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Methods Affecting The Efficiency Of Chlorate Weed Killers

By

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Summary

1. Considerable variation occurs in the kills secured from the use of chlorates upon various species of perennial weeds. Many of these variations can be controlled by careful chemical applications.

2. Nozzles delivering a fine penetrating spray at a definite rate per unit area are most efficient for the application of chlorates.

3. Except for weeds unusually difficult of eradication repeat sprays need not be used except for follow-up work the subsequent season.

4. Time of application of chlorates to morning glory under non-irrigated conditions was of little importance except for the control of seedlings.

5. Highly concentrated solutions or more than one pound of chlorate per gallon are of little value except for covering scanty plant growth.

6. Rate of application is not only dependent upon the weed species but is apparently affected by moisture, soil types, and seasonal conditions.

7. Sodium chlorate alone is more effective, pound for pound, for the control of weeds than when it is used in mixtures with deliquescent salts.

8. Tests conducted by this Experiment Station indicate that hydrogen-ion concentration of spray solution has not proven of value in increasing the killing power of chlorates.

Methods Affecting the Efficiency of Chlorate Weed Killers

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CHLORATES have been used extensively in Idaho for the control of perennial weeds with running rootstalks since 1927. During this period nearly 2,500,000 pounds of chlorates have been used with generally satisfactory results. The amount of the chemical used annually is shown in *Table I.*

TABLE I.

Pounds of chlorate used in Idaho for commercial eradication of perennial weeds, 1927-1930 inclusive.

Year	Pounds of Chlorate	Acreage treated
1927	7,796	18.1
1928	367,134	648.5
1929	885,715	1,937.2
1930	1,147,392	2,028.0
Total	2,408,037	4,631.8

Some variation in the effectiveness of the results secured is likely to occur in any commercial weed eradication program conducted on such a large scale. Such variations may be caused by irrigation, seepage, high water table, careless application, concentration of solution, rate and date of application. The development of methods necessary to secure more uniform kills and the underlying reasons for variations in kill have been the major objects of this experimental study. The results of such investigations are a part of the material used in this paper. The data shown are largely the results of plot trials located in the various areas of the state where perennial weeds are a serious problem. A portion of the conclusions presented were secured from a careful study of several hundred commercial applications.

Method of Application

It has been considered by most users of chlorates that the type of spray, the pressure used and the general method of application were not important in treating weed growth with chlorates. A study of several hundred commercial treatments in Idaho has shown conclusively that the method of application is oftentimes the deciding factor in complete eradication. The use of a high pressure power sprayer equipped with a nozzle

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capable of delivering the spray in the form of a fine penetrating mist is essential. A nozzle that is calibrated to apply a definite amount of chemical per unit area is especially desirable to insure the application of sufficient chemical to completely kill the weed growth.

Nozzles designed and adjusted for orchard work as used by the average operator are not satisfactory because uneven and spotted applications are made which result in non-uniform kills. The tendency of the operator when using such equipment is to attempt to cover weed growth at as great a distance as the nozzle will throw the solution. This method does not allow a thorough covering of the weed growth, especially when it is high or densely matted. A nozzle delivering a fine mist under pressure throws the spray only a few feet and requires the operator to come in closer contact with his work. A fine mist also allows a thorough coverage of the under as well as the upper sides of the leaves. Usually such methods produce more highly satisfactory results.

Repeat Applications

The general practice in commercial weed work in Idaho has been to re-spray weed patches after new growth appeared. In many cases this was done to prevent the re-growth from seeding. Oftentimes, the farmer felt that because of this new growth the chemical had not been effective and an additional application was necessary to complete eradication. Careful experimental work has shown that repeat applications are unnecessary, except on a few weeds, if the chemical has been thoroughly applied so that all top growth was burned down.

Chemical applications made on morning glory *(Convolvulus arvensis)* early in the 1930 season completely killed the top growth. The plants sent out a new, vigorous growth and half of the various plots were re-sprayed at their original rate. The data secured from these treatments are shown in *Table II*. The date of the first application of the chemical is shown in the table. The second application was made at the original rate on October 6, 1930, in each case. Careful checks in 1931 showed no difference in proportion of kill between the plots receiving only one and those receiving two applications.

Experimental results show conclusively that certain weeds require heavier applications of chemical than others to effect eradication. White top *(Lepidium draba)* usually requires two applications of three pounds per square rod each during a single season to completely eradicate it. More than 100 complete kills have been secured by this method in the Boise

TABLE II.

Effect of re-spraying upon the eradication of morning glory on non-irrigated land, 1930 treatments.

