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# Chemical Control of Rabbitbrush with Emphasis upon Simultaneous Control of Big Sagebrush[1]

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Only a few reports have been published on the susceptibility of rabbitbrush *(Chrysothamnus* spp.) to chemical herbicides (1, 2, 5, 6, 7). From these publications the following conclusions may be made: (a) 2,4–D (2,4–dichlorophenoxyacetic acid) is more effective on rabbitbrush than 2,4,5–T (2,4,5–trichlorophenoxyacetic acid), (b) June applications are generally best, (c) rabbitbrush is more tolerant to growth regulators than big sagebrush *(Artemisia tridentata),* and (d) resprouting from the stem base is common.

A great deal of demand for more information has been expressed. Variations in kill from extremely poor to very good have caused special concern about timing of spray applications. The need for and value of rabbitbrush control is largely empirical.

The present paper is a compilation of mortality results from five experiments on green (or Douglas) and grey (or rubber) rabbitbrush *(C. viscidiflorus* and *C. nauseosus),* and big sagebrush. These experiments were conducted in central and southeastern Oregon, and included various dates of application, herbicides, and acid rates. The results obtained support previous publications and offer new information on the chemical control of rabbitbrush. In particular the results provide new information on the timing of spray applications to obtain simultaneous control of rabbitbrush and big sagebrush in mixed stands.

## Materials and Methods

Spraying trials were made in 1950, 1954, and 1955. A compressed-air back-pack sprayer employing a single 8001 nozzle under a pressure of 35 psi was used in four trials, and a jeep-mounted power sprayer employing a 13-foot boom mounted with 8001 nozzles under a pressure of 30 psi was used in one trial. Applications were made at solution volumes of 5 to 10.9 gal/A, at acid rates from 0.5 to 4.0 lb/A, and on various dates throughout the growing season. Further details are included in the discussion of results of individual experiments.

The herbicides included were as follows:

(a) 2,4–D butoxy ethanol ester,
(b) 2,4–D butyl ester,
(c) 2,4–D methoxy polyethylene glycol 350 ester (2,4–D MPGE),
(d) 2,4–D propylene glycol butyl ether ester (2,4–D PGBE),

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(e) 2,4–D sodium salt,
(f) 2,4,5–T butoxy ethanol ester,
(g) 2,4,5–T propylene glycol butyl ether ester (2,4,5–T PGBE),
(h) 2,4,5–T and 2,4–D isopropyl esters in 1:1 mix,
(i) 2–methyl–4–chlorophenoxyacetic acid (MCPA) as a butoxy ethanol ester,
(j) 4–chlorophenoxacetic acid (4–CPA) as a butoxy ethanol ester,
(k) 3,4–dichlorophenoxyacetic acid (3,4–DA) as an iso–octyl ester,
(l) 2,3,6–trichlorobenzoic acid (2,3,6–TBA) as a sodium salt,
(m) 2–(2,4,5–trichlorophenoxy) propionic acid (silvex) as a butoxy ethanol ester,
(n) 2–(2,4,5–TP) propylene glycol butyl ether ester (silvex PGBE), and
(o) 3–amino–1,2,4–triazole (amitrol).

All live brush plants were counted on each plot before spraying and again one year after spraying to determine mortality in most trials.

## RESULTS

*Screening trials on rabbitbrush species.*

Screening trials on green and grey rabbitbrush were conducted in 1954 using the following materials; 2,4–D butoxy ethanol ester, 2,4,5–T butoxy ethanol ester, MCPA butoxy ethanol ester, 4–CPA butoxy ethanol ester, 3,4–DA iso–octyl ester, 2,3,6–TBA sodium salt, silvex butoxy ethanol ester, and amitrol. All materials were applied at the rate of 3 lb/A on plots 0.5 square rod in size using a back-pack sprayer. The plots were arranged in three randomized blocks on each species of rabbitbrush. Spraying was accomplished on June 5, 1954, and ocular estimates of mortality were made on July 25, 1955. Independent estimates were made of mortality on rabbitbrush seedlings, young-mature plants, and old-mature plants. The data were not subjected to statistical analysis.

