Bulletin No. 364 - The Halogeton Problem in Utah

C. Wayne Cook

L. A. Stoddart

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Bulletin 364 November 1953

AGRICULTURAL EXPERIMENT STATION
Utah State Agricultural College
In cooperation with the
BUREAU OF LAND MANAGEMENT
United States Department of the Interior

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RECOMMENDATIONS

SINCE HALOGETON is likely to remain on Utah ranges regardless of control measures, the following suggestions are advanced to aid ranchers in keeping livestock losses at a minimum.

1. Trail animals slowly and openly so they may select the more palatable and harmless forage. Hungry animals are more likely to graze halogeton and small quantities may be fatal unless eaten along with other feed.

2. Feed alfalfa or, still better, alfalfa-calcium pellets when trailing through halogeton-infested areas. The best pellet developed thus far appears to be one consisting of 83 percent alfalfa, 15 percent calcium carbonate, and 2 percent molasses. Do not feed a calcium fortified pellet over extended periods, however, as it prevents the animal from making use of phosphorus and thereby may have deleterious effects.

3. Avoid at all times grazing areas heavily infested with halogeton, especially in the fall when plants are heavily laden with seed. Seeds are somewhat palatable and seem to mask the acrid taste of the halogeton stems and leaves.

4. Relieve the grazing burden on infested ranges so that native forage plants can gain in vigor and crowd out halogeton. Light grazing also decreases the likelihood that animals will consume lethal doses of halogeton since native forage plants are preferred to halogeton and animals consume lethal doses only when forced by hunger to do so.

5. Avoid destroying native vegetation by plowing or by spraying unless the area can be revegated by perennial plants with a high degree of success.

ACKNOWLEDGEMENTS

THE AUTHORS WISH to acknowledge the assistance of Dr. Wayne Binns, head of the Department of Veterinary Science, for post-mortem descriptions and histological sections; of D. O. Williamson for the chemical analyses of plant material; of Virgil Hart and Ben Gomm for collecting samples and assembling data; and of the Bureau of Land Management for financial support during this study.

SUMMARY AND CONCLUSIONS

HALOGETON WAS introduced into the United States about 1930 but not until 1942 were actual livestock losses attached to it.

During the winter grazing seasons from 1951 to 1953 studies were conducted on desert ranges infested with halogeton in an effort to determine the conditions of poisoning.

Movable woven-wire paddocks were used to study the effect of intensity of grazing, plant association, and climatic conditions upon halogeton consumption. Forced-feeding trials were also conducted in order to determine lethal doses under various conditions.

Diets under natural grazing composed of as much as 29 percent halogeton averaging 10.5 percent soluble oxalates produced no ill effects. Animals ate more halogeton when they had only an alternate choice of big sagebrush than when halogeton was in association with any other range plant or combination of plants. Likewise, as the intensity of grazing increased, consumption of halogeton increased, but, even under extremely heavy grazing, lethal doses were not consumed. Animals mainly consumed seeds and small plants, avoiding stemmy material unless it supported an abundance of seed.

Lack of salting was not a factor since some animals were not given salt for more than a year and did not eat halogeton to satisfy this deficiency. Likewise, lack of water or infrequent watering did not induce animals to consume lethal doses of halogeton.

Halogeton plants contained as much as 28 percent soluble oxalates during the early fall but the oxalate content dropped to as low as 5 percent in the spring unless the plants were covered with snow during the winter. A cover of snow preserves the oxalates and prevents leaching or loss of leaves and seeds. Seeds averaged 8.1, leaves 28.1, and stems 3.6 percent soluble oxalates in the winter grazing season. It was found that small plants contained slightly more oxalates than large plants, possibly because of their lower stem-to-leaf ratio.

The consumption of certain salts such as sodium and potassium oxalates causes acute hypocalcemia by precipitating the calcium out of the blood and death is believed the result of asphyxia or heart failure brought about by muscular spasms.

The Halogeton Problem In Utah

By C. Wayne Cook and L. A. Stoddart[1]

INTRODUCTION

HALOGETON *(Halogeton glomeratus)* although introduced into Utah only 20 years ago, has spread widely on the west desert and into extensive areas on the east desert. This plant has become the most feared poisonous plant in the state because people have been lead to believe that it would limit livestock production to areas kept free of the weed.

Halogeton was reported by Dayton (1951) as being an abundant plant on dry saline clay soils of the desert steppes of northwestern China and southwestern Siberia. The general belief is that the plant was unintentionally introduced into the United States about 1930 and was first collected and identified as *Halogeton glomeratus* in 1934. The first collections for identification purposes were made near Wells, Nevada, by Ben Stahmann. At this time the plant was considered fair forage for livestock and was believed to have promise as a fire lane if seeded in cleared strips. The plant now has spread over most of Nevada and has moved into Utah and southern Idaho in great quantities. Small areas of infestation are now reported from all the 11 western states except New Mexico, Arizona, and Washington.

Sheep losses from halogeton were suspected in the late thirties, but it was not until 1942 that actual losses were attributed to halogeton consumption. During the fall of 1942 more than a hundred sheep died near Wells, Nevada, and stomach contents showed that large quantities of halogeton had been consumed. Feeding tests the following year at the University of Nevada confirmed that halogeton was poisonous and could be responsible for serious livestock losses on the range (Fleming *et al.* 1952).

Where It Grows on Ranges of the West

HALOGETON IS AN aggressive invader and is widely adapted to conditions found in the saltbush and sagebrush range types of the Intermountain Area. Infestations have been reported at eleva-

[1] Associate professor and professor of range management, respectively. Report on project 375, cooperative with Region 4, Bureau of Land Management.

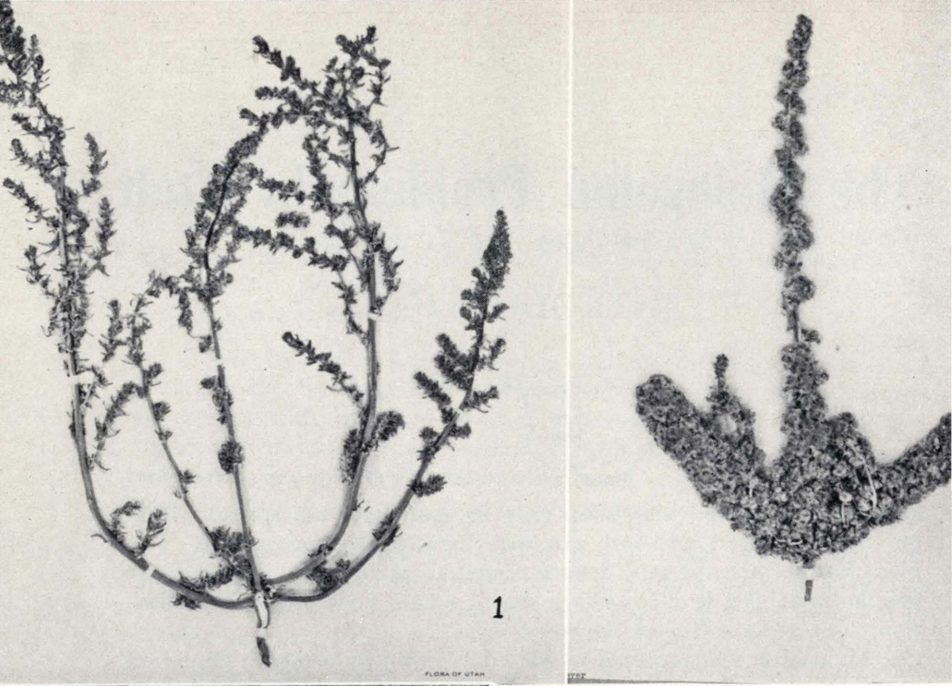

Fig. 1. (1) Midsummer flowering plant of halogeton, (2) fall fruiting plant, (3) much enlarged five-parted winged seeds of halogeton which appear in such profusion in the fall

tions up to 7,000 feet in juniper types and the plant occurs in areas having from 3 to 20 inches in annual precipitation. Halogeton thrives on arid lands especially where soils have been disturbed or where native plant cover is thin or low in vigor. Dense stands are found on burned-over areas, abandoned fields, railroad right-of-ways, around sheep-watering places, old bed grounds, along sheep drive ways, and along highway shoulders and road cuts.

Heavy production of halogeton one year often is followed by low production the next, possibly because soil moisture was so depleted the first year. Likewise, the amount of halogeton in mixed stands of native vegetation will vary with the amount of summer precipitation since it can respond and utilize the moisture more rapidly than can most native perennials.

It seems logical to assume that halogeton will eventually invade all disturbed areas in the saltbush and sagebrush ranges of the Intermountain Area. It may even follow closely the distribution of Russian-thistle throughout the Great Plains and the Southwest.

