ground will be more or less covered with dead grasshoppers, mostly males.

Number of Eggs Laid.

Each female deposits a single egg mass at this time ranging from nineteen to twenty-three eggs, most of them containing twenty-one or twenty-two. After depositing these she returns to the field, where she feeds for a week or two, and then returns to deposit her second and last egg mass. This second egg pod is usually smaller than the first, ranging from thirteen to nineteen eggs. Taking both egg masses together, each female lays about forty eggs (which would give a possible increase of about twenty times in one year).

The eggs are usually deposited so thick that in the main part of the breeding grounds the ground is filled with them. Each female bores a slightly sloping hole three-fourths of an inch to one inch in depth and deposits the eggs in a regular manner, each egg curving slightly and standing obliquely in the hole, slightly overlapping each other, so that the pod is three or four eggs wide and five to seven eggs long. The hole is first lined with cement-like material and then the eggs are packed in the same material and finally the hole plugged with it and the opening filled with dirt, so that each egg pod if undisturbed is protected by a water-tight and air-tight coating and is located with the top end about a third to one-half of an inch below the surface. As one female after another bores into the same locality the egg masses are broken up more or less and the entire ground from about one-third of an inch under the surface down to a depth of an inch is filled with eggs. In a number of places on taking a shovel and scraping a half inch off from the surface nothing but a solid mass of eggs could be seen.

Why Males Are So Numerous on the Breeding Grounds.

From the first gathering of the season until frosts come the males spend most of their time on the breeding grounds, rarely leaving it except in cold, rainy weather, when it will be entirely deserted. At the first appearance of the sun the males return in numbers and after a half a day or more scattering females will be found at work again. But as the females only spend a day or two each of the two times they deposit an egg mass and the rest of the time are in the fields feeding, it follows that at any given time there will be from seven to ten males to one female on the breeding ground and just about the reverse proportion in the fields, where the damage is being done.

Estimates of Actual Numbers.

A rather small swarm near Ephraim in June, 1913, was carefully estimated as to numbers as follows: The central part or thickest area was estimated at one hopper to a square inch for an area of three hundred and twenty acres, or practically **two billion hoppers**. Around this center there were ten to fifteen to a square foot on four square miles, or about **one and one-third billions** more, or a total for this swarm of **three and one-third billions**. This was considered to be a rather insignificant swarm as compared with those of 1902. There were only a few tons caught from the swarm and only twenty-eight tons caught in the county that year, as compared with twenty-eight tons from a single swarm in one month and two hundred and seventy-four tons in the county in 1902, when the largest swarms occurred.

To get some estimate of the number of hoppers in a ton at different ages, several weighings were made, which are recorded in Table No. 1. The eggs and just-hatched hoppers weighed one and one-half millions to the pound, or three billions to a ton.

Very small hoppers, as small as could be caught by the machine, ran one hundred and sixty million to the ton. An average lot of hoppers as caught from the above swarm, ranging all the way from very small to nearly grown and a few winged ones, and averaging probably about half grown, ran eight million to the ton.

TABLE NO. 1.—NUMBER OF GRASSHOPPERS IN DIFFERENT WEIGHTS AT DIFFERENT AGES.

	Per Ounce	Per Pound	Per Bu. (60 lb)	Per Ton
Eggs or just hatched hoppers	96,000	1,500,000	92,000,000	3,000,000,000
One week old.....	5,000	80,000	5,000,000	160,000,000
1-4 to 1-3 grown (large enough to catch).....	1,000	16,000	1,000,000	32,000,000
Avg. catch in June and early July; from small to adult (½ grown)	250	4,000	250,000	8,000,000
Adults .. .. .	.....	.....	.....	.....

Estimating that there were five tons caught from this swarm (there were a number of other swarms that year) and that they averaged eight million to the ton, this would give us forty million caught out of a swarm of three and a half billion, or one in every eighty-seven hoppers. If all the twenty-eight tons caught that year had been taken from the one swarm it would only account for one-thirteenth of them.

The two hundred and seventy-four tons caught in 1902, if they averaged eight million to the ton, would only have amounted to two-thirds as many as this small swarm. On the other hand, if they caught the same proportion of the swarms in 1902 that they did of this one the two hundred and seventy-four tons would indicate about **two hundred billion** grasshoppers in Sanpete Valley alone that year.

In all cases the catching has been continued as long as they could make "wages" at 1 cent per pound. This required the catching of four hundred to eight hundred pounds per day per outfit.

In 1903 an estimate was made of the number of eggs per square inch in a breeding ground in Sevier Valley. A space three by six inches was marked off and the eggs counted, giving an average of one hundred and seventy-five to the square inch or twenty-five thousand to the square foot, or **one billion** per acre. The eggs were much thicker than that in a number of places in Sanpete County in the spring of 1914 and there were probably twenty acres that would have averaged that much in the breeding places from which the swarm on which the estimates were made came from—or twenty billion eggs ready to hatch.

The Number of Pounds Caught for Bounty.

Table No. 2 gives the total number of pounds of grasshoppers on which counties have paid bounty to date by years

TABLE NO. 2.—TOTAL NUMBER OF POUNDS OF GRASSHOPPERS PAID FOR BY THE COUNTIES TO DATE.