The most effective herbicide on each species was 2,4–D (Table 1). Grey rabbitbrush was as susceptible to 2,4–D as green rabbitbrush, but was apparently more resistant to the other materials used. In particular one may note that amitrol was ineffective on grey rabbitbrush but provided moderate control on green rabbitbrush. The comparison among age classes in terms of herbicidal effectiveness was inconclusive.

*Test of additives with 2,4–D and 2,4,5–T on green rabbitbrush.*

In 1954 and 1955, 2,4–D and 2,4,5–T (as propylene glycol butyl ether esters) were applied at acid equivalent rates of 0.5, 0.75, and 1.0 lb/A on 1/50-acre plots arranged in split-plot field design with three randomized blocks. A 2 x 3 factorial of herbicides and acid rates was assigned to whole plots, and eight levels of additive were assigned to sub-plots.

The eight levels of additive were as follows: (a) non-additive check, (b) urea at 5 lb/A of elemental nitrogen, (c) boric acid at 0.5 lb/A of

*Table 1.* Estimated mortality of green and grey rabbitbrush sprayed on June 5, 1954 with eight herbicides, each applied at an acid equivalent rate of 3 lb/A.

| Herbicide | Percentage mortality by visual estimate | | | |
|---|---|---|---|---|
| | Seedlings | Young mature | Old mature | Average |
| Green rabbitbrush | | | | |
| 2,4-D butoxy ethanol | 65 | 90 | 95 | 83 |
| MCPA butoxy ethanol | 70 | 70 | 50 | 63 |
| Amitrol | 40 | 65 | 70 | 58 |
| 2,4,5-T butoxy ethanol | 35 | 50 | 50 | 45 |
| silvex butoxy ethanol | 40 | 50 | 20 | 37 |
| 3,4-DA iso-octyl | 10 | 10 | 10 | 10 |
| 4-CPA butoxy ethanol | 0 | 0 | 0 | 0 |
| 2,3,6-TBA sodium salt | 0 | 0 | 0 | 0 |
| Average | 32 | 42 | 37 | 37 |
| Grey rabbitbrush | | | | |
| 2,4-D butoxy ethanol | 100 | 100 | 100 | 100 |
| MCPA butoxy ethanol | 35 | 50 | 25 | 37 |
| 2,4,5-T butoxy ethanol | 20 | 30 | 0 | 17 |
| silvex butoxy ethanol | 5 | 20 | 5 | 10 |
| 3,4-DA iso-octyl | 5 | 10 | 5 | 7 |
| 4-CPA butoxy ethanol | 0 | 0 | 0 | 0 |
| 2,3,6-TBA sodium salt | 0 | 0 | 0 | 0 |
| Amitrol | 0 | 0 | 0 | 0 |
| Average | 21 | 26 | 17 | 21 |

elemental boron, (d) $Na_2Fe$ EDTA (disodium ferric ethylanediamine tetraacetate) at 0.5 lb/A of elemental iron, (e) $Na_2Cu$ EDTA at 0.5 lb/A of elemental copper, (f) $Na_2Zn$ EDTA at 0.5 lb/A of elemental zinc, (g) magnesium diacetyl acetone at 0.5 lb/A of elemental magnesium, and (h) maleic hydrazide at 1 lb/A of actual MH.

All materials were emulsified in water and applied at 6 gal/A with a back-pack sprayer. The three blocks of plots were sprayed on separate dates as follows: May 18, 1954, May 28, 1955, and June 7, 1955.

Green rabbitbrush mortality percentages were converted to angles for statistical analysis. Dates of spraying, herbicides, and additives were sources of significant variation in rabbitbrush mortality.

Among the additives, only zinc-containing solutions gave as much kill as the non-additive check solutions. Mean kills were 30 and 34 per cent respectively with non-additive and zinc-containing solutions. Three of the additives (boron, iron, and magnesium) gave mean kills of 2 per cent or less, which were significantly lower than that obtained with the non-additive, urea, copper, zinc, and MH solutions.

