Radioisotope Uptake by Selected Range Forage and Weed Species[1]

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Highlight

Two wheatgrasses, one annual grass, and one annual forb were used to evaluate the uptake of fourteen gamma-emitting isotopes from an important range soil. Uptake of copper, molybdenum, and selenium ranged from moderate to very good from all soil horizons. Uptake of iodine and chromium was poor from the surface and lower soil horizons, respectively, but moderate to very good from other horizons. Other desirable characteristics of these isotopes for root-tracing studies are half-lives of from 12.8 hours to 128 days, and energy differences which permit detection of each isotope in the presence of others.

The growth and survival of perennial grass seedlings on rangeland are closely related to the depth, spread, and volume of root systems of competing species. The rooting characteristics of plants can be traced by injection of a radioisotope into the root zone and measurement of activity in the aerial portion of the plant. Radiophosphorus has been the most commonly used tracer isotope in plant research. Recently, more emphasis has been placed on other isotopes. Siaz del Rio et al. (1961) used ^{86}Rb to find the active root region of coffee trees. Price (1965) described a field method for use of ^{131}I to study root systems in shrub–steppe vegetation. In 1966, Cohen and Tadmore investigated the uptake of ^{32}P, ^{137}Cs, ^{60}Co, ^{22}Na, ^{85}Sr, and ^{90}Sr. These authors also evaluated a two layered injection system in which two isotopes were placed at different depths in a soil column. The appearance of isotope activity in leaf tissue indicated that roots had elongated to the depth of injection.

A prerequisite for use of any tracer material or placement system is a determination of isotope uptake by the species and in the medium to be used. In our range reseeding work (Eckert and Evans, 1967; and Evans et al., 1967), species of primary importance are the introduced perennial grasses, Nordan crested wheatgrass (*Agropyron desertorum*); and Amur intermediate wheatgrass (*A. intermedium*); the weedy annual grass, downy brome (*Bromus tectorum*); and weedy broadleaf-annual, tumble mustard (*Sisymbrium altissimum*).

The objectives of this study were to evaluate the uptake of a group of gamma-emitting isotopes from an important range soil by range plants, and to estimate their value for root-tracing studies.

Methods and Materials

Fourteen gamma-emitting isotopes were evaluated: Barium-Lanthanum ($^{140}BaLa$), Cesium (^{137}Cs), Cobalt (^{60}Co), Chromium (^{51}Cr), Copper (^{64}Cu), Iron (^{59}Fe), Iodine (^{131}I), Potassium (^{42}K), Molybdenum (^{99}Mo), Rubidium (^{86}Rb), Ruthenium-Rhodium ($^{106}RuRh$), Selenium (^{75}Se), Zinc (^{65}Zn), and Zirconium (^{95}Zr). Half-life and gamma-ray energy characteristics are given by Crouthamel (1960).

A soil classified as a member of a coarse loamy, mixed, mesic family of Durustollic Camborthids was the medium. Uptake of all isotopes was evaluated in the A_{12} horizon (5–10 cm), pH 6.8. More promising isotopes were also evaluated in the B_2 (20–35 cm), pH 7.0; B_3 (35–53 cm), pH 7.2; and IICI (53–71 cm), pH 7.8 horizons. Soil was screened and placed in 0.9 liter containers.

Five plants of intermediate wheatgrass, crested wheatgrass, downy brome, or tumble mustard were established in each container. When plants were about 6 weeks old, the isotope was injected with a spinal tap needle to a depth of 7.6 cm in the center of the container. Each isotope was injected at a rate of 10 μCi in 0.1 ml of water. At this rate, no isotope was toxic. Most isotopes were evaluated alone and with a suitable carrier.