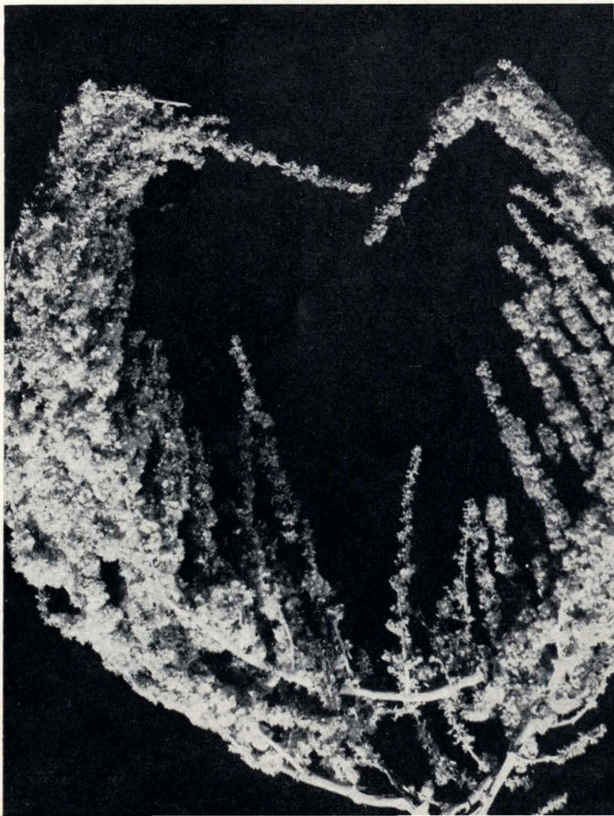

Fig. 2. A mature halogeton plant heavily laden with seed

Description of Halogeton

HALOGETON IS AN annual plant whose appearance somewhat resembles Russian-thistle, species of pigweed *(Amaranthus* spp.), and smother weed (*Bassia* spp.) The stems are often tinged with red or purple with a great deal of color variation, and are branched from the base. The leaves are fleshy, wiener shaper, round in cross section, and tipped with a delicate spine or bristle-like hair (see picture on cover). The seeds are, for the most part, enclosed in five wing-like bracts (fig. 1) and at maturity may cover the plant in an almost solid mass from the ground to the tips of each branch so that the fleshy leaves are entirely hidden from view (fig. 2).

Young, immature halogeton plants contain an enormous amount of moisture and are dull green to blue-green with red stems. The plant fades and becomes straw colored after it has frozen and weathered. Plants in dense stands may not attain a height of more than a few inches; whereas, widely spaced plants under favorable moisture conditions may reach a height of 1 to 2 feet or more. Even though some plants are only an inch or so high, they produce viable seed in relative abundance.

Seeding Habits

MOST HALOGETON SEEDS germinate early in the spring but growth is slow and the young usually plants will not be observed until late spring. Some seeds may also germinate during the summer when moisture from late rains is available. Therefore, plants of various sizes and ages generally are present in halogeton stands. Most seeds are produced late in the summer, but they remain on the plant until late fall or winter. By the middle of the winter most of the seeds have fallen from the stems but even as late as March a few remain on the plant.

Halogeton makes its greatest growth in midsummer when most winter annuals and desert plants, except sagebrush, have either produced seed and become dormant or are approaching maturity. Thus, halogeton utilizes moisture from summer rains often without serious competition from other plants. Few plants compare with halogeton in ability to absorb moisture rapidly and store it against desiccation for growth and seed production.

The U. S. Bureau of Entomology and Plant Quarantine (1953) reports that wind carries halogeton seeds only short distances by blowing them along the ground to be accumulated in a wash or against shrubs and other obstructions. However, where vegetation is sparse and there are few obstructions, there is reason to believe that the prevailing winds sweeping across the desert areas day after day blow seed over the ground surface or over the snow for considerable distances. In addition, the seeds that accumulate along washes may be carried by water for many miles. Thus, wind and water are important avenues of seed transportation. Livestock, rabbits, and perhaps birds are believed responsible for the seeding of driveways and introductions into distant areas previously free of the plant.

Halogeton will remain on areas where continued disturbance prevents establishment of perennial plants. Therefore, a source of seed always will be available around watering places and along roads and trails for rapid invasion once the native forage species are reduced in vigor and abundance. For this reason, learning how to manage grazing lands to prevent halogeton infestations and minimize livestock losses is of extreme importance.

Livestock Poisoning

DURING THE PAST few years halogeton has received much publicity as a poisonous plant. This publicity has been misleading because it has been written with an alarmist attitude to arouse public sentiment. Many newspaper releases have inferred that the livestock industry of the West is faced with complete liquidation unless measures to control the spread of halogeton are taken immediately. However, after preliminary study, range technicians have generally agreed that the proper solution to the problem of halogeton poisoning lies, not in the eradication of the plant, but rather, in learning how to graze infested ranges with a minimum of livestock losses and in preventing the spread of the plant by maintaining a good cover of native vegetation through good range and livestock management.

Learning to live with poisonous plants is not a new idea; literally hundreds of poisonous plant species grow on Utah's ranges but stockmen have learned through experience or scientific reports to hold livestock losses to a surprisingly low figure. Heavy losses from loco (*Astragalus* spp.), larkspur (*Delphinium* spp.), greasewood (*Sarcobatus vermiculatus)* and others have been reported in previous years and these plants were thought at one time to threaten livestock production on ranges occupied by them. In 1920, at Harper, Oregon, 1,000 head of ewes out of a herd of 1,700 head died overnight from consuming greasewood (Couch 1937). In Utah (Stoddart *et al.*

1949) in 1942, 260 sheep died from lupine in a single day on a range where poisoning was previously unknown. Losses of 200 head of cattle from a single herd were reported from larkspur poisoning in 1913 (Marsh, *et al.* 1913). In 1917, 736 sheep died from a band of 1,000 in western Colorado from milkweed poisoning (Marsh *et al.* 1920).

In Montana, 700 sheep died out of 2,000 trailed over a lupine range and in another herd 1,150 out of 2,500 died from the same poison (Chestnut & Wilcox 1900).

In 1909, 500 sheep from a herd of 1,700 died from death camas poisoning in Wyoming and in one county alone 20,000 died from the same cause (Chestnut & Wilcox 1901). Other such losses have been reported from New Mexico and Utah from consumption of greasewood, larkspur, and loco (Chestnut & Wilcox 1901, March *et al.* 1913, Stoddart *et. al.* 1949). Thus, a number of phenomenal losses have occurred from poisonous plants. None of these plants has been eradicated over an extensive area, yet the same ranges are grazed with few or no losses today.

Phenomenal losses of sheep from halogeton have been recorded also *but these are rare.* By far the most severe losses were reported in the Raft River region of Idaho in 1945 when 750 animals died from one flock and 275 from another (Twin Falls Times-News 1945).

These records of poisoning from other plants are quoted here, not to belittle the importance of the halogeton problem, but to show the parallelism between the history of halogeton poisoning and that of numerous other poisonous weeds. Stockmen have never found a way to eliminate a single poisonous species on a practical scale. Yet they have learned to live relatively safely with every one of more than 400 known species of poisonous plants in the United States. It must be remembered that halogeton has certain characteristics which make it more serious than some other poisonous plants. These include its prolific seeding habits, its wide range of adaptability to various conditions of soil, topography, and climate, and the relative ease with which the seed is transported by wind, water, animals, and other means.

Reasons for Study

During the fall and winter grazing seasons from 1951 to 1953 the Utah Agricultural Experiment Station conducted an extensive grazing study on halogeton-infested areas of typical desert winter ranges in northwestern Utah in an effort to answer the following questions.

1. Can halogeton ranges be grazed certain times of the year without danger?
2. Are natural range plants more palatable than halogeton so that animals will not be poisoned with normal grazing?
3. How much halogeton can grow in combination with native forage and not be dangerous to livestock?
4. Does a shortage of salt or water cause animals to consume halogeton when otherwise they would not?
5. How does intensity of grazing affect the consumption of halogeton on various range types?
6. Do animals acquire an immunity to halogeton if given access to the plant in moderate quantities for an extended period?
7. Do animals consume halogeton more readily after a snow or rain, after a quick frost, or after some unusual combination of weather conditions?
8. How does site or location affect the oxalate content of halogeton?
9. How does the content of poison of halogeton vary during the winter?
10. How does the content of poison vary in different portions of the plant and in plants of different sizes?
11. Can animals tolerate larger quantities of halogeton if consumed in small units throughout the day as contrasted with an equivalent amount all at one time?
12. How does calcium content of the diet affect the quantity of halogeton necessary to cause death?
13. Do small amounts of halogeton over long periods of time cause harmful effects upon the animal such as abortion or other temporary or permanent physiological disturbances?
14. Do hungry sheep which have been shipped or trailed eat halogeton more readily and, if so, what is the tolerance of sheep with partially empty stomachs compared to sheep that have had access to full feeds of range forage?
15. Does trailing have an abnormal effect upon the appetite of a sheep causing it to select halogeton?
16. How does age affect the viability of halogeton seed?
17. Can halogeton seed be carried in the digestive tract of animals such as sheep and rabbits without losing viability?
18. Can chemical sprays control halogeton effectively?

Fig. 3. A balling gun used to force-feed halogeton to animals by inserting the small cylinder down the esophagus and releasing the material beyond the throat

METHOD AND PROCEDURE

DURING THE FALL seasons of 1951 and 1952 large quantities of halogeton were collected in the green stage before the frost and in a relatively dry stage after killing frosts. This material was ground and pelleted for experimental feeding trials to be conducted during the winter. Part of the ground halogeton was pelleted with a small quantity of molasses to bind it together whereas additional pellets were made containing equal amounts of alfalfa and halogeton with a small quantity of molasses to increase the palatability so animals would consume them free choice.

The halogeton-alfalfa pellets were fed to ewes free-choice throughout the grazing season from October to April to determine the effects of continued consumption of sublethal doses on general health and reproductive capacity.

Pure halogeton pellets were force-fed by means of a balling gun (fig. 3). These pellets were fed following a 36-hour fasting period and also following normal range foraging. Under each condition, various quantities were fed either all at one time or at various intervals over a 12-hour period both with and without calcium supplements.

Blood samples were taken previous to, during, and following the feeding period and were analyzed for blood calcium. Post mortem examinations were made on all animals dying from halogeton feeding and histological sections were taken from the liver and kidneys for observation.

