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TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR

COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 464 NOVEMBER, 1932

DIVISION OF ENTOMOLOGY

IN COOPERATION WITH
LIVESTOCK SANITARY COMMISSION OF TEXAS

Control of The Bitterweed Plant Poisonous To Sheep In The Edwards Plateau Region

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**In cooperation with U. S. Department of Agriculture.
†As of November 1, 1932.

Bitterweed attracted little attention as long as it grew only in a few of the basins and draws of the Edwards Plateau range country, but the ranchers became alarmed about 1924 when it had spread over the ranges and began causing the death of sheep. This increase in the amount of bitterweed followed heavy stocking of the ranges, which resulted in overgrazing and making such areas favorable for bitterweed to grow. When palatable vegetation is scarce during the winter months, sheep will feed on the obnoxious bitterweed plant and become poisoned.

In the fall of 1931, investigations were begun to determine the best means of controlling bitterweed. It was assumed that any control measures adopted must take into account an adjustment of stocking, and the rotation, or resting, of pastures so as to restore a good grass turf and consequently choke out the bitterweed. In places where erosion or silting prevents the establishment of a heavy turf, the best methods of killing these seed producing centers, or hazards, were studied.

It was found that hazard areas could be economically sprayed with 12 pounds of "calcium chlorate" in 200 gallons of water per acre to kill bitterweed. This spray was effective during humid weather and most effective following rains, but did not kill the bitterweed during dry weather when the relative humidity averaged 59.5 per cent or less for a period of two weeks following the treatment. Sulphuric acid and petroleum oil sprays were ineffective. Burning the bitterweed proved to be ineffective and is a bad practice. Scattered plants may be economically pulled along roadways and ditches, and in small areas around headquarters and watering places.

Ten species of insects were found feeding on bitterweed, four being new to science. Damage was done to the seed, leaves, stems, and roots. During the winter of 1931-32, a weevil destroyed about 20 per cent of the seed heads in 11 counties. Although insects aid considerably in limiting the abundance of bitterweed, it is not expected that this plant will be eradicated by these natural agencies.

It is thought that bitterweed can be eradicated in places when weather conditions are favorable and insect damage is considerable, and provided conscientious effort is made for several years. Bitterweed seed may not all germinate in years when weather conditions are not favorable, but some remain viable for at least a year and develop into seedlings the second season. The stocking should be adjusted so as to reestablish a good grass turf; the seed-producing centers should be destroyed by spraying, and the remaining scattered plants pulled.

CONTENTS

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CONTROL OF THE BITTERWEED PLANT POISONOUS TO SHEEP IN THE EDWARDS PLATEAU REGION

S. E. JONES
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About ten years ago a new and hitherto unknown sickness affecting sheep of all ages began to appear during the winter months in the Edwards Plateau region. The unpublished report of D. H. Bennett (2), Veterinarian at Substation No. 14, Sonora, Texas, in January 1924, describes the symptoms as follows: "The sheep grow suddenly weak in the hind legs, stagger, and fall to the ground where they would remain quiet unless helped to their feet, when they would walk a few steps and fall again, always righting themselves to the sternal position. They appear to be dazed or in a semiconscious state. The eyes and visible mucous membranes were cyanotic, green foam coming from the mouth with attempts to vomit." He further reports that 8 per cent of the sheep in the Sonora, San Angelo, Mertzon, and Sterling City areas were affected with this sickness and that about 5 per cent of the sick sheep died.

The green discharge, or foam, appearing on the muzzle naturally caused certain plants to be suspected as being poisonous. It was thought that liveoak leaves which were killed by frost caused the sickness, but Bennett found the same trouble at Sterling City and Mertzon, where this brush did not occur. He reported that there was less grass in February than had previously occurred that winter and that the only weeds growing were bitterweeds. This led him to believe that bitterweed caused the trouble (3).

Several tests (10) were conducted in which sheep were confined to bitterweed areas or offered only bitterweed in dry lot, and in all cases the animals faced starvation rather than eat the weed. It became necessary, therefore, to resort to forced-feeding tests. On the whole these proved unsatisfactory although the tests strongly suggested the toxic character of this plant. In the 1929 Annual Report for Substation No. 14 of the Texas Agricultural Experiment Station, the following statement is made: "Obnoxious as is the weed, some sheep will eat it during the late winter when other weeds or grass are not available or at least very scarce." In August, 1931, definite information was published showing that bitterweed killed sheep (10).

Why the animals consume enough bitterweed to cause sickness in spite of their apparently instinctive dislike for the plant has not been determined, but it is probable that some of the weeds are accidentally con-

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The authors wish to express their appreciation of the guidance and suggestions given by Judge J. A. Whitten, Chairman Livestock Sanitary Commission of Texas, A. B. Conner, Director, Texas Agricultural Experiment Station, Dr. F. L. Thomas, Chief Division of Entomology, Texas Experiment Station, and W. H. Dameron, Superintendent Substation No. 14.

sumed when the young weeds are closely associated with the grass. This accidental feeding may cause poisoning or it may overcome the marked distaste which the animals have so that some of them later eat the weed voluntarily. There is no indication whatever that sheep eat the weed in preference to grass when the latter is readily available.

Fig. 1. Sheep killed as a result of poisoning by bitterweed. The vegetation consists almost entirely of bitterweed and constitutes a "hazard", or seed-producing center. (Courtesy of H. P. Malloy, Tierra Alta, Texas.)

In general, the losses among sheep increased from year to year, reaching a maximum in 1931. One ranchman near San Angelo stated that he lost 28 per cent of his ewes in 1929 and in 1930 would have lost all his sheep if they had not been placed in the feed lot. Another ranchman near Sonora lost 3,200 sheep during the two winters of 1929-30 and 1930-31.

Investigations were begun in the fall of 1931 to determine the best means of controlling bitterweed. The Texas Agricultural Experiment Station and the Livestock Sanitary Commission of Texas cooperated in this work. The Division of Entomology was charged with the responsibility of testing and finding chemical or physical measures that could be used economically to kill this weed under the range and climatic conditions of West Texas.

