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Effect of Form and Rate of Active Ingredient, Spraying Season, Solution Volume, and Type of Solvent on Mortality of Big Sagebrush, *Artemisia tridentata*

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Effect of Form and Rate of Active Ingredient, Spraying Season, Solution Volume, and Type of Solvent on Mortality of Big Sagebrush, *Artemisia tridentata*

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Previous spraying trials (Hyder, 1953) on big sagebrush (*Artemisia tridentata*) established the feasibility of obtaining chemical control with growth regulators, and indicated the need for more information regarding time of spraying, growth regulator material, acid rate, solvent material, and solution volume. This paper presents the results from subsequent trials involving those factors.

The information presented is helpful in understanding some of the contradictory conclusions drawn from sagebrush-spraying trials. A lack of intensity in experiments has sometimes led to correct but limited conclusions. Although the study reported in this paper leaves much to be desired in basic physiological phenomena, it provides new information which may be used in adjusting spray solutions to certain physical and physiological conditions.

Procedure

The experiment was conducted as a complete factorial in randomized blocks with 2 replications each in 1952 and 1953. The factors involved were:

1. Six dates of spraying beginning in late April and extending into July, with intervals between spraying dates of approximately 2 weeks.
2. Three growth regulator materials as follows:
   M-1 Propyleneglycol butyl ether ester 2,4-D.
   M-2 Propyleneglycol butyl ether ester 2,4,5-T.
   M-3 Butyl ester 2,4-D.
3. Two acid rates of 1 pound and 2 pounds per acre acid equivalent.

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4. Three solvents as follows:
   S-1 Water plus Tween 20 at 0.1 per cent by volume.
   S-2 Diesel oil.
   S-3 Diesel oil emulsion with a water to oil ratio of 2:1 and emulsified with Tenlo 400 at 5 per cent of total oil volume.
5. Two solution volumes of 3 and 6 gallons per acre.

A total of 864 plots was included in the experiment.

A complementary experiment, which included the three growth regulator materials above and 14 different solvents, was completed in 1953. Those materials were applied at an acid rate of 1 pound per acre and in a solution volume of 3 gallons per acre. The experiment was a factorial in three randomized blocks. The solvents included were as follows:

S-1 Water.
S-2 Water plus TCA at 2 pounds per acre.
S-3 Water plus TCA at 4 pounds per acre.
S-4 Water plus TCA at 2 pounds per acre plus Tween 20 at 0.1 per cent by volume of total solution.
S-5 Water plus Tween 20 at 0.1 per cent by volume of total solution.
S-6 Water plus Santomerse No. 1 at 2 per cent by volume of solution.
S-7 Water plus Summer Spreader Oil at 1 per cent by volume of solution.
S-8 Water plus Multifilm L at 0.1 per cent by volume of solution.
S-9 Helix oil.
S-10 Aromatic oil.
S-11 Diesel oil.
S-12 Helix oil emulsion with a water to oil ratio of 2:1 and emulsified with Tenlo 400 at 5 per cent of total oil volume.
S-13 Aromatic oil emulsion with a water to oil ratio of 2:1 and emulsified with Tenlo 400 at 5 per cent of total oil volume.
S-14 Diesel oil emulsion with a water to oil ratio of 2:1 and emulsified with Tenlo 400 at 5 per cent of total oil volume.

The procedures used in preparation and hand application of spray solutions, and in obtaining sagebrush mortality data, were the same as in previous trials (Hyder, 1953).

An additional complementary experiment was conducted to test under aerial application the information gained from previous trials. The trials were made by airplane spraying on May 11, 1953 using butyl ester 2,4-D at 1 pound acid equivalent per acre. Solvents were:

(1) diesel oil, and (2) water, each at total solution volumes of 1, 2, 3, 6, and 9 gallons per acre. Plots were four swaths wide, one-fourth mile long, separated 100 feet for drift allowance, and were arranged in two replicate blocks. Individual swath width was 30 feet

