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Control of the Mormon Cricket by the Use of Poisoned Bait

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INTRODUCTION

The Mormon cricket (*Anabrus simplex* Hald.)[1] is indigenous to the Northwestern and northern Rocky Mountain States, its range extending north into Canada, south to New Mexico, east to the Missouri River in North Dakota and South Dakota, and west to the Cascade Mountains and the Sierra Nevada. It is a destructive pest, feeding on every class of vegetation, including native grasses and range plants, and on cultivated crops. Widely separated and sporadic outbreaks of the Mormon cricket have been recorded over most of the infested area since 1847. The most general and widespread outbreak, with the exception of the one now being combated, reached its peak in 1904 and 1905. It extended over Colorado, Nevada, Wyoming, and probably Idaho and Montana. The present outbreak has been gradually increasing in scope and intensity since 1920, until Mormon crickets now (1939) are a menace to crops in parts of 11 of the Western States. Improved control methods during the last 3 years have served to protect crops and are gradually decreasing the size and intensity of the outbreak.

[1] Order Orthoptera, family Tettigoniidae.

Dusting with arsenicals, the most effective control method to date, has proved expensive and was always accompanied with risk to grazing livestock. The baits formerly tried, although less costly, did not attract the crickets in sufficient numbers. When a Mormon cricket project was authorized in 1935, attention was given to the development of an effective bait and to determining the proper time for spreading it. This circular is designed to give the results of these investigations up to and through the season of 1939.

PAST AND PRESENT METHODS OF CONTROL

Until 1927 the most widely used methods of control consisted in the application of modified grasshopper baits containing sodium arsenite and the use of trenches, cricketproof fences, and barriers of oil and water. Barriers of various kinds are still used, but baiting was discarded by entomologists several years ago as impractical. Satisfactory kills occasionally were obtained, but more often crickets refused to eat the bait, and as a result little dependence could be placed on this method of control.

Control by dusting with powdered sodium arsenite and a suitable diluent was developed by Shotwell and Cowan [2] in 1926 and 1927. Since that time this has been recognized as the most reliable method of killing crickets, but it has several serious disadvantages. (1) Unless handled under the closest supervision, sodium arsenite dust is a menace to the health of mixing and dusting operators and creates a hazard to livestock when distributed on crops and range plants. (2) The results of dusting are sometimes slow in appearing and are much affected by weather conditions; and the crickets, especially the adults, may die several miles distant from where they were dusted. Failure to find dead crickets on a dusted area frequently created the impression that the work was ineffective. (3) Dusting is most successful in a closely supervised, paid-crew type of control campaign. Individual farmers and ranchers generally hesitate to use such dangerous material and seldom possess the necessary equipment for mixing and distributing the dust. (4) From an economic standpoint the greatest disadvantage of the dusting method of control is the high cost, which ranges from about 60 cents to $2.50 per acre, according to local conditions and the equipment used.

In spite of these disadvantages dusting with sodium arsenite powder is an effective method of control, especially on extremely heavy concentrations of crickets. Such concentrations usually occur during the early instars on the hatching grounds, and in the later stages while the crickets are roosting during periods of hot weather.

NEED FOR CONTROL BY POISONED BAITS

Because of the high cost and other disadvantages of dusting with sodium arsenite powder, it was felt that finding an effective bait was essential in developing an economical method of Mormon cricket control that would be generally adopted. The long and widespread use of poisoned baits for controlling grasshoppers has built up confidence

[2] SHOTWELL, R. L., and COWAN, F. T. SOME PRELIMINARY NOTES ON THE USE OF SODIUM ARSENITE DUST AND SPRAY IN THE CONTROL OF THE MORMON CRICKET (ANABRUS SIMPLEX HALD.) AND THE LESSER MIGRATORY GRASSHOPPER (MELANOPLUS ATLANIS RILEY). Jour. Econ. Ent. 21: 222–230. 1928.

in that method, and it was believed that if a successful bait for the Mormon cricket could be developed it would become equally popular, and that the one bait might control both insects. The use of bait would materially reduce the cost of Mormon cricket control and lower the danger of injury to man and animals. The necessity of special equipment would be eliminated, as the same machines used for mixing and distributing grasshopper bait could be used during outbreaks of the Mormon cricket.

BAIT-TESTING METHODS

Prior to 1935 experimental baiting of Mormon crickets consisted of broadcasting the baits over selected areas and estimating the percentage of kill. This method has several disadvantages, most impor-

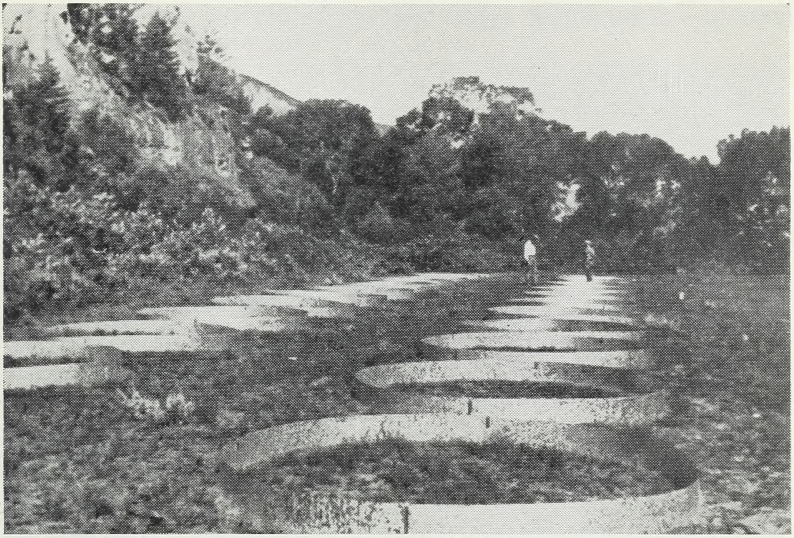

FIGURE 1.—Series of closed pens used in early bait tests against the Mormon cricket.