This is a preliminary report on the results obtained during the first year of this investigation, and is published in order to supply the demand for information on bitterweed control.

Bitterweed (*Actinea odorata* (DC.) Kuntze) occurs in the greater part of West Texas (10). (See Fig. 2.) The distribution in other parts of the United States is limited to western Oklahoma and Kansas, eastern and southern New Mexico, and to southern Arizona and California (5). Similar plants also known as bitterweed grow during the summer months in other sections, but are different

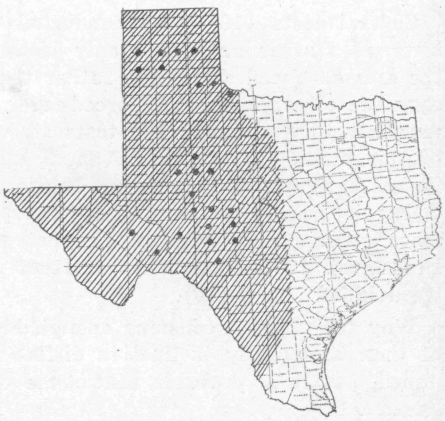

Fig. 2. Bitterweed occurs generally throughout the shaded portion of the map, though not necessarily in every county. The black dots show counties where the bitterweed weevil (Brachytarsus sp.) was found.

species, and in some cases belong to a different genus. Some of these plants are responsible for a bitter taste sometimes occurring in milk, but, so far as is known, they are not poisonous.

DEVELOPMENT OF THE BITTERWEED PLANT

Bitterweed may germinate at any time from September to May and occasionally during other months when moisture and temperature conditions are favorable, but the crops which have killed sheep germinated in October and November. In places where there is a heavy grass turf, the seed may never reach the ground and germinate, or crowding by other plants may prevent the growth of the bitterweed seedlings. The seedlings mature in one to five months, or longer, depending upon weather conditions. Normally the weather conditions of the Edwards Plateau region are more favorable for germination and growth of bitterweed during the fall, winter, and early spring months. Like many other weed seed, however, those of bitterweed may remain viable for periods of at least a year under exposed conditions without germinating, especially if weather conditions are somewhat unfavorable during this period.

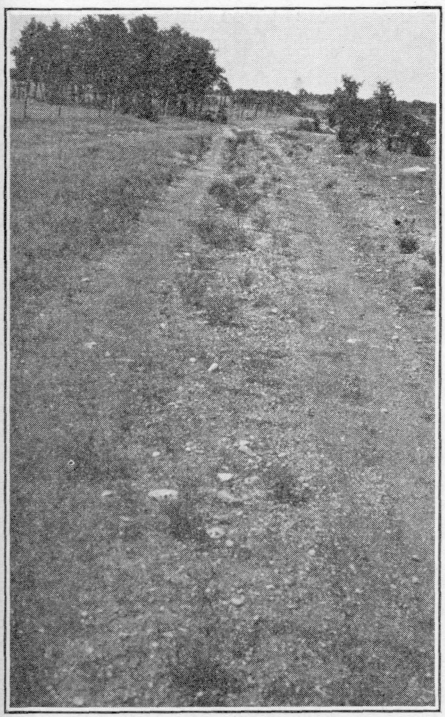

Fig. 3. Scattered bitterweed growing along roadway. Seed from these plants may be transported by passing vehicles.

During dry weather, the plants may mature but do not grow to be very large. Crowding also forces maturity and leads to early seed production, but in heavy grass turf the plants may never mature seed, thus indicating that the plant can stand strong competition with itself but not with grass. The number of flower heads per plant may vary from a few to as many as 1800, and probably more. Each head contains as many as 100 seed, or achenes. Each seed "is densely hairy and has several awned or sharply pointed, very thin, chaffy scales" (10).

MEANS BY WHICH BITTERWEED IS SPREAD

Flooding rains are no doubt responsible for spreading bitterweed. Entire plants may be carried down ditches and draws for considerable distances by flood water before being deposited in low places devoid of other vegetation, which are ideal for the growth of new plants. In

determining if bitterweed is present on a ranch, the best places to look, therefore, are in ditches, draws, and "hog wallow" spots, along roads, and around corrals, headquarters, and watering places. From these areas an infestation might spread over an entire range.

Roadways, through ranch pastures, are common locations for bitterweed. Automobiles which travel these roadways frequently catch portions of the plants possessing seed heads, and also seed may be picked up in mud and transported many miles before being dropped from the car.

Evidence that bitterweed seed may be transported in wool is found in the presence of bitterweed plants on the bedding ground of sheep. Bitterweed seed are not washed on to such grounds, as sheep usually bed on well-drained and elevated areas. Another indication that seed are carried by sheep is the growth of bitterweed plants on spots where sheep died and not on surrounding areas.

CONDITIONS RESPONSIBLE FOR INCREASE OF BITTERWEED

Range Management

The ranges of the Edwards Plateau region are well adapted to the grazing of sheep, cattle, and goats. These three classes of livestock are usually kept on every ranch and should be stocked in proportion

