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A Large-volume Rhizotron for Evaluating Root Growth Under Natural-like Soil Moisture Conditions

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Abstract. **An experimental system that allows imposition of precise irrigation treatments with easy and quick observations of unrestricted root growth of woody plants was developed. The system mimics natural deep soil percolation and facilitates rapid assessment of large root populations. It was designed to be relatively inexpensive to build so that treatments could be efficiently replicated. Designs for this star-shaped rhizotron were developed and evaluated with the goals of: 1) optimizing volume and shape for minimal physical restriction and use with mature woody plants; 2) developing a drainage system comparable to natural deep soils; and 3) facilitating ease, accuracy, and duration of data acquisition. The final design allows efficient root observation, uses a wick-type drainage system to provide a near-uniform profile of soil moisture, and is easily manageable for precise long-term data acquisition. This rhizotron has eight independent viewing/sampling windows and holds 0.16 m^3 of soil. An associated lightweight and compact camera positioning frame was developed that facilitates acquisition of digital photographs of soil profiles for time-series assessment of morphological and architectural parameters.**

Although root growth is central to overall plant performance, the study of natural root development has remained a challenge as a result of the difficulty of observation. Attempts to observe roots over time date back to at least the early 1900s (McDougall, 1916). However, most methods used to study root development are extremely time-consuming and tedious (Calfee, 2003). A rhizotron is a device for non-destructively observing plant roots over time (Garrigues et al., 2006). Root observation facilities described by Karnok and Kucharski (1982), Soileau et al. (1974), and Taylor and Bohm (1976) consisted of underground laboratories with transparent windows. Root observation windows installed in native soil (Gallandt et al., 1990; McDougall, 1916; Metcalfe et al., 2007) were less elaborate but also below soil level. A different approach used transparent tubes (Schoene and Yeager, 2006) or tube-type rhizotrons, which controlled soil temperature (Bland et al., 1990). However, the majority of root development research has relied on narrow observation boxes usually made of Plexiglas (Boukcim et al., 2001; Busch et al., 2006; Devienne-Barret et al., 2006; Garrigues et al., 2006; James et al., 1985; Misra, 1999; Stepniewski et al., 1991; Ugoji and Laing, 2008; Wiese et al., 2005). Although these devices enabled studies on root growth under greenhouse conditions, soil volume exploited by roots was severely reduced, narrowing applicability of these approaches to seedlings or cuttings. Moreover, root architecture was subjected to artifactual conditions because roots were forced to grow in narrow spaces, forming an unnatural root arrangement. Wright and Wright (2004) developed a star-shaped rhizotron with eight glass panels suitable for greenhouse or field use that overcame many limitations of past approaches. However, it did not fully mimic in-ground conditions. A large rhizotron, designed around concepts of enhanced root observation and tracking strategies, would enable researchers to study growth of whole mature root systems as they develop. Understanding the effects of environmental factors and cultural practices on root growth of mature plants would be of great benefit for applied and fundamental goals ranging from ecology to agriculture, landscaping, and forestry.

The objective of this research was to design and refine an aboveground rhizotron that would enhance observation and recording of undisturbed, natural root growth of woody plants. A primary goal was to mimic in-ground conditions, including minimum physical restrictions and enhanced drainage, the latter being especially valuable for evaluating effects of soil moisture deficits on root growth.

Material and Methods

Stage 1: Designs for containment and observation ports. A prototype rhizotron was constructed in May 2006 to evaluate different materials and designs for root observation and sampling. The shape was that of a star with four arms radiating from a central rectangular frame (Fig. 1). This star-shaped rhizotron enclosed 0.18 m^3 of soil, measured 2.1 m across, and was 0.31 m deep at the tip of the arms. The central frame was 0.25 × 0.25 × 0.37 m tall. The bottom of each arm was made from expanded white polyvinylchloride (PVC) board (6 mm; Kommerling Inc., Huntsville, AL), which was sealed along the edges with silicone caulk (DAP Products Inc., Tipp City, OH) and was sloped toward the center frame to facilitate drainage and to reduce perched water tables common in flat-bottomed containers (Bilderback and Fonteno, 1987; Spomer, 1980). The bottom of the center frame consisted of a plastic mesh (12.5 mm square) over which woven groundcover (Lumite Inc., Gainesville, GA) was placed to support the substrate. The frame of this prototype rhizotron was welded from angle-iron strips [L-shaped cross-sections (18 × 18 mm) of 3-mm iron] with narrower width (12.5 × 12.5 mm) at the top of the frame to facilitate transplanting root balls (typically 11.4 L from standard nursery containers). To facilitate observation, the rhizotron was supported by four legs (60 cm) at the tip of each arm.

Each lateral side of an arm of the rhizotron was used to evaluate different systems for non-disruptive visualization of roots while holding substrate in place. Four different viewing port designs were evaluated: 1) a single door the length of a lateral attached by two brass hinges (Fig. 1A); 2) a single sliding panel the length of a lateral (Fig. 1B); 3) two independent doors each held by two brass hinges (Fig. 1C); and 4) a side panel with two smaller doors attached to the panel (Fig. 1D). For some configurations, 12.5-mm square wire mesh was placed laterally to hold substrate in place. Two materials were evaluated for doors: 2.2-mm clear Plexiglas and 8-mm Thin-wall polycarbonate (Lexan; General Electric, Fairfield, CT). In addition, different methods were tested for sealing doors to avoid moisture loss and to remain closed.

After construction, a *Ligustrum japonicum* Thunb. from an 11.4-L container was transplanted into the rhizotron using a commercial substrate composed of Canadian sphagnum peatmoss, processed pine bark, perlite, vermiculite, starter nutrients, wetting agents, and dolomitic limestone (Mix #4; Conrad Fafard Inc., Agawan, MA). Irrigation was supplied daily with three bubbler emitters per arm (Model Shrubbler 360°; Antelco, Longwood, FL). Rhizotron arms were covered with opaque woven groundcover (Lumite Inc.) to exclude light. Groundcover was removed from the arms only for root recording and monitoring. Roots were traced using permanent markers on Plexiglas door models. For polycarbonate doors, transparent plastic sheets (20 × 25 cm) were placed on the side of a soil profile for tracing roots.

Stage 2: Designs for drainage systems allowing natural soil profiles and substrate

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