Belowground management of trees: novel perspectives on imaging

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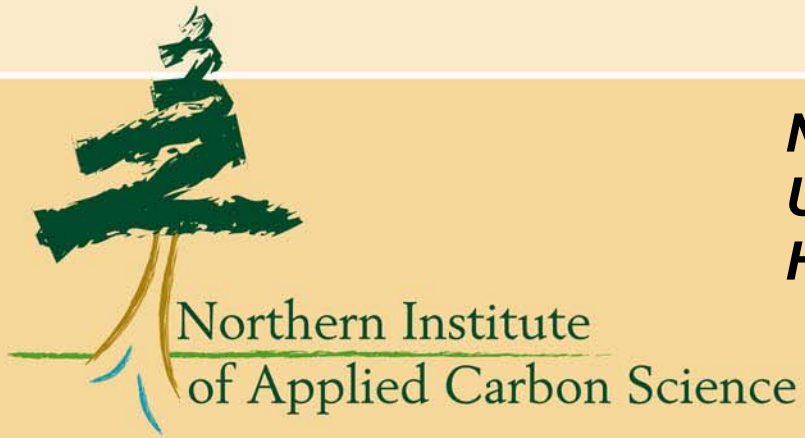

Northern Research Station
U.S. Forest Service
Houghton, Michigan

in partnership with Michigan Technological University and the National Council for Air and Stream Improvement

Purpose

1. Communicate our belowground processes work from the Northern Research Station.
2. Stimulate the increased use of root traits in tree cultural practices and ecosystem management.

A root is not a root!

Characterizing root systems by length or weight misses many features of functional relevance

- Morphology (length per unit weight)
- Symbioses and other soil organismal interactions
- The functional state
- Architecture and arrangement (structure)
- Deployment (depth and location)
- Root-environment interactions
  - Proliferation
  - Rhizosphere interactions: biotic-abiotic
  - Interactions between soil heterogeneity and root form

Outline for presentation

1. Rhizotron basics: justification
2. Rhizotron basics: features
3. Rhizotron data and implications from pilot studies
4. X-ray basics
5. X-ray utility
6. X-ray data and implications from pilot studies
7. Conclusions

Rhizotron basics: justification

Purpose: Improve sustainable forest management by increasing our understanding of belowground processes.

Ongoing lines of inquiry:

- How can we enhance soil **carbon** storage/retention?
- Can forest ecosystem services be enhanced by:
  - Understanding spatially explicit responses of roots to their environment, including biological interactions.
  - Understanding the functional differences among various root types
  - Focusing on the specific functions of mycorrhizae in effecting root-soil interactions.

Rhizotron basics: physical setting

Built, Fall 2005, in Houghton, Michigan to view the root systems from an existing Northern Hardwoods stand

