Use of Radiophosphorus and Soil-Block Techniques to Measure Root Development[1]

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Highlight

A radiophosphorus and soil-block technique of root study gave comparable results when studying root growth of switchgrass (*Panicum virgatum*) and sideoats grama (*Bouteloua curtipendula*). Roots of switchgrass penetrated 60 inches laterally from the culms while the sideoats grama root system was much less extensive. The primary advantage of the radioisotope technique of root study is that it allows seasonal root developmental data to be easily collected while soil-block observations are laborious and depict root expanse at only specific times.

A knowledge of the size and extent of grass root systems is an important factor upon which management should be based. This study was initiated to gain a more thorough knowledge of the root systems of "Premier" sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) and "Grenville" switchgrass (*Panicum virgatum* L.). These species, established 1 year prior to the study, occur in plant communities of the central United States.

Root excavation, a laborious and time-consuming procedure, has been eliminated in much ecological research. With the advent of radioisotopes and particularly with the development of radiophosphorus (^{32}P) in 1935, an entirely new field of study was opened (Hendricks and Dean, 1947). Radioisotopes have thus provided an important tool for basic research in the study of root systems.

^{32}P is particularly well-suited for root-tracer studies (Arnon et al., 1940). It has a half-life of 14.3 days (Desrosier and Rosenstock, 1960) and behaves normally in plant physiological reactions (Kamen, 1957). Under normal soil phosphorus conditions, ^{32}P can still be detected after 6 half lives, a characteristic which makes it ideal for short-term studies.

The objectives of this study were (1) to determine the extent of root development of sideoats grama and switchgrass, and (2) to compare the indirect radioisotope method of root study with the direct soil-block washing technique.

Procedures

"Grenville" switchgrass and "Premier" sideoats grama were planted in 40-inch row spacings on formerly cultivated land of the Texas Tech University Research Farm near Lubbock. Four rows of each species were planted adjacent to each other in 100-foot rows (Fig. 1). The outer row of grass in the 4-row planting was used to detect ^{32}P uptake and provided the sample area for the soil-block technique. A fallow area, 16.7 feet wide and weed free, provided ample room to make soil placements of ^{32}P.

Two replications of randomized complete blocks were established. Nine placement plots were located adjacent to each 100-foot study row. Four identical placement zones, ten inches apart, were located within each plot. A distance of 7.75 feet separated each plot to prevent roots from one area entering an adjacent radioactive plot. Lateral and vertical placement intervals were made 10 to 60 inches from the center of the row of grass clones.

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[1] Cooperative research of Texas Tech and Texas A & M Universities. This paper is part of a manuscript submitted by the senior author to Texas Tech University in partial fulfillment of the requirements for the Master of Science degree. Received January 1, 1970; accepted for publication April 4, 1970.

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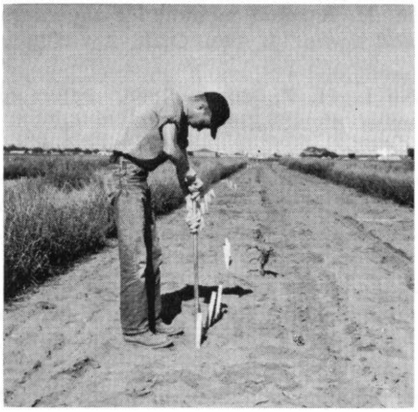

FIG. 1. Field design showing four rows of grass at left and individual placement plots in fallow area.

FIG. 2. Soil-block encased in "steel frame" ready for removal to laboratory for washing. This block weighed in excess of 3400 pounds.

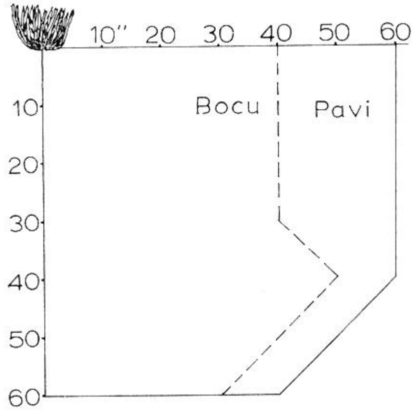

FIG. 3. Expanse of sideoats grama (Bocu) and switchgrass (Pavi) roots as determined by radiophosphorus.

A radiophosphorus technique modified from Mathis, Jaynes, and Thomas (1965) was used. Weak hydrochloric acid containing $^{32}PO_4$ ions was placed in enough distilled water to give a specific activity of 0.00225 mc/ml. Paper cups, each having a capacity of 20 ml were filled with the tracer and then placed on dry ice. When solidified, the paper containers were removed and the radioactive "ice cubes" were transported to the study area.

In each plot four channels had previously been formed with a hydraulically-operated soil-core sampler. One cube of radioactive material was dropped into each channel. Soil was then firmly tamped into the channels.

The presence of ^{32}P in the aerial portion of grass plants, as detected by a portable Geiger-Müller counter, was considered evidence that a part of the root system had entered a placement zone. Plants were monitored every two to seven days throughout the summer until radioactivity could no longer be detected above background radiation.

Pavlychenko's (1937) method of encasing a block of soil in the field was modified for use in this study. A "steel frame" with 76 by 62-inch dimensions was used to encase a block of soil which had been excavated with a trenching machine (Fig. 2). A 30-cubic-foot soil block was taken to the laboratory for removal of the soil from the root system.

Results and Discussion

Isotope Method

Switchgrass roots grew a lateral distance of 60 inches from the culms (Fig. 3). At this lateral distance, roots penetrated to a 40-inch depth. Forty inches from the grass culms, roots were found to a depth of 60 inches.