Plants used to evaluate uptake of short half-life isotopes were sampled about 6 to 8 hours after injection and on 2 consecutive days after injection. Plants with longer half-life isotopes were sampled on 3 consecutive days after injection. A 1-g fresh-weight sample consisted of 1 or 2 culms from each grass plant, or 2.5 to 5.0 cm of growth from each mustard plant. Samples were placed in plastic vials, and radioactivity was determined with a multichannel gamma-ray spectrometer. A 10 by 20 cm NaI crystal was used. The resolution of the gamma-ray spectrometer, as the full-width at half-maximum, was 0.060 MeV for the 0.662 MeV gamma-ray of ^{137}Cs. This corresponds to 17 channels. As a measure of radioactivity, the three peak channels in any one gamma-ray peak were summed and divided by the counting time. The background count rate of the same channels was subtracted. The uptake of each isotope was converted to the following empirical rate scale: very good uptake—more than 1000 counts per minute; good—100 to 1000 cpm; moderate—50 to 100 cpm; poor—10 to 50 cpm; and very poor—0 to 10 cpm. This scale reflects the relative radioactivity of isotope in shoot tissue. Since samples were taken frequently, the speed with which activity appeared in the shoot after injection could be estimated.

Results and Discussion

An evaluation of all isotopes in soil from the A_{12} horizon showed poor or no uptake of Co, Fe, K, Rb, Zn, or Zr by the grasses and forb used. Cohen and Tadmore (1966) attributed poor uptake of Co to adsorption in a loess soil. The uptake of Zn and Zr, and Co, K, and Rb was not increased by addition of 1 mg and 10 mg of carrier, respectively. Uptake of Fe was not increased by additions of 1, 10, 100, or 1000 mg of carrier. Fe and Zn are bound tightly to the soil colloids and they, as well as Co and Zr, have low solubility in phosphate solution at the pH of the soil used. Macro quantities of K occur in soil and the amount of radioisotope used was probably insufficient to adequately label both soil and plant potassium. This group of isotopes does not appear useful for tracer studies in soil, however, they may be useful in sand or nutrient culture where adsorption would not occur and where pH could be adjusted. The long half-life of Co (5.27 years) makes this isotope undesirable for field studies due to health–physics problems.

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Table 1. Relative uptake of five isotopes by four species grown on soil from four horizons (depth in cm). The rate scale was based upon activity counts in leaf and stem tissue.[1]

Isotope	Intermediate wheatgrass–crested wheatgrass				Downy brome				Tumble mustard			
	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)
Cr + 10[2]	G	VG	P	P	G	M	P	P	G	VG	M	G
Cu + 10	G	G	VG	VG	VG	G	G	VG	G	G	G	G
I	P	VG	VG	VG	G	VG	VG	VG	G	G	M	G
Mo + 10	G	G	VG	VG	M	VG	VG	VG	G	VG	VG	VG
Se + 10	G	VG	G	G	VG	G	G	G	G	M	G	G

[1] Rate scale: VG = very good uptake, more than 1000 counts/minute; G = good uptake, 100–1000 cpm; M = moderate uptake, 50–100 cpm; P = poor uptake, 10–50 cpm.
[2] 10 mg of suitable carrier injected with isotope.

The uptake of BaLa, Cs, and RuRh by grass species was generally poor; uptake by mustard was generally moderate to good. The total uptake and speed of uptake of these isotopes possibly could be improved by the use of carriers. For example, plant tissue grown in soil treated with Cs without carrier had a very poor activity rating and activity was not detected for 8 days after treatment. The average activity of plant tissue grown in soil treated with Cs plus 10 mg of carrier was rated moderate, and activity was detected 3 days after injection. The long half-life of Cs (30.0 years) would limit the use of this isotope for field studies. However, ^{134}Cs with a 2.0 year half-life could be used.

The uptake of Cr, Cu, I, Mo, and Se from soil of the A_{12} horizon ranged from poor to very good (Table 1). Data for intermediate and crested wheatgrass were combined since uptake was similar. Isotopes with activity rating of moderate, good, or very good are well suited as tracers for use with the species and soil evaluated. The use of I is questionable. All three grass species had less uptake of this isotope from the A_{12} horizon than from other horizons. The retention of I may be due to a reaction with organic matter (Raja and Babcock, 1961 and Price, 1965). This problem may be overcome by use of a higher, but non-toxic, level of I; by use of a carrier; or by use in horizons with low organic matter. Mustard plants grown in the A_{12} soil did not show a depression in I activity.