Rhizotron basics: interior

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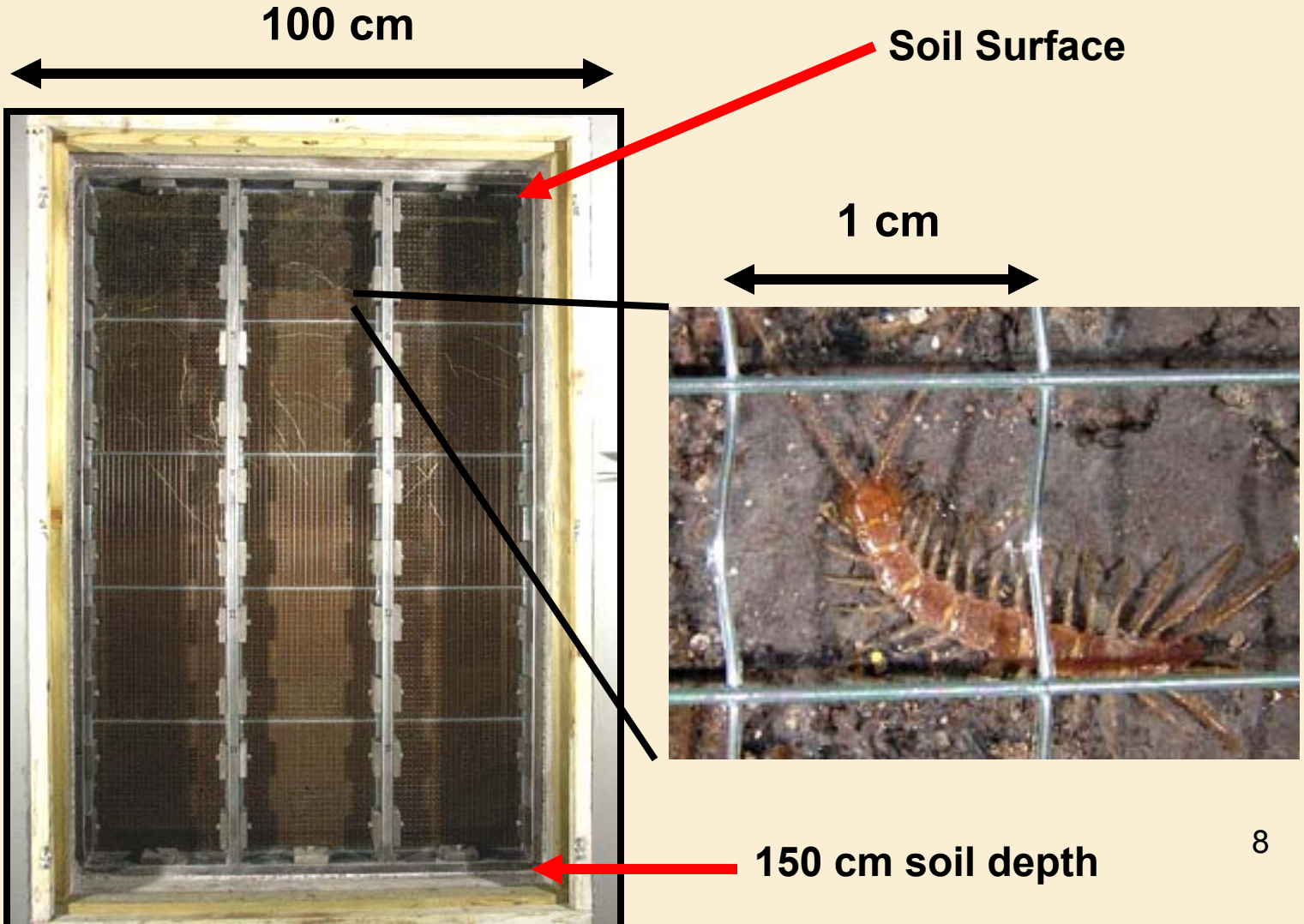
Rhizotron basics: window detail

