The Influence of Greasewood on Soil-Moisture Penetration and Soil Chemistry[1]

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THE NATIVE shrubs of desert steppe vegetation are of small size and are widely spaced. This natural arrangement of plants offers opportunities to evaluate the influences of individual plants on their immediate soil environment not possible in more closed kinds of vegetation. Increase of sodium in soil beneath greasewood, *Sarcobatus vermiculatus* (Hook.) Torr., has been previously reported by Fireman and Hayward (1952). Certain nanophyllous Australian shrubs tended to channel precipitation along main stems resulting in increased soil moisture beneath their canopies (Specht, 1957). A circular pattern of pH of surface soil occurred beneath a lodgepole pine canopy with the lowest pH values found near the tree trunk (Zinke, 1962).

This paper presents observations of the influence of greasewood on the depth of soil-moisture penetration and on certain soil-chemical properties, and the pattern of soil-chemical changes as indicated by soil pH.

Methods

Soil samples at 0 to 1 and 1 to 2 dm depths were taken from beneath four greasewood shrubs and from four adjacent intershrub areas with a soil auger. These samples were analyzed for conductivity of saturation extract, cation exchange capacity, and exchangeable sodium and potassium at the soils testing laboratory at Washington State University. The area occupied by the canopies of four shrubs in summer foliage was determined. Entire plants were harvested and the leaves plucked by hand. Leaves were oven-dried at 105° C, reduced to ash, and analyzed quantitatively for major cations with a flame spectrophotometer.

Observations and measurements on the depths of soil-moisture penetrations were made in late January and early February at the time of optimal soil-moisture accretion on the Hanford Reservation, southeastern Washington, in 1963. A soil pit was excavated beneath two greasewood shrubs. Each pit was oriented in an east-to-west direction in such a fashion that one wall

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passed through the main stem structure of the shrub and extended beyond the canopy margins. The pits were dug below the depth of moisture penetration so that the front of moisture penetration was readily discernible. Samples collected for pH determinations were taken from the walls of the same pits used to observe moisture penetration. Soil samples were collected from the sides of the pits in a systematic grid pattern beneath the canopy spread and extending beyond the canopy margins and analyzed for pH. The pH of surface samples (0 to 0.5 dm deep) were taken at regular intervals along radii projected from the main stem of each of two additional shrubs. These lines, 9 dm long, extended beyond the canopy margins in eight compass directions. Fresh soil samples wetted with distilled water to paste consistency were used for pH determinations. A battery-operated, glass electrode pH meter graduated in 1/10 pH units was used to obtain readings.

Results and Discussion

A line intercept vegetational analysis of a 30 x 30 meter plot showed that 20 per cent of the ground was occupied by shrub canopies. Greasewood occupied 15 per cent of the ground area, and hopsage, *Grayia spinosa* (Hook.) Moq., 5 per cent. The herbaceous vegetation was comprised largely of grasses. The winter annual cheatgrass, *Bromus tectorum* L., was ubiquitously distributed as a uniform sward with lesser amounts of the small perennial bunchgrass, Sandberg bluegrass, *Poa secunda*, Presl. The depth of moisture penetration in relation to the canopy spread of greasewood shrubs is illustrated in Figure 1. Moisture clearly did not penetrate as deeply under the plant canopy as it did in the region beyond the canopy margins. Moisture penetration was less deep on the eastern side of shrubs where leaf litter also tended to accumulate. Stem-flow was apparently not operable in channeling precipitation along the main stems of the shrubs. Winter precipitation may not be as effective in producing stem-flow as summer precipitation (Specht, 1957). Soil-moisture accretion began in the autumn, and by the first of February only 2.25 inches of precipitation in the form of rain and snow had fallen. Only a trace of rain fell in the entire month of February. Deep moisture penetration in winter is of great importance to plants in this region where the climate is characterized by low annual precipitation (6.73 inches) and hot, dry summers. Deep moisture is relatively free from evaporation losses and is probably exploited less by the shallow-rooted grasses. This moisture can be expected to be stored for use in the spring when air and soil temperatures are more optimal for plant growth.