Table 1. ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Mean square
Between years (Y)	1	3,280**
Between replications	2	2,668**
Among dates of spraying (D)	5	12,122**
Among materials (M)	2	3,172**
Between acid rates (R)	1	10,164**
Among solvents (S)	2	18
Between volume rates (V)	1	13,360**
Y x D	5	3,698**
Y x M	2	43
Y x R	1	20
Y x S	2	595**
Y x V	1	913**
D x M	10	612**
D x R	5	170
D x S	10	144
D x V	5	111
M x R	2	20
M x S	4	187
M x V	2	182
R x S	2	160
R x V	1	7
S x V	2	138
Y x D x M	10	273**
Y x D x R	5	83
Y x D x S	10	67
Y x D x V	5	299*
Y x M x R	2	41
Y x M x S	4	75
Y x M x V	2	138
Y x R x S	2	42
Y x R x V	1	295
Y x S x V	2	127
D x M x R	10	690**
D x M x S	20	120
D x M x V	10	114
D x R x S	10	86
D x R x V	5	89
D x S x V	10	125
M x R x S	4	72
M x R x V	2	52
M x S x V	4	154
R x S x V	2	34
Error	675	109
TOTAL	863	

** Indicates highly significant variation (probability level 0.01).
* Indicates significant variation (probability level 0.05).

for the 9 gallon volume, but was 40 feet for all other volumes. Percentage kills on big sagebrush were obtained by a list count of individual plants (before spraying and 1 year after spraying) on three 10- by 100-foot samples per plot. Spraying was accomplished in the afternoon while the wind was gusty, with velocity up to 15 miles per hour in gusts.

Results

Percentage kills on individual plots were converted to angles (Snedecor, 1946) for use in analysis of variance. All main effects and first- and second-order interactions were segregated in analysis with the sums of squares for higher than second-order interactions included in error. The resulting significant mean squares are presented in Table 1. Unless otherwise noted in the text, only those sources of variation having significant mean squares are discussed. The coefficient of variation in this experiment was 16 per cent.

Time of spraying

Average kills were 80 and 85 per cent respectively for 1952 and 1953. The most important outcome in the year difference was due to a longer effective spraying season in 1953 (Table 2) that was associated with weather conditions. Total May-June precipitation was 2.53 inches in 1952 and 6.03 inches in 1953. Temperature and humidity records also emphasize the great difference between years

Table 2. PERCENTAGE OF BIG SAGEBRUSH KILLED, BY DATES, 1952 AND 1953

Spraying date[1]	Percentage of plants killed[2]		
	1952	1953	Average
A	87	76	82
B	90	88	89
C	91	90	90
D	88	94	91
E	64	93	80
F	50	61	55
Average	80	85	

[1] Corresponding dates of spraying for the 2 years were:

	1952	1953
A	April 24	April 20
B	May 3	May 4
C	May 15	May 18
D	May 27	June 1
E	June 13	June 17
F	July 3	July 8

[2] The percentage values are conversions from average angles, and the average percentages presented are not necessarily arithmetic averages of preceding percentage values.

with mean monthly temperatures for May and June of 51° F. and 56° F. in 1952, and 45° F. and 52° F. in 1953.

Highly significant year x date interaction provides proof that the longer growing season of 1953 influenced the trend in mortality.

Growth regulator materials

There was no significant difference between the low volatile (propyleneglycol butyl ether ester) and butyl esters of 2,4-D, but 2,4,5-T killed an average of 87 per cent of the sagebrush as compared with 79 and 80 per cent respectively for low volatile and butyl esters of 2,4-D. Thus, average results for the two formulations of 2,4-D are used in the remainder of this paper.

Highly significant date x material interaction is of special interest because an answer to the question, "Which growth regulator is best on big sagebrush?" depends to some extent on when the spraying is accomplished. The percentage kill in favor of 2,4,5-T decreased as the season progressed (Table 3). The differences between growth regulators in favor of 2,4,5-T were 14, 11, 7, 6, 1, and −5 per cent respectively by dates in chronological order.

The failure of date x material interaction to be the same each year is indicated by highly significant year x date x material interaction. In 1953 the trend of differences between 2,4-D and 2,4,5-T was more pronounced than in 1952 as a result of the longer growing season. Using only 1953 data the differences in percentage kill favoring 2,4,5-T were 20, 12, 7, 6, −3, and −11 per cent respectively by dates of spraying.

