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Soil beneath Shrub Halophytes and Its Influence upon the Growth of Cheatgrass[1]

Introduction

Greasewood, *Sarcobatus vermiculatus,* and spiny hopsage, *Grayia spinosa* (Chenopodiaceae), dominate a plant community that supports a sparse understory of cheatgrass *Bromus tectorum.* Because the shrubs accumulate large amounts of salt in their leaves and live for a long time, each shrub has created an island of mineral-rich soil beneath its canopy. Greasewood contributes quantities of sodium to the soil surface through leaf fall, and subsequent leaf decay and hopsage contributes potassium. The community has a history of soil-plant investigations (Rickard, 1964; Rickard, 1965; Rickard and Keough, 1968). These studies showed that although pH values and sodium content of the soil beneath greasewood are much higher than in the adjacent open soil, the total salt content of the soil is only slightly increased. The main source of sodium for greasewood plants probably is located deeper in the soil profile. The main water source for greasewood is the permanent water table located as deep as 12 meters (Harr and Price, 1972).

Cheatgrass often grows more luxuriantly near shrubs than in the adjacent open ground. The more luxuriant growth of cheatgrass near shrubs could be attributed, at least in part, to a more favorable microclimate created by the physical presence of shrubs. However, a more favorable soil nutrient supply could also contribute to increased growth.

This investigation employed controlled climate chambers and a nonstressed soil moisture regime to determine the influence of soil from beneath and between halophytes upon the growth of cheatgrass.

Materials and Methods

Soils from a greasewood-hopsage community located on the United States Atomic Energy Commission's Hanford Reservation in Benton County, Washington, were selected for study. Three separate clumps of greasewood, as well as three clumps of hopsage, were chosen as representative of the shrubs in the plant community. The accumulation of dead leaves, twigs, and grass beneath the canopy of each shrub was scraped away to expose the underlying mineral soil. The exposed soil was then taken to a depth of about 1 decimeter. The soil in three areas located between shrubs was collected in the same manner.

Each soil collection was passed through a 2-mm-mesh screen, and an aliquot was chemically analyzed for pH, Kjeldahl nitrogen, and exchangeable potassium, calcium,

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magnesium, and sodium by the methods described by Schollenberger and Simon (1945). Phosphorus was measured as described by Olsen and Dean (1965).

Fifteen cheatgrass caryopses of local origin were planted in a kilogram of soil and kept in a growth chamber. Soil water was maintained at near field capacity by daily weighing and irrigation. The growth chamber was programmed for 12 hours daylight with a 74°F daytime temperature. Nighttime temperatures were maintained at 60°F. The plants were harvested at 30 days of age. At the time of harvest the number of leaves were counted on each plant individually, and the height of the tallest leaf of each plant was measured to the nearest millimeter. All shoots in each container were pooled to obtain a dry weight (65°C). The dried leaves were analyzed for nitrogen content. Correlation coefficients were computed to help identify soil properties which best predict cheatgrass biomass (Snedecor and Cochran, 1967).

To determine the response of cheatgrass to nitrogen fertilization 500 ppm of NH_4NO_3 was added to a new soil collection. The experimental treatment was the same as described previously except that 2 kilograms of soil was used instead of 1 kilogram.

Results and Discussion

The open soil was less rich than the shrub-influenced soils in nitrogen, phosphorus, and potassium (Table 1). This soil also had a lower pH and a lower value for total

TABLE 1. Chemical analyses of soil samples collected beneath individual shrubs of hopsage and greasewood and in the adjacent open areas.

	Greasewood	Open	Hopsage
Nitrogen %	.13 ± .02	0.059 ± .002	0.12 ± .01
P (ppm)	23 ± 4	15 ± 1	67 ± 18
K (ppm)	1480 ± 38	1033 ± 67	2006 ± 145
Ca (meq/100g)	12.0 ± 1.5	9.3 ± 1.0	8.0 ± 0.7
Mg (meq/100g)	2.3 ± 0.4	3.0 ± 0.5	4.2 ± 0.3
Na (meq/100g)	4.7 ± 2.7	0.3 ± 0.1	0.1 ± 0.0
Total bases (meq/100g)	18.1 ± 1.9	14.9 ± 0.9	17.5 ± 1.0
pH	8.9 ± 0.1	7.7 ± 0.3	8.3 ± 0.0

Data are x ± S.E. (n=3).

exchangeable bases. The soil beneath greasewood differed from soil beneath hopsage by having a higher exchangeable sodium content and a higher pH. The soil from beneath hopsage had the highest phosphorus and potassium values. From the soil chemical analysis it was expected that the hopsage soil would provide the most favorable soil nutrient medium for the growth of cheatgrass. The high pH of the greasewood-affected soil and its associated higher sodium content were anticipated to interfere with the uptake of essential ions and to be reflected in reduced yields of cheatgrass. The low nitrogen content of the open soil suggested that a nitrogen deficiency might be expected.

Hopsage soil yielded an average dry shoot biomass of 0.949 grams ± .06 (standard error) as compared with 0.341 ± .09 for the greasewood soil and only 0.146 ± .01 for the open soil. Cheatgrass plants also produced more leaves per plant when grown in the hopsage soil, 8.4 ± .21 as compared with 5.5 ± .25 for greasewood soil and only 3.8 ± .13 for the open soil. The plants grown in hopsage soil averaged 16.5 ± .25 cm for the tallest leaves as compared with average heights of 11.6 ± .31 for greasewood soil and 8.7 ± .24 in the open soil. Clearly in this experiment the hopsage soil provided the more favorable growth medium.

