UNIVERSITY OF IDAHO

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Halogeton and Its Control

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Bulletin No. 307

November, 1959

THE growth habits, the soil and climatic requirements of this annual poisonous weed are such that several million acres in Idaho lie open to its invasion. Any plant having such characteristics can seriously interfere with normal ranch operations and the continuity of a sustained livestock industry. A discussion of the problem and the results of 7 years of research studies on this plant and its control are given in this publication.

COVER PHOTO — Halogeton plant in full seed. Russian thistle plant in right background.

Halogeton and Its Control[1]

HOWARD L. MORTON, ROBERT H. HAAS, and LAMBERT C. ERICKSON[2]

HALOGETON (*Halogeton glomeratus*) was recognized as a serious problem in Idaho in the fall of 1945, when about 1620 sheep were poisoned in a single day near Bridge, Idaho. Following the initial large losses, poisoning from this source was drastically reduced. The reduction in losses due to halogeton poisoning has been accomplished largely by the educational efforts of livestock growers' organizations, extension meetings, and other forms of publicity including several extension and research bulletins (1, 2, 3, 6, 7, 8, 9, 17, 18). But, as in practically all instances of plant poisoning, all of the contributing factors involved in widespread livestock losses are rarely recognized or understood. Therefore, the efforts of the foregoing agencies are only partially responsible for the reduction in losses.

It is estimated that halogeton now infests about 10.5 million acres in the western states and about 605,000 acres in Idaho (4). The primary infestations are found on saline, depleted desert shrub type land, but the weed is also found competing in crested wheatgrass (*Agropyron desertorum*) seedings and in alternate wheat-fallow fields. Infestations have been found in 15 counties ranging from Owyhee to Custer. In addition to being poisonous, halogeton is aggressive and invades small open spaces and large areas of depleted rangeland. Here it competes for space, nutrients and moisture, and creates a serious problem in range maintenance and livestock production.

The botanical characteristics of halogeton have been discussed by several investigators (3, 7, 8, 18). From the standpoint of controlling this weed, it is essential to be aware of its profilic seed production which evidently contributes to its rapid spread. Halogeton produces two types of seed: a brown type whch is largely dormant, and a black type which will germinate soon after the plant matures. Single plants produce up to 50,000 seeds, and dense stands yield up to 500 pounds of seed per acre. Seed dormacy, high seed yields, and wind and other means of distribution are important when control measures for halogeton are considered.

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[1] Cooperative investigations of the Idaho Agricultural Experiment Station and the Crops Research Division, ARS, USDA. A part of the funds for this research was supplied by the Bureau of Land Management, USDI.

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Results of studies (10, 13, 18) relating to seed germination and seedling and plant development are diagrammatically presented in Figure 1. In southern Idaho, germination frequently begins in January and vegetative development commonly continues to early July. The black, non-dormant seeds have a tremendous affinity for water. Conseqeuntly, germination may follow summer showers

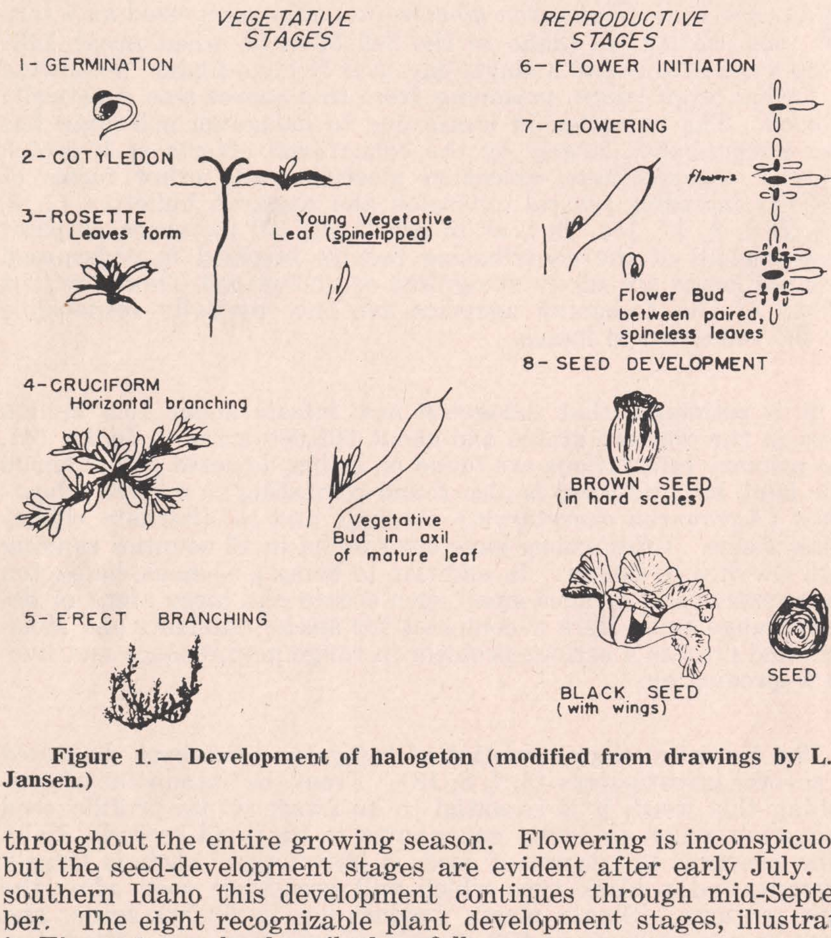

Figure 1. — Development of halogeton (modified from drawings by L. L. Jansen.)

throughout the entire growing season. Flowering is inconspicuous, but the seed-development stages are evident after early July. In southern Idaho this development continues through mid-September. The eight recognizable plant development stages, illustrated in Figure 1, can be described as follows:

1. **Germination — The absorption of water, rupture of the seed coat and the uncoiling of the embryo.**
2. **Cotyledon — The seedling root is developing and elongating and the cotyledons are fully expanded, but no true leaves are formed.**
3. **Rosette — The first spine-tipped leaves are formed in a cluster while there is little stem elongation.**
4. **Cruciform — The first horizontal branching takes place and the first four branches form a cross-shaped horizontal plant.**

5. **Erect branching — The horizontal branches tend to grow rapidly upward, and the vegetative buds are present in the axis of mature leaves. The central axis also grows rapidly giving a five-stemmed plant.**

6. **Flower initiation — The first non-spine tipped leaves are formed. This initiation of spineless leaves forewarns the development of flowers.**

7. **Flowering — The flower buds are formed between paired, spineless leaves.**

8. **Seed development — The brown seed, enclosed in hard (calyx) scales is formed first, and black seed, enclosed in large, showy, parchment-like sepals, is formed later. Coloring or bleaching of the winged sepals harboring the black seeds is followed by desiccation of the plant and shedding of the seed.**

Scope and Purpose of the Studies

The major field studies were conducted in the Raft River Valley of Cassia County. This is the major area of halogeton infestation in Idaho and probably presents all the major problems inherent to the extensive invasion of Idaho's rangelands by halogeton.

