Long-Term Effects of 2,4-D on Lanceleaf Rabbitbrush and Associated Species

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Highlight

If properly applied, 2,4-D reduces rabbitbrush and forbs and allows grass to increase. This would be a desirable management tool on cattle ranges. The most effective kill of rabbitbrush was obtained with a treatment applied in June 1956 when soil was moist and when rabbitbrush was nearly in full leaf. When soil was dry and rabbitbrush was in bloom, spraying had no effect. Spraying before rabbitbrush was in full leaf reduced forbs but increased production of rabbitbrush.

Herbicide sprays have been used to control lanceleaf rabbitbrush (*Chrysothamnus viscidiflorus* var. *lanceolatus* (Nutt.) Greene) and other varieties of low rabbitbrush on many western ranges. Results have varied. The short-term effects of such sprays have been studied but not the effect on the plant communities over a long period. The long-term ecological effects must be known if herbicide spray is to be evaluated as a method of range improvement.

The study reported here was started in 1956 on high-elevation cattle range on the Humboldt National Forest in northern Nevada. Objectives were to determine how effectively different application dates, rates, and chemical formulations of 2,4-D reduce lanceleaf rabbitbrush and undesirable forbs, and increase grass production. Data taken in 1964 show some long-term effects of the different 2,4-D treatments.[2]

Research by other workers done after this study was begun has shown that stage of growth, soil moisture, and temperature are important in obtaining a good kill of rabbitbrush with 2,4-D. Hyder et al. (1958, 1962) obtained about 80% kill of Douglas rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.) by spraying with 3 lb/acre of 2,4-D in late spring, when twigs had attained about 3 inches of new growth and soil moisture was adequate for continued plant growth. A smaller percentage of rabbitbrush was killed when sprayed before and after the time of maximum susceptibility and also in dry years when soil moisture was low. Cook et al. (1965) found that high soil moisture coupled with high temperature (above 70 F during the day and above 40 F at night) in late spring gave best kill of Douglas rabbitbrush sprayed with 2,4-D and with Tordon 22K (picloram). Less rabbitbrush was killed in cooler, drier years.

Cords (1966) demonstrated the importance of high soil temperature on kill of rubber rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britt.) plants sprayed with 2,4-D. In laboratory and greenhouse experiments, three-fourths of the sprayed rabbitbrush plants died at 75 F root temperature but no plants died at 45 F.

Another factor that often contributes to failure of herbicides to reduce rabbitbrush effectively is the ability of rabbitbrush to sprout from the base even though the tops of all plants are killed. Hull and Vaughn (1951), Hull et al. (1952), Blaisdell and Mueggler (1956), and Cook et al. (1956) all noted this tendency in different varieties of Douglas rabbitbrush.

Experimental Area and Procedures

The experimental area is located on a relatively level area near the Pole Creek Ranger Station at an elevation of 8,100 ft in the Jarbidge Mountains, 75 mi north of Elko, Nevada. Average annual precipitation at the nearest climatic station, Jarbidge, Nevada (9 mi from the study area but 1,800 ft lower in elevation), is approximately 22 inches. The vegetation of the area before treatment consisted of lanceleaf rabbitbrush and perennial grasses and forbs (see Table 2 for a list of the major species).

Spray Treatment.—A 20-acre experimental area was fenced and has been protected from livestock grazing since the spring of 1956. Within the area, four blocks (replications) were laid out, each consisting of 21 treatment plots 25 × 75 ft. Within each block, a plot was randomly assigned for treatment according to each combination of three dates, three rates, and two chemical forms of spray. An unsprayed check plot was randomly assigned for each date within each block. Treatments were applied from June 22 to 25, 1956, and on August 9, 1956; the third treatment was a double spray consisting of applications on August 9, 1956, and again on June 14, 1957. The soil moisture conditions and stage of plant development at the three dates of spraying are shown in Table 1.

Rates were 1, 2, and 4 lb/acre acid equivalent of 2,4-D. Forms of spray were low-volatile (butoxy ethanol ester) and high-volatile (butyl ester) 2,4-D.