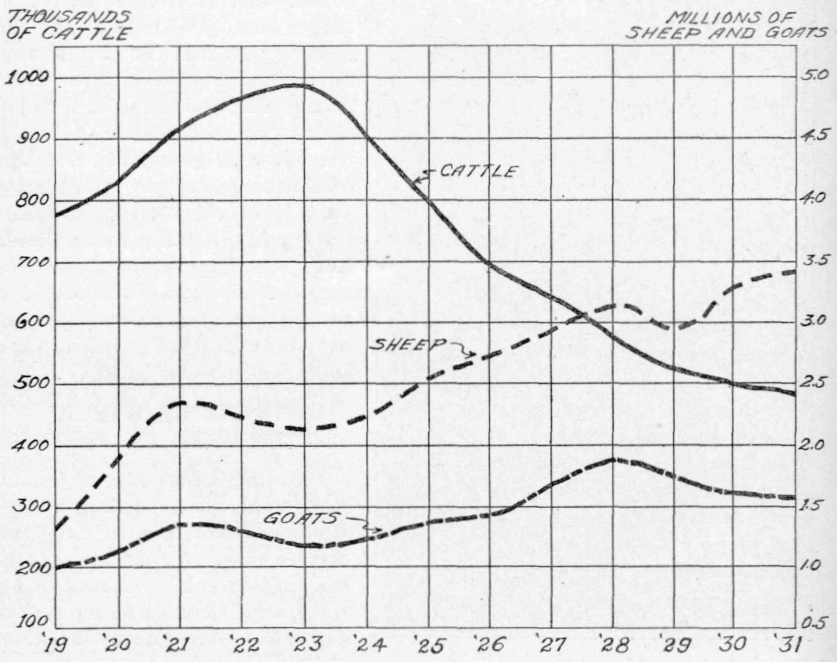

Fig. 4. Trend in production of cattle, sheep, and goats in the Edwards Plateau region, 1919-31, incl. (Comptroller's Report, Texas.)

to the amount of feed available to each class (12). Cattle prefer taller grass and some weeds; sheep feed best upon weeds and short grass; while goats eat practically all vegetation but seem to feed extensively on browse (8).

Since 1923 the number of sheep and goats has been increased, and the number of cattle has been reduced in the Edwards Plateau region, as shown graphically in Fig. 4. This change in stocking the ranches was made because of the financial returns from each class of animals (9). The large increase in the number of sheep in Edwards, Schleicher, and Sutton counties from 1923 to 1931, inclusive, is also shown graphically in Fig. 5. As a result of this increase the range has been over-grazed especially the grasses and weeds. Places where mesquite grass and other palatable vegetation once grew now became practically bare, or covered with less desirable plants. Such conditions were favorable for a tremendous increase in bitterweeds. The three counties named are located in the center of the area where bitterweed became so abundant and where the greatest losses from bitterweed poisoning have occurred.

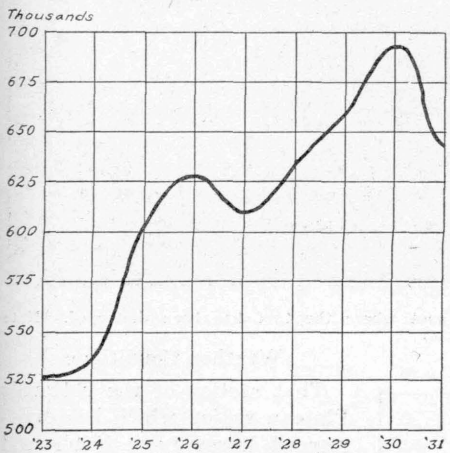

Fig. 5. Trend in sheep production in Sutton, Schleicher, and Edwards counties. Note the large increase which has resulted in many ranches becoming over-grazed. (Comptroller's Report, Texas.)

On every ranch there are certain locations, such as around watering places, near the headquarters, sometimes in the corners of a pasture, and places where supplemental feed is given, where the turf is killed by the trampling of livestock. The size and shape of a pasture and the topography of the country may also tend to produce overgrazing in portions of a pasture.

Before the ranches were over-grazed bitterweed grew only in "hog wallow" spots, in draws where erosion destroyed the turf, and in low places where the grass had been killed by water. As over-grazing killed the turf, many places became favorable for bitterweed to grow without competition from the desirable grasses and weeds. The bitterweed spread and grew densely, and the weakened grass was further choked out by crowding and shade from the bitterweeds. Bitterweed grows during the winter months while the grass is dormant, and develops into a large plant. The grass runners grow off the ground and through the dead bitterweed plants during the summer and cannot become anchored to the soil to form a solid turf. As a result bitterweed spreads very rapidly, completely covering the ground in many places, giving these areas the appearance of almost a solid mass of yellow flowers when this weed blooms in the spring.

Such bitterweed areas occurring around watering places, headquarters, and draws are a menace to the range as a source of seed supply, and sheep are likely to become poisoned from eating the weed in the frequented places. These bitterweed areas constitute what are called "hazards".

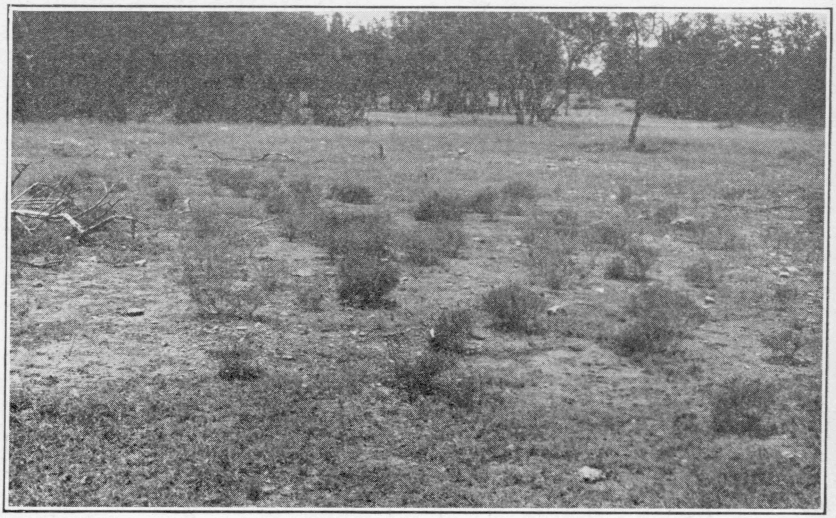

Fig. 6. Bitterweed growing in a spot where the turf has been destroyed. Note the absence of bitterweed in the grassy area.