The vegetation of the valley is representative of the Intermountain shrub region. The mean annual precipitation varies from about 9 inches at the lower elevations to about 14 inches at the higher elevations. Elevations range from 4,200 feet to 5,000 feet. Summer temperatures range from minimums of 34° F. at night to over 110° F. during the day.

It was recognized at the beginning that an extensive study of this problem would require several divisions. First, what were halogeton's basic characteristics and growth habits? Second, what was the consistency and persistence of the poisonous factors previously reported (3, 5, 11)? Third, how would halotegon respond to selective and non-selective herbicides? Fourth, what was the plant's adaption to soil types and its salt tolerance? Fifth, what was the relationship of the infestations to past conditions and how could herbicides be used in promoting natural or artificial revegetation with desirable forage species? Certain phases of the study already have been reported (6, 7, 12, 13, 16, 18), and other phases will be covered in subsequqent publications.

Primary emphasis in the chemical control studies has been to determine how to control and eradicate small infestations and how to contain the larger ones. Four specific objectives were outlined for detailed study relative to determining the place and value of herbicides for halotegon control. These objectives were to determine:

1. The toxicity of different hebicides to halogeton.
2. The influence of hour, date and rate of application on the toxicity of herbicides.

3. The influence of spray volume and carriers on the toxicity of hebicides.

4. The toxicity of different herbicides to desirable forage species.

Experimental Results

GROWTH AND DEVELOPMENT OF HALOGETON

The fact that halogeton is a halophyte complicates its control. Its seeds can germinate in very salty soils or media, and the plants can grow under extremely high moisture stress. Thus, halogeton is ideally adapted to the saline or alkaline soils of the intermountain region. These soils support vegetation which is difficult to replace once it is removed. This is illustrated in Table 1 which shows the percent of soluble salts in artificially salinized soils and the number of halogeton, crested wheatgrass, Russian thistle (*Salsola Kali*), and other plant species established on the soils

Table 1. — Influence of soil salinity on the establishment of halogeton and other plants in artifically salinized soil. [1]

		Salinity levels		
	None-saline	Low	Medium	High
Soluble salts[2]	0.067	0.132	0.289	0.503
Plant species				
Halogeton	27.9	48.6	102.7	116.6
Russian thistle	26:7	19.8	13.0	7.6
Crested wheatgrass	14.8	8.9	7.4	4.7
Other plants[3]	3.6	3.3	2.3	0.9

[1] Data are number of plants per square foot.
[2] Soluble salts are mean percentages from four soil depths.
[3] **Lepidium perfolatum, Descurainia** spp., and **Opuntia** spp.

following artificial salinization. The numbers of crested wheatgrass, Russian thistle and other plant species decreased with each increase in salinity, whereas the number of halogeton plants increased with increased salinity. Similar increases in numbers of halogeton plants have been recorded on naturally saline soils. The salt tolerance of halogeton and the lack of tolerance in crested wheatgrass prevents halogeton control on saline and alkaline soils by growing crested wheatgrass. It also reduces the number of soil sterilant herbicides effective in controlling halogeton or at least the rate of application necessary for control is increased.

The anatomical characteristics of halogeton influence its control. As the plant grows, it develops additional series of vascular tissues. This may be a factor in limiting translocation. Other anatomical or physiological factors, which are not wholly understood, hinder the movement of translocated herbicides from one side of the plant to the other. As a consequence, poor spray coverage can result in killing the branches on one side of the plant and no injury to branches on the other side.

Halogeton plants are susceptible to 2,4-D and similar herbicides until early July when there is a sudden change from susceptibility to resistance. This change seems to be related to poor absorption of herbicides into the plant but cannot be explained by any single structure or physiological change.

OXALATE ACCUMULATION AND PERSISTENCE

The poisonous property in halogeton was discovered by investigators (11) at the University of Nevada in 1942. Dried plants were found to contain total oxalates equivalent to 19 percent anhydrous oxalic acid. At this high oxalate concentration they found that 9 ounces of the dried plant material could kill a 150-pound sheep. Studies in Utah (3) yielded similar results showing that 1 to 2 ounces of plant oxalates could kill a mature sheep. It has since been learned that the quantity of plant material required for a lethal dosage depends upon the quantity of oxalates present and moisture content of plants at that specific time.

When the present study was initiated in 1950, there was no information on how early in the spring the plants became poisonous or how long the dried plants remained poisonous during the winter and early spring. Consequently, a series of oxalate accumulation and persistence studies were conducted over a period of 3 years (12) at several locations. It was found that on a dry-weight basis the oxalate content was highest in June and remained consistently high through November. Thereafter the typically dry standing plants lost oxalates gradually and progressively into the following April. The loss of oxalate resulted almost completely from leaf drop and only a very small reduction could be attributed to leaching from winter rain.

There were large differences in the rate of oxalate loss from halogeton plants among locations. These differences were found to be due to weather and plant-growth differences which affected the rate of leaf drop. Figure 2 shows the average percentage of anhydrous oxalates present at ten intervals throughout the year, and the approximate ounces of air-dried halogeton required to kill a 100-pound sheep at the indicated intervals. It also shows the approximate number of ounces of plant material required for a toxic dosage under average range conditions, recognizing that the plant's moisture content varies from 85 percent in June to 10 percent the following April.