	Other Counties			Utah County		
	1904	1905	1906	1904	1905	1906
June ..	.....	.....	.....	.....	.....	.....
July ..	.....	808†	1,177†	.....	16,834	.....
August ..	.....	1,056†	1,960†	.....	142,429	15,056
.....	.....	9,682*	.....	.....	.....	.....
September ..	.....	2,279*	.....	11,425	36,316	9,564
October ..	.....	.....	.....	11,359	593	2,140
Nov. and Dec.....	21,477**	180*	.....	2,701	6,577	760
Total ..	21,477	14,005	3,137	25,485	202,749	27,520

	Sanpete County					
	1902	1903	1904	1905	1912	1913
June ..	117,236	57,353	51,708	.....	.....	.....
July ..	399,038	49,177	59,750	565	.....	36,266
August ..	31,035	11,442	.....	.....	.....	7,807
September ..	.....	6,680	.....	1,219	6,622	11,457
October ..	.....	.....	.....	298	.....	180
Nov. and Dec.....	.....	.....	.....	.....	.....	.....
Total.....	547,309	124,652	111,458	2,082	6,622	55,710

Total for Misc. Counties.....	38,600 lbs.; 19.3 tons
Total for Utah County.....	255,750 lbs.; 127.9 tons
Total for Sanpete County.....	847,830 lbs.; 423.9 tons
Grand Total	1,142,000 lbs.; 571 tons

**Millard County.

*Juab County.

†Grand County.

and months. A state bounty law was passed in 1903 providing that the state would reimburse the county for two-thirds of the bounty offered by the county. The bounty offered was either fifty cents or sixty cents per bushel of sixty pounds. The extra expense of receiving the hoppers was more than sufficient to bring the whole cost up to 1 cent per pound, or \$11,500.00. The largest part of this was paid by Sanpete County before the state law went into effect. This does not by any means represent the total number of hoppers destroyed, as Sanpete

County was the only one to offer bounty in 1902 when the hoppers were the worst and when more were destroyed than in the entire twelve years since, and many counties have never offered any bounty.

The Amount of Injury.

It is hard to estimate the amount of damage caused by the species, as a great deal of its injury is to pastures and meadows and no definite amounts can be given. For three years many square miles of the meadows of Sanpete County were very largely eaten down by this pest. The migrating swarms of young often attack grain crops, when, of course, the destruction is complete. Besides this the swarms of winged ones fly over wide areas and leave destruction in their track, while straggling individuals damage all the crops in the region.

Methods of Control.

As has been suggested above, this pest cannot be controlled by the individual farmer, but must be handled by counties or communities as a whole to be successful. So the directions given below are for application by such organizations.

If taken in time this is an easy pest to control and with our present knowledge there is no excuse for a community continually suffering from its ravages.

The bounty system, while better than nothing, is probably the poorest and least efficient of all the methods of control, and at the same time the most expensive. Its chief drawback is that most of the injury is done before the hoppers are destroyed and that at the best probably not over 2 to 5 per cent will be caught for bounty, and the rest are scattered over a still larger area and their opportunity for damage increased. Under the bounty system a number of persons will be working on a swarm at one time and each one trying to catch as many as possible, so they all rush right into the center of the swarm and scatter it out.

Sanpete County paid out over \$5000 in bounty in 1902 and suffered an immense amount of damage. It would have taken \$500,000 to have paid for all these two hundred billion grasshoppers, while probably \$2000 would have destroyed 90 per cent of the eggs.

Location of Breeding Grounds.

The easiest, least expensive and most efficient method of control is to locate the breeding grounds and destroy the eggs. To do this effectively, everyone working on the meadows should keep a sharp lookout from the first of August up to the middle of September for swarms of adults on breeding grounds. These should be reported to someone in charge, who should at least once a week on warm, sunny afternoons visit such places and stake off the boundaries of the area in which eggs are being deposited. In addition this person should watch the flight of the females and locate any other places. All suspected breeding places should also be visited and in this way every place where eggs were deposited should be marked off.

In 1904 the writer spent about ten days in August and the same amount of time in September in the Sanpete Valley, and was able in this time to locate every locality in which eggs were laid that year.

Destruction of the Eggs.

All places where eggs have been deposited should be thoroughly disced or worked up with a springtooth harrow in the fall. At least three discings should be made, lengthwise, crosswise and cornerwise, and more would be better. This treatment will break up a very large per cent of the egg masses and disturb many of the rest so that they will be exposed to drying and frost action during the fall and winter. In the early spring this process should be repeated and most of the rest of the eggs will be turned up and exposed to the drying action of the sun and wind and to attacks of predaceous insects.

In places where the harrows fail to turn up a large per cent of the eggs a sulky plow set very shallow and driven very fast would turn them up to the air. Ordinarily this is all that it will be necessary to do.

At Ephraim in the spring of 1914 the weather was so cold and wet that the eggs did not dry out at all. A mass meeting was called and volunteers to the number of about sixty turned out with teams and implements and the eggs were plowed under to a depth of eight inches or more, and the land rolled and packed. This with the continued wet weather destroyed them so that very few hoppers ever appeared. As the eggs are confined to a very few acres, and these usually of rather loose and

easily worked land, the expense of destroying a billion eggs this way would not amount to as much as the bounty on ten million grasshoppers, and by destroying in this way the damage would be entirely prevented.

Destruction of the Migrating Swarms of Young.

Some small patches of eggs may be missed and in this way swarms may appear. In some cases where treatment of the eggs has not been thorough sufficient young hoppers may appear to warrant after treatment.

Spraying.

In these cases spraying the thickest parts of the swarms with crude oil, a strong kerosene emulsion (diluted only four times) or with a strong tobacco solution or a solution of sheep dip will destroy them completely and can be applied as soon as they appear and before any damage is done. This is an effective but very expensive method of destroying them.

Brush Harrow.

Where they are more or less scattered or in rank vegetation and spraying would be difficult and expensive, a brush drag heavily weighted with small stones in large gunny sacks, so that the harrow will go down into crevices and depressions, will destroy a large percentage of them quite cheaply. The brush harrow may be used on the thick part of the swarm as well if desired and with much less expense.

Trenching.