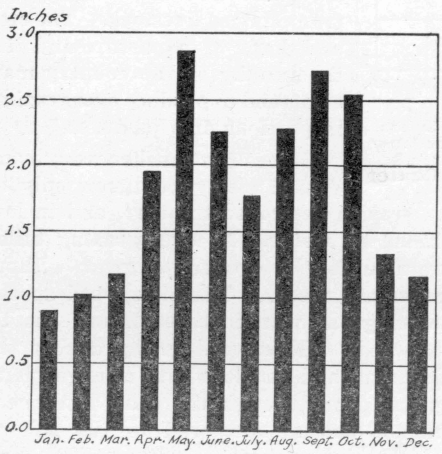

Fig. 7. Average normal precipitation in the area where greatest losses from bitterweed poisoning have occurred, recorded at San Angelo, Knickerbocker, Ft. McKavett, and Substation No. 14 near Sonora (U. S. Weather Bureau).

Weather Conditions

That section of the Edwards Plateau region which has experienced losses from bitterweed poisoning has an average rainfall of 22.05 inches, based on records of U. S. Weather Bureau Stations at Ft. McKavett, Knickerbocker, San Angelo, and Substation No. 14, near Sonora. This rainfall is fairly well distributed, only one month in the year having less than one inch. The heaviest precipitation of the year occurs in May, September, and October, when the monthly amount is more than 2.5 inches. This distribution of rainfall is favorable for growth of bitterweed in the spring and for the germination of seed in the fall.

Table 1 shows the rainfall at San Angelo, Knickerbocker, Ft. McKavett, and the Ranch Experiment Station, near Sonora, during August, September, and October, 1930 and 1931. The heavy rains of 10.62 inches over this part of the Edwards Plateau area in September and October, 1930, were followed by the largest and most widely scattered bitterweed crop ever observed in this region. In contrast to this condition a small to medium

Table 1. The Relation of the Late Summer and Early Fall Rains to the Bitterweed Crops of 1930-31 and 1931-32.

Location	Period	Rainfall in Inches		Size of Crop
Edwards Plateau Region (Four U. S. Weather Bureau Stations)	1930 Aug. Sept. Oct.	1.12 0.73 9.89	10.62	1930—31 Largest ever observed in this region
San Angelo	1931 Aug. Sept. Oct.	0.40 0.67 2.08	2.75	1931—32 Medium to small.
Substation No. 14	1931 Aug. Sept. Oct.	2.10 0.03 0.52	0.55	1931—32 Practically no bitterweeds.

crop of bitterweed developed in the vicinity of San Angelo when the rainfall was 2.75 inches, or 2.04 inches below normal, during September and October, 1931. At the Ranch Experiment Station, the rainfall during these months was 0.55 inches, or 5.44 inches below normal, and practically no bitterweed grew during the following winter. In August, 1931, bitterweed did not germinate at the Ranch Experiment Station even though the rainfall during this month was 2.10 inches, or 0.02 inches above normal.

It appears that under normal conditions enough rain falls in the Edwards Plateau region for a crop of bitterweed to develop practically every year. This means that as long as bitterweed hazards exist, the sheep men on those ranches must plan to use supplemental feeds during winter months, kill out the hazards, or suffer losses from bitterweed poisoning, unless through proper management the native grasses are conserved for grazing during the winter months.

EXPERIMENTS ON CONTROLLING BITTERWEED

Investigations of weed control in the past have been chiefly directed toward the control of perennial weeds during the summer months in cultivated fields, lawns, and along railroad rights of way and public roads. Several states now have weed-control laws.

In general the following methods have been recommended for the control of weeds: (1) Mechanical means, such as cultivation, mowing, flooding, pulling and burning; (2) soil management, such as crop rotation, pasturing, and choking out with crops; and (3) use of chemicals, especially chlorates, oils, acids, arsenicals, iron sulfate, and common salt.

As soon as the bitterweed plant was found responsible for the poisoning of sheep, it was realized that any successful control measures must take

into account an adjustment in the stocking of the range to prevent overgrazing, resulting in control of this weed under range conditions (7). It is expected that this annual plant cannot survive when crowded by native grasses, since it is seldom seen growing in native turf. These measures which are designed to build up the carrying capacity of the range must be supplemented by the destruction of bitterweed seed-producing centers, or hazards, located ordinarily where the turf has been destroyed by standing water, deposition of silt, or by livestock trampling out the grass around watering places and corrals. In such places the turf cannot be expected to be restored as long as the processes that are responsible continue to operate.

Spraying Bitterweed

Preliminary spraying tests were conducted by Jungherr (11) in 1929. The results of these experiments indicated that chemical sprays might be used in controlling bitterweed. In November of 1931 investigations were begun to study the practicability of spraying to control bitterweed hazards. The chemical sought was one which would kill bitterweed quickly, involve the least expense of labor and material, cause little or no injury to desirable vegetation and soil, and not be toxic to livestock when sprayed vegetation is consumed. Arsenicals were not tested because of the danger of poisoning livestock. Of the various herbicides recommended in other states, chlorate sprays, petroleum oils, and sulphuric acid appeared to be most promising in meeting the above-mentioned requirements.

It should be understood that it was never thought possible that an economical means of spraying an entire range could be developed. Spraying, if found practical, was intended to be used in conjunction with developing a good turf by proper range management to choke out bitterweed, and to be supplemented by destruction of scattered plants by hand pulling. It was thought that spraying might be used to kill bitterweed hazards more easily and cheaply than by any other means.

Spraying tests were begun November 19, 1931, and continued at short intervals through May 9, 1932. A double-action hand sprayer was used until March 17 in treating plats of four square rods each. Thereafter, a power sprayer with a boom attachment was used and the size of the plats was increased to about one-third of an acre. The spray was applied at a pressure of 150 pounds with the hand machine and 300 to 350 pounds with the power machine. Spraying may be done with a small compressed-air machine.

Chlorate Spray. Chlorates have been successfully used to control perennial weeds during the past few years. Sodium chlorate, which has been extensively used in controlling bindweed in the Middle West, is dangerous to use under some conditions, as sprayed vegetation might catch fire after drying, and it therefore was not tested. The chlorate solution used in the bitterweed tests is a commercial preparation known as "Atlacide." It appears to be a mixture of calcium chloride and sodium chlorate. The manufacturer claims that it contains not less than 54.6 per cent calcium

chlorate equivalent. In this report it will be referred to as "calcium chlorate."

