Soil Moisture Response to Spraying Big Sagebrush with 2,4-D

RONALD D. TABLER

Hydrologist,
Rocky Mountain Forest and Range Experiment Station,
Forest Service, U.S.D.A.,
Laramie, Wyoming.[1]

Highlight

Spraying big sagebrush with 2,4-D reduced the rate of soil moisture withdrawal. About 75% of the difference in total moisture depletion occurred within the 3- to 6-ft soil depth; an opposite effect in the second foot indicated that the increase in grass herbage production is most strongly reflected in that zone. Total evapotranspiration losses from the 0- to 6-ft soil profile were reduced about 14% over the 4-month growing period the second year after spraying.

Much research has been oriented toward perfecting methods of sagebrush control and analyzing the effect of such treatment on forage production. Effects of sagebrush conversion on such factors as the soil moisture regime, snowpack, and microclimate, however, have not been given attention commensurate with their probable significance. Hydrologic features of the big sagebrush (*Artemisia tridentata* Nutt.) community are for the most part unknown.

The primary objective of this study was to determine the response of the soil moisture regime to spraying big sagebrush. Measurements were made over a period of 3 years following treatment as grass production increased and subsequently diminished. In this manner some insight was gained into the hydrologic significance of chemical control of big sagebrush.

Review of Previous Work

A study of herbage response to sagebrush spraying in Oregon indicated the greatest grass yield the first year after spraying, with yields decreasing slightly the second and third years (Hyder and Sneva, 1956). Vegetative response was thought to result from a release from competition for both soil nitrogen and soil moisture. Competition changed at different soil moisture levels the first year after treatment, and depletion was more rapid on treated than on untreated areas.

Sonder (1959) studied effects of chemical control of big sagebrush on soil moisture retention and snow holding capacity in Wyoming. He concluded that 80% to 100% kill of big sagebrush in the Red Desert (elevation 7,000 ft, average annual precipitation 10 inches) significantly increased soil moisture one year after initial chemical control at the depths sampled (6–7, 12–13, and 18–19 in.). He implied that grass production had increased 100% after spraying. A second study area in the Big Horn Mountains (elevation 8,200 ft, average annual precipitation 20 in.) showed that, 6 years after 100% chemical sagebrush control, soil moisture was significantly higher in late July in the treated area. Native grass production was said to have increased over 400% as a result of spraying. Fall soil moisture levels were the same on treated as on unsprayed areas at both study sites. Spring snow depth on the unsprayed area in the Big Horn Mountains was less than on the treated area; in addition, snow disappeared more rapidly from the unsprayed area. No differences were observed between treatments in the Red Desert with regard to snow accumulation or disappearance.

Cook and Lewis (1963), in a study of competition between big sagebrush and seeded grasses in Utah, took paired soil moisture samples in sprayed and unsprayed areas at 12 sample locations during three consecutive summers following spraying. Depths of 1, 2, and 3 ft were sampled. They concluded that soil moisture content generally was significantly greater on sprayed plots at the 2- and 3-ft depths the first two growing seasons after spraying; in only one case was the difference significantly greater in the surface foot. In general, soil moisture differences between treatments increased with soil depth. No significant differences in soil moisture due to treatment were detected during the third year after spraying.

Methods

Study Area.—The study area, located about 15 air-miles northeast of Dubois, Wyoming, lies at an elevation of about 9,500 ft. Six years of data show a mean annual precipitation of about 20 inches; snow from October 1 to June 1 accounts for about two-thirds of the total.

[1] In cooperation with the University of Wyoming; central headquarters maintained at Fort Collins in cooperation with Colorado State University.

FIG. 1. Winter soil moisture measurements with neutron-probe equipment.

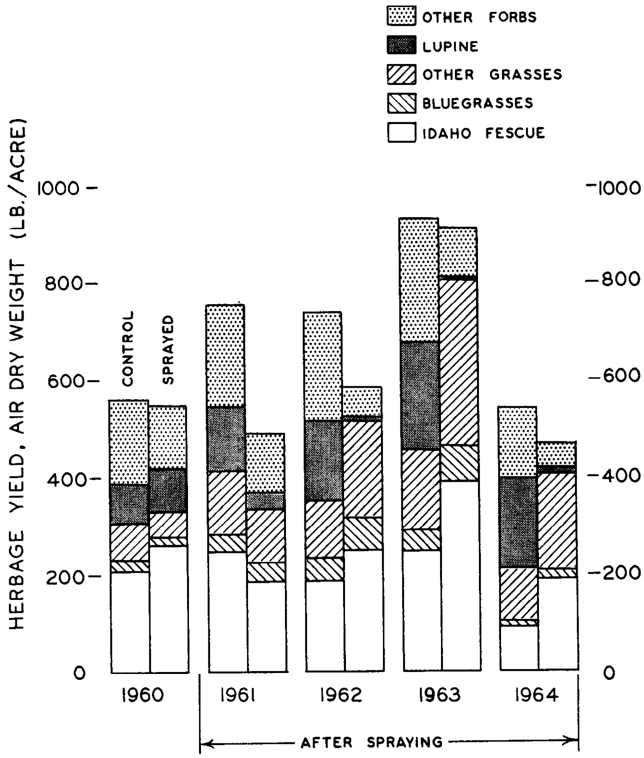

FIG. 2. Herbage production on control and sprayed plots.