An oil-water emulsion of herbicide was applied at 20 gal/acre, by means of a 20-ft boom on a tractor. A strip 2.5 ft wide was left as an untreated buffer strip at each edge of the plots.

Because a poor initial kill of rabbitbrush was obtained

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[1] Forest Service, U.S. Department of Agriculture, with headquarters at Ogden, Utah. The Station's Forestry Sciences Laboratory at Logan, Utah, is maintained in cooperation with Utah State University.

[2] The authors gratefully acknowledge assistance from W. C. Robocker, Agricultural Research Service, Pullman, Washington, in the original design of the study; and from M. A. Marsden, Intermountain Forest and Range Experiment Station, Moscow, Idaho, in the analysis of data.

Table 1. Soil moisture and stage of plant development of three spray dates.

Date of spraying	Soil condition	Plant development
June 22–25, 1956	Moist.	Chrysothamnus—three-quarter to full leaf. Eriogonum, Lupinus, and Potentilla—full leaf; flower heads had formed but no flowers.
August 9, 1956	Very dry. Little precipitation since mid-June.	Chrysothamnus—early bloom. All forbs had set seed and some were dry.
June 14, 1957	Very wet. Heavy 3-inch snow the night after spraying.	Chrysothamnus—half leaf. Forbs—half to three-quarters leaf growth completed, no flower stalks formed.

with 1 lb/acre of 2,4-D, some of the plots were resprayed with 2 lb/acre and some with 3 lb of the butyl ester of 2,4-D on July 24, 1959. The soil was dry and rabbitbrush was nearly in full bloom. Because this partial respray confounded the results of the 1 lb/acre spray treatment, data for the respray treatments were analyzed separately and will be discussed later.

Vegetation Sampling.—Data on quantitative yield or density were not taken for rabbitbrush or associated species immediately before or after spraying. Lack of initial data reduces the value of the study somewhat but the comparison of vegetation on sprayed and unsprayed areas 8 years after treatment provides range managers with vital information on the long-term effects of herbicides.

In July 1964, vegetation in the treatment plots was sampled by the weight-estimate method (Pechanec and Pickford, 1937) on ten 0.96 ft^2 subplots evenly spaced along the long axis of each treatment plot. Green weight of each species was estimated in grams and later converted to air-dry production in pounds per acre. The average production for the 10 subplots was used in all analyses.

Statistical Analysis of Data.—Analysis of variance was used to compare production on the plots in 1964. The three dates of spraying and the five treatments (2 lb low-volatile, 4 lb low-volatile, 2 lb high-volatile, 4 lb high-volatile, and unsprayed) were considered fixed effects in a randomized block design. A separate analysis of data was made for each date, in addition to the overall analysis for all dates. Separate analyses of total production were made for all plants, all grasses, and all forbs, and for each of the following important species: lanceleaf rabbitbrush, bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Smith), Idaho fescue (*Festuca idahoensis* Elmer), yarrow (*Achillea millefolium* L.), Wyeth eriogonum (*Eriogonum heracleoides* Nutt.), lupine (*Lupinus laxiflorus* Dougl.), and potentilla (*Potentilla gracilis* Dougl.).

Data were checked for homogeneity of variance by Bartlett's technique (Snedecor, 1956). When the variances were found to be heterogeneous, data were transformed using $\sqrt{x + 0.5}$, where x is the original observation (Bartlett, 1947).

Results

Date of Spraying.—The 2,4-D had a different effect on the vegetation at each of the three dates (Table 2). Only the June 1956 spray resulted in a lasting reduction of rabbitbrush. Plots treated on this date produced significantly less rabbitbrush and forbs and significantly more grass in 1964 than unsprayed plots. In pounds of forage, the reduction of forbs was considerably greater than the reduction of rabbitbrush.

Table 2. Forage production (lb/acre air-dry)[1] in 1964 on areas sprayed with 2,4-D on three different dates in 1956–57, and on unsprayed areas.

