

Detecting Depth and Lateral Spread of Roots of Native Range Plants Using Radioactive Phosphorus

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Abstract

Radioactive phosphorus (P^{32}) was used to measure root depth and lateral spread of four native plant species which had been subjected to heavy grazing for many years. Compared with root excavation measurements from an earlier study on the same area, rooting depths of all species tested were found to be quite similar by the two methods. Lateral spread differed substantially, however. Roots were found to have a greater lateral spread by the P^{32} estimate. The isotope method using autoradiography was found to be a sensitive method of determining depth and lateral spread of *in situ* plant roots in a mixed plant community.

A number of investigators have used radioactive phosphorus, P^{32} , to determine plant rooting characteristics (Aeberold 1953). Mathis et al. (1965) evaluated growth, activity, and varietal differences in cotton, corn, peanuts and tobacco roots using a tracer technique. Root growth of sorghums was measured by McClure and Harvey (1962) by use of radioactive phosphorus. Nye and Foster (1961) in Ghana determined the relative uptake and use of several short-term annual and perennial plants from various root zones using labelled P^{32} . Boggie et al. (1958) in Scotland use radioactive tracers to investigate plant root systems growing in peat and mineral soils. The methodology was found very useful in both soil types, and they suggested that P^{32} could be used to determine maximum rooting depth of each species composing a community. They also suggested it could be adapted for determining lateral spread of root systems. Their work was based on placement of P^{32} at different levels within the soil of four different grassland communities and measuring the specific activity of P^{32} uptake by each species. A modification of this technique was used in the present study to determine depth and lateral spread of roots of four major species in the ponderosa pine-bunchgrass type of Colorado. Results are compared with those for a root excavation technique used by Schuster (1964) from a study made on the same heavily grazed experimental sites.

Study Area

The work was conducted at the Manitou Experimental Forest 45 km northwest of Colorado Springs, Colo., at approximately 2,375 m elevation. Annual precipitation in this area averages about 400 mm

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with nearly three-fourths occurring during the spring and summer growing season, from April through August. Soils are derived from Pikes Peak granite and they are a sandy loam or sandy clay loam with low fertility and moderate amounts of organic matter. These soils are porous when wet but very hard when dry.

Vegetation is characteristic of the ponderosa pine-bunchgrass type of the central and southern Rocky Mountains. It is characterized by a complex of plant communities with open grassland parks interspersed among irregular stands of ponderosa pine (Currie 1975). The most important forage species are Arizona fescue (*Festuca arizonica* Vasey) and mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.). Other abundant species include fringed sagebrush (*Artemisia frigida* Willd.), blue grama (*Bouteloua gracilis* (H.B.K.) Lag.), pussytoes (*Antennaria* spp.), and sedges (*Carex* spp.).

Arizona fescue and mountain muhly produce the most forage and cover on ungrazed areas, but both are reduced by continued, season-

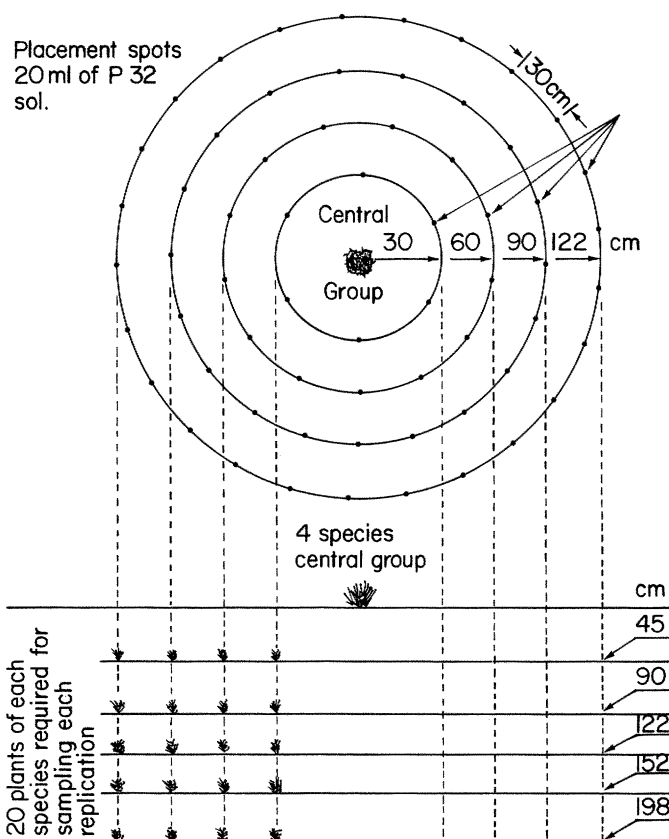


Fig. 1. Schematic diagram of drill hole arrangement for placement of P^{32} . Holes were drilled to one specific depth and concentric circle size around a closely associated grouping of four plant species at each site.

long grazing. The less desirable blue grama and fringed sagebrush become more abundant on heavily grazed ranges. The pastures used in this study had been grazed heavily since 1941. Effects of this grazing treatment on plants and animals are discussed in detail by Smith (1967). Specifically, pasture 1 described in this earlier research was used as the site for the present study.

