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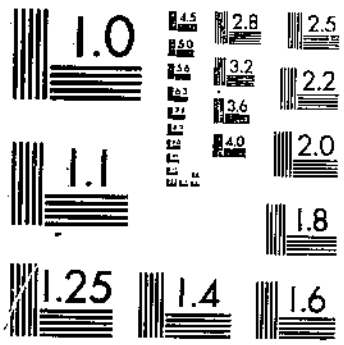

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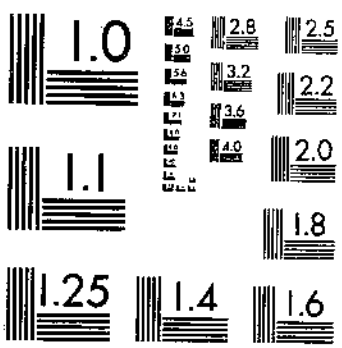

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Technical Bulletin No. 1436

Weed Control in Sugarbeets With Cycloate

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

in cooperation with

Washington State University
College of Agriculture

Acknowledgments

The Utah-Idaho Sugar Company, Moses Lake and Toppenish, Wash., supplied the sugarbeet seed used in these studies, provided sugarbeet planters and herbicide injectors, and analyzed sugarbeet roots from the experiments for sucrose content. The cycloate was provided by Stauffer Chemical Company, Mountain View, Calif., as a liquid formulation under their trade name Ro-Neet. These contributions to the research are gratefully acknowledged.

Contents

Washington, D.C. Issued August 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 20 cents

Weed Control in Sugarbeets With Cycloate

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INTRODUCTION

A previous publication reported evaluations of soil-applied herbicides for prethinning weed control in sugarbeets (*Beta vulgaris* L.) *(2)*.[1] In each of 4 years, the performance of *S*-ethyl *N*-ethylthiocyclohexanecarbamate (cycloate) was outstanding with respect to both weed control and crop tolerance when applied at 3 pounds per acre and incorporated with the soil. Additional investigation of methods of applying cycloate indicated that 3 pounds per acre thoroughly mixed with the soil to a depth of 3 inches controlled common lambsquarters (*Chenopodium album* L.), barnyardgrass (*Eichinochloa crusgalli* (L.) Beauv.), and certain other annual weeds selectively in sugarbeets *(3)*. Results were similar when cycloate was applied to either moist or dry soil in 2 years that differed considerably in temperature and rainfall. Furthermore, incorporation 2 or 4 inches deep was usually as effective as incorporation 3 inches deep. In addition to controlling weeds without seriously injuring the crop, cycloate has flexible requirements for satisfactory application. Thus, cycloate showed much promise as a selective herbicide in sugarbeets.

In Nebraska also, cycloate was one of the most effective herbicides for selective weed control in sugarbeets (*7*).

Although cycloate performed well when incorporated to a depth of 3 inches, incorporation may create a soil moisture problem (*2*). With the light soil, low rainfall, low humidity, and frequent winds that prevail when sugarbeets are planted in Washington, moisture in the upper 1½ inches of soil into which the seeds are planted may be marginal, even though the soil below this depth may contain adequate moisture from fall irrigation and winter rains. When incorporation of cycloate decreases seedbed moisture, the field usually must be irrigated to promote germination. Consequently, emergence is usually delayed and an otherwise unneces-

[1] Italic numbers in parentheses refer to Literature Cited, p. 24.

sary irrigation adds to the cost of producing the crop. Sugarbeet growers would benefit by methods of application that would retain the effectiveness of cycloate without drying the seedbed.

This bulletin reports research conducted in 1967–69 on weed control in sugarbeets with cycloate. The objective of this research was to evaluate the response of sugarbeets and weeds to cycloate applied by various methods under various soil and climatic conditions.

All experiments were conducted at the Irrigated Agriculture Research and Extension Center at Prosser, Wash., on Ritzville and Warden fine sandy loams that had about 1 percent organic matter. The two most important weeds in sugarbeets in Washington, barnyardgrass and common lambsquarters, were abundant in all experiments. Redroot pigweed (*Amaranthus retroflexus* L.) and nightshade (*Solanum sarachoides* Sendt.) also were present in some experiments.

CYCLOATE APPLIED ON DIFFERENT DATES AND BY DIFFERENT METHODS IN 1967 AND 1968

In Washington, sugarbeet growers plant sugarbeets from early March until late April. Consequently, conditions of soil and weather vary widely when sugarbeets are planted. If cycloate is to be used successfully for weed control in sugarbeets, its performance under the different conditions of a wide range of planting dates must be determined.

Lyons and Takatori (*5*) have reported that a petroleum mulch applied over certain herbicides that normally require incorporation may make incorporation unnecessary. The possibility that such a practice might replace the need to incorporate cycloate seemed worthy of investigation.

The main objective of the research described here was to determine the response of sugarbeets and weeds to cycloate at 3 pounds per acre incorporated, with the soil before planting sugarbeets on different dates. A second objective was to determine whether the use of a petroleum mulch would substitute for thorough incorporation of cycloate or accelerate emergence and early growth of sugarbeets. A third objective was to determine the effect of tillage for incorporation of cycloate on emergence of sugarbeets.

Experimental Procedure

In 1967 and 1968, sugarbeets were planted within one day of the following dates: March 6, March 18, April 3, April 18, and May 3. On each date, they were seeded where cycloate had been broadcast at 3 pounds per acre and where no herbicide had been applied. Within 20 minutes after spraying, and

before seeding, both the treated and untreated plots were tilled 3 inches deep with a power-driven rotary tiller with L-shaped blades. The effect of tillage on emergence of sugarbeets during the early season when soil moisture is most apt to be critical was determined by also seeding sugarbeets in untilled soil at the first two dates.