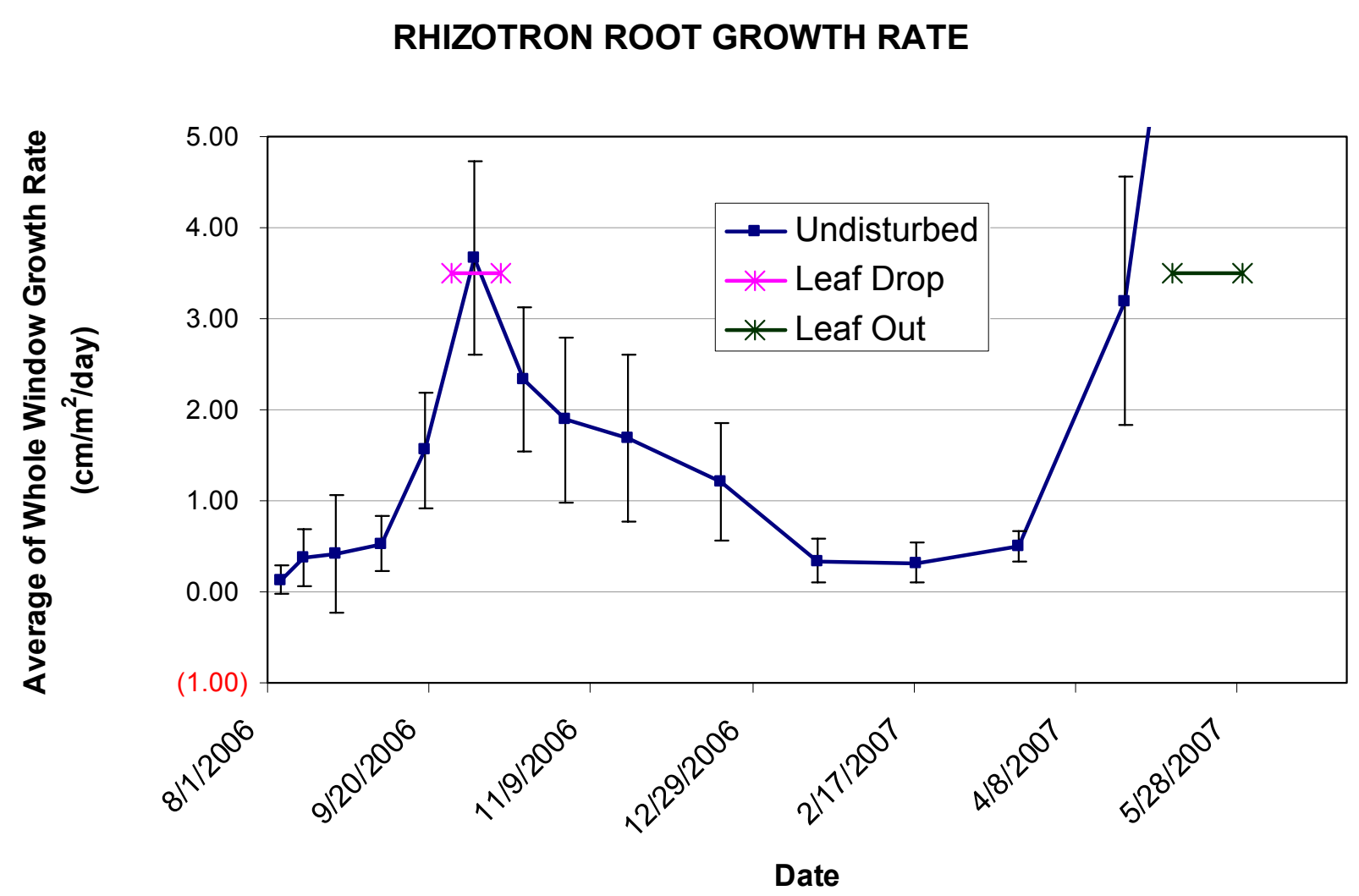


Rhizotron data: Winter root growth

Synopsis of methods and results

- Line intersect method
- 12 windows on intact forest side
- Monitored biweekly in growing season, monthly in winter
- Despite leaf drop, root growth continued
- Greatest rate 20-60 cm depth

Rhizotron data: Winter root growth



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Winter root growth summary

Roots were active despite leaf-drop and snow pack

Soil was not frozen

Similar findings to those of Hendrick and Pregitzer (1996) J. Ecol. 84:167-176.

Of interest is understanding which roots grow and which do not grow (architectural precision)

Also of interest is a refined understanding of spatial/temporal dynamics

Understanding which roots grow when will improve precision in modeling root nutrient availability/acqusition.

Time lapse IR photography system

Attributes

- Above and belowground imaging
- “web cam” concept; to be on www

Purpose

- Improved temporal precision
- US Forest Service R&D mission to provide reliable inventory and monitoring information on forests.
- Ecological research tool
- Public resource and information
- Educational resource

Each belowground IR camera is housed in a rigid steel box. The window is insulated around the box.

Images are collected every ½ hour and stored on an in-house server, accessible via the internet.

Cameras are aimed at the upper soil layers where the majority of soil activity occurs.

6 outdoor cameras record aboveground information to correlate with belowground activity.

Time lapse infrared photography

Continuous recording of shoot and root images

..\The worms crawl in the worms crawl out.mov

Rhizotron visualization summary

The previous image used 1 hour increments, smaller increments will allow even greater understanding of soil faunal activity.