Uptake of Cr and Se was enhanced by injection of 10 mg of the metal as chromic acid or sodium selenate, respectively, as carrier. For example, Se injected alone did not appear in intermediate wheatgrass samples until 2 days after placement; and the average 3-day activity rating was very poor. When injected with carrier, Se was detected in intermediate wheatgrass samples the day following placement, and the average 3-day activity rating was good. The same trend was found when Cr was injected with and without carrier. The uptake of Cu and Mo was not enhanced by use of carrier.

Isotopes of Cu, I, Mo, and Se had moderate to very good uptake from subsoil horizons (Table 1) and are well suited as tracers for the species and soil used. The poor uptake of Cr by the grass species from soil of the B_3 and IICI horizons would limit its use in soil of this type. In some manner the Cr ion injected became unavailable to the grass species used. This response may be due to a decrease in the solubility of this ion with increased pH. Uptake of Cr by mustard showed a similar trend, however, activity was rated moderate. Increased isotope dose or increase in carrier may correct this problem. The increased uptake of Mo by all species from the subsoil horizons may be due to increased solubility of Mo at higher pH.

As a group, Cr, Cu, I, Mo, and Se give the researcher a series of tracers with markedly different half-lives and gamma-ray energies. Because of energy differences, these isotopes can be determined individually in the presence of each other. The very short half-life of Cu makes it especially valuable for short-term studies or where exclusion and disposal are problems. The longer half-life of Se suggests its possible use where long term measurements are necessary. For studies that require a longer half-life than 12.8 hours or shorter half-life than 128 days, Cr, I, and Mo could be used. The rapid uptake of Mo is evidenced by activity counts in excess of 10,000 counts per minute in leaf tissue 6 to 8 hours after injection. Since these isotopes are gamma emitters, no special sample preparation is needed prior to counting.

The solubility of isotopes in water and subsequent leaching from zone of placement is important in root-tracer technique. Schultz (1965) points out that a consideration of inorganic soil chemistry together with all other possible influences is necessary to predict movement of ions through soil.

Based upon the work of Jackson (1958), Bear (1964), Menzel (1965), and Schultz (1965), the mobility of chromium, copper, iodine, molybdenum, and selenium can be estimated. Of this group, chromium is the least soluble with the degree of solubility dependent upon type of clay mineral and soil pH. When soluble copper is added to the soil it tends to become less soluble due to formation of hydroxides or adsorption on soil colloids. In these forms copper is less soluble than most of the alkaline earth elements. Iodine is somewhat less strongly adsorbed than copper and therefore is more mobile in the soil solution. Molybdenum undergoes fixation in the molybdate form similar to phosphate, however, solubility is strongly influenced by soil pH. In general, molybdenum is more mobile than chromium, copper, or iodine. Selenium oxidizes to selenate and has leaching characteristics similar to sulfur. Selenium appears to be the most mobile of the elements discussed.

In spite of the apparent solubility and mobility of some isotopes in the soil, placement and sampling techniques could be devised to minimize leaching. For example, isotopes could be injected when soil moisture content was near or below field capacity. At this moisture level, movement of isotopes in soil solution would be restricted because of unsaturated flow conditions and a marked decrease in water movement through soil. Rapid uptake of some isotopes suggests that an adequate activity measurement could be obtained shortly after placement and thereby minimize leaching problems.

Conclusions

Our evaluation of the uptake of fourteen isotopes showed Cu, Cr, I, Mo, and Se were, with few exceptions, well suited for use as tracers with the species and soil used. These isotopes can be determined in the presence of each other by gamma-ray spectrometry. In our opinion, these results can be extrapolated for use with other species of perennial and annual grasses and annual forbs. These isotopes can also be used in soils with low organic matter, near neutral reaction, and loamy texture. Further study is needed to evaluate: (1) isotope uptake by perennial forb and shrub species; (2) isotope uptake from soils with acid or alkaline reaction, high organic matter, and very light or heavy texture; and (3) leaching of isotopes from zone of placement.

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