ROOT SURVEY METHODS FOR HYDROLOGICAL EXPERIMENTS

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INTRODUCTION

The roots of a plant are those parts which are normally below the surface of the soil. Root distribution is a very important factor in many hydrological studies and may be defined by the volume and/or weight of roots present, their mode of branching and diameter, their vertical distribution, and their lateral distribution in the soil profile. Evapotranspiration, infiltration, soil moisture and ground water are all affected by the presence or absence of roots. The primary functions of the root are anchorage, the absorption of water and inorganic salts in solution, the conduction of these to the stem, and the modification of moisture stresses and porosity of the soil.

Methods of root measurement are many and varied. Troughton (1959), the American Society of Range Management (1962), the Commonwealth Bureau of Soils (1963), and Schuurman and Goedewaagen (1965) outline these in detail with extensive bibliographies. For this reason, only the more important methods are commented on here.

DIRECT FIELD METHODS

Profiles

Weaver (1926) dug trenches at distances from a tree stem and isolated the roots from the trench walls with hand tools. More recent methods (Upchurch, 1951) have used water to sluice away the soil with moderate success, depending on the soil type. Oskamp and Batjer (1933) attempted to quantify the method by placing a grid over the trench wall to count the tangential and radial roots. Its main use has been with woody plants.

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Monoliths

Used first by Rotmistroff (1908), this method employs a board lined with plastic sheet and gridded with spikes. A hole is dug, observations are made of soil composition and root spread, and the spikes are pressed against the root system to be sampled. The mixture of soil and roots attached to the spiked board is then extracted with a wire-cutter and taken to a laboratory for washing by either hand or mechanical techniques. Sand and silt samples do not present many problems, but clay samples must first be heated (100°C) and immersed in sodium pyrophosphate solution (or another peptizing agent) before washing. If root hairs are to be preserved, the washing process requires extreme care. Once cleaned of soil and foreign matter, the board and roots are placed in water to allow the roots to return to their natural position for photography and analyses.

Although the method produces a very detailed result, it is time consuming. For large plants, only part of the root system can be sampled. It favours fibrous root systems and is not very satisfactory for woody plants. It may be difficult to separate roots in close-growing systems, and the hole required for sampling may influence the experiment.

Soil Cores

This is the best quantitative method for basin use, provided that the sampling procedure is statistically sound. Soil samples containing the roots are collected with a variety of augers. A cylindrical type of auger with a diameter of 70 mm is good, as this reduces boundary damage to roots. Samples obtained by hammering or pressing the auger into the soil are less disturbed than samples obtained by boring. These samples are collected in relation to the position of the plant stem. Samples in the vertical are then collected down to the depth at which the roots cease. If a core is to be analysed for other characteristics, for example soil-moisture tension, this must be done before root separation commences. Samples are washed, as described for monolith sampling, on a gauze screen. Soil is removed by decanting, and organic impurities are removed with tweezers. The samples are then dried and weighed. Dead and live roots may be separated if required. A modification to determine quickly the quantity of roots present involves splitting the core into halves or quarters and assessing, by eye, the number of roots present.

This method gives a reasonable estimate of root quantity and relevant soil data. Obviously, it does not give the root detail obtained by monolith sampling, but a combined sampling programme of the two methods could satisfy most sampling needs.

INDIRECT FIELD METHODS

These methods involve the determination of root extent by measuring a closely related characteristic, for example the movement of a tracer, the soil moisture, or the crown weight.

Tracers

Dye, rare elements, and isotopes are all available for substitution in the soil and subsequent detection in plant tissues.

The use of environmental isotopes in hydrology is a rapidly growing field (International Atomic Energy Agency, 1967). They have advantages over other tracers and cycles that parallel the hydrological cycle.

Little information has yet been obtained on the relationship between root-system and soil-moisture characteristics using isotopes. However, a number of authors have expressed interest in the subject, and Tamási *et al.* (1961), in a study of nutrient uptake by apple trees using labelled superphosphate (P^{32}) and different levels of soil moisture, suggested that the different absorption rates obtained resulted from the differences in water supply to the roots and the number of root hairs present. Therefore, by statistically varying the position of the tracer injection point, it is possible to obtain a measure of the extent of the root system — in particular its field of influence.

Witkamp and Frank (1964), working in tulip poplar, injected the tree stems with Cs^{137} and found that differences in the Cs^{137} content of core samples caused by downward translocation in the stem were sufficient to determine differences in root distribution. Even after leaf fall the roots contained 75 percent of the original Cs^{137} in the root and mineral soil samples. Neilson (1964), with a similar technique, used C^{14} to separate the root systems of interlocking plants.

Considerable research is still required, but it would appear that radioisotopes provide a quick means of estimating the spatial extent of rooting systems.

Soil Moisture

Specht (1957) showed that spheres of moisture are related to plant species and, if measured, will give an estimate of root distribution. A variety of techniques are available, including gravimetric, gypsum-block, tensiometer, and neutron methods.

Correlation with other Physical Features

Root characteristics can be correlated with other more easily measured features although much still remains to be done in this aspect of hydrology. Whatever features are used, care should be taken to ensure that they are independent. Numerous authors, for example Fox *et al.* (1953), have shown that root growth can be classified according to soil horizons. A degree of correlation exists between horizons and root quantity. If significant, soil horizons are more easily measured than root quantity and can be used to indicate root quantity.

Correlation of roots with other more easily measured phytomorphological features is a possibility (Hosegood and Howland, 1966). A good relationship between stem diameter and root quantity, depth, or lateral extent would provide a quick survey technique for these characteristics.

LABORATORY METHODS

Several methods are available for the detailed study of root systems in a laboratory. Lack of space restricts these studies to small root systems and environmental conditions that often differ from conditions in the field. Schuurman and Goedewaagen (1965) describe methods using cylinders, cases, boxes, and pots filled with soil which is easily removed for root analyses. The methods are often modified, for example by the use of glass panels to observe root growth, to meet local research requirements. Plant growth in water cultures provides an easily analysed root system, although the growth conditions are very different from field conditions. This applies to all laboratory methods.

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