THE MORMON CRICKET AND ITS CONTROL

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THE MORMON CRICKET AND ITS CONTROL

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The mormon cricket, *Anabrus simplex* Hald., was undoubtedly present in the northwestern part of Colorado long before the advent of the white man. During that time it was well known to the Indians of the region and probably constituted a portion of their diet. Reports from some of the earliest cattle-men show that at times this insect increased to enormous numbers and practically over-ran the range.

The damage done to crops at that time is hard to estimate, since very few crops were grown, and range land was so plentiful that if the range was damaged in one place, the cattle were moved to more abundant pastures.

However, with the coming of the homesteader and dryland farmer, the scene changed. These people had to depend on what they could wrest from the soil for their livelihood, and so we have the mormon cricket playing an important part in the agricultural development of the infested areas.

**ECONOMIC IMPORTANCE IN COLORADO**

The earliest recorded outbreaks in Colorado (6) occurred in 1879, 1882, 1895, 1900, 1902 and 1904. During the period from 1904 to 1922 natural conditions apparently kept the cricket in check and little serious damage was done. In 1922 a scattered infestation extended from Price Creek in Moffat County on the east, to the Utah line on the west. This was bounded on the north by the Bear River and on the south by the Moffat County line, the largest and thickest bands occurring on Blue Mountain and in the Danforth Hills. Damage to crops in this region varied from partial, in some places, to total in others. The total estimated crop loss (3) was $15,000 to $20,000.

A control campaign in which poisoned bran-mash was the principal weapon, was inaugurated in 1923 under the direction of the State Entomologist’s office. A great deal of good was accomplished, but, owing to the inaccessibility of a large part

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Figures in parentheses refer to “Literature Cited” in the back of this bulletin.
of the infested territory, making it almost impossible to get action on certain bands, coupled with a shortage of funds, the campaign, from a control standpoint, could not be termed a complete success.

Since 1923 the infestation has slowly spread eastward, keeping for the most part within its former north and south boundaries. In 1927, it had penetrated 7 miles into Routt County, which joins Moffat County on the east, and had covered an area of over 1 million acres. During this time the practicability of using corrugated-iron roofing and galvanized tin as barriers and traps was proved. Altho this method of control was used only in a small way by a few individual farmers, it more or less paved the way for control on a larger scale, which followed.
Damage to crops in the infested area during the period between 1923 and 1927 is hard to estimate because of an almost utter lack of reliable statistics. Undoubtedly great damage was done, because we do know that the numbers of occupied farms in the cricket-infested territory fell off from 429 in 1920 to 258 in 1927. This rapid decrease was probably not due entirely to the cricket, because some of the farmers north of the Bear River, remote from the cricket district, also left, but it is the belief of many business men of Craig, and also farmers still living in the infested area, that the cricket formed the principal reason for many leaving.

**NATURE OF AN INFESTATION**

Crickets ordinarily occur in bands varying in extent from one or two acres to a square mile or more. In the early stages of their development they are heavily concentrated on the ground, it being possible to find as many as 100 to 500 per square foot. As they develop in size, they spread over a larger territory, but usually remain in their respective bands. During a severe outbreak, these bands may be so numerous as to merge into an enormous horde, covering thousands of acres.

**NATURE OF INJURY TO FIELD CROPS**

Altho some damage is done to small grains in the spring, the greatest injury is done after the heads are formed and the kernels are in the dough, or even after they have hardened. At this time only the heads are attacked, but they are thoroly stripped of seed, so that a field of grain may be almost a total loss.

Alfalfa is damaged at all times of the year, altho the first crop usually suffers more than the succeeding ones. The reason for this is that the crickets will ordinarily forsake the alfalfa for newly-headed grain about the time the first cutting is being taken off.

**LIFE HISTORY AND DESCRIPTION**

The egg of the mormon cricket is about one-fourth inch in length and about one-third as wide as long, resembling to some extent a kernel of rye. When first laid, the egg is chocolate-brown in color, but changes to a milky-white almost immediately on coming in contact with the soil. As the young cricket develops within the tough, leathery shell, the egg again changes to a light gray and becomes swollen at one end. This development takes
place in the fall of the year, so that by the time winter arrives the young cricket is fully developed and ready to step out of its shell with the first warm days of spring.

The eggs are placed in the soil by the adult females some time between June 15 and September 1, at depths of from $\frac{1}{4}$ to 1 inch. They are laid singly, but often as many as 15 or 20 eggs are laid in a small group, presumably by the same female. There seems to be no special arrangement of the eggs in the soil, since they have been found sticking in the soil at practically all angles.

**NYMPHS.**—When the frost goes out of the ground in the spring and the soil warms up to 40 degrees F. or more, the young crickets make their appearance. At this time they are singularly delicate creatures, hardly visible to the casual observer. Farmers are then prone to pray for a snow storm or a good hard freeze, thinking, of course, that such a delicate creature as the young cricket seems to be could not possibly withstand it. Usually their surprise is great to find on a nice warm day following such a storm or hard freeze that the young insects are as hale and hearty as ever, having come thru the inclement weather with little or no mortality.