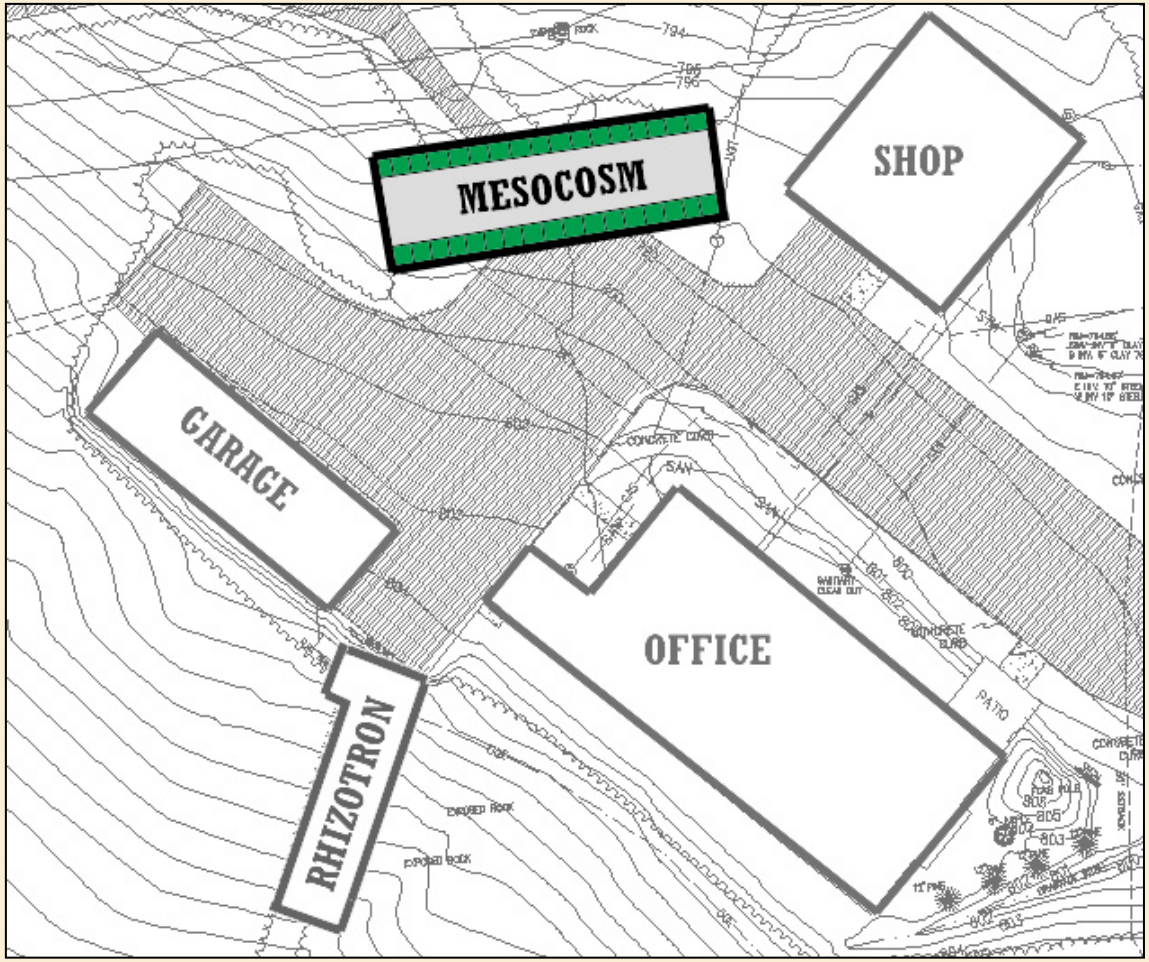
This tool will allow us to understand diurnal, seasonal, and spatial variations in feeding by root herbivores.

We will also study above and belowground phenology and phenological synchrony

Mesocosm studies

Purpose:
The Mesocosm will reproduce a natural system, but allow for replicated and controlled tests of the effects of different soils, trees, and soil organisms on ecosystem function. These tests will involve a high-level of micromanipulation, observation, analysis that would otherwise be infeasible in a natural setting.

Companion facility: Mesocosm



- Total facility length: 96 feet
- Total facility width: 28 feet
- 24 stainless steel bins
- Bins lowered in and out of belowground laboratory
- 1 m3 of soil per bin
- Planted trees grow at ground level
- Bins accesible from belowground
- Soil visible through window in bin
- Sample ports to collect water from soil
- Tubes for root imaging
- Soil temperature and moisture sensors
- Located near Forest Service lab, companion facility (Rhizotron), and Michigan Technological University
- Construction 2008

X-Ray basics: justification

X-ray-based plant root visualization system

Purpose: low-energy x-ray imagery to identify and evaluate plant root system development.

