
Toppling and Root Development in Container Seedlings
Tom Starkey
Southern Forest Nursery Management Cooperative
School of Forestry & Wildlife Sciences
Auburn University

Outline

- Occurrences of toppling
- A review of factors affecting toppling
- What happens with container tap roots
- Loblolly pine plexiglass box study
- Longleaf pine plexiglass box study

Tree *toppling* is a term used to define instability in young stands: trees are not completely windthrown, but lean at various angles and continue to grow.

G.F. Dykstra 1975
Tree Planters' Notes 25:21-22

Reports of Toppling

Species	Year	Hurricane
Loblolly (SC)	1989	Hugo
Longleaf (AL)	1995	Opal
Loblolly (NC)	1998	Bonnie
Longleaf (NC)	1999	Floyd
Loblolly (NC)	1999	Floyd
Loblolly (NC)	1999	Floyd
Longleaf (LA)	2002	Lili
Longleaf & Loblolly pine (GA)	2004	Winds >45 mph
Longleaf (AL)	2004	Ivan ?
Longleaf & Slash (LA)	2005	Rita & Katrina
Longleaf (AL) (425 acres)	2015	???????

Reports of Toppling

Species	Year	Hurricane
Loblolly (SC)	1989	Hugo
Longleaf (AL)	1995	Opal
Loblolly (NC)	1998	Bonnie
Longleaf (NC)	1999	Floyd
Loblolly (NC)	1999	Floyd
Loblolly (NC)	1999	Floyd
Longleaf (LA)	2002	Lili
Longleaf & Loblolly pine (GA)	2004	Winds >45 mph
Longleaf (AL)	2004	Ivan ?
Longleaf & Slash (LA)	2005	Rita & Katrina
Longleaf (AL) (425 acres)	2015	???????

Reports of Toppling

Species		Year	Hurricane
Loblolly (SC)	Bareroot	1989	Hugo
Longleaf (AL)	Container	1995	Opal
Loblolly (NC)	Container	1998	Bonnie
Longleaf (NC)	Container	1999	Floyd
Loblolly (NC)	Container	1999	Floyd
Loblolly (NC)	Container	1999	Floyd
Longleaf (LA)	Container	2002	Lili
Longleaf & Loblolly pine (GA)	Container	2004	Winds >45 mph
Longleaf (AL)	????????	2004	Ivan ?
Longleaf & Slash (LA)	Container	2005	Rita & Katrina
Longleaf (AL) (425 acres)	Container	2015	???????

Factors that may attribute to toppling

Wind effects on juvenile trees: a review with special reference to toppling of radiata pine growing in New Zealand

J. R. MOORE[1]*, J. D. TOMBLESON[2], J. A. TURNER[3], AND M. VAN DER COLFF[3]

[1]Centre for Timber Engineering, Napier University, Merchiston Campus, 10 Colinton Road, Edinburgh EH10 5DT, UK
[2]Scans NZ Ltd, Rotorua, New Zealand
[3]Scion, Rotorua, New Zealand
*Corresponding author. E-mail: j.moore@napier.ac.uk

2008 http://forestry.oxfordjournals.org/cgi/content/full/cpn023v2

Factors that may attribute to toppling

- Site Factors
  - Degree of wind exposure
    - Worse with wind turbulence and channeling
  - Soil texture & consistency
    - *Clay vs sand determine the formation and spread of roots as they develop*
  - Fertility
    - Worse on fertile soils
    - Worse with trees that grow rapidly the 1st two years (root:shoot ratio out of balance)

Factors that may attribute to toppling

- Genotype
  - Lodgepole Pine
    - Worse on faster growing coastal provenances
  - Radiata Pine
    - Less toppling with genotypes having prominent taproot development.

Factors that may attribute to toppling

- Soil Cultivation & Planting Practices
  - Most tree stock (in NZ) planted by hand.
  - Worse when planters are paid by number of trees planted/day.
  - Ripping and bedding better than disc cultivated due to greater taproot development in fractured subsoil.
  - *Planting deep may reduce toppling.*
  - The impact of weed control has not been tested experimentally.

Factors that may attribute to toppling

- Stock type
  - Seldom a problem with direct seeding
  - Bareroot toppling a problem in NZ - due to frequent lateral and taproot pruning
  - Container subject to toppling
    - Sweden – worse with small container volume, small drainage hole, no container ribs
    - Halter et al. (1993), 15% of the containerized seedlings had a basal sweep and/or indications of toppling. Most striking was the lack of deep roots
  - Rooted cuttings from older hedges had stiffer root system and more open top – less toppling

Why Container Trees?

- The tap root of container trees becomes air pruned within first 2 months in nursery
- Over growing season the callus that forms grows larger
- After outplanting the callus on some seedlings never forms a new tap root

Points to Ponder…….

- It is unrealistic to think that all container trees will develop a “normal” tap root after out planting. A certain percentage of container trees will not develop a taproot.
- Seedlings grown on the outside container edge of a bench system may not develop normal lateral root system.
- There is a similar occurrence with rooted cuttings. Not all cuttings that form a callus will grow roots.

Root Growth Morphology of Container Loblolly & Longleaf Pine

Tom Starkey
Southern Forest Nursery Management Cooperative
Auburn University

Study Disclaimer

A Few Brief Facts

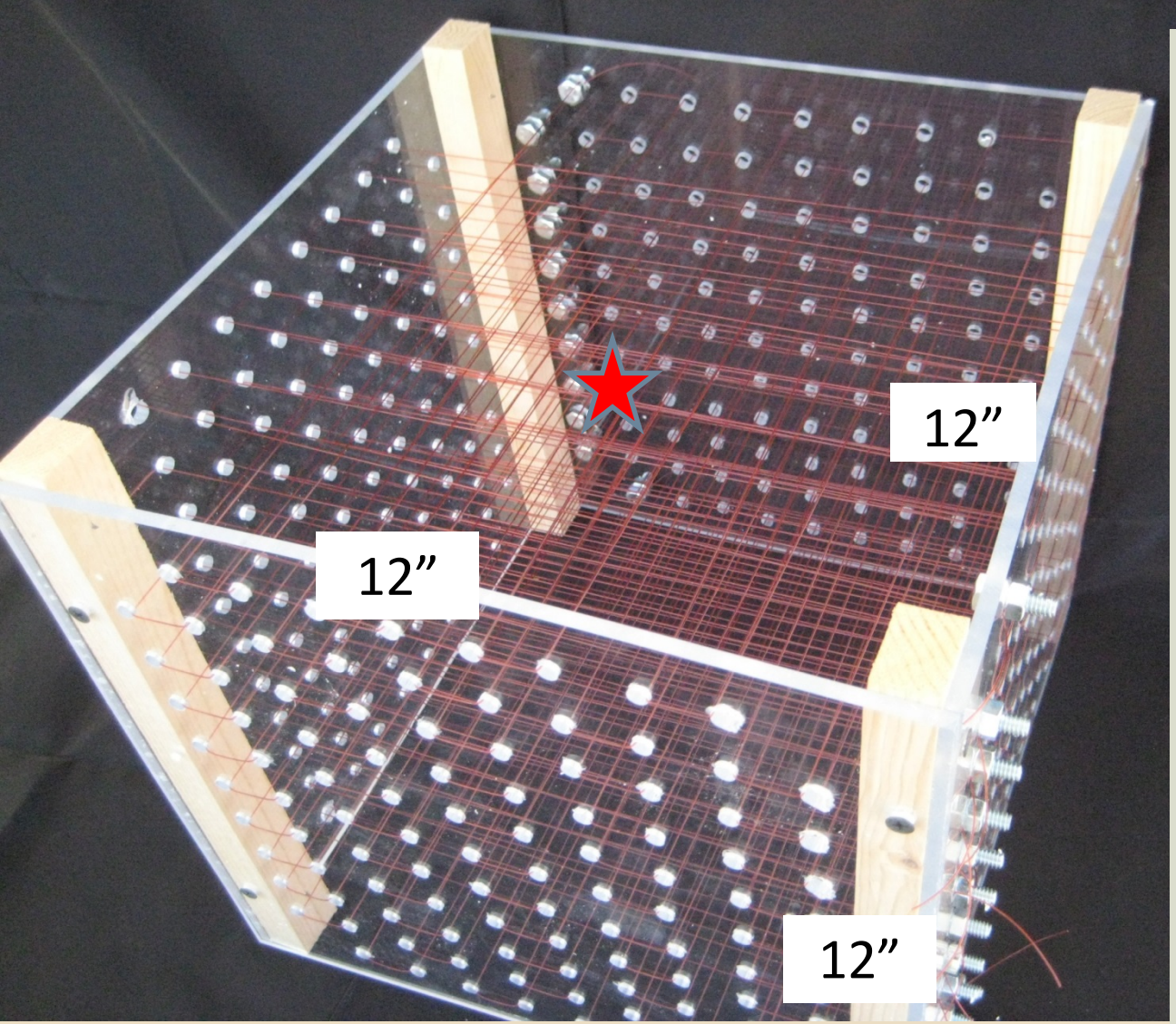
- Production: Over 1 billion seedlings are grown in the southern US for reforestation every year. (80% of US production)
- Stock Type: 80 % bareroot, 20% container
- Containers: Over 80% of container seedlings are grown in a hard plastic container
- Pine Species: 95% of all longleaf are grown in containers, 10% of all loblolly are grown in containers