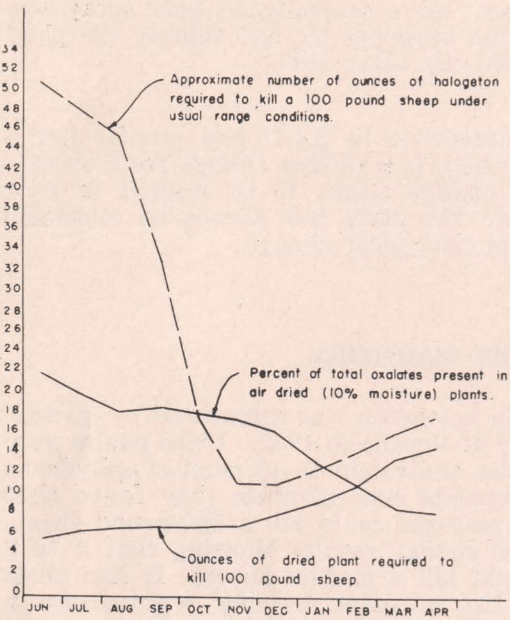

Figure 2. — Concentration of oxalates in halogeton from June to following April, and the number of ounces required to kill a 100-pound sheep under range and under dried plant conditions.

CONTROL STUDIES WITH POST-EMERGENCE HERBICIDES

Studies conducted during the first season, 1950, revealed that plots as small as 3 by 12 feet were adequate for preliminary evaluation of herbicides on halogeton. Thereafter, plot size and shape was varied to meet the requirements of the specific study. Plots as large as 1 acre in area were sometimes used. However, the plot size was kept at a minimum at all times to reduce variability in weed stands and soil types. Treatments were replicated a minimum of three times in the more common plot designs, (i.e., randomized block, randomized block split-plot, and Latin square).

Numerous sampling techniques were tried. A modification of Parker's (14) three-step-method, and Sharp's (16) loop procedure was adopted. This method consisted of counting the plants within a 2-inch diameter circle at 1-foot intervals throughout the plot length. Plants were counted at least twice each season, first when the plots were established and again at the end of the growing season. Halogeton stands were found to contain up to 450 plants per square foot.

Toxicity of Different Herbicides to Halogeton — With the tremendous advance in the development of agriculture chemicals, several new herbicides have become available each year. One of the primary functions of this study was to evaluate these herbicides to determine their potential value in halogeton control in the western states. These evaluation studies have included evaluating their toxicity to halogeton and their selectivity to desirable forage species at several rates of application. Table 5 contains a complete list of the herbicides used, and their toxicity to halogeton when applied at a rate of 2 pounds acid equivalent per acre.

It soon became evident that the application of 2,4-D (2,4-dichlorophenoxyacetic acid) compounds were the most consistently effective and satisfactory post-emergence treatment. There were, however, significant differences in the toxicity of the different formulations of 2,4-D. Of the two most common formulations, esters and amines, the esters proved to be more efficient. Furthermore, the more complex esters (defined as those containing a side chain of six or more carbon atoms), hereafter called the "low-volatile esters", were more toxic that the less complex esters, commonly classed as "high-volatile esters." Detailed studies determined the relative toxicity of different low-volatile ester formulations showing that they are practically equal in their toxicity to halogeton.

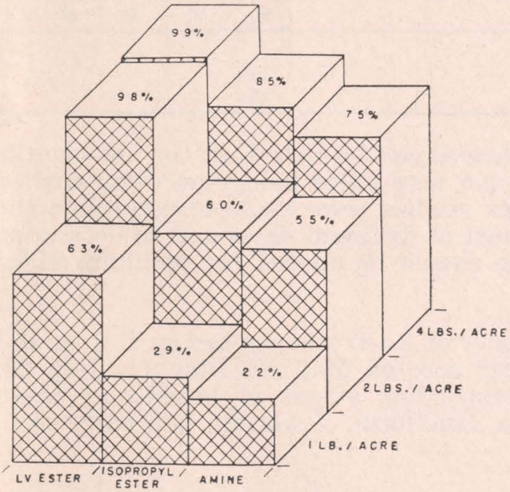

Figure 3. — Average percent of halogeton kills obtained from each of three 2, 4-D formulations, applied at three rates per acre as post emergence spray applications, June 15 to July 10. Four-year average.

Figure 3 shows the average results of numerous tests conducted on a continuing basis through several years. It shows the results of the three most common 2,4-D formulations at three rates applied while the plants were in the vegetative or susceptible growth stages. Only the low-volatile esters at the 2 and 4 pound per acre rates gave satisfactory kills.

Influence of Hour, Date, and Rate of Application and Plant Age on the Toxicity of Herbicides. — There were occasional reports that hour of herbicide application influenced results. To evaluate this variable, the ester and amine forms of 2,4-D were applied at three rates of application at 6 a.m., 12 noon, and 6 p.m., in mid-June, July, and August to determine whether halogeton could be killed more easily at one hour of day than another. The trials failed to show any practical differences in the effects from treating at any particular hour of the day.

Because of the inseparability of the effects of rate and date of application on herbicide toxity, these two variables were studied simultaneously. Tests involving these factors were conducted annually for 7 years. As the results accumulated these continu-

Table 2. — Halogeton killed by application of low-volatile ester of 2,4-D at four rates on four dates during 1953.

Stage of growth	Date of application	Active ingredient per acre 1 lb.	2 lb.	4 lb.	8 lb.	Date mean
		Pct.	Pct.	Pct.	Pct.	Pct.
Early rosette	May 27	68	60	74	97	75
Cruciform	June 11	88	100	100	100	97
Flowering	July 23	28	32	43	91	49
Early seed set	August 31	31	30	24	42	32
Rate mean		54	56	60	83	63
L S D 5% level						
Rate means		15.8				
Date means		15.6				

ing herbicide evaluations showed conclusively that the low-volatile esters of 2,4-D at 2 pounds per acre killed halogeton when applied at the proper date. Further studies were made to determine the effectiveness of this treatment at different dates and to determine whether the treatment rate should be altered for optimum efficiency at different dates.

In 1953, a low-volatile ester of 2,4-D was applied at 1, 2, 4, and 8 pounds acid equivalent per acre on May 27, June 11, July 23, and August 31. The corresponding stages of growth at these dates were the early rosette, cruciform, flowering, and early seed, respectively.

