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Root systems

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16.1 INTRODUCTION

Although root system studies are generally conceded to be important, the difficulties in such study are sufficiently daunting that root systems have received comparatively little attention in physiological ecology. The problems involve, in part, the sizable labor and time investment, the variability in root locations and activity, and the inadequacies of many root measures. The difficulties are often exacerbated for very fine roots and deep root systems. In spite of these difficultties, a judicious selection of experimental approaches, including indirect assessments, can yield meaningful results and can contribute significantly to an understanding of plant function in the field. Many new techniques have become available in the last few years. This chapter outlines a broad range of techniques for assessing root system structure and function in the field. Boehm (1979) has thoroughly described the classical, and still useful, root evaluation techniques. Emphasis here is, therefore, directed to newer techniques not covered to a great extent by Boehm (1979). This chapter treats methods as they relate primarily to the study of root systems in the field.

Individuals working with root systems have displayed a certain proclivity to coin new terms for the ecological lexicon. In this chapter one encounters terms such as a 'hydropneumatic elutriation system', a 'microrhizotron' and a 'perforon'. Of course, we feel a certain obligation to define such terms but at the same time to employ more conventional English descriptors.

16.2 ASSESSING ROOT SYSTEM STRUCTURE AND BIOMASS IN THE FIELD – DETERMINING WHAT IS THERE

16.2.1 Profile wall root mapping, monoliths, soil core extraction

The only way to examine the entire root system of the plant is by direct excavation and mapping or recovery of roots from the soil. This approach has been widely applied to describe the depth and lateral extent of root systems (Boehm, 1979). Excavation can provide an accurate description of the morphology of the root system and may be useful

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in studying root overlap between neighboring plants (Kummerow, 1981). This approach, however, is very labor intensive and provides an observation of the root system at only one point in time. Therefore it is of a limited value in studying root function and root growth. For deeply rooted plants, excavation may not be possible as roots may follow cracks in rocks or move through stony soil difficult to excavate without specialized equipment or root disturbance.

Investigators have taken advantage of eroded stream banks and gullies or excavations for roads to observe deep root systems since large volumes of soil have already been removed. Large-scale root excavations have also been conducted. Kummerow *et al.* (1977), Hellmers *et al.* (1955) and Hoffmann and Kummerow (1978) used water under pressure to expose roots of woody chaparral and matorral plants. Air pressure and vacuum have also been used to expose roots in forest studies (i.e. Boehm, 1979). The above techniques can remove large volumes of soil, but recovery of fine roots may be incomplete and can be difficult in clay soils.

The depth and size class distribution of roots can be determined by digging a trench adjacent to the plant and mapping the exposed roots. A trench approximately 1 m wide is dug at the point of interest. Care must be taken to extend the trench below the maximum depth of rooting for a complete description. Deep trenches may require shoring for safe use. If the root system is to be excavated, the soil is carefully removed using hand tools to expose the roots. The profile wall may be smoothed and the location and size of roots can be mapped or photographed against a grid system. It may be possible to use image analysis techniques to process photographic images of roots if the contrast in color between the roots and the substrate is sufficient. Trenching approaches require considerable labor and are time consuming. Particular care needs to be taken in preparation of the wall surface so as to expose the fine roots. However, no specialized or expensive equipment is required and this approach provides a direct and complete description of a plant's root morphology. It is especially useful to determine if roots are following cracks or discontinuities in the soil. Root descriptions for many systems have been made using this technique (Boehm, 1979).

When root recovery is required, monoliths can be extracted from the soil and the roots separated by washing. Monoliths can be cut from the soil using a grid to gain a three-dimensional view of the root system. If the soil lacks sufficient structure to extract intact monoliths, a metal frame can be driven into the soil to support the monolith during extraction. Other modifications include the box method where a large monolith encased in a box is removed from the face of a trench and washed free of roots to provide a view of the depth distribution of roots. A needle board can be driven into the monolith to keep roots in their natural position prior to washing the soil free. This maintains three-dimensional information from the monoliths. Further details are in Boehm (1979).

Coring methods have increased in popularity as better equipment has been developed. This is especially true for deep drilling (> 1 m, Boehm, 1979). The Viehmeyer tube (Viehmeyer, 1929) can be rammed into the soil using a drop weight and extracted with jacks or pulleys to give a relatively intact core up to 180 cm in length if the soil is not too stony. Larger mechanical equipment has been developed for deeper sampling (e.g. Kelley *et al.*, 1947; Boehm, 1977).

Undisturbed cores can be obtained with equipment that contains at least two sets of bits, usually an outer rotating bit which cuts the hole and a nonrotating inner coring bit (Fig. 16.1). Usually the coring bit slightly precedes the outer bit in order not to disturb the core. The outer bit cuts and/or removes the soil (if it contains auger flights) and allows the inner bit to enter the soil with relatively little pressure required. Single core