Container Specifications

	C1	C2	C4	C5	C6	C7
Species Evaluated	Lob & LL	Lob & LL	LL	LL	Lob & LL	Lob & LL
Seedling/sq foot	49.4	51.7	52.0	52.0	54.0	50.0
Cavity Diameter (in)	1.40	1.50	1.55	1.55	1.50	1.40
Cavity Length (in)	5.9	4.7	5.3	6.0	5.0	6.0
Cavity Volume (ml)	108	110	110	131	113	100
Cavities/tray	115	128	128	128	135	112
Chemical root pruning?	Yes	No	No	No	No	No
Side root pruning holes?	No	Yes	Yes	No	No	Yes
# root pruning holes	0	8	4	0	0	3

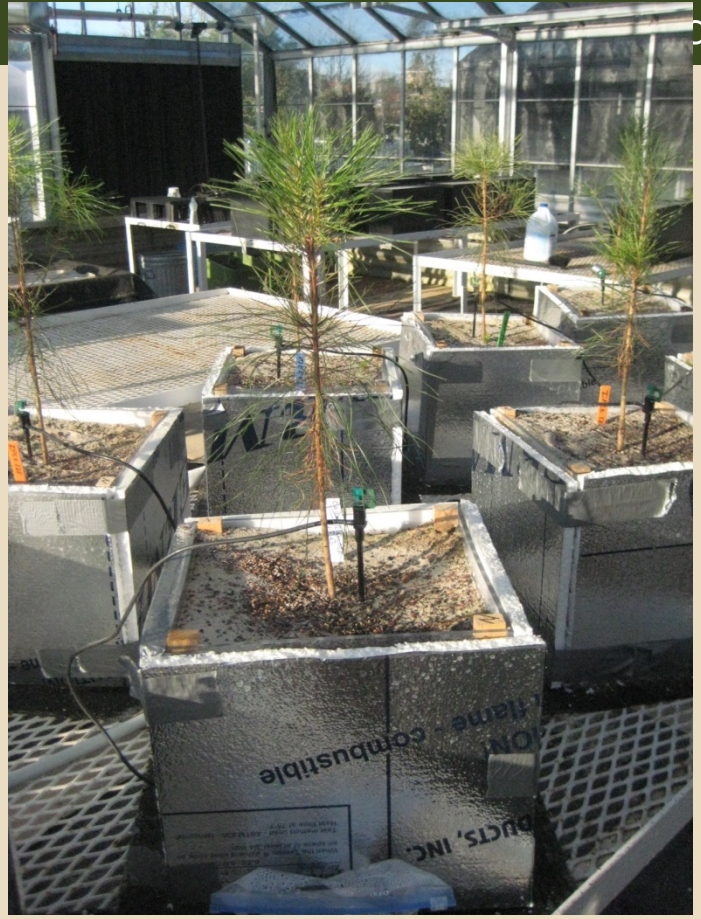
Generalized Study Outline

- Seeds of loblolly and longleaf pine sown in each container on April 1, 2013 (Loblolly) and April 1, 2014 (Longleaf).
- Same media and growing conditions used for all trays.
- In early Nov, 2013 and 2014 1 seedling from each container set placed in box and filled with sand mix. Loblolly replicated 4 times, Longleaf replicated 5 times.
- After 5 months, sand was dropped out of the bottom of the box leaving the seedling suspended. Roots growing out of the plug that were >1/2”were counted, weighed and root architecture studied.

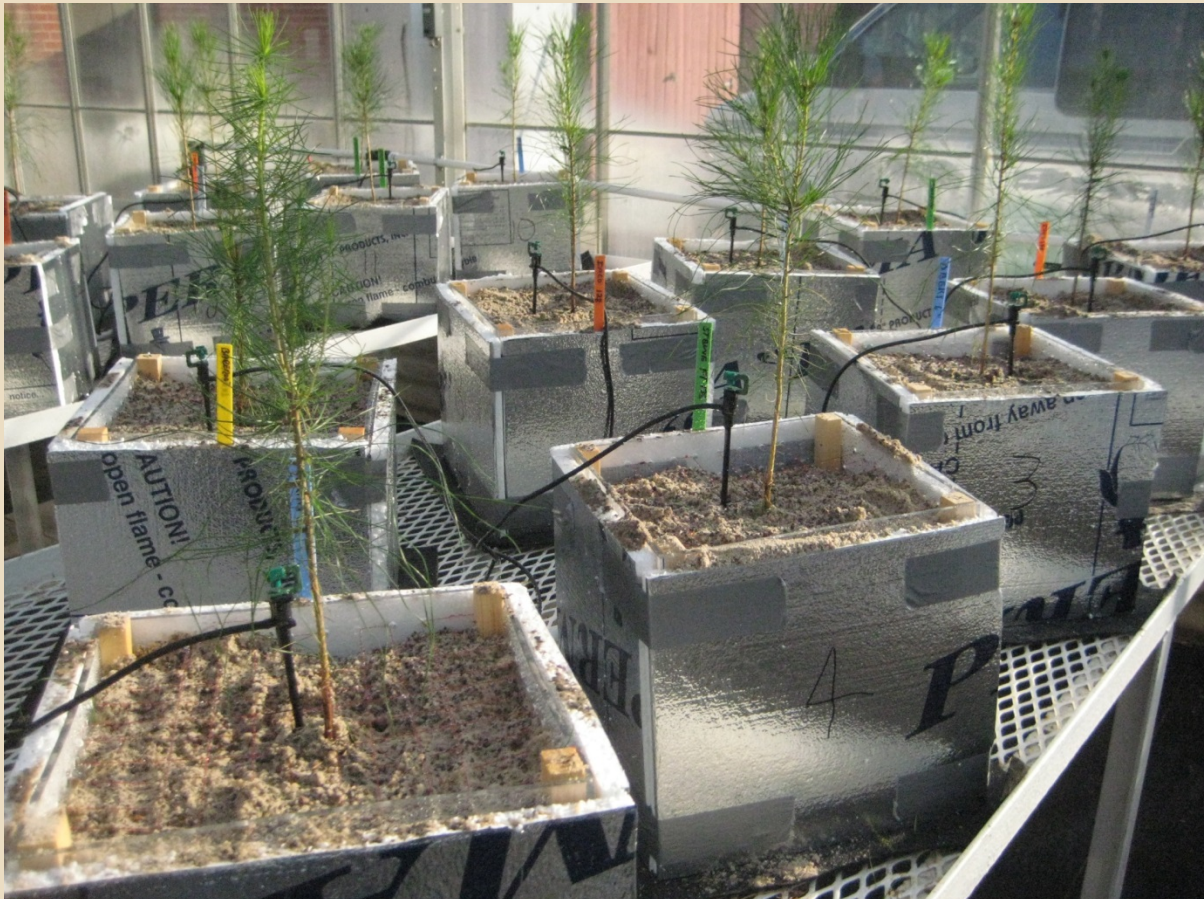


- 1 cubic foot
- Nylon line strung on 1” grid
- Filled with sand, finely crushed brick
- Box sat on horticultural ground cloth
- 1” insulation sheet covered all sides
- One seedling planted in center of each box
- Irrigated and fertilized as needed

