Keeping an Eye on Root Development

A novel way to check out root growth—without disturbing the root system—shows promise for improving propagation success.

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A large portion of the U.S. green industry is involved with growing plants in containers, and so it is important to understand the factors that influence root growth to attain optimal benefits from container production. Several factors that affect root growth include the physical and chemical properties of substrates: Physical properties include porosity and water holding capacity, percentage of fine particles and bulk density; chemical properties include pH, cation exchange capacity and soluble salts. There are several familiar techniques used to measure these factors, but methods used to measure the *whole* root system, or to measure the growth of roots over time, are not as widely available. It is also not well understood how roots change and affect the physical properties of substrates in the container over time.

Until now, the most common root system measurements employed by growers have been subjective root ratings and root dry weight measurements. Root rating, while being nondestructive, is completely subjective; that is to say, it is based upon the perception of the person rating the root system, and this can vary from person to person. On the other hand, root washing is widely accepted as a valid determination of root mass, but it is well understood that a percent of root (particularly fine roots) mass is lost. In fact, researchers have reported that almost 20 to 40 percent of the original root weight is lost during root washing of certain plant species.

A clear vision

An innovative technique for measuring horizontal root growth was developed at Auburn University and Virginia Tech, and it offers a simple, nondestructive means to measure root growth over time. Called the Horhizotron™, the tool is constructed out of eight panels of glass attached to an aluminum base to form four wedge-shaped quadrants. The Horhizotron™ was built to fit a plant removed from a 1- to 3-gallon container and placed in the center so the quadrants extend away from the root ball. This technique is most appropriate for assessing and observing root growth from rootballs likely to exhibit post-transplant root response; it does not allow for observations and study of small plant root development, such as herbaceous plugs and nursery liners.

In order to study root growth of seeds, liners and plugs during production, new techniques need to be developed and evaluated—a task we pursued in the horticulture department at North Carolina State University (NCSU) in Raleigh. The objectives of our study were to design and test a small-scale version of a Horhizotron™ suitable for small plant material, and to design and test the Rhizometer, an *in situ* technique for determining the influence of plant roots on the physical root environment.

The study

Mini Horhizotrons. A small-scale version of a Horhizotron™— a "mini Horhizotron"—was produced with a three-arm configuration suitable for observing root growth of small plant material. The clear arms, similar to the quadrants of the original Horhizotron™, allow for visible access to the roots, and transparent grids can be placed on them to allow measurements to be taken. Potential measurements include root length, speed of root growth, presence and quantity of root hairs, and root branching and architecture. Shade panels were constructed to restrict light from the arm faces (rhizosphere), and three drainage holes were drilled in the bottom of each arm to allow proper drainage.

Three substrates were used in the initial testing of the mini Horhizotron: 70:30 (v/v) peat:perlite, peat:pine-woodchips and peat:shredded-pine-wood. The wood was processed from delimbed loblolly pine trees (*Pinus taeda* L.), harvested in January 2012 and either chipped or shredded, then processed in a hammermill through a 6.35-mm screen. The substrates were mixed and amended with 3.86 kg/m^3 dolomitic limestone on June 1, 2012. Three mini Horhizotrons were filled with each individual substrate the next day, tapped three times to settle substrate and then filled to the top with substrate again. One *Echinacea purpurea* 'Prairie Splendor' plug was planted into the center of each. One mini Horhizotron was considered a replication, because all three arms contained the same substrate. Three substrates times three replications of each substrate made a total of nine mini Horhizotrons.

Above, plugs are readied for planting in rhizometers for growth growth study and comparisons. Left, To construct the Rhizometer, clear, cylindrical Plexiglas tubes were cut, and a collar was attached to the top of the core with parafilm. The collar extension is attached to the top of the core to aid in packing the core; it also allows extra space for planting a plug. A 20-mesh fiberglass screen was cut to fit the bottom of the core and attached with a hose clamp.

Photos courtesy of Brian E. Jackson

Mini Horhizotrons were completely randomized on a greenhouse bench and fertigated with 200 ppm 20-10-20 Peters Professional® water-soluble fertilizer. Root-length measurements (cm) were taken on the three longest roots appearing on the face of each arm on 11, 25 and 39 days after planting (DAP). Each arm has two measurable faces, giving a sum of six arm faces per mini Horhizotron. Measuring three roots per arm face times six arm faces per root box times three root box reps per substrate equals 54 data points. Data were analyzed using Linear Regression ($P \leq 0.05$).

Rhizometers. Physical properties of substrates, including total porosity (TP), container capacity (CC) and air space (AS), can be measured with the NCSU Porometer method. This method uses aluminum 7.6 cm cores to measure physical properties. James Altland and others reported using these aluminum cores to grow nursery crops in pumice to test the changes in

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air space and porosity over time. Based on the work of these authors, we designed an apparatus—called the Rhizometer—to allow for both viewing a growing root system and *in situ* measurement of substrate physical properties.