When a large swarm is advancing in a definite direction many of them may often be destroyed by trenching in advance of them. A trench one foot wide and one and a half feet deep, with the outside wall slightly cut under and the inside one slightly sloping, will collect them. If the trench is made slightly oblique to the line of advance the hoppers will follow the trench to the advance end. Here a deep pit may be dug and the hoppers pushed in and buried. A shallower pit with someone stationed there to shovel them into gunny sacks will accomplish the same purpose. Some bore post holes along the trench and as they fill up others are made.

As has been noted above, a small stream of water will stop them and this may often be used on one side and a trench at right angles to it to capture them as they work along the ditch. A portable board fence, made of twelve-inch boards set slightly sloping and held by stakes, may often be used to advantage on one or two sides of a swarm to keep them from spreading, or canvas or even unbleached muslin may be used.

Oftentimes a combination of fencing and driving may be used to advantage to concentrate a swarm and then the brush drag, crude oil spray, roller or balloon or a combination of them may be used to exterminate them. In using the balloon in this way the work should be done around the edges, gradually working in towards the center and thus concentrating rather than spreading them.

The "Balloon" Hopper Catcher.

This special device has been in use in Sanpete and Sevier Counties for years, and in fact has been the only means used in capturing the hopper for bounty, except in a few instances where the trenching and shallow pit method has been employed. Of the four hundred and twenty-four tons of hoppers on which bounty has been paid in these counties, at least four hundred tons have been caught by the balloons.

While these balloons have been of great service in helping to rid the meadows of swarms of these destructive pests in the past, they should not be used to any extent in the future. The destruction of the eggs is far cheaper and more effective, and even if swarms are allowed to hatch out, as will occasionally happen, they should be destroyed by spraying or brush dragging before they are large enough to balloon successfully. In this way they will be destroyed before they do any damage and before they have time to scatter.

The balloon consists of a light frame twelve feet long and two feet high with two or three cross bars to give it more rigidity. This frame has attached to it a bag, of which it forms the mouth and which tapers back to a point about ten feet back of the frame. The point is open and when in use is fastened with a string tied around it like a sack is tied. In fact, a seamless sack makes a good point to this large bag. The bottom of the bag, which drags on the ground, is often made of heavy canvas, while the upper side is of ordinary sheeting. The frame is

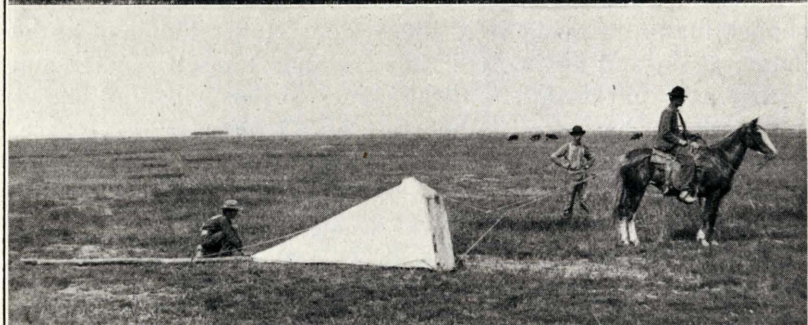


Plate 3—Figs. 7 and 10—Balloons in action. Fig. 8—Balloon at rest to show detail. Fig. 9—Sacking a “catch.”

usually made of one by four inch stuff and the whole thing is drawn by a single light rope, which forks to the two ends and forks again to each corner. This rope is either fastened to the pommel of a saddle or else to a light whiffletree of a light harness. The pony is started off at a fast trot. The air inflates the open-mouthed sack, which "balloons" up and draws along the ground over the meadow grass or grain crop. The bottom of the frame draws along on the ground, and as a young grasshopper jumps to avoid it it slides along under him and as he jumps again and again each time he finds himself farther and farther back in the sack until he comes to rest with his fellows in the tip. The rider of the pony starts off at a good pace, swinging back and forth across the swarm until his sack has a bushel or so of grasshoppers in the apex. Then he dismounts and helps his partner lift up the frame, shake all the hoppers back into the sack at the apex, then another sack is held over the end, the string untied and the hoppers sacked. The string is again tied and the balloon is ready for another trip. It takes two men or preferably light boys, as they are easier on the ponies, and about three ponies to keep the balloon working all the time. The extra man helps sack up, finds where the hoppers are thickest, changing off with the rider from time to time. Where the ground is rough the lower side of the frame catches and the top flops over and closes the mouth. To obviate this a rope is fastened to the top of the frame and a small fence post is drawn along back of the sack, thus serving to pull the top back up and keep the mouth open. A better plan would be to have a semi-circular iron hoop at each end and in the middle of the frame, which would keep the mouth open all the time and would not draw as heavily as the post. Practically all the wear comes on the bottom of the sack, so this is made of heavier material or, better still, a second strip is fastened to the frame and draws underneath the sack and protects it from injury. Old binder canvas and such material make excellent pieces for this use.

Destroying the Adults.

After they get their wings there is very little use in trying to destroy them. The same amount of time and energy had better be used in locating their eggs and destroying them. Some adults have been caught on the breeding grounds by

using a balloon and a fast horse so as to move very swiftly, but the most of those captured would be males. The destruction of a few males in this way would be of very little value, as it would not decrease the eggs laid for another year, nor decrease the damage a swarm would do, as the males feed very little after the breeding season begins.

Natural Enemies.

Late in the fall of 1904, after the swarms of that season had laid their eggs, the writer placed his hand over a patch of the breeding ground west of Ephraim, cut out the outline of his hand with a knife, and then took out the earth and eggs under the hand, expecting to count the number of eggs in the area. Instead of finding eggs, as expected, almost every egg pod had a curved white grub in it, and several had more than one. Over one hundred of these grubs were taken out of this area. These were sufficient to have eaten every egg left before hatching time the next spring. These grubs were the larvae of a yellowish bee-like fly that is often seen hovering over the ground in harvest fields and such places.