On two planting dates, March 18 and April 18, two treatments were included in which petroleum mulch was applied. The rate was 450 g.p.a. (area actually sprayed) in 7-inch bands over the planted rows after an application of cycloate at 3 pounds per acre. In one treatment, cycloate was incorporated to a depth of 3 inches before sugarbeets were planted. In the other, it was applied on the soil surface without incorporation after planting.

Treatments were made in a split plot design with four replicates. Dates of application were assigned to main plots and cycloate and mulch treatments were applied to subplots. Each subplot consisted of four sugarbeet rows 22 inches apart. Rows were 35 feet long in 1967 and 30 feet in 1968.

Weed control was evaluated by counting the weeds in each plot at appropriate times. Sugarbeets were counted after emergence was complete. They were also counted at various times before full emergence to measure the effect of tillage and petroleum mulch on rate of emergence.

Soil moisture was assessed visually in the seed zone before and during emergence in plots planted on the first two dates each year. In addition, soil samples to a depth of 2 inches were collected within the sugarbeet rows on March 14, 1967, in plots planted 1 week previously with and without soil incorporation. Moisture content on an oven-dry basis was determined. Each sample consisted of soil from six sites in one plot.

After weed control had been evaluated, and before weeds were large enough to compete appreciably with the crop, the weeds were hoed out and the crop was thinned to approximately one plant per foot of row in all plots. Weeds that emerged after thinning were removed by hand as needed. The yield and sucrose content of sugarbeet roots were measured from 30 or 25 feet (1967 and 1968, respectively) of the two center rows of each plot at normal harvesttime.

Results and Discussion

Date of Application

Barnyardgrass and common lambsquarters emerged abundantly in the plot area each year. Regardless of date of application, cycloate consistently controlled a high percentage of barnyardgrass and a lesser percentage of common lambsquarters. Control of barnyardgrass ranged from 90 to 100 percent (97 percent average) (table 1). Control of common lambquarters ranged from 60 to 95 percent (77 percent average). Pigweed and nightshade were less numerous than common lambsquarters, but control thereof was similar.

TABLE 1.—*Weed control from cycloate at 3 lb./A. incorporated with the soil to a depth of 3 inches before planting sugarbeets on 5 dates in each of 2 years*

Planting date	Reduction in stand[1] of—			
	Barnyardgrass in—		Common lambsquarters in—	
	1967	1968	1967	1968
	Percent	*Percent*	*Percent*	*Percent*
March 6	94	99	62	81
March 18	94	98	80	86
April 3	90	100	68	82
April 18	99	95	72	60
May 3	100	98	95	88
Average of 10 dates	97		77	

[1] Average number (all dates) of barnyardgrass and common lambsquarters in 20 feet of each of 2 rows in the untreated checks was, respectively, 351 and 22 in 1967 and 245 and 121 in 1968.

Tolerance of sugarbeets to cycloate was consistent among the different dates of planting (table 2). Cycloate did not affect the stand of sugarbeets at any planting date, but temporary symptoms of injury were often present. Symptoms were limited to young shoots and consisted of abnormally deep green color, brittle leaves, and reduced size. Symptoms were never seen in roots. Roots of injured sugarbeets usually appeared similar in size to those of untreated plants of the same age.

Cycloate did not decrease significantly the yields or sucrose content of sugarbeet roots from any date of planting, as compared with the untreated, hand-weeded plots. In 1968, the average yield of cycloate-treated sugarbeets from all dates was higher than that of the untreated ones. This difference was statistically significant ($P<0.02$). Suppression of the crop by weeds would be the probable reason for such a difference. However, judging from studies of weed competition with sugarbeets conducted in the same geographic area (*1*), the weeds were probably removed before they had opportunity to cause yield reductions. Thus, there is no explanation for the higher yields from cycloate-treated sugarbeets in 1968.

In both years, yields of sugarbeet roots were similar when the crop was planted March 6, March 18, or April 3. Yields from later plantings were significantly lower in 1967 and tended to be lower (but not significantly so) in 1968. Effect of date of planting on sucrose percentage was variable, but the sucrose content tended to be higher in sugarbeets planted in March than in those planted in April or May.

TABLE 2.—*Response of sugarbeets to cycloate at 3 lb./A. incorporated with the soil before sugarbeets were planted at 5 dates in each of 2 years*

Planting date and treatment[1]	Emerged seedlings per foot of row[2] in—		Yield[3] of roots per acre in—		Sucrose content[3] of roots in—	
	1967	1968	1967	1968	1967	1968
	Number	*Number*	*Tons*	*Tons*	*Percent*	*Percent*
March 6:						
No cycloate	4.0	4.5	30.6	27.2	15.8	16.4
Cycloate	3.5	4.7	31.3	31.9	15.7	16.6
Average	--	--	31.0a	29.6a	15.8ab	16.5a
March 18:						
No cycloate	3.6	3.4	31.8	32.2	16.2	16.5
Cycloate	3.5	3.0	30.0	33.8	16.2	16.6
Average	--	--	30.9a	33.0a	16.2a	16.6a
April 3:						
No cycloate	4.0	2.3	29.4	27.1	16.0	15.9
Cycloate	4.4	2.2	31.6	30.2	15.2	15.9
Average	--	--	30.5a	28.7a	15.6ab	15.9b
April 18:						
No cycloate	--	5.4	23.3	24.5	15.2	16.0
Cycloate	--	4.9	25.3	28.7	15.5	16.4
Average	--	--	24.3 b	26.6a	15.4 b	16.2ab
May 3:						
No cycloate	--	4.2	18.3	24.4	15.2	16.4
Cycloate	--	4.6	16.0	27.8	15.3	16.0
Average	--	--	17.2 c	26.1a	15.3 b	16.2ab

[1] Weeds were removed from treated and untreated plots before they could compete appreciably with the sugarbeets.

[2] Seedlings were counted after emergence was complete for each date.

[3] Within each year, average values not followed by the same letter are significantly different at the 5-percent level of probability, based on Duncan's multiple range test.

Tillage

The physical effect of tilling the soil to incorporate cycloate tended to reduce seedbed moisture and affected sugarbeet emergence adversely when soil moisture was marginal.