tant of which are the following: (1) Estimates are subject to all types of error in addition to those due merely to chance and require a great many replications to arrive at a true average. (2) The crickets that were on the area at the time the bait was broadcast are likely to have migrated some distance by the time the estimates of results are made. Therefore, it was necessary at the start to develop a method of sampling whereby the mortality from various baits could be accurately ascertained. Three methods were used: (1) Baiting in closed pens, (2) baiting in front of wing pens into which the crickets moved after feeding, (3) pan baiting, and (4) baiting of large fields.

In the first method the crickets were trapped and then placed in pens built of 10-inch galvanized iron strips set on edge to form a circle 9 feet in diameter (fig. 1). The bait was broadcast in the pens. Each day the dead crickets were taken out and counted and on the fourth day a record was made of those still alive. The percentage

killed for each bait was then calculated by dividing the total number dead by the total caged. This system was used during the seasons of 1935 and 1936, but was discarded early in 1937 because the percentages killed from most of the baits were so nearly alike. Confinement of the crickets directly on the bait apparently resulted in their eating whatever was offered them with slight regard to the content of the m xture.

In 1937 the system now in use was devised, and it was not until then that marked differences in the efficiency of various baits became evident. This was called the "wing-pen" method. It consisted of a small pen about 4.5 feet in diameter built of 10-inch galvanized iron with two 16-foot wings of the same material forming a V and set in front of and adjacent to it. The V was connected with the pen at its apex by a 4-foot removable chute. This chute consisted of a 1- by 6-inch pine board with 5-inch sides of galvanized iron nailed to the edges.

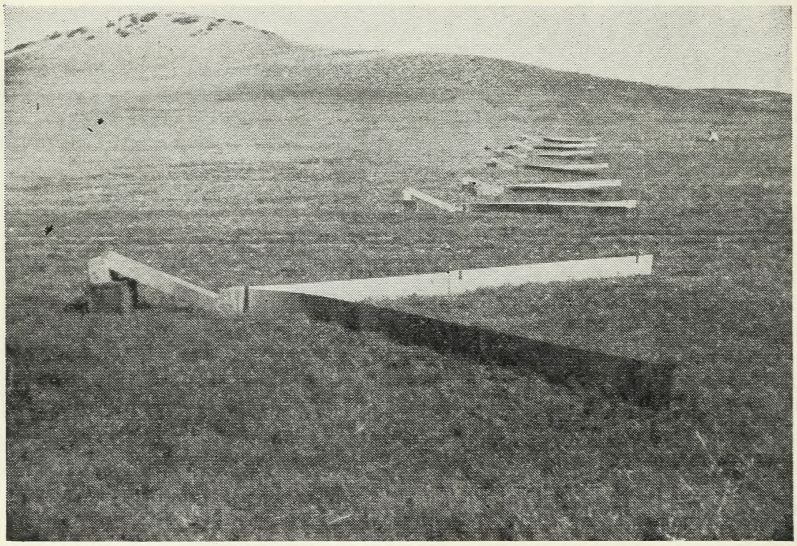

FIGURE 2.—Series of wings, chutes, and cages used in the wing-pen method as modified in 1939.

The poisoned bait was spread in front of and within the V. The crickets were allowed from 20 minutes to 1 hour to feed and move into the pens of their own accord. If a sufficient number had not been captured at the end of 1 hour those within the V were driven up the chute and into the pen, where they were held for 4 days. As before, the dead crickets were removed each day and the remaining live ones counted on the fourth day. The final percentage of kill was calculated from the total dead and the total caged. The method was revised somewhat in 1939, when a small cage was substituted for the pen (fig. 2). The crickets were driven into the cage and then transferred to pens at a central location.

In the wing-pen method the crickets were not forced to feed on the bait, as was the case in the first method, where they were confined in the pen with the bait. Real differences between the efficiency of the

baits became apparent immediately on adoption of this method. Unpoisoned crickets captured by the same method and held in check pens showed little or no mortality in 4 days.

In each series of tests the baits were replicated from 7 to 15 times. The data were then analyzed by the method of analysis of variance whereby an estimate of error associated with the mean percentage kill of each bait was obtained. With the aid of this statistic the significance of the difference between any two means could be judged.

The pan-bait method developed by Parker and Seamans [3] to test grasshopper baits was used to determine the effect of weather and time of day on cricket baiting. Small pans, each containing a bait, were arranged in a row in an infested field. Counts of the number of crickets feeding on the different baits were made every 10 minutes throughout the day. At the same time records of air and soil temperatures, as well as the extent of cloudiness and velocity of wind, were made. Baits were stirred or changed every half hour in order that fresh bait would be available at all times.