Besides these grubs there were several large beetle larvae (*Calosoma* sp.), slender, tapering things with large jaws and long legs, that were also burrowing around and devouring these eggs. As a result very few hoppers appeared in the spring of 1905 from this area.

In early April of 1914, while examining a breeding ground on the Kesko farm, northwest of Ephraim, that had been disced in the fall, to see what per cent of the eggs had survived, the writer found six to ten of the beetle larvae to each square foot, and scarcely any eggs left in this area. The same conditions existed in several places in this particular region. But down on the breeding grounds west and south of Ephraim practically no beetle larvae were found, and the eggs were found by the millions.

These two species are apparently of the most benefit in destroying the eggs of the Warriors and are probably the cause of its sudden disappearance. During the latter part of the serious infestation of 1902-1904 the meadows were swarming with the adults of this beetle, while a few years later scarcely one could be found.

"NATIVE" OR "ALFALFA" GRASSHOPPERS.

As has been stated, these grasshoppers are non-migratory. If sufficient feed is found near the place where they hatch they will remain there during their entire life. They are, therefore, very largely a problem for the individual farmer, the same as any other crop pest.

Distribution.

The injury from these grasshoppers in this state in recent years has been limited to comparatively small areas and to particular and rather widely separated seasons. They have occurred sporadically in nearly every section of the state, in old and thickly settled areas, as well as in the new and sparsely settled valleys.

Injury.

In a number of instances the damage from this source has been very severe, practically all the crops after the first cutting of alfalfa being destroyed, and, in extreme cases, many young orchards. Even old orchards have been so badly injured that most of them died. Besides these severe losses there have been thousands of acres of crops that have been considerably reduced in value from year to year by these pests. Young orchards especially have suffered from their attacks, the leaves being stripped from the newly set trees at a time when many of them could not stand the loss. Alfalfa seed growing also suffers seriously, as the dry conditions required to produce alfalfa seed are ideal for the development of grasshoppers.

Recent Outbreaks.

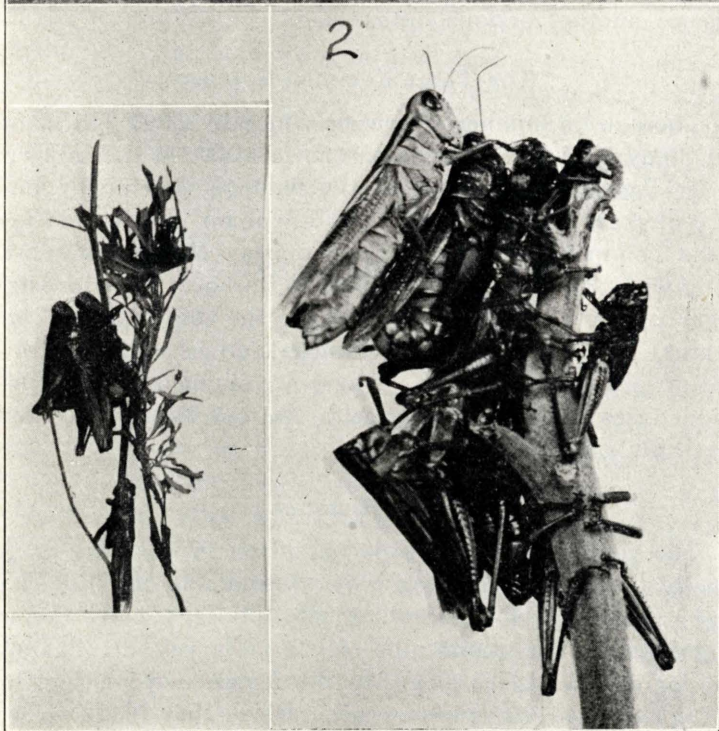
It is hard to tell just how much of the damage in early years in the state was due to native grasshoppers and how much to the "Ironclads" from the Rockies. Practically all

Plate 4—Fig. 1—Edge of an alfalfa field where the alfalfa has been killed out by repeated attacks of grasshoppers.

Fig. 2—A sunflower stalk on which sick and dead grasshoppers are clinging—the result of an attack of the fungus disease.

Fig. 3—Alfalfa stalk with dead grasshoppers.

(Figs. 1 and 2 were taken by writer while in the employ of the Colo. Agr. Exp. Station, and plates were loaned by that Station. Fig. 3 by Titus & Hagan.)



damage done was attributed to the latter species until they disappeared; in fact, until long after that time.

In 1895 there was serious and widespread damage throughout the state, all due to the native species. Although we have no records to show it, this was no doubt the culmination of a two or three year period of increase. In 1902 and 1903 a great deal of damage was done along the base of the Wasatch range, from Spanish Fork on the south to the state line on the north. In 1904, 1905, 1906 and 1907 there were sporadic outbreaks in a number of places, as seen by the bounty records. The year 1905 saw the worst of the outbreak in Utah County and the beginning of one in Davis County, Bear River Valley and Cache Valley, which culminated in 1907 with serious damage throughout a wide area in northern Utah. Last season (1914) they began to appear again in this same area, becoming quite serious in parts of Davis County, and if climatic conditions should be favorable it is likely that in 1915 or 1916 this region will experience another serious outbreak.

The Three Common Species.

There are a number of species which in a bad "grasshopper year" may be sufficiently numerous to assist in the injury, but by far the greater amount of the damage is done by one or more of three species. The most abundant one in this region is the common red-legged grasshopper (*M. fermur-rubrum*). Along with this and very similar in appearance, but with slightly longer wings, comes *M. atlanis*, while the third species (*M. bivittatus*) is much larger and clumsier and is marked with two light stripes down the back. There are slight differences in the life histories of these three species, but the treatment for all is practically the same.