This phenomenon would not be so mystifying if one would take the time to investigate a few dry pieces of cow dung or turn over a few loose stones during the time the thermometer registers 40 degrees F. or less. It is not unusual to find the tiny insects piled up under such places by the hundreds. It is thus easy to see why they will all disappear during a cold spell in the spring and then appear again in seemingly greater numbers than ever on the first warm day following.

As the young cricket feeds, growth must necessarily take place, and, since the body covering will not stretch to accommodate this growth, a complete shedding of the covering is necessary. This process, which is termed molting, is quite an interesting one to watch, requiring about 10 to 15 minutes. The young cricket crawls up on a stem of grass or other object, where it fastens itself by the hind pair of legs, with the head downward. Soon a swelling is noticed on the back just behind the head, caused by muscular contraction within the body. This swelling serves to split the old covering down the center of the back from about the center of the top of the head to half way back on the abdomen. Thru this vent the body, by a series of twisting movements from side to side, is pushed out from the old skin, commencing with the head, antennæ and mouth-parts
and continuing with the two front pairs of legs. The hind legs are then withdrawn with the aid of the two front pairs and further twisting movements of the body. The tip of the abdomen is finally freed and the young cricket drops to the ground with a new and larger covering of pinkish-brown.

It will usually remain quietly where it falls until the new coat has hardened. In the first four stages, the color is usually black with white markings on the top of the body and on the side of the prothoracic shield. In the more advanced stages the color may vary to a green and black, red or brown. The lighter markings are retained. This process takes place every ten days or two weeks until seven molts have been accomplished, or, in other words, until the cricket reaches the adult stage.

In the female of this insect, the growth of the ovipositor is the best index to the various stages of growth or instars. During the first two instars the ovipositor is not visible to the naked eye. In the third it is plainly visible, but does not extend past the tip of the abdomen. From this time on it doubles in length after each molt, with the exception of the sixth, or next to the last. That is, the seventh instar females have an ovipositor practically as long as the adult, the only difference being that the ovipositor of the adult is much heavier and stouter at the base.

The adult.—Ordinarily the cricket completes its growth in from 75 to 90 days under field conditions, bringing it to the adult stage some time between June 15 and July 1. After the last molt, those specimens that are not already black slowly change to that color, until about a month after reaching the adult stage, when practically all have assumed a uniform black color. The insect is also sexually mature and copulates in about 10 days after reaching maturity. The females are ready to start egg laying soon after.

Al tho classed as wingless, in reality very small vestiges of wings are present and can be seen by lifting the long shield that extends back, covering practically the whole of the thorax. In the female the wings are very rudimentary and are not functional in any sense of the word. In the male the two fore wings overlap and are equipped with sounding organs, so that when they are drawn across one another a distinct chirping noise “not unlike the ticking of a watch,” as Criddle (4) describes it, is produced. This chirping is used a great deal during mating and to express alarm when the insect is frightened.
HABITS

PROTECTION.—The habit of seeking protection during too cold or too hot weather and going into shelter at night and when alarmed, is very pronounced in the mormon crickets. Throughout their entire lives, they will invariably seek shelter under anything offering the least bit of protection as soon as the temperature drops in the evening or during cloudy, wet weather. They have been observed to stop and cluster, a custom which precedes the actual seeking of shelter, while on the march, during the day when a cloud momentarily obscures the sun. A short summer shower will almost always drive them to shelter, from which they emerge after the shower has passed to cluster again in great bunches until warmed by the sun.

A soil surface temperature of 95 degrees F. or more during the day will halt their activities and drive them up on sage brush or any other objects which will bear their weight. The sight of a band resting during the heat of the day in this manner reminds one of a great many low bushes laden with rich, ripe fruit. The habit of clustering before seeking shelter and after coming out of it, however, affords many advantages in the control of this insect, as will be discussed more thoroughly under “Control.”

FOOD PLANTS.—Altho the mormon crickets are omnivorous to a certain degree, the main part of their diet is made up of vegetable matter. A great many uncultivated plants and shrubs are eaten, including those in the following list:

1. Tumbling mustard 6. Russian thistle
2. Common mustard 7. Sage brush
3. Hare’s ear mustard 8. Buck brush
4. Dandelion 9. Scrub oak
5. Prickly lettuce 10. Willow

To our knowledge there are no agricultural plants that they do not feed upon and damage. All field crops, including the cereal and forage varieties, are eaten with relish at any time during their growth, and garden vegetables seem to be special delicacies that are eaten to the ground.

CANNIBALISM.—Among the crickets cannibalism is quite marked. During the nymphal and adult stages they have been
observed feeding on the bodies of dead and dying members of
the band, even tho other
food was plentiful. This
would tend to show that
a scarcity of food is not
necessarily an incentive
to cannibalism. There is
also no discrimination
between sexes, since
males have been ob-
served feeding on fe-
male and vice versa.
Females may be more
susceptible than males,
especially during the
egg-laying season, be-
cause of the possibility
of their becoming weak-
ened thru oviposition,
and from the fact that
they are forced to re-
main quiet for some lit-
tle time while depositing
an egg, thus making
them more liable to attack. Nymphs are especially susceptible
during the molting process.