MATERIALS TESTED

Over a period of 5 years 40 different baits were tested. In these baits attractants such as cane and beet molasses, amyl acetate, and salt, which were commonly used in grasshopper baits, were tested either alone or in combination with one another with standard bran as the carrier. In addition to these so-called grasshopper attractants, several materials, including tankage, ground onions, tobacco extract, and dried orange pulp, thought to be especially attractive to the Mormon cricket, were tested.

In other tests various carriers, including bran, dried beet pulp, and cracked wheat, were used alone; and mill-run bran, shorts, flour, rolled wheat, and ground soybeans were tried in various combinations with sawdust.

Various poisons, including liquid sodium arsenite, sodium fluoride, sodium fluosilicate, paris green, crude arsenic, calcium fluoride, and synthetic cryolite were tested at some time during the period 1935–39.

EXPERIMENTS TO DETERMINE THE BEST CARRIER

The experiments of 1935 were conducted to determine the efficiency of various carriers. Sampling was made by the closed-pen method, in which the percentage kill from each bait was obtained from 14 replications. One quart of sodium arsenite (8-pound material, approximately 60 percent As_2O_3) and 12 gallons of water was used with 100 pounds of each carrier. The results of the tests are as follows:

Carrier	*Average kill (percent)*
Standard bran	37. 0
Sawdust, 1 part; mill-run bran, 3 parts	28. 8
Sawdust, 3 parts; flour, 1 part	27. 5
Sawdust, 3 parts; shorts, 1 part	27. 4
Cracked wheat	21. 2
Dried beet pulp	10. 3

Standard error of any average, 3.42 percent.
Minimum significant difference, 9.61 percent.

[3] PARKER, J. R., and SEAMANS, H. L. EXPERIMENTS WITH GRASSHOPPER BAITS. Jour. Econ. Ent. 14: 138–141. 1921.

These results, while far from conclusive because of the experimental method, show that standard bran was the most promising carrier. This has been borne out by tests in subsequent years. Mill-run bran, flour, and shorts, combined with sawdust, although not so effective as standard bran, proved to be better than dried beet pulp or cracked wheat.

EXPERIMENTS TO DETERMINE THE BEST ATTRACTANTS

The first series of experiments in 1936 was designed to test the value of common attractants previously used in grasshopper baits, and others thought to be particularly attractive to crickets. The same poison and carrier were used in all tests, namely, 2 quarts of sodium arsenite (4-pound material, 32 percent As_2O_3) mixed with 100 pounds of bran and 12 gallons of water. Each test was replicated seven times. The mortalities obtained by the closed-pen method and listed below are indices of the value of the popular attractants used in grasshopper baits.

Attractant	*Average kill (percent)*
Beet molasses, 2 gallons; amyl acetate, 3 ounces	94. 4
Amyl acetate, 3 ounces	89. 8
Cane molasses, 2 gallons; amyl acetate, 3 ounces	89. 1
Beet molasses, 2 gallons; salt, 5 pounds	88. 5
Cane molasses, 2 gallons	88. 4
Beet molasses, 2 gallons	87. 0
Standard bran	86. 7
Cane molasses, 2 gallons; salt, 5 pounds	86. 3
Salt, 5 pounds	85. 8
Cane molasses, 2 gallons; amyl acetate, 3 ounces; salt, 5 pounds	85. 6
Beet molasses, 2 gallons; amyl acetate, 3 ounces; salt, 5 pounds	84. 7

Standard error of any average, 3.58 percent.
Minimum significant difference, 10.12 percent.

There was no significant difference between any of the percentages obtained. The bait containing bran, poison, and water was as effective as the baits containing attractants. It may be noted that the average kills were much higher than those obtained in the experiments of 1935. This was probably due to the more active feeding of the crickets which accompanies higher temperatures and lack of moisture. The tests of 1935 had been conducted at a much higher altitude, with greater soil moisture and lower temperature.

The materials thought to be especially attractive to crickets were then tested. With the exception of the attractant, the same bait formula, the same number of tests, and the same method were used as in the previous test. The mortalities listed below serve as an index of the value of the attractants.

Attractant	*Average kill (percent)*
Tankage, 20 pounds	86. 2
None (standard bran, sodium arsenite, and water only)	86. 0
Ground onions, 20 pounds	85. 7
Tankage, 10 pounds	85. 3
Nicotine sulfate (40-percent), 3 ounces	83. 7
Dried orange pulp, 10 pounds	81. 5

Standard error of any average, 2.85 percent.
Minimum significant difference, 8.14 percent.

None of the baits containing these attractants gave materially better results than the one containing only bran, water, and poison.

EXPERIMENTS TO DETERMINE THE VALUE AND MOST EFFICENT STRENGTHS OF DIFFERENT POISONS

Tests were also conducted in 1936 to determine the best kind of poison and the proper quantity for use in control of the Mormon cricket. These tests were made at Pryor, Mont., at an altitude of approximately 3,500 feet under conditions characterized by higher temperatures and lack of moisture. One hundred pounds of bran and 12 gallons of water were used in all cases, and the mortalities shown below are the averages of seven replications:

Kind and quantity of poison	*Average kill (percent)*
Sodium fluoride, 4 pounds	94. 9
Sodium fluosilicate, 4 pounds	93. 3
Paris green, 4 pounds	92. 2
Sodium arsenite,[1] 4 quarts	86. 1
Crude arsenic, 5 pounds	81. 3
Sodium arsenite,[1] 2 quarts	79. 7
Sodium arsenite,[1] 1 quart	77. 8
Sodium fluosilicate, 2 pounds	74. 5

Standard error of any average, 2.83 percent.
Minimum significant difference, 8.00 percent.