Calcium chlorate is sold in a dry crystalline form. The present price is about 10 cents per pound F. O. B. in 200-pound drums. It may be applied as a dust or as a spray. It is readily soluble in water. When the soil and air are not extremely dry and and hot, the chemical absorbs moisture from the air and goes into solution; it is then absorbed by the plants if applied to them dry or in crystalline form. Although warning is given in many experiment station publications of the danger of fire after applying "chlorates" to vegetation, no such trouble was encountered after using calcium chlorate. If the chemical is spilled on the floor of a storehouse, precaution should be taken to thoroughly wash the floor as a fire preventive measure. Since calcium chlorate corrodes certain metals, care should be used also to thoroughly wash with water all equipment with which it has been in contact.

The first evidence of the effect of calcium chlorate on bitterweed plants is a discoloration of the lower branches and tips of the upper leaves. Gradually the discoloration and dying spread until the terminal bud is the only part of the plant remaining green. The plant may retain a small amount of green color for more than two months and then finally die. Sometimes the plants may appear to be dead but later put out new growth. Large bushy plants, which are not entirely covered with spray, have been observed to have dead foliage on one side while on the other it was alive.

Table 2. Effect of Variations in Humidity on Quantity of Calcium Chlorate and Water Needed to Kill All Bitterweed in Spraying Experiments, 1931-32.

Average Per Cent Humidity for Two Weeks after Spraying*	Date Sprayed	No. Plats in Test	Pounds of Calcium Chlorate per Acre	Gallons of Water per Acre	Smallest Amount of Calcium Chlorate That Killed All Bitterweed
79.2	Feb. 11, 1932	15	12	100	Spots not killed
			4, 8, 12, 16, 32, 64, 96	200	12 lbs.
			6, 12, 24, 48, 96, 144	300	12
			12	400	12
78.5	Dec. 12, 1931	12	2, 4, 8, 16, 32, 48	100	32
			6, 12, 24, 48, 96, 144	300	12
76.2	Nov. 18, 1931	10	8, 16, 32, 64, 96	200	16
			16, 32, 64, 128, 192	400	16
72.1	May 8, 1932	6	12, 18, 24, 36, 72, 144	200	12
70.0	May 9, 1932	9	108, 144		
			2, 4, 8, 16, 32, 48	200	12
68.2	Jan. 7, 1932	12	8, 12, 18, 24, 36, 48, 72,	100	32
			6, 12, 24, 48, 96, 144	300	12
59.5	Apr. 13, 1932	5	20, 30, 40, 50, 60	300	Badly burned but recovered
45.9	Mar. 17, 1932	18	4, 8, 12, 16, 20	100	No injury
			4, 8, 12, 16	150	No injury
			4, 8, 12, 16, 20	200	No injury
			4, 8, 12, 16	300	No injury
44.8	Mar. 18, 1932	1	13.5	150	No injury

*Humidity records taken daily at 8:00 A. M. and 6:00 P. M. at Substation No. 14 near Sonora, Texas.

To determine the value of calcium chlorate in controlling hazards, 147 plats of bitterweed were treated with one spray application of this chemical during the winter and spring of 1931-32. In the first part of the winter rain fell frequently, and it was thought that better results would be obtained during clear, dry weather. About the middle of March the weather cleared and the mean relative humidity was low, but these conditions proved to be unfavorable for killing the weeds by spraying.

The humidity following the application of spray is particularly significant. Table 2 shows the relation of the humidity to the effectiveness of calcium chlorate spray on bitterweed. Several plats were sprayed each month from November 18, 1931 to May 9, 1932. The results from 88 plats are given. The percentage of humidity is shown for two weeks following each application since it appears that the effectiveness of the chemical depends largely upon the amount of moisture present in the air at the time or soon after bitterweed is sprayed.

Fig. 8. Spraying a large patch of seedling bitterweed with a power machine, using 12 pounds of calcium chlorate in 200 gallons of water per acre.

Twelve pounds of calcium chlorate per acre was the smallest amount that killed all bitterweed on the experimental plats when the humidity was 68.2 per cent or above for two weeks after the application was made. In the tests when bitterweed was killed, the humidity varied from 68.2 per cent to 79.2 per cent for a period of two weeks following each application. When the humidity is about 75.0 per cent, the ranchmen usually speak of the weather as being damp or humid. At this humidity calcium chlorate will become moist after being exposed to the atmosphere for a few minutes

During the dry weather in March and April, 1932, bitterweed was not killed with calcium chlorate. In three series of tests on 24 plats, bitterweed was not killed even though as much as 60 pounds of calcium chlorate per acre were applied. The average per cent humidity for two weeks following these tests varied from 44.8 per cent to 59.5 per cent.

Rains following the applications on February 11 apparently increased the effectiveness of calcium chlorate. A trace of rain fell the day the application was made and 0.06 inches fell three days later. During the 10 days following the application, the rainfall was 1.47 inches. Even though rain fell on seven of the ten days after the spray was applied, all bitterweed was killed where 12 pounds or more of calcium chlorate per acre were used. The average humidity during the two-weeks period following the spraying in this series of tests was 79.2 per cent.

When bitterweed was sprayed during dry weather, the chemical disappeared from the plant and did not become effective later when the humidity increased. The bitterweed on the plats treated April 13 did not die even though 0.41 inches of rain fell on April 23, or ten days later, and 1.56 inches fell on April 28, 1932. The humidity for two weeks following this application was 59.5 per cent. This indicates that damp weather is necessary at the time or shortly after the spraying is done in order to kill bitterweed with 12 pounds of calcium chlorate per acre.

Since the source of water supply may be a considerable distance from some bitterweed hazards, it appeared desirable to determine the smallest amount of water that could be used and yet get maximum control with calcium chlorate. Tests were conducted in which sprays with varying amounts of calcium chlorate were applied at the rate of 100, 200, 300, and 400 gallons of water per acre. The results are shown in Table 3.