Six days after ^{32}P was placed in the soil, roots entered a radioactive zone at two 10-inch and one 20-inch lateral placement levels located at vertical depth of 10-inches and 30-inches respectively.

Sideoats grama roots grew in a lateral direction as much as 50 inches from the culms (Fig. 3). At this lateral distance, the maximum depth of root penetration was 40 inches. At a lateral distance of 40 inches, the depth of root penetration was 30 inches. The maximum distance penetrated by roots was 30 inches laterally and 60 inches vertically. One 30-inch and one 10-inch lateral placement, each at a depth of 10 inches, were the first zones to be penetrated by roots as indicated by radiation from aerial tissues.

Extreme care was used during the monitoring process. A lead shield was used to isolate specific culms and plant parts during the monitoring process. Part of the culms emitted radiation while others did not which indicated that specific culms of a grass clone have roots entering different areas of the soil. Apparently very little or no lateral translocation of phosphorus occurs in the crown region of these species. Additionally, those culms located at the back or away from the placement plots were attached to the roots entering the radioactive zones at the lower depths. Culms located towards the placement zones generally contained the beta radiation from the upper 30 inches or less of the radioactive zones. Further research is needed, however, before positive statements can be made concerning translocation and individual root penetration patterns.

Phenological changes in the plant were responsible for causing large variations in radioactivity within a culm. Lower nodal areas emitted more radiation than older leaf tissues. Also during flowering and when seeds began to develop, ^{32}P was concentrated in the inflorescence. This response was expected and is directly related to the role of phosphorus in plant growth and development.

Soil-block Method

Direct observations showed switchgrass roots to be less extensive than was indicated by the

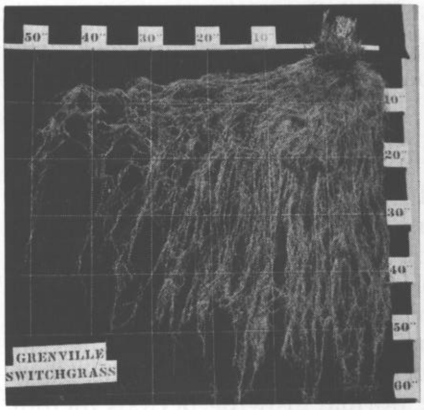

FIG. 4. Exposed root system of switchgrass after soil-block from Fig. 2 was washed.

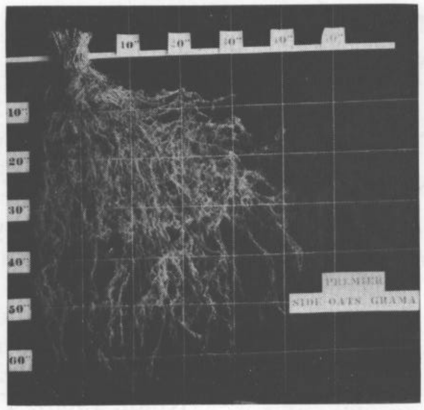

FIG. 5. Sideoats grama root development showing a vertical orientation of roots.

tracer technique. Maximum lateral extension was slightly over 50 inches (Fig. 4). Outward growth from the culms was uniform.

Switchgrass primary and secondary roots were characterized by having a woody-like nature throughout. The tertiary roots and other lower order roots were fragile and thus lost during the washing process.

Sideoats grama roots extended downward 60 inches at a 30-inch lateral distance from the culms (Fig. 5). Few roots were found beyond 30 inches from the culms.

Sideoats grama root diameters were approximately one-half as large as those of switchgrass roots. The roots of sideoats were more vertically orientated than those of switchgrass. These differences are likely due to genetic differences between species as soil moisture levels were similar in all plots. Extra care was necessary in washing the sideoats grama block to avoid loss of roots.

Comparison of Methods

The expanse of switchgrass root systems varied 10 inches between the two methods of study. The soil-block was encased August 1, and on this date, roots had not extended into the 60-inch lateral zone as indicated by the Geiger-Müller counter. All the 60-inch lateral readings were recorded in August; therefore, it is assumed that the roots grew an additional 10 inches after August 1.

Little variation was found between the two methods used in the root study of sideoats grama. Excavation for direct study was not made until August 15, at which time most roots had apparently reached their maximum penetration.

Soil moisture stresses are believed to have played a significant role in determining the results of this study. Available soil moisture was low directly beneath culm areas throughout August. The capillary movement of soil moisture from the fallow area toward the drier soil plus a general growth response of root systems may have caused roots to extend outward abnormally far from the culms.

These two methods of root study are comparable. Direct observation of root systems requires more labor and time than the isotope technique. Possibilities of errors are greater when using the soil-block for at least three reasons: (1) a much smaller area is sampled by the soil-block than by the isotope, (2) a 12-inch wide sample may not include all primary laterals, and (3) variations in sampling areas may increase errors.

The ease of placing radioisotopes into soils with their subsequent uptake by plants makes the isotope technique a preferred method of root study. Greater precaution must be exercised in handling tracer solutions, but results appear to be more accurate in determining root growth over a period of time.

Isotopic tracers can be used on most range lands. The primary limitation would be in placing them at sufficient depths in areas with rocky substrata. Also, the possible occurrence of amorphous soil colloids such as allophane renders ^{32}P unusable since phosphorus fixation is a problem in these soils. The soil-block method requires an abundant water supply, and a winch truck or similar power source is necessary to lift blocks from the soil.

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OVERSEAS OPPORTUNITIES

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