[1] 32 percent As_2O_3.

This series of tests showed sodium fluoride, sodium fluosilicate, and paris green to be the most effective poisons under the conditions of the experiment, but the lower cost of sodium fluosilicate would recommend it over the other two poisons for use in large-scale campaigns. The bait containing 4 pounds of sodium fluosilicate was significantly more effective than that with only 2 pounds, and it was better than any of the sodium arsenite baits except that containing 4 quarts of the poison.

EXPERIMENTS BY THE WING-PEN METHOD TO COMPARE THE MORE PROMISING BAITS OF PREVIOUS TESTS

In 1937 the wing-pen method of collecting the crickets, in which the insects had more liberty to feed on or reject the poisoned baits, was put into practice, and with this more reliable index it was desired to test again those bait combinations that had given the best results in 1935 and 1936. In addition to these a bait containing 2 gallons of black distillate oil was tested. In all the baits 100 pounds of standard bran was used as the carrier, moistened with 12 gallons of water. The mortality figures are shown in table 1.

The sodium fluosilicate bait was outstanding in these tests. This not only reflected the greater accuracy of the new method of collecting the samples, but also indicated that sodium fluosilicate had a distinct advantage over sodium arsenite as a killing agent in Mormon cricket bait. The black oil distillate used in this bait was thought at the time to be mainly responsible for the outstanding results. This was disproved, however, in the tests of 1938.

TABLE 1.—*Mortality of the Mormon cricket as an index of the efficiency of baits containing different poisons and attractants, Billings, Mont., 1937*

Poison [1]	Attractant	Average [2] kill (9 replications)
		Percent
Sodium fluosilicate, 4 pounds	Black distillate, 2 gallons	87.32
Sodium arsenite, 2 quarts	Cane molasses, 2 gallons; amyl acetate, 3 ounces.	60.52
Do	None	59.36
Do	Cane molasses, 2 gallons	52.91

[1] Carrier, 100 pounds bran, 12 gallons water.
[2] Standard error of any average, 4.4 percent.

Minimum significant difference, 12.58 percent.

EXPERIMENTS TO DETERMINE FURTHER THE VALUE OF THE ATTRACTANTS AND THE MOST EFFICIENT STRENGTHS OF SODIUM ARSENITE AND SODIUM FLUOSILICATE

The experiments of 1938 were designed to test, by means of the wing-pen method, the value of two attractants, cane molasses and oil, when used with sodium fluosilicate, and also to determine how small a quantity of sodium fluosilicate would give the maximum kill. The sodium arsenite bait used in all previous tests was also included for comparison. The results are given in table 2.

TABLE 2.—*Mortality of the Mormon cricket as an index of the efficiency of baits containing attractants and different quantities of poison, Benteen, Mont., 1938*

Poison [1]	Attractant	Average [2] kill (15 replications)
		Percent
Sodium fluosilicate, 4 pounds	Cane molasses, 2 gallons	89.3
Do	None	86.3
Do	Black distillate, 2 gallons	83.9
Sodium fluosilicate, 2 pounds	do	79.7
Do	None	75.2
Sodium arsenite, 2 quarts	None	41.8

[1] Carrier, 100 pounds bran, 12 gallons water.
[2] Standard error of any average, 2.84 percent.

Minimum significant difference, 7.97 percent.

The results shown in table 2 prove conclusively that sodium fluosilicate is far superior to sodium arsenite as a killing agent, even when used at the rate of only 2 pounds per 100 pounds of bran. Two pounds of fluosilicate, however, was decidedly less efficient than 4 pounds. The mortality obtained with the bait containing cane molasses was not significantly higher than that obtained with the one containing oil or the one containing no attractant, and according to these figures the added cost of the molasses in baits for large-scale use is not warranted.

These results were further substantiated by pan-baiting tests covering a period of 28 days in which the sodium arsenite bait was fed upon by only 2.8 percent of the total number of crickets feeding,

while the fluosilicate-molasses bait was fed upon by 34.6 percent, the fluosilicate-oil bait by 31.1 percent, and the plain fluosilicate bait by 30.5 percent. This would indicate that sodium arsenite, when used in bait, is distasteful to Mormon crickets, and further pan-baiting tests were conducted to determine the smallest quantity of sodium arsenite that would make the bait unattractive.

Six baits were prepared to compare 4 different strengths of sodium arsenite used with 100 pounds of bran with a mixture of bran and water alone and also with 4 pounds of sodium fluosilicate to 100 pounds of bran. There were in all 369 crickets feeding in this test, and the percentages feeding on the various baits were as follows:

Bait	*Percentage of total crickets feeding*
Bran and water (no poison)	47. 7
Sodium fluosilicate, 4 pounds	38. 4
Sodium arsenite, 2 quarts	2. 9
Sodium arsenite, 1 quart	2. 5
Sodium arsenite, 1 pint	4. 2
Sodium arsenite, ½ pint	4. 2

Unfavorable weather conditions terminated the experiments at the end of 4 days; and although the results cannot be taken as conclusive because of the limited number of observations, they indicate that even a small amount of sodium arsenite is distasteful to Mormon crickets.

