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Isotope Uptake from Halophyte-Affected Soil[1]

Abstract

This paper presents the effects of greasewood-modified soil on the uptake of ^{45}Ca, ^{65}Zn, ^{32}P, and ^{35}S by barley plants. Concentrations of ^{45}Ca and ^{32}P were significantly reduced in plant growth in the soil, but ^{35}S was reduced tenfold compared to plants grown in control soil. Barley grown in the modified soil accumulated four times more ^{65}Zn than plants grown in control soil.

Introduction

Greasewood, *Sarcobatus vermiculatus* (Hook.) Torr., is a brittle-stemmed, deciduous, halophytic shrub that is widely distributed throughout the semiarid regions of the western United States. In the steppe region of Washington, greasewood is commonly associated with sodic soils, and the herbaceous understory usually consists of salt grass, *Distichlis stricta* Torr. Rydbg. (Daubenmire, 1970). Rickard and Keough (1968) showed that greasewood growing on the United States Atomic Energy Commission's Hanford Reservation accumulated large amounts of sodium in its leaves and that subsequent leaf fall and decay created islands of sodium-rich soil beneath individual greasewood shrubs in a soil matrix that otherwise had low amounts of sodium in the surface few decimeters of soil. A shallow water table, 3-12 m below the surface, provides a permanent source of water for deep-rooted greasewood shrubs and permits greasewood leaves to remain succulent while the leaves of spiny hopsage and sagebrush are desiccated (Harr and Price, 1972).

This investigation compares the uptake of four different radioisotopes by barley plants grown in mineral soil affected by the greasewood leaf fall and in adjacent soil not affected by leaf fall.

Methods Employed

Two kinds of soil were selected for the study: that affected by the leaf fall of greasewood was collected from beneath several shrubs; that not affected was collected from spaces between shrubs. In each instance, the surface decimeter of soil was collected after the surface accumulations of mulch had been removed. The samples were pooled and sieved and thoroughly mixed to obtain a homogeneous soil for potting purposes.

The isotopes ^{35}S, ^{45}Ca, ^{65}Zn, and ^{32}P were separately mixed into 1-kg aliquots of soil at a concentration of 0.1 μCi/gm of dry soil. Each isotope treatment was replicated four times. The isotope-treated soil was placed into containers and seeded to barley, *Hordeum vulgare* L. The seeds were covered with a 1-cm deep layer of coarse quartz

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granules and the pots irrigated daily to maintain a moisture content of 20 percent of the dry weight (field capacity). Growth conditions were maintained for 30 days within a growth chamber programmed for a 16-hour light period with day and night temperatures of 27°C and 16°C respectively.

The plants were harvested by cutting 1 cm above the quartz granule surface to avoid contaminated soil particles. The harvested material was dried at 65°C and weighed. The tissues containing ^{35}S, ^{45}Ca, and ^{32}P were digested in nitric acid. The acid solutions of ^{45}Ca and ^{32}P were dried on planchets and counted using a wide-angle beta counter. Sulfur-35 was counted using liquid scintillation techniques. Zinc-65 was determined by placing unprocessed dry tissues in test tubes and counting in an automated gamma ray spectrometer.

Results

Chemical analyses of soil collected from beneath greasewood shrubs and in adjacent open areas showed that soil affected by greasewood mulch is richer in total organic matter, soluble salts (as measured by electrical conductivity of saturation extract), sodium, calcium, potassium, phosphorus, and sulfur than is the soil from adjacent open spaces (Table 1).. The zinc content was similar in the two kinds of soil, but the sulfur content of the open soil was tenfold less than that of the soil from beneath greasewood shrubs.

TABLE 1. Chemistry of soils collected from beneath greasewood shrubs and from adjacent areas.

Soil Properties	Source of Soil	
	Greasewood	Open
pH	9.5	7.3
Organic matter (%)	1.2	0.8
Conductivity (mmhos/Cm)	1.8	0.3
Na (meq/100g)	4.1	0.2
Ca (meq/100g)	6.7	5.6
K (μg/g)	1500	550
P (μg/g)	17	8
S (μg/g)	38	3
Zn (μg/g)	0.4	0.3

With such strongly contrasting soil chemistry, it was expected that there would be differences exhibited in plant uptake of the selected isotopes. Radio-calcium was taken up in small amounts, ^{65}Zn and ^{32}P in moderate amounts, and ^{32}S was taken up avidly (Table 2). Plants grown in the soil collected from the open spaces between greasewood shrubs had a higher uptake of added isotopes of calcium, phosphorus, and sulfur than did plants grown in the soil taken from beneath shrubs. This fact may be partially explained by dilution of isotope in relation to chemically similar stable ions, but such was not observed for ^{65}Zn. Barley raised in the open soil had a ^{35}S uptake ten times greater than that of barley grown in the shrub-affected soil.