Three movable woven-wire paddocks enclosing from 4 to 6 acres each were used to study the effects of intensity of grazing, plant association, and climatic conditions upon halogeton consumption.

Each paddock was stocked with sheep which grazed under close observation (fig. 4). These enclosures were moved every two to three weeks depending upon the intensity of grazing desired. The areas were selected to represent ranges containing different forage species growing in combination with various amounts of halogeton.

The botanical composition of the diet was determined for each area including the daily consumption of halogeton by the method proposed by Cook *et al.* (1950). Observations were made to determine preference for halogeton when growing in complex mixtures with native desert plants, in association with only one other plant, and under various weather conditions.

Halogeton plants were collected at frequent intervals throughout the fall and winter season from different areas in an effort to deter-

Fig. 4. Sheep grazing a desert range area where halogeton has invaded because of past misuse. The vegetation consisted of 38 percent halogeton, 30 percent shadscale, 5 percent winterfat, and 27 percent black sage, with a total density of about 12 percent and low plant vigor

mine the effect of soil type and weathering upon the poisonous oxalate content of the plant. Various parts of halogeton (stems, leaves, and seeds) were analyzed separately to determine the variability of soluble oxalate content throughout the plant. Likewise small plants about 4 inches in height were analyzed and compared with tall plants approximately 12 inches in height to determine the effect of size upon soluble oxalate content of plants growing side by side.

Each sheep used in the grazing and feeding was identified with an ear-tag number and also a painted number on its back so that observations of symptoms could be made in the field and attached to the history of the animal. Some sheep that received a known quantity of halogeton over extended periods were slaughtered to determine whether sublethal quantities injured kidney and liver tissue permanently.

A young, vigorous buck was placed in each pasture and rotated every 9 days with the other bucks so that each buck was with each ewe at least 3 times during the breeding season. Each buck was equipped with a marking harness so that a record of each breeding could be determined. The color of chalk in the marking harness was changed every 18 days so that a record of the number of times each ewe was bred could be maintained.

A number of plots 100-feet square were laid out in various types of natural vegetation where halogeton was relatively dense and native plants had been reduced by grazing or by past cultivation. These plots were sprayed with various rates of low-volatile tetrahydrofurfuryl alcohol esters of 2, 4-D alone, 2, 4, 5-T alone, and equal mixtures of the two in an effort to determine the effect upon the native vegetation when sufficient quantities were applied to control the growth of halogeton intermixed with perennial forage plants. Rates of application varied from one-half pound to 14 pounds of the active ingredients per acre.

RESULTS AND DISCUSSION

FOR CONVENIENCE of discussion, the results have been divided into seven phases: (1) halogeton poisoning and symptoms, (2) grazing studies, (3) oxalate content of plants, (4) feeding trials, (5) effect upon animal production, (6) seed germination and dissemination, and (7) control measures.

Halogeton Poisoning and Symptoms

THAT IMPROPER metabolism of calcium causes an ailment called "tetany" has been known for a hundred years or more. This was first observed and identified with human infants and later was termed "infantile tetany". As early as 1901 it was discovered that certain salts such as sodium and potassium oxalate precipitated calcium out of the blood and caused increased irritability (Hess 1929). This has been explained by the theory that increased sodium and potassium ions in the blood tend to increase neuromuscular excitability, whereas, increased calcium and magnesium ions depress it. Lowering the ionic calcium of the blood produces an improper balance of minerals in the extracellular fluids and within the tissues of the cells. As a result, nerve stimuli are disturbed. If this drop in serum calcium is rapid, it is described as "acute hypocalcemia".

The first manifestations of acute hypocalcemia are loss of balance, incoordination, and muscular spasms. Death usually occurs from asphyxia, resulting from spasm of the laryngeal and thoracic muscles (Best & Taylor 1943). However, death may occur from heart failure caused by a sudden lowering of the blood calcium which interferes with the normal heart contraction and rhythmicity (Hess 1929, Cantarow 1933).

Occasionally death occurs when the total serum calcium has not dropped appreciably, whereas, in other cases, the serum calcium has dropped to less than half normal. Death without apparently severe serum calcium decrease is believed a result of lowering of ionic calcium without substantial decreases in total serum calcium. The sudden lowering of ionized calcium causes acute hypocalcemia and not necessarily a substantial lowering of total blood calcium (Shohl 1939). Ordinary blood calcium analyses are poor indexes to the true level causing disturbance, but accurate analysis for ionized blood calcium is extremely difficult to make.

Halogeton contains large amounts of soluble oxalates of sodium and potassium. When consumed in appreciable quantities, the oxalates unite with the calcium of the blood and produce acute hypocalcemia. Lowering of blood calcium and findings from post-mortem examinations in sheep which die from feeding on halogeton are identical to clinical symptoms of induced hypocalcemia in small animals as described by Hess (1929), Best & Taylor (1943), and Cantarow (1933).

The symptoms of halogeton poisoning, as determined from the present experiments were first noticed as dullness, lowering of the head, loss of appetite, and reluctance to follow when the rest of the band moves away. These generally occur about 4 hours after feeding. Next, there may be a slight drooling and a white froth on the mouth and lips. At about the same time the sheep may cough up halogeton or other ingested material. Then a noticeable lack of coordination develops, especially in the hind legs. Following this, the animal begins

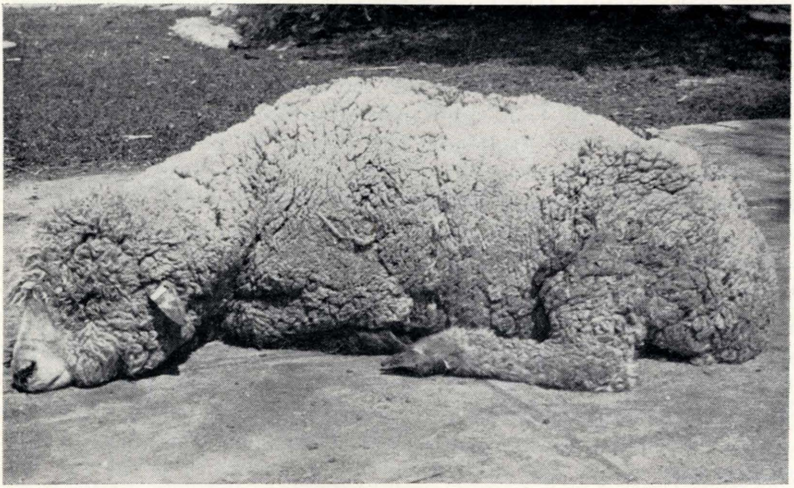

Fig. 5. A sheep displaying typical symptoms of halogeton poisoning, lying on the stomach with the head outstretched along the ground

to weaken and stiffen, and breathing becomes rapid and shallow. During this stage it will lie down, generally 5 to 6 hours after feeding. It may lie down and then stand up repeatedly in the next half hour or more. Each time, standing becomes increasingly more difficult. The animal lies on its stomach (fig. 5) and, as coordination becomes poorer, it may throw its head back and to one side in an effort to regain its feet. As coordination continues to deteriorate, repeated attempts to rise gradually move the animal over onto its side. Following this, it goes into a coma and breathing becomes hard, deep, and irregular. Legs are frequently stiff and project straight outward. The legs jerk and breathing becomes increasingly rasping and wheezy. The eyes may appear to be somewhat glazed, even before the animal dies.

The most important post-mortem findings visible to the unaided eye are lung hemorrhages. The lungs are filled with blood and are a dark red or purplish color, rather than the normal pink. This is characteristic of animals dying from asphyxia. Small blood vessels and capillary tubes are ruptured along the inside of the sternum next to the skin, and frequently in other places. The kidney tubules are filled with calcium oxalate crystals, with a concentration around the cortex. Slight bloat may be present and there generally is a strong characteristic odor. Mucous membranes around the eyes and mouth may be slightly cyanotic.

Histological examinations of the kidneys show that the uriniferous tubules are almost completely filled with calcium oxalate crystals, and many of the tubules are ruptured and the lining somewhat degenerated.

Preliminary data were collected from 4 animals fed in the laboratory. Three animals were fed halogeton and the other was fed sodium oxalate. The symptoms and post-mortem findings were almost identical in both cases. Data taken included: blood clotting time; hemoglobin level; specific gravity, nitrogen, and soluble oxalate content of the urine; blood urea nitrogen; soluble oxalate content of kidneys and liver; and percent soluble oxalate in the contents of the rumen.

The kidneys and livers had an average of 0.21 to 0.31 percent soluble oxalate, respectively, at the time of death. The liver contained slightly more in all cases. The rumen contents contained an average of 0.14 percent soluble oxalate 6 to 10 hours after feeding. Blood clotting time diminished from about 8 minutes at the time of feeding to about 4½ minutes at death.

There was no appreciable change in the specific gravity, nitrogen, or sugar content of the urine and the soluble oxalate content was within normal limits both before and after feeding. Blood urea nitrogen increased slightly from about 49 milligrams per 100 cubic centimeters before feeding to about 54 milligrams 5 hours after feeding. The results on hemoglobin were inconclusive, since in some cases, there was a slight drop and in others there was a rise.

Because of the identical behavior and symptoms of these animals it was concluded that soluble oxalate is the poisonous element in halogeton and that there is no reason to suspect presence of any other toxic material.