The data in Table 2 show that halogeton develops a tolerance to 2,4-D as the season advances. Only the treatments applied on June 11, while the plants were in the cruciform stage, were satisfactory. By July 23, halogeton was resistant to all the rates. Typically, the poor results obtained from the May 27, early rosette stage, applications were not due to lack of kill of the then existing plants but to germination when rains followed the herbicide applications.

In 1954, the 2,4-D treatments were modified to include rates of 1, 1.5, 2, 3, and 4 pounds per acre at each date of application. Stages of growth rather than calendar dates were used to determine times of application. These treatments were applied at three locations: Meadow Creek, Bridge, and Red Butte.

Table 3. — Halogeton killed by application of a low-volatile ester of 2,4-D at five rates and three locations in the Raft River Valley during 1954

Location	Stage of growth	Date of Application	Active ingredient per acre 1 lb.	1.5 lb.	2 lb.	3 lb.	4 lb.	Date mean
			Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Meadow Creek	Seedling	April 16	66	92	92	98	99	89
	Cruciform	June 17	99	100	100	100	100	99
	Early erect branching	June 29	87	100	100	100	100	97
	Late erect branching	July 12	20	23	57	70	76	49
	Early flowering	July 27	7	4	9	37	38	19
	Early seed	August 27	0	13	0	0	27	8
	L S D 5% level							
	Rate means within dates			19				
	Date means			12				
Bridge	Cruciform	June 18	100	100	99	100	100	99
	Early flowering	June 29	93	97	99	100	100	98
	Late flowering	July 27	12	32	52	45	73	43
	Early seed	August 23	3	4	9	13	8	7
	L S D 5% level							
	Rate means within dates			10				
	Date means			5				
Red Butte	Early erect branching	June 18	66	98	100	100	100	93
	Late erect branching	July 7	38	32	87	91	98	69
	Early flowering	July 27	4	12	16	15	22	14
	Early seed	August 23	3	6	3	9	4	5
	L S D 5% level							
	Rate means within dates			16				
	Date means			10				

Table 3 shows that the results were generally uniform at the three locations. The treatments applied in June, while the plants were in the cruciform or early branching stage were successful and those applied on July 7 or later were unsuccessful regardless of the rate of application or the growth stage.

Detailed studies in 1955 on the influence of date of application of 2,4-D began on July 7 and continued through August 4. These studies showed that halogeton was susceptible to the standard treatment of 2 pounds of 2,4-D per acre on July 7. The plants had developed tolerance to 2 pounds-per-acre by July 14 and were tolerant to 4 pounds-per-acre by July 23.

For several years it was observed that halogeton germinates over a long period during the spring and summer. Studies were set up to determine the influence of chronological plant age on herbicide tolerance. Included in this experiment were plants which germinated on April 1, May 1, June 1, and July 1. Plants germinating at each of these dates were sprayed with 2 pounds of the low-volatile ester of 2,4-D on July 17, July 27, August 6, August 16, and August 27.

Table 4. — Relationship of chronologic age of halogeton plants to their susceptibility to 2,4-D when treated at two pounds per acre of 2,4,-D low-volatile ester

Date of application	Date of germination							
	April 1		May 1		June 1		July 1	
	Age[1]	Kill[2]	Age	Kill	Age	Kill	Age	Kill
	Days	Percent	Days	Percent	Days	Percent	Days	Percent
July 17	108	51.5	78	67.8	47	98.8	17	97.0
July 27	118	11.2	88	13.8	57	62.5	27	99.2
August 6	128	0.8	98	5.2	67	30.8	37	69.8
August 16	138	5.2	108	12.2	77	10.2	47	21.8
August 27	149	0.0	119	6.5	88	4.2	58	10.5

[1] Age of plants is number of days from germination until date of spraying.

[2] Kills are percentage of the plants on plots dead at the end of the growing season as determined by counts made at the time of spray application and at the end of the growing seaason. Data are average of four replications.

Table 4 shows the relationship between the susceptibility of the plants sprayed on the above dates and their chronological age. The plants which germinated on April 1 developed 50 percent tolerance by about July 14 or 105 days after germination. Those which had germinated on May 1, June 1, and July 1 developed 50 percent tolerance in approximately 80, 61, and 41 days following germination, respectively. Plants which had germinated on April 1, May 1, June 1, and July 1, were equally tolerant showing a susceptibility of only 10 to 12 percent, 118, 88, 77, and 58 days after germination, respectively. Thus, halogeton which had germinated on July 1 developed equal tolerance of 2,4-D in 60 days less than halogeton which germinated on April 1.

It is evident from these results that the tolerance in halogeton to 2,4-D is influenced more directly by physiological development or condition than by chronological age. The increasing seasonal temperatures from April to August probably account for the progressively reduced time interval required for the development of tolerance to 2,4-D. Under the conditions of this study herbicide tolerance developed simultaneously with the erect branching stage and not with the reproduction stage of plant development illustrated in Figure 1.

The results illustrate that halogeton progresses from being susceptible to tolerant to 2,4-D very rapidly. Therefore, if satisfactory results are to be obtained with 2,4-D the date of treatment must be timed to coincide with period of susceptibility. Figure 4 shows the average and minimum results obtained from applications of 2,4-D low-volatile esters at 2 pounds per acre on different dates over a 4-year period. This establishes the period

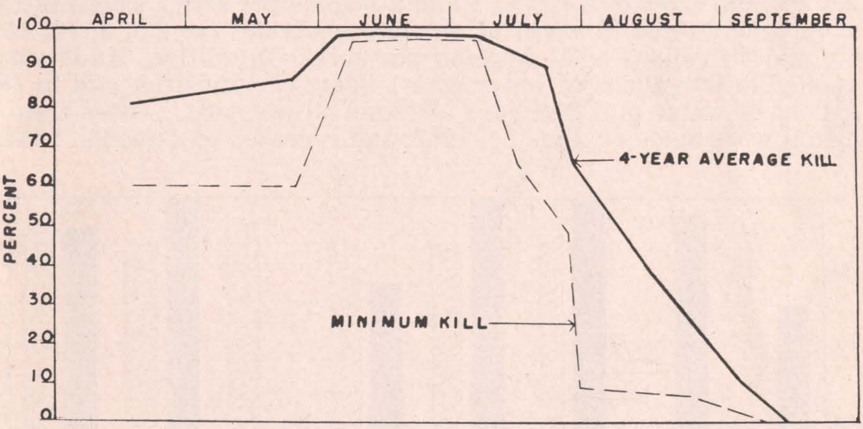

Figure 4. — Average and minimum percent halogeton control obtained by spraying with the low-volatile ester of 2, 4-D at 2 pounds per acre, over a 4-year period.

from June 15 to July 10 as the average date limits for successful treatment of halogeton with 2 pounds of 2,4-D low-volatile ester per acre in southern Idaho. Although the plants are susceptible to 2,4-D before June 15, subsequent germination of soil-borne seed causes the very early treatments to be unreliable.