Species	Sprayed			
	June 1956	August 1956	August 1956 & June 1957	Unsprayed
Agropyron spicatum	**298	171	197	144
Festuca idahoensis	**624	478	535	484
Poa secunda[2]	25	20	25	15
Other grass[2]	63	14	23	15
Total grass	**1,010	683	780	658
Achillea millefolium	26	19	14	24
Eriogonum heracleoides	49	52	58	64
Lupinus laxiflorus	*4	54	*10	81
Potentilla gracilis	**4	60	**6	80
Other forbs[2]	38	67	13	67
Total forbs	**121	252	**101	316
Shrubs (*Chrysothamnus viscidiflorus* var. *lanceolatus*)	*63	141	*240	134
Total production	1,194	1,076	1,121	1,108

[1] Averaged for four treatments for each date, since there was no significant difference in production between areas sprayed with 2 and 4 pounds per acre nor between those sprayed with low- and high-volatile esters of 2,4-D.
[2] No statistical analysis made of these species or groups.
* Production significantly different from production in unsprayed areas at the 5-percent level of probability.
** Production significantly different from production in unsprayed areas at the 1-percent level of probability.

Sprays applied in August 1956, when the soil and many plants were dry, had no lasting effect on the vegetation. Yields of grasses, forbs, and rabbitbrush in the areas sprayed at this date were not significantly different in 1964 from yields in unsprayed areas. Observations in the fall of 1956 indicated that the 2,4-D killed the aboveground portions of many rabbitbrush plants. Most of these shrubs sprouted from the base the following year, however, and total production was not affected.

Rabbitbrush production actually increased in the areas sprayed in August 1956 and again in June 1957. In 1964, these areas produced significantly more rabbitbrush but significantly less forbs than unsprayed areas. Total production of all grasses was somewhat higher in sprayed than in unsprayed areas, but the difference was not statistically significant.

Rate and Form of Spray.—Rate of spraying 2,4-D did not strongly influence production. In general, plots sprayed with 4 lb 2,4-D produced slightly less rabbitbrush and forbs, and slightly more grass than those sprayed with 2 lb, but the differences were not statistically significant. Similarly, the low- and high-volatile sprays did not produce significantly different results. Therefore, production figures for the various treatment combinations of rate and form of spraying 2,4-D were averaged for each date in Table 2.

Response of Individual Species.—The response of individual species to 2,4-D generally was the same as that of the class of vegetation to which it belonged. In 1964, production of bluebunch wheatgrass and Idaho fescue was somewhat higher in sprayed than in unsprayed areas, but the difference was statistically significant only on plots sprayed in June 1956 (Table 2). Some 2,4-D treatments appeared to favor Sandberg bluegrass (*Poa secunda* Presl.) and other grasses, but no statistical analyses were made.

Lupine and potentilla were reduced by 2,4-D and produced significantly less in 1964 on sprayed plots than on unsprayed areas. In plots sprayed in June 1956 and in those sprayed twice (August 1956, and June 1957), production of lupine and potentilla was only 4 to 12% of that in untreated plots (Table 2). The August 1956 application of 2,4-D was less effective, and production of these species in 1964 was 67 to 75% of that in untreated areas.

The other two major forbs on the study area, yarrow and Wyeth eriogonum, were not significantly affected by 2,4-D or at least had recovered from any effect by 1964. Blaisdell and Mueggler (1956) listed yarrow as a species unharmed by 2,4-D, and Wyeth eriogonum as only lightly affected, in the sagebrush type in Idaho.

Areas Resprayed in 1959.—The 1 lb/acre application of 2,4-D at the three dates in 1956 and 1957 and the subsequent respray in 1959 did not significantly affect production of rabbitbrush or grass in 1964. However, production of forbs was reduced somewhat by the original spray and further reduced by the respray.

Discussion

The causes of the effective, long-lasting kill of rabbitbrush in areas sprayed in June 1956 apparently were: (1) rabbitbrush was in the full-leaf stage and thus physiologically susceptible to damage by 2,4-D; and (2) the moisture in the soil was adequate to insure continuing growth, which is necessary for absorption and translocation of 2,4-D. The August 1956 spray was ineffective because the rabbitbrush was past the full-leaf stage and the soil was dry. Observations indicated that the tops of some rabbitbrush plants were killed by the August 1956 spray, but almost all of these plants resprouted vigorously in 1957.