The sagebrush stand in the vicinity of the study has a density of about 10,000 mature plants/acre, and a dominant age class of 25–35 years. Average height of the sagebrush plants is about 20 inches, and average crown area is about 1.4 ft^2. Idaho fescue (*Festuca idahoensis* Elmer), the dominant grass species, accounts for nearly 25% of total herbage production. Major forbs include *Lupinus cericeus* Pursh, *Geum triflorum* Pursh, and *Agoseris glauca* (Pursh) D. Dietr.

Plot Layout.—Four contiguous 0.4-acre plots, each 2 chains on a side, were laid out in a single row on each side of a gentle ridge (slope about 10%). East and west exposures were represented in the study to permit evaluation of a treatment-exposure interaction, since prevailing westerly winds favor snow accumulation on east-facing slopes.

Boundary effect was minimized by confining the sampling area to a 0.1-acre area in the center of each plot, thus providing a perimeter buffer strip 33 ft wide around each sampling area.

The plots were established in June 1960, and pretreatment data were collected until July 1961, at which time half the plots were selected at random and hand-sprayed with 2,4-D (Esteron 76-E, Dow Chemical Corporation)[2] in water at a rate of about 3 lb acid equivalent/acre. Posttreatment measurements were continued until September 1964. Significant mortality of sagebrush attributable to stem girdling by rodents during the 1963–64 winter forced the close of the study.

Measurements.—Gravimetric soil moisture samples were taken initially at six locations selected at random on each sampling area at 2- to 3-week intervals during the growing season (June 1 to September 30). King (Veihmeyer) tubes were used to obtain these samples, which were taken to depths of 6 ft where possible. In 1961, sampling intensity was increased to 9 samples/plot. Bulk density samples from three locations permitted estimation of soil moisture content by volume.

In June 1962, six aluminum access tubes for neutron probe measurements were installed at locations selected at random on each of the eight plots. All tubes were installed to 8 ft on the west exposure, but stony soil on the east-facing plots restricted some depths to 6 ft. Back-fill around tubes was allowed to settle and equilibrate for 2 months prior to the first probe measurements.

In addition to growing-season measurements, soil moisture content was determined throughout the 1963–64 winter and the following spring (Fig. 1).

Summer precipitation was measured by a standard rain gage with the orifice at ground level, and snowfall was measured by an accumulation gage near the study plots. Snow depth and water equivalent were determined with a Mount Rose snow sampler on about three dates each spring.

Production of herbaceous vegetation was estimated yearly on permanent 2 × 2 ft plots by the weight estimate method (Pechanec and Pickford, 1937) with double sampling (Wilm et al., 1944). Fifteen such plots were established on each 0.1-acre sampling area.