Table 3. PERCENTAGE OF BIG SAGEBRUSH KILLED BY 2,4-D AND 2,4,5-T

Spraying date[1]	Percentage of plants killed[2]					
	2,4-D[3]		2,4,5-T[4]		Average	
	1952	1953	1952	1953	2,4-D	2,4,5-T
A	83	69	93	89	77	91
B	85	83	96	95	84	95
C	88	87	96	94	88	95
D	85	91	91	97	89	95
E	61	94	69	91	80	81
F	50	64	50	53	57	52
Average	77	83	85	89	80	87

[1] See footnote 1, Table 2.
[2] See footnote 2, Table 2.
[3] Propyleneglycol butyl ether and butyl esters of 2,4-D are averaged.
[4] Propyleneglycol butyl ether ester 2,4,5-T

Acid equivalent rates

One pound of acid per acre killed an average of 78 per cent and 2 pounds killed 87 per cent of individual sagebrush plants. These averages cover all dates and materials, however, and it is of more practical interest to see averages by dates and growth regulators. The effectiveness of 2,4-D and 2,4,5-T at each acid rate may be observed by dates of spraying in Table 4. The percentages in Table 4 are of additional interest in considering the highly significant date x material x rate interaction. Date x material interaction was not the same at both acid rates, but the difference was only a matter of degree because at both rates the percentage-kill value in favor of 2,4,5-T over 2,4-D became progressively smaller as the season progressed.

Table 4. PERCENTAGE OF BIG SAGEBRUSH KILLED BY 2,4-D AND 2,4,5-T AT ACID EQUIVALENT RATES OF 1 AND 2 POUNDS PER ACRE

Spraying date[1]	Percentage of plants killed[2]			
	2,4-D[3] at acid rate of—		2,4,5-T[4] at acid rate of—	
	1 lb.	2 lbs.	1 lb.	2 lbs.
A	74	79	88	94
B	80	88	94	96
C	81	93	91	98
D	84	92	92	97
E	76	83	75	87
F	48	65	45	59
Average	72	84	83	91

[1] See footnote 1 Table 2.
[2] See footnote 2, Table 2.
[3] Propyleneglycol butyl ether and butyl esters of 2,4-D are averaged.
[4] Propyleneglycol butyl ether ester 2,4,5-T.

Solvents

The lack of significant differences among the three solvents is worthy of note. Average kills were 83, 82, and 82 per cent respectively for water, diesel oil, and diesel oil emulsion. The year by solvent interaction, however, indicated that the comparison among solvents was not the same each year (Table 5). Diesel oil was generally the best (by as much as 5 per cent in kill) through 1952, but was generally lower in kill than water and oil-emulsion solvents through 1953.

In the complementary experiment comparing 14 different solvents, there was no significant difference due to solvents, although the three materials were different. Average kills by material were

Table 5. PERCENTAGE OF BIG SAGEBRUSH KILLED USING THREE DIFFERENT SOLVENTS, 1952 AND 1953.

Solvents	Percentage of plants killed[1]		
	1952	1953	Average
Water[2]	79	85	83
Emulsion[3]	77	86	82
Diesel oil[4]	82	83	82

[1] See footnote 2, Table 2.
[2] *Water* plus Tween 20 at 0.1 per cent by volume.
[3] Diesel oil *emulsion* with a water to oil ratio of 2:1 and emulsified with Tenlo 400 at 5 per cent of total oil volume.
[4] *Diesel oil.*

68, 74, and 84 per cent respectively for butyl ester 2,4-D, low volatile 2,4-D, and low volatile 2,4,5-T. The range in average kills among solvents was 62 to 79 per cent with a mean of 72 per cent.

Solution volume

Three gallons of solution killed an average of 77 per cent and 6 gallons killed 87 per cent of individual sagebrush plants. Under the conditions of this study, solution volume was equally as important as amount of acid. At the rates and volume levels used, there was no interaction between the two sources of variation. At each acid rate the increase in volume was equally effective, and, likewise, at each solution volume an increase in acid concentration was equally effective (Table 6).

Table 6. PERCENTAGE OF BIG SAGEBRUSH KILLED USING DIFFERENT ACID EQUIVALENT RATES AND SOLUTION VOLUMES PER ACRE

Acid rate	Percentage of plants killed[1] at solution volume of—		
	3 gallons	6 gallons	Average
1 pound	72	83	78
2 pounds	81	91	87
Average	77	87	

[1] See footnote 2, Table 2.

The difference between 3 and 6 gallons of solution was not the same each year, as indicated by highly significant year x volume interaction (Table 7). The difference between the two volumes was greater in 1952 than in 1953. Dates of spraying also were involved in year x volume interaction as indicated by significant year x date x volume interaction. In other words, the difference due to volume seemed to depend on factors which varied with each time of spraying.

Table 7. PERCENTAGE OF BIG SAGEBRUSH KILLED IN 1952 AND 1953 USING SOLUTION VOLUMES OF 3 AND 6 GALLONS PER ACRE

Year	Percentage of plants killed[1] at solution volume of—		
	3 gallons	6 gallons	Average
1952	72	86	80
1953	81	88	85
Average	77	87	

[1] See footnote 2, Table 2.