Grazing Studies

DURING THE WINTER grazing seasons of 1951-52 and 1952-53, flocks of 10 to 25 range-raised sheep were grazed in small enclosures 4 to 6 acres in area. These enclosures were moved about on the range to obtain various amounts of halogeton along with various plant combinations. Other plants grazed with halogeton were sagebrush *(Artemisia tridentata)*, squirreltail grass *(Sitanion hystrix)*, black sage, *(Artemisia nova)*, shadscale *(Atriplex confertifolia)*, greasewood *(Sarcobatus vermiculatus)*, molly *(Kochia vestita)*, winterfat *(Eurotia lanata)*, Russian-thistle *(Salsola kali)*, pepper grass

Table 1. *Composite averages of available forage, percent utilization, and composition of diet for sheep grazing halogeton-infested areas during winter grazing seasons,* 1951-53*

Species	1951-52									1952-53								
	Period 1 Sept. 12-Oct. 22			Period 2 Oct. 23-Dec. 19			Period 3 Dec. 20-Mar. 15			Period 1 Oct. 6-Dec. 24			Period 2 Dec. 25-Feb. 9			Period 3 Feb. 9-April 6		
	Percent available forage	Percent utilization	Percent of diet	Percent available forage	Percent utilization	Percent of diet	Percent available forage	Percent utilization	Percent of diet	Percent available forage	Percent utilization	Percent of diet	Percent available forage	Percent utilization	Percent of diet	Percent available forage	Percent utilization	Percent of diet
Halogeton	21	10	5	35	13	10	28	8	4	50	15	23	63	13	23	56	15	24
Big sagebrush	30	18	12	27	40	40	49	80	69	28	32	27	7	35	7	18	36	18
Shadscale	19	65	30	30	60	40	17	70	21	9	82	23	5	88	12	10	86	24
Squirreltail grass	1	85	2	1	80	2	3	70	4	4	85	10	4	95	11	6	94	16
Black sage	29	75	51	2	62	3	—	—	—	—	—	—	—	—	—	—	—	—
Russian-thistle	—	—	—	5	45	5	3	47	2	9	58	17	18	76	39	5	84	12
Kochia	—	—	—	—	—	—	—	—	—	—	—	—	3	95	8	2	90	5
Greasewood	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	5	1
Average density		23			15			11			26			18			15	
Animal days use per acre		88			102			129			115			155			82	

* Each figure represents an average of 3 to 5 areas grazed within the period.

(Lepidium perfoliatum), and downy brome *(Bromus tectorum).* In some cases, these plants occurred alone with halogeton whereas in others they composed complex mixtures along with halogeton.

During two grazing seasons, 20 different plant combinations were grazed and the quantity of halogeton varied from 10 to as much as 75 percent of the available herbage. The utilization varied from moderate to extremely heavy and was determined by estimates based upon removal of current year's growth. Preferred species frequently were utilized to the extent that only coarse woody stubs remained. In many cases, ranges were grazed two to three times heavier than ordinarily considered proper and sheep lost as much as 15 pounds per head in a three-week period because of lack of feed. Although halogeton made up as much as 75 percent of the range vegetation the amount in the daily diet was never greater than 29 percent even under heavy overgrazing. That weight loss was not a result of halogeton consumption is evidenced by instances in which animals consumed similar amounts of halogeton and made significant weight gains.

It was calculated that 1 ounce of soluble oxalate was required to kill a 110 pound sheep if all fed at one time to a fasted animal but 4.1 ounces were required when eaten a little at a time throughout the day along with native range forage. Therefore, when halogeton contains about 17 percent soluble oxalate a hungry sheep would require about 0.37 pound of dry halogeton eaten at one time to cause death or about 12 percent of his capacity. However, if eaten throughout the day along with other forage as much as 1.51 pounds or 47 percent of the diet would be required to cause death.

Composite averages of forage composition and percentage of each species in the diet are shown in table 1. Each period represents an average from 3 to 4 grazing areas. During the first period from September 12 until October 22, 1951, the halogeton plants were still green and had a high moisture content. During this time there was no precipitation and sheep avoided halogeton except small amounts of seed and small plants. The amount of halogeton in the diet varied from 2 to 9 percent with an average of 5 percent.

At the beginning of the second period, October 23, temperatures were slightly below freezing at night and halogeton plants became dry and straw-colored. During this time there were frequent rains and snows. Snow accumulated from 3 to 4 inches on five different occasions but soon melted. There was only slight evidence that softening of halogeton from rains or snows made it more palatable to the grazing animals. However, the sheep ate halogeton more readily after the plants were frozen than before. Halogeton made up from 6 to 15 percent of the diet and averaged 10 percent for this period (table 1).

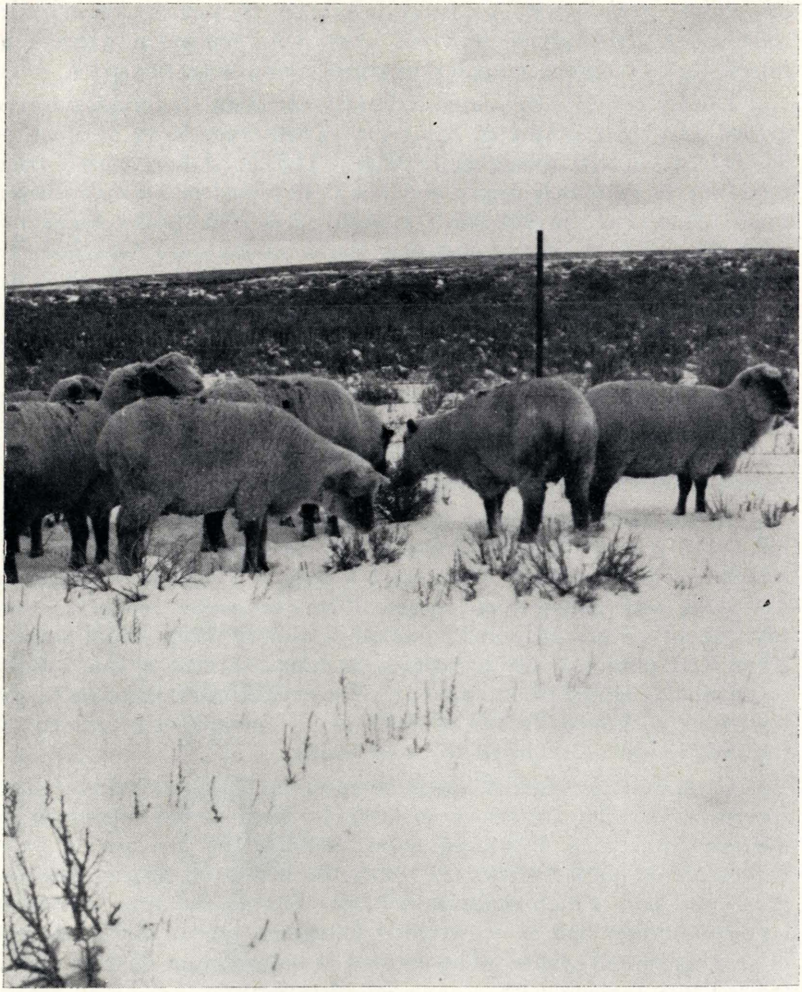

Fig. 6. Occasionally sheep were observed digging through the snow to graze halogeton stems late in the grazing season when other vegetation had been grazed closely. Plants above the snow in the foreground are halogeton

The sheep consumed the smaller plants ranging from 2 to 4 inches high and the tips of the stems of the larger plants producing an abundance of seed.

The third period during the winter grazing season of 1951-52 was started December 20 and terminated March 15. During this period there were frequent snows and snow accumulated until most areas were not grazable because of deep snow. Animals ate dry, coarse stems of the halogeton more readily as the period advanced and dug down through the snow to find them in many cases (fig. 6). This was especially true when animals were confined to big sagebrush as an alternate forage. The diet, however, never contained large amounts of halogeton because deep snow made it difficult to obtain.

Grazing the following winter was not started until after the first killing frost which was about October 4, 1952. The first period started October 6 and terminated December 24. During the latter part of this period there were frequent light showers with occasional snow. It was observed again this season that softening of halogeton by rain and snow only slightly increased the consumption of the plant. Animals consumed small halogeton plants 3 to 5 inches tall and seeds from the ground. Small stems heavily laden with seed on the more robust plants were readily eaten also. During this period, halogeton on the different areas varied from 15 to 26 percent of the diet and the average was 23 percent. All areas during this period were extremely heavily grazed in an effort to force sheep to consume lethal doses but consumption as great as 26 percent of the diet was insufficient even to cause toxic effects.

The second period started on December 25 and ended February 9. The halogeton plants had lost most of their seed and the large plants were stemmy with a scarcity of leaves. There were 6 light rains and 7 light snows during the period. Areas again were grazed heavily to force animals to consume a larger amount of halogeton. During this period, increased intensity of use resulted in increased consumption of halogeton. This was particularly true as the season advanced. Animals first consumed the smaller plants and with more intense grazing ate the larger and more stemmy plants. The amount of halogeton in the diet on the various areas ranged from 16 to as high as 28 percent but no deaths occurred. During this period, frequent rain and snow kept the Russian-thistle soft and sheep ate the plant readily throughout the period on all areas.

The third period began February 9 and ended on April 6. Most range sheep had been taken from the desert 2 to 3 weeks prior to this ending date but soluble oxalate content of the halogeton remained relatively high and it was believed desirable to study the effects of late spring grazing on sagebrush and shadscale ranges infested with halogeton. By this time, only occasional seeds were found on the plants and many leaves had fallen with only the coarser stemmy material remaining.

With extremely close grazing on some areas it was found that halogeton was eaten more readily. This was particularly true on areas where the forage consisted largely of big sagebrush. Diets were composed of as much as 29 percent halogeton on individual areas but there were no ill effects. Smaller plants were preferred but they were largely weathered away by this time. No losses were encountered from voluntary consumption of halogeton under any of the conditions of grazing even though forced utilization of halogeton was the objective.