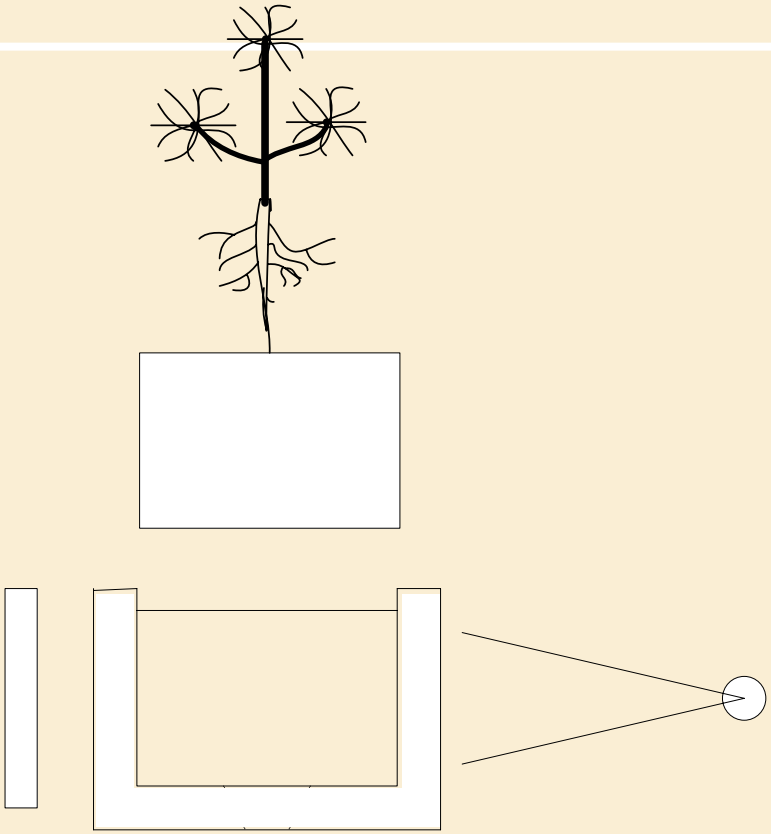
System is non invasive and non-destructive,

Advantage: images have more 3-D information than rhizotrons, which are 2-D.

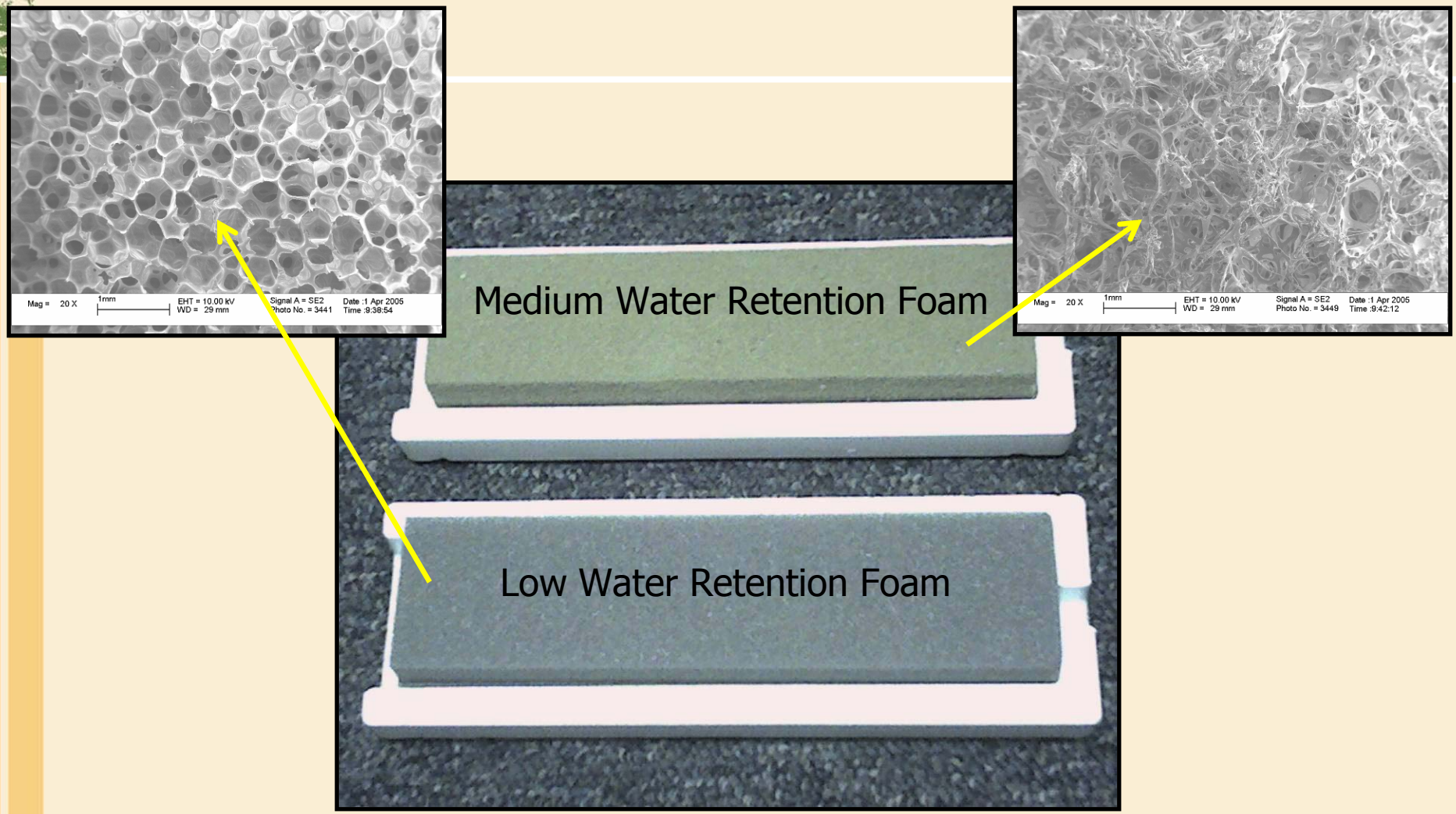
Application: small container size, roots grown in artificial medium