It was thought that temperature and humidity at the time of spraying might be important factors involved in the amount of solution needed to obtain thorough spray coverage of the vegetation. Observational comparison of the records showed no evident relation to temperature, but the differences in mortality between solution volumes varied inversely with relative humidity. This observation of the data could not be defined by correlation analysis because of the many extraneous sources of variation.

Airplane spraying

No significant difference in percentage kill occurred between oil and water solvents. Also there were no significant differences among volumes of 1, 2, and 3 gallons of solution per acre, but the differences among 3, 6, and 9 gallons were significant at the 0.05 probability level. The adjustment of percentage kill data in analysis of covariance by the numbers of sagebrush before spraying reduced the relative importance of difference between solvents, and markedly increased the significance of variation due to volumes. The correlation coefficient between sagebrush density and per cent kill was -0.536.

Six and nine gallons were better than three gallons by an average of 14 per cent, but replication and sampling were inadequate for proper evaluation of the treatments included in the experiment. Overall average kill was 55 per cent—well below what could be expected at 1 pound of 2,4-D. The average kill at 6 gallons of solution was 68 per cent—slightly below an expected 70 to 80 per cent kill. The relatively low kills were partly due to wind conditions. Many plants were observed to be dead on the north (windward) side and alive on the south side. Flight direction from west to east and vice versa alternately had no apparent influence on the individual-crown kill pattern. Top kill, in general, looked good, but at close inspection it was evident that spray penetration into the vegetation was rather poor.

Discussion

Time of spraying

The higher effectiveness in 1953 as related to weather conditions supports the earlier conclusion (Hyder, 1953) that the duration of spray effectiveness is contingent on exhaustion of soil moisture and the resulting termination of active growth.

The need for a field method in choosing the period for best spray results led to further consideration of Sandberg bluegrass (*Poa secunda*) as an indicator. The beginning of the period of peak effectiveness was associated with "heads showing" on Sandberg bluegrass. Initial spray applications in 1952 were made when "heads-showing" development was complete, but in 1953 heading occurred mostly between the first two dates of spraying. Therefore, the "heads showing" stage of development appears to be a reliable indicator that may be used in judging when to begin spraying.

Termination of the period of peak effectiveness was associated with the loss of green color in Sandberg bluegrass, because that aspect was an indication of soil moisture depletion. The loss in green color occurred in early June, 1952, but in 1953 was judged to be "one-half gone" on July 5. Because of the long, wet season in 1953 and the resulting extension of the green-color period, the last spraying date was delayed until July 8 to test the green-color index in an unusual year. The drop in mortality shown in Table 2 occurred at the time when Sandberg bluegrass was losing green color.

In 1951, using 17 dates of spraying at weekly intervals, it was found that sagebrush kill dropped drastically in a single week, and occurred at the time when the green color of Sandberg bluegrass was judged to be one-half gone (unpublished data). We believe the index to be well established as reliable, and see no reason why it will not serve equally as well in other areas. Nevertheless, a plant development index should be accepted as nothing more than an indicator, and stretching the index on either end is not considered wise.

As an additional index, it is worthy to note that leaf abscission was not complete following late season spraying. Many of the dry leaves were still present a year after spraying. Apparently the leaves are retained when spraying is done just prior to or during the period of moisture stress. When the retention of dead leaves is observed a year after spraying, one should suspect that spraying was too late for best kill.

Materials

Spraying trials have generally shown 2,4,5-T to be more effective on big sagebrush than 2,4-D (Hull et al., 1952). It has also been found that the comparison between those two growth regulators may depend on time of spraying with reference to vegetative development (Hull, et al., 1952). Hull reported that 2,4,5-T "appeared to be effective earlier in the season and for a longer period than 2,4-D." Results from this study show that 2,4,5-T does reach peak effectiveness earlier in the season, but that 2,4-D gradually overcomes that lead as the season progresses. Previous trials led to the assumption that in a long, wet season 2,4-D might eventually be superior to 2,4,5-T in killing big sagebrush. Precipitation during May and June, 1953, was sufficient to promote active growth until July, and it was found that 2,4-D killed more sagebrush than 2,4,5-T on the last two dates of spraying—June 17 and July 8. Apparently a physiological change occurs in big sagebrush as the growing season progresses that causes the sagebrush to become more susceptible to 2,4-D. Where long growing seasons are more the rule than the exception, late season spraying (beginning about flowering stage of development for Sandberg bluegrass) with 2,4-D is suggested.

