Yield Comparisons from Chemically and Hand-Weeded Sugar Beets Under Several Watergrass Conditions in California

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Watergrass (*Echinochloa crusgalli*), an annual grass which does not germinate at low temperatures and is killed by frost, is a common weed in the Central Valley of California from May to October. Since, in watergrass areas, most sugar beets are planted in January, February, and March, watergrass does not usually become a problem until after beets are thinned and off to a good start. Watergrass in these fields thus becomes serious in summer after beet foliage development prohibits efficient machine cultivation.

In recent years, a number of trials have been conducted in California in an attempt to control annual grasses with chemicals — especially watergrass in established sugar beets. One material, sodium 2, 2 dichloropropionic acid (dalapon), has offered considerable promise in that it has reportedly been applied directly to beets at rates which will kill grasses without showing serious injury to beets (1) (3)[2]. Although sugar beets are tolerant to dalapon, yield reductions have occurred where the material has been applied directly to sugar beet foliage, especially when the material has been used at temperatures above 70° F. (2). The adverse influence of dalapon on yields suggests directed or shielded sprays be used under California watergrass conditions. Southwick *et al.* (2) report a cooperative experiment with Loomis at the University of California, Davis, showing less toxicity with directed sprays than with over-all sprays applied to beets two months after thinning.

The reported effectiveness of dalapon in controlling annual grasses in sugar beets without excessive damage to the crop suggested possible application to the watergrass problem in sugar beets under California's Central Valley conditions.

Since 1955, a series of experiments have been conducted with the following objectives:

(1) To determine the quantitative effect of watergrass competition on sugar beet yields under actual field conditions.
(2) To improve sugar beet yields by hand hoeing and by use of dalapon both by directed and over-all sprays.
(3) To compare the effectiveness of single and repeated applications on the above treatments.

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[2] Numbers in parentheses refer to literature cited.

(4) To test sugar beet varieties for possible tolerance to dalapon.

Methods and Materials

Four experiments were conducted in order to compare grass control effectiveness of 5 or 6 treatments under a wide range of watergrass conditions. A randomized block design with 5 or 6 replications was used with individual plots consisting of 4 (single or double row) beds 60 or 80 feet long. Yields were obtained by hand harvesting the center 2 beds of each plot. A small trailer-mounted sprayer was developed to apply both directed and over-all applications of chemical.

Hoeing as required for complete control, and an uncontrolled grass check were included in all comparisons. Spray treatments were applied at least once when beet foliage was 8 to 16 inches high and most of the watergrass about 3 to 6 inches in height but with sizes ranging from newly emerged seedlings to small amounts in the heading stage. All applications were made in midsummer with temperatures ranging from 80 to 95° F. Dalapon (85 percent sodium salt) was applied in thirty to fifty gallons of water per acre at 30 p.s.i. gage. Ground speed varied from ½ to 1½ m.p.m. and fan type Teejet nozzles (80° angle), numbers 8001 and 8002 were used to obtain desired coverage and rates. In the case of broadcast applications, nozzles were arranged on the boom for full coverage. For directed applications, shields were designed to permit full ground coverage around the crown of the beet and in the row center as well as the entire area between rows. In actual field practice some of the older, lower leaves of beets received some spray.

Observations and Results

Severe Watergrass Infestation

The first experiment was established on beets expected to be severely infested with watergrass although the field was relatively weed free when selected for the experiment. On May 28, 1957, the plots designated for hand weed control were hoed for the first time.

By mid-June, newly emerged watergrass was thick in the irrigation furrows and on the bed centers. Grass in the beet rows (untouched by cultivation) was now about six inches high. The grass in the hoed plots was again removed on June 15.

The dalapon treatments were applied on July 11 at five pounds per acre. At this time the grass ranged in size from newly emerged seedlings to grass in full bloom with most grass ranging from four to six inches high and beet foliage about 14 inches high. Grass was growing actively with adequate moisture and

temperatures were about 90° F. when the material was applied. Coverage and wetting of the grass appeared to be excellent, but the application might have been more effective had it been possible to have applied the material a week earlier.

Dalapon plots could easily be distinguished by dry appearance and purplish color of grass by the end of July. The hoeing treatment, while outstanding by comparison with all other treatments, showed solid grass coverage nearly as high as the foliage. The third and final hoeing was completed on August 20. Observations in late August showed the dalapon holding older grass in fair control with the directed application showing only slightly less control than the over-all application, however, newly emerged grass was apparent in all dalapon treated plots.