Mean kills by dates of spraying were 0, 47, and 20 per cent respectively on May 18, 1954, May 28, 1955, and June 7, 1955. The growing seasons in 1954 and 1955 were unusually short and dry, and periods for effective spraying were therefore short. Applications on May 18, 1954 and June 7, 1955 were near the termination of active rabbitbrush growth. The average mortality obtained by spraying on May 28, 1955 was fairly good considering the low acid rates used.

Average kills were 29 and 2 per cent respectively for 2,4–D and

2,4,5–T over all dates, acid rates, and additives but on May 28, 1955 mean kills with 1 lb/A were 85 and 70 per cent respectively for 2,4–D and 2,4,5–T.

*Tests of spraying green rabbitbrush twice in one season.*

In 1954 a jeep-mounted power sprayer was used to apply 2,4–D butyl ester (emulsified in water at 9 gal/A) on a mixed stand of green rabbitbrush and big sagebrush. The 100- by 100-foot plots were arranged in three randomized blocks of four plots each, to compare four treatments as follows: (a) untreated check, (b) a split application of 2 lb/A, in which 1 lb/A was applied on March 22 when green rabbitbrush leaf buds were beginning to swell and 1 lb/A on May 14 when associated sandberg bluegrass *(Poa secunda)* was flowering, (c) 1 lb/A on May 14, and (d) 2 lb/A on May 14.

Dead and living plants of green rabbitbrush and big sagebrush were counted on five 100-square-foot samples per plot in 1955 to determine mortality.

Mean kills of rabbitbrush were 0, 34, 72, and 85 per cent respectively for untreated check, 2 lb/A split application, 1 lb/A single application, and 2 lb/A single application. With treatments in the same order, sagebrush kills were 0, 100, 100, and 100 per cent respectively. In the split application, the initial treatment killed most of the leaf and terminal buds of rabbitbrush and induced vigorous lateral and basal sprouting. It was thought that this resprouting would cause the plants to be highly susceptible to 2,4–D applied later in the season; however, the split application of 2 lb/A was far less effective than a single application of either 1 or 2 lb/A when applied in an active stage of growth.

*Tests of rate and time of application on green rabbitbrush.*

In 1950, 10- by 50-foot plots were sprayed with a back-pack sprayer on nine dates (Table 2). The experiment constituted a 9 x 4 x 3 complete factorial with a single replication. (Three replications were involved in this experiment to determine mortality of big sagebrush, but stands of green rabbitbrush were sufficient for consideration on only a single replication. Big sagebrush mortalities resulting from those applications were reported by Hyder (3).) Since a single replication was involved in the consideration of rabbitbrush mortality, tests of significance in the analysis of variance were made by using interaction mean squares as estimates of error. Morality percentages were converted to angles for compilation and analysis.

The factorial experiment included four herbicides as follows: A 1:1 mix of 2,4–D and 2,4,5–T isopropyl esters in 20 per cent diesel oil emulsion, 2,4–D sodium salt in 20 per cent diesel oil emulsion, 2,4–D butyl ester in 20 per cent diesel oil emulsion, and 2,4–D butyl ester in water. Each herbicide was applied at acid equivalent rates of 1, 2, and 3 lb/A in a total solution volume of 10.9 gal/A. Notes on vegetative development and soil moisture levels were obtained throughout the spraying season.

*Table 2.* Mortality of green rabbitbrush and big sagebrush sprayed on nine dates in 1950 with 2,4-D butyl ester at 1, 2, and 3 lb/A.