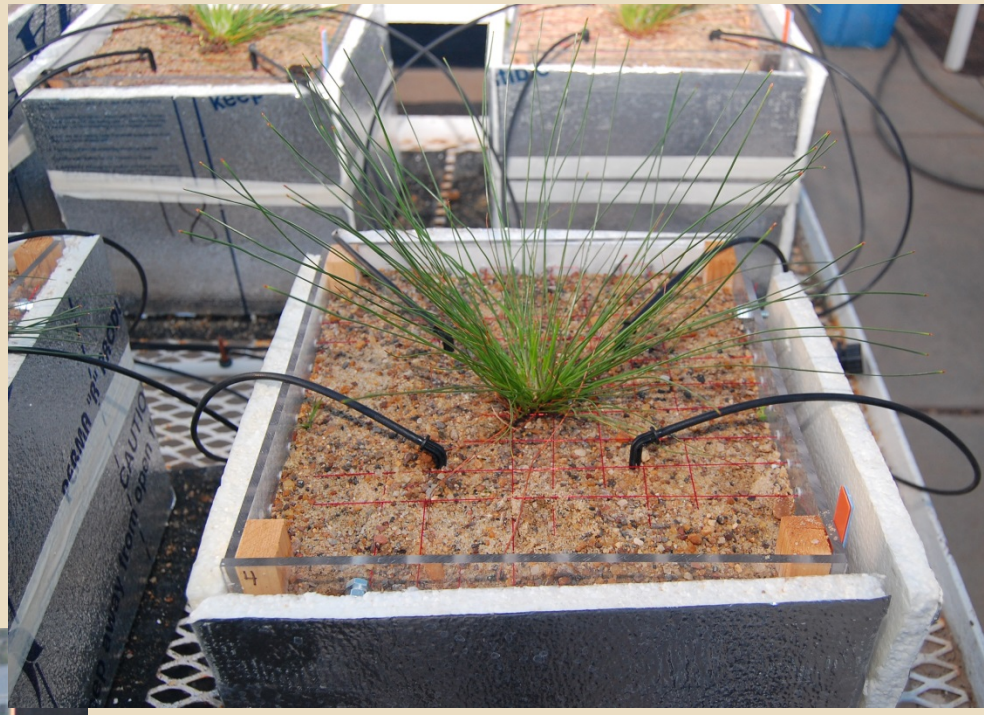
Cooperative

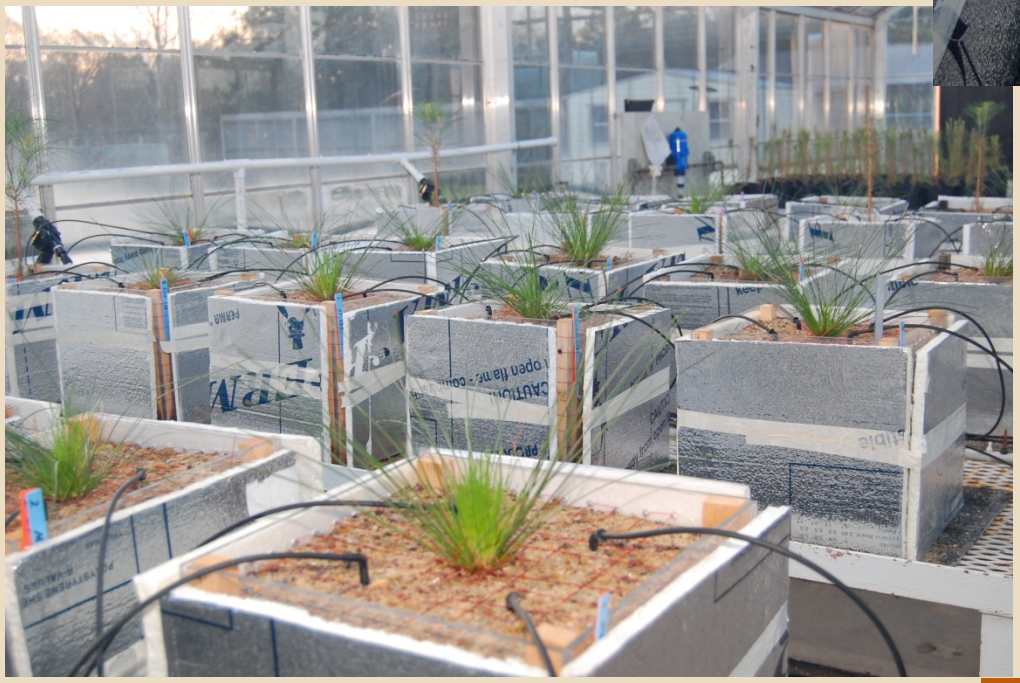


Loblolly Pine 2013



Longleaf Pine 2014



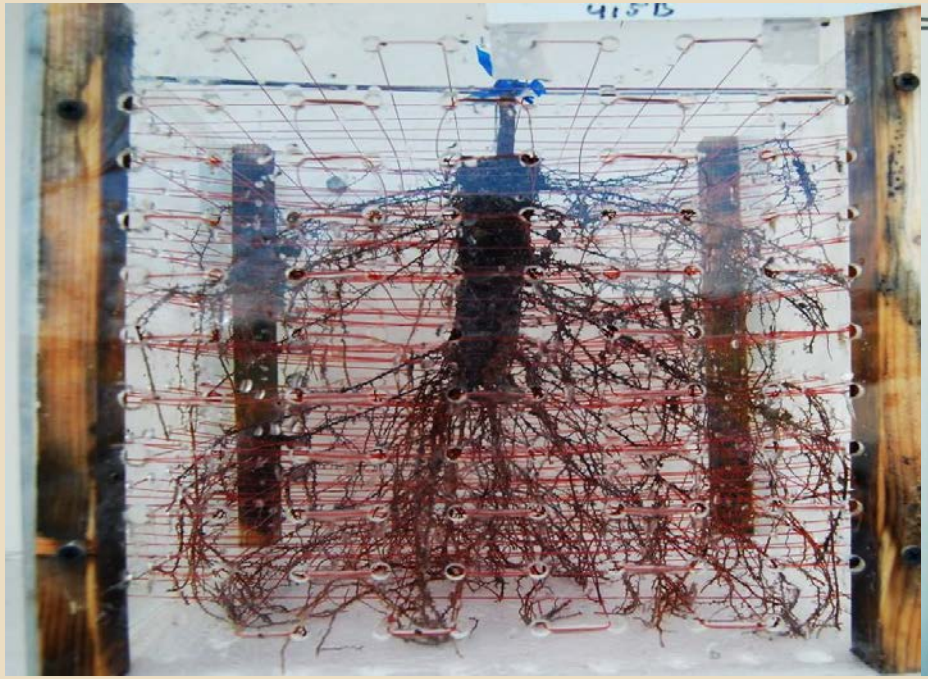


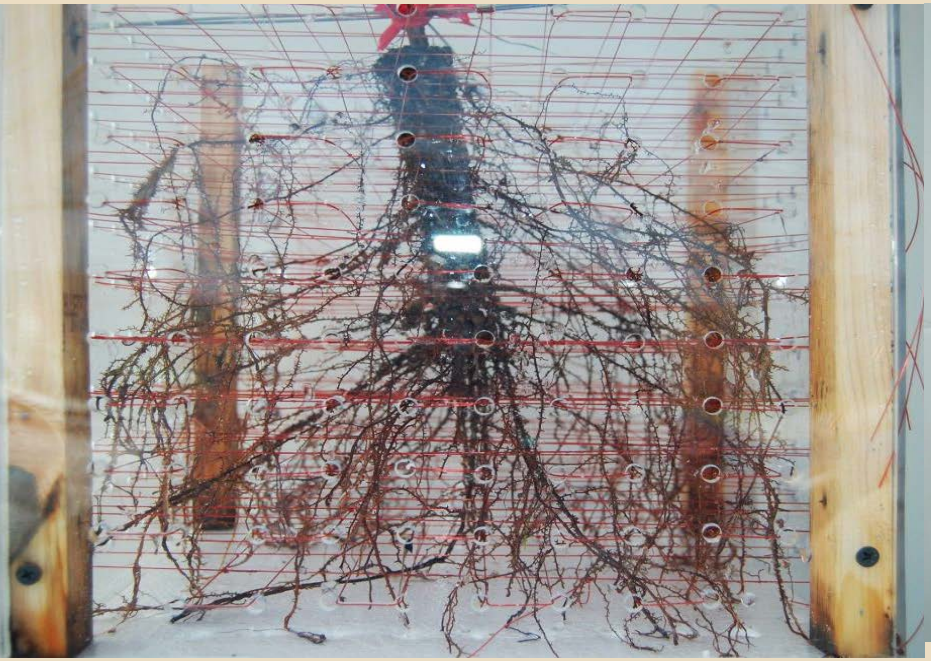
Loblolly Root Morphology

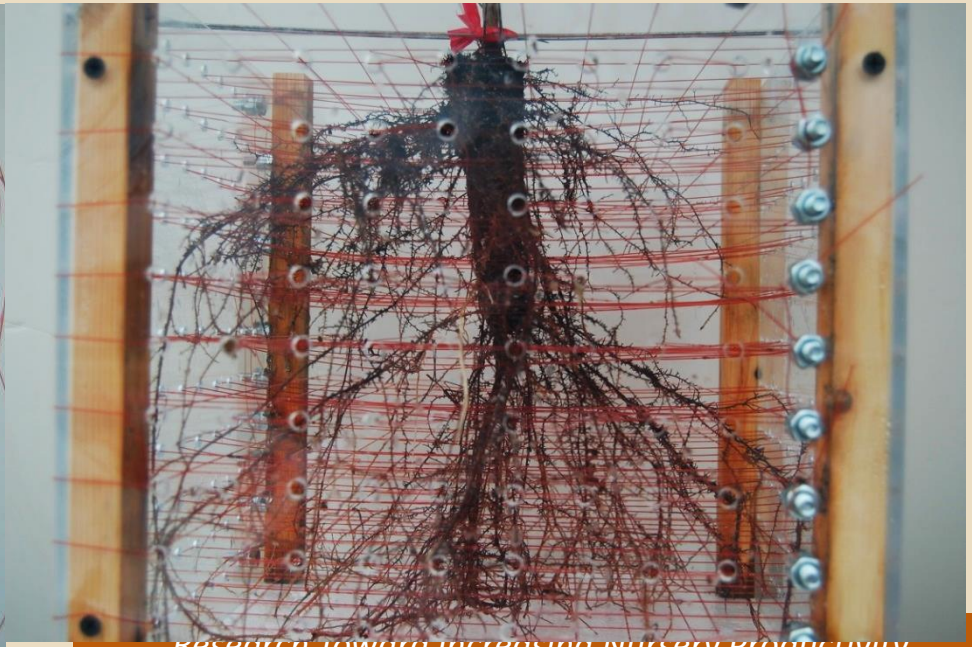
Container Specifications for Loblolly study