After July 10, when halogeton has become tolerant to 2 pounds of 2,4-D per acre, a contact herbicide must be added to the spray solution to succesfully kill halogeton. When it is necessary to spray halogeton after July 10, a treatment of 4 pounds low-volatile ester of 2,4-D, 1 quart of DNBP (4,6-dinitro-ortho-sec. butylphenol) and 15 gallons of diesel oil per acre should be used. The treatment is effective until mid-August, when halogeton seed begins to mature. Since the treatment is not effective after seeds have developed on the halogeton plants, spraying halogeton after mid-August should be avoided.

Influence of Spray Volume and Carriers — Since halogeton occurs on arid lands, the spray operations are usually a long distance from a water supply. The use of a minimum amount of carrier, whether it be water or oil or other diluent, is desirable for several economic reasons. Furthermore, large quantities of diluent could place limitations on the use of ground or air equipment.

Preliminary tests indicated the necessity of a spray volume sufficient to obtain complete coverage of the foliar parts. The preliminary tests emphasized the need of a study to determine the lowest volume of carrier that could be used and still assure optimum herbicide effectiveness for halogeton control.

A detailed study was conducted over a 2-year period with a low-volatile ester of 2,4-D at 1 and 2 pounds per acre. These rates were then diluted in water at volumes equivalent to 2.5, 5, 10, 15, 20, and 40 gallons total solution per acre. In adition, 2,4-D was applied in 20 gallons of water plus 1 quart of emulsifier and in 18 gallons of water plus 2 gallons of diesel oil per acre. These treatments were made on June 20, 1952, and repeated on June 29, 1953.

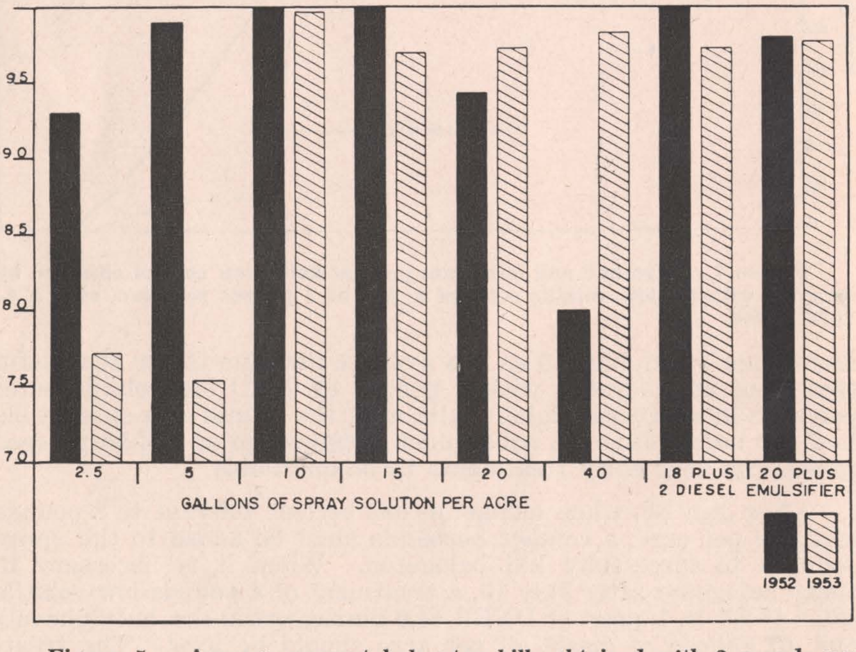

Figure 5. — Average percent halogeton kills obtained with 2 pounds per acre of low-volatile ester of 2, 4-D when applied in six different spray volumes per acre, and with spray fortifiers added.

Figure 5 shows that treatments using 2 pounds of 2,4-D in 10 or 15 gallons of water per acre were equal or superior to using greater or costlier volumes. The mixture of 18 gallons of water plus 2 gallons of diesel oil gave equally good results, but it is more expensive. Less than 10 gallons per acre did not produce consistently good results. Likewise, 40 gallons per acre was less effective than 10 to 20 gallons per acre. This may be due to run-off when spraying this smooth, waxy, small-leaved plant.

Application of 1 pound of 2,4-D per acre did not produce satisfactory results in any of the carrier treatments. At this rate of application, 15 gallons per acre was superior to other volumes.

Repeated studies showed that less than 10 gallons of carrier gave inadequate plant coverage, whether the carrier was water, water plus various additives, or oils. When the same quantity of herbicide was used 5 gallons of carrier produced about 20 percent less halogeton control than 10 gallons of carrier per acre. These results are in agreement with work conducted on aerial applications (15) which show that gallonages up to and including 5 gallons per acre gave 90 percent or less control.

All these studies support the conclusion that treatments at 2 pounds of a low-volatile ester of 2,4-D in 10 to 15 gallons of water per acre will give the most efficient kills of halogeton. Treatment must be made between June 15 and July 10.

Toxicity of Post-emergence Herbicides to Desirable Forage Species — The desirable forage types in which halogeton infestations are found are badly depleted and need revegetation. The use of herbicides on ranges is limited not only by their effectiveness in killing halogeton but also by their injury to the desirable forage species.

Large scale use of herbicides will be limited until chemicals or methods of application which give greater selectivity in broad-leaved or desert shrub type species are found. At present, halogeton competition often slows or prevents normal development and succesion of desirable forage species even where grazing pressure is removed.