During both grazing seasons the experimental animals were not allowed salt and some animals did not have salt for a period of 20 months. This lack of salt for extended periods did not cause them to develop depraved appetities and consume increased amounts of halogeton in an effort to satisfy the demand for salt.

During intervals when snow was not sufficient for the grazing animals to satisfy their thirst, water was hauled. During these periods the sheep occasionally were watered only once every 4 days to test the effect of lack of water upon halogeton consumption. Sheep did not consume green halogeton for its water content. However, it was observed that they ate more halogeton immediately after being watered than at any other time during the tests. This was more noticeable when sheep were watered infrequently.

Blood samples for serum calcium determinations were taken at the beginning of grazing, again in the middle of the grazing season, and at the end of the season. It was found that even though animals occasionally consumed as much as 29 percent of halogeton in their diet there was no appreciable change in the level of blood calcium.

An extensive area supporting a cover of vegetation consisting of 60 percent halogeton, 6 percent crested wheatgrass, 3 percent greasewood, 5 percent smother weed (*Bassia* spp.), and 26 percent Russian-thistle near Kelton, Utah, was grazed by cattle from November until March with little supplement other than barley straw during inclement weather (fig. 7). Cattle ate halogeton sparingly and only occasionally. Animals were observed for periods while grazing and according to total feeding minutes their diet was never composed of more than 20 percent halogeton during any feeding period. No losses of cattle occurred during the winter grazing period; therefore, it was assumed that cattle dislike halogeton and losses under moderate or even heavy infestations would be rare.

Oxalate Content of Plants

According to studies in Wyoming (Bahmont 1951) halogeton grows in soils high in saline salts and likewise in soils rela-

Fig. 7. Cattle grazing an area containing a rather dense stand of halogeton along with a sparce stand of other plants. These animals grazed this area throughout the winter grazing season without detrimental effects

tively free of salt. In both cases, however, the plants contain high percentages of oxalates.

During the winter grazing season of 1950-51, collections of halogeton were made periodically from two sites 14 miles apart in order to determine the effect of site and season upon the oxalate content of the plants. One of the sites was located in a sagebrush area on a high plateau where the soil was light in texture and free from excessive salts. The other was in a shadscale area in a broad valley where the soil was heavy clay and high in salts.

The soluble oxalate content decreased gradually on both areas, from well over 20 percent during October and November to 4 or 5 percent during March (table 2). There was rain or snow between

Table 2. *Oxalate content of halogeton in percent on a dry weight basis from two sites during the grazing season of* 1950-51

Date	Water soluble	Insoluble	Total
	percent	*percent*	*percent*
Shadscale area			
October 26	23.9	0.2	24.1
November 12	24.0	0.9	25.9
December 9	13.2	1.5	14.7
January 7	10.8	3.9	14.7
February 10	5.1	4.4	9.5
March 24	3.6	7.8	11.4
Average	13.5	3.1	16.6
Sagebrush area			
October 26	20.3	0.1	20.4
November 19	22.2	0.1	22.3
December 9	13.9	5.3	19.2
January 7	10.1	4.8	14.9
February 10	6.2	5.5	11.7
March 24	5.0	5.0	10.0
Average	13.0	3.5	16.5

every collection but there never was substantial accumulation of snow on either area. It was interesting to note that as the season advanced soluble oxalates decreased and insoluble oxalates increased. Since total oxalates decreased, some leaching losses are indicated and soluble oxalates do not merely change over to insoluble forms.

Both areas produced halogeton which contained about the same amount of the oxalates as shown in table 2. Plants from the sagebrush area contained an average of 13 percent soluble oxalates compared with 13.5 percent on the shadscale area.

During the grazing trials in the winter of 1951-52, collections of halogeton were made from each area grazed and these were analyzed for soluble oxalates. The average soluble oxalate content from September 12 to October 22 was 19.2 percent, ranging from 15.7 to 22.4 among the various areas. The halogeton collections from the areas grazed between October 23 and December 19 had an average soluble oxalate content of 22.4 percent ranging from 18 to 28 percent among the areas.

There was a rather gradual accumulation of snow after December 19 and some plants were covered completely until March 15. The average soluble oxalate content for this period was 8.6 percent, ranging from as low as 4.4 to as high as 24 percent among the various areas. The halogeton analyzing only 4.4 percent was collected at the end of the season on a south-facing sagebrush area where the snow melted gradually and bare ground was exposed intermittently between storms. The halogeton analyzing 24 percent was collected at approximately the same date on a north-facing slope where the plants had been covered with snow since December. A similar comparison on another area during this period showed a south-facing slope yielding halogeton containing only 4.6 percent whereas a north-facing slope with a protecting mantle of snow only a short distance away yielded halogton containing as much as 10.5 percent. A cover of snow apparently protects the halogeton plant from loss of soluble oxalates brought about by leaching and also prevents loss of leaves which contain the greatest quantity of oxalates.

The weather conditions during the 1952-53 grazing season were considerably different from the previous year. There was no accumulation of snow and total precipitation was light.

Soluble oxalate content of the halogeton material averaged 25.2 percent between October 6 and December 24, ranging from 19 to 29 percent among the various areas. This was considerably higher than during the previous year and might be explained by the almost total absence of rain or snow to leach the plant material.

There was a slight drop in soluble oxalate content during the remainder of the winter. The average content from December 25 to February 9 was 19.7 percent and it dropped to 15.9 percent between February 9 and April 6 with only a small variation among the grazing areas.

From November to April 1952-53 plants were collected from one location after each snow or rain and separated into seeds, leaves, and stems to be analyzed for soluble oxalates. From these analyses it was found that winged fruits contained an average of 8.1 percent, leaves 28.1 percent, and stems 3.6 percent soluble oxalates (table 3). There did not appear to be appreciable loss of the oxalates as a result of

Table 3. *Soluble oxalate content of various parts of halogeton from November* 1952 *to April* 1953 *in percent of dry weight**

	Seeds		Leaves		Stems	
Month	Soluble oxalate	Total oxalate	Soluble oxalate	Total oxalate	Soluble oxalate	Total oxalate
Nov.	10.7	12.6	30.0	31.2	2.7	4.7
Dec.	9.6	11.8	31.9	35.7	4.3	8.0
Jan.	3.9	10.7	30.0	36.6	4.4	9.0
Feb.	——	——	27.5	34.0	3.6	7.2
Mar.	——	——	23.6	25.8	3.3	6.7
April	——	——	25.7	31.0	3.3	6.6
Average	8.1	11.7	28.1	32.4	3.6	7.0

* All figures represent averages from 3 to 6 collections.

leaching but this might be expected since this was a mild winter with little moisture. However, the soluble oxalate content of the seeds did drop from 10.7 percent to 3.9 percent. These last collections were made on the ground under the plants and the material had been moistened a few times by light snows.

In another location, halogeton plants were collected during the grazing season and separated according to size. Plants ranging from 3 to 5 inches high were classified as small and plants ranging from 10 to 14 inches as large. These two classes of plants were found growing in association with one another and differed because of season of germination and growth rate. Sheep were found to prefer the smaller plants during all grazing periods except when the larger plants possessed an abundance of seed in early fall.

It was found that there was some decrease in the soluble oxalate content in both the small and large plants as the season progressed,

Table 4. *Percent oxalate content of large and small halogeton plants from November* 1952 *to April* 1953 *on a dry weight basis**

	Large plants		Small plants	
Date	Soluble oxalates	Total oxalates	Soluble oxalates	Total oxalates
November	25.2	28.1	24.2	27.8
December	20.2	25.7	24.4	28.3
January	18.5	24.9	18.7	23.7
February	20.4	27.2	19.6	24.4
March	13.9	17.7	18.4	22.0
April	12.8	15.8	15.7	18.8
Average	18.5	23.2	20.2	24.2

* All figures represent averages from 3 to 6 collections.

with small plants generally containing slightly larger amounts of the oxalates. This is perhaps caused by the higher percentage of leafy material in small plants compared to large plants (table 4).

Feed Trials to Determine Lethal Doses

THE FIRST FEEDING trials were concerned with determining the quantities of soluble oxalates that were lethal under various range conditions when consumed at one time. The halogeton used in these feeding trials was collected in the fall after a killing frost when the plants were beginning to lose their green color. Plants were dried, ground in a feed mill, sprayed with a small quantity of molasses, and pelleted so that the material could be fed with a balling gun. These pellets contained 8.7 percent soluble oxalates, calculated as oxalic acid.

During the course of the winter grazing seasons 1951-53 sheep weighing from 109 to 121 pounds were fed various amounts of halogeton with and without a 36-hour fasting period. This period without food was intended nearly to empty the stomach and to be representative of sheep conditions after shipping or trailing.

1951-1952 trials

For the first trial 2 sheep were taken from the range herd and confined for 36 hours without food. At the termination of this fasting period 2 more sheep not having a fasting period were taken from the herd. These 4 sheep were all fed 8 ounces of the halogeton pellets and turned out to graze on native, desert range in small enclosures. None of these sheep showed symptoms of poisoning and no significant change occurred in blood calcium (table 5).

During a second trial 4 more sheep were treated as in trial one with the exception that 10 ounces of halogeton were fed instead of 8 ounces. Again there were no symptoms of poisoning and the blood calcium was essentially unaltered.

In the third trial an additional 4 sheep were treated as before except the amount of halogeton fed was raised to 12 ounces.

