The Use of Dalapon for Grass Control in Sugar Beets

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Introduction

During 1954, 1955 and 1956, a considerable number of experiments were undertaken in most sugar-beet growing areas to determine the possibilities of using dalapon, sodium salt (Dowpon) to control grass weeds in beets. In this connection, it is of interest to note that annual planting of sugar beets in this country amounts to more than three-fourths million acres and represents commercial production in some 20 states; from Ohio and Michigan in the East to Texas and California in the South and West and in the intermountain and northwest areas. This wide area of production represents widely diverse conditions in regard to soils, air temperatures, broadleaved and grass weeds involved, beet varieties, and production techniques, including irrigation practices, irrigation versus no irrigation as well as mechanical versus hand thinning and harvesting.

Literature Review

As early as 1953 L. E. Warren (8)[2] conducted extensive trials in California with dalapon to control annual grasses—particularly water grass (*Echinochloa crusgalli*), in sugar beets. Conclusions resulting from the field and laboratory work were: dalapon, sodium salt controlled seedling grasses from the germination to early stooling stages when applied at temperatures ranging from 55° to 100° F. in spray volumes of 12.5 to 100 gallons per acre; 3 to 4 pounds (acid equivalent) of dalapon, sodium salt per acre controlled water grass when adequate wetting of the grass was obtained; more than 4 pounds as an over-all foliage treatment or more than one application tended to cause some yield reduction in weed-free beets; rates up to 7 pounds per acre did not affect sucrose content.

In Manitoba, Canada, Friesen (4) reported post-emergent treatment with Dowpon at 2 and 4 pounds dalapon equivalent gave complete control of green foxtail. Fair suppression of wild oats and mustard was obtained with the high rate. There was no injury to the sugar beets.

In Wyoming, studies by Alley and Bohmont (1) during the period 1953-1955 showed that the sodium salt of dalapon at 6 pounds acid equivalent per acre gave good grass control without reducing beet yield. Grasses controlled included tame oats, foxtail, and water grass. At 10 pounds, yields were adversely affected. Sucrose percentage was not affected by any dalapon rate. It was concluded that air temperature at the time of treatment may be an important factor in the use of dalapon for selective weed control in beets. At temperatures above 70° F., selectivity may be lessened. At 60° F., good grass control could be expected with no measurable adverse effect on the beets. Also, up to 50 percent of the broadleaves was controlled in some experiments.

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[1] Agricultural Chemical Development, The Dow Chemical Company. Located at Midland, Michigan; Oklahoma City, Oklahoma; San Francisco, California; and Minneapolis, Minnesota, respectively.

[2] Numbers in parentheses refer to literature cited.

Anderson and Helgeson (2) in North Dakota found that Dowpon at 5½ pounds applied anytime from the cotyledon stage to the 4 true-leaf stage in weed-free beets, caused no reduction in yield but at 8 pounds did cause a reduction. When applied at the 6 to 10 true-leaf stage two weeks later, the yield reduction at 5½ and 8 pounds was approximately the same and was small. There was no effect on the sugar content. Surprisingly, application of 8 pounds caused less yield reduction at the 6 to 10 leaf stage than at the 4 leaf stage. In pre-emergence applications, 8 pounds Dowpon caused no reduction in yield of weed-free beets. Continuing their studies under weed-free conditions, Anderson and Helgeson* substantiated their earlier results in that dalapon at 4 and 6 pounds per acre gave a reduction in yield, but not to sugar percentage, when applied to beets at the 6 to 8 or 10 to 14 true-leaf stage. The four-pound rate applied at the 6 true-leaf stage, or earlier, did not reduce yield or sugar percentage of beets.

In Nebraska, Keyser (5) found that Dowpon at 2 to 8 pounds gave 50 to 90 percent control of green foxtail when applied just prior to beet emergence and caused no permanent damage to the beets. In Ohio and Colorado, workers (6), (7) report good grass control with little or no injury to beets.