| Acid rates of 2,4-D in lb/A | Percentage mortality in 1950[a] | | | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| | April 18 | May 2 | May 16 | May 24 | May 30 | June 8 | June 15 | June 20 | July 6 | |
| | | | | | Green rabbitbrush | | | | | |
| 1 | 0 | −7 | −1 | 72 | 3 | 46 | 57 | 72 | −28 | 10 |
| 2 | −93 | −19 | 38 | 57 | 66 | 94 | 59 | 52 | 19 | 20 |
| 3 | 12 | 1 | 41 | 69 | 89 | 90 | 92 | 89 | −66 | 41 |
| Average | −10 | −4 | 17 | 66 | 50 | 80 | 71 | 72 | −12 | 22 |
| | | | | | Big sagebrush | | | | | |
| 1 | 54 | 71 | 64 | 74 | 65 | 71 | 61 | 40 | 5 | 56 |
| 2 | 71 | 82 | 79 | 86 | 82 | 86 | 82 | 52 | 23 | 71 |
| 3 | 80 | 94 | 87 | 90 | 87 | 96 | 91 | 67 | 25 | 80 |
| Average | 68 | 82 | 77 | 83 | 78 | 84 | 78 | 53 | 18 | 69 |

[a]Because of the small numbers of rabbitbrush, mortality percentages were transformed to angles for statistical analysis. Sagebrush mortality percentages were not transformed. The rabbitbrush mortality percentages given in this table are re-transformations from mean angles, consequently, "average" percentages are not arithmetic averages from the body of the table.

Herbicides, acid rates, and dates of spraying were sources of significant variation in rabbitbrush mortality. Rabbitbrush density increased 73 per cent on unsprayed check plots. Consequently, negative mortality values are real in the consideration of herbicidal effectiveness. The mean number of rabbitbrush before spraying was 12 plants per 500 square feet.

Mean kills were −9, 7, 22, and 23 per cent respectively for 2,4–D sodium salt, 1:1 mix 2,4–D and 2,4,5–T isopropyl esters, 2,4–D butyl ester in oil emulsion, and 2,4–D butyl ester in water. The 2,4–D sodium salt was significantly less effective than the 1:1 mix, and the 1:1 mix was significantly less effective than 2,4–D butyl ester. For simplification, the presentation of differences among acid rates and dates of spraying will be restricted to 2,4–D butyl ester.

Acid rates of 1, 2, and 3 lb/A of 2,4–D butyl ester gave mean kills of 10, 20, and 41 per cent respectively (Table 2). The 3 lb/A rate gave mean kills of 89, 90, 92, and 89 per cent respectively on May 30, June 8, June 15, and June 20. Acid rates of 1 and 2 lb/A did not give high kills consistently.

Time of spraying was obviously critical to herbicidal effectiveness. Green rabbitbrush had produced 3 to 4 inches of new twig growth by the first of June. Squirreltail *(Sitanion hystrix)* and Thurber needlegrass *(Stipa thurberiana)* were heading and sandberg bluegrass was in early flower when green rabbitbrush susceptibility reached maximum. The development of those grass species and others are summarized in Table 3. Seasonal soil moisture levels were reported by Hyder (3).

*Tests of rate and time of spraying on mixed stands of green rabbitbrush and big sagebrush.*

In 1955 applications were made on a mixed stand of green rabbit-

*Table 3.* Vegetative and reproductive development of grasses associated with green rabbitbrush and big sagebrush in 1950.