One week after planting on March 6, 1967, the moisture content of the surface 2 inches of tilled soil was 8.5 percent and of untilled soil, 9.3 percent. The difference was significant ($P<0.05$). Although the moisture content of tilled soil was reduced, the remaining moisture was sufficient for uniform emergence. Sugarbeets emerged equally well in tilled and untilled soil when planted March 6 either year (table 3). In contrast, tillage reduced early emergence of sugarbeets planted March 18 each year.

TABLE 3.—*Effect of tillage[1] on emergence of sugarbeets planted on 2 dates in each of 2 years*

Planting date and treatment	Emerged seedlings per foot of row on—	
	April 10, 1967	May 2, 1967
	Number	*Number*
March 6, 1967:		
Not tilled	4.1	--
Tilled	4.1	--
March 18, 1967:		
Not tilled	2.3	3.4
Tilled	1.6**	3.6
	April 3, 1968	May 1, 1968
March 6, 1968:		
Not tilled	4.8	--
Tilled	4.6	--
March 18, 1968:		
Not tilled	3.1	4.1
Tilled	1.2**	3.4*

[1] Soil was thoroughly mixed to a depth of 3 inches with a power-driven rotary tiller with L-shaped blades.

* Significantly less than nontilled at 5-percent level of probability.

** Significantly less than nontilled at 1-percent level of probability.

Between March 6 and March 18, little or no rain fell, and the surface soil dried. Tillage mixed the dry surface three-fourths inch of soil with deeper, moist soil. After mixing, the soil at the 1-inch depth, where the seeds were placed, was too dry for uniform germination. Without mixing, the seeds were planted into soil moist enough to promote germination and emergence.

After irrigation and rainfall in April, additional seeds germinated from the March 18 seeding each year. In 1967 the final stand was not affected by the tillage before planting, but in 1968 the final stand consisted of significantly fewer sugarbeet plants in the tilled than in the untilled plots.

Petroleum Mulch

Petroleum mulch was not a satisfactory substitute for incorporation of cycloate. Although some weeds were killed where petroleum mulch was applied over unincorporated cycloate, the control was markedly inferior to that where cycloate was incorporated. Weed control was excellent where the petroleum mulch

was applied over incorporated cycloate on both dates in 1968 and on April 18, 1967. In contrast, after treatments made March 18, 1967, weed control from incorporated cycloate was inferior with petroleum mulch than without the mulch. There was no evident reason for this difference.

In 1967, the mulched sugarbeets planted on both dates yielded significantly more than those without the mulch (table 4). They emerged earlier and the top growth was markedly larger through April and May.

Sugarbeets did not respond to petroleum mulch in 1968. Winds in March and April drifted soil over the mulch and reduced its exposure to the sun. Consequently, the mulch probably did not increase soil temperatures in 1968.

Petroleum mulch partly compensated for the reduced emergence caused by tillage for incorporation on March 18, 1967 (table 5). Possibly, higher temperatures under

TABLE 4.—*Response of sugarbeets to petroleum mulch applied in 7-inch bands over the rows after planting on 2 dates in each of 2 years*

Planting date and treatment	Emerged seedlings[1] per foot of row	Yield of roots per acre	Sucrose content of roots
	Number	*Tons*	*Percent*
March 18, 1967:			
No mulch	0.5	30.9	16.2
Mulch	2.6***	33.8*	16.3
March 18, 1968:			
No mulch	3.1	33.0	15.4
Mulch	3.8	31.7	15.8
April 18, 1967:			
No mulch	.6	24.3	16.6
Mulch	1.8**	27.3*	16.3
April 18, 1968:			
No mulch	4.9	26.6	16.2
Mulch	5.2	27.5	15.6

[1] Seedlings were counted 14 to 18 days after planting. Sufficient seedlings emerged later in the season to make a full stand after thinning in all plots.

* Significantly greater than the no-mulch treatment at the 5-percent level of probability.

** Significantly greater than the no-mulch treatment at the 1-percent level of probability.

*** Significantly greater than the no-mulch treatment at the 0.1-percent level of probability.

the mulch accelerated germination and allowed seedlings to become established before the limited moisture dissipated. In addition, the mulch may have retarded moisture loss. In 1968, mulch did not improve emergence.

TABLE 5.—*Effect of petroleum mulch on emergence of sugarbeets where tillage had reduced the moisture content of the soil*

Treatment	Emerged seedlings[1] per foot of row on—	
	April 10, 1967	April 3, 1968
	Number	*Number*
Tilled, not mulched	1.1a	1.2a
Not tilled, not mulched	2.3 b	3.1 b
Tilled, mulched	3.2 c	1.2a
Not tilled, mulched	4.0 d	3.8 b

[1] At each date, means not followed by the same letter are significantly different at the 5-percent level of probability, based on Duncan's multiple range test.

APPLICATION OF CYCLOATE BY SUBSURFACE LAYERING

In previous research (*3*), herbicidal activity of cycloate was greater when the herbicide was layered 1 or 2 inches deep in the soil than when it was incorporated. At the commonly used rate of 3 pounds per acre, sugarbeets were injured severly when cycloate was layered. The experiments described here were conducted to determine whether satisfactory selective weed control would result from subsurface layering of lower rates of cycloate.

Experimental Procedure

Cycloate was applied at 1, 2, and 3 pounds per acre in subsurface layers 1 or 2 inches deep. An untreated check and cycloate at 3 pounds per acre incorporated 3 inches deep as a standard were included for comparison. Each treatment was evaluated in two separate experiments in each of 2 years. In one experiment each year, the soil was too dry for sugarbeet germination at the time of application. In the other, the soil was moist.

The herbicide was applied and sugarbeets were planted in dry soil on April 6, 1967, and on April 1, 1968. The field was furrow-irrigated the day after planting. After irrigation, a seedbed was prepared and the treatments were repeated

in moist soil on April 17, 1967, and on April 6, 1968.