Blouch and Gaskill (3) found that for the control of oats in beets the best application was at the cotyledonary stage of the sugar beets when the oats were 3 to 4 inches tall. Dowpon was used at 4, 6, and 10 pounds dalapon equivalent per acre. The high rate gave the best and only permanent control. The sharp inhibition of growth of the beets (7 to 14 days after spraying) disappeared and all treatments appeared approximately the same in 30 days. With regard to yield, there was no adverse effect from applications at the cotyledonary stage of beet growth, whereas, there was some effect from application at the 2 and 4 leaf stages. Tame oats were used in these experiments, since its response to dalapon was found to be the same as the response of wild oats.

Tests and Results

Studies in California conducted by The Dow Chemical Company during 1955 evaluated the efficiency of directional sprays versus over-all sprays. In a replicated experiment of randomized block design, Dowpon at 4 and 6 pounds dalapon acid equivalent, was applied with drop nozzles to the base of sugar beets infested with water grass that had regrown after thinning. The beets and grass were 10 to 12 inches high. The field was irrigated soon after treatment. Since the rows only were treated, the net amount actually used per acre was one-half the over-all dosage. Flat fan nozzles were oriented about 45° to the vertical and the fan set about 45° to the row line to achieve coverage of only the lower two to three inches of beet petioles and about five inches away from the row. The beet leaves were not shielded nor lifted, but coverage of the main portions of the grass growth was obtained. The data presented in Table 1, indicate no effect on yield from the 4 pound dalapon equivalent rate when compared to the yield of the hoed check. There seemed to be some effect from the 6-pound application but the somewhat poorer grass control, which was not explained, may have had some effect on the yield. Note the low yield in the untreated check.

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Table 1.—Sugar Beet Yields and Grass Infestation at Harvest—California, 1955.

Treatment	Yield Tons Beets	Percent Grass Infestation at Harvest
Untreated	7.2	75
5.5 lb. Dowpon (4 lb. dalapon equiv.)	18.9	13
8.0 lb. Dowpon (6 lb. dalapon equiv.)	15.3	21
Hoed clean	18.8	4

Over-all and placement sprays were also made one month later to grass regrowth following hoeing. The growth of grass was stopped by the over-all sprays, but the beets did not outgrow the dalapon symptoms by harvest time three months later. The placed spray gave excellent grass control with little visible effect on the beets.

In Michigan where quack grass (*Agropyron repens*) is a major problem, preplanting treatments with Dowpon have given promising control. Application rates of 5 to 20 pounds per acre applied in late fall or in early spring prior to plowing have given commercial control of quack. One disadvantage of spring treatment is the planting delay that is caused. Whether spring or fall application is employed, it is important to treat the grass when it is growing well and when it has sufficient foliage for adequate up-take of the dalapon. A delay of three days after spraying is adequate to obtain near-maximum herbicidal effect. It has been found that by combining tillage, i.e., plowing, with treatment, much improved results over dalapon application alone can be expected. In other tests, applications were made to beets as over-all treatments during the growing season and quack grass was stunted and reduced considerably, although not eliminated, using about 6 pounds of Dowpon per acre, and wetting the grass well.

In eastern Canada at the Experimental Station at L'Assomption, Quebec, dalapon was used pre-emergence at 8 pounds per acre for the control of grasses. Results were encouraging and good control was obtained. At the Lethbridge, Alberta, Experimental Station, results on green foxtail in beets over a two-year period were such that a recommendation was made to apply 2 to 4 pounds acid equivalent of sodium dalapon after the foxtail reached the 2 leaf stage. Both pre- and post-emergence sprays of Dowpon were suggested in the recommendations of the National Weed Committee for 1956.

Reports furnished The Dow Chemical Company by independent workers at Rocky Ford, Swink, and Fort Collins, Colorado, Huntley and Hardin, Montana, Salt Lake City, Utah, and Mason City, Iowa, reveal results for 1955 in which rates of 3-10 pounds Dowpon per acre were tested on sugar beets for control of grass. A general summarization indicates the results were favorable from the standpoint of killing or stunting the grass including foxtail grass, and tame and wild oats. Some leaf burn on the beets was noted by direct sprays of dalapon, but adverse effects on yields and sugar production were not reported.