An approximation of the amount of precipitation intercepted by the leafless canopies of shrubs in winter condition and by accumulations of leaf litter was made by comparing the areas of dry soil and wetted soils beneath

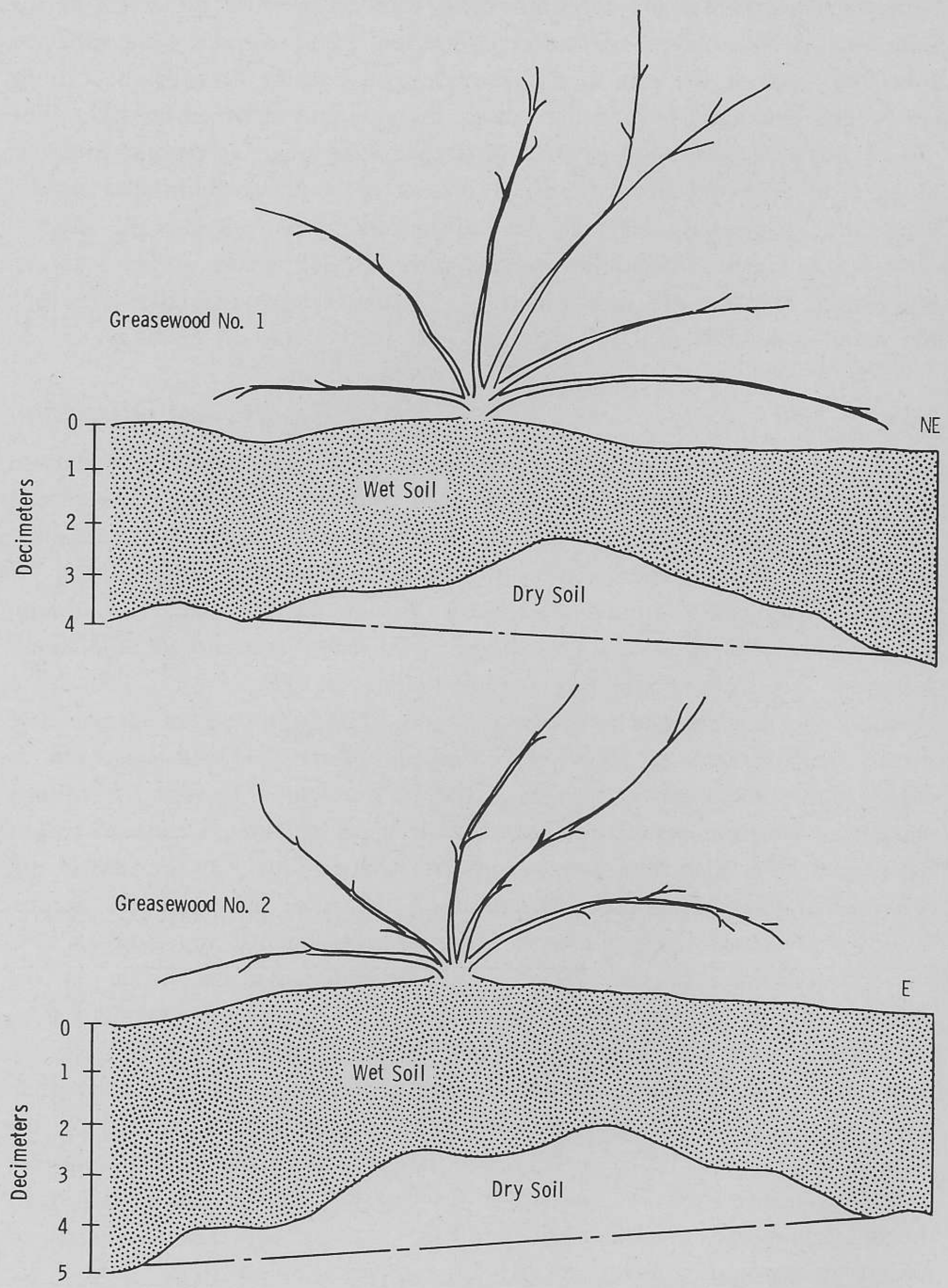

Figure 1. Depth of soil-moisture penetration beneath greasewood canopies.

the canopies as delimited by the depth of moisture penetration beyond the canopy margins (Figure 1). Such a comparison showed that about one-fifth of the precipitation available for soil-moisture replenishment was intercepted by canopy and litter.

The small canopy sizes and wide spacing of shrubs would appear to be of benefit to shrubs by allowing precipitation to penetrate more deeply into the soil in the intershrub areas. However, the factors involved in the persistent maintenance of wide spacing of shrubs are not readily apparent.

The leaves of greasewood accumulated large quantities of sodium (Table 1). The entire leaf crop of four shrubs averaged 232 ± 14 (S.E.) grams of dry leaf per square meter of canopy and yielded 31 grams of mineral cations per square meter of canopy. Of this total 25.5 grams or 82 per cent was sodium.

The soil beneath greasewood canopies reflected the mineral content of the leaves. More exchangeable sodium was measured in the surface decimeter of soil beneath greasewood canopies than in adjacent intershrub areas (Table 2). Similar findings are reported by Fireman and Hayward (1952). Electrical

TABLE 1. The Cation Content of Greasewood Leaves Harvested from Four Shrubs in July, Hanford Reservation, Washington

	mg cation/g dry leaf	g cation/m^2 of shrub canopy/yr
Na	110 ± 5.2	25.5
K	12 ± 2.2	2.8
Ca	10 ± 1.2	2.3
Mg	1.8 ± 0.37	0.42
Total	133.8	31

± Standard error of mean.