Because of the greater difference between the two growth regulators early in the season, spraying with 2,4,5-T as Sandberg bluegrass heads begin to show might provide more control for the money than 2,4-D at the same time. If the cost difference declines, more consideration should be given to the seasonally greater effectiveness of 2,4,5-T. At present costs, we advise the use of an ester 2,4-D, and spraying from the time Sandberg bluegrass is fully headed to "green color about one-half gone."

Mixtures of 2,4-D and 2,4,5-T in proportions of 0:4, 1:3, 2:2, 3:1, and 4:0 have been applied in other Squaw Butte trials (unpublished data). No interaction gain or loss occurred as a result of the mixtures. Therefore, if it is profitable to use any 2,4,5-T, it is profitable to use all 2,4,5-T, and shall remain true as cost differences fluctuate.

When considering the lack of difference between the low volatile and butyl esters of 2,4-D, it is well to remember that these trial applications were made in early morning under conditions of no wind and relatively low temperatures and high humidities. With other atmospheric conditions, volatility of the formulating materials might result in real differences in kill due to physical phenomena. It may be concluded, however, that there is no difference in the physiological effectiveness on big sagebrush between butyl ester 2,4-D and propyleneglycol butyl ether ester 2,4-D.

A lot of confusion exists regarding different formulating esters. As an example, isopropyl ester 2,4-D usually appears to be less effective and less consistent than butyl ester 2,4-D, but such difference in effectiveness is difficult to understand and difficult to accept as real. Trials with standardized materials are needed, but perhaps the basic physical and physiological phenomena which may cause variability to be different among formulating esters must be found before real progress can be made in making a choice. At the present time we choose butyl ester 2,4-D on the basis of cost and reliability in effectiveness.

Acid equivalent rates

The most practical degree of control is more a matter of conjecture than of fact, and may continue to be so. We have felt that emphasis should be placed on sagebrush control rather than eradication, because the sagebrush will come back to some extent—depending on weather conditions and understory competition. With ideal weather conditions for germination and establishment of big sagebrush following the spraying year, respraying could be feasible in 6 to 10 years. It is advisable to spread the spraying job over a number of years to prevent catching the kind of year on all of the area when sagebrush will become readily established.

The same kind of thinking seems justified with reference to amount of acid and the degree of kill desired. It appears that a kill of 70 to 80 per cent of individual plants (with the remainder of crowns partially killed) is sufficient in a practical control program. One pound of butyl ester 2,4-D can provide that degree of kill. If more was known about the influence of atmospheric conditions and variations in equipment on spray effectiveness so that spraying could be done only in the most suitable time and by the best procedure of distribution, it would not be necessary to apply more than 1 pound of 2,4-D. One must now conclude that it is probably better to allow an extra half-pound of acid for unknown factors to insure satisfactory kill. Since isopropyl ester 2,4-D seems less reliable than the butyl ester, it should be applied at 2 pounds per acre. One pound of an ester form of 2,4,5-T is fully adequate when applied at the proper time. The rate at which other formulations should be applied may be judged from the results reported in the literature concerning the spraying of big sagebrush.

We recognize the possibility of area differences in degree of kill which may be due to generic strain, soil, brush density, species and density of companion vegetation, and possibly other factors. For instance, percentage kill has been found to vary inversely with brush density, but as brush density increases a higher percentage kill is needed to provide good control—as brush density increases, one should increase the acid rate. Thus we advise that extensive spraying be guided by experience gained through preliminary trials at the rates given above.

Solvents

In Squaw Butte trials there has been only one indication of gain in effectiveness due to solvent. That indication was that a wetting agent should be added to a water solvent. Strong evidence that this is true is found in Colorado results (unpublished data). Spraying trials on big sagebrush have not shown to our satisfaction a clear and consistent benefit in kill that must be attributed to an oil solvent. The strongest evidence of such possibility is perhaps found in Wyoming trials, but the difference in favor of oil was consistent only with isopropyl ester 2,4-D (unpublished data). We conclude that an oil solvent is not more effective physiologically than water with wetting agent additive for foliage applications on big sagebrush. Atmospheric conditions or spray equipment, however, may induce physical factors which cause a real difference in kill between water and oil.

It appears doubtful that an oil solvent will ever be justified on the basis of cost and return over water as solvent. If so, it will probably be determined by the total cost of delivering the respective solvents to the spraying site, rather than on differences in sagebrush kill.