http://www.phenotypescreening.com

Stock Slide of System

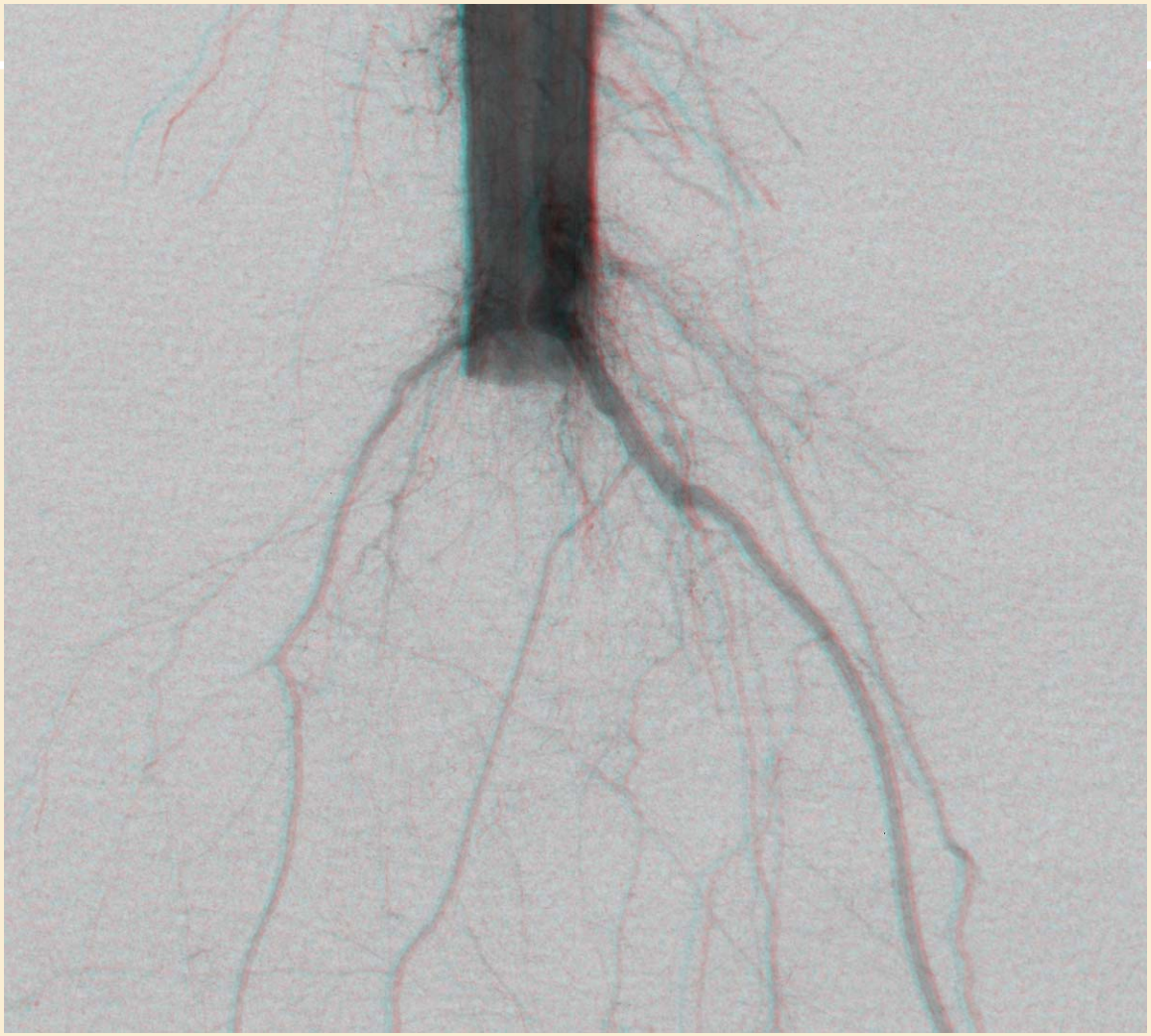


Substrate is Matched to Application



Data generated in collaboration with:
Dr Roberto Benson, Dept Materials Science & Engineering
University of Tennessee, Knoxville, TN