The sheep that had not fasted showed no symptoms and their blood calcium remained normal. The two sheep that had received no food for 36 hours prior to the ingestion of halogeton died 9 and 20 hours after feeding with characteristic oxalate poisoning symptoms. The blood serum calcium had dropped from 12.6 and 13.8 milligrams per 100 cubic centimeters to 5.4 and 5.6, respectively, 6 hours after feeding.

Table 5. *Results of 1951-52 halogeton feeding trials showing blood calcium levels**

Trial	Condition of trial	Halogeton fed†	Blood calcium: Before feeding	Blood calcium: 6 hrs. after feeding	Remarks
		oz.	*mg./100 ml.*		
1	36-hr. fast	8	11.5	13.6	Normal
	36-hr. fast	8	9.4	9.2	Normal
	No fast	8	9.9	11.4	Normal
	No fast	8	10.1	10.4	Normal
2	36-hr. fast	10	11.4	11.2	Normal
	36-hr. fast	10	10.5	10.8	Normal
	No fast	10	9.7	10.3	Normal
	No fast	10	10.4	10.0	Normal
3	36-hr. fast	12	12.6	5.4	Died in 9 hrs.
	36-hr. fast	12	13.8	5.6	Died in 20 hrs.
	No fast	12	8.7	7.2	Normal
	No fast	12	9.9	7.8	Normal
4	36-hr. fast	16	11.1	4.4	Died in 9 hrs.
	36-hr. fast	16	10.8	4.8	Died in 10 hrs.
	No fast	16	8.9	8.9	Normal
	No fast	16	11.4	10.4	Normal
5	No fast	18	12.3	7.2	Died in 7 hrs.
	No fast	18	9.9	5.3	Died in 7½ hrs.
	No fast	18	10.7	13.6	Normal
	No fast	18	8.9	7.2	Normal
6	36-hr. fast	10	9.3	9.9	Normal
	36-hr. fast	10	10.5	9.5	Normal
	36-hr. fast and 16 grms. CaO	10	8.8	9.9	Normal
	36-hr. fast and 16 grms. CaO	10	9.1	9.0	Normal
7	36-hr. fast	12	8.7	6.0	Died in 10 hrs.
	36-hr. fast	12	9.9	6.1	Died in 10 hrs.
	36-hr. fast and 20 grms. CaO	12	9.2	7.5	Normal
	36-hr. fast and 20 grms. CaO	12	7.9	7.2	Normal
8	36-hr. fast and 24 grms. CaO	14	8.3	9.6	Normal
	36-hr. fast and 24 grms. CaO	14	9.5	9.7	Normal
	36-hr. fast and 26 grms. CaO	16	10.5	4.6	Died in 19 hrs.
	36-hr. fast and 26 grms. CaO	16	8.5	6.0	Died in 42 hrs.
	36-hr. fast and 30 grms. CaO	18	9.6	4.7	Died in 20 hrs.
	36-hr. fast and 30 grms. CaO	18	10.7	5.4	Died in 18 hrs.
	No fast and 30 grms. CaO	20	9.5	4.2	Died in 20 hrs.
	No fast and 30 grms. CaO	20	9.6	9.7	Normal

* Animals ranged in weight from 109 to 121 pounds.

† Contained 8.7 percent soluble oxalate.

The fourth feeding trial was similar to the third except that the quantity of halogeton fed was raised to 16 ounces. As would be expected from the results of the previous feeding trial, the two sheep fed after the fasting period died. Symptoms were observed about 5 hours after feeding and both were dead 10 hours after feeding. Blood samples taken 6 hours after feeding showed that the blood calcium had dropped from 11.1 and 10.8 milligrams per 100 cubic centimeters to 4.4 and 4.8, respectively. Animals that were taken directly from the herd without a fasting period showed no symptoms and the blood calcium remained normal (table 5).

Having established that 12 ounces or more of halogeton containing 8.7 percent soluble oxalates was lethal when the stomach was empty, it was no longer necessary to continue raising the quantity of halogeton fed under fasting conditions. Therefore, the fifth trial dealt with increased quantity of halogeton fed without fasting. Four sheep were taken directly from the herd in the morning before they left the bed grounds and fed 18 ounces each. Two sheep showed signs of halogeton poisoning 5 hours after feeding. Their blood calcium had dropped from 12.3 and 9.9 to 7.2 and 5.3 milligrams per 100 cubic centimeters, respectively. These two animals died about 7 hours after feeding. In the case of the other 2 sheep, blood calcium was only slightly altered and both lived after showing slight symptoms of poisoning.

It was theorized that if there is sufficient calcium in the paunch or digestive tract when halogeton is consumed, this calcium will unite with the soluble oxalates before they are absorbed into the blood stream. Consequently, the oxalates could be carried through the digestive tract in the insoluble form and eliminated, thereby causing no harmful effects to the animal.

There are two probable reasons why an animal after a full feed can consume more halogeton without harmful results than one that has been fasted. First, the forage provides a supply of calcium that transforms a portion of the harmful soluble oxalates into unharmful insoluble oxalates. Second, the forage in the paunch causes the oxalates to be absorbed at a slower rate and the animal has an opportunity to draw upon calcium reserves to maintain the blood calcium level. Under natural conditions, of course, a well-fed animal will not consume large quantities of halogeton.

Calcium supplements as counteracting agents

In order to test the effectiveness of calcium in counteracting the poisonous oxalates in halogeton, feeding trials were carried on using various forms of calcium, fed in various amounts. Calcium oxide (lime), calcium carbonate, and dicalcium phosphate were tested. Calcium carbonate was found most suitable as a counteracting agent, since it was cheap, easy to pellet along with the alfalfa, harmless to the animal, and effective. Lime was found somewhat toxic and caused physiological discomfort even in small doses. Dicalcium phosphate was difficult to pellet and was more expensive than calcium carbonate. During the first winter grazing season, feeding trials using calcium oxide as a counteracting agent were conducted. All sheep were fasted for 36 hours previous to being fed halogeton and calcium oxide. The calcium was fed either with the halogeton or a few minutes previous.

Two hungry sheep were fed 10 ounces of halogeton and 16 grams of calcium oxide each, whereas, two more were fed only 10 ounces of halogeton without any calcium oxide. None of these sheep died or suffered serious drop in blood calcium (table 5, trial 6). Two additional sheep were fed 12 ounces of halogeton and 20 grams of calcium oxide and two more were fed 12 ounces of halogeton, only. In this case, the sheep receiving no calcium died in about 10 hours and showed drops in blood calcium from 8.7 and 9.9 milligrams per cubic centimeters to 6.0 and 6.1 milligrams 4 hours before death (table 5, trial 7). The two sheep receiving calcium oxide showed no apparent symptoms of poisoning and there was only a slight drop in the level of blood calcium.

In subsequent trials two sheep were each fed 14 ounces of halogeton and 24 grams of calcium oxide, two were fed 16 ounces of halogeton and 26 grams of calcium oxide, two were fed 18 ounces of halogeton and 30 grams of calcium oxide, and two others were fed 20 ounces of halogeton and 30 grams of calcium oxide. The sheep receiving the 14 ounces of halogeton and the 24 grams of calcium showed no symptoms of poisoning. All but one of the remaining sheep died but did not display all the symptoms characteristic of halogeton poisoning. It was believed the large amounts of calcium oxide were as much responsible for death as the halogeton. Blood calcium, however, in these cases showed marked decreases 6 hours after feeding (table 5, trial 8).

Thus, there was evidence that calcium supplements did increase the tolerance for halogeton consumption. Without calcium, 12 ounces were lethal whereas with added calcium oxide it required about 16 ounces to kill an animal.

1952-1953 trials

During the winter grazing season of 1952-53, feeding calcium as a counteracting agent along with halogeton was continued. All ani-

Table 6. *Results of 1952-53 halogeton feeding trials showing effect of calcium supplements and also blood calcium levels**

Trial	Condition of trial	Halogeton fed†	Blood calcium: Before feeding	Blood calcium: 6 hrs. after feeding	Remarks
		oz.	*mg./100 ml.*		
1	36-hr. fast and 8 oz. $CaCO_3$ pellet	8	10.3	10.9	Normal
	36-hr. fast	8	10.4	11.0	Normal
	36-hr. fast	12	9.5	6.3	Died in 14 hrs.
	36-hr. fast	12	9.1	6.0	Died in 16 hrs.
2	36-hr. fast and 12 oz. $CaCO_3$ pellet	12	10.9	8.7	Normal
	36-hr. fast and 12 oz. $CaCO_3$ pellet	12	10.0	10.4	Normal
	36-hr. fast and 25 grms. CaO	12	9.1	9.0	Normal
	36-hr. fast and 12 oz. of $CaHPO_4$ pellet	12	10.8	8.8	Normal
	36-hr. fast and 46 grms. CaO	16	14.6	5.2	Died in 18 hrs.
3	36-hr. fast and 16 oz. $CaCO_3$ Pellet	16	10.4	11.4	Normal
	36-hr. fast and 16 oz $CaHPO_4$ pellet	16	9.3	8.3	Normal
4	36-hr. fast and 24 oz. $CaCO_3$ pellet	24	11.9	10.0	Normal
	36-hr. fast and 24 oz. of alfalfa	24	10.0	5.5	Died in 6 hrs.
	36-hr. fast and 32 oz. of $CaCO_3$ pellet	32	10.9	11.6	Normal
5	36-hr. fast and 32 oz. $CaCO_3$ pellet	32	10.7	8.8	Normal
	36-hr. fast and 32 oz. alfalfa	32	10.2	5.3	Died in 6 hrs.
	36-hr. fast and 32 oz. alfalfa	32	9.7	4.6	Died in 6 hrs.