Studies were initiated to determine the relative injury of post-emergence herbicides to several desirable forage species, and to determine if injury could be prevented while bringing halogeton under control. Experiments were conducted in four shrub-vegetation types: budsage (*Artemisia spinescens*), saltsage (*Atriplex-nuttallii*), shadscale (*Atriplex confertifolia*), and winterfat (*Eurotia lanata*). Herbicide treatments consisting of the amine and ester of 2,4-D and the ester of 2,4,5-T (2, 4, 5-trichlorophenoxyacetic acid) were applied at 0, 0.5. 1, 2, and 4 pounds per acre.

Results revealed that the range forage plants of southern Idaho, except grass and grass-like species, are killed or severely injured by post-emergence sprays applied in sufficient concentration and at the optimum time for controlling halogeton. Spraying early in the season caused less injury to some shrub species, while spraying late in the growing season caused less injury to others. However, all treatments in June which gave effective halogeton control caused severe injury to the range forage shrubs.

Occasionally it became desirable or necessary to control halogeton in crested wheatgrass in the first or subsequent years after seeding. Studies on a first-year seeding show that fall-sown crested wheatgrass is tolerant to 2 pounds of 2,4-D per acre applied the following June. At the end of the first growing season crested wheatgrass plants per square foot averaged 5.8 in sprayed plots 4.5 in the non-sprayed plots. Although these differences in stands are small, they emphasize the tolerance of the grass seedlings to 2,4-D.

CONTROL STUDIES WITH DORMANT OR PRE-EMERGENCE HERBICIDES

The recent activity in the development of herbicides presents the interesting possibility that surface soil sterilants may be found that would control halogeton seedlings but relatively harmless to established perennial broad-leaved forage plants.

These treatments could be applied in late fall or early winter when the desirable vegetation has a minimum amount of foliage and is semi-dormant. Such treatment would thereby be dormant in respect to the perennial forage plant and pre-emergent to the halogeton which begins germinating as early as January.

Initial tests have been directed toward finding effective compounds. Of the compounds evaluated to date three appear promising when applied at 4 pounds per acre. The three compounds are: 2,3,6-TBA (2,3,6-trichlorobenzoic acid); silvex (2-(2,4,5-trichlorophenoxy) propionic acid); and diuron (3-(3,4-dichlorophenyl)-1,1-dimethyl urea).

Further studies are in progress to determine the optimum rates and dates of application for most efficient selective control with these and additional chemical compounds. Because of the greater selectivity of these compounds when applied as dormant sprays, and the recent development of dry or granular formulations, investigations in this field hold promising possibilities at present.

CONTROL STUDIES WITH SOIL STERILANT HERBICIDES

Soil-sterilant herbicides have been under test throughout the duration of this study. Others were added as they became available. Therefore, the number of years of evaluating the selected herbicides has varied. Generally, soil sterilants have only limited use on rangelands because of their high cost and their long-term non-selective toxicity. The high rates required for halogeton control are ultra long lasting under the moisture and soil conditions common to rangeland. However, because of this characteristic they can also be the most economical treatment in special situations.

The results have shown that halogeton is relatively tolerant of borax and other boron-containing compounds. Mixtures and complexes of boron fortified with various proportions of sodium chlorate have shown toxicity in direct proportion to the quantity of sodium chlorate present. One compound containing 25 percent sodium chlorate prevented seed production for one season when applied at 2 and 4 pounds per square rod (320 to 640 lb/A), and for two seasons when applied at 8 pounds (1280 lb/A). Sodium chlorate alone has not been used because of the hazards of fire and livestock poisoning.

Monuron (3-(p-chlorophenyl)-1,1-dimethylurea) has provided complete soil sterilization for 5 years when applied at the rate of ¼ pound per square rod (40 lb/A) on a medium-textured soil. However, it should be emphasized that this rate of monuron has failed to produce more than 2 years halogeton control on coarse-textured soils.

In preliminary tests the sodium salt of 2,4,6-TBA has given halogeton control for 3 years when applied at the rate of ⅛ pound per square rod (20 lb/A). The chlorinated benzoic acid compounds merit further study as soil sterilants for halogeton control.

Table 6 gives data on the compounds tested and their performance as soil sterilants.

Discussion

Control of halogeton has been studied in Idaho since 1950. The studies have been concerned with finding means of controlling this range weed through the use of herbicides alone and combined with range improvement methods.

Certain characteristics of halogeton complicate its control. Seeds are produced in such numbers that even if only 1 percent of the plants survive a herbicide treatment and produce seed, a full stand will be present the following season. The large quantity and the germination habits of the two types of seed produced by this plant make control a continuing program. The black seeds germinate readily and assure a full stand the year following production. The brown seeds do not germinate immediately after being formed. They may remain at or near the soil surface for one to several years before germinating. These seeds provide a viable seed reserve and assure perpetuation of the species when seed production is prevented. If halogeton is to be eradicated, adequate control measures must continue until the supply of viable seed in the soil is exhausted.

The salt tolerance of this weed also makes its control difficult. It thrives on saline soils not tolerated by crested wheatgrass and other grasses which normally suppress halogeton on non-saline soils. The grass plants which do survive on saline soils are often in a weakened condition and provide little competition. Revegetating these areas with desirable salt-tolerant vegetation is at present slow and difficult.

Anatomical and physiological features of halogeton which restricts herbicidal effectiveness also complicates its control.

Early research studies were concerned with post-emergence treatments. This early work revealed that the ester formulations, particularly the low-volatile esters of 2,4-D, were more toxic to halogeton than the salt formulations. From this long series of studies, recommendations for halogeton control have been formulated. These recommendations consist of three esential points:

1. Spray in June with a low-volatile ester of 2,4-D at 2 pounds acid equivalent per acre diluted in 15 gallons of water.

2. Before July 10 inspect all the areas sprayed in June. The treated areas must be **checked thoroughly** for surviving plants. All surviving plants must be killed. They should be re-sprayed, hoed or pulled by hand, depending on the number of plants remaining.

3. Before seed is produced, late July or early August, **recheck** treated areas. If a large number of plants or seedlings are present, spray them with a solution of 4 pounds of low-volatile ester of 2,4-D plus 1 quart of DNBP, and 15 gallons of diesel oil per acre. This spray is effective through early August. All infestations found after July 10 should be sprayed with this spray solution.