Stock Slide of Image in 3-D



Willow *(Salix eriochephala)* Rooting from Cutting

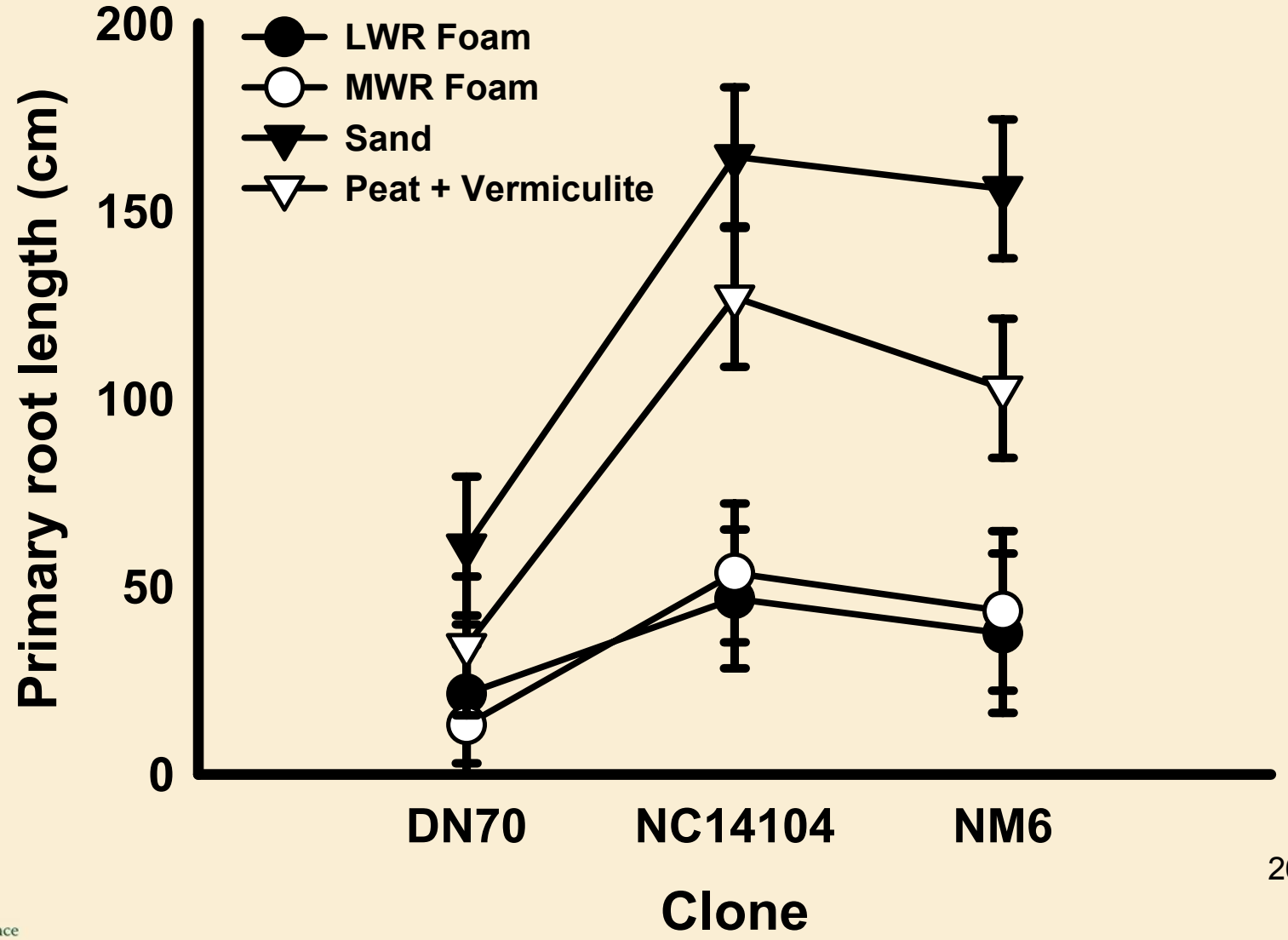
Populus pilot study

Objective

- Compare root and shoot properties of plants grown in two soil media with the those grown in the artificial foam used for imagery.