The plot was harvested on October 15. The treatments used, cost, degree of weed control, yield, sucrose content, sugar per acre, and stand of the plot are shown in Table 1. It is apparent that uncontrolled watergrass decreased yields from 28.4 to 16.3 tons per acre. Control of watergrass by three hoeings was good but cost approximately $90.00 an acre. Control of watergrass by dalapon with shields was about equal to the over-all application but neither treatment was significantly better in yield than the check. The July 11 application controlled most of the grass present at the time of application, except for large grass in bloom, but provided no control over grass emerging after treatment.

Table 1.—Sugar Beet Yields Under Severe Watergrass Conditions as Influenced by Hand-Hoeing, Cultivation, and Post-Emergence Chemical. Beets Were Planted in February, Near Firebaugh, California, and Dalapon Was Applied on July 11[1].

Treatment	Rate	Approx. Cost	% Grass Control at Harvest[3]	Gross Sugar Tons/Acre	Beets Tons/Acre	Sucrose %	Beet Stand at Harvest (100′ Row)
Hoeing[2]	3 Times	$90	88	4.28	28.4	15.1	156
Dalapon (Directed)	5 Lbs.	$ 9	42	2.64	17.9	14.7	128
Dalapon (Over)	5 Lbs.	$ 7	44	2.53	17.4	14.6	131
Cultivation	2 Times	$ 4	25	2.48	16.5	15.0	145
None			20	2.40	16.3	14.6	123
Mean				2.87	19.3	14.8	137
LSD P = .05				0.54	3.3	NS	
LSD P = .01				0.74	4.5	NS	

[1] Beet foliage varied from 10 to 14" in height and the majority of watergrass was 5 inches in height when treated. Some leaf burn was observed on dalapon treated beets.

[2] May 28, June 15, August 20.

[3] Percent grass control is based on quantitative visual percentage estimate with 0% indicating solid grass coverage and no beets visible through the grass.

Moderate Watergrass Infestation

Another experiment was established July 19, 1957, on beets planted in late March and thinned in late May. Beet foliage was approximately 15 inches high with an intermediate infestation of watergrass present. Watergrass ranged in size from 2 inches to 10 inches, with about 10 percent beginning to bloom. Most of the grass present was in the beet row (30" single rows) and on the bed shoulders with only small amounts present in the furrows.

Hoeing was completed on July 20. Three dalapon treatments were established on July 19, one over-all rate at 3.2 pounds per acre, a directed rate at 3.2 pounds, and a heavier directed rate of 4.7 pounds per acre.

Observations taken on August 1 showed considerable tall grass (30 inches high) in the checks and very little response to dalapon. By August 15, however, some leaf burn was noticed on the over-all application and grass stunting and die-back was noticeable, even on the lower dalapon rates. By harvest, most grass was nearly 5 feet high and the infestation was more severe than had been expected from notes taken in mid-July. Checks showed heavy grass concentrations between beets in the row and on the shoulders of the beds with some grass in the furrows. Plots treated with dalapon showed nearly as much grass as the check treatments. The vigor of the grass was reduced by all applications, however. The results of this test are shown in Table 2.

Table 2.—Sugar Beet Yields Under Moderate Watergrass Conditions as Influenced by Hand-Hoeing, Directed and Over-Foliage Sprays of Dalapon. Beets Were Planted in Late March Near Yuba City, California, and Hoeing and Chemical Treatments[1] Were Applied on July 19-20, 1957.

Treatment	Rate	Approx. Cost	% Grass Control at Harvest[2]	Gross Sugar Tons/Acre	Beets Tons/Acre	Sucrose %	Beet Stand at Harvest (100′ Row)
Hoeing	1 Time	$12	90	3.92	26.2	15.2	170
Dalapon (Directed)	3.5 Lbs.	$ 7	50	3.24	21.6	15.1	152
Dalapon (Over)	3.5 Lbs.	$ 5	50	3.22	21.8	14.8	184
Dalapon (Directed)	4.7 Lbs.	$ 9	50	3.03	19.8	15.3	140
None			40	3.01	19.9	15.2	140
Mean				3.28	21.9	15.1	157
LSD P = .05				0.62	4.6	NS	
LSD P = .01				NS	NS	NS	

[1] Beet foliage averaged 15" in height and watergrass ranged from newly emerged to near maturity when treated. Leaf burn was observed on dalapon treatments.