* Animals ranged in weight from 97 to 115 pounds.

† Contained 10.3 percent soluble oxalates.

mals were fasted 36 hours previous to feeding halogeton. However, in most cases the calcium-fortified pellet was fed 24 hours after fasting started and 12 hours before feeding the halogeton. The first of the trials was begun by feeding two sheep 8 ounces of halogeton containing 10.3 percent soluble oxalate. In addition, one was fed 8 ounces of a calcium-alfalfa pellet (table 6). This calcium alfalfa pellet was composed of about 83 percent alfalfa, 15 percent calcium carbonate, and 2 percent molasses. Chemical analysis showed that the pellet contained 6.5 percent calcium. Neither of these animals showed any symptoms of poisoning or showed significant drop in blood calcium.

In trial 2, two sheep were each fed 12 ounces of halogeton and 12 ounces of the calcium carbonate pellet. Two animals were each fed 12 ounces of halogeton with one receiving 25 grams of calcium oxide and the other receiving 12 ounces of dicalcium phosphate pellet containing 80 percent alfalfa, 2 percent molasses, and 18 percent dicalcium phosphate. Two others were each fed 12 ounces of halogeton only. The latter two died and blood calcium dropped from 9.5, and 9.1 milligrams per 100 cubic centimeters to 6.3 and 6.0, respectively. The other 4 showed no symptoms of poisoning and their blood calcium remained normal.

In a third feeding trial dealing with calcium as a counteracting agent three sheep were each fed 16 ounces of halogeton. One of these was previously fed 46 grams of calcium oxide, another 16 ounces of calcium carbonate-alfalfa pellet, and the third 16 ounces of dicalcium phosphate-alfalfa pellet. The sheep receiving the calcium oxide died 18 hours after feeding and the blood calcium level dropped from 14.6 milligrams to 5.2 in six hours. The other two sheep showed no apparent symptoms of poisoning and the level of blood calcium remained normal.

In order to determine whether alfalfa alone was as effective as the calcium-carbonate pellets in counteracting oxalate poisoning, one sheep was fed 24 ounces of calcium-carbonate pellet 12 hours previous to feeding 24 ounces of halogeton. Another sheep received 24 ounces of pure alfalfa pellet 12 hours previous to receiving 24 ounces of halogeton. The halogeton in both cases was fed at the end of a 36-hour fasting period. The sheep receiving the alfalfa pellet died 6 hours after feeding and the blood calcium level dropped from 10.0 milligrams per 100 cubic centimeters at the time of feeding to 5.5 milligrams at death. The second animal showed no symptoms, (table 6, trial 4).

In a similar trial, 4 sheep were each fed two pounds of alfalfa alone and the other two were each fed two pounds of calcium carbonate alfalfa pellet 12 hours previous to receiving halogeton. All four of these animals were fed two pounds of halogeton each. The animals receiving the alfalfa alone died 6 hours after feeding. Blood calcium dropped from 10.2 and 9.7 milligrams to 5.3 and 4.6, respectively, just before death. The animals receiving the calcium carbonate alfalfa pellet showed no symptoms of halogeton poisoning and the blood calcium remained normal (table 6, trial 5).

During the fall of 1952, 60 head of sheep were fasted for 36 hours, after which half of them were fed one pound of the calcium carbonate-alfalfa pellets per head. All sheep were then trailed over a regular sheep driveway which contained 60 to 80 percent halogeton as a vegetation cover. These animals were trailed over this driveway for 12 hours starting early morning and terminating at dark in the evening. The animals were constantly urged forward and were never allowed to stop and graze freely.

The sheep were observed to eat rather large quantities of halogeton stem tips possessing an abundance of seed and also seed that had fallen to the ground under the plants. They were also observed to eat sparingly of the smaller halogeton plants, they nibbled at the big sagebrush plants as they walked along, and ate greedily of the shadscale and winterfat plants when they happened upon them.

In spite of the large consumption of seed, which at this time contained 10.7 percent soluble oxalate, there were no losses or apparent ill effects on either group of sheep.

Effect of halogeton consumed over a 12-hour period

It was believed that animals might be able to consume large quantities of halogeton if the consumption were distributed throughout the day as compared to large doses at one feeding.

Such trials were started by fasting two sheep for 36 hours followed by feeding one sheep one fourth pound of halogeton every 3 hours until 1 pound had been consumed. The other sheep consumed one-third pound every three hours until 1⅓ pounds had been consumed. Blood samples were taken shortly after each feeding. These animals showed no symptoms of halogeton poisoning and the blood calcium remained normal (table 7).

A similar trial was conducted later except that the quantity of halogeton was raised to 6 ounces at each feeding making a total of 24 ounces fed. This animal likewise showed no symptoms of halogeton poisoning and the blood level appeared little affected.

In a third trial three sheep were used. One was fasted for 36 hours, and another was fasted for 24 hours and fed one pound of calcium carbonate pellet and again fasted 12 hours before being fed halogeton. A third sheep was taken directly from the range without any previous fasting period. Each of these three animals received 8 ounces of halogeton at 3-hour intervals until a total of 32 ounces had been consumed. The animal that was fasted for 36 hours and received no calcium died 2 hours after the final feeding. The level of blood calcium became very low as the feeding continued. The

Table 7. *The effect of halogeton consumption upon serum calcium when fed intermittently over a period of 12 hours with and without a fasting period and with and without calcium supplements**

Condition of trial	Total halogeton fed†	Blood calcium				Remarks
		First feeding	Second feeding	Third feeding	Fourth feeding	
	oz.	*mg./100 ml.*				
36-hr. fast						
Fed 4 oz. every 3 hrs.	16	9.8	10.2	9.9	8.7	Normal
Fed 5⅓ oz. every 3 hrs.	22	12.6	10.9	13.1	12.6	Normal
Fed 6 oz. every 3 hrs.	24	12.6	13.1	12.5	10.7	Normal
Fed 8 oz. every 3 hrs.	32	10.8	11.2	8.7	6.3	Died 2 hrs. after last feeding
36-hr. fast and fed 1 lb. $CaCO_3$ pellet 12 hrs. before feeding halogeton						
Fed 8 oz. every 3 hrs.	32	10.8	10.6	11.1	10.2	Normal
Fed 8 oz. every 3 hrs.	32	9.7	10.3	13.4	9.4	Normal
Fed 10 oz. every 3 hrs.	40	13.2	12.8	11.2	6.4	Died during last feeding
No fast period						
Fed 8 oz. every 3 hrs.	32	9.3	9.6	9.5	9.0	Normal
Fed 10 oz. every 3 hrs.	40	9.7	10.0	13.4	9.4	Normal

* Animals ranged in weight from 94 to 105 pounds.

† Contained 10.3 percent soluble oxalates.

remaining two sheep did not display symptoms typical of halogeton poisoning and the blood calcium remained within normal limits.

Two other sheep were fed halogeton at the rate of 10 ounces every 3 hours over a 12 hours period until each had consumed 40 ounces. One of these was taken directly from the range whereas the other was fasted 24 hours and fed one pound of a calcium-fortified pellet and again fasted 12 hours before receiving the first halogeton. The latter sheep died at the completion of the last feeding, but the sheep taken directly from the range showed no signs of poisoning and the blood level remained normal (table 7).

This represents a total consumption of 2½ pounds of halogeton over a 12-hour period. Therefore, it appears an animal can tolerate as much as two thirds to three fourths of a full feed of halogeton containing 10.3 percent soluble oxalates as long as it is consumed over a period of 12 hours and along with range feed or a calcium-alfalfa supplement but only 1½ pounds when eaten over the same period of time on an empty stomach.

Treatment of poisoned animals with calcium

Research in Nevada (Fleming *et al.* 1950) showed that attempts to replace the sudden loss of serum calcium with intravenous administration of calcium chloride or calcium gluconate, or oral dosing with a watery suspension of calcium sulfate, were not successful. The treatments were not started until the animals showed definite signs of halogeton poisoning, generally 5 or 6 hours after feeding.

In the present study, 13 sheep were treated with solutions containing 15 and 25 percent calcium gluconate. These solutions were administered intravenously at various stages of sickness and in various quantities. First, five sheep were treated with 50 cc of 25 percent solution of calcium gluconate after they had lain down and were unable to get on their feet. Two of these animals regained their feet in 20 to 30 minutes after receiving the treatment but were down again in about 2 hours. At this time the treatment was repeated without any apparent responses and death followed soon after. The other three sheep receiving the treatment did not regain their feet after the injection and died in a few minutes to 3 hours after treatment.

Later, three more sheep that were in the advanced stages of poisoning were treated with 50 cc of a 15 percent calcium gluconate solution. All three sheep regained their feet and acted normally for several hours but finally became dull, lost coordination of the hind quarters, and became prostrate. The treatment was repeated but only one of the three regained a standing position for any period of time. All three animals died and showed typical post mortem characteristics of halogeton poisoning.

In subsequent feeding trials five more sheep were treated in various stages of sickness. Two were treated with 50 cc of 15 percent solution while still in the stages of dullness before becoming prostrate and the remaining three were treated when lack of muscular coordination was first observed. This treatment prolonged the period the animals remained on their feet. However, all five eventually lost their balance and fell to the ground. All five received a second treatment but only two regained their feet a second time and only one regained its feet after a third injection. All finally died after a prolonged illness of several days.

In spite of the repeated injections, the blood calcium in no case regained normal level after lethal doses of halogeton had been eaten. The serum calcium level at the time of feeding averaged about 10.5 milligrams per hundred cubic centimeters and dropped to an average of 5.2 milligrams before administration of the gluconate. However, the highest level reached after treatment in any case was 7.2 milligrams.