It appears that the insects prefer eating those more unfor-
tunate ones that have met with a mishap in which they have
suffered the loss of legs, or in which part of the body has been
brushed. Seldom are those individuals that are physically able
to avoid attack killed and eaten. They also seem to avoid those
that have been dead for some little time.

MIGRATIONS.—This one habit of the mormon crickets has
caused more conjecture and comment than all their other habits
combined. Ever since their first attack on the crops of the
Mormons in 1848, men have been wondering why they migrate
and what influences their direction of march. To date we know
little more about this than the Mormons did 80 years ago.
Various ideas have been advanced, in fact most everyone has
his pet theory, as to whether the wind, sun, food, or topography
of the land over which they travel is the deciding factor in
directing their march. Of all these ideas, however, it is doubtful
if there is one that will hold true.

We do know that practically all their time, after they reach

Fig. 2. Crickets are very cannibalistic. A
group of crickets feeding on an in-
jured member of the band.
the third or fourth instar, except that spent in feeding, resting during the extreme heat of the day and at night, and egg laying, is spent on the march. It is also a fact that different migrating bands can be found boxing the compass, marching up hill and down, toward and away from crops, all in one day and within a radius of a few miles.

The distance this insect is capable of covering in one day has been placed at from \( \frac{1}{8} \) to \( 1\frac{1}{4} \) miles. Surely, if they travel steadily from the time they start in the morning until they stop at night, they will cover much more territory, because in watching a single cricket marching along, one will find its rate of speed to be at least \( \frac{1}{4} \) mile an hour. However, frequent stops cut down on the total distance and the longest recorded day’s march is 1 and \( \frac{1}{4} \) miles. Dr Gillette has suggested that “apparently, this marching tendency is an inherited instinct that has been useful in the past in enabling this insect to find its food and reproduce its kind.”

REPRODUCTION.—About ten days or two weeks after reaching maturity, the insects are ready to copulate and start laying eggs. Unlike many insects, the female of the mormon cricket copulates several times during the course of her egg-laying season, which extends over a period of from 30 to 40 days. Oviposition may take place at any time during the day, altho the greater number of eggs are laid in the afternoon.

Just how many eggs one female will lay during the course of an egg-laying season is not definitely known. Fifteen females held in separate cages at the United States Bureau of Entomology laboratory at Billings, Montana, averaged 85 eggs each, while one individual laid a total of 160. Undoubtedly greater numbers may be laid under natural conditions in the field an1 the average might easily be placed as high as 150.

When a female cricket is ready to deposit an egg, she walks around with the tip of her abdomen raised and the ovipositor pointed downward in an almost vertical position. In this way, the soil is tested in several places until a suitable one is found. The ovipositor is then worked into the soil by a shuttle-like movement of the right and left halves, to its maximum depth. The egg is then passed down between the two halves by means of a pair of long inner valves. After the egg is placed in the ground, the ovipositor is withdrawn and the opening to the hole closed by means of a few quick, backward movements of the ovipositor.

Practically all types of soil are used by ovipositing females, with a light, sandy soil perhaps a trifle favored. A sunny ex-
posure is usually chosen, where the ground is more or less bare of vegetation.

NATURAL CONTROL

BIRDS.—Cricket bands are, as a rule, marked by a following of birds. We have no records in Colorado of birds occurring in sufficient numbers to totally destroy cricket bands, but we know that they do greatly reduce the cricket population, and deserve protection for this, if for no other reason. A list of birds that feed on crickets or cricket eggs would contain most of the species of the area under discussion. For western Colorado, blackbirds, crows, hawks, horned larks, meadow larks, sparrows, magpies, ravens and sage chickens should be regarded as the most common. The sea gull, which has been credited with the destruction of large bands of crickets in Utah, unfortunately does not occur in numbers in western Colorado.

POULTRY.—Crickets are highly recommended for chickens and turkeys as a growing and fattening food. The quality of eggs obtained from hens fed on a heavy cricket diet has been criticized.

MAMMALS.—Prairie dogs, ground squirrels and chipmunks are quite fond of crickets. The toll taken when a band crosses a heavily populated prairie dog town must be heavy. Badgers, coyotes and skunks have been reported as feeding on crickets. Hogs eat crickets with apparent relish, but the value of crickets as a food for hogs has not been fully investigated. Sheep have been reported as feeding on crickets, but this observation has not been made in Colorado.

INSECT PARASITES.—There are two recognized insect parasites of the mormon cricket. One, a small, wasp-like insect, Sparaisson pilosum Ash, which lays its egg inside the egg of the cricket, is known to exist in Colorado. The other, Palmodes laeviventris Cress, a large wasp which preys upon the cricket, does not occur here so far as is known at this time, but is rather common in Montana.