Life Histories.

The young hoppers usually hatch out in late May or June. Usually just before the first crop of alfalfa is cut. They take three or more weeks to develop into adults, usually becoming winged before the second crop of hay is harvested. The adults feed for several weeks and then the females lay one egg mass in August or early September, after which they feed two weeks or more again and then deposit another egg mass and soon die, the males disappearing early in the fall, while a few of the

later females of the smaller species and many of the females of the large one are still alive even after heavy frosts.

Number of Eggs Laid and Rate of Increase.

The two smaller grasshoppers lay from twenty-five to twenty-eight eggs in the first egg pod and from twenty-one to twenty-five in the second one, giving a total of about fifty, or a possible increase under favorable conditions of twenty-five times in one year. The large two-striped grasshopper lays from seventy to eighty-two eggs the first egg pod and from fifty to seventy the second, or a total of from one hundred and twenty to one hundred and fifty, or a possible increase of sixty to seventy-five times.

From these figures it is easy to see how these hoppers can increase so enormously in numbers in a few years. It would be possible, if only half of them should survive, for the smaller ones to increase seventeen hundred and eighty times in three years and the larger ones forty-three thousand times. If all survived the smaller ones might increase fifteen thousand times and the large ones three hundred and forty thousand times in three years. These computations also shed light on the reason why the large grasshoppers are so much more numerous comparatively in bad grasshopper years than in ordinary times.

Feeding Habits.

The young larvae do not eat very much and usually stay very close to the ditch bank or other dry places from which they hatched out. At first they cannot stand cold, wet weather, and a cold, wet spell will often kill many of them. They congregate at night on the driest, most open spot available and remain there until the sun warms them thoroughly the next morning. As they grow larger they eat much more and spread out from the dry spots to the general field, still roosting on dry places well up on the vegetation to keep away from the damp earth. As they change to adults they spread still more thoroughly over the field, leaving the dry places and congregating on the rankest vegetation, avoiding the damp earth by roosting high on the stalks from before sundown at night until well into the forenoon on dry days, and all day long on wet ones.

The habit of leaving the dry places where they hatched and spreading to the greener crops as they grow larger leads many to believe that these grasshoppers migrate, and in that sense they do, but as the dry places are usually the borders of the fields and the roadways, or, in extreme cases, from dry pastures or hillsides adjoining, the migration is simply that necessary to obtain food. In the writer's experience but one case in which they moved over half a mile has been observed and in this case they ate up every green thing before spreading to the adjoining fields. They often leave an alfalfa field when the second crop is cut and go into adjoining grain or sugar beets. In no case is there any concerted movement any more than that they travel towards food and on steep hillsides, down hill.

Where the Eggs Are Laid.

As soon as the females have matured an egg mass they return to the dry places to lay. With rare exceptions, which are not worth considering, these grasshoppers never lay eggs in cultivated fields of any kind—sugar beets, corn or potatoes—that have been well cared for. They never disturb stubble land that has previously been well plowed and is in ordinary good mellow condition, nor do they lay in alfalfa fields with young, thick stands, nor in grass sod.

The kind of land they seek for egg laying is dry, hard places where there are few small roots in the first inch or two. Such places as ditch banks, fence rows and corners, roadways, old thin and bunched alfalfa that had not been thoroughly worked up in the spring, worn-out pastures grown up to weeds, and side hills or mountain slopes where the land has been tramped by cattle are usually selected. In soft ground they are not able to bore a hole and keep it open until they can cement it. In grass sod or other places where there are fine roots they cannot force their boring apparatus down. If the ground is too hard they cannot bore into it, but in such cases they utilize a crack or work down alongside the stem of a weed, or in many cases wait until a light rain softens up the first few inches, when thousands of eggs will be laid within the next day or two. In general, any place where sunflowers and coarse weeds grow is a good place to look for grasshopper eggs.

Losses Caused by Native Grasshoppers.

The losses by the alfalfa or native grasshoppers are much more widely distributed and universal than those of their migratory brother, although the latter is the most dreaded. Because they are a common pest and more or less loss from this source is expected, the farmer suffers much of this loss and make no complaint. Often the borders of his field are damaged year after year until the alfalfa is killed out and weeds take its place. The edge of the grain fields are eaten until they are ragged and weedy, and yet if they do not become numerous enough to take the entire crop nothing is said about the injury.

Periodically they increase in numbers sufficient to clear up the entire crop in a given region and then there is consternation and loud complaint, when, in reality, the damage done from year to year over the wider area far outweighs the former loss and both are readily preventable.

A number of cases have occurred in the state where they have been thick enough during July and August to eat everything bare. The outbreak in Cache Valley in 1907 left the ground as bare as if no crops had been grown.

METHODS OF CONTROL.

The secret of success in destroying these grasshoppers, as with the migratory forms, is to destroy them before they have time to damage the crops. They can be successfully destroyed any time from the egg to the adults, but the earlier they are attacked the easier and cheaper it is done. Practically all the loss from this class of hoppers is due to neglect.

Destroying the Eggs.

The disc or spring tooth harrow should be run several times over all ditch banks, fence corners and waste places where the ground is dry and hard and weeds are growing. Old, thin alfalfa fields should also be torn up. This should be done late in the fall and repeated in the spring. One community where the hoppers had been numerous for several years sowed all such places thickly to oats, after working them up thoroughly in the spring. The discing killed most of the eggs and the oats grew so thick that the few surviving hoppers found no dry places to roost and most of them died off while young.

If ditch banks and waste places were sowed down to grass they would no longer be grasshopper breeding grounds.

Destroying the Young Hoppers.