Increase of rabbitbrush in areas sprayed in August 1956 and again in June 1957 cannot be explained so easily. The August application of 2,4-D had little effect and the respray treatment the following June probably was ineffective because (1) the rabbitbrush was not as fully developed as it had been in June 1956; (2) the air was cool following spraying; and (3) the heavy snow that fell the night after the spray was applied in June 1957 may have reduced the effectiveness of the herbicide. The rabbitbrush plants that were not damaged and those that resprouted evidently increased in vigor and production as a result of significantly reduced competition from the forbs. Rabbitbrush increased much more than the grasses.

A similar increase in size and production of individual rabbitbrush plants after removal of competing vegetation was noted by McKell and Chilcote (1957). They concluded that "range improvement programs which remove vegetation competing with rabbitbrush but do not control the rabbitbrush itself, merely encourage these undesirable shrubs." Results in the present study bear out this statement.

Properly timed applications of herbicide can result in lasting reduction of rabbitbrush and forbs and increased grass production. In 1964, grass production was still 352 lb/acre higher in areas sprayed in June 1956 than in unsprayed areas. This is desirable on cattle ranges. On sheep range, however, the reduction in production of forbs accompanying the kill of rabbitbrush would not be desirable, and spraying probably should not be attempted. Any decision to spray ranges similar to those studied must also take into account the effect on overall soil fertility produced by nitrogen-fixing bacteria in the root nodules of lupine.

Reduction of lupine over a long period might affect fertility, but the magnitude of the effect is not known.

One of the main contributions of this study is evidence of the possible harmful effects of improperly timed sprays. Herbicides applied at the wrong time are simply ineffective on most species. However, as shown in the double-spray plots in this study, 2,4-D applied at an unsuitable time may reduce forbs and allow rabbitbrush to increase. Rabbitbrush control programs using 2,4-D should be undertaken only when conditions are such that an effective kill of rabbitbrush can be obtained. Other herbicides now available, such as picloram (Cook et al., 1965; Tueller and Evans, 1965), appear to be more effective than 2,4-D in killing rabbitbrush; and for them, time of application may not be as critical as it is for 2,4-D. However, further research is needed to determine the effect of such herbicides on rabbitbrush and associated plants when applied under various conditions of plant development and soil moisture.

Summary

The long-term ecological effects of herbicide spray on vegetation must be known if this means of range improvement is to be evaluated. Areas on high-elevation cattle range on the Humboldt National Forest in northern Nevada were sprayed with 2 and 4 lb/acre of high- and low-volatile esters of 2,4-D at various times in 1956 and 1957 to determine the best time to control lanceleaf rabbitbrush. Effects of the 2,4-D were quite different at the various dates, because stage of plant growth and soil moisture were different. Only the June 1956 spray, applied when rabbitbrush was nearly in full leaf and soil moisture was adequate for continued growth, reduced rabbitbrush; in 1964, areas that had been sprayed still produced significantly more grass and less rabbitbrush than unsprayed areas. Plant yields from plots treated with 4 lb of 2,4-D did not differ significantly from those treated with 2 lb.

Sprays applied in August 1956, when plants and soil were dry, had no significant effect. However, a subsequent early spraying increased rabbitbrush. The second spray, in early June of 1957, was applied at a very early growth stage of rabbitbrush and was followed by a heavy snow. The forbs were reduced significantly and the rabbitbrush, relatively unharmed by the herbicide, increased as a result of reduced competition from the forbs.

Properly timed applications of herbicide can have long-lasting effects on the reduction of rabbitbrush and forbs and the increase of grasses. In this study, 8 years after applying 2,4-D in June 1956, sprayed areas still produced 352 lb/acre more grass than unsprayed areas. This change in composition would be desirable and spraying should be a useful management tool on cattle range. On sheep range, loss of forbs is not desirable and spraying is not recommended. Sprays intended to reduce rabbitbrush, if applied at an unsuitable time, might reduce other species and allow rabbitbrush to increase. Programs to control rabbitbrush with 2,4-D should be undertaken only when conditions of plant growth, soil moisture, and temperature are such that an effective kill of rabbitbrush can be obtained.

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