It was expected that an unfavorably high soil pH, e.g., 9.5, and a high exchangeable sodium content might deleteriously affect the growth of barley; however, the yields obtained in greasewood-affected soil and open soil were similar (Table 2). The amount

TABLE 2. Herbage yields, daily water usage, and the uptake of four radionuclides by 30-day-old barley plants grown in soil collected beneath greasewood shrubs and from adjacent open areas.

	Greasewood Soil	Open Soil
Yield (g/pot)	0.31 ± .02	0.32 ± .01
Water used (ml/pot/day)	14.4 ± 1.1	31.2 ± 1.1
^{45}Ca (nCi/g)	.89 ± .11	7.7 ± .7
^{65}Zn (nCi/g)	95 ± 4	22 ± 6
^{32}P (nCi/g)	42 ± 1	210 ± 9
^{35}S (nCi/g)	3700 ± 380	37200 ± 1200

$\overline{X} \pm$ S.E.
n = 4

of water used by the plants grown in the open soil was greater than that used by those grown in the sodic-greasewood soil. The results of this simple study show contrasting mineral relationships between plants and soils within distances measured in feet. The contrasts in soil chemistry observed are induced by the unusual physiology and longevity of greasewood shrubs. Barley plants grown experimentally under identical climatic variables but for which the soils are different indicate that soil chemistry plays an important role in determining the amounts of various isotopes which plants can obtain from soil.

Discussion

Clearly, a long-lived halophytic shrub like greasewood can substantially alter the chemistry of the surface soil in the vicinity of its canopy spread. Greasewood plays important roles in mineral nutrition within this plant-soil system: (1) it increases soil organic matter and soil nitrogen content. This increase can be beneficial to the growth of herbaceous plants found in the vicinity of greasewood shrubs and to the shrubs themselves in terms of nitrogen recycling; and (2) greasewood increases the soil sodium content, which in turn increases soil pH and alters the ion-uptake and water-use activity of associated herbaceous glycophytes.

The greater uptake of radiozinc by barley plants grown in greasewood-affected soil was not expected because high soil pH values generally act to depress zinc uptake (Lindsay, 1972). The greasewood-affected soil had a higher organic-matter content than the adjacent nonshrub-affected soil. Martens *et al.* (1966), experimenting with soils with similar relationships of clay and organic-matter content, showed that zinc was more readily extracted by solutions of 0.1 N HCL from soils with higher organic-matter contents. The increased extractability of zinc was explained by the formation of organo-clay complexes. Such complexes may occur in the greasewood soil and enhance the uptake of radiozinc even though soil pH values are relatively high.

The low water use by barley plants grown in greasewood-affected soil is probably due, at least in part, to relatively poor root growth. Although root biomass was not measured, observations of root distributions showed that fewer roots were produced in the greasewood-affected soil than in the nonshrub-affected soil and that the roots were largely confined to the upper one-third of each pot. The adverse effects of high sodium content on the root growth of barley have been described by Allison (1964).

One of the environmental concerns of industrialized societies is the contamination of surface soils with levels of long-lived radioactive isotopes and heavy metal ions that are potentially harmful to biota, including man. A bioassay technique in common use is to grow plants in soil with known quantities of added contaminants and to determine their concentrations in the plant tissues. These values are then used to determine how much herbage would have to be consumed by an animal to obtain a body burden deleterious to health. Ecological knowledge of plants and soils of regional landscapes is important in making assessments of their potentials for biological transfers of mineral nutrients through food webs.

The short physical half-life of ^{65}Zn, ^{32}P, ^{45}Ca, and ^{35}S precludes them from participating as radioisotopes in the long-term, mineral-nutrient cycling process in terrestrial ecosystems. However, they can serve as short-term tracers for identifying organisms in complex food webs. Sulfur-35 would be useful as a tracer for sulfur in the environment of coal-fired steam electric plants that have the potential for releasing large amounts of sulfur-bearing fumes into the surrounding atmosphere, resulting in subsequent sulfur depositions on surface soils and vegetation.

Summary

A comparison was made among herbage yields, water utilization, and concentrations of four isotopes (^{45}Ca, ^{65}Zn, ^{32}P, and ^{35}S) in barley plants grown in greasewood-modified soil and plants grown in soil collected from between greasewood clumps. The dry-weight yields of the two soils did not differ, but water utilization in shrub-modified soil was reduced by approximately one-half. The concentrations of ^{45}Ca and ^{32}P were moderately reduced in plants that grew in the greasewood-modified soil; however, ^{35}S concentrations were reduced tenfold as compared with those of plants grown in the nonshrub-modified soil. The plants grown in the greasewood-modified soil accumulated nearly four times more ^{65}Zn than did plants from the nonshrub-influenced soil.

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