[2] Percent grass control is based on quantitative visual percentage estimate with 0% indicating solid grass coverage with no beets visible through the grass.

One hoeing at an estimated cost of $12.00 provided excellent grass control for the season and significantly increased tonnage over all other treatments. Dalapon treated plots showed some yield increase over the check but this increase was not significant at the 5% level of probability.

Sparse Watergrass Infestation

Another experiment was established on a field planted May 1 and thinned June 15, 1957. The field was selected as being typical of a light watergrass infestation on a late planting. The furrows were clean and the grass was small, three to six inches high on beets having foliage 10 inches high.

The soil was fairly dry, but both beets and grass showed good color and appeared to be growing actively. One over-all and two directed applications of dalapon were made on July 24. Rates were increased to 6.5 lbs./acre on this experiment to attempt a wider range of control, and one high rate (9.6 lbs./acre) was included to determine if some pre-emergence grass control might be obtained in the furrows later in the season. Directed applications overlapped around the crown as before, but a larger percentage of the lower leaves received material because of the small beet size. The hoeing treatment was completed at an estimated cost of $7.00 per acre.

By August 8, leaf burn and stunting was evident on the over-all treated plots and on the outer leaves of the beets receiving directed applications. The center leaves of the shielded beets were free from injury symptoms except for some burn present on the center leaves at the highest rate of dalapon. By late August, all sprayed treatments were clearly defined. Grass was severely stunted and dying, the hoed plots were clean, but grass competition in the check plots was less than had been expected. Late emerging watergrass did not develop as expected and the experimental area remained much the same until harvest in November with only scattered grass showing above the foliage. Only the check area showed much tall watergrass and it was concentrated mainly in the beet row.

Harvest results obtained on November 6, showed that the grass problem was not severe for any treatment (Table 3). A single hoeing again produced the cleanest beets having the highest yield. Yields were reduced in the dalapon treatments largely from beet injury; however, the treatments were satisfactory in controlling watergrass. The directed treatments showed effective grass control with lower yield reductions than the over-all treatment although none of the differences reached statistical significance at the 5% level.

Table 3.—Sugar Beet Yields Under Sparse Watergrass Conditions as Influenced by Hand-Hoeing, Directed and Over-Foliage Sprays of Dalapon. Beets Were Planted Near Tracy, California, in May and Hoeing and Chemical Treatments[1] Were Applied on July 25-26, 1957.

Treatment	Rate	Approx. Cost	% Grass Control at Harvest[2]	Gross Sugar Tons/Acre	Beets Tons/Acre	Sucrose %	Beet Stand at Harvest (100′ Row)
Hoeing	1 Time	$ 7	95	3.01	19.3	15.6	180
None			75	2.72	17.4	15.6	164
Dalapon (Directed)	9.5 Lbs.	$15	85	2.64	17.5	15.1	178
Dalapon (Directed)	6.5 Lbs.	$11	85	2.54	16.7	15.1	168
Dalapon (Over)	6.5 Lbs.	$ 9	80	2.37	15.4	15.5	174
Mean				2.66	17.3	15.4	173
LSD P = .05				NS	NS	NS	

[1] Beet foliage averaged 10" in height and watergrass ranged between 3 and 6" in height. Leaf burn was observed on dalapon treatments.

[2] Percent grass control was based on quantitative visual percentage estimate with 0% indicating solid grass coverage with no beets visible through the grass.

The experiments conducted in 1957 indicated clearly that one application of dalapon was not sufficient for seasonal control of watergrass under severe conditions. Single and repeat applications of the hoe should be compared with directed sprays of dalapon in order to obtain more economical seasonal control of watergrass.

Single and Repeat Applications on Severe Watergrass Infestations

An experiment, designed to make these comparisons, was established July 22, 1958, on beets planted in late May and thinned about July 1. Beet foliage was approximately eight inches high with a severe watergrass problem present. Watergrass ranged in size from one to five inches. The experiment was replicated six times in a randomized block design. The hoeing treatments were completed on July 22 at an estimated cost of $45 per acre. Three dalapon treatments were also established on July 22 at rates of 4.7 pounds of dalapon per acre. One treatment was applied over the foliage of the beet, but the remaining treatments were directed as in the 1957 experiments.

Heavy infestations of grass appeared in all plots in early August. On August 19 all beets designated for extra hoeing were hoed at an estimated cost of $33 per acre. On August 20, directed sprays of dalapon were applied to all beets previously sprayed over the foliage and to one set of treatments that had received early directed sprays.