EXPERIMENTS TO COMPARE NEW CARRIERS AND POISONS WITH THE BEST BAITS OF PREVIOUS TESTS

Additional experiments were designed in 1939 to test again the effectiveness of various poisons and carriers by using the wing-pen method of collecting the samples of crickets. Several of these had been tested by the closed-pen method, but the results were not considered conclusive.

Two series of experiments were made; the first, including both nymphs and adults, was conducted at an altitude of about 3,000 feet, as were most of the earlier experiments. The second series included only adults, and this was conducted at about 8,000 feet altitude. At this altitude the vegetative cover differed considerably from that at 3,000 feet, the temperature was lower, and the soil moisture greater. The conditions here probably represented about the least favorable conditions for successful tests with baits. For these two reasons—the stages of the insect represented and the effects due to the altitude—the two series are presented separately, although two of the baits appear in both. The results of the first series are given in table 3.

The mortality associated in table 3 with the bait consisting of 4 pounds of sodium fluosilicate and 100 pounds of bran is only slightly higher than that obtained with 3 pounds of the same poison. Sodium fluoride was only a little less effective, but synthetic cryolite and calcium fluoride were far below these in the list. It is of interest that the three baits in which sawdust made up a portion of the carrier are in effectiveness well below those with the standard bran alone, but they showed little or no difference among themselves.

The second series of experiments, in which adults only were used and which was conducted under adverse conditions, is detailed in table

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4. In this series, as in the one reported in table 3, the mixture of 4 pounds of sodium fluosilicate and 100 pounds of bran gave the best results, although the crude arsenic bait was only slightly less effective. The crude arsenic, possibly because of its being less soluble, does not seem to be so distasteful to the Mormon crickets as is the sodium arsenite, but it should be used with caution on account of the danger of poisoning grazing animals. The baits containing sawdust were again well below the most effective mixture.

TABLE 3.—*Mortality of the Mormon cricket, including both nymphs and adults, as an index of the efficiency of baits containing different poisons and carriers, Benteen, Mont., altitude 3,000 feet, 1939*

Poison	Quantity of poison	Carrier [1]	Average [2] kill (11 replications)
	Pounds		*Percent*
Sodium fluosilicate	4	Bran	90.6
Do	3	do	88.5
Sodium fluoride	4	do	86.9
Sodium fluosilicate	4	Mill-run bran, sawdust (1:1)	68.8
Do	4	Ground soybeans, sawdust (1 : 3)	63.5
Do	4	Mill-run bran, sawdust (1 : 3)	57.8
Synthetic cryolite	4	Bran	23.3
Calcium fluoride	4	do	16.3

[1] 100 pounds in all cases.
[2] Standard error of any average, 5.48 percent.

Minimum significant difference, 15.38 percent.

TABLE 4.—*Mortality of adults of the Mormon cricket as an index of the efficiency of baits containing different poisons and carriers, Bear Lodge, Wyo., altitude 8,000 feet, 1939*

Poison [1]	Carrier [2]	Average [3] kill (12 replications)
		Percent
Sodium fluosilicate	Bran	93.4
Crude arsenic	do	85.6
Sodium fluosilicate	Rolled wheat, sawdust (1:3)	80.6
Do	Mill-run bran, sawdust (1:3)	77.8
Do	Flour, sawdust (1:9)	74.3

[1] 4 pounds in all cases.
[2] 100 pounds of carrier in all cases.
[3] Standard error of any average, 3.49 percent.

Minimum significant difference, 9.86 percent.

TIME AND TEMPERATURE FOR OPTIMUM FEEDING ON BAITS

The effect of temperature and time of day on feeding and other activities of the Mormon cricket were determined from counts obtained from tests made by the pan-bait method. The results of 28 days' observations on adult crickets made during July and August 1938 are shown in figure 3. Figure 3, *A*, shows the number of crickets feeding in relation to air temperatures both in the forenoon (ascending temperatures) and in the afternoon (descending temperatures). The optimum temperature for feeding was found to be 86° F., although active

feeding was recorded between 68° and 95°. Soil temperatures in relation to the number of crickets feeding are shown in figure 3, *B*. The range of temperatures in which numbers of crickets were observed feeding falls between 75° and 130°, with the peak at about 108°.

The time of day as affecting feeding is shown in figure 3, *C*. The peak in the number feeding was observed between the hours of 8 and 10 a. m., with numbers ascending toward a peak after 4 p. m. Baiting on a large scale, however, has shown that late afternoon baiting of adult crickets is not so effective as that done during the morning.