The comparative freedom of this insect from parasites may be accounted for by its extreme cannibalistic habits. Since a great many of our beneficial parasites are by nature internal, it is easy to see how the destruction of a parasitized cricket by his stronger and more active mates would almost necessarily destroy the parasite as well.

The egg parasite, S. pilosum, lays its egg inside that of the cricket, probably some time after the egg is deposited. The parasitized eggs can be distinguished from fertile ones in a
month or six weeks, as they have a bluish color and do not show any external signs of development. Those that are fertile and unparasitized become much swollen at one end and acquire a dull gray color. Since the parasites develop only at high temperature (85 to 95 degrees F.), practically all their development takes place the following spring and summer. This delay serves them well, tho, because it allows them to emerge just at the time when the crickets are busy laying eggs.

It has appeared, in rearing this parasite in the laboratory, that moisture is quite essential at the time of its emergence. This was substantiated by field observations in September, 1928. While digging for eggs in the Danforth Hills, Moffat County, a number of those of the previous season were discovered. Several contained fully developed parasites that were determined to be Sparaison pilosum Ash. Why these parasites failed to emerge is not known. This locality had suffered from drought since early summer and the shell of the eggs was quite dry and hard.

Altho the egg parasite has never been recorded as plentiful in Colorado, there is little doubt that in other states it has helped a great deal in bringing the mormon cricket under control. During the outbreak in Montana in the fall of 1926, one district in Lake County, which had perhaps been the most heavily infested for two years, showed a remarkable number of parasitized eggs. In this district in the spring of 1927, so few crickets hatched that little or no control work was necessary. Other districts in Lake County showing varying degrees of parasitism in 1926 had materially less crickets in 1927 than the year before. Practically the same thing happened in the fall of 1927 in all other districts in both Lake and Sanders counties.

Altho a strenuous campaign in 1927 decreased the number of crickets remarkably, there were enough left to lay eggs, so it seemed that it would be necessary to continue the campaign in 1928. Eggs taken in the field that fall showed a high degree of parasitism, and practically all the eggs that were not parasitized seemed infertile. What caused this infertility of the egg is not definitely known, but it seems to occur wherever the crickets have been strenuously fought. With these two observations in mind, it was predicted that the campaign in Montana during 1928 would be short. It was. In fact, practically all dusting operations had ceased by the first of May.

The other known parasite, Palmodes laeviventris, mentioned above, was observed in Montana for the first time in 1927. Its method of procedure is to sting the cricket, bringing about a
state of paralysis, and then drag it into a burrow in the soil. Here an egg, which soon hatches into a small grub-like larva, is deposited on the side of the paralyzed cricket. This larva feeds on the body of the cricket and finally pupates without having changed positions materially from the time the egg was laid. The exact number of generations of this parasite annually is not known, altho there are thought to be several.

Little can be said as to the value of this parasite since it was only under very limited observation for one year. However, if the numbers increase as rapidly as it seemed they did in Montana in 1927, there is no doubt that they will become a big factor in control.

**ARTIFICIAL CONTROL**

**CULTURAL.**—While it is possible to plow eggs under so deep that the insects cannot emerge, this method of control is not applicable to the great areas of uncultivated land that crickets infest. Disking and harrowing may be of some value at time of hatching, if the soil permits, but, on the whole, cultural methods are of little practical value in the large permanent breeding areas of the mormon cricket.

**FIRE.**—Fire has served to help combat crickets for many years, and very successfully in some instances. The limiting factor in the use of fire is that crickets seldom infest the type of land that can be readily burned over without hazard or loss.

**NOISE.**—Of all control methods employed by man, probably the use of noise is the oldest. In 1848 (2) the Mormon pioneers employed noise in attempts to drive crickets from their crops. They are, as a rule, of very nervous temperament. When a cricket is suddenly disturbed, it will immediately jump away from the source of disturbance, exciting others near by. The excitement spreads in waves that may be compared to the spreading of waves resulting from casting a stone into a pool of water. The waves of jumping crickets will gradually recede as the distance from the origin is increased.

It has been observed that certain noises may be used to cause a cricket band to execute a flank movement, but these results are not consistently secured. The crickets may become so accustomed to the din that they are not influenced by it.

**BARRIERS.**—Certain types of fences can be made 100 percent effective in stopping migrations and in trapping the insects. The fences or barriers consist of some material which the insects cannot climb. To be the most effective, they must have pits dug at intervals to trap the crickets coming up against them.
The main objections to such barriers are: (1) The cost; (2) difficulty in handling; (3) attention required for operation.

Several types of barrier have proved quite successful. The galvanized-tin barrier now in use in Colorado is perhaps the best, but has probably the highest initial cost. During the season of 1928, two types of barrier were used in Routt and Moffat counties. The most common type consisted of galvanized-tin strips, 6 to 8 feet long and 8 to 15 inches wide. The second type was made of valley tin or a light weight of galvanized tin in 50 to 100 feet lengths, with a width of 8 to 10 inches. The advantage of the latter type is that the barrier can be rolled into compact bundles that are easily transported and quickly set up. Altho strips 8 inches in height have proved effective, much of the fence now in use is much higher. The cost of the tins discussed varies from 4 to 10 cents per linear foot.