	C1	C2	C6	C7
Seedling/sq foot	49.4	51.7	54.0	50.0
Cavity Diameter (in)	1.40	1.50	1.50	1.40
Cavity Length (in)	5.9	4.7	5.0	6.0
Cavity Volume (ml)	108	110	113	100
Cavities/tray	115	128	135	112
Chemical root pruning?	Yes	No	No	No
Side root pruning holes?	No	Yes	No	Yes
# root pruning holes	0	8	0	3

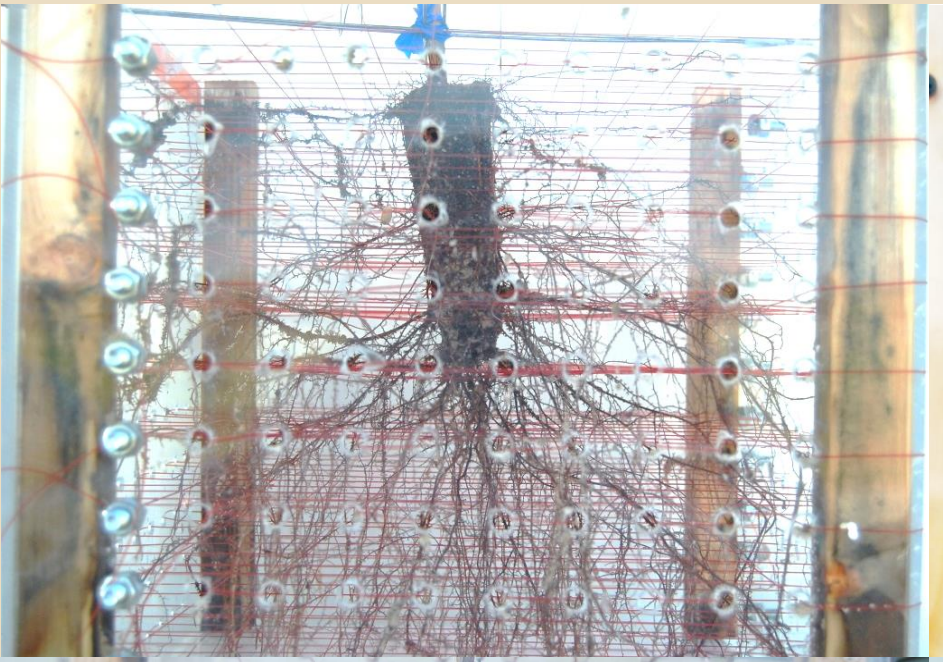
Container C1