Study Methods

Root study locations were confined to the open grasslands away from the direct influence of ponderosa pine. Each site selected had four species, Arizona fescue, mountain muhly, blue grama, and fringed sagebrush, growing in very close proximity to one another, usually within an area of 15×15 cm. Three replications were established, and each replication included 20 sites. Each site had holes drilled around the central plants at one of five depths and four lateral distances out from the plant grouping (Fig. 1). Thus, 240 plants, or 20 of each species in each replication, were required to sample all depths and lateral distances. For any given depth and distance, 4-cm diameter holes were drilled at 30-cm intervals surrounding the central plant grouping. Placement access holes were drilled into the soil using a pickup mounted, commercial soil auger. Soil was saved and replaced in each hole following the isotope placement.

Isotope material was injected using the continuous pipetting instrument described by Loewenstein (1965). Treble superphosphate in water was used as the carrier, and 20 ml of P^{32} solution was injected in each placement hole. The labelled P^{32} used was potassium dihydrogen phosphate ($KH_2P^{32}O_4$). It had a specific activity of 0.003 millicuries (.003 mc) per ml.

Care was exercised in lowering and lifting the probe to avoid touching the sides and contaminating soils above the desired placement levels. The probe was always moved outside the ring of placement holes to avoid an accidental drip onto plants to be monitored. An additional one-way Luer-Lok¹ connector was installed below the syringe and above the injection probe described by Loewenstein (1965). This safety feature did not permit leakage during movement from hole to hole. Also, the syringe was kept in an upright position when being moved to avoid any dripping and contamination.

Starting 12 days after the initial injection, plant crowns and leaves were monitored with an end window Geiger-Muller (G.M.)¹ counter to determine if P^{32} was being translocated. Because some roots might have been cut by hole drilling, monitoring with the G.M. counter was continued for several of the 14.3-day half-lives of P^{32} . It was assumed that new roots could move into the phosphorus banded zone, and this activity could be detected if the P^{32} activity remained sufficiently high. In this interim period, additional radioactivity tests on aboveground parts were made using autoradiography on nonscreen x-ray film. A few leaves, culms, or stems of each species were clipped to crown level. These samples were placed on sealed individual packets of x-ray film and allowed to expose in the laboratory for 12 hours. The film was then developed to determine if photons from the radioactive phosphorus had exposed the film.

Results and Discussion

Autoradiography was found to be much more sensitive than field monitoring using a G.M. counter. As shown in Figure 2, Arizona fescue readily exposed the x-ray film, and the amount of plant material and radioactivity, except for illustrative purposes, was in excess of that needed for analytical comparisons. Autoradiography also avoided the problem of detecting radioactivity from more than one plant species in the mixed community, as was encountered in using the G.M. counter. Individual species and plant parts from all portions of the crown