Date of application	Soil Moisture %	Rate of application pounds per square rod	Stage of growth, first application	Per cent kills shown on Oct. 6, 1930	Per cent kills shown on September 15, 1931	
				First Application	First Application	Second Application
5-18	20	1	2 inches high	0	100	100
		2		0	100	100
		3		0	100	100
5-24	24	1	3 to 4 inches high	0	100	100
		2		0	100	100
		3		0	100	100
6-6	25	1	7 to 8 inches high	Trace	100	100
		2		10		100
		3		10	100	100
6-14	23	1	9 to 10 inches high	7	100	100
		2		10	100	100
		3		50	100	100
6-27	18	1	Beginning bloom	50	100	100
		2		30	100	100
		3		80	100	100

Valley. In most cases the second application was made after the new growth was well started. In Bonneville County, at a considerably higher elevation, the best results were secured when the second application was made on the dead growth a week or ten days after the first treatment. Either of the above methods were more effective than the application of the total amount of chemical at one time.

Commercially treated areas infested with white top in 1930 showed better control on those patches receiving the chemical in two applications. Seven areas treated with one application of seven pounds of sodium chlorate per rod gave an average control of 95 per cent. Two areas sprayed twice with four and two pounds of sodium chlorate respectively, showed an average kill of 97.5 per cent. Using commercial calcium chlorate, 14 areas receiving two applications gave a seven per cent better kill than that secured from the average of 26 patches treated with an equivalent amount applied in one treatment.

One hundred sixty-three commercially treated areas of Canada thistle, morning glory, and Russian knapweed treated with both sodium and commercial calcium chlorate showed no advantage from applying a portion of the total chemical used as a repeat spray.

Perennial weeds that usually can be eradicated by a single application using a definite amount of chemical need not be sprayed again until the following spring. Then it is necessary to make such an application only if scattering plants appear.

Time of Application

Previous recommendations made by most experiment stations have indicated that the chemical should be applied after the weed plants had bloomed. In extensive commercial campaigns under Idaho conditions, this limits the spraying operations to a three or four months period. Experiments to determine the killing ability of the chemical upon morning glory *(Convolvulus arvensis)* throughout the season were begun in the spring of 1930. The results of these trials, applied at frequent intervals throughout the season, beginning at the time the plant first appeared and continuing until late fall, are shown in *Table III.* These experiments were carried on in the Palouse area on a silt loam, wind-blown soil which had produced a crop of winter wheat in 1929. The field was summer-fallowed in 1928 so it had not been disturbed by plowing for two years previous to the application of the chemical. Surface cultivation sufficient to keep down annual weed growth had been practiced during the summer of 1928.

TABLE III.

Effect of date of application of sodium chlorates upon eradication of morning glory. Chlorate applied at rate of one pound per square rod, 1930 treatments.

Date of Application	Stage of Growth	Per cent kills shown on	
		Oct. 6, 1930	Sept. 15, 1931
5-18	2 inches high	0	100
5-24	3 to 4 inches high	0	100
6-6	7 to 8 inches high	Trace	100
6-14	9 to 10 inches high	7	100
6-27	Beginning to bloom	50	100
7-6	2/5 in bloom	60	100
7-12	1/10 seeded	65	100
7-19	5/10 seeded	60	100
7-26	Mature	50	100
8-2	Mature	50	100
8-9	Mature	70	100
8-15	Mature	90	100
8-30	Mature	100	100

Equally good results were secured at all dates of application throughout the growing season with one, two, and three pound applications. All of the areas treated previous to June 27, showed heavy seedling infestation. On plots treated after

that date few seedlings made their appearance at any time throughout the 1931 season. Since later applications were apparently more effective in the prevention of seedling growth, it would seem desirable to postpone the treatments until later in the season.

Mowing the first growth of the weed and spraying the second growth at maturity has been used very successfully in a commercial way in Idaho. In many instances more satisfactory kills have been secured by this method. The effectiveness of this method has been especially noticeable in the control of weeds which are usually found to be most difficult to eradicate. Such a practice eliminates seed production and cleans the weed patch of other plant growth, thus facilitating the spraying operation.

Concentration of Spray Solution

Morning glory sprayed with sodium chlorate in 1927 under non-irrigated conditions at Coeur d'Alene with 7½, 10 and 12½ per cent solutions, using two pounds of chemical per square rod gave 100 per cent control. These plots were still undisturbed and free from the weed in 1931. This work indicated that the concentration of chlorate solutions was not an important factor in eradication provided a sufficient quantity of chemical was applied to kill the plants.