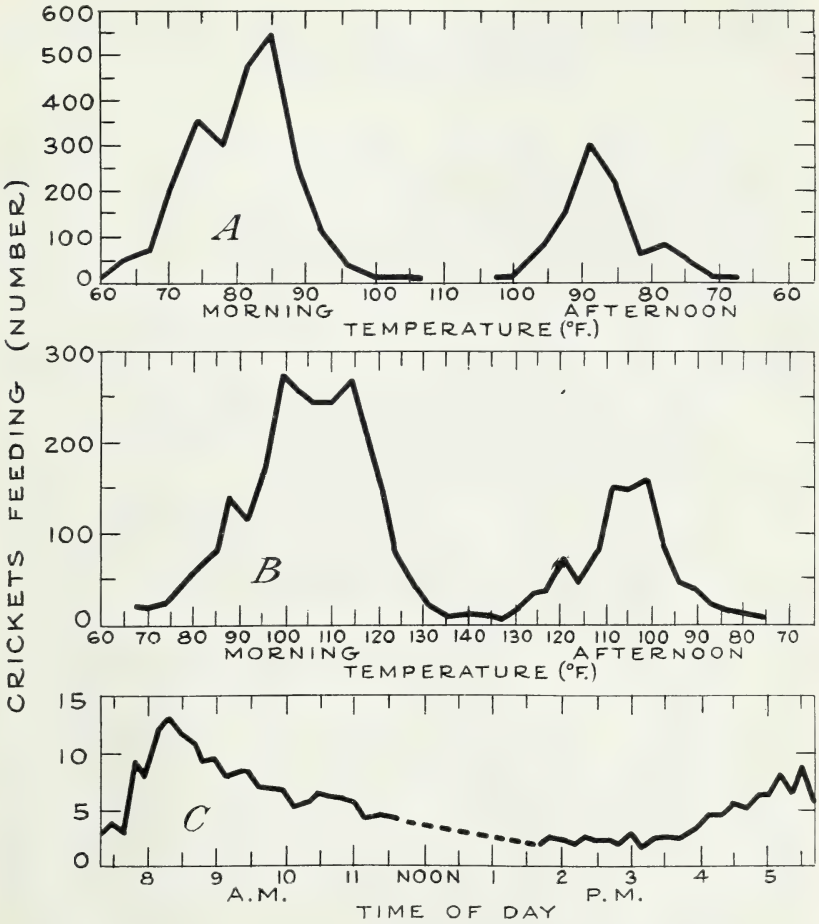

FIGURE 3.—The numbers of crickets feeding on pan baits during 28 days, correlated with air temperatures (*A*), soil temperatures (*B*), and time of day (*C*).

MIGRATION AND BAITING

The temperatures and time of day governing the feeding period also govern migrations. In other words, feeding and migrating occur under the same general conditions. This was brought out in the pan-baiting experiments of 1938 with adults and also just as definitely

in the experiments in 1939 with nymphs. Thus it is possible to recommend to farmers and control agencies that cricket bait should be spread only during migrations. This automatically excludes periods during which the insects are clustered or in shelter, as in the early morning and when they are roosting on vegetation during the heat of the day. The recommendation also applies to a lesser extent to first- and second-instar nymphs. During the period of these instars little migration has been observed, little feeding was recorded on pan baits, and less satisfactory results from field baiting were obtained than with later instars.

FIELD DEMONSTRATIONS OF CONTROL BY THE USE OF POISONED BAIT

Broadcasting bait in field plots was begun in May 1938 for first- to third-instar nymphs. Five baits were used in these early tests, although not all the five were used in each series. The baits consisted of standard bran to which was added 2 or 4 pounds of sodium fluosilicate, with and without oil, or 2 quarts of sodium arsenite. Results were uniformly poor, because continued rains and low temperatures inhibited the normal activities of the crickets. As little was then known concerning the correct time for baiting, most of the bait was broadcast when the insects were not active, and poor kills resulted.

This work was continued during June on large-scale plots in which samples (obtained from the wing pens) were taken from the baited area. The crickets at that time were mostly in the sixth and seventh instars. More favorable weather conditions were encountered and the kills averaged from 67 to 97 percent.

Field baiting was continued throughout July and August when adult crickets were present. In all, about 1 ton (dry weight) of the bran and sodium fluosilicate bait was used. At this time the results obtained were exceptionally good in all instances.

Early in the spring of 1939 baiting was begun on a large scale on first- to fourth-instar nymphs, in cooperation with the Mormon cricket control unit of the Division of Domestic Plant Quarantines of the Bureau of Entomology and Plant Quarantine. A total of 4,300 pounds (dry weight) of cricket bait was spread over 418 acres of infested areas in Washington, Nevada, and South Dakota. Of this 3,400 pounds was with standard bran as the carrier, while the remaining 900 pounds consisted of 1 part mill-run bran to 3 parts sawdust. The latter was all used in South Dakota. All baits contained 4 pounds of sodium fluosilicate per 100 pounds of carrier. Results were generally satisfactory, although in some instances it was difficult to estimate kills because the small size of the first- and second-instar nymphs made it extremely hard to see the dead ones.

In the large-scale tests in South Dakota, where the mill-run bran-sawdust carrier was compared with standard bran, samples taken by the wing-pen method showed kills of from 72 to 90 percent, with the mill-run bran-sawdust giving the higher kill in every instance. Closely supervised experimental tests have not substantiated these results, although it has been found that during periods of relatively high temperatures and little soil moisture results with the mill-run bran-sawdust mixture approach those obtained with the standard bran.

Such conditions existed in South Dakota at the time the large-scale tests were made and undoubtedly accounted for the higher percentage of kill obtained with mill-run bran and sawdust as the carrier.