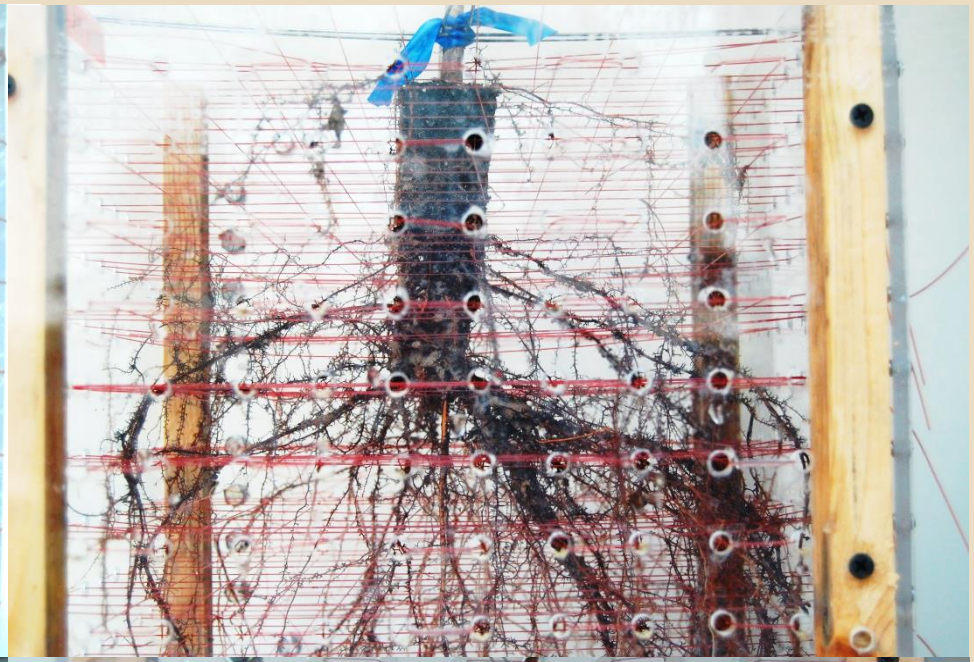


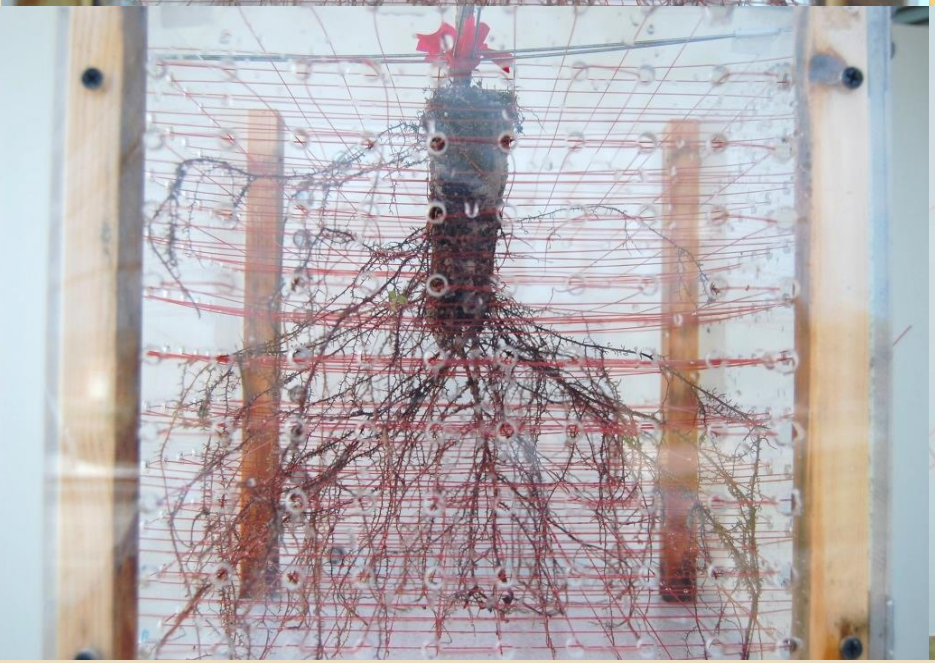


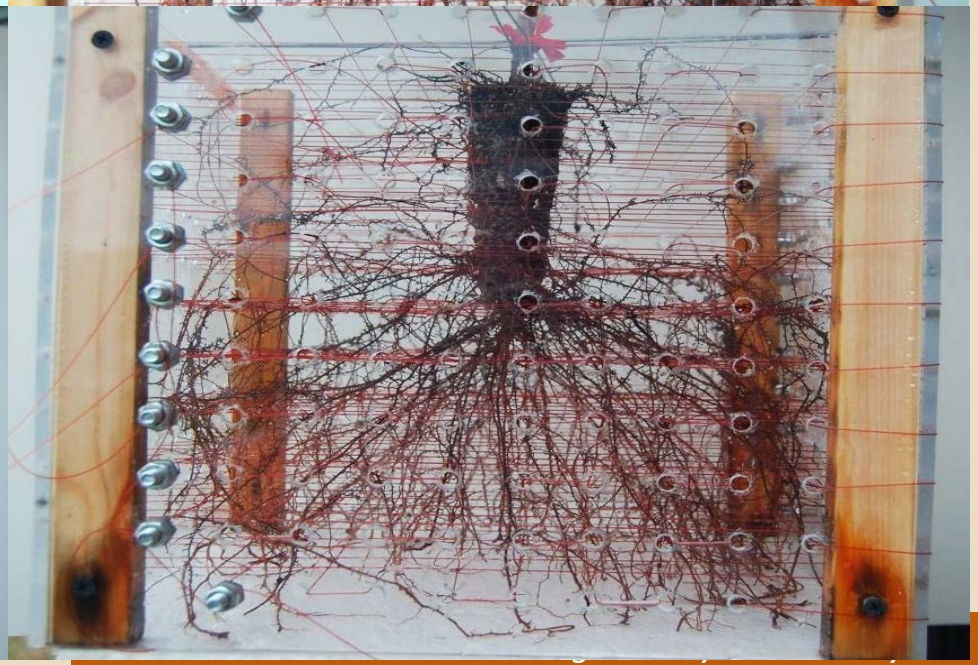


Container C2

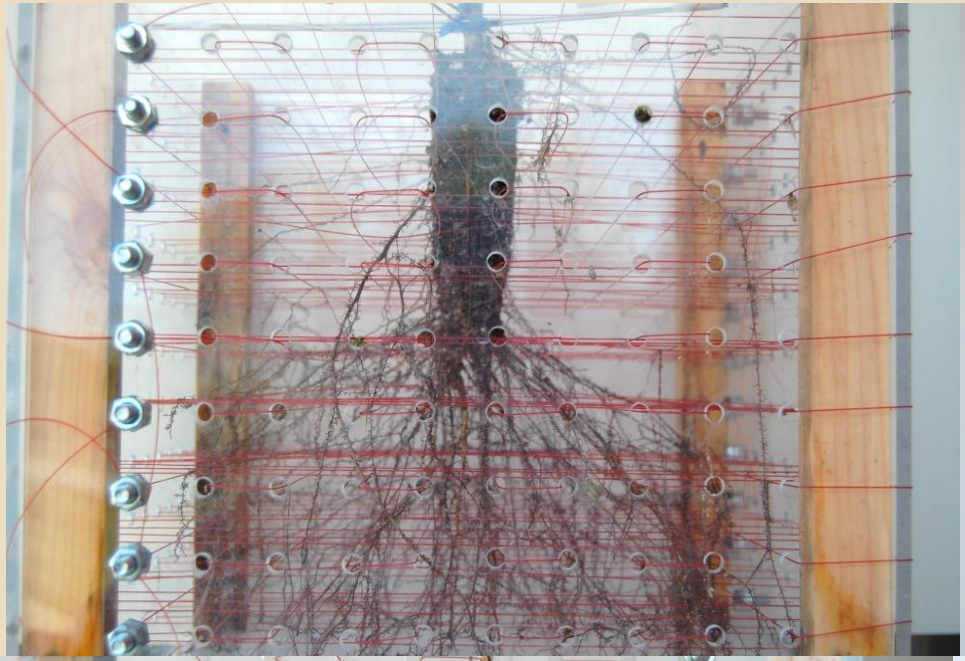


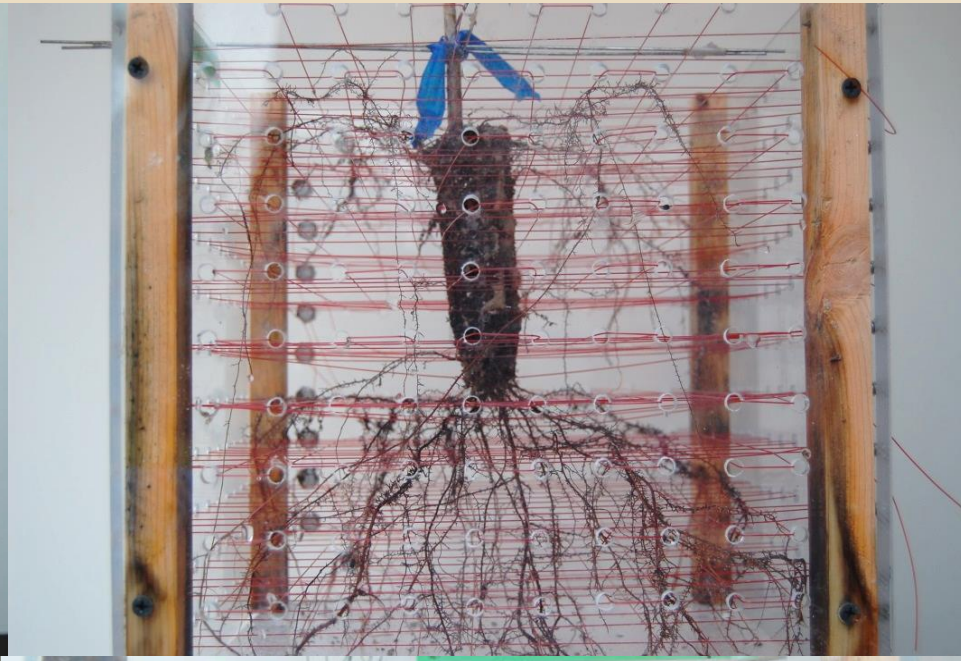


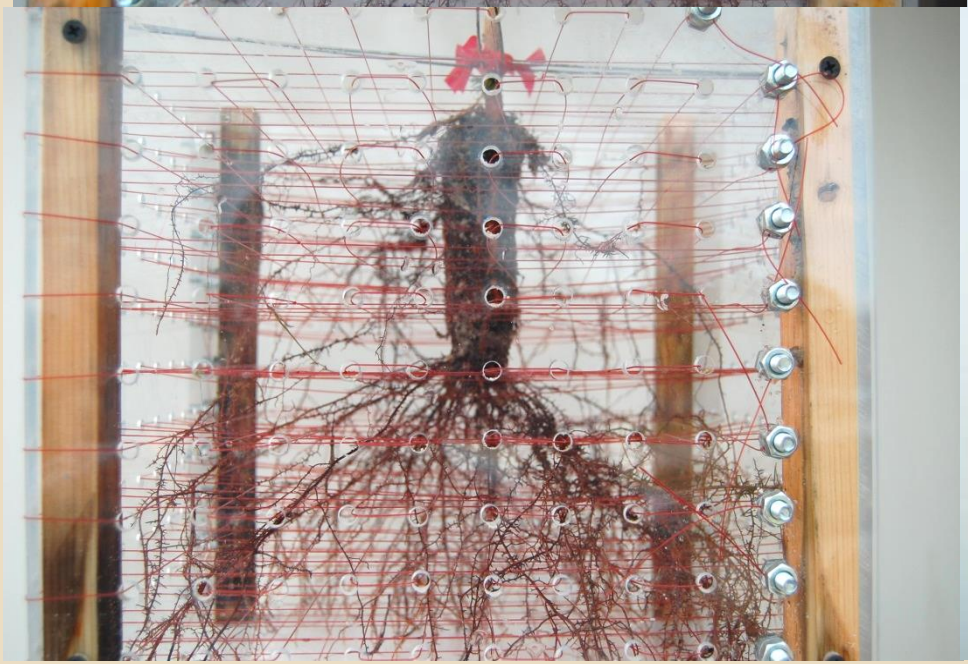


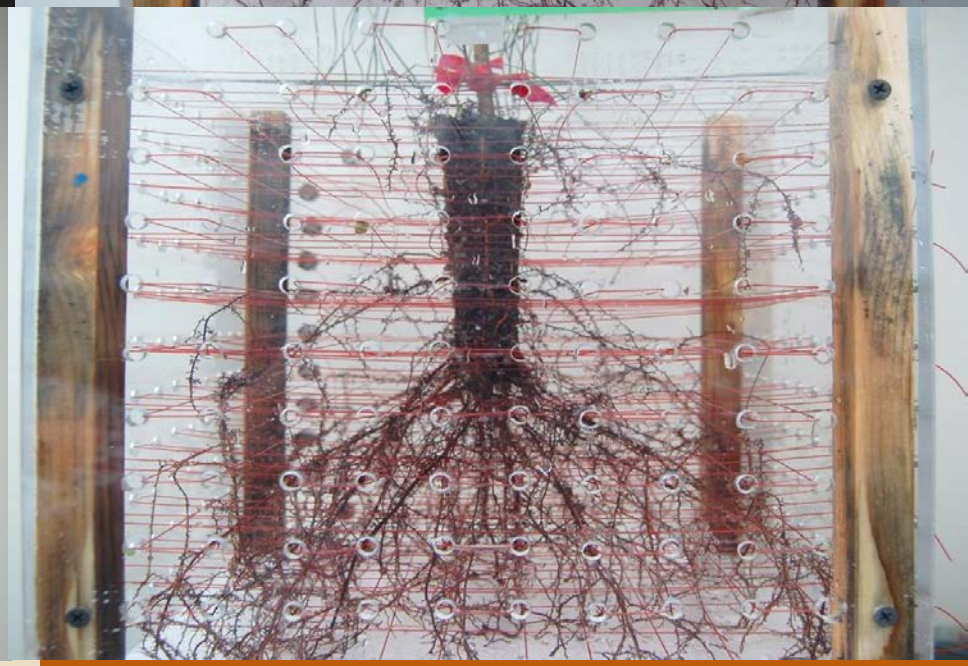


Container C6