A very serviceable trap may be formed by lining the sides of a pit with barrier tin, but a more satisfactory method is to lay tin flat on the surface of the ground bordering the pit, so that about 6 inches project over the banks of the excavation. The tin may be held in position by placing a few shovelfuls of dirt on the edge away from the pit. The edge overlapping the trap should be slightly dipped so that crickets will slide into traps readily.
The board-and-tin barrier used in Washington against the coulee cricket is very good. It consists of an 8-inch board set on edge, with a 4-inch strip of tin nailed on top, projecting outward toward the on-coming crickets. This barrier will cost in the neighborhood of $250 per mile, depending upon the cost of lumber for any particular region. While quite effective, it requires more attention than the tin barrier, and is more difficult to transport and erect.

![Fig. 4. Where it became necessary to cross the road, a panel was constructed that could be removed to allow the passage of vehicles. (Photo by R. W. Schafer.)](image)

Probably the cheapest type of barrier is one devised in western Montana, and consists of an 8-inch board set at an angle of 45 or 50 degrees, with a 3-inch strip of oilcloth pasted to the inner side near the top. The cost of this barrier should not exceed $150 per mile, but requires constant attention, and, like the board-and-tin barrier, is difficult to transport and erect.

It is believed by many that any of the above barriers are too expensive to use in actual control work. They are, however, very useful in stopping migrating bands when the depth of the band is much greater than the width. They have been used quite effectively in Washington (8), Idaho (1), and Nevada (5). During the campaign in Routt and Moffat counties in Colorado, in the season of 1928, about 13 miles of tin barrier were used very effectively in connection with dusting.
TRENCHES.—The following quotation is taken from Aldrich (1):

"Others have used a dry ditch around the field, making a smooth vertical surface on the inner side. In this ditch at intervals deep holes are dug, into which many fall and cannot get out. Others, instead of the deeper holes, use a post of heavy timber, drawn along in the ditch by a horse, which crushes many crickets. Those not killed outright, if at all injured, are immediately seized upon and eaten by their uninjured companions."

The trench method is mentioned here as a possible means of control, but its practical application to field conditions in Colorado is very limited.

KEROSENE ON WATER.—During the season of 1928, the junior author treated a small, slow-moving stream with kerosene, while a cricket band was crossing. The migration stopped within a few minutes. All crickets that entered the film-coated water died very quickly, about 15 minutes being the maximum period required for the kerosene to cause death. Altho the kerosene is very effective in its killing properties, it is doubtful if a practical application of this method of killing crickets will often be used in Colorado.

There are many known liquids, such as tar products, heavy oils, and caustic materials, that may be used to trap or kill insects, but none have ever been practically and successfully employed to fight crickets when they exist in large numbers.

POISONED BAITS.—For years experiments have been carried on with bran mash and other poisoned baits to find an effective method of controlling the mormon cricket, but, on the whole, poisoned baits have not given reliable results. The crickets are very erratic in their feeding, thus giving varying results. Then, too, since the insects are almost constantly on the move, it is very hard to see results. The following bran bait has been selected as the best:

Bran ........................................ 100 lbs.
Amyl acetate .................................. 3 oz.
Salt .............................................. 5 lbs.
Liquid sodium arsenite (8-lb. material)* .... 3 to 4 qts.
Water ............................................. 11 gal.

ARSENITES.—Due to the fact that the use of poisoned bran-mash and other methods of control for the mormon cricket had not proved entirely satisfactory, experiments were started at the Billings, Montana, United States Entomological Station with various dusting and spraying materials designed to give kills by direct or indirect contact with the insect. Of the materials tested, sodium arsenite proved to have the most possibilities.

*Eight-pound material refers to the arsenical content of the liquid, there being eight pounds of arsenic to the gallon of liquid sodium arsenite.
Sodium arsenite has been used in South Africa as a locust poison for some years and has proved highly successful (7). Their method of application is to spray a mixture of the sodium arsenite, water and molasses upon the vegetation in front of a migrating swarm of nymphs. Recently sodium-arsenite dust has practically replaced the spray because it is more easily transported and applied. Washburn (10) carried on some experiments with a liquid spray in the United States in 1911, but, altho very good results were obtained, he did not continue the work. No work was done from that time until R. L. Shotwell and F. T. Cowan of the United States Bureau of Entomology began experimenting with sodium-arsenite dusts and sprays in Montana in 1926 (9).

During the summer of 1926, experiments with sodium arsenite consisted mainly of tests with various mixtures of the liquid arsenite and water and with the undiluted sodium-arsenite dust. This work demonstrated the killing power of the material when used either as a spray or a dust, but also showed it to be very expensive and unsafe to use in crops because of the danger of burning the foliage. Accordingly, further experimental work was conducted during the following winter, with the idea in mind of eliminating this burning hazard, and also to cheapen the material so that it could be used economically. Hydrated lime was chosen as a diluent for sodium-arsenite dust because of its cheapness and the ease with which it could be procured. Pure sodium arsenite was mixed with the hydrated lime in the following proportions: 1 to 1, 1 to 4, 1 to 8, 1 to 12.