Burtch[4] made investigations at Woodland, California, on the tolerance of varieties of sugar beets. Yields of all varieties were somewhat lower in the treated plots which were sprayed overall with dalapon, sodium salt at 4 pounds acid equivalent per acre. Late application, 3 months before harvest, was more drastic than application immediately following thinning. Placement sprays were not included in the experiments.

Preliminary data on the 1956 trials have been received from various cooperators. Loomis[5] conducted a test in California using a rate of 6 pounds Dowpon in 50 gallons water per acre. Directional and over-all sprays were applied July 9 to beets that had been planted March 15 and thinned May 10. Two weeks later, margins of recently matured leaves in the over-all spray plots showed necrotic areas. Beets which had received directed sprays showed only slight damage which was outgrown by September 9. On October 6, yield sampling was undertaken. Tonnage was low due to nematode infestation and virus.

Table 2 gives yields in tons of beets and tons of sugar for six replicates.

Table 2.—Results on Sugar Beets, in California, Sprayed at the Rate of Six Pounds Downpon Per Acre, 1956.

Treatment	Replicate						Mean
	1	2	3	4	5	6	
	Tons of Clean Roots per Acre						
Untreated	17.1	13.8	15.0	21.8	14.3	22.9	17.5
Directed spray	14.3	20.5	13.9	21.2	15.3	15.4	16.8
Over-all-spray	12.8	15.1	11.1	13.1	13.0	17.6	13.8
	Tons of Sugar per Acre						
Untreated	2.58	2.03	2.28	3.40	2.14	3.44	2.65
Directed spray	2.20	3.15	2.07	3.20	2.30	2.19	2.52
Over-all spray	1.89	2.14	1.61	1.74	1.82	2.50	1.95

The data show no consistent differences between the untreated beets and those which received six pounds of Dowpon per acre as a directed spray. Late application as an over-all spray on large plants, resulted in some yield reduction.

Bohmont[6] has reported results in Wyoming where grass control averaged 96 percent with eight pounds of Dowpon with no reduction in sugar beet stands. Yields in all locations averaged 20 and 22 tons respectively for the treated and untreated plots.

Through cooperative effort of The Great Western Sugar Company and The Dow Chemical Company, extensive field trials with Dowpon were completed in Colorodo and Nebraska. Dowpon was applied post-emergence at the two true-leaf stage of beets with a low volume, low pressure sprayer equipped with flat fan-spray nozzles. The width of the band was adjusted by raising or lowering the nozzles. The grass, mostly *Setaria viridis*, was

[4] Personal communication.
[5] Personal communication.
[6] Personal communication.

usually less than two inches tall. Yields and stands of beets were calculated from 20 samples per treatment per location. Results are summarized in Table 3.

Table 3.—Harvest Results Giving Stand, Yield and Sugar Percentage for Dalapon Treated and Non-treated Sugar Beets in Each of Nine Widely Separated Fields—1956.

		Dalapon Post-emergence			Check		
Location	Application[1]	Beets per 100 ft. of row	Tons/A	Sugar %	Beets per 100 ft. of row	Tons A	Sugar %
Brighton, Colo.	1.5 lb/A in 6" band	75	19.47	14.30	77	20.27	14.85
Brush, Colo.	1.5 lb/A in 6" band	79	23.08	17.52	80	23.44	17.10
Sterling, Colo.	1.5 lb/A in 6" band	99	22.41	17.06	100	23.81	16.48
Ovid, Colo.	1.5 lb/A in 6" band	120	19.41	16.86	105	18.98	17.03
Bayard, Nebr.	1.5 lb/A in 6" band	109	11.30	17.77	108	11.49	17.76
Gering, Nebr.	1.5 lb/A in 6" band	140	19.73	16.93	132	20.19	16.19
Lyman, Nebr.	1.5 lb/A in 6" band	108	20.11	17.01	106	20.90	17.17
Eaton, Colo.	2 lb/A in 7" band	107	24.05	16.50	103	22.80	16.44
Longmont, Colo.	2.4 lb./A in 10" band	78	15.39	17.34	89	16.64	17.43
Longmont, Colo.	3.5 lb/A in 10" band	88	17.68	17.40	89	16.64	17.43
	Mean	100.3	19.26	16.87	98.9	19.52	16.79
	LSD 5% pt.	NS[2]	NS	NS			

[1] Amount of Dowpon sprayed over beet row prior to thinning. Equivalent rates broadcast would approximate 5.5 to 7 pounds per acre Dowpon or 4 to 5.2 pounds per acre dalapon equivalent.