A randomized block design with four replicates was used for each experiment. Plots consisted of one row 14 feet long. Space between rows was 28 inches in 1967 and 22 inches in 1968.

The herbicide was applied in water at the rate of 230 g.p.a. as 12-inch bands centered on the rows. For the layered applications, trenches 12 inches wide and 1 or 2 inches deep (±⅛ inch) were dug with hand tools. All soil was placed on canvas. It was replaced and firmed after the herbicide had been sprayed in the trench. In the standard treatment, a hooded, 12-inch rotary tiller with L-shaped blades mounted on a garden tractor was used to incorporate the herbicide with the soil. A positive depth control device maintained a 3-inch depth of incorporation (±⅓ inch). After the cycloate applications, sugarbeets were seeded 1 inch deep.

Effects of the treatments were measured by counting the stand of sugarbeets, barnyardgrass, and common lambsquarters. Vigor of the sugarbeets was estimated visually. The sugarbeets were not thinned, and no yield data were collected.

Results and Discussion

Weed control and crop tolerance were good where cycloate at 3 pounds per acre was applied by the standard method of thorough incorporation to a depth of 3 inches. Barnyardgrass control varied from 91 to 100 percent, and common lambsquarters control ranged from 50 to 97 percent (84 percent average) (table 6). This method of application did not affect the stand of sugarbeets, and at most reduced vigor only moderately and temporarily (table 7).

These results corroborate a previous report that subsurface layering increased the herbicidal activity of cycloate (*3*). The 3 pounds per acre rate layered 1 inch deep provided outstanding weed control, but it reduced the stand of sugarbeets in 1967 and 1968 (moist soil) and injured the surviving plants severely (tables 6 and 7). When the rate was reduced to 2 pounds per acre, the subsurface layered application (1 inch deep) was usually similar to 3 pounds per acre incorporated with respect to both weed control and crop tolerance. Even at 1 pound per acre, weed control from cycloate layered 1 inch deep was sometimes similar to that from 3 pounds per acre incorporated.

There was definitely less activity from cycloate layered 2 inches deep than 1 inch. This difference is most evident in the data on control of common lambsquarters (table 6). Many common lambsquarters and sugarbeets were severely injured but not killed where cycloate at 2 or 3 pounds per acre was layered 2 inches deep. Both species tended to recover from this injury.

TABLE 6.—*Control of 2 species of weeds by cycloate applied at 3 rates by 2 different methods in moist and dry soil in 2 years*

Rate of cycloate per acre, pounds	Application method and depth	Reduction in stand of—							
		Barnyardgrass when cycloate was applied to—				Common lambsquarters when cycloate was applied to—			
		Moist soil in—		Dry soil in—		Moist soil in—		Dry soil in—	
		1967	1968	1967	1968	1967	1968	1967	1968
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
	Layered:								
1	1 inch	97	100	99	45	60	81	96	19
	2 inches	86	90	99	64	17	50	15	0
2	1 inch	99	100	96	91	89	100	89	60
	2 inches	86	100	100	82	9	81	71	41
3	1 inch	99	100	100	100	94	100	99	87
	2 inches	80	100	99	91	14	100	81	66
3	Incorporated, 3 inches	98	100	99	91	96	97	94	50

TABLE 7.—*Response of sugarbeets to cycloate applied at 3 rates by 2 methods in moist and dry soil in 2 years*

Rate of cycloate per acre, pounds	Application method and depth	Stand[1] when cycloate was applied to—				Vigor[2] when cycloate was applied to—			
		Moist soil in—		Dry soil in—		Moist soil in—		Dry soil in—	
		1967	1968	1967	1968	1967	1968	1967	1968
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
	Layered:								
1	1 inch	93	138	92	131	73	95	83	98
	2 inches	104	111	102	131	88	99	90	90
2	1 inch	98	111	80	146	70	96	70	93
	2 inches	102	59	102	85	75	91	70	89
3	1 inch	69	84	57	154	53	96	48	95
	2 inches	89	105	88	146	65	88	50	98
3	Incorporated, 3 inches	103	108	119	146	73	99	85	99

[1] Stand relative to untreated.

[2] Vigor estimated in late May or early June without regard for stand.

APPLICATION OF CYCLOATE BY SUBSURFACE LINE INJECTION

Workers in Mississippi and Georgia found that certain herbicides related to cycloate were effective when injected into the soil in lines ½ to 4 inches deep (*4, 6, 8*). This method was attractive for applying cycloate in sugarbeets because it did not involve mixing the soil and therefore should not cause excessive moisture loss. Results from preliminary trials using this method in 1966 by personnel of the Utah-Idaho Sugar Company[2] and by the author were favorable. Therefore, several experiments concerning the application of cycloate by injection were conducted in 1967–69.

Depth and Spacing of Injected Lines of Cycloate

Experiments were conducted in 1967 and 1968 to determine crop tolerance and weed control from injected cycloate as influenced by depth and spacing of the injectors in the soil.

Experimental Procedure

An adjustable injector[3] was used to inject two lines of cycloate, the arrangements of which are shown in table 8. Sugarbeets were seeded with a one-row planter mounted integrally with the injector on the toolbar of the tractor. Seed was planted 1 inch deep in the center of the space between the two injected lines at the same time the herbicide was applied. Cycloate was applied at the rate of 3 pounds per acre in 36 g.p.a. of water (calculated on the basis that a 5-inch band of soil was treated, regardless of injector spacing).

In addition to the six injected treatments, an untreated check and cycloate at 3 pounds per acre incorporated 3 inches deep as a standard were included. Each plot consisted of one row of sugarbeets 14 feet long. The experimental design was a randomized complete block with four replications.

The treatments were applied in April 1967 on dry soil and followed by furrow irrigation the next day. They were applied in April 1968 on soil moist from recent irrigation.