Table 3. Showing the Effect of Using Varying Amounts of Water on the Bitterweed Killed by Calcium Chlorate.

Gallons of Spray per Acre	Date Sprayed	Pounds of Calcium Chlorate per Acre	Smallest Amount of Calcium Chlorate That Killled All Bitterweed
100	Dec. 12, 1931	2, 4, 8, 16, 32, 48	32
100	Jan. 7, 1932	2, 4, 8, 16, 32, 48	32
100	Feb. 11, 1932	12	Not all killed
200	Nov. 18, 1931	8, 16, 32, 64, 96	16
200	Feb. 11, 1932	4, 8, 12, 16, 32, 64, 96	12
200	May 8, 1932	12, 18, 24, 36, 72, 144	12
200	May, 9, 1932	8, 12, 18, 24, 36, 48, 72, 108, 144	12
300	Dec. 12, 1931	6, 12, 24, 48, 96, 144	12
300	Jan. 7, 1932	6, 12, 24, 48, 96, 144	12
300	Feb. 11, 1932	6, 12, 24, 48, 96, 144	12
400	Nov. 18, 1931	16, 32, 64, 128, 192	16
400	Feb. 11, 1932	12	12

There was little, if any, difference in the amount of bitterweed killed when the spray contained 12 pounds of calcium chlorate or more and was applied at the rate of 200, 300, or 400 gallons per acre. One hundred gallons were not sufficient to secure a thorough wetting of the plants, and consequently some did not die. Bitterweed may be thoroughly wetted if sprayed at the rate of 200 gallons per acre with a pressure of 150 pounds.

In the calcium chlorate spraying tests, it was found that all ages of plants could be killed with this chemical when applied at the rate of 12 pounds per acre during humid weather. During November, December, and January small seedling plants sprayed with calcium chlorate were not killed as quickly as nearly matured plants which were treated in the spring, (see Table 4). Spraying may be delayed to kill the bitterweed which germinates during the spring months, but it should be done before the seeds mature.

In order to determine if calcium chlorate is toxic to sheep when sprayed vegetation is consumed, four tests were conducted on dry grass and one on seedling oats. Fenced plats of 16 square rods each were sprayed at

Table 4. Relation of the Age of Bitterweed Plants to the Time Elapsing before Kill is Obtained in Spraying Experiments Using Calcium Chlorate.

Age of Plants in Months	Date Sprayed	No. Plats in Test	Pounds of Calcium Chlorate per Acre	Gallons of Water per Acre	Smallest Amount of Calcium Chlorate That Killed All Bitterweed	No. Days before All Plants Killed
1	Nov. 18, 1931	10	8, 16, 32, 64, 96	200	16	74
			16, 32, 64, 128, 192	400	16	74
2	Dec. 12, 1931	12	2, 4, 8, 16, 32, 48	100	32	47
			6, 12, 24, 48, 96, 144	300	12	47
3	Jan. 7, 1932	12	2, 4, 8, 16, 32, 48	100	32	49
			6, 12, 24, 48, 96, 144	300	12	49
4	Feb. 11, 1932	15	12	100	---	---
			4, 8, 12, 16, 32, 64, 96	200	12	15
			6, 12, 24, 48, 96, 144	300	12	15
			12	400	12	15
7	May 8, 1932	6	12, 18, 24, 36, 72, 144	200	12	35
20%-3 mo. 80%-9 mo.	May 9, 1932	9	8, 12, 18, 24, 36, 48, 72, 108, 144	200	12	36

the rate of 192 pounds of calcium chlorate in 400 gallons of water per acre. A total of 18 sheep were confined on these areas until the vegetation was practically all consumed, or until rains fell and it was thought that the chemical was washed off the plants. The results in Table 5, reported by the veterinarians at the Ranch Experiment Station, show that all of the sheep remained healthy after feeding on the vegetation which was sprayed with a strong calcium-chlorate solution. It appears that this chemical may be used to destroy bitterweed in pastures which are being grazed without danger of poisoning sheep.

Table 5. Effect of Calcium Chlorate on Sheep when Sprayed Vegetation Is Consumed.

Date Test Begun	Kind of Vegetation Sprayed	No. Sheep on Test	No. Days Sheep Were on Test	No. Days before First Rain Fell after Spraying	Results
Nov. 20, 1931	Dry grass	4	9	4	Remained healthy
Dec. 31, 1931	Dry grass	4	13	4	Remained healthy
Jan. 12, 1932	Dry grass	4	7	5	Remained healthy
Feb. 13, 1932	Dry grass	3	3	3	Remained healthy
Mar. 22, 1932	Seedling oats	3	8	8	Remained healthy

Observations were made to determine the effect of calcium chlorate on vegetation other than bitterweed which grew on the treated plats. Hazards which may be sprayed are usually thickly covered with bitterweed and carry little other vegetation. During the winter months few plants were growing other than bitterweed, but many annuals and perennials appeared in the early spring. Where 24 pounds per acre or less were applied no killing of any desirable vegetation was observed. There seems to be more resistance among these species of plants to calcium chlorate poisoning than is found in bitterweed.

Tests to determine the effect of calcium chlorate on dormant curly mesquite grass were made in November. Five plats were sprayed November 13 using 16, 32, 64, 128, and 192 pounds of calcium chlorate in 400 gallons of water per acre. No effect on this grass was noticed until April, 1932. The plats receiving 16 and 32 pounds were not injured, but where more calcium chlorate was used there was some grass killed.

Petroleum Oils. Since oil is produced in West Texas and is available in large quantities, its value in killing bitterweed was tested. Oils have been found to be more effective on annual than on perennial weeds, especially in warm weather (1). The various grades of petroleum oils available to the ranchers were used. Twelve plats were sprayed during the winter of 1931-32 at the rate of 100 gallons per acre, the spray being applied at a pressure of 150 pounds. The following oils were used: kerosene, crude oil, gas, fuel, gas and fuel (mixed 50-50), and fuel and kerosene (mixed 50-50).