Experiments to determine the toxicity of post-emergence treatments to desirable forage plants have shown that the desirable shrub type forage plants associated with halogeton are severely injured by post-emergence spray treatments which kill halogeton. However, spraying halogeton as recommended in June following fall seeding of crested wheatgrass will not injure the crested wheatgrass seedlings and may aid in their establishment.

Preliminary investigations indicate that three compounds, 2,3,6-TBA, silvex, and diuron, are promising for selective preemergence control of halogeton. These herbicides are applied in late fall or early winter when the forage species are semi-dormant. Under these conditions there is reduced toxicity to the desirable species and residual toxicity to the subsequently germinating halogeton seedlings.

Several soil sterilants are effective against halogeton growth for from two to several years. Boron-sodium chlorate mixtures at 8 pounds per square rod, monuron at ¼ pound per square rod, and sodium TBA at ⅛ pound per square rod are effective against halogeton growth for one to several years, depending upon local soil and climatic conditions.

The successful control of halogeton does not depend upon any single control method. Rather, the possibilities of reseeding, deferred grazing, herbicides and other range management tools must be included when halogeton control is considered. Ultimate control of halogeton depends upon the restoration of vigor and productivity to good range forage plants.

Herbicides best fit into the overall halogeton control program in areas where the infestations are small, where adequate equipment is available, and above all where there is dedicated local personnel who will get the job done. The possibilities of controlling or eradicating halogeton in any given situation will be determined by the equipment and monetary support available and the size of the infestation. Herbicides should not be used promiscuously on large areas of rangeland. They should be used in combination with reseeding and other range improvement practices wherever possible.

Table 5. — A list of compounds applied to halogeton as post-emergence sprays at two pounds per acre in water equivalent to 15 or 20 gallons per acre to determine their toxicity.

Herbicide and formulation	Date of application	Percent halogeton control
2,4-dichlorophenoxyacetic acid, emulsifiable acid	6-29-56	76
2,4-dichlorophenoxyacetic acid, dimethyl amine salt	6-20-50	0
" " " " "	7-20-50	0
" " " " "	8-20-50	0
" " " " "	6-20-51	55
" " " " "	7-20-51	64
" " " " "	8-20-51	58
2,4-dichlorophenoxyacetic acid, alkanolamine salts	6-17-55	75
" " " " "	6-29-56	6
2,4-dichlorophenoxyacetic acid, isopropyl ester	6-20-50	61
" " " "	7-20-50	77
" " " "	8-20-50	54
" " " "	6-20-51	60
" " " "	7-20-51	57
" " " "	8-20-51	47
" " " "	6-22-54	75
2,4-dichlorophenoxyacetic acid, propylene glycol butyl ether ester	6-20-50	99
" " " " " " "	7-20-50	99
" " " " " " "	8-20-50	58
" " " " " " "	4-26-51	95
" " " " " " "	6-11-51	97
" " " " " " "	6-20-51	96
" " " " " " "	7-18-51	100
" " " " " " "	7-20-51	51
" " " " " " "	8-20-51	11
" " " " " " "	9- 4-51	7
" " " " " " "	6-25-52	100
2,4--dichlorophenoxyacetic acid, propylene glycol butyl ether ester	6-30-52	100
" " " " " " "	6-26-53	97
" " " " " " "	6-22-54	95
" " " " " " "	6-29-56	86
2,4-dichlorophenoxyacetic acid, tetrahydrafurfuryl alcohol ester	6-30-52	97
" " " " " "	6-22-54	92
2,4-dichlorophenoxyacetic acid, butoxy ethanol ester	6-30-52	100
" " " " "	6-22-54	95
" " " " "	7-16-54	40
" " " " "	6-17-55	100
2,4-dichlorophenoxyacetic acid, oil soluble amine + 3 gal. fuel oil	4-25-51	78
" " " " " " " " "	6-11-51	89
" " " " " " " " "	7-18-51	32
" " " " " " " " "	9- 4-51	0

Herbicide and formulation	Date of application	Percent halogeton control
2,4dichlorophenoxyacetic acid, dimethyl amine salt + 3 gal fuel oil	4-25-51	92
" " " " " " " " "	6-11-51	93
" " " " " " " " "	7-18-51	43
" " " " " " " " "	9- 4-51	8
2,4-dichlorophenoxyacetic acid, butyl ester + 2 gal. diesel oil	6-27-51	95
2,4-dichlorophenoxyacetic acid, water soluble wax	6-30-52	99
2,4,5-trichlorophenoxyacetic acid, emulsifiable acid	6-29-56	85
2,4,5-trichlorophenoxyacetic acid, triethanol amine	6-20-50	6
" " " "	7-20-50	68
" " " "	8-20-50	51
" " " "	6-20-51	43
" " " "	7-20-51	46
" " " "	8-20-51	62
2,4,5-trichlorophenoxyacetic acid, isopropyl ester	7-18-50	60
2,4,5-trichlorophenoxyacetic acid, propylene glycol butyl ether ester	6-20-50	99
" " " " " " "	7-20-50	99
" " " " " " "	8-20-50	62
" " " " " " "	6-20-51	73
" " " " " " "	7-20-51	46
" " " " " " "	8-20-51	28
" " " " " " "	6-30-52	100
2,4,5-trichlorophenoxyacetic acid, tetrahydrafurfuryl alcohol ester	6-30-52	99
2,4,5-trichlorophenoxyacetic acid, butoxy ethanol ester	6-30-52	100
" " " " "	6-17-55	100
" " " " "	6-29-56	75
2-methyl-4-chlorophenoxyacetic acid, butoxy ethanol ester	6-30-52	93
" " " " " "	6-22-54	59
" " " " " "	6-17-55	87
" " " " " "	6-29-56	56
4-chlorophenoxyaacetic acid, butoxy ethanol ester	7-16-54	36
" " " " "	6-17-55	53
" " " " "	6-29-56	5
2-(2,4-dichlorophenoxy) propionic acid, butoxy ethanol ester	6-29-56	62
2-(2,4,5-trichlorophenoxy) propionic acid, butoxy ethanol ester	6-29-56	63
2-(2,4,5-trichlorophenoxy) propionic acid, propylene glycol butyl ether ester	6-22-54	96
" " " " " " " "	6-29-56	47
2-(2,4,5-trichlorophenoxy) propionic acid, iso-octyl ester	6-22-54	88
" " " " "	6-17-55	96
" " " " "	6-29-56	23