| Species | Development criteria | April 24 | May 8 | May 15 | May 23 | May 29 | June 5 | June 14 | June 19 | July 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Poa secunda* | Leaves (inches)[a] | 2.0 | 2.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | | |
| | Stems (inches)[a] | | | 4.0 | 5.5 | 7.0 | 7.0 | 8.0 | 9.0 | |
| | Reproductive[b] | | boot | heading | | e.f. | f.f. | s.d. | h.s. | |
| | Herbage color[b] | | | | | l.c. | l.c. | l.c. | b. | b. |
| *Sitanion hystrix* | Leaves (inches) | 5.0 | 4.0 | 4.5 | 5.0 | 6.0 | 5.0 | 5.0 | | |
| | Stems (inches) | | | | | 6.5 | 6.0 | 8.0 | 8.0 | 8.0 |
| | Reproductive | | | | boot | heading | | e.f. | f.f. | s.d. |
| *Stipa thurberiana* | Leaves (inches) | 4.0 | 6.0 | 8.0 | 7.0 | 7.5 | 7.0 | 7.5 | | |
| | Stems (inches) | | | | | 6.0 | 7.0 | 9.0 | 12.0 | 17.0 |
| | Reproductive | | | | boot | heading | | e.f. | f.f. | h.s. |
| *Koeleria cristata* | Leaves (inches) | 3.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | | |
| | Stems (inches) | | | | | | 10.0 | 12.0 | 14.0 | 15.0 |
| | Reproductive | | | | | boot | heading | e.f. | f.f. | l.f. |
| *Agropyron spicatum* | Leaves (inches) | 4.5 | 6.5 | 6.5 | 7.5 | 9.0 | 9.0 | 10.0 | | |
| | Stems (inches) | | | | | | | | 15.5 | 20.0 |
| | Reproductive | | | | | | boot | | heading | e.f. |
| *Elymus cinereus* | Leaves (inches) | 5.0 | 7.0 | 8.5 | 10.0 | 11.5 | 12.5 | 16.0 | | |
| | Stems (inches) | | | | | | | | | 26.0 |
| | Reproductive | | | | | | | | boot | heading |

[a]Maximum leaf (stem) length was measured on ten or less of each species on each of 14 plots chosen at random, mean maximum leaf (stem) length is reported.
[b]Abbreviations are: e.f. = early flower, f.f. = full flower, l.f. = late flower, s.d. = soft dough, h.s. = hard seed, l.c. = loosing color, b. = brown.

brush and big sagebrush with a back-pack sprayer. This was a split-plot experiment in 3 replications with 7 dates of spraying on whole plots and a 4 x 2 factorial of herbicides and acid rates on sub-plots. Individual plots were 10 x 88 feet in size. The four herbicides applied were as follows: 2,4–D butyl ester, 2,4–D MPGE, 2,4,5–T PGBE, and silvex PGBE. These herbicides were applied at acid equivalent rates of 2 and 4 lb/A in water at 6 gal/A. Live plants were counted prior to spraying and again one year after spraying to determine mortality. Percentage-kill data for each species were subjected to statistical analysis. Notes on vegetative development were obtained on each date of spraying.

Herbicides, acid rates, and dates of spraying gave highly significant differences in green rabbitbrush mortality, but the interactions of these main effects were not significant.

Mean rabbitbrush kills were 16, 16, 8, and 3 per cent respectively for 2,4–D butyl ester, 2,4–D MPGE, 2,4,5–T PGBE, and silvex PGBE. The consideration of acid rates and dates of spraying will be restricted to the two 2,4–D materials, which were equal in effectiveness and significantly more effective than the other two herbicides.

Rabbitbrush mortality averaged 10 and 22 per cent respectively with 2,4–D at 2 and 4 lb/A (Table 4). Of greatest interest is the fact that kills did not reach 50 per cent at any time in 1955. This was an extremely dry year with moisture penetration into the soil not exceeding 10 inches. The two best dates for spraying were June 28, when green rabbitbrush was in full leaf but twig elongation was

*Table 4.* Mortality of green rabbitbrush and big sagebrush sprayed on seven dates in 1955 with 2,4-D esters at acid rates of 2 and 4 lb/A.

| Acid rates of 2,4-D in lb/A | Percentage mortality in 1955 | | | | | | | Average |
|---|---|---|---|---|---|---|---|---|
| | April 29 | May 9 | June 3 | June 28 | July 14 | July 26 | Aug. 10 | |
| Green rabbitbrush | | | | | | | | |
| 2 | 2 | −3 | 15 | 20 | 20 | 10 | 6 | 10[b] |
| 4 | −2 | 3 | 23 | 48 | 36 | 20 | 27 | 22 |
| Average | 0[a] | 0 | 19 | 34 | 28 | 15 | 17 | 16 |
| Big sagebrush | | | | | | | | |
| 2 | 70 | 97 | 94 | 12 | 4 | 1 | 2 | 40[b] |
| 4 | 80 | 96 | 97 | 47 | 11 | 6 | 3 | 48 |
| Average | 75[a] | 96 | 96 | 30 | 8 | 4 | 2 | 44 |