In these tests oil at the rate of 100 gallons per acre was not satisfactory in killing bitterweed, as shown in Table 6. Crude oil and fuel oil gave the best results but in no case was more than 80 per cent of the bitterweed killed. Kerosene had very little effect on the plants. At the pressure of 150 pounds, it was difficult to get a uniform distribution of spray when 100 gallons were applied per acre. As a result there were many spots in each plat where the bitterweed was not killed, probably because of not being sprayed. This indicates that more than 100 gallons per acre of oil might kill all the bitterweed. However, the cost of this amount of oil and its transportation in most cases would prohibit its use.

Table 6. Percentage of Bitterweed Killed by Different Oil Sprays.

Kind of Oil	No. of Plats in Test	Gallons per Acre	Per Cent Killed in 40 Days
Kerosene	2	100	0
Gas Oil	2	100	20
Crude	2	100	80
Fuel	2	100	80
Fuel and Gas (Mixed 50-50)	2	100	75
Fuel and Kerosene (Mixed 50-50)	2	100	70

Sulphuric Acid. Sulphuric acid spray has been recommended by the Arizona Experiment Station as being a practical means of controlling weeds in that state. Investigations conducted there showed that high temperature and low humidity are favorable to effective spraying (4). Wilting and discoloration of weeds occurred within twenty or thirty minutes after the application was made.

Eighteen bitterweed plats were sprayed with sulphuric acid during the winter of 1931-32. Applications were made with a hand and power machine at the rate of 200 gallons per acre. Sulphuric acid solutions of one-fourth per cent to six per cent (by weight) were tested. Bitterweed in

all stages of development was sprayed and applications were made during various weather conditions.

Sulphuric acid failed to kill all bitterweeds on any plat even where a 6 per cent solution (by weight) was used. The plants wilted and turned brown within thirty minutes after spraying, but some recovered even where the strongest solution was used. The drifting acid spray of the strong solution made spraying disagreeable and damaged clothing and machinery. The strength of the solution was not increased since this chemical did not appear to be promising for controlling bitterweed during winter months.

Hand Pulling

Hand pulling as a method of controlling bitterweed may at first thought appear to be impractical. However, it was found to be of considerable importance in some locations. In many natural hazards where erosion has destroyed the turf, bitterweed grows in small areas which are too rough or rocky to be sprayed conveniently. Applications of a spray material to scattered plants are often impractical, as a large portion of the chemical may be wasted. The use of hand or compressed-air sprayers is limited because of their small capacity of three to five gallons and the necessity of using them long distances from a water supply.

On the Ranch Experiment Station, 612 pounds of bitterweed plants were pulled in 125 hours. This was done during the latter part of June while the large plants were flowering and could be seen easily. They were collected in sacks and burned so as to kill any seed that might have matured. In this test an average of about one thousand plants were pulled per hour. These plants averaged about 2700 heads per pound.

Fig. 9. Small area covered with bitterweed (left). Less than 20 minutes work of one man was required to pull the weeds which contain approximately 100,000 seedheads (right).

Pulling bitterweed is not as tiresome as may be considered. When one realizes that the destruction of a single large plant may reduce the seed supply by many thousands, interest in the work increases. Hand pulling may be done around headquarters and along roadways, such as illustrated in Fig. 3, during spare time, and weeds in small areas may be pulled when seen while working with livestock on the range. The great value of the hand-pulling method is that it can be used immediately, and without

preparation, any time when a person is near scattered weeds and has a few moments to spare.

Mowing and Burning

Some bitterweed was mowed and removed at Substation No. 14 late in the spring of 1931 after it was nearing maturity. This bitterweed was tall and growing upright so that the plants could be cut near the ground. After the bitterweed was mowed, the grass in this area grew fast during the summer, and a better turf developed than on the adjacent areas. In the spring of 1932 there was less bitterweed on the mowed area than on the outside where it had not been mowed.

From this test it appears that mowing and raking in the late spring, where bitterweed plants are large and abundant, will help to improve the grass and reduce the seed supply. The mowed bitterweed should be raked up and burned to destroy the seed and to prevent the dead vegetation from hindering the growth of grass.

One plat of bitterweed was mowed and left on the ground November 29, 1931. The bitterweed was about eight inches tall and beginning to bloom. It was spreading rather low, and even though the cutter bar was run as close to the ground as possible, some branches were left uncut and matured blooms. By June 15, 1932, a second crop of bitterweed had come up and was in bloom. The bitterweed on the mowed area was thicker than that on the outside. It appeared that mowing the weeds in fall actually made conditions better for another crop of bitterweed to germinate by removing the larger scattered plants and giving the seedlings an opportunity to grow.

Tests were conducted during the winter to determine if burning would kill living bitterweed. A number of attempts to burn living bitterweed were made after spraying it with kerosene, crude oil, gas oil, and fuel oil, at the rate of 100 gallons per acre, but in no case would the bitterweed burn.

Bitterweed is sometimes burned during July and August when the plants have dried but this has not proved to be a good practice. During the summer of 1931 several ranchers in the vicinity of San Angelo burned the bitterweed, but the rains in October brought up more bitterweed in the burned areas than in nearby places where weeds were not burned. Explanations for this probably are, first, that burning destroyed the flower stem and permitted the heads to fall to the ground uninjured, where the seed germinated even better than if the head had remained on the standing plants; and, second, that burning destroyed the grass that was present and left a clean seed-bed in which the seed could germinate and grow. The tender grass, which grows after burning, attracts sheep which graze it close and cause further injury to the grass turf, thus aiding the development of young bitterweed. Should burning be practiced, it is very necessary that no livestock be run on the land that has been burned, as otherwise the grass may be damaged by burning and grazing to such an extent that several years are required to reestablish a good turf.

INSECT ENEMIES OF BITTERWEED

Insects feed on the bitterweed plant, but the amount of damage each species does is not known. It is suspected that the feeding of some insects causes the involucre to close tightly and prevents the liberation of the seed except during damp weather and thereby reduces the germination. Evidences of other damage are the destruction of the seed in the head, tunnels in the stem, and insect injury to the foliage and roots. Some insects are attracted to the aromatic plant, but though often seen on bitterweed, they do little or no damage.