In the first part of these experiments, grasshoppers in the third and fourth instars were dusted lightly with the various mixtures and placed in glass tubes, closed at each end with gauze. Food, in the nature of sprouted wheat, was given the hoppers each day. A check cage containing grasshoppers which had not been dusted was also kept.

In the second part of the experiment, flower pots containing sprouted wheat were dusted with the various mixtures. The grasshoppers were held on the dusted plants in wire-screen cages for a period of 24 hours, after which they were removed to glass tubes. In this way, a check on the burning qualities of the various dusts was obtained, as well as a check on the mortality of insects, not previously dusted, that came in contact with vegetation that had been so treated.

It was found in these experiments that the 1 to 4 mixture gave better kills than either the 1 to 8 or 1 to 12, and did not burn the foliage. The 1 to 1 mixture gave 100 percent kills in a short time, but burned the foliage almost as severely as did
the pure arsenite dust. The 1 to 4 mixture reduced the price of the final material so that when applied at the rate of 5 pounds per acre, the cost would be between 45 and 50 cents.

Following this work, in the spring of 1927, practical demonstrations were made with a 1 to 4 mixture of sodium arsenite and lime. These proved very successful and dusting finally formed the basis for the control campaign in western Montana. The only drawback to the use of sodium arsenite is the difficulty of obtaining the material in sufficient quantities for practical purposes. W. B. Mabee, State Extension Entomologist for Montana, solved this problem when he suggested the substitution of calcium arsenite for the sodium. This proved to be an excellent suggestion, for not only did calcium arsenite prove equally as effective, but it was cheaper and easier to procure.

THE 1928 CRICKET CAMPAIGN IN ROUTT AND MOFFAT COUNTIES

Plans for the 1928 cricket campaign date back to early in August, 1927. At that time F. T. Cowan, of the United States Bureau of Entomology, and George S. Langford, of this office, met at Craig, Colorado, with local farmers, business men and county commissioners from Routt, Moffat, and Rio Blanco counties. An outline of the 1927 campaign in Montana in which arsennites were used was given. The principal point raised at this
meeting was that of obtaining funds for a cricket campaign. On October 7 and 8, 1927, at the Northwestern Colorado Agricultural Economic Conference, Steamboat Springs, a committee met to discuss the cricket problem. On February 21, 1928, a meeting was held at the Colorado Agricultural College. There
were present representatives from Routt and Moffat counties, the United States Bureau of Entomology, the Colorado State Entomologist's office, and the Extension Service of the Colorado Agricultural College. Plans for the year's work were made. It was decided that the work would be started on a demonstrational basis, and organization plans were so drawn.

Early in April, 1928, dusting demonstrations were begun in the Cross Mountain district by the Bureau of Entomology. Kills resulting from the use of sodium and calcium arsenite varied from 75 percent to 100 percent. Calcium arsenite was the dust selected for the year's campaign, because it gave as good results as the sodium and was much easier to obtain in large quantities.

A cricket meeting on April 13, 1928, at Craig, Colorado, was attended by commissioners from Grand, Routt, and Moffat counties, as well as by local business men and farmers. Several subsequent local meetings were held in Routt and Moffat counties. After a dusting demonstration in Breeze Basin on May 20, resulting in 100 percent destruction of one band and about 90 percent of another, the farmers of that district bought 1,000 pounds of calcium arsenite, and prorated the expense on a crop-acreage basis.

Dusting in the Stokes Gulch districts began on May 22. An approximate kill of 75 percent resulted from the first application. Dusting began in the Aylshire Gulch territory the fourth week of May, marked by very satisfactory kills. Rainy, cold weather during the latter part of May and the first two weeks of June prevented the campaign in western Routt and eastern Moffat counties gathering the early momentum expected.

However, at this time individual farmers in the Maybell district, where the rains were not so continuous, succeeded in killing large numbers of crickets and turning bands away from crops with calcium-arsenite dust. In the Breeze Basin and western Routt County districts, fence was being placed at strategical points. When weather conditions permitted, dusting was done. The dusting operations reached a peak shortly after June 15 and began to drop off about July 4. The last dusting done in the Routt County area was about July 28, and in Moffat County about August 4. The season's activities did not close until all materials, such as tin barrier, dust guns, and mixers had been stored in order that they might be in good condition for the next season's work.

In preparation for the 1929 campaign, a survey was made of the cricket-infested territory. Egg beds were located and
their positions mapped so that this information will be available next season. During September, eggs were gathered from various localities and tested to ascertain the percentage fertile. This fertility test gave an idea of the numbers of crickets to be expected next season.

Fig. 7. Accumulation of dead crickets shoveled from one trap during a period of six days. This pile contains approximately 50 bushels.

**Pen Tests of Calcium-Arsenite Dust as Killing Agent for Mormon Crickets**

During the course of the season's work, the following experiments were conducted for the benefit of a few local farmers, who had become a little skeptical regarding the killing power of calcium-arsenite dust. Crickets were retained as nearly as possible under the natural conditions of their habitat by the use of tin fence. Each pen contained food native to that locality. This included sage brush that might serve for shelter and protection.