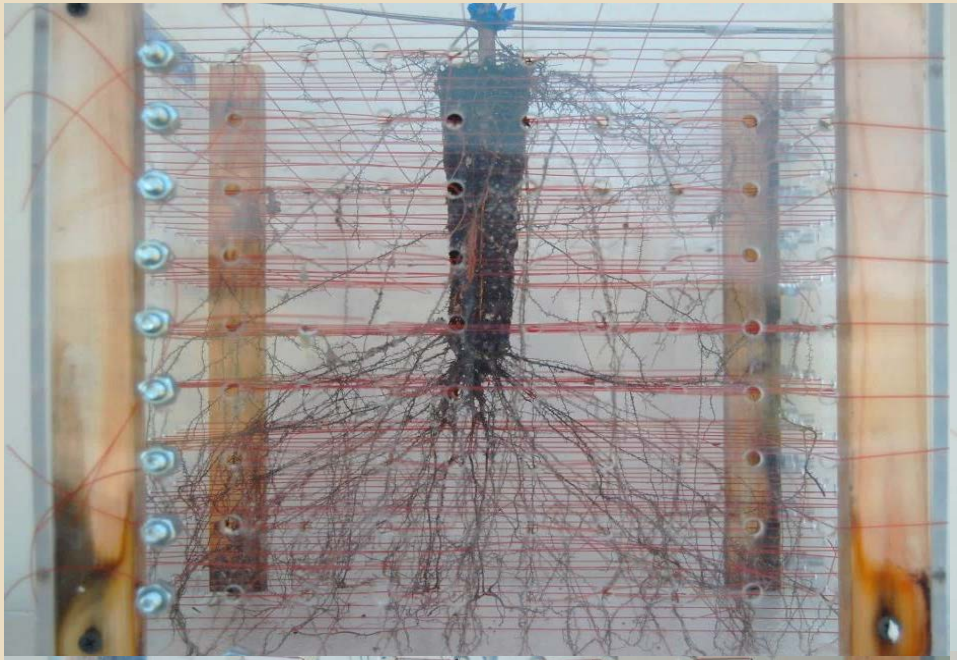


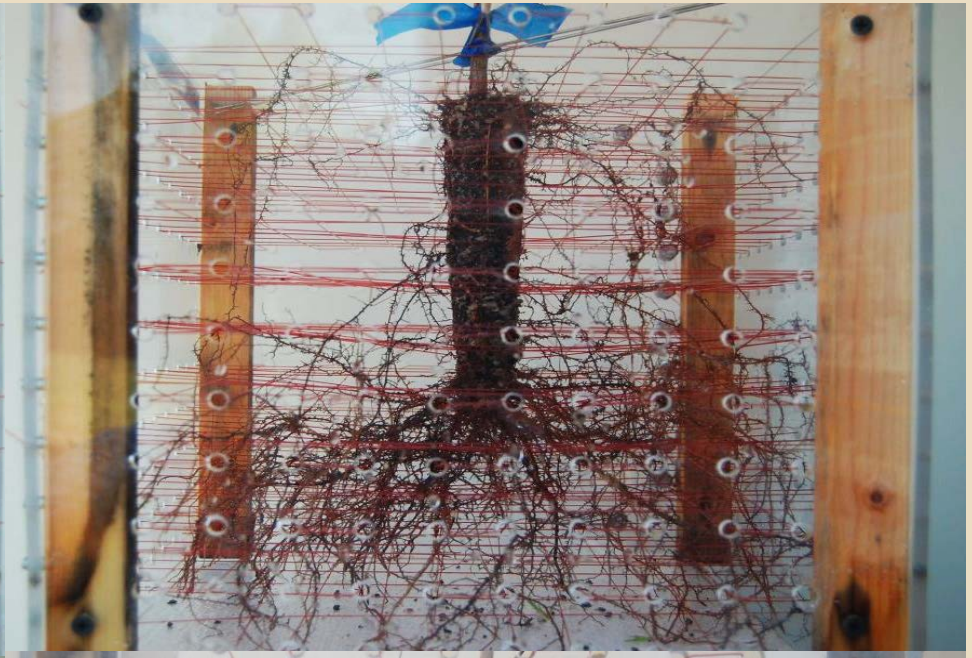


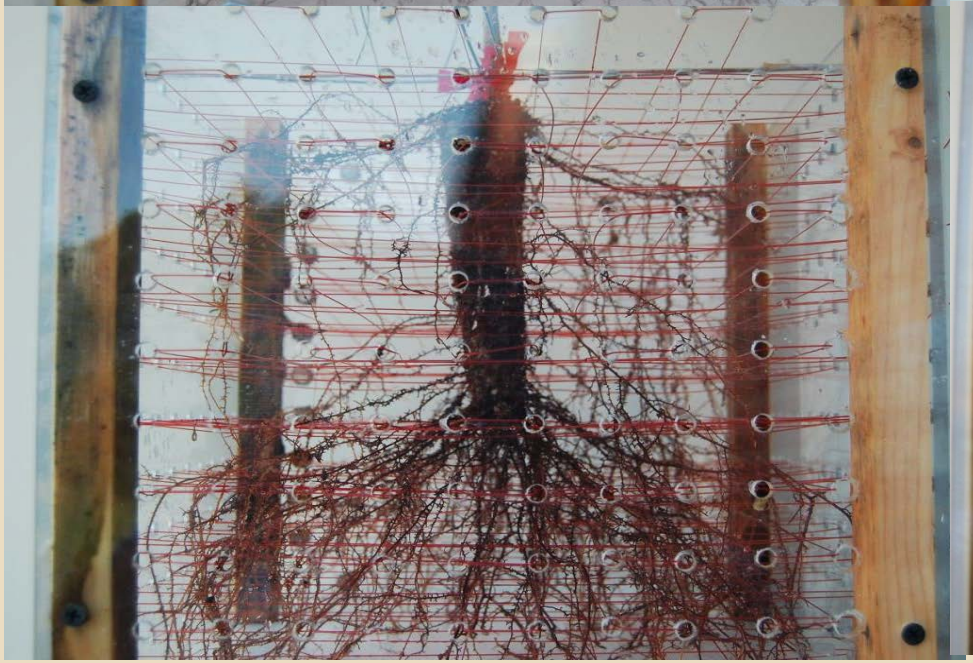


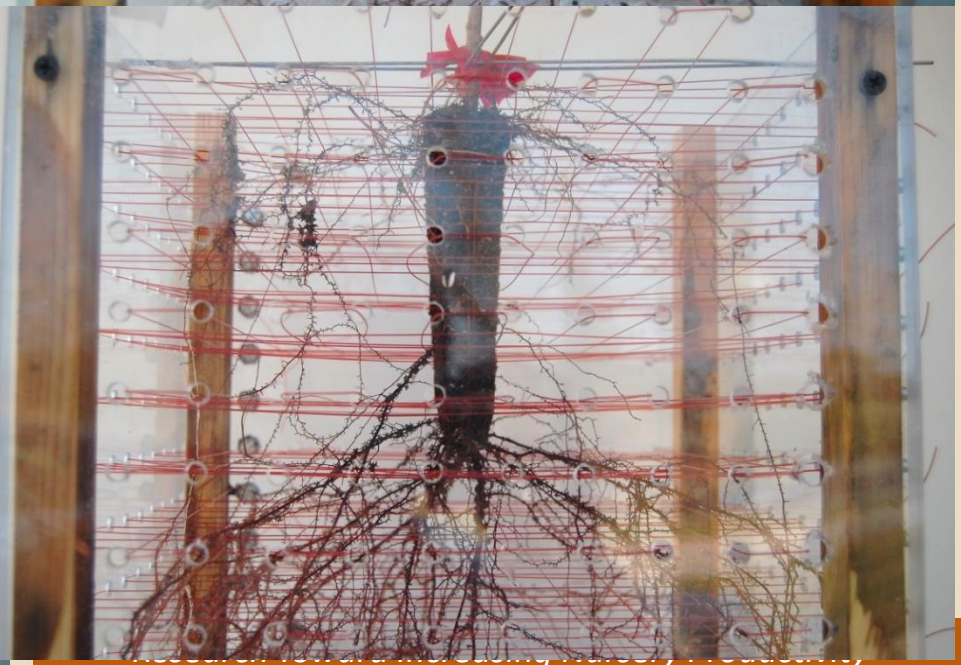


Container C7







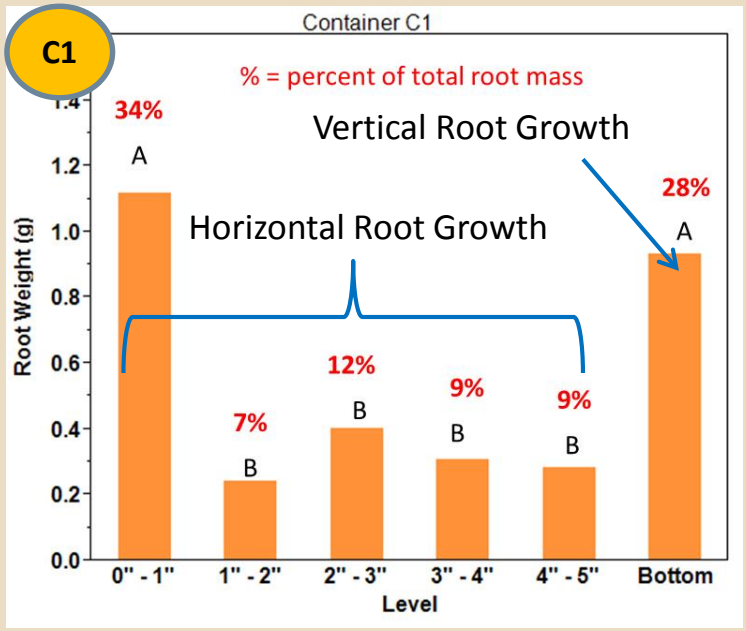


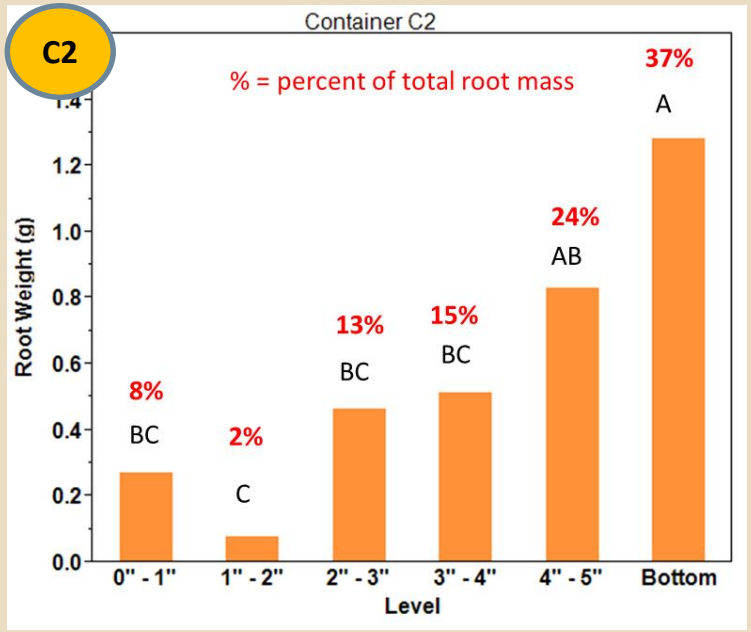
Average number of roots and root weight (plus taproot) after 5 months - Loblolly