Observations taken after the July treatments and prior to the August treatments showed leaf burn on all dalapon sprayed beets with watergrass showing stunted new growth and a gray-green color. Hoeing treatments were outstanding and the check beets were completely hidden by watergrass. New grass growth was apparent in all plots. By mid September, beets treated twice, were improved over those receiving single applications. All beets hoed twice were outstanding, however, and beets hoed once were nearly as vigorous. Beets in check plots were extremely stunted and completely hidden by tall watergrass.

Harvest results obtained on November 11 are shown in Table 4. The extreme reduction in yields resulting from watergrass competition is apparent from the data. Satisfactory yields were obtained only where watergrass was effectively controlled by hand hoeing. Dalapon treatment, in the other experiments, failed to improve yields sufficiently to be practical.

Variety Tolerance

Possible varietal tolerance to dalapon in the absence of watergrass was tested in 1955 when five pounds of dalapon was applied at two stages of beet growth to six sugar beet varieties differing

Table 4.—Sugar Beet Yields Under Severe Watergrass Conditions as Influenced by Hand-Hoeing, Directed and Over-Foliage Sprays of Dalapon. Watergrass Condition Was Severe. Beets Were Planted Near Davis, California, in Late May and Treatments[1] Were Started on July 22, 1958.

Treatment	No. Applications	Approx. Cost	% Grass Control at Harvest[2]	Gross Sugar Tons/Acre	Beets Tons/Acre	Sucrose %	Beet Stand at Harvest (100′ Row)
Hoeing	2	$78	95	2.83	17.6	16.1	90
Hoeing	1	$45	75	2.28	14.3	15.9	75
Dalapon (Overall + Directed)	2	$15	55	1.10	7.0	15.5	65
Dalapon (Directed)	1	$ 7	30	1.06	6.9	15.4	55
Dalapon (Directed)	2	$16	20	0.91	5.9	15.4	55
No Control			5	0.49	3.2	15.3	40
*Rate consisted of 4.7 lbs. per acre of dalapon each application.							
Mean			47	1.44	9.2	15.6	63
LSD P = .05				0.35	2.3	0.4	
LSD P = .01				0.47	3.1	0.5	

[1] Beet foliage averaged 8″ in height and watergrass ranged between 1 and 5 inches in height. Leaf burn was observed on all dalapon treatments.

[2] Percent grass control was based on quantitative visual percentage estimate with 0% indicating solid grass coverage with no beets visible through the grass.

widely in genetic background. The experiment was planted on May 24, and harvested November 15, 1955. Varieties tested were US 400, S-1 (a selection from US 15), US 75, US 56 and two experimental varieties. Untreated checks of each variety were replicated six times in a randomized block design. Applications of dalapon were made in late June, shortly after thinning, and in early August.

Table 5.—The Influence of Foliar Applications of Dalapon at 5 Pounds per Acre on Six Varieties of Sugar Beets Under Weed-Free Conditions. Values Given are Averages of Six Replications. Dalapon Was Applied at Two Stages of Growth, Shortly After Thinning and Six Weeks Later.

Treatment	Application Date	S-1	US 400	US 75	US 56/2	A5327	A54103	Mean
Sugar per Acre—Expressed as Percent of Check								
None (Check)		100	100	100	100	100	100	100
Dalapon	6/25	89	87	80	84	82	89	85
Dalapon	8/3	66	66	73	71	65	78	70
LSD between varieties at P = .05 (Var)		13						
LSD P = .01 (Var)		17						
Beets per Acre—Expressed as Percent of Check								
None (Check)		100	100	100	100	100	100	100
Dalapon	6/25	93	87	84	91	87	92	89
Dalapon	8/3	74	76	80	80	76	83	78
LSD between varieties at P = .05 (Var)		10						
LSD P = .01 (Var)		13						
Sucrose Percent—Expressed as Percent of Check								
None (Check)		100	100	100	100	100	100	100
Dalapon	6/25	95	100	95	100	95	95	96
Dalapon	8/3	92	86	90	92	92	93	90
LSD between varieties at P = .05 (Var)		3						
LSD P = .01 (Var)		5						

The results of this experiment are shown in Table 5. The statistical interaction of variety times treatment did not reach the five percent level of significance for sugar per acre, tonnage, or sucrose percentage indicating that all varieties reacted similarly to the application of dalapon. The results indicate that dalapon reduced yields for all varieties and that late applications produced more serious yield reductions than the early application.