TABLE 2. Comparison of Soil Properties beneath Four Greasewood Shrubs and Adjacent Ground, Hanford Reservation, Washington

	Beneath Greasewood		Open Ground	
Depth of soil sample (dm)	0-1	1-2	0-1	1-2
Conductivity mmhos/cm	1.2±0.10	1.7±0.49	0.35±0.041	0.25±0.084
Cation exch. capacity	14 ±1.7	13 ±0.48	13 ±0.48	13 ±0.34
Exch. sodium meq/100 g	7.3±1.3	6.8±0.61	0.082±0.027	0.060±0.024
% Exch. sodium	52	49	0.63	0.46
Exch. potassium meq/100 g	3.5±0.78	2.9±0.92	2.0±0.065	2.4±0.022
% Exch. potassium	25	22	15	18
pH	9.6	9.4	7.6	7.8

± Standard error of mean.

conductivity, pH, and exchangeable potassium were also higher beneath shrub canopies.

Soils with high pH values, i.e., those greater than 8.5, are almost always indicative of high sodium content (U.S. Salinity Laboratory, 1954), and this appears to be an efficient way to detect the distribution of soil sodium in relation to shrub canopy spread. Isopleths of pH of surface soil in relation to canopy spread are shown in Figure 2. The highest pH values, i.e., >9, were restricted to a small circular zone adjacent to the stem. This zone was surrounded by a zone ranging in pH from >8.6 to <9.0. Zones of lesser pH occurred at greater distances from the main stem. Shrub canopies and the zones of high soil pH tended to be skewed toward the east, probably as a result of the strong westerly winds of this region. A similar influence of wind on soil pH is reported by Zinke (1962).

Irregular vertical zonation of pH occurred beneath greasewood canopies (Figure 3). The irregular zonation is probably influenced by the chemical heterogeneity of parent soil material and soil mixing by burrowing rodents as well as by leaching and decomposition of leaf litter. Zones of high pH occurred on the lee side of shrub canopies beneath the region of maximal litter accumulation. It is apparent that greasewood contributes large amounts of sodium to the soil beneath plant canopies. The time required to produce the changes is not known. The usual means of aging woody stems is not applicable to greasewood because it appears to have a discontinuous cambium. However, by assuming that an annual average leaf yield is about 232 grams with an average sodium content of 110 mg/g, it would require only about 16 years to provide 7 meq of exchangeable sodium per 100 g in the upper 1 m^2 x 0.2 m deep volume of soil (bulk density 1.32). Many factors would tend to extend the time required to attain this concentration. One of the most important factors is the effect of strong winds in blowing the leaves far from the vicinity of the shrub canopy. The rates of leaf composition and downward leaching of leaf minerals by precipitation are unknown. The processes involved in placing leaf sodium on the exchange complex of the soil are unknown, but the organic acids in the leaves are believed to play a major role in the exchange reactions (Fireman and Hayward, 1952). It seems reasonable to expect that the soil changes reported in this paper could have occurred within the past 100 years.

Summary

Greasewood shrubs increased exchangeable sodium, potassium, and pH of soil beneath their canopies. The pattern of soil pH corresponded generally