If the eggs are not destroyed the young hoppers will appear in larger numbers on the margins of the fields and on any dry spots. At first they will keep near the open dry places and congregate on them at night to roost. The best method of destroying these is to poison them with a bran mash made as follows: 20 lbs. bran, 1 lb. paris green or white arsenic, 2 qts. syrup, 3 oranges or lemons, $3\frac{1}{2}$ gals. water.

The bran and poison should be thoroughly mixed together while dry, care being taken not to breathe the poison. Then the water, syrup and the orange or lemon should be mixed together and the dry bran sprinkled with the mixture, not wet, but simply dampened until the poison will adhere to the particles of bran.

This mixture should then be sown broadcast wherever the little hoppers are. This amount should be enough to scatter over several acres. The best time to sow it is late in the afternoon or evening after the air is damp, or, better still, very early in the morning before the hoppers are moving. The hoppers will then find it before it has had time to dry out. Their sense of smell seems to be very acute and they will travel several rods to get the "bait."

This method of poisoning can be used on the young hoppers at any time, or even on the adults, but is most successful if used while they are young and before they have been generally distributed in the fields.

Grasshoppers are hard to poison and it will take a day or two before the effects of the poison can be estimated.

The Grasshopper Catcher.

After the young hoppers spread out into the fields or where the adults are distributed over any considerable area, the best and cheapest method of getting rid of them is by the use of the grasshopper catcher. This machine can be run over hay and grain crops, sugar beets and potatoes; in fact, over practically everything except corn and ripening grain. It has been used quite successfully on seed alfalfa by running over the field about every ten days. The details of the machine are illustrated on plate 6, which, with the pictures, should enable anyone to make one of them without difficulty. The writer first saw and used this machine in Colorado in 1902. The false front

as used there was a simple, straight piece of tin. The grasshoppers falling down struck on the bottom and many of them jumped back out. When we began to use them in Utah the curved front was added, which made them much more efficient, as the hoppers now slide clear back into the box and cannot jump back out.

The principle of the machine is very simple—a box about two feet square and sixteen feet long on runners, a two by four extending out four feet at each end, to which a horse is at-

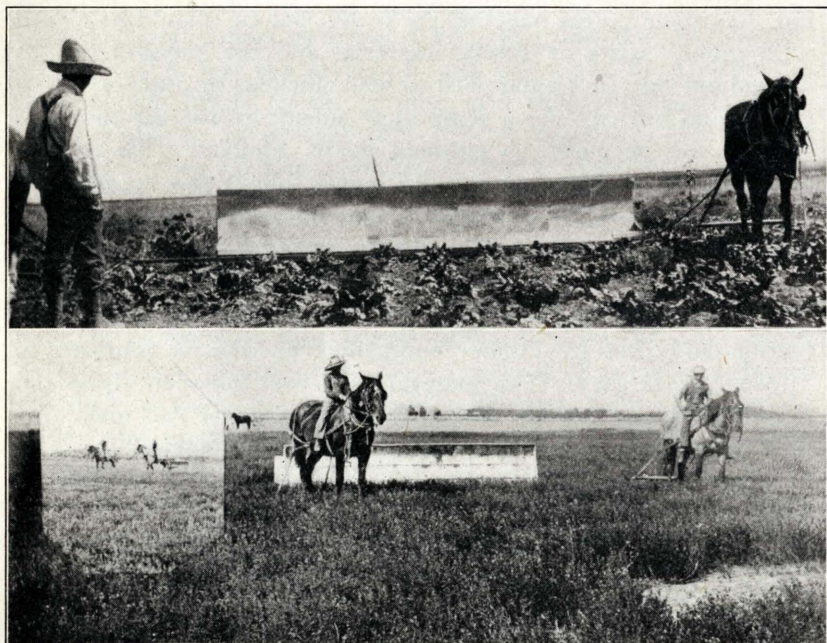


Plate 5—Two Views of Grasshopper Machines.

tached. The horses then travel twenty-four feet apart, driving the grasshoppers in until most of them are in front of the sixteen-foot machine. A rope fastened to the hame on the inside of each horse and dragged just in front of the machine causes the hoppers to jump just as the machine gets to them. The front of the machine is made of tin and is about two and a half feet high and slightly curved. This front does not extend quite down to the bottom and about two inches in front of it and about four inches high there is a false front, a second piece of

tin, which curves back down and into the box. A grasshopper hitting the tin face cannot get a foothold and is perfectly helpless and slides down between the two pieces of tin, strikes the curve and is thrown well back into the box, far enough so that he cannot see the opening through which he entered. The top and back of the box are made of wire mosquito netting and the hopper immediately jumps towards the light and clings to the netting, never seeking the hole through which he came in. Several bushels can be gathered in this way before they will shake down onto the bottom sufficiently to choke up the front opening. As soon as this happens the front opening should be closed with gunny sacks or similar material and the hoppers can be shoved out into sacks and used to feed chickens or dumped into a trench and buried. As a temporary substitute for the tin front oilcloth can be used. A six-inch board, hinged to the bottom of the box and extending the full length, about five inches back of the front, could be arranged to fold down and close the front while at rest, or stand up at a slight angle to keep the hoppers from rolling down and choking the opening.

Dozens of these machines were built under the writer's direction and sold by lumber companies in 1907 at fourteen to fifteen dollars each. The material will cost between eight and nine dollars and anyone with a saw and hammer can make one in a very short time. The runners should be spaced so as to fit sugar beet or potato rows, if the machine is to be used on these crops.

A machine if protected will last for years, and as it takes twenty-four feet at a sweep will cover forty to fifty acres in a day, and will thus handle a large area. As there is no expense to the operation except the team and a man to drive, or preferably two small boys to ride the horses, the cost per acre is trifling.