It has been demonstrated repeatedly under California conditions that the presence of an excess of nitrogen at harvest has a depressing influence on the sucrose concentration in sugar beets. Since the late application of dalapon reduced top growth and root development, it is possible that the reduction in sucrose concentration was the result of unused nitrogen at harvest, rather than a direct influence of dalapon.

Discussion

Watergrass has long been recognized as the most serious weed problem in the Central Valley area of California. Because watergrass generally becomes most severe in midsummer and fall after the last cultivation, post-emergence chemical control methods seem most desirable. This approach permits dealing with the problem as it arises, but also places severe restrictions on the material to be used. Dalapon almost conforms to these limitations in that it kills watergrass and volunteer grain at rates which will not kill sugar beets. Unfortunately, dalapon, even at low rates, has retarded beet growth under California conditions, and this has been reflected in reduced yields at harvest. This is particularly true when dalapon is used as a foliar application, but directed or shielded application should reduce this toxicity.

In all tests reported, dalapon provided some control over watergrass under all conditions tested, but the control was not as effective as needed, and yields were not satisfactorily improved by its use. The reasons for this apparent lack of control have been two-fold. 1. sensitivity of beets to dalapon and 2. the continued appearance of new grass throughout the summer. Since it would be most desirable to use dalapon only once during the season, a small portion of early emerging grass was approaching maturity (generally in the beet row) in most of the experiments reported by the time the main infestation reached the stage for most effective control. After treatment, more grass usually emerged with successive irrigations. Thus, the time for most efficient chemical application is very important and it will be difficult to find one period during which a single foliar application of post-emergence chemical will control all grass present and also prevent future germination of watergrass seeds.

This same objection holds true for hoeing except that hoeing will generally control grass over a wider size range than chemicals, and also corrects the unsightly appearance of the larger watergrass. Furthermore, hoeing destroys some of the newly emerged grass that is too small to be destroyed by absorbed chemicals. Dalapon, for example, is absorbed largely through the leaves, action is slow and newly emerged grasses have such

a small leaf area that they often escape contact and absorption of the material.

Chemical application with dalapon could not be considered satisfactory in controlling watergrass in any of the tests reported. Under severe watergrass conditions, neither one nor two chemical applications were sufficient to provide seasonal weed control. The data indicate, however, that watergrass control is highly desirable from an economic standpoint and in two of four tests, $7.00 to $15.00 in hand labor adequately controlled the grass problem for the season. In the severe infestations (Tables 1 and 4) the grass infestation was so heavy that the fields would have been better not planted to a row crop.

The second 1957 experiment which was carried out under moderate watergrass infestation might well have been improved had the application of dalapon been earlier and at higher rates (Table 2).

Repeated observations of fields with a serious watergrass problem show that obtaining and holding a good stand of beets down the row is one of the best methods of discouraging watergrass growth in summer and that late cultivations with side knives can save many dollars in hoeing and in reducing harvest costs. Further work with directed sprays with emphasis on materials, timing, and frequency of application could be of value because hand labor in sugar beet fields is becoming scarce as well as expensive. As long as hand labor is available, however, judicious use of the hoe may often pay dividends in increased yields and clean fields. (Tables 1, 2, 4.)

Summary and Conclusions

Several experiments testing dalapon for control of watergrass in sugar beets and the resulting influence of the material on sugar beet yields are reported. Comparisons included timing, frequency of application, directed and over-all sprays, and several rates of material. Hand hoeing checks were included together with checks in which the watergrass was not controlled (field practice).

All dalapon applications were made in mid-season when beet foliage was 8 to 15 inches high with watergrass ranging from newly emerged to 12 inches high with most about 5 inches in height.

Dalapon was found to provide some, but insufficient, control over watergrass under all situations and yields were not satisfactorily increased by its use.

Uncontrolled watergrass reduced yields from 2 to nearly 14 tons per acre depending on severity of grass competition as compared to hand hoed plots that were kept relatively clean.

Hand hoeing produced the best economic control of watergrass and resulted in the highest yields in all cases.

Studies on differential response to dalapon by different sugar beet varieties showed no significant variety times treatment interaction, indicating that none of the varieties tested appeared more or less affected by the dalapon. Yields of all varieties were reduced by the use of dalapon.

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