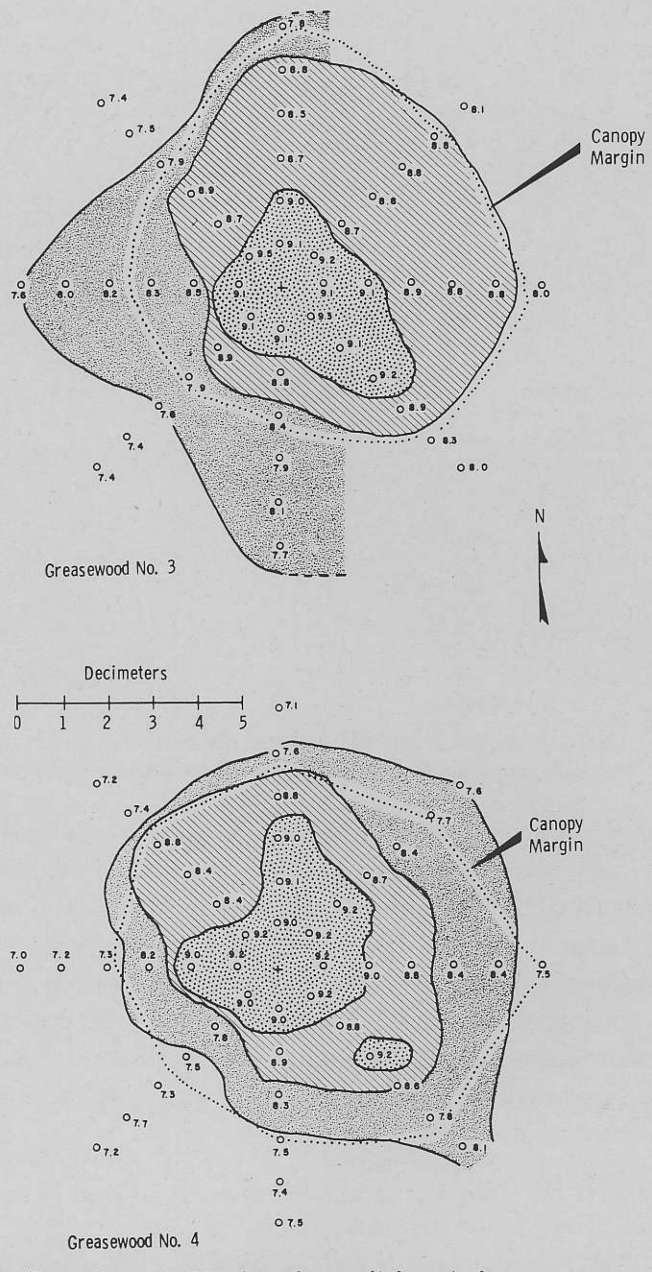

Figure 2. Zonation of pH of surface soil in relation to compass direction and canopy spread of greasewood. Isopleths encompass the following ranges of values: > 9.0 coarse stipple, 8.5 to 8.9 cross-hatch, 7.6 to 8.4 fine stipple, and < 7.5 clear.

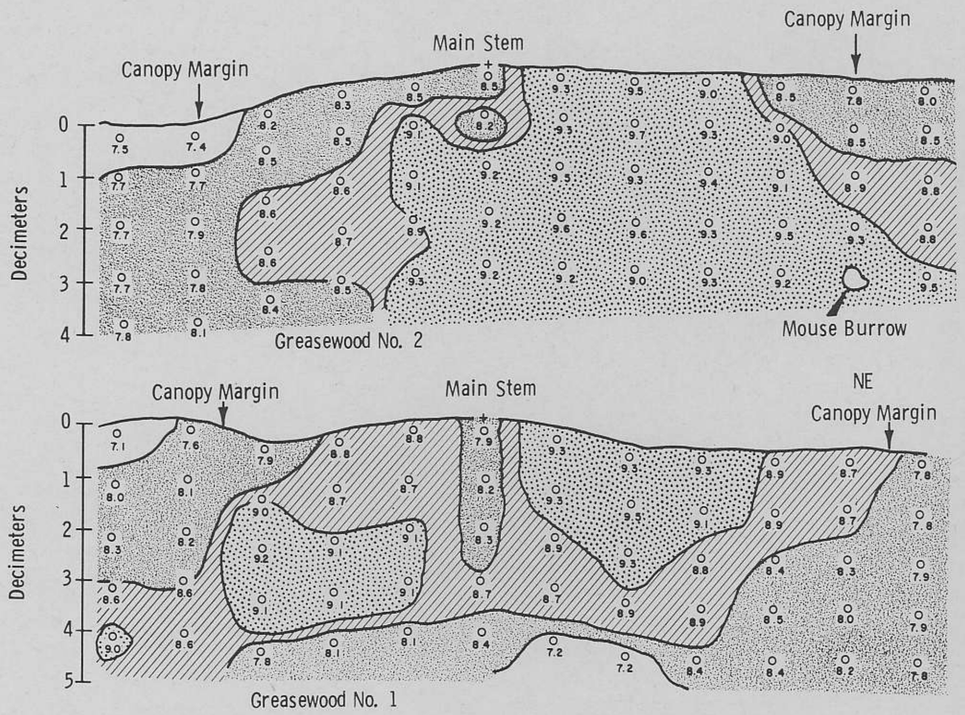

Figure 3. Vertical zonation of pH in soil in relation to canopy spread of greasewood. Isopleths encompass the same values as shown in Figure 2.

to the outline of shrub canopies. The circular pattern of shrub canopy and the pattern of pH were skewed to the east or downwind side of the shrubs. An irregular zonal distribution of pH with soil depth was also observed with maximal pH values confined to the eastern side of the shrubs.

Soil-moisture penetration in winter was less deep beneath shrub canopies than in adjacent intershrub areas. About one-fifth of the moisture available for soil-moisture replenishment was intercepted by shrub canopies and litter. Soil moisture penetrated less deeply on the eastern sides of the shrubs.

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