The response of sugarbeets and weeds was measured each year by counting the stand of sugarbeets, barnyardgrass, common lambsquarters, and nightshade and by visually estimating the vigor of the sugarbeets.

Results and Discussion

All applications of cycloate controlled 93 to 100 percent of the barnyardgrass (table 8). Some treatments did not control lambsquarters and nightshade effectively.

[2] Francom, Farrel. 1966. Private communication.

[3] Specially built for this work by Farrel Francom of the Utah-Idaho Sugar Company, Moses Lake, Wash.

TABLE 8.—*Weed control from cycloate at 3 lb./A. injected into the soil in 2 lines at various depths and spacings and incorporated 3 inches deep*

Application method and depth of injection	Distance between injectors, inches	Reduction in stand of—			
		Barnyardgrass[1] in 1967	Lambsquarters[2] in—		Nightshade[3] in 1967
			1967	1968	
Injected:		*Percent*	*Percent*	*Percent*	*Percent*
2 inches	2	99	90	88	83
Do	2½	100	94	81	89
Do	3	100	82	81	78
Do	4	93	21	68	28
1 inch	2½	99	65	29	67
3 inches	2½	100	68	70	61
Incorporated, 3 inches	---	99	94	97	82

[1] Average stand per 10 feet of row in the untreated rows was 82.

[2] Average stand per 10 feet of row in the untreated rows was 62 in 1967 and 69 in 1968.

[3] Average stand per 10 feet of row in the untreated rows was 18.

The best selective weed control resulted when the injectors were set 2 inches deep and 2½ inches apart. Except for less control of common lambsquarters in 1968, weed control from cycloate injected 2 inches deep and 2½ inches apart was as good as that from incorporated cycloate (table 8). Weeds that survived were usually directly within the sugarbeet row. Evidently, the herbicide did not always spread uniformly to the center of the row from the injected lines. Sugarbeets were injured somewhat more severely when cycloate was injected 2 inches deep and 2½ inches apart than when it was incorporated (table 9).

Cycloate applied at the closest spacing, 2 inches, killed some sugarbeets and reduced the vigor of those that survived. No weeds survived within the rows, but a few were found on the outside edges of the 4-inch bands in which weeds were counted.

When the spacing was widened to 4 inches, many weeds survived directly in the rows (table 8). There was also less effect on the sugarbeets. Obviously, the farther apart the injectors were set, the less herbicide reached the center of the sugarbeet row.

Where the injectors were 2½ inches apart, but the depth was only 1 inch, many common lambsquarters and nightshade survived directly within the sugarbeet rows (table 8). As the cycloate moved upward and outward from the injected lines, it probably reached the soil surface before reaching the row. Thus, an area directly in the row was not adequately protected.

TABLE 9.—*Response of sugarbeets to cycloate at 3 lb./A. injected into the soil in 2 lines at various depths and spacings and incorporated 3 inches deep*

Application method and depth of injection	Distance between injectors,[1] inches	Emerged seedlings per foot of row in—		Vigor[2] relative to untreated in 1968
		1967	1968	
Injected:		*Number*	*Number*	*Percent*
2 inches	2	4.8	2.9	70
Do	2½	5.8	4.0	63
Do	3	5.0	3.2	60
Do	4	6.0	4.0	89
1 inch	2½	6.1	4.3	76
3 inches	2½	5.3	3.1	66
Incorporated, 3 inches	--	--	3.8	84
Untreated check	--	5.8	4.6	100

[1] The sugarbeet seeds were planted in the center of space between the lines of injection.

[2] Vigor estimated on May 28 without regard for stand.

Broadleaf weed control was less satisfactory from injections 3 inches deep than from those 2 inches deep.

Position of Sugarbeet Seed Ralative to Injected Cycloate

In 1967, an experiment was conducted to determine the effect on sugarbeets of the location of the seeds in the soil relative to the injected lines of cycloate.

Experimental Procedure

Cycloate at 3 pounds per acre was injected at 2- or 3-inch depths in two lines 2½ inches apart. Rows of sugarbeets were seeded by hand in eight different positions relative to the injected lines. The following diagram of an end view of the rows of seed and lines of herbicide shows the arrangement.

A— 1 2 3 4 5 6 7 8
B— ————————————————
C— o o o o o o o o
D— o o

A = Position numbers
B = Soil surface
C = Rows of sugarbeet seed 1 inch deep and 1 inch apart.
D = Cycloate injected in two lines 2½ inches apart and 2 or 3 inches deep.

In each of four replicated plots, 72 seeds were planted by hand in each position within a distance of 60 inches. Congestion was avoided by planting the seeds in positions 1, 3, 5, and 7 in separate subplots from positions 2, 4, 6, and 8.

The soil was too dry for uniform emergence of the sugarbeets. Therefore, the plot area was irrigated from furrows on each side of the seeded areas the day after application and seeding.

Response of the sugarbeets was evaluated by counting the emerged seedlings and observing their vigor.

Results and Discussion

The response of sugarbeets to injected cycloate varied greatly in relation to the location of the planted seeds. Where the seeds were planted directly over one of the lines (position 4) or between the lines but only ½ inch from one of them (position 6) the sugarbeets were injured severely and many were killed.

Injury was more severe when the depth of injection was 2 inches than when it was 3 inches.

When the seeds were placed ½ inch outside the pair of injected lines of cycloate (position 7), the stand was not affected. Furthermore, plants from seeds located ½ inch outside the lines were injured less than those from seeds located ½ inch inside the lines. Probably water from the furrow irrigation tended to move the cycloate toward position 6 and away from position 7. Such movement has been demonstrated under greenhouse conditions.[4]

[4] Stanger, E. C., Jr. The lateral movement of cycloate as affected by three soil types and four methods of irrigation when applied to the soil by injection incorporation. 1970. (Unpublished master's thesis, Oregon State Univ.)

Emergence was not affected in position 5 (between the two lines of cycloate—1 inch from one and 1½ inches from the other), and seedling effects were limited to the temporary symptoms typically caused by cycloate. These results indicate the need for planting sugarbeet seeds precisely between the two injected lines to avoid crop injury.