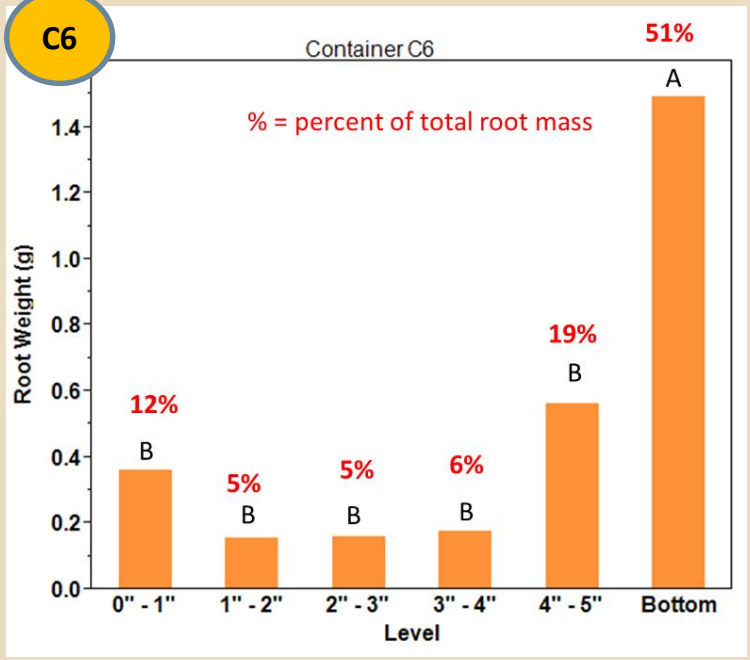
Container	Average total number of roots	Average weight of roots (g) (Total)
Bareroot	20	3.5
C1	64	6.1
C2	82	7.7
C6	71	6.3
C7*	82	5.3

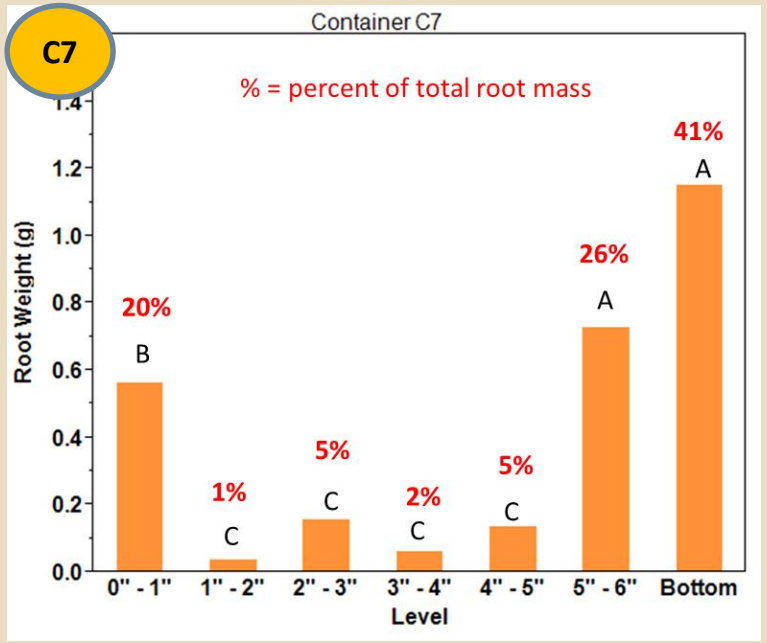
* 1 extra level of plug

Loblolly Pine



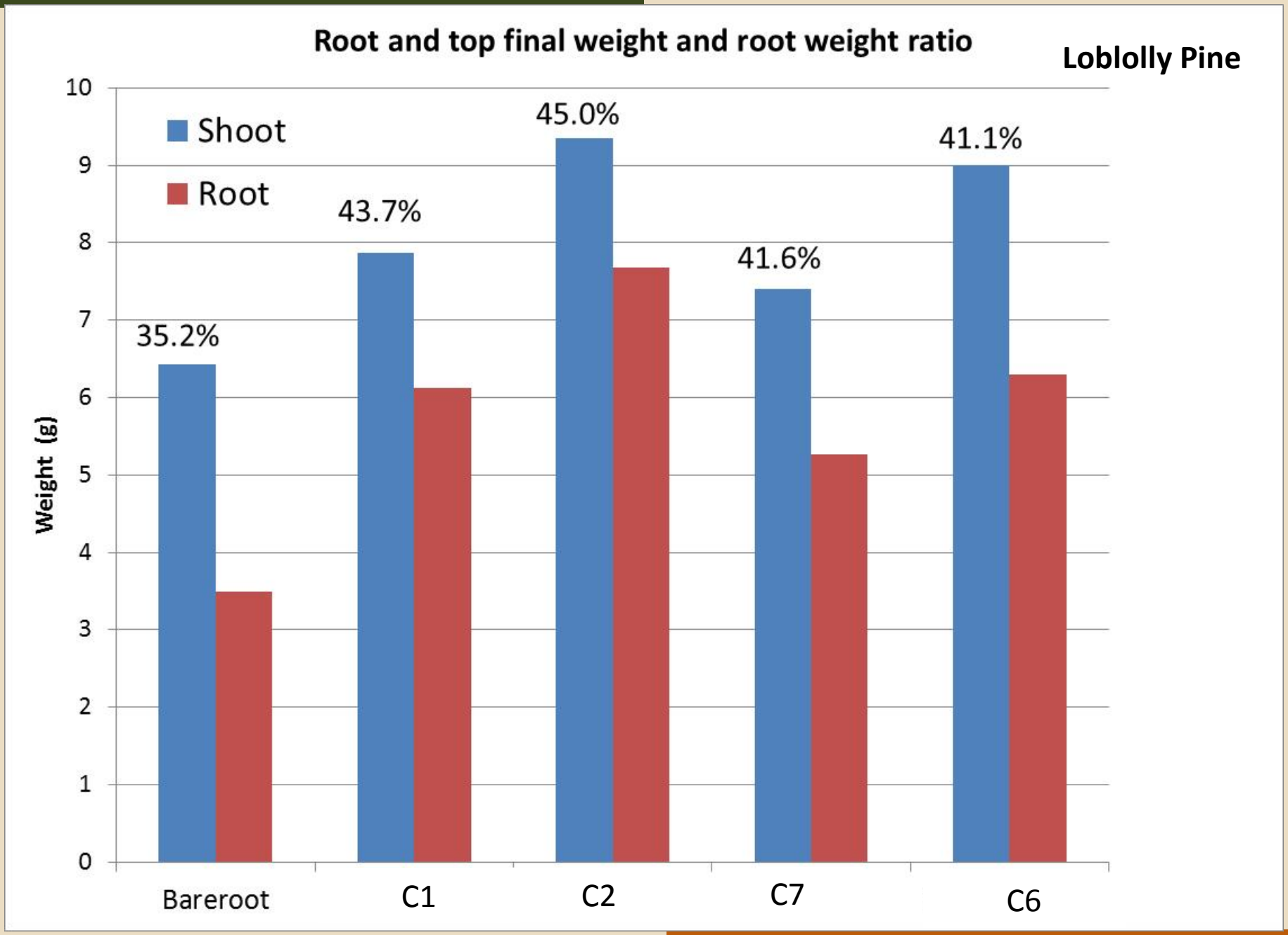






Where are the first 50% of the loblolly pine roots?