Solution volume

The consideration of different solvents has been closely related to solution volume. It has been assumed that with an oil solvent less solution volume is needed to obtain thorough spray coverage and the desired degree of kill. The present study refutes such argument. There was no difference among solvents, and that lack of difference was consistent at each volume rate of 3 and 6 gallons through all 12 spraying times. Thus, thoroughness in spray coverage is far more important to mortality than material "creep" and penetration when ester materials are used in the foregoing solvents at the stated volumes.

It is concluded that about 5 or 6 gallons of solution is needed to obtain thorough spray coverage, but it is recognized that the equipment used will vary the thoroughness of spray distribution.

It is important to note that under the conditions of this study solution volume was equally as important as acid rate. This introduces an economic consideration in a practical spraying program. If the cost of carrying an additional 3 gallons of solution is greater than the cost of an additional pound of acid, the volume rate may be reduced and the acid rate increased to take advantage of the cost difference. We want to warn against the tendency, however, to choose from various recommendations the lowest acid rate and the lowest volume rate as a suitable combination.

Experimental methods

Using individual sample areas (plots) of 500 square feet, we have found that about 50 replications of main effects are needed to provide an adequate experiment in which differences of 5 per cent or more in kill will be significant. The most satisfactory type of experiment has been one of factorial combinations as in the present experiment. This provides more than an adequate number of main effect replications and also provides opportunity to consider the influence of variation in one main effect upon other main effects. We wish to stress the importance of interactions, because they provide the only means in applied research of finding limits and trends in major factors. Of special value has been the inclusion of a number of dates of spraying as main effects. Inspection of Table 1 will show that all significant interactions involve time (years or dates) of spraying.

Hand applications of spray solutions may be criticized because solution distribution over the vegetation may be very different from that obtained with equipment which could be used on a practical basis, and especially different from that obtained with an airplane. Spray distribution patterns were obtained in the manner described by Graham (1953) to compare spray distribution by airplane and hand equipment. At 3 and 6 gallons there was no apparent difference due to equipment, but the difference due to solution volume was readily apparent with each. Even so, there may be a lot of difference among the types of equipment which could be used on a practical basis. Therefore, we believe it best in research to separate variability due to equipment and spraying procedure from basic effectiveness of materials. The possibility of interaction between equipment and basic effectiveness of materials is visualized, especially with regard to solvent and solution volume. Spraying equipment may become more efficient in spray distribution, so that less solution volume is needed. Furthermore, the efficiency in spray distribution with certain spray equipment may be different with an oil solvent than with water. We do not extend the results from present trials over all such physical factors, but offer them as a sound basis from which knowledge regarding practical spraying may be extended.

As a test of the knowledge gained in these trials, airplane applications were made on May 11, 1953. The aerial spraying emphasized the difficulty of using airplane applications in applied research trials—large areas with variable stands and ages of brush, a small number of treatment factors and replications, and a long time-interval in spraying with possible source of error due to variation in atmospheric conditions. Even so, the results provide assurance in the conclusions drawn from other trials.

Summary

1. Spraying trials on big sagebrush were made in 1952 and 1953 to find the variation in kill due to time of spraying, growth regulator material, acid equivalent rate, solvent, and solution volume.

2. Spraying was sufficiently effective throughout the season beginning with Sandberg bluegrass in "head" and ending with Sandberg blue grass showing about "one-half green color gone." The time and length of this spraying season was not the same each year.

3. In general, 2,4,5-T killed more big sagebrush than 2,4-D, but relative effectiveness varied with time of spraying. The average difference between growth regulators in favor of 2,4,5-T were 14, 11, 7, 6, 1, and –5 per cent mortality respectively by dates of spraying in chronological order. In the longer growing season of 1953 that trend of differences, in which 2,4-D eventually became more effective than 2,4,5-T, was more pronounced.

4. Propyleneglycol butyl ether ester 2,4-D and butyl ester 2,4-D were equally effective.

5. One pound (acid equivalent) per acre killed an average of 78 per cent and two pounds killed 87 per cent of individual sagebrush plants.

6. Solvents of water, diesel oil, and diesel oil emulsion were equally effective. In supplementary spraying trials there were no significant differences among 14 different solvents.

7. Three gallons of solution killed an average of 77 per cent and 6 gallons killed 87 per cent of the big sagebrush plants. Under the conditions of this study, solution volume was as important as the amount of acid.

8. The results of this experiment are reported as a sound basis from which knowledge regarding practical spraying may be extended.

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