Recently, commercial concerns have recommended the use of more concentrated chlorate solutions, stating that they were more satisfactory in effecting eradication. To secure accurate information upon this recommendation, a number of plots of several weed species were treated with various concentrations. *Table IV.* shows the data secured from such treatments upon Russian knapweed *(Centaurea picris)* growing on irrigated land in Jerome County. The spray was applied to the new, sparse, re-growth which appeared after mowing.

TABLE IV.

Effect of concentration of solution upon the killing efficiency of various chlorates on Russian knapweed, 1930 treatments.

Concentration and rate of application per square rod	Per cent Kill		
	Commercial calcium chlorate	Commercial magnesium chlorate	Sodium chlorate
½ lb. to 1 gallon	Trace	Trace	50
1 lb. to 1 gallon	50	40	75
2 lbs. to 2 gallons	90	85	85
2 lbs. to 1 gallon	90	90	93
3 lbs. to 1 gallon	100	95	100
4 lbs. to 1 gallon	100	100	100

Results of similar treatments on Canada thistle *(Carduus arvensis)* growing on sub-irrigated soil are shown in *Table V.* The spray applications were made September 14, on new growth after the thistles were mowed on August 15. The sub-water was approximately two feet below the soil surface at the time of spraying.

TABLE V.

Effect of concentration of solution upon the killing efficiency of various chlorates on Canada thistle, 1930 treatments.

Concentration and rate of application	Per cent Kill		
	Commercial calcium chlorate	Commercial magnesium chlorate	Sodium chlorate
½ lb. to 1 gallon	None	None	....
1 lb. to 1 gallon	Trace	Trace	....
2 lbs. to 2 gallons	50	50	98
2 lbs. to 1 gallon	60	60	....
3 lbs. to 3 gallons	90	90	100
3 lbs. to 1 gallon	98	95	....

The concentration of solution experiments were made upon morning glory that had attained its normal growth in 1927, while the 1930 experiments were conducted upon weeds which had not yet attained their full size. These weeds had been mowed off and the new growth sprayed when it was from 6 to 8 inches in height. Under such growth conditions the data show a slight advantage in favor of solutions of higher concentration. This advantage is probably due to the fact that more chemical adheres to the vegetative portions of the plant when the more highly concentrated solutions are used. However, for average weed growth and in instances where the weeds have been allowed to reach their normal development, higher concentrations have no value.

Farmers using highly concentrated solutions, even upon sparse growth, will undoubtedly increase the cost of eradication materially unless the spray outfit is equipped with carefully calibrated nozzles. Nozzles applying a definite amount of solution in a given length of time are essential so that a smaller amount of solution is used, otherwise the plants will probably be given the customary wetting. Thus the usual practice will nearly double the amount of chemical actually used and the excess applied is of no material benefit in securing kills, although it materially increases the cost of eradication.

Rate of Application of Chlorates

A large number of factors affect the rate of chlorate application that is necessary to secure complete kills of weed

growth. Under Idaho conditions it is interesting to note that considerably less chemical is required to eradicate weeds under non-irrigated and dry farm conditions than in the irrigated sections. Weeds growing on sub-irrigated soils are usually more difficult to eradicate than those growing on soils surface-watered. The results of chemical treatments under apparently similar conditions indicate differences in the ease of eradication upon adjoining farms and occasionally even on the same farm. Therefore, a set of general recommendations stating the rate of chlorate application for the eradication of the various weed species must be sufficiently inclusive to care for all sorts of different conditions. Thus, it is apparent that the amounts used in the many localities must be determined by the results of experiments carried on in those immediate sections. Even then some variation will occur and definite recommendations, when carefully followed, will, under certain conditions, give unsatisfactory results. In general, the amounts indicated in *Table VI* will give satisfactory results in Idaho.

TABLE VI.

Showing the rate of application of chlorates necessary to eradicate various perennial weeds in Idaho.

Kind of Weed		Rate of Application in Pounds per Square Rod			
		Sodium chlorate		Commercial calcium or magnesium chlorate	
Common Name	Scientific Name	Irrigated soil	Non-Irrigated soil	Irrigated soil	Non-Irrigated soil
Morning glory	**Convolvulus arvensis**	4	2	5	3
Canada thistle	**Carduus arvensis**	4	2	5	3
Russian knapweed	**Centaurea picris**	4	2	5	3
White top	**Lepidium draba**	6	5	8	6
Perennial sow thistle	**Sonchus arvensis**	6	5	8	6
Quack grass	**Agropyron repens**	4	2	5	3
Blue flowering lettuce	**Lactuca pulchella**	6	5	8	6
Poverty weed	**Iva axillaris**	4	2	5	3
Yellow toad flax	**Linaria vulgaris**	*	3	*	4
Leafy spurge	**Euphorbia esula**	*	5	*	7

* Not yet found under irrigation.