There are perhaps two explanations why intravenous injections of calcium gluconate were not successful in the treatment of halogeton poisoning. First, continued absorption of residual oxalate from the alimentary tract results in relapse. Second, there is the possibility of permanent injury to the heart, lungs, and kidneys once lethal doses have been consumed.

Effect of Halogeton Consumption on Reproduction

THERE ARE SOME reports that halogeton may interfere with normal reproduction if consumed in sublethal quantities over an extended period of time.

Fleming *et al.* (1951), in Nevada, ran feeding trials with halogeton to determine the effects of daily intake of sublethal quantities on pregnant ewes receiving an adequate basal diet. Animals received daily feedings of concentrates and hay mixtures with from one to four ounces of halogeton containing 18.3 percent soluble oxalates measured as oxalic acid. All ewes dropped vigorous lambs at term without difficulty and levels of blood calcium remained normal at all times. It was concluded that continuous intake of as high as 40 percent lethal dose, as long as ewes had a good basal diet relatively high in calcium, was not detrimental to the welfare of the animal.

Burge and O'harra (1952) reported that the only ill effect from feeding sublethal quantities of halogeton over an extended period of time was the interference with reproduction. Their results showed that 50 percent of a lethal dose fed over an extended period of time caused abortion in 4 ewes out of 8 before normal gestation had been completed.

In the present study 5 ewes were fed daily doses of one-half pound of halogeton-and-molasses pellets containing 8.3 percent soluble oxalates from October 1, 1951, until March 15, 1952, to determine the effects upon reproduction and general health. Feeding was carried on early each morning before the animals left the bed grounds to graze. This daily amount of halogeton was about 67 percent of a lethal dose for a fasted sheep and about 42 percent for a full-fed animal. Animals received in addition to the pellets a basic diet composed of native vegetation representive of desert ranges of the Intermountain Area.

Blood samples were taken intermittently to determine the level of calcium. The 5 ewes were bred in December and lambed in May. All but one conceived and produced normal lambs. The sheep not lambing was bred four times but did not conceive. An examination of this animal after slaughter showed a normal reproductive tract and there was no apparent explanation for the lack of conception.

During the winter of 1952-53, 12 more ewes were fed from one-half to three-fourths of a pound of halogeton daily from October 26 until April 3. This halogeton was collected in the fall after a killing frost when the halogeton was rather dry and light in color. This material was mixed with a small amount of alfalfa and molasses and contained 5 percent soluble oxalates in pelleted form. Most of these animals were fed three-fourths of a pound daily during this period; however, one or two ate only one-half pound for short periods during the trial. Three-fourths of a pound was 60 percent of a lethal dose for a fasted sheep and 38 percent of a lethal dose for a full-fed sheep.

These ewes were bred in November and December and lambed in April and May. All 12 ewes produced normal lambs and remained in apparently good health other than being thin at the time of lambing. From this study it was concluded that consumption of sublethal quantities of halogeton over extended periods of time did not affect reproduction.

Blood analyses from intermittent sampling likewise showed that the calcium content of the blood was not changed by prolonged consumption of halogeton during the two years of study.

From February 15 until March 15, 22 pregnant ewes were fed large quantities of halogeton at three separate feedings to see whether they would abort their lambs. Some were fed as much as one pound of pellets containing 10.3 percent soluble oxalates which approached a lethal quantity for full-fed sheep. These animals were grazed on ordinary winter ranges and were fed halogeton in the morning before leaving the bed ground without any previous fasting period. From 5 to 6 animals were fed each morning until the entire group had received at least two heavy doses, one consisting of one-half pound and the other three-fourths pound. A third group of these ewes, totaling 10 head, was fed one pound, but 4 of this group died. Therefore, the dose was lethal in some cases and sublethal in others. The 6 sheep that lived showed early symptoms of halogeton poisoning and were off feed for a day but on the second day were normal again. In spite of the relatively heavy doses of halogeton consumed 3 to 4 weeks prior to lambing none of the animals aborted and all that lived produced normal lambs.

Fifty percent of these ewes were slaughtered 4 months after lambing and thoroughly examined. In no case was there any evidence that injury to the kidneys or blockage of the tubules was caused by calcium oxalate crystals. Organs such as heart, lungs, liver, kidneys, and reproductive tract appeared normal.

Seed Germination and Dissemination

IT HAS BEEN theorized that the seed of halogeton do not remain viable over an extended period of time since they germinate so readily when conditions are favorable. In the present study, some winged seed germinated within a few hours after being moistened and placed in a germinator. The majority of viable seeds germinated within 12 to 48 hours at high temperatures.

Germination tests on seed collected in 1947 have been run from time to time since. The germination of winged seed the year following collection was 90.8 percent and, five years after collection, was 60.1 percent. This seed has been kept in a pasteboard box at room temperatures since its collection without special treatment. Therefore it is concluded that halogeton seed will retain its viability over a long period of time under dry storage.

Since it was noticed that both sheep and rabbits ate considerable quantities of the halogeton seed it was of interest to determine whether the seed retained its viability after passing through the animals' digestive tract.

The first study on this phase was made by collecting feces of sheep and jackrabbits from the ground where the animals had been grazing areas heavily infested with halogeton. The droppings were brought to the laboratory and placed in germination dishes. For every 500 grams of dry sheep feces, 14 halogeton seedlings were produced. For every 500 grams of dry rabbit feces, 18 seedlings were produced. These seedlings were grown out in soil to insure proper identification.

A second observation was made by equipping 2 wether sheep with specially designed fecal bags in order to collect all of the material passing through the digestive tract for a period of 6 days. The fecal bags were emptied and the material weighed each 24-hour period. A composite sample of the 6-day collection was taken to the laboratory for testing. Each wether was allowed to consume two quarts of halogeton seed per day from individual feed buckets. It was calculated that each sheep ate an average of 42,690 winged seed per day and voided them in 2.54 pounds of dry fecal material. Therefore for every 10 grams of fecal material, 371 viable seeds were consumed. The average germination obtained in controlled tests was 3.78 seedlings for every 10 grams of fecal material. This represents a germination of only 1.02 percent of the viable seed entering the animal but it means a total of 435 potential seedlings passing through each sheep daily. These could be transported considerable distances from the point of production. It would require approximately 3 days for the seeds to be completely eliminated from the digestive tract. Therefore, the place of excretion may be many miles away from the place of consumption. A band of 1,000 sheep might feasibly introduce 435,000 seedlings daily from an infested range to a halogeton-free range 25 to 50 miles distant.

Halogeton Control Measures

ATTEMPTED CONTROL OF halogeton by mechanical means or by chemical sprays is expensive and may actually increase the stand rather than decrease it since native vegetation may be destroyed, thereby making more space available for halogeton invasion. Control by chemical sprays or by tillage may be desirable on local areas where dense halogeton stands are a source of seed or around strategic water holes where hungry animals are apt to concentrate. However, such areas must be revegetated, otherwise, halogeton will reinvade and control measures must be repeated again and again.

Checking the spread of halogeton or reducing the abundance of the plant through seeding adapted species is highly desirable but such practices must be confined to sites where successful stands of grass are reasonably certain. The site should possess productive soil and receive 11 inches or more of precipitation annually. Otherwise, native shrubs and grasses may be destroyed by tilling, and pure stands of halogeton may prevail. In all areas receiving less than 11 inches of precipitation, all highly saline areas, and indeed, on many good sites as well, effective control should be directed to better management so that native species already present may gain in vigor and abundance and thus crowd out halogeton.

2, 4-D will kill halogeton but it also kills many desirable range forage species. Two pounds of active ingredient per acre of the heavy ester of 2, 4-D applied in June and a second application later in the summer after late germination effectively controlled halogeton in Idaho (Zappetteni 1953).

In the present study less than 1½ pounds of 2, 4-D low volatile esters killed winter fat, kochia, and shadscale but only killed the tops of halogeton associated with them.

A series of plots covered almost completely with halogeton was sprayed on June 18 and another series on July 1, 1952. Both applications were made with various quantities of low volatile esters of 2, 4-D; 2, 4, 5-T; and 50 percent mixtures of these. These materials were mixed at the rate of two pounds of the ester for every 5 gallons of water plus 1 gallon of diesel oil. The sprays were applied at a rate of one-half pound of the ester per acre up to and including a rate of 14 pounds per acre. At the time, halogeton was actively growing and was approximately 10 to 12 inches high.

It required as much as 6 pounds per acre of the low volatile esters of either the 2, 4-D or 2, 4, 5-T to kill all halogeton. Intensities less than 6 pounds per acre did not produce complete kills because of incomplete coverage of individual plants. In many cases, all the upper stems were curled and dead; whereas, the lower ones were alive and produced seed. This suggests that the spray material is not readily translocated to the lower branches of the halogeton plant and, in order to obtain an effective kill, complete coverage is necessary.

The 2, 4-D spray and the mixture of 2, 4-D and 2, 4, 5-T produced about the same results and were better than 2, 4, 5-T in all cases for controlling halogeton.

In the present study, spraying intensities from 2 to 5.5 pounds per acre effectively killed from 70 to 95 percent of the plants but the remaining plants used the relinquished space and moisture to produce larger and more prolific growth. In some cases more seed actually was produced by the remaining plants after spraying than by the total population on unsprayed areas. Therefore it appears that spraying to control seed production is not satisfactory unless done several times a year with heavy applications each time. Following this, the area must be revegetated for permanent control.

Variations in the results obtained by various experiment stations suggest need for continued research regarding spraying halogeton. Such research will permit a more decisive evaluation of the chemical spray methods.

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