The Rhizometer is made from a clear cylinder that allows for visible observations for data collection, including root count, root branching and architecture, quantifying root growth, and so on. Clear, cylindrical Plexiglas tubes were cut to the measurement of 7.6 cm tall by 7.6 cm inside diameter to make a core the same dimensions as the aluminum NCSU

Porometer cores, and a 3.8 cm tall by 7.6 cm inside diameter collar is attached to the top of the core with parafilm. The collar extension is attached to the top of the core to aid in packing the core; it also allows extra space for planting a plug. A 20-mesh fiberglass screen was cut to fit the bottom of the core and attached with a hose clamp. Dark-colored foil was used to restrict light and was held in place with rubber bands.

Rhizometers were filled on May 18, 2012, with a 60:20:20 peat:perlite:vermiculite substrate and tapped five times to achieve similar bulk density in every core, mimicking the porometer process. Marigold (*Tagetes erecta* 'Inca Orange') plugs were planted into the packed core, which was then wrapped with foil for light restriction. Ten Rhizometers were harvested at 7, 14, 21 and 28 DAP, with five to be used in the porometer method to determine physical properties and the other five used to determine root mass.

Rhizometers were completely randomized in the greenhouse and fertigated as needed with 200 ppm N 20-10-20 Peters Professional® water-soluble fertilizer. To prepare the Rhizometer for the porometer method, shoots were severed and the collar was removed, revealing 1 to 2 cm of substrate. This substrate and any roots above the 7.6-cm-long core were removed, such that the substrate surface within the core was level with the top of the core. The bottom screen was removed, leaving a level core ready for the porometer method. From the porometer, TP, CC and AS were measured and compared to the root dry mass from every harvest. Data were analyzed using least significant difference ($P \leq 0.05$).

The results

Mini Horhizotrons. In this first plant growth trial using the mini Horhizotron, root growth was easily visible (similar to the original Horhizotron™), and the potential of data collection was possible as was anticipated during the design phase of this apparatus. At 11 and 25 DAP, root growth among the three substrates was similar; however, at 39 DAP, root growth/length was greater in the shredded wood substrate. These data prove the mini Horhizotron can be used to show treatment effects on root growth. Based on this trial experiment, it seems that data can be collected on root growth of small plants in the same manner the large Horhizotron™ is used with large rootballs.

A seedling germinates in the mini Horhizotron (shown left). Root growth is easily visible in the mini horhizotrons when the shade panels are removed; this allows for measurements and study.

Planted Rhizometers are placed on a greenhouse bench and are cloaked with foil wrappers to exclude sunlight during plant growth. Planted mini Horhizotrons can be seen in the background.

Rhizometers. Rhizometer data show that marigold roots have no effect on substrate CC over four weeks (all measurement dates), but that a slight decrease in total porosity does occur. The decrease in TP from 7 to 28 DAP can be attributed to the decrease in AS. The decrease in AS can likely be explained by the increase in root mass over time. As roots grew, it is possible that they filled the pore space, therefore causing a decrease in the substrate air space. These data suggest that even though air space decreases slightly over time, few changes occur to a substrate as a result of marigold root growth. The effect that different species and root types have on changes to physical properties during crop production is unknown and needs further investigation.

What does it mean?

These initial experiments testing the usefulness of two new techniques for assessing and quantifying undisturbed root growth have yielded promising results. The mini Horhizotron has endless potential for studying numerous factors affecting root growth of greenhouse plugs and nursery liners during production. The ability to visualize, observe and measure the growth of small plants in a

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Above, mini Horhizotrons are shown with shade panels in place during the plant growth trial. Right, holly and other woody liners are planted in mini Horhiztrons, with shade panels removed to show the soil profile.

nondestructive way will further expand root growth research and understanding.

Both the mini Horhizotron and Rhizometer offer potential as techniques to study undisturbed root systems—which most importantly includes fine root mass (root hairs)—that is often lost during traditional root washing methodology. Propagators of important ornamental crops can more closely—and more efficiently—observe growth progress in a way that preserves the health and integrity of their plants, leading to greater success in the lab, on the bench and in the market.

Results of this study were originally reported to the meeting of the International Plant Propagator's Society, Southern Region, in Auburn, Ala.

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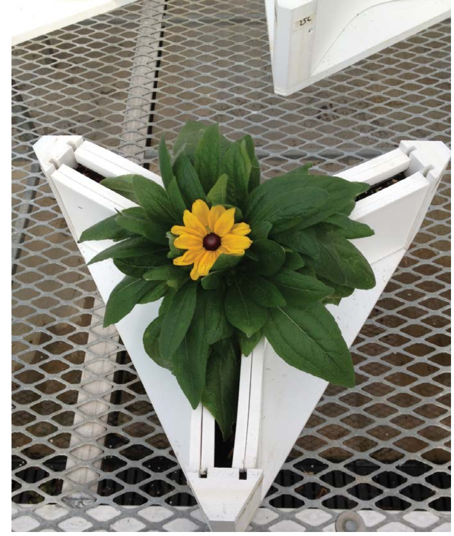
Above, with shade panels removed, root growth of *Rudbeckia* in a mini Horhizotron can be monitored.



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