It is not possible to catch all the hoppers by going over a field once, but under favorable conditions a very large per cent of them can be caught. If the crop is fairly high the best time to catch the hoppers is in the morning and evening. At these times they are roosting and are quite sluggish. On low crops during the heat of the day, when the hoppers jump readily, will be the best. If the tin front is kept bright and shiny the grasshoppers apparently are not able to see it at all and fly against it readily. Six to ten bushels of grasshoppers have been collected

in an hour with one of these machines where they were numerous and conditions favorable, and thirty to forty bushels per day taken from fields where they did not appear to be very abundant.

If grasshoppers are abundant in an alfalfa field a strip should be left next to any sugar beets, potatoes or other crops and not cut until after the rest of the field has started to grow again. By leaving this strip and a strip in the center of the field most of the hoppers will gather on these strips and can be readily caught or poisoned and the field practically freed of the pests without their being distributed to the surrounding crops. Grasshoppers entering a field of grain that has headed out will often bite the stems off just below the head, dropping most of the heads to the ground and thus ruining the crop. Care should be taken that they do not enter the field at this time, or if they do that they are promptly poisoned or caught.

Protecting Young Orchards.

Very severe losses have been sustained by allowing grasshoppers to migrate into young orchards after adjacent crops have been cut. Even where there is a crop of beets or potatoes growing between the trees they will often strip the trees of leaves and girdle the smaller limbs, killing or badly stunting the trees. The reason the trees are damaged so badly is because the hoppers roost in them at night and then feed there for some time in the morning before jumping down. Often the damage is done before it is realized. The writer has seen hundreds of acres of young trees destroyed in this way, where a very little work would have prevented any serious damage. Vigorous measures should be taken at once to eliminate the hoppers. The grasshopper catcher should be run up and down between the rows, the poisoned bran mash sown wherever the hoppers occur. A boy with a flat paddle can knock the grasshoppers out of ten acres of trees between the time they go to roost and dark. Once driven out at that time of night they will not come back again. A still better method is to take a barrel hoop, put it into the mouth of a gunny sack, tie a rake handle across this and hold it on one side of the tree and knock the hoppers off into this. A few hours spent in this way will often save a valuable orchard from entire destruction.

Handling the Swarms That Come Down From the Dry Benches.

Along the west slope of the Wasatch range, from the Idaho line south for one hundred and fifty miles to Nephi the mountains drop abruptly away in a series of benches. On these lower benches and the upper parts of the sloping valley floors adjacent are some of the best and most extensive fruit districts of the state. Above the irrigation ditches the upper benches are either dry farmed or used for grazing, and where overgrazed or carelessly farmed these benches and slopes are the best kind of breeding grounds for grasshoppers. Located on the sunny western side of the mountain chain these slopes warm up early in the spring and grasshoppers hatch out early. A little later the vegetation on these slopes dries up and the half to two-thirds grown grasshoppers following the line of least resistance start down hill, gathering in numbers as they go and devouring everything before them.

To successfully control these swarms and prevent damage to the crops and orchards below requires special care and preparation. If the breeding area is small it may be possible to destroy most of the eggs, but usually the area is too large and the ground too rough, stony or broken to allow of this, and the only method of preventing the swarms from forming is to scatter poison mash. In this case it is well to have everything ready, but wait until they have started down and concentrated on as small an area as possible. With food short they will eagerly snatch at the poison bait. The first line of poison should be put out at some distance from the upper limit of crops and should be renewed daily until the migration ceases. A second line should be established just above the crops to catch those crossing the first line.

A strip of dry farm grain just above the orchard will often be of great value in stopping the hoppers until they can be poisoned or caught with the grasshopper catcher.

Driving the Hoppers.

Because a grasshopper can make one or two long jumps if disturbed many people think that it would be easy to chase them out of an orchard or grain crop, and it can be done, but not in the way one would drive stray cows or horses out. After making four or five jumps a grasshopper is exhausted and will

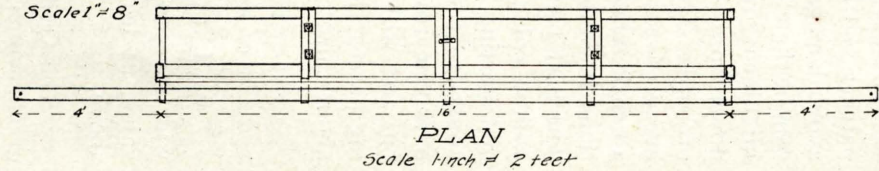
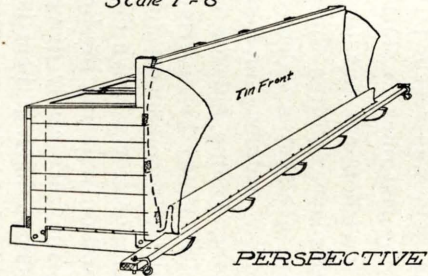
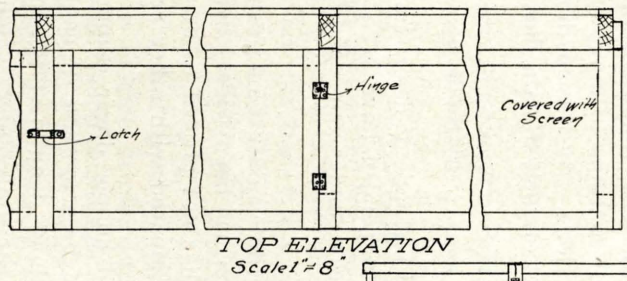
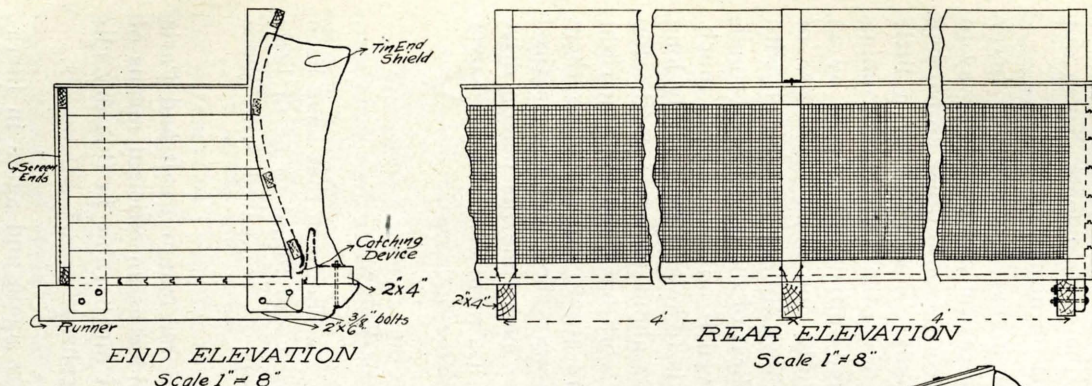