[2] Mean value not significantly different from mean of check at indicated level.

None of the differences in Table 3 reached the 5 percent point of significance. While there was usually visible injury to beets following Dowpon application, recovery was good as indicated by the data on stand and yield.

The delayed action of dalapon on grass is becoming better understood. This chemical often affects and kills grass slowly, particularly under low temperature or other conditions favoring slow growth. Its action on grass is similar to the action of 2,4-D on broadleaved weeds. Even though stunted grass may remain green and even though some live grass seedlings are present at thinning, the job of weeding and thinning is greatly facilitated.

Registration[3]

The use of an herbicidal chemical on a food crop such as sugar beets, where residues may be present at harvest, is regulated by both the Federal Insecticide, Fungicide, and Rodenticide Act, and the Federal Food, Drug, and Cosmetic Act. In order to register the use of Dowpon on sugar beets under the Insecticide, Fungicide, and Rodenticide Act, residue determina-

[3] Use of Dowpon on sugar beets in accordance with label directions now has full clearance. A tolerance of five p.p.m. in roots and tops was established (Federal Register, January 3, 1957) and the recommended use of Dowpon will not result in a higher residue and is considered a safe and useful practice.

tions were required on both sugar-beet roots and tops collected from Dowpon-treated plots. The analytical determination of small amounts of a pesticide-chemical residue in a crop such as sugar beets was time consuming. The development of a satisfactory analytical method required about a year and the analysis of an adequate number of dalapon treated samples, both tops and roots, required many work weeks. However, the analyses have been completed as have also the toxicological studies which included chronic dietary feeding tests for two years with rats and one year with dogs. Residue determinations were made separately on beet roots and tops from Michigan, California, North Dakota and Montana. More than 50 percent of the samples of beet tops and 80 percent of the samples of beet roots showed less than 1 p.p.m. dalapon or essentially nil residue. The highest residues found in tops and roots were 4 p.p.m. and 2 p.p.m., respectively. A petition requesting a tolerance of 5 p.p.m. for dalapon in sugar beet roots and tops was accepted for filing by the Food and Drug Administration and an application for registration has been submitted to the U.S.D.A. It is anticipated that a tolerance and registration will be granted early in 1957 which will permit the use of dalapon on sugar beets for the 1957 and subsequent seasons.[7]

Analysis of Dalapon in Plant Tissue

The method for the analysis of 2,2-dichloropropionic acid or its sodium salt in biological materials is based on the conversion by hydrolysis to pyruvic acid, the latter then being estimated colorimetrically as the 2-4-dinitrophenylhydrazine derivative.

In order to carry out this procedure, it is necessary to first isolate the 2,2-dichloropropionic acid from naturally occurring a-keto acids and other compounds which will be converted to a-keto acids during the hydrolysis reaction. The sample is acidified to insure conversion of the sodium 2,2-dichloropropionate to the acid form. The organic acids and other ether-soluble compounds are removed from the sample by continuous ether extraction. The acidic compounds can then be extracted from the ether with a sodium hydroxide solution. The a-keto compounds present in this solution are removed by converting them to their corresponding 2,4-dinitrophenylhydrazone derivatives and then passing the solution through a siliconized super cel (a diatomaceous earth) column saturated with benzyl alcohol. The hydrazones remain on the column while the 2,2-dichloropropionic acid and other constituents pass through. Since each component in the system will pass through the column at a specific rate, additional separation of the components can be obtained by taking cuts of the effluent from the column and saving only those known to contain the dichloropropionic acid.

The dichloropropionic acid can further be separated from interfering substances by heavy metal precipitation using copper sulfate and calcium hydroxide. Under these conditions the interfering substances are precipitated while the dichloropropionic acid remains in solution.