Ten species of insects have been observed feeding on bitterweed, four being new and unnamed. A weevil whose grub feeds on the seed is the most beneficial in aiding to control bitterweed. This new weevil belongs to the genus *Brachytarsus,* and the common name "bitterweed weevil" may well be given to this insect. The eggs are deposited singly in the flowers and hatch into small white grubs, which feed on the seed during the winter. The grubs pupate and transform into weevils from February to June. The adult weevils begin to emerge in April and feed on the flowers of bitterweed and other composites during the spring. The bitterweed weevil, or its grub, was found during 1932 in every location where bitterweed was examined. (See map, Fig. 2.) Of 4,742 seed-heads examined which were collected at 14 places in 11 counties, an average of 20 per cent were infested with grubs. Practically all the seed were destroyed in the infested heads, as shown in Fig. 10. The heads were sorted into large, medium, and small sizes, and the infestation of each class recorded. Of the 402 large heads examined, 63 per cent were infested; of 2,264 medium heads, 24 per cent were infested; and of 2,076 small heads, 8 per cent were infested. This indicates that the large heads, which most likely contain viable seed, are damaged oftener than the small ones.

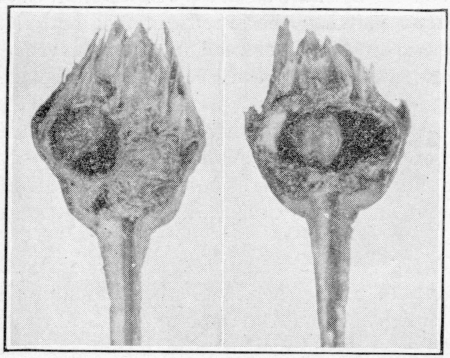

Fig. 10. Cross sections of bitterweed heads destroyed by the bitterweed weevil (Brachytarsus sp.).

Bitterweed is the preferred host plant of this weevil, but it has been observed to feed on many other composite flowers which bloom during the spring. This insect has never been found in a locality where bitterweed was not growing.

A cutworm (*Euxoa sp.*) fed on bitterweed in places near San Angelo and Sonora during February and March, 1932. Old fields, which formerly had been in cultivation, and lake beds were especially heavily infested. In places the plants were almost completely destroyed. Some of the plants never recovered, but by June the bitterweed which survived covered

the ground so that the injury was not noticeable. It is interesting to note that about the middle of February the cutworms began dying on the plants and by March 20 very few could be found alive.

Insects may aid considerably in limiting the abundance of bitterweed, but there is little possibility that insects alone will completely eradicate the plant.

POSSIBILITIES OF BITTERWEED ERADICATION

Weed eradication is difficult and is seldom accomplished unless persistent effort is made before the weed spreads over a large area. Oftentimes a new weed may be introduced with seed and an infestation begun. In such cases, the weed may be eradicated before it becomes well established.

It is thought that bitterweed can be eradicated in places if weather conditions and insect damage are favorable, and provided the proper program is conscientiously carried on for a number of years. The first step would probably be an adjustment of stocking so as to restore a good turf to the range. The bitterweed plants when abundant in hazards may then be destroyed by the use of sprays, and scattered weeds may be pulled. This work should be begun on the highest land on the ranch and continued until the weeds are killed on the lowest land so that the bitterweed seed will not be washed to land which has been freed of this weed. If weather conditions are favorable for grass to grow and the insect enemies of bitterweed continue to feed upon and destroy a portion of the plants, eradication might not be as difficult as imagined and well worth the attempt.

SUMMARY

Bitterweed is a poisonous plant which has caused losses among sheep since 1924. These losses increased from year to year, reaching a maximum during the winter of 1930-31. Since 1932 the number of cattle has been decreased and the number of sheep and goats increased. This change in stocking resulted in over-grazing most grass and a consequent replacement by less desirable vegetation.

The annual bitterweed plant is apparently unable to compete with perennial weeds and grasses when there is a good turf in November and December. Bitterweed is seldom seen growing in heavy grass, and the occasional plant that does grow is choked out or else produces few if any viable seed.

Any control measures adopted must take into consideration an adjustment of stocking the ranges so as to give the desirable vegetation an opportunity to compete with and eventually choke out bitterweed. Special attention must be given hazards in order to destroy these seed-producing centers, which will be a menace to the range as long as conditions exist which form these hazards.

Experiments conducted to determine the most economical means of destroying hazards show that bitterweed may be killed with a spray solution of twelve pounds of calcium chlorate in 200 gallons of water per acre.

This spray is effective only during humid weather, and is most efficient following rains. All plants must be thoroughly covered in order to get a complete kill. A solution of this strength will not kill perennial plants nor has it been observed to kill other annuals during winter months. It is not toxic to sheep when sprayed vegetation is consumed. Petroleum oils or sulphuric acid did not prove to be practical for killing bitterweed. Burning also appeared to be impractical. Mowing large plants in spring before seed matured reduces the seed supply and aids the development of a turf.

Hand pulling is a practical means of destroying bitterweed along ditches and in places too rough and rocky to be sprayed; scattered plants in pastures may also be destroyed in this manner. Pulling should be done before the seed matures and falls to the ground. It may be delayed until the plants are in bloom, when they may be easily seen; but the plants should be gathered and destroyed.

Ten species of insects have been found which feed on bitterweed. An average of 20 per cent of the seed heads were infested and the seed were destroyed in fourteen localities during 1931-32, by the bitterweed weevil, but it is not likely that insects alone can control this weed. Advantage should be taken of the damage done by insects to further control bitterweed.

It is believed that bitterweed may be eradicated in some places if weather conditions are favorable for grass to grow and insects continue to destroy a portion of the plants. The turf should be conserved by resting the pastures so that grass can replace bitterweed, and the hazards, or seed-producing centers, should be destroyed.

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