Root Development

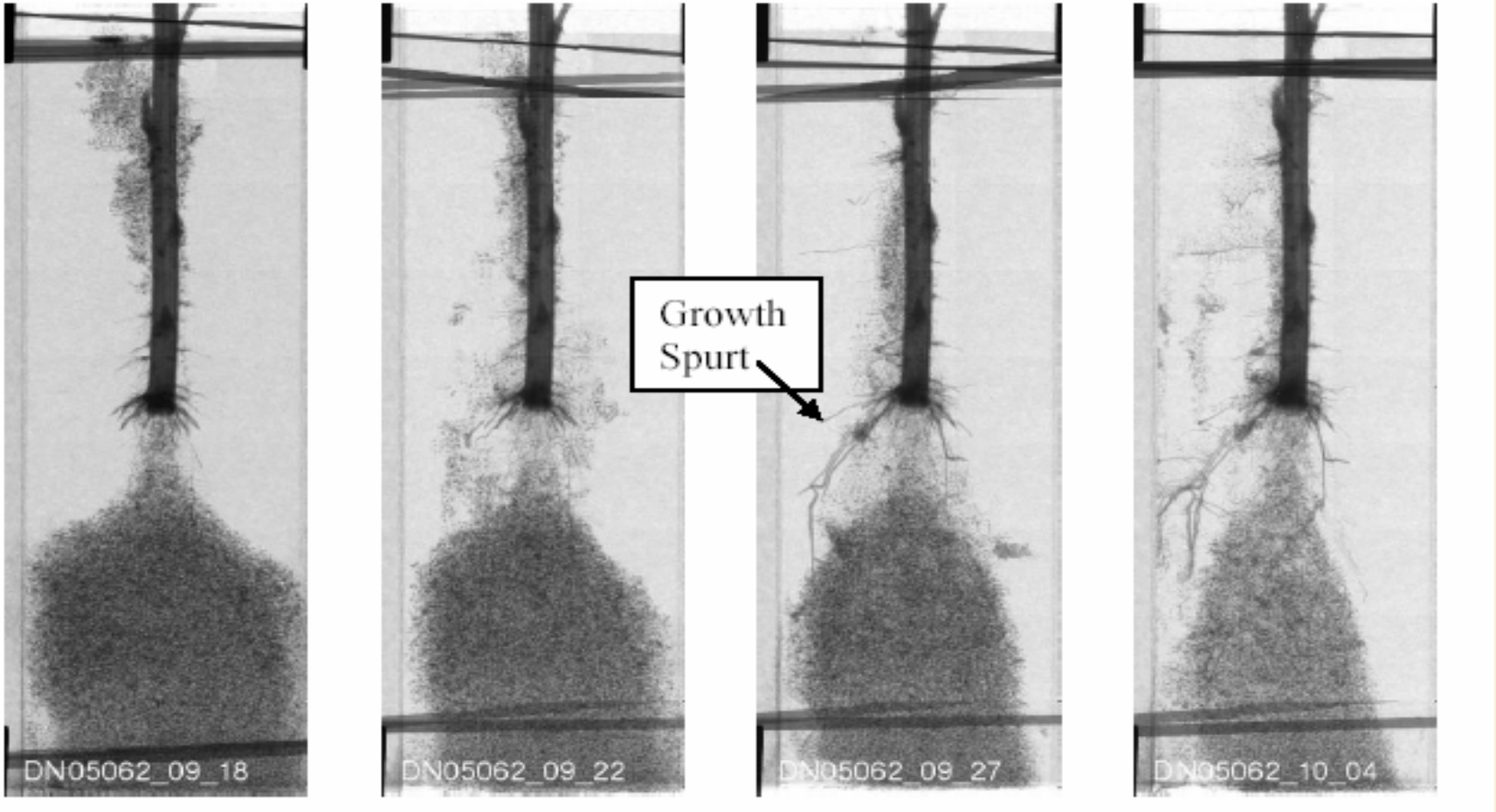
Populus study results



Populus study results

- The synthetic foam substrate supported growth of Populus cuttings of normal morphology
- Absolute growth of roots was less in foam than in sand or peat/vermiculite; however, clonal rankings were similar.

X-ray images of Populus rooting



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X-ray summary

- The x-ray imaging technique previously applied to crop plants was successfully applied to trees.
- The technique offers great potential in rapidly screening plant material for developmental and architectural traits.
- Though roots grew less in the synthetic foam medium, the expression of traits was similar to soil-like media.
- The next challenge is to evaluate the relevance of early traits to field performance.

Come to Houghton and the UP!

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