[a]LSD 5% level for comparing date means: 14 percent for rabbitbrush; 6 percent for sagebrush

[b]LSD 5% level for comparing acid rate means: 5 percent for rabbitbrush; 4 percent for sagebrush

slow, and July 14, when rabbitbrush flower buds were full and beginning to show some color. Mean maximum twig elongation was 3 inches on June 28 and 4.5 inches on July 14. Twig elongation was essentially complete by July 14. In a preceding section rabbitbrush kills from another site sprayed on May 28, 1955 were fairly good at the low acid rates applied. This suggests that better results might have been shown in the present experiment with closer timing of applications in late May and early June.

Soil moisture was depleted and sandberg bluegrass herbage was brown by the middle of June 1955. It has been reported that big sagebrush susceptibility to 2,4–D terminated with the depletion of soil moisture (3, 4). Tables 2 and 4 present the mortality of big sagebrush on the same plots from which green rabbitbrush mortality was obtained. Good sagebrush susceptibility to 2,4–D occurred 3 to 5 weeks prior to the occurrence of rabbitbrush susceptibility and appeared to drop more rapidly as soil moisture became limiting. Satisfactory kills of green rabbitbrush and big sagebrush in mixed stands were obtained in years with favorable moisture conditions, but not in the abnormally dry season of 1955.

## DISCUSSION AND CONCLUSIONS

Green and grey rabbitbrush were more susceptible to ester forms of 2,4–D than to other herbicides used. Good rabbitbrush control was obtained with 2,4–D esters at an acid rate of 3 lb/A if treated at the proper time under favorable growth conditions. The 2,4–D was prepared in water or diesel oil emulsion at a total solution volume of 5 to 10.9 gal/A. Presumably, straight diesel oil also would be a suitable carrier.

With proper timing, big sagebrush and green rabbitbrush were controlled simultaneously. However, susceptibility in big sagebrush developed earlier in the season and green rabbitbrush did not reach the susceptible stage of development in an abnormally dry year. Green rabbitbrush growing on some dry range sites might never be controlled satisfactorily. These facts present a hazard in the chemical control of big sagebrush, because selective killing of sagebrush in mixed stands of rabbitbrush and sagebrush would release the rabbitbrush for rapid increase, and create a more difficult brush problem.

It is suggested that in the chemical control of rabbitbrush favorable seasons must be chosen. A preliminary index in choosing favorable times for spraying is as follows: New twig growth on rabbitbrush must exceed 3 inches in length, sandberg bluegrass must have reached flowering development, squirreltail and Thurber needlegrass must be heading, and sandberg bluegrass herbage must retain some green color. With this timing, big sagebrush may also be killed satisfactorily.

## SUMMARY

Green and grey rabbitbrush *(Chrysothamnus viscidiflorus* and *C. nauseosus)* were sprayed with various formulations of 2,4–D, 2,4,5–T, MCPA, 3,4–DA, 2,3,6–TBA, silvex, and amitrol at acid equivalent rates from 0.5 to 4.0 lb/A. Spraying was done in 1950, 1954, and 1955 with timing varying from late dormancy to early flowering of green rabbitbrush. Results from five separate experiments are reported.

Green and grey rabbitbrush were more susceptible to 2,4–D esters than to any of the other herbicides used. With 2,4–D esters, an acid equivalent rate of 3 lb/A gave good rabbitbrush control.

Proper timing for the control of green rabbitbrush requires the choice of favorable years as well as the susceptible stage of development. A preliminary index to rabbitbrush susceptibility is as follows: New rabbitbrush twig growth must exceed 3 inches in length, sandberg bluegrass *(Poa secunda)* must have reached flowering development, squirreltail *(Sitanion hystrix)* and Thurber needlegrass *(Stipa thurberiana)* must be heading, and sandberg bluegrass herbage must retain some green color. With this timing, big sagebrush *(Artemisia tridentata)* may also be killed satisfactorily.

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