**Experiment No. 1.**—This experiment started June 15 and terminated June 21. The crickets were in the fifth, sixth and seventh instars, the majority being in the sixth.

Pen No. 1, containing approximately 200 crickets, was dusted as nearly as possible at the rate of 8 pounds of dust per acre. This dust was mixed at the rate of one pound of calcium arsenite to three pounds of lime.
Pen No. 2, also containing approximately 200 crickets, was not dusted but used as a check pen. Each enclosure was 16 feet long by 8 feet wide. On the sixth day the crickets in Pen No. 2 were eaten by blackbirds. Birds did not bother Pen No. 1, which was about 200 feet from Pen No. 2, until after all the crickets had died from poison.

TABLE No. 1

<table>
<thead>
<tr>
<th>Pen Number and Poison Used</th>
<th>Number of Crickets in Pen</th>
<th>PERCENTAGE OF CRICKETS DEAD AT END OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pen No. 1, calcium arsenite, 1 to 3 mixture</td>
<td>200</td>
<td>25% 50% 80% 100%</td>
</tr>
<tr>
<td>Pen No. 2 Check</td>
<td>200</td>
<td>None None None 10% All eaten by birds</td>
</tr>
</tbody>
</table>

Results of Experiment No. 1, as tabulated in Table No. 1, show that 48 hours were required to obtain a 25 percent kill and that a 100 percent kill resulted only after the lapse of six days. With the crickets migrating, it is not surprising that some farmers were disappointed in the number of dead they found near the place where dust was being applied.

EXPERIMENT No. 2.—Approximately 500 crickets were confined in a pen 8 feet square and dusted at the rate of 8 pounds per acre with calcium-arsenite dust. Experiment started June 15 and terminated June 22.

TABLE No. 2

<table>
<thead>
<tr>
<th>Pen No. and Poison Used</th>
<th>No. of Crickets in Pen</th>
<th>PERCENTAGE OF CRICKETS DEAD AT END OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pen No. 3, calcium arsenite, 1 to 3</td>
<td>500</td>
<td>Rain check 50% 75% 94% 99%</td>
</tr>
</tbody>
</table>

Results of Experiment No. 2, as tabulated in Table No. 2, agree very closely with those obtained in Experiment No. 1. This pen was placed along the side of the Breeze Basin road and attracted considerable attention.

EXPERIMENT No. 3.—The object of this experiment was to determine if unpoisoned crickets would be killed by eating crickets dead from poison. As only one cricket was eaten during the experiment, this point was not proved. However, some very interesting data were obtained that should be checked by further experiments. A pen 24 feet in circumference was placed around 100 normal crickets. Then 125 crickets that had been dusted heavily with calcium arsenite were placed in the pen. Observations were made of this pen as follows:
Crickets began to cluster in sage brush. When undusted crickets came in contact with dusted ones, the feet or antennae that formed the contact were cleaned by being pulled thru the mouth. A 100 percent kill was obtained in this experiment on undusted as well as dusted crickets. Table No. 3 tabulates the results of Experiment No. 3.

<table>
<thead>
<tr>
<th>Pen Number</th>
<th>No. of Crickets Used</th>
<th>NUMBER OF CRICKETS DEAD AT END OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pen No. 4, calcium arsenite, 1 to 3</td>
<td>225</td>
<td>65</td>
</tr>
</tbody>
</table>

Two plans of fighting crickets were followed in Routt and Moffat counties this year. Each proved highly effective in its particular usage.

CROP PROTECTION BY DUSTING

In sparsely settled localities, where farmers are separated by distances of miles, it is not practical to try to put on a clean-up campaign. The infested area far exceeds the area that could be covered by the citizens thereof, and the cost of dust required to completely treat the crickets of such an area would be much in excess of the total crop value. We find this condition existing in localities that consist largely of public lands. Here attention should be directed only toward those bands that threaten crops. This last season where dust was applied before the crickets invaded crops, no loss was suffered. The following recommendations are offered for those so situated:

1. The farmer should watch the cricket population of the lands surrounding his farm. Should crickets hatch on farm or lands adjacent, they should be dusted as early as possible. A constant vigilance must be kept as the season progresses. When a band of crickets approaches within half a mile of crops, dusting should be started immediately.

2. Always dust the band on the side adjacent to crops.

3. Do not try to dust all the band or the same crickets more than once.

4. Do not be alarmed if the crickets continue to advance for awhile, for the dusted ones will not be likely to feed even tho they reach the crop.

5. Labor and dust may be expended most economically early in the morning and late in the afternoon, when crickets are clustered.
The following farmers practiced the crop-protection method successfully during 1928 in Moffat County:

John Sweeney—Juniper Mountain
Joe Blecka—Danforth Hills
N. P. Nicodemus—Jessie Flats
Dale Hunt—Dry Lakes
John Kramer—Dry Lakes

The materials needed for effective crop protection are:

DUST GUN.—A reliable rotary type of hand or saddle gun. The hand gun was found to be better adapted for all types of dusting during the past season in Colorado.