Volume of Carrier and Rates of Injected Cycloate

Experiments were conducted in 1968 and 1969 to determine the effect on sugarbeets and weeds of cycloate injected at different rates and in different volumes of water.

Experimental Procedure

Cycloate was injected in two lines 2 inches deep and 2¼ inches apart with a Francom Injector. Concurrently, sugarbeets were seeded 1 inch deep midway between the lines. Cycloate was applied at 3 pounds per acre in 9, 18, 36, 72, and 144 g.p.a. of water.[5] In addition, rates of 2, 4, 6, 9, and 12 pounds per acre were applied in 36 g.p.a. of water. The treatments were replicated four times. The plots contained three rows of sugarbeets 25 feet long and spaced 22 inches apart. The treated plots were bordered on each side by an untreated row.

Applications were made in late

[5] Calculated on the basis of the area actually treated, considered to be a band 4½ inches wide.

March each year. In 1968, the plot area was furrow-irrigated in early April to provide adequate moisture for germination. In 1969, preemergence irrigation was unnecessary because favorable rains fell before and shortly after planting.

Effects of the treatments were evaluated by counting weeds and sugarbeets in the treated rows and in adjacent untreated rows, and by estimating the vigor of the sugarbeets as a percentage of that in the untreated rows before weeds were large enough to suppress the growth of crop plants. Yields of sugarbeets were not measured.

Results and Discussion

When cycloate at 3 pounds per acre was applied in volumes of water that ranged from 18 to 144 g.p.a., all the limited population of barnyardgrass and 76 to 94 percent of common lambsquarters were controlled (table 10). In 1969, control of common lambsquarters tended to be less when the cycloate was applied in 9 g.p.a. of water.

Cycloate at 2 pounds per acre controlled common lambsquarters effectively in 1968, but it controlled only 55 percent of this species in 1969.

No rate of cycloate affected the stand of sugarbeets significantly in 1969, but many sugarbeets were killed at 9 and 12 pounds per acre and some were killed at 6 pounds per acre in 1968. Some sugarbeets in all cycloate-treated plots displayed symptoms each year. This was reflected in reduced vigor ratings (table 10). Injury was severe at the 9 and 12 pounds per acre rates. Nevertheless, symptoms were temporary and had disappeared in all treated plots by late May, except for a general reduction in size in plots treated at the higher rates.

These results demonstrated that sugarbeets tolerate cycloate injected at 3 pounds per acre and that there is an adequate margin of safety at this rate. Furthermore, cycloate is equally active whether applied in low or high volumes of water.

RATES OF CYCLOATE, 1968

Several rates of cycloate had been evaluated for their effects on sugarbeets and annual weeds in 1965, 1966, and 1967 (*2*). In 1968, the same type of work was repeated to provide additional data.

Experimental Procedure

On plots that consisted of four rows 30 feet long, cycloate at 0, 3, 4, and 6 pounds per acre was broadcast as a spray in 50 gallons of water per acre. The soil was thoroughly mixed to a depth of 3 inches with a rotary tiller within 20 minutes after application. The cycloate treatments plus an untreated check were replicated four times in a randomized block design.

TABLE 10.—*Response of sugarbeets and common lambsquarters to cycloate injected into the soil at several rates and in several volumes of water when sugarbeets were planted in late March*

Rate of cycloate per acre,[1] pounds	Volume of water per acre, gallons	Sugarbeet stand relative to untreated in—		Sugarbeet vigor[2] relative to untreated in—		Reduction in stand of common lambsquarters[3] in—	
		1968	1969	1968	1969	1968	1969
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
2	36	89	101	97	98	88	55
3	36	85	117	95	97	93	76
4	36	90	121	95	100	89	83
6	36	77	111	90	93	96	85
9	36	36	105	77	92	97	88
12	36	20	95	83	72	97	92
3	9	99	107	94	98	86	67
3	18	86	114	88	95	94	87
3	72	113	127	97	99	88	76
3	144	112	127	97	98	89	80

[1] Cycloate injected in two lines, 2 inches deep and 2¼ inches apart. Rates are based on treated area, assumed to be 4½ inches wide.
[2] Vigor estimated in late May without regard for stand.
[3] Average stand in untreated rows was 82 and 560 per 60 feet of row in 1968 and 1969, respectively.

Soil moisture was marginal when the herbicide was applied on March 18. Consequently, early emergence was uneven. The field was furrow-irrigated on April 5 to promote uniform emergence.

Sugarbeet seedlings were counted in 20 feet of each of the two center rows on May 6. Sugarbeet vigor was estimated visually on May 27.

Weed control was evaluated by counting stands of nightshade, common lambsquarter, and barnyardgrass in early May. Because many barnyardgrass seedlings frequently emerge and subsequently die in cycloate-treated soil, evaluation of control of barnyardgrass was based on uninjured seedlings counted 2 weeks after emergence when injured and noninjured plants could be differentiated.

After control had been evaluated, the weeds were removed from all plots, including the untreated checks, and the sugarbeets were thinned to a stand of approximately one plant per foot of row. Weeds that emerged subsequently were removed by hand to keep the crop free of weeds until harvest. The sugarbeets in 25 feet of the two center rows were harvested in October. The number of plants and the weight of roots that had been freed of excess soil were determined. A representative sample of the roots from each plot was analyzed for sucrose content.

Results and Discussion

The three rates of cycloate controlled 81 to 100 percent of the weeds (table 11). Abundant barnyardgrass seedlings emerged in all treated plots. Most of these were lethally injured.

TABLE 11.—*Weed control from 3 rates of cycloate in 1968*

Rate of cycloate per acre, pounds	Reduction in stand of—		
	Common lambsquarters[1]	Nightshade[1]	Barnyardgrass[2]
	Percent	*Percent*	*Percent*
3	92	81	92
4	93	94	100
6	96	100	100

[1] Based on numbers of these weeds in the treated rows compared with those in untreated rows on May 6. Average stands of common lambsquarters and nightshade in untreated rows were, respectively, 134 and 16 plants per 20 feet of each of two rows.