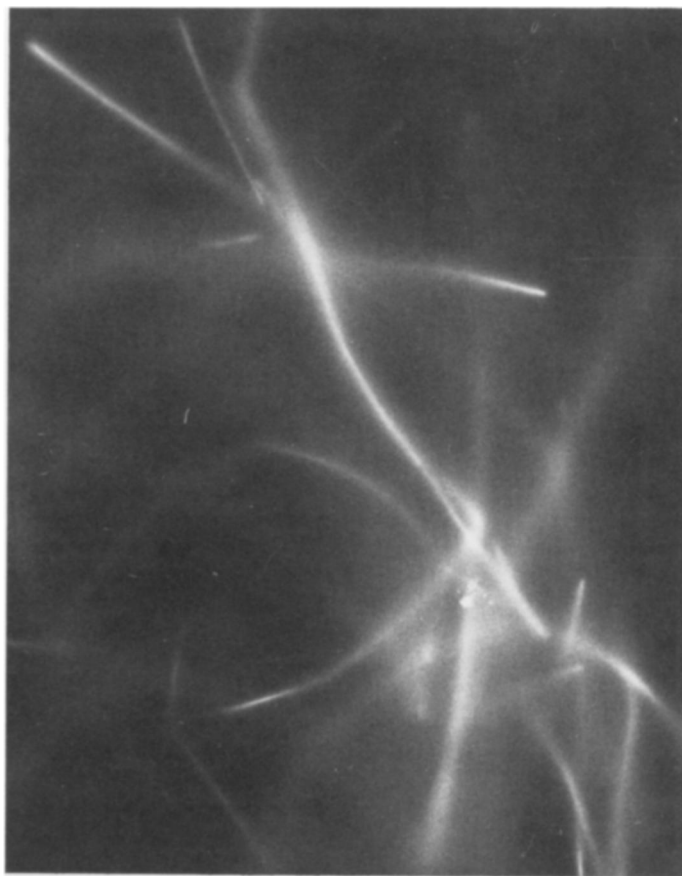


Fig. 2. Autoradiograph of Arizona fescue leaves and stems following translocation from roots. This method of radioisotope detection was found very useful and sensitive for evaluating depth and lateral spread of roots following translocation to aboveground parts. Aerial parts shown were from a site where P^{32} was injected to 46 cm deep and 30 cm out from the central grouping.

could be readily sampled and monitored for the translocation of the P^{32} . Thus, the problem of some roots picking up the phosphorus and translocating it to only one part of the crown or leaves in very small amounts did not occur, since samples were analyzed from all portions of each plant. Very small amounts of radiation, which only slightly exceeded background on a G.M. counter, also were readily detected.

All four species—Arizona fescue, mountain muhly, blue

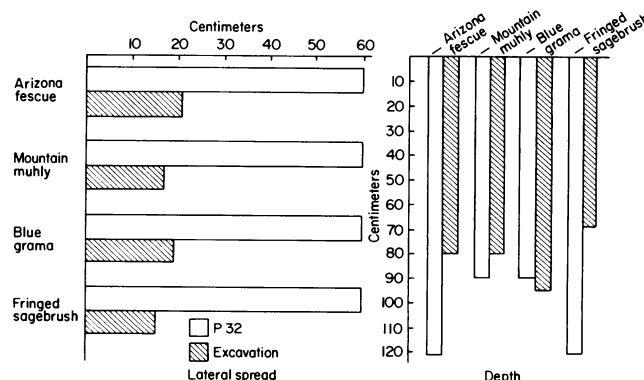


Fig. 3. Average lateral spread and average root penetration of four plant species on a heavily grazed range as measured with radioactive phosphorus and by the root excavation technique. (Adapted from Schuster 1964.)

¹ The use of trade names in this publication is for the information and convenience of the reader and does not constitute an official endorsement or approval of any product or service by the U.S. Department of Agriculture to the exclusion of others which may be suitable.

grama, and fringed sagebrush—had rooting depths and lateral root distributions which were quite similar and did not differ significantly. The maximum depth of penetration generally did not exceed 90 cm except for one individual plant of Arizona fescue and one fringed sagebrush. These two plants each reached a depth of 122 cm. These results on depth of rooting were quite similar to those of Schuster (1964) using the excavation technique (Fig. 3). The depths of penetration were also similar to those for a different species of fescue and other species growing on sand and sandy-loam soils reported by Boggie et al. (1958) in Scotland.

The lateral spread of roots, however, differed substantially from those determined by Schuster (1964) (Fig. 3). Roots of Arizona fescue, mountain muhly, blue grama, and fringed sagebrush were found to extend outward to about 60 cm by the isotope tracer technique. Occasionally, lateral spread reached only 30 cm for each of the four species, but at least one plant of each species had roots extending to the 60-cm lateral distance. These distances were somewhat less but more closely approximated lateral spread reported by Mathis et al. (1965) for plains bristlegass. They reported a lateral spread of 76 cm for plants which had been clipped and about 100 cm for plants on unclipped plots.

The difference in measured lateral spread between the excavated and isotope monitored roots could be caused by several factors. The same plants and their root distributions were not measured during the same years or for exact comparative purposes in the two studies. Only one plane and a profile of usually less than 20 cm in thickness was sampled by the excavation-washing technique. Small segments of roots may have been cut off or lost in washing by the excavation technique; whereas, comparable roots remained intact or grew where the

isotope injection method was used. Other factors which gave an advantage to using isotope methodology included sampling from all planes within the soil in relation to individual plant crowns. The sample size for individual species was larger, which increased the opportunity to sample plants with greater root spread. This *in situ* method was nondestructive, which permitted sampling species in a competitive situation with root systems fully intact.

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