DUST MIXER.—The barrel type of mixer may be readily made by running an iron bar diagonally thru a barrel so as to give a figure-eight motion when in action. As the dust is very fine, a tight barrel and lid must be used. Steel drums make good dust mixers.

Fig. 8. A home-made dust mixer for mixing the calcium arsenite and hydrated lime. Good results cannot be expected unless the dust is carefully mixed.

CALCIUM OR SODIUM ARSENITE.—These arsenite dusts are comparatively new products and should be bought thru the county extension agent or other officials who are familiar with the quality necessary for effective dusting. Due to the time re-
quired to secure dust, orders should be submitted at least a month before needed.

HYDRATED LIME.—For each pound of calcium arsenite, three pounds of hydrated lime will be needed. Needless to say, both lime and arsenite must be kept dry, as a lumping of either renders it partially or wholly unfit for use.

CLEAN-UP CAMPAIGN BY USE OF TIN-BARRIER TRAPS AND POISON DUST

The crop protection method of cricket warfare that is applicable to the isolated farmer is not practical in well-populated farming communities. A farmer dusting crickets away from his crops would be driving them toward his neighbor, who in turn might drive them back. Such methods cause a loss of much time and labor that may be avoided by the community organizing its efforts and putting on a clean-up campaign.

During the past season, farmers in eastern Moffat and western Routt Counties were able to free large areas of cricket infestation. The early season's work consisted of locating the bands of crickets and thoroly dusting them. Several bands were brought under control by this method, but after the crickets had reached the fourth instar, they began to migrate. At this point the tin barriers and traps came into use. On the extreme eastern limits of the infestation in Routt County tin barrier was

Fig. 9. Saddle dusters in operation. This type of duster is very efficient over the type of land shown, but cannot be used effectively over brushy land.
placed and traps dug at suitable intervals. With the eastern battle front taken care of, further erection of barrier was necessary at certain strategical places. These places were where cultivated lands were adjacent to cricket-infested waste land, which was too rough to allow dusting operations.

With the battle line defended by barriers and traps and a man placed in charge to see that the barrier was kept in order and that all pits were emptied as fast as they filled with crickets, the larger part of the fighting force was free to take up the dusting operations. Cricket bands were located and dusted by starting on the side farthest away from the barrier. In this way the crickets were directed toward the barrier and entire bands were destroyed. Those that did not die from the dust fell victims to the traps. As fast as an area was cleaned of crickets, the barrier was advanced. By this method large areas were permanently freed and next year's campaign may be taken up where last year's stopped.

A few observations drawn from this year's campaign may prove of value in future work.

1. Egg beds should be watched and dusting begun when the crickets first hatch. The newly-hatched crickets are heavily concentrated on a comparatively small area, and at this time an entire band may be dusted more effectively than at a later date. In Breeze Basin, Moffat County, early in the past season, bands were totally destroyed with one thorough dusting. A band that covers from 15 to 20 acres of ground during the first, second and third instars may cover a square mile by the time it reaches the sixth and seventh instars.

2. Do not be too hasty in erection of the barrier. First see how much territory can be cleaned by early dusting operations, and then select the site for the barrier.

A road grader will do much toward cleaning the line for the barrier. After the barrier is placed in position, make it cricket tight by banking the back side with dirt. Remove all brush and weeds that might form a ladder over the barrier. Dig pits as soon as the barrier is erected, because without pits a barrier is of little use. Several miles of well-constructed barrier, supplemented with pits, can be patrolled by one man.

Trapped crickets may be killed quickly by throwing a small amount of gasoline into the pit and lighting it by tossing in a lighted match. The high temperature resulting from such a
fire kills the crickets in a very few minutes, so little time is required to kill and empty a pit full of crickets.

3. Farmers must be depended upon to furnish all the labor incidental to control operations, altho one salaried man in charge is advised.

![Fig. 10. Crew equipped with hand dusters. A very practical type of duster for treating cricket bands with calcium-arsenite dust.]

**SUMMARY**

1. Calcium-arsenite dust mixed at the rate of 1 part to 3 parts hydrated lime and dusted on the cricket bands at the rate of 8 pounds of the mixture per acre, is a reliable means of control for the mormon cricket. Not only does it kill great numbers of the insect, but it also serves as a protective agency for crops in cricket-infested territory.

2. Due to the rough, broken country encountered in northwestern Colorado, the calcium-arsenite dust should be used in conjunction with barriers for a clean-up campaign.

3. Galvanized tin 8 to 10 inches high serves very well as a barrier, and after the first cost is probably cheaper than any other kind.

4. Hand dust guns are superior to saddle guns in most of the cricket territory in Colorado.
5. Crop loss where dust was used amounted to practically nothing and large areas were completely cleared of crickets.

6. Cricket outbreaks should be anticipated in order that supplies may be purchased and on hand as soon as the spring hatch is completed.

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