Some statistical correlations among biomass, average leaf heights, and average number of leaves per plant and soil properties are shown in Table 2. Biomass was

TABLE 2. Some statistical correlations between average biomass, and average number of leaves, leaf height measurements, and soil properties.

	Correlation coef.
Avg. height	.982
Avg. number leaves	.982
Potassium	.926
Phosphorus	.833
Magnesium	.604
Nitrogen	.525
Total bases	.323
pH	.162
Sodium	–.322
Calcium	–.404

highly correlated with leaf height and number of leaves produced. Low correlations were obtained among biomass, pH, and total exchangeable bases. Negative correlations were obtained between biomass and sodium and calcium contents. Potassium content was most highly correlated with biomass, followed in decreasing order by phosphorus, magnesium, and nitrogen. The low correlation for nitrogen is not unexpected because Kjeldahl-measured soil nitrogen is not necessarily a reflection of the amount of nitrogen that is available for plant uptake. When the nitrogen content of plant tissues was measured, the plants grown in soil from beneath greasewood had the highest values (6.1 ± .13 percent on a dry weight basis) as compared with 4.2 ± .37 for plants grown in hopsage soil and only 2.7 ± .19 for plants grown in open soil. The total amount of nitrogen assimilated in shoots averaged 40 mg in the hopsage soil as compared with only 21 mg and 4 mg for greasewood and open soil, respectively. Clearly the nutrient quality of cheatgrass, as judged by nitrogen content and total biomass, was much greater when produced in shrub-affected soil.

Because soil nitrogen is often limiting for plant growth, it was decided to add nitrogen to the various soils to determine its influence upon the growth of cheatgrass. The results of these experiments are shown in Table 3. Since not enough soil was collected in the first experiment to allow a repeat experiment using the same soil, a second soil collection was made involving different shrubs and different open areas.

TABLE 3. Average biomass (grams dry weight ± standard error) of cheatgrass produced in halophyte-influenced soil and in adjacent open soil with and without added nitrogen fertilizer.

Soil source	Nitrogen added none	Nitrogen added 500 ppm NH_4NO_3
Hopsage	.766 ± .056	1.985 ± .054
Greasewood	.799 ± .083	1.392 ± .185
Open	.343 ± .021	1.437 ± .099

Undoubtedly soil chemistry was slightly different between this and the previous collections, and the amount of soil used to grow plants also differed from the first experiment. For these reasons the results of the two experiments are not entirely comparable. However, the results obtained between those plots with and without added nitrogen are comparable (Table 3). Added nitrogen increased yields in all cases. When nitrogen was added to the hopsage soil, it produced more biomass than did other soils. Without benefit of added nitrogen, the hopsage and greasewood soil produced about the same amount of biomass. The greatest response to nitrogen in terms of percent increase over control was noted in the open soil. The response of cheatgrass to nitrogen fertilization in the open soil is dramatic while the response to nitrogen fertilization in the greasewood soil is not so well expressed. This finding suggests that other factors such as soil pH and sodium content and increased salinity are involved in limiting yields in the greasewood soil. The electrical conductivity of aqueous extract from soil beneath greasewood averages 1.2 millimhos/centimeter as compared with only 0.35 in the adjacent open soil (Rickard, 1964). And electrical conductivity of 4 millimhos/centimeter is deleterious to salt-sensitive crop plants (Richards, 1954).

From these simple observations it was concluded that shrub-influenced soils provided a more favorable media for plant growth than soils not having a history of shrub influence. As expected, added nitrogen greatly increased shoot biomass. The response was most pronounced in the nitrogen-poor open soil. Following nitrogen fertilization, the largest amount of biomass was produced in the hopsage-affected soil and is attributed to the availability of the macronutrients potassium and phosphorus. The high correlations between biomass and potassium and phosphorus also suggest that this is the case (Table 2). These data also suggest that the pool of available potassium is directly proportional to the exchangeable potassium level of the soil.

The presence of greasewood and hopsage shrubs in a community otherwise dominated by grasses plays a strong role in altering soil chemistry. Changed soil chemistry enhances the nutrient quality and biomass of herbage growing in the proximity of the shrubs. This conclusion has implications concerning the mineral nutrient requirements of animals that forage on the herbage in such communities.

The deep rooting habit of shrubs permits the exploitation of nutrient elements in soil below the rooting depth of annual grasses. By bringing nutrients from deep in the soil and releasing them through leaf fall and subsequent decay, essential minerals are placed in the soil surface, and are leached downward to be exploited by shallow-rooted plants growing intermingled with the shrubs. Greasewood has the special ability to accumulate sodium and introduces sodium to the soil surface.

A recent literature review indicated that little information is available concerning the role of halophytes in plant communities (Waisel, 1972). The data presented in this investigation provide some insight concerning the role of halophyes in altering soil chemistry and the impact on the growth of associated glycophytes in the steppe region of south-central Washington.

Summary

Shrub halophytes have the ability to change soil chemistry beneath their canopies through leaf fall. Greasewood shrubs contribute large amounts of sodium annually to the soil surface, and hopsage contributes large amounts of potassium. The litter of both kinds of shrubs contributes to an increased soil nitrogen content.

Cheatgrass grown in shrub-influenced soil under controlled moisture and temperature regimes produced more biomass with a higher nitrogen content than it did when grown in soil collected from the spaces between shrubs. Although soil beneath greasewood had a high pH and a high sodium content, it produced more biomass than the nonshrub-influenced soil.

When nitrogen was added the most pronounced growth response was in the nonshrub-influenced soil, but more biomass was produced in the hopsage-influenced soil.

It was concluded that shrubs provide a soil media richer in mineral nutrition than adjacent grass-dominated areas.

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