As a result of the large-scale tests in South Dakota, the cricket-control program in two counties in that State, Mellette and Jones, was switched over almost entirely to baiting with 1 part of mill-run bran to 3 parts of sawdust and 4 pounds of sodium fluosilicate per 100 pounds of carrier. The final results of this campaign are not available, but good kills were reported by farmers and control officials throughout the season.

Other large-scale tests were made in Wyoming through a cooperative project between the Office of the Wyoming State Entomologist and the Bureau of Entomology and Plant Quarantine. The final results of this program, as given in a report by Robert Pfadt,[4] show that an area containing 10,240 acres, east of Sheridan, Wyo., was entirely cleared of crickets through the use of bait alone. In all, 22,250 pounds (dry weight) of bait was used on 1,584 acres, or an average of 14 pounds per acre. The total cost of the project, including the cost of materials, labor for mixing and spreading, and transportation of bait spreaders, was $881.21, or an average of 56 cents per acre treated. This cost was unusually high because of the demonstrational character of the project. Based on the experience gained from large-scale grasshopper baiting projects, this cost should not exceed 30 cents per acre with use of the standard bran formula, or 25 cents per acre with the mill-run-bran-and-sawdust bait.

Samples from the fields were collected by the wing-pen method and the numbers dying in 96 hours or less after baiting ranged from 73.3 to 100 percent, with an average of 91.9 percent over the period of 34 days of baiting. Practically all the bait used in Sheridan County was spread during the forenoon.

Additional data on seven tests in Crook County, Wyo., in which the bait was spread during the afternoon, showed mortalities, of 36 to 89 percent, and an average mortality of 69 percent, in 96 hours. Practically all the bait had 1 part of mill-run bran and 3 parts of sawdust as the carrier. Four pounds of sodium fluosilicate to each 100 pounds of carrier was used in all tests.

RECOMMENDATIONS FOR BAITING CAMPAIGNS

As a result of the 4 years' experimental work summarized in this circular, highly effective and practical baits for the control of the Mormon cricket have been developed, the best time for applying them and the rate at which they should be spread have been determined, and recommendations can now be made for large-scale field-control projects.

Recommended Bait Formulas

In areas where cricket control is the main objective the following formula is most likely to give best results under all conditions:

Standard bran	100 pounds
Sodium fluosilicate	3 pounds
Water	10 to 15 gallons

[4] Report to the Division of Domestic Plant Quarantines, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Although the use of standard bran in baits is somewhat more expensive than the use of sawdust, it has given the highest and most consistent kills under all conditions in experimental plot tests. Furthermore, crickets are known to feed readily on the standard bran bait even after it has become dry. For this reason the effective period of the bait is lengthened considerably.

Although the formula containing 3 pounds of sodium fluosilicate has not been used on a large scale, the results obtained during 1939, which included trials against both nymphs and adults under rather unfavorable conditions, indicate conclusively that the amount of poison can be reduced to 3 pounds without reducing the efficiency of the bait.

In areas of mixed grasshopper and cricket populations where grasshopper control is the more important, or for crickets alone during extremely dry weather, the cost of control may be reduced by using the following formula:

Mill-run bran	25 pounds
Sawdust	3½ bushels
Sodium fluosilicate	3 pounds
Water	8 to 10 gallons

Mixing the Bait

In using either formula all the dry ingredients should be mixed thoroughly and then sufficient water added to make a wet mash which will spread readily without lumping. The exact amount of water needed will vary according to the character of the bran and sawdust used.

Spreading the Bait

Bait should be spread in the morning on bright, sunny days while the crickets are migrating. It is useless to spread bait during cool periods when the crickets are clustered or in shelter or during the heat of the day when they are roosting on brush and other vegetation. Occasionally early-afternoon baiting is effective if the first migration of that day has just started. Baiting late in the afternoon is not recommended.

All bait should be spread at the rate of 10 pounds (dry weight) per acre, either with mechanical spreaders or by hand.

Precautions

Even though sodium fluosilicate is known to be less toxic to warm-blooded animals than arsenicals, precautions should be taken to keep the bait away from livestock and irresponsible people. When spread at the recommended quantities there is absolutely no danger to livestock or game birds. Workers in mixing stations should avoid breathing the dry sodium fluosilicate dust.

SUMMARY

Dusting with sodium arsenite powder mixed with a suitable diluent has been the basic method of Mormon cricket control since 1927. Various objectionable features in this method brought out the neces-

sity for an efficient poisoned bait. Work was begun in 1935 and continued through 1939 to develop a satisfactory bait for the Mormon cricket.

In the earliest tests crickets were caught and confined in large enclosures where they were given the poisoned bait. This did not give the crickets enough choice of food, so beginning in 1937 tests were made with a smaller pen, and the crickets, after they had been permitted to feed normally, moved naturally forward and were directed by converging sheet-metal barriers (wings) into a chute which led them either directly to the observation pen or to a cage from which they were transferred to the pen.

The tests in 1935 showed standard bran to be the best carrier. The tests in 1936 showed that attractants do not add to the efficiency of the bait. Sodium fluosilicate was used for the first time that year. In 1937 sodium fluosilicate at the rate of 4 pounds per 100 pounds of bran was used successfully in an oil bait under the improved system of experimentation and proved superior to a bait containing sodium arsenite. It was found in 1938 that the oil was not necessary and that 2 pounds of sodium fluosilicate is not sufficient to give the maximum kill. Although a bait containing 2 gallons of cane molasses gave a slightly greater mortality than the one containing no attractant, it was evident that the small increase in efficiency did not warrant the additional cost of the molasses. In these tests sodium arsenite was proved to be repellent to Mormon crickets.