[2] Based on numbers of uninjured barnyardgrass in the treated rows compared with those in untreated rows on May 22. Average stand in untreated rows was 121 per 20 feet of each of two rows.

Symptoms of cycloate injury to sugarbeets were observed at all rates of application. The stand was not reduced significantly at 3 pounds per acre and injury was mild. At 4 and 6 pounds per acre, the stand was significantly reduced and the surviving seedlings were severely retarded (table 12). However, after thinning, the stand was adequate and the sugarbeets recovered. Yields and sucrose content of roots were not significantly affected by any rate of cycloate (table 12).

TABLE 12.—*Response of sugarbeets to several rates of cycloate applied broadcast and incorporated 3 inches deep before planting on March 18, 1968*

Rate of cycloate per acre, pounds	Emerged seedlings per foot of row	Vigor[1] relative to untreated	Yield per acre	Sucrose content of roots
	Number	*Percent*	*Tons*	*Percent*
3	2.9	89	32.9	16.1
4	2.4	66	27.5	15.8
2	2.0	59	27.8	16.1
None	3.5	100	30.2	16.1
L.S.D. (0.05)	.7	--	NS	NS
L.S.D. (0.01)	.9	--	NS	NS

[1] Vigor estimated on May 27 without regard for stand.

METHODS OF APPLICATION, 1969

An experiment was conducted in 1969 to compare the response of sugarbeets and weeds to one rate of cycloate applied by three practical methods.

Experimental Procedure

Cycloate at 3 pounds per acre was applied by the following three methods on March 25: (a) sprayed broadcast and incorporated to a depth of 3 inches with a power-driven rotary tiller; (b) sprayed as 7-inch bands and incorporated to a depth of 3 inches by hooded, power-driven tillers of the same width; and, (c) injected in two lines 2¼ inches apart and 2 inches deep.

For the broadcast application, the soil was tilled and packed and sugarbeets were planted as separate operations within 2 hours after spraying. For the band-incorporated application, implements for spraying, tilling, packing, and planting were mounted on one tractor and all operations proceeded simultaneously. Where cycloate was injected, injectors and planters were mounted on one tractor. Sugarbeet seed was planted directly between the two lines of injection as the herbicide was applied.

Treatments were made on March 24 and 25 in plots four rows wide and 40 feet long. The treatments and an untreated check were replicated four times in a randomized block design.

Common lambsquarters and barnyardgrass were abundant in the plots. Percentage control of these species was estimated on May 2 and 12. Sugarbeet plants were counted in 60 feet of row in each plot in late April, and their vigor was estimated visually as a per-

centage of that of the untreated checks on May 2 and 12.

Treated and untreated plots were weeded and thinned to a stand of approximately one plant per foot of row in May. Weeds that emerged subsequently were removed by hand. The sugarbeets in 30 feet of the two center rows were harvested in October. Numbers of plants and weights of roots that had been freed of excess soil were determinded. A representative sample of the roots from each plot was analyzed for sucrose content.

Results and Discussion

Cycloate at 3 pounds per acre controlled 85 to 94 percent of the common lambsquarters and 96 to 100 percent of the barnyardgrass when applied by different methods (table 13). Injected cycloate controlled common lambsquarters somewhat less than did incorporated cycloate. Most of the common lambsquarters that survived the injected treatment were located directly in the sugarbeet row. Evidently, cycloate sometimes failed to diffuse uniformly across the row from the injected lines.

Soil moisture was favorable for sugarbeet germination; hence, there were no detrimental effects of tillage on emergence. None of the cycloate treatments affected sugarbeet stands. On May 2, mild injury symptoms were evident in the sugarbeets from all treatments (table 14). By May 12, symptoms were less evident. After thinning, treated and untreated sugarbeets looked similar.

The cycloate-treated sugarbeets yielded more than 30 tons per acre, which is excellent production. Although the difference was not significant at the 5-percent level of probability, the treated sugarbeets tended to outyield the untreated ones. Weeds were taller than the sugarbeets when the sugarbeets were thinned and weeded. Competition from the weeds in the untreated checks before they were removed may have depressed yields to some extent.

TABLE 13.—*Weed control from cycloate at 3 lb./A. applied by different methods in 1969*

Application method	Reduction in stand[1] of—	
	Common lambsquarters	Barnyardgrass
	Percent	*Percent*
Broadcast incorporated	94	100
Band incorporated	90	98
Band injected	85	96

[1] Average of two visual estimates of reduction in stand. Average stand in untreated plots was 835 lambsquarters and 126 barnyardgrass in 60 feet of row.

TABLE 14.—*Response of sugarbeets to cycloate at 3 lb./A. applied by different methods on March 25, 1969*

Application method	Seedlings per foot of row	Vigor[1] relative to untreated on—		Yield of roots per acre	Sucrose content of roots
		May 2	May 12		
	Number	*Percent*	*Percent*	*Tons*	*Percent*
Broadcast incorporated	2.3	86	95	35.2	16.5
Band incorporated	2.5	86	91	32.4	16.4
Band injected	2.7	90	96	33.2	16.2
Untreated check	2.5	100	100	27.7	16.4
L.S.D. (0.05)	NS	--	--	NS	NS

[1] Vigor estimated without regard for stand.

GENERAL DISCUSSION AND CONCLUSIONS

The major annual weeds in sugarbeets before thinning in Washington are barnyardgrass, common lambsquarters, nightshade, and, to a lesser extent, redroot pigweed. During 6 years of evaluation (3 years covered in this report and others in previous reports (*2*, *3*), cycloate applied to the soil at 3 pounds per acre controlled these weeds without permanently harming the sugarbeets. Cycloate was effective when applied under a wide range of conditions.