[2] Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

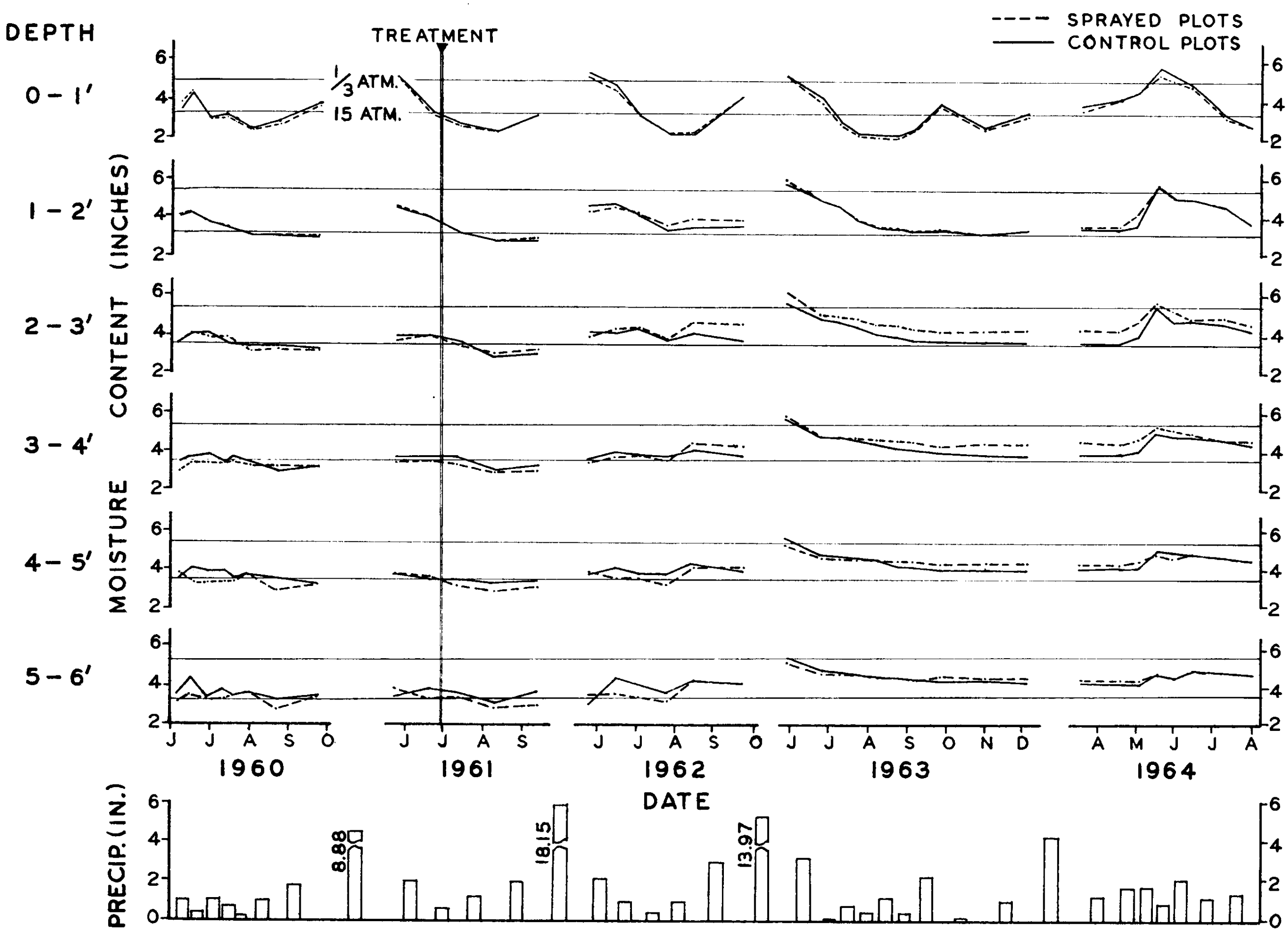

FIG. 3. Soil moisture contents for all sampling dates averaged over both exposures. Neutron probe measurements began August 13, 1962.

Vegetative Response to Treatment

About 90% of the sagebrush plants on the treated plots were killed by spraying, leaving a density of about 1,000 plants/acre. Sagebrush reinvasion was not apparent at the close of the study.

Forb production was greatly reduced during the treatment year, resulting in a significant depression in total herbage production (Fig. 2). Grass production increased significantly in 1962, the year after spraying, but forb production diminished further; the net effect was to depress total production below control plot levels.

The proportion of grasses in the total herbaceous production increased from about 60% before treatment to a high of 89% in 1963, the second year after spraying. Because forbs remained low, total production on treated plots was about the same as on control plots. The relative proportion of forbs increased slightly during 1964, the third year after spraying.

Soil Moisture Response to Treatment

Treatment effects generally were the same on east and west exposures, with few exceptions; thus, data summarized in Fig. 3 are averages for both aspects.

No significant differences between treatments were detected by gravimetric sampling the first three years of study. Neutron probe measurements, however, afforded a better opportunity to compare treatments for progressive change in soil moisture content with a relatively high degree of precision.

Second Year After Spraying.—Soil moisture sampling began when the entire 6-ft profile was above field capacity, and measurements were continued throughout the fall and winter months.

Moisture was first measured on May 28, about one week after the disappearance of snow from the east exposure; snow on the west aspect had been gone for about two weeks. Although there was no significant overall treatment effect, initial moisture volume in the 6-ft soil profile on the west exposure was 4.4% greater on control than on treated plots. One reason for this difference was observed in 1964: snow melts earlier on the west-facing treated plots, presumably because of the absence of shade afforded by live sagebrush crowns and greater snow