The tests of 1939 further substantiated the fact that standard bran is the best carrier, although in large-scale baiting tests in South Dakota and Wyoming high mortalities were obtained with a bait containing 1 part of mill-run bran to 3 parts of sawdust. Sodium fluosilicate, at the rate of 3 pounds per 100 pounds of bran, proved as effective as 4 pounds against both nymphs and adults in 11 replications by wing-pen tests. This material and sodium fluoride proved more effective than synthetic cryolite or calcium fluoride. According to these tests, crude arsenic at the rate of 4 pounds per 100 pounds of bran is not distasteful to the crickets and may be substituted for the sodium fluosilicate. However, the danger to livestock from a bait containing crude arsenic is much greater than from one containing sodium fluosilicate.

Pan baiting tests conducted in 1938 on adult crickets and also in 1939 on nymphs showed that feeding is so closely correlated with migrations that it is possible to recommend to farmers and other control units that the bait should be spread only while the crickets are migrating.

Large-scale baiting tests in 1938 and 1939 proved conclusively that effective and economical control of both nymphs and adults can be obtained by the proper use of sodium fluosilicate bait with standard bran or, under restricted conditions, with mill-run bran and sawdust as the carrier.

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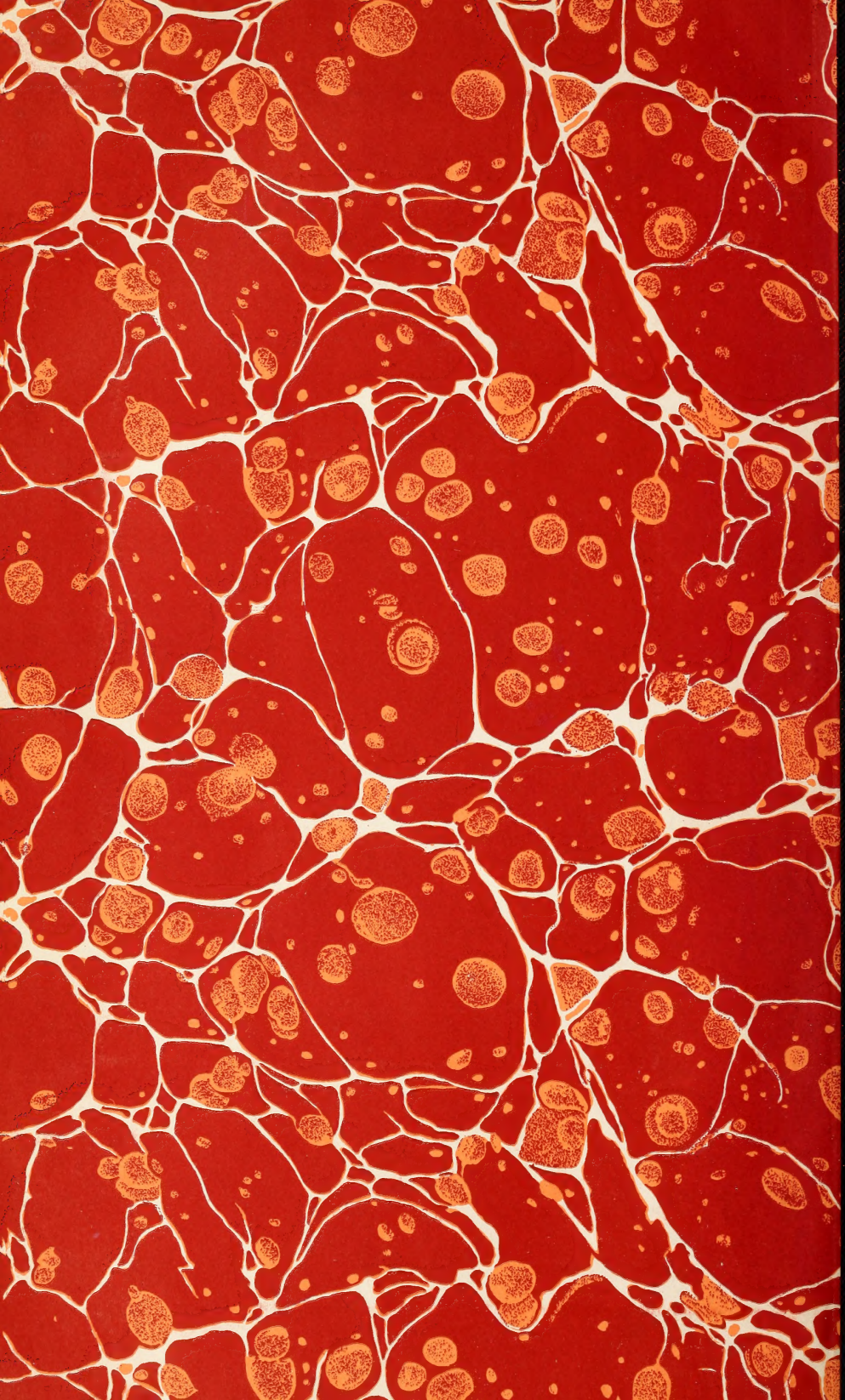

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