The dichloropropionic acid is then converted to pyruvic acid by hydrolysis. Once the pyruvic acid has been formed, it can be measured by the standard colorimetric procedure used for estimating this acid in biological materials.

Brief Statement on Toxicology of Dowpon

Dalapon, sodium salt (Dowpon) is one of the least toxic and one of the safest of the many chemicals used in agriculture today. It is low in systemic toxicity; ingestion or inhalation of small amounts, such as might be encountered when the material is used as recommended, do not constitute a hazard to health. The feeding of single doses to various species of animals, including mice, rats, guinea pigs, rabbits, chicks, and steers has shown the material to be less toxic acutely than ordinary table salt. The acute oral LD_{50} values for these species range from 3 to 8 grams per kilogram of body weight.

Studies have been conducted to determine the effect of feeding Dowpon repeatedly to rats, dogs, and cattle. These studies have shown that rats can tolerate, without effect, a dosage level between 15 and 50 mg./kg./day for two years; that dogs can tolerate without effect for at least one year, daily doses of at least 50 mg./kg.; and that a bull suckling calf tolerated without effect a daily dose of 1000 mg./kg. on 10 of 11 successive days. Lake Emerald Shiners were maintained for three days in water containing 3,000 p.p.m. by weight of the material without apparent adverse effect; 5,000 p.p.m., however, was lethal. This illustrates probably low toxicity to fish although the reactions of other species have not been determined.

These observations emphasize the low degree of systemic toxicity of Dowpon. Furthermore, Dowpon is not likely to cause irritation of the skin unless exposure is unusually severe, that is, prolonged or frequently repeated. The probability that exposures of short duration will be injurious is small. The ability of the material to cause irritation is markedly reduced by dilution; hence, the prompt flushing of exposed areas with water essentially eliminates the possibility of irritation occurring. The material is not absorbed through the skin to any appreciable degree, if at all. It does not present a serious hazard of eye injury. If contact occurs, pain and irritation can be expected but serious injury is not probable, particularly if the contaminated eye is promptly and thoroughly flushed with flowing water.

The experience gained in manufacturing, handling, and using Dowpon has borne out the conclusion that it does not present any serious handling hazards.

Conclusions on Performance and Use of Dalapon

1. Dalapon is a useful tool in controlling grass in sugar beets.

2. It is effective against most seedling grasses including wild oats when applied post-emergence and also against certain perennial grasses like quack grass when used in pre-planting applications. Pre-emergence application can be effective against seedling grasses.

3. Dalapon can temporarily affect beets adversely under some growing conditions, but where a grass problem is severe, this temporary effect is more than compensated for by the increased growth and yield due to the control of the grass and by the comparative ease of subsequent production practices.

4. Normally, a foliage application of 4 to 6 pounds Dowpon (sodium dalapon) on seedling grasses is adequate and safe. In some areas where relatively high temperatures are likely to occur at the time of, and following spraying, the effect on the beets may be more pronounced than in areas where lower temperatures prevail.

5. Results in California seem to indicate that it may be advisable to use placement sprays to decrease the beet response.

6. Dalapon, as Dowpon, is finding its place as a sugar beet herbicide and should aid in the realization of a complete mechanization program for sugar beet production.

7. Suggestions for use of Dowpon are: To control water or barnyard grass, foxtail or pigeon grass, and other grass seedlings, use 4 to 6 pounds per acre of Dowpon (over-all treatment) in sufficient water for good spray coverage of the grass. Band treatment may be used with a proportionate reduction in the amount of Dowpon per acre of beets. Application may be made from the time of beet emergence until the beets are in the 4 leaf stage. For best results, the grass seedlings should be small. Older seedlings and wild oats (*Avena fatua*) are more tolerant and may require 7 to 9 pounds for most effective control. Rates above 6 pounds per acre may cause some yield reduction. In cases where such rates are needed, and in certain areas having relatively high temperatures during the application period, the use of directed sprays after thinning is suggested so that the grass foliage is sprayed without spraying the beet foliage. Dowpon acts slowly, and a 2 to 3 week interval after spraying may be required before grasses die. Thinning operations may be started 7 days after Dowpon application, if desired.

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