Herbicide and formulation	Date of application	Percent halogeton control
4-(2,4-dichlorophenoxy) butyric acid, amine salt	6-17-55	43
" " " " "	6-29-56	7
4-(2,4-dichlorophenoxy) butyric acid, iso-octyl esther	6-29-56	32
4-(2,4-dichlorophenoxy) butyric acid, butoxyenthoxy-2-propanol ester	6-29-56	68
4-(2,4,5-trichlorophenoxy) butyric acid, amine salt	6-17-55	48
" " " " "	6-29-56	1
4-(2-methyl-4-chlorophenoxq) butyric acid, amine salt	6-17-55	65
" " " " "	6-29-56	2
4-(2-methyl-4-chlorophenoxy) butyric acid, amine salt	6-17-55	51
4-(2-methyl-4-chlorophenoxy) butyric acid, iso-octyl ester	6-29-56	4
4,6-dinitro-ortho-secondary butyl phenol, ammonium salt	4-25-51*	0
" " " " " " "	6-11-51	20
" " " " " " "	7-18-51	35
" " " " " " "	9- 4-51	0
Maleic hydrazide	7- 5-50	0
" "	7- 1-51	0
" "	6-22-54	20
2,3,6-trichlorobenzoic acid, sodium salt	6-29-56	6
Polychlorobenzoic acid, emulsifiable acid	6-29-56	15
N-1-naphthyl phthalamic acid	6-22-54	41
N-1-naphthyl phthalamic acid, sodium salt	6-22-54	11
3-amino,-1,2,4-triazole	7-16-54	37
" " "	6-17-55	15
3-amino-1,2,4-triazole + 2,4-dichlorophenoxyacetic acid	7-16-54	44
3-amino-1,2,4-triazole + 2,5,5-trichlorophenoxyacetic acid	7-16-54	70
3-amino-1,2,4-triazole + 2-methyl-4-chlorophenoxyacetic acid	7-16-54	47
Alpha-chloro-N, N-diallylacetamide	6-17-55	10
2-chloroallyl-diethyldithiocarbamate	6-17-55	10
3,6-endoxohexahydrophthalic acid, disodium salt	6-30-52	78
2-chloro-4,6-bis (diethylamino)-S-triazine	6-29-56	3
2-(2,4,5-trichlorophenoxy) ethyl 2,2-dichloropropionate	6-29-56	1

* Applied at a rate equivalent to 1 gallon per acre

Table 6. — A list of soil sterilant compounds tested and the length of complete effectiveness for halogeton control.

Herbicide and formulation	Rate of application	Date of application	Duration of effectiveness
	Lbs./A.		Years
Sodium pentaborate and borax	320	7- 7-50	0
" " " "	640	7- 7-50	0
" " " "	1280	7- 7-50	0
Sodium pentaborate, boraax and sodium chlorate	320	7- 7-50	2
" " " " " "	640	7- 7-50	2
" " " " " "	1280	7- 7-50	3
Sodium tetraborate and 2,4-dichlorophenoxyacetic acid	40	1- 4-56	0
" " " " "	80	1- 4-56	0
" " " " "	160	1- 4-56	0
3-(p-chlorophenyl)1,1-dimethyl urea	2.5	4-16-52	0
" " "	2.5	9-28-53	0
" " "	5	4-16-52	0
" " "	5	9-28-53	0
" " "	10	4-16-52	0
" " "	10	9-28-53	0
" " "	20	10-17-51	0
" " "	20	4-16-52	1
" " "	20	9-28-53	0
" " "	40	10-17-51	5
" " "	40	4-16-52	2
" " "	40	9-28-53	4
" " "	80	10-17-51	5
" " "	80	9-28-53	4
Isopropyl N-phenyl carbamate	2.5	4-16-52	0
" " "	5	4-16-52	0
" " "	10	4-16-52	0
" " "	20	4-16-52	1
" " "	40	4-16-52	1
2,3,6-trichlorobenzoic acid, soduim salt	5	2-10-56	1
" " " "	10	2-10-56	2
" " " "	20	2-10-56	2
Trichloroacetic acid, sodium salt	2.5	4-16-52	0
" " " "	5	4-16-52	0
" " " "	10	4-16-52	0
" " " "	20	4-16-52	0
" " " "	40	4-16-52	0

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Table 6. — A list of soil sterilant compounds tested and the length of complete effectiveness for halogeton control.

Herbicide and formulation	Rate of application	Date of application	Duration of effectiveness
	Lbs./A.		Years
Sodium pentaborate and borax	320	7- 7-50	0
" " " "	640	7- 7-50	0
" " " "	1280	7- 7-50	0
Sodium pentaborate, boraax and sodium chlorate	320	7- 7-50	2
" " " " " "	640	7- 7-50	2
" " " " " "	1280	7- 7-50	3
Sodium tetraborate and 2,4-dichlorophenoxyacetic acid	40	1- 4-56	0
" " " " "	80	1- 4-56	0
" " " " "	160	1- 4-56	0
3-(p-chlorophenyl)1,1-dimethyl urea	2.5	4-16-52	0
" " "	2.5	9-28-53	0
" " "	5	4-16-52	0
" " "	5	9-28-53	0
" " "	10	4-16-52	0
" " "	10	9-28-53	0
" " "	20	10-17-51	0
" " "	20	4-16-52	1
" " "	20	9-28-53	0
" " "	40	10-17-51	5
" " "	40	4-16-52	2
" " "	40	9-28-53	4
" " "	80	10-17-51	5
" " "	80	9-28-53	4
Isopropyl N-phenyl carbamate	2.5	4-16-52	0
" " "	5	4-16-52	0
" " "	10	4-16-52	0
" " "	20	4-16-52	1
" " "	40	4-16-52	1
2,3,6-trichlorobenzoic acid, soduim salt	5	2-10-56	1
" " " "	10	2-10-56	2
" " " "	20	2-10-56	2
Trichloroacetic acid, sodium salt	2.5	4-16-52	0
" " " "	5	4-16-52	0
" " " "	10	4-16-52	0
" " " "	20	4-16-52	0
" " " "	40	4-16-52	0