Barnyardgrass was very susceptible to cycloate at 3 pounds per acre; such a treatment usually controlled 95 to 100 percent of this weed. Broadleaf weeds were less susceptible. Common lambsquarters, which was abundant in all experiments, was seldom controlled completely; usually 10 to 25 percent of the population survived. Increasing the rate of cycloate increased the percentage control. However, even rates as high as 6 to 12 pounds per acre sometimes failed to control all the common lambsquarters.

The application of more than 3 pounds per acre of cycloate on sandy loams does not appear to be a practical method for achieving complete control of common lambsquarters and other broadleaf weeds. Secondary control measures are needed for broadleaf weeds that escape control by cycloate. In unreported research conducted by the author in 1968 and 1969, methyl *m*-hydroxycarbanilate *m*-methylcarbanilate (phenmedipham) at 1 pound per acre applied postemergence effectively controlled those common lambsquarters and nightshade that survived the effect of cycloate. A program including cycloate applied preplanting followed by phenmedipham applied postemergence effectively controlled early-season weeds so that sugarbeets were essentially free of weeds at thinning time.

At 3 pounds per acre, cycloate incorporated or injected (2 inches

deep in lines at least 1 inch from the seed row) never reduced stands of sugarbeets below levels acceptable for thinning. However, temporary symptoms of injury such as deep green color, brittle leaves, and reduced size were often apparent in the cotyledonary and first true leaf stages. Such symptoms increased as the rate of cycloate increased. Sugarbeets stands sometimes were not affected by rates as high as 9 pounds per acre, but in one instance the stand was reduced by 4 pounds per acre. Under conditions similar to those under which these experiments were conducted, 3 pounds per acre appears to be the most satisfactory rate of cycloate for selective weed control in sugarbeets.

When cycloate killed sugarbeets, they died before or very soon after emergence. Even though severely injured, sugarbeets that survived for 1 week after emergence usually recovered fully. When sugarbeets were severely injured, symptoms occurred early enough so that sugarbeets could have been replanted successfully.

Cycloate mixed thoroughly with the surface 3 inches of soil controlled weeds consistently. Unfortunately, mixing the soil often dried the seedbed and inhibited germination, particularly when soil moisture was marginal. Less seedbed moisture was lost when cycloate was injected because the soil was not mixed. Cycloate injected in two lines 2 inches deep and 2¼ or 2½ inches apart controlled weeds in a band 4 to 5 inches wide. Preservation of seedbed moisture, reduction in amount of herbicide required, and ease of operation are advantages of the injection method for applying cycloate.

Weed control from injection of cycloate has tended to be somewhat less than from incorporation of cycloate. Usually, neither method controls weeds completely, so weeds that escape must be controlled by a second method. Therefore, the slight reduction in weed control with the injection method is not serious.

Successful injection demands precise application. The seed must be planted directly between the two lines of injected cycloate. Seeds more than ½ inch from center can be severely injured. However, crop tolerance was satisfactory when the injector and seeder were properly alined.

Layering cycloate 1 inch deep also resulted in effective weed control. When layered, 3 pounds per acre sometimes severely injured or killed sugarbeets. Sugarbeets tolerated 2 pounds per acre layered 1 inch deep, and this rate controlled weeds effectively. Subsurface layering evidently increased the activity of cycloate; and, hence, it might be used as an alternate method of applying reduced rates for weed control.

The application of cycloate at 3 pounds per acre by either incorporation or subsurface injection appeared safe and effective for control of a high percentage of those weeds in sugarbeets that emerge before thinning.

SUMMARY

Experiments were conducted during 1967–69 on weed control in sugarbeets (*Beta vulgaris* L.) with *S*-ethyl *N*-ethylthiocyclohexanecarbamate (cycloate). Cycloate at 3 pounds per acre, mixed thoroughly with the soil to a depth of 3 inches or injected in two lines (one on each side of the row) 2 inches deep and 2¼ or 2½ inches apart, consistently controlled 95 to 100 percent of barnyardgrass (*Echinochloa crusgalli* (L.) Beauv.) and 75 to 90 percent of common lambsquarters (*Chenopodium album* L.), nightshade (*Solanum sarachoides* Sendt.), and redroot pigweed (*Amaranthus retroflexus* L.). Higher rates of cycloate increased the control of broadleaf weeds, but usually did not eliminate them.

In each of 2 years, cycloate at 3 pounds per acre was incorporated 3 inches deep before planting sugarbeets on five dates from March 6 to May 3. At each date, cycloate controlled the above weeds and did not injure sugarbeets significantly. When soil moisture was marginal at the time of application, thorough tillage to incorporate cycloate sometimes inhibited sugarbeets emergence by depleting seedbed moisture.

Sugarbeets tolerated cycloate applied by subsurface injection in two lines, provided the seeds were centered between the two lines. If seeds were planted within ½ inch of one of the lines of cycloate, the sugarbeets were killed or severely injured. Weed control was sometimes slightly less effective when cycloate was injected than when incorporated, but it was satisfactory.

Response of weeds and sugarbeets was similar where cycloate at 3 pounds per acre was injected in volumes of water from 18 to 144 g.p.a. (based on the area actually treated in bands 4½ inches wide). Weed control was slightly less effective when the volume of water was reduced to 9 g.p.a.

Herbicidal effects of cycloate were often greater when it was applied as a subsurface layer 1 inch deep than when it was incorporated. A rate of 3 pounds per acre, applied as a layer 1 inch deep, controlled weeds well, but sometimes it injured the sugarbeets severely. Performance of a rate of 2 pounds per acre layered 1 inch deep was similar to that of 3 pounds per acre incorporated.

In 2 years of evaluation, weed control was ineffective where a 7-inch band of petroleum mulch was applied over surface-applied cycloate. Petroleum mulch did not substitute for incorporation of cycloate. In 1 of 2 years, the mulch accelerated sugarbeet growth and increased yields significantly.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1971 O—422-408

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