Plate 6—Details of Construction of Grasshopper Machine. (From Drawing by Humphries.)

crawl under any convenient shelter and hide. By this time others will be jumping and he would not be missed, but when the edge of the field was reached the grasshoppers driven out would be only the last ones to start up near the edge.

To drive grasshoppers out of orchards, vineyards, berry patches and like places is often the easiest and quickest way to avoid damage. Once they are driven out onto other crops they can be handled by ordinary methods. Sometimes by a little intelligent driving to one side or the other, a swarm coming down from the hills may be diverted sufficiently to pass by an orchard. To drive them successfully one must make use of every advantage possible. Drive down hill, or on a level, with a gentle wind and only during the heat of the day. With conditions favorable they are easily driven if not hurried too much. The best method of driving them is to take a moderately long willow pole with the leaves on for about two feet at the top and starting at the top of the field work back and forth at right angles to the direction the hoppers are to go, crowding them over one row at a time. In this way they will not be tired out and will continue to move over each time the person driving passes along. By this method a swarm can be moved over about thirty or forty rods a day.

Methods of Less Value.

Several methods of destroying grasshoppers that have been widely recommended have been tried and found to be of little value, at least under our conditions, as compared with those above.

The Criddle mixture of fresh horse manure, salt and Paris green, which has been widely heralded as an efficient means of poisoning, has not proved to be of much value in this dry climate, as compared with other poisons.

The old hopper dozer reappears again and again in literature as the best method of capturing the adult hoppers, but usually without definite statements of results. In the writer's experience the grasshopper catcher has been much more effective and, as it is much less expensive to operate and covers a much greater area in a day, even those who already had the hopper dozers quickly abandoned them for the new machine.

The use of turkeys and chickens to control grasshoppers is often advocated by enthusiastic poultry writers, but never by entomologists nor farmers who have had experience with large swarms of hoppers. Chickens and especially turkeys will chase and capture grasshoppers when the insects are scarce as part of a mixed diet, but when grasshoppers are abundant the fowls soon get sick of them and practically cease to eat them. The writer has seen grasshoppers so thick that thirty to fifty would be hanging to one clump of alfalfa, fairly bending it down with their weight within two or three rods of the coops of a thousand chickens. The man who waits for his fowls to rid his crops of a bad grasshopper attack will not need to worry about the harvest. Where there are only a few grasshoppers in a field the fowls may clean them up. Even here the turkeys are likely to do as much damage as the hoppers would have done. When, however, a real outbreak of grasshoppers occurs and swarms numbering into the billions have to be handled and handled quickly a flock of chickens would be as effective as a flock of fighting cocks would be in stopping the present European war.

Grasshopper Diseases and Parasites.

The same parasites and carnivorous insects that have been mentioned as attacking the Warrior hopper's eggs also prey upon the "Native's" eggs, and, in addition, several others are commonly found destroying them, among the most common being the larvae of the gray potato beetles and the red mites.

The larvae and adult hoppers are also attacked by a number of enemies. Among them are the hair snake, a large fly that deposits tiny grubs on them, from which maggots enter the body, and red mites that infest their bodies and occasionally kill them.

When the larger species of grasshopper become exceedingly numerous there is often a disease breaks out that kills large numbers. It also attacks the smaller species, but not as readily. This disease which is caused by a fungus (*Empusa grilli*) causes the adults to become sluggish and cling to the tops of the vegetation, where they finally die. This fungus works more rapidly in wet weather and dead grasshoppers are often seen clinging to the vegetation along ditch banks when it is not working anywhere else. Oftentimes these grasshoppers

will be found to be still alive, but so sluggish that they do not move when the branches are disturbed.

Another fungus obtained from South Africa was distributed by the government for several seasons, but had little effect. Most of the reports of success of this fungus in Colorado were investigated by the writer and found to be based on destruction caused by the native fungus.

DESTROYING THE BIG BLACK CRICKETS.

From time to time swarms of these large wingless crickets (*Anabrus simplex*), often called Black or "Mormon" crickets because their first injury was to the crops of the early settlers of Utah, appear in the mountain districts and slowly but steadily travel down onto the cultivated fields and meadows of the farmers in the adjacent valleys.

Not enough observations have been made to discover what guides these swarms in their selection of a route. Apparently, however, in the swarms that the writer observed descending on Vernon in April, 1904, there was no tendency to follow the sun, but rather to travel down hill.

These swarms come early in the season before the first cutting of alfalfa and are a serious menace to that crop in some of the outlying districts.

On account of the rocky and broken character of the ground little can be done with these swarms until they get down into the lower lands. Here they can be poisoned, crushed with a heavy brush drag or guided into pits by means of fences or trenches set at an angle to their line of march.