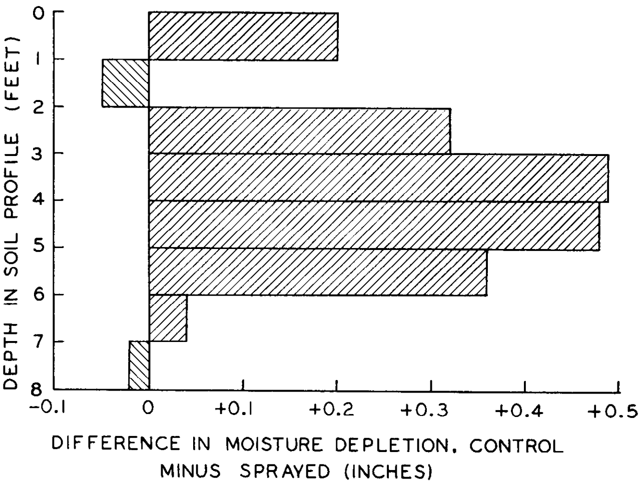

FIG. 4. Total differences, by depths, in soil moisture depletion amounts, control minus sprayed, for the period June 24 to September 3, 1963.

accumulation on unsprayed plots, as indicated by snow measurements. Thus, recharge is delayed under unsprayed sagebrush.

On all other sampling dates no significant difference was detected between treatments with regard to soil moisture level, due in part to the differential snowmelt effect accrued earlier.

The *change* in moisture volumes between sampling dates is a particularly useful factor, which minimizes certain carry-over effects from the snowmelt period. Initial change in moisture content between the first two sampling dates for the year again was not significant because initial moisture volume greater than field capacity was lost by percolation through the soil profile.

Depletion throughout the remainder of the summer reflects, for the most part, only differences in evapotranspiration between treatments. Soil moisture depletion rate in all cases was greater on control than on sprayed plots, irrespective of exposure. The depth-treatment interaction generally was significant, suggesting differences in relative root distributions within the 6-ft profile (Tabler, 1964). Fig. 4 shows that about 75% of the difference in total depletion occurs within the 3- to 6-ft zone. The bar graph can be considered as representing relative number of vacancies in the active root population created by herbicidal treatment. A reverse effect within the second foot suggests that the increase in grass herbage production is most strongly manifest in that zone, total root activity being increased as a consequence of vegetative conversion. That this same effect is not present in the 0–1 ft zone can be explained by the dense network of big sagebrush roots at that depth.

The 1963 data provide an opportunity to express treatment differences in terms of actual evapotranspiration. Assuming surface runoff for storms to be negligible[3] and the net moisture flux across the 6-ft depth to be small, accumulated average evapotranspiration losses (soil moisture change + precipitation) during the period June 24 to October 29 were 12.16 and 10.44 inches on control and sprayed plots, respectively. This difference, 1.72 ± 0.89 inches, is about 14% of the control mean. Most of the difference in evapotranspiration (1.48 ± 0.57 inches) accrued between June 24 and August 22.

Observations during the 1963–64 winter indicated no differences between treatments in relation to change in moisture content. This implies that big sagebrush does not use a detectable amount of water during winter months.

Third Year After Treatment.—Soil moisture was well sampled during 1964 spring recharge. In general, the same observations were made as during the preceding year: treated plots recharged earlier than control plots on the west exposure. Differential snowpack water equivalent between treatments is reflected in smaller recharge at greater depths on the treated plots. Soil moisture recharge was generally greater on unsprayed than on sprayed plots.

Treatment effects were confounded in 1964 by mortality of sagebrush on control plots resulting from rodents girdling the stems during the winter. It appears, however, that there is a tendency for differences in moisture regimes between treatments to continue during the third year following treatment, although there is little basis for inferring the magnitude of the difference.

[3] This assumption is based on data from nearby gaged watersheds, recording rain gage records, and field observations by the author.

LITERATURE CITED

COOK, C. WAYNE, AND CLIFFORD E. LEWIS. 1963. Competition between big sagebrush and seeded grasses on foothill ranges in Utah. J. Range Manage. 16:245–250.

HYDER, DONALD N., AND FORREST A. SNEVA. 1956. Herbage response to sagebrush spraying. J. Range Manage. 9:34–38.

LEVY, E. B., AND E. A. MADDEN. 1933. The point method of pasture analysis. New Zeal. J. Agr. 46:267–279.

PECHANEC, J. F., AND G. D. PICKFORD. 1937. A weight estimate method for determination of range or pasture production. J. Amer. Soc. Agron. 29:894–904.

SONDER, LESLIE W. 1959. Soil moisture retention and snow holding capacity as affected by chemical control of big sagebrush (*Artemisia tridentata* Nutt.). M.S. Thesis, Univ. of Wyoming. 46 p.

STEWART, GEORGE, AND S. S. HUTCHINGS. 1936. The point-observation-plot (square-foot density) method of vegetation survey. J. Amer. Soc. Agron. 28:714–722.

TABLER, R. D. 1964. The root system of *Artemisia tridentata* at 9,500 feet in Wyoming. Ecology 45:633–636.

WILM, H. G., D. F. COSTELLO, AND G. E. KLIPPLE. 1944. Estimating forage yield by the double sampling method. J. Amer. Soc. Agron. 36:194–203.