Experimental and commercial results of chlorate treatments in Idaho show conclusively that larger amounts of the commercial mixtures of sodium chlorate with deliquescent salts are necessary to secure the same kills that are usually

obtained from straight sodium chlorate. Experimental evidence confirming this statement is shown in *Tables IV and V.* Data from a large number of commercial applications upon several weeds are shown in *Table VII.* Apparently the chlorate (CLO_3) content of the chemical applied largely determines the killing ability of the herbicide.

TABLE VII.

Results secured from commercial applications of chlorates on perennial weeds in Idaho, 1930.

Kind of Weed	Sodium chlorate			Commercial calcium chlorate		
	No. Observations	Ave. application lbs. per sq. rod	Per Cent Kill	No. Observations	Ave. application lbs. per sq. rod	Per Cent Kill
Canada thistle	21	3.65	90.8	50	4.00	80.4
Morning glory	15	3.66	97.6	36	4.90	94.0
Russian knapweed	5	2.40	91.6	17	4.60	83.0
White top	7	7.00	95.0	26	6.80	77.6
Average	48*	4.01	93.62	129*	4.91	84.00

* Represents total number of observations.

On the average, 18 per cent less chemical was applied to the areas treated with sodium chlorate. However, this chemical applied at the lower rate was 11 per cent more efficient in its weed-killing ability than commercial calcium chlorate. If each pound of chemical used is considered accountable for its proportionate amount of the kill obtained, sodium chlorate, under Idaho conditions, is 26.6 per cent more efficient in its weed-killing ability than commercial calcium chlorate. Sodium chlorate was outstandingly effective in the control of Canada thistle, white top and Russian knapweed. Morning glory was quite satisfactorily controlled with commercial calcium chlorate, although 34 per cent more of this chemical was required than in the cases where sodium chlorate was used as the herbicide.

Hydrogen-ion Concentration of Chlorate Solutions

Laboratory experiments demonstrated that freshly cut stems of white top and Canada thistle wilted more rapidly when immersed in chlorate solutions having the same hydrogen-ion concentration as the expressed cell sap of the plants. The hydrogen-ion concentration of these plants approximates a pH of 5.35. The stems of weed plants immersed in chlorate solution of a pH of 6.00 or below wilted very quickly. In solutions of higher hydrogen-ion concentration wilting required a period of from four to five times longer.

Apparently satisfactory kills are secured when a lethal dose of chlorate is taken up by the plant. Since more rapid wilting took place when the solutions were of the same hydrogen-ion concentration as the expressed cell sap, it would seem to be caused by a more rapid absorption of the chlorate. Such a condition would seem desirable under commercial usage of the chemical.

Plots of morning glory were sprayed with corrected solutions having the same hydrogen-ion concentration as the expressed cell sap of the plants. These plots were treated at the same rate and date of application. In addition, different acids were used as the corrective to adjust the pH of the solution to the proper point. The kills secured from the various treatments, together with other available data, are shown in *Table VIII.* The data indicate that no advantage was gained by the use of solutions properly adjusted to the hydrogen-ion contration of the expressed cell sap.

TABLE VIII.

Effect of hydrogen-ion concentration of the killing ability of sodium chlorate solutions upon morning glory. Date of application, July 26, 1930.

pH of solution	Rate of application pounds per square rod	Kind of Acid	Per cent Kill as Shown on	
			October 16, 1930	September 15, 1931
7	1	None	30	100
5	1	HCl	50	100
5	1	Glacial acetic	60	100
4	1	HCl	60	100
7	2	None	60	100
5	2	HCl	30	100
5	2	Glacial acetic	90	100
4	2	HCl	75	100
7	3	None	50	100
5	3	HCl	65	100
5	3	Glacial acetic	100	100
4	3	HCl	60	100

Results of kills as indicated by counts made in October, 1930, the fall immediately following the spray application, indicated that corrected solutions were of considerable value. Similar results on St. Johnswort are reported by the California Experiment Station.[1] However, since one is not certain

1. Bul. 503 St. Johnswort on Range Lands of California. Arthur W. Sampson and Kenneth W. Parker.

of the results of chlorate treatment until the following season, the 1930 readings are inaccurate and at best indicate only that acidity may play a part in securing kills. This point can be checked only by treating weed infested areas with carefully adjusted solutions containing less than lethal doses of chlorate. Such work with several weeds is already under investigation.

Other trials made in a commercial way on several different species of weeds using corrected and uncorrected solutions gave no indication that acidity was a factor in weed eradication with chlorates.