Level	C1	C2	C6	Level	C7
0-1"				0-1"	
1"-2"				1"-2"	
2"-3"				2"-3"	
3"-4"				3"-4"	
4"-5"				4"-5"	
Bottom				5"-6"	
				Bottom	

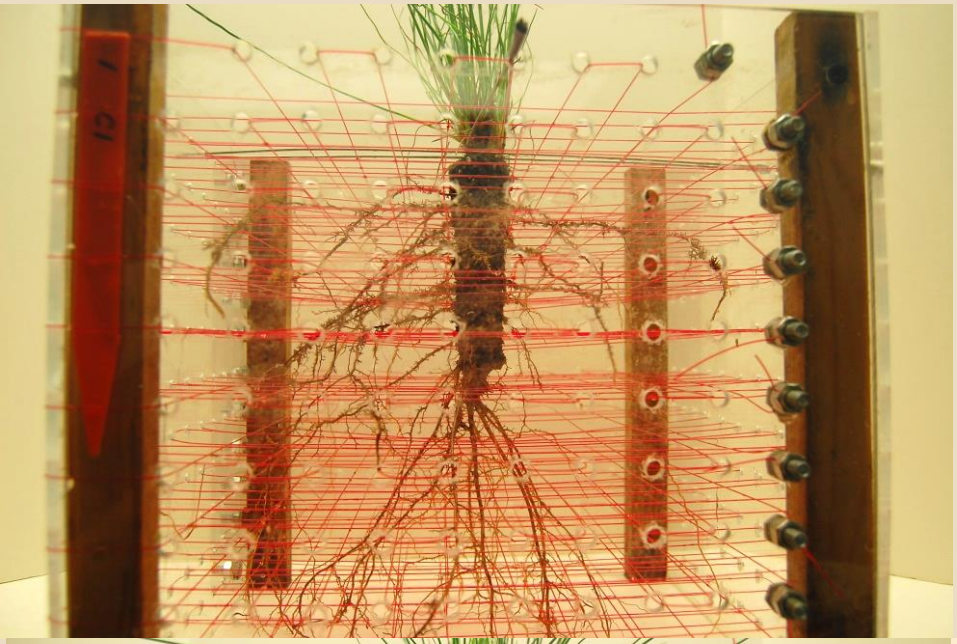

Root and top final weight and root weight ratio
Loblolly Pine
Shoot
Root
Weight (g)
10
9
8
7
6
5
4
3
2
1
0
35.2%
43.7%
45.0%
41.6%
41.1%
Bareroot
C1
C2
C7
C6

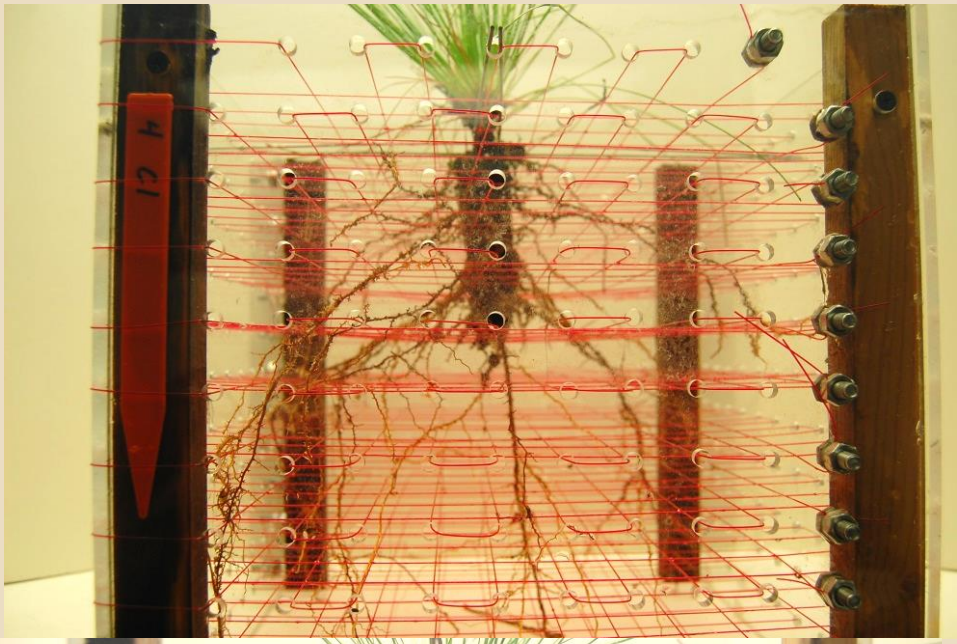
Longleaf Root Morphology

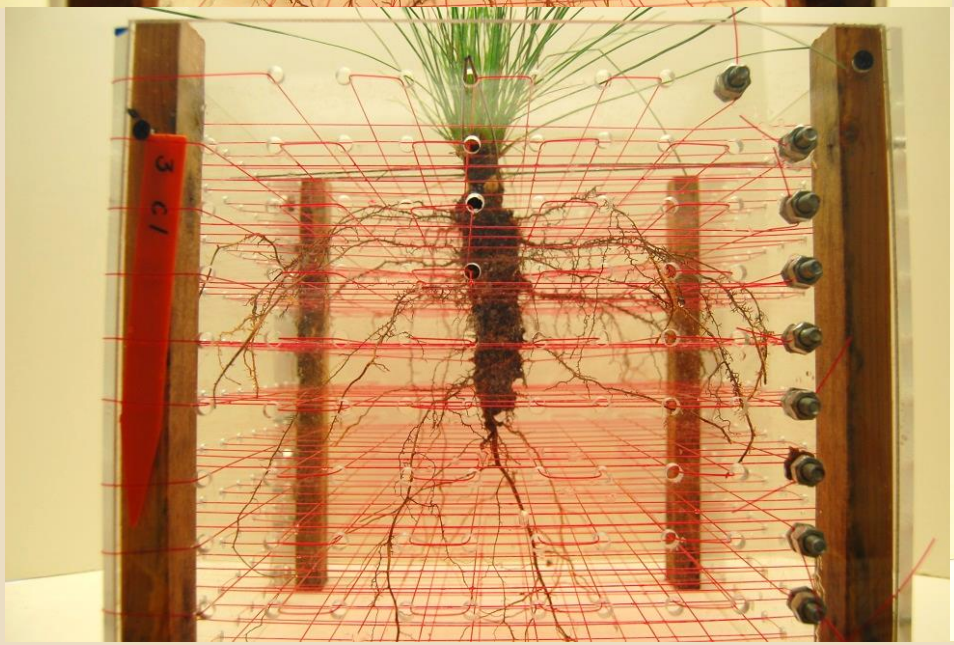
Container Specifications for Longleaf Study

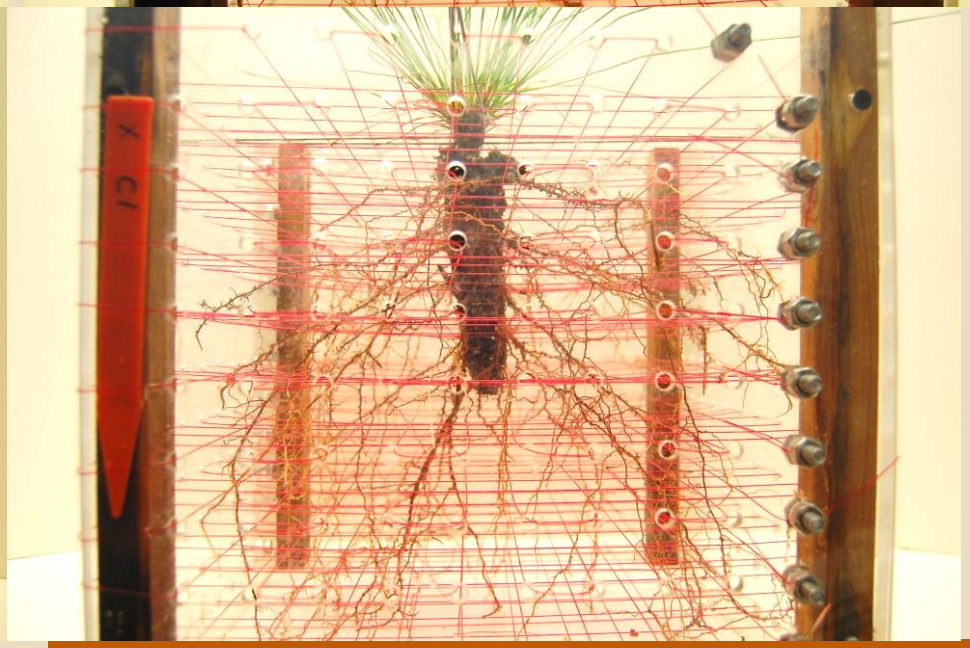
	C1	C2	C4	C5	C6	C7
Seedling/sq foot	49.4	51.7	52.0	52.0	54.0	50.0
Cavity Diameter (in)	1.40	1.50	1.55	1.55	1.50	1.40
Cavity Length (in)	5.9	4.7	5.3	6.0	5.0	6.0
Cavity Volume (ml)	108	110	110	131	113	100
Cavities/tray	115	128	128	128	135	112
Chemical root pruning?	Yes	No	No	No	No	No
Side root pruning holes?	No	Yes	Yes	No	No	Yes
# root pruning holes	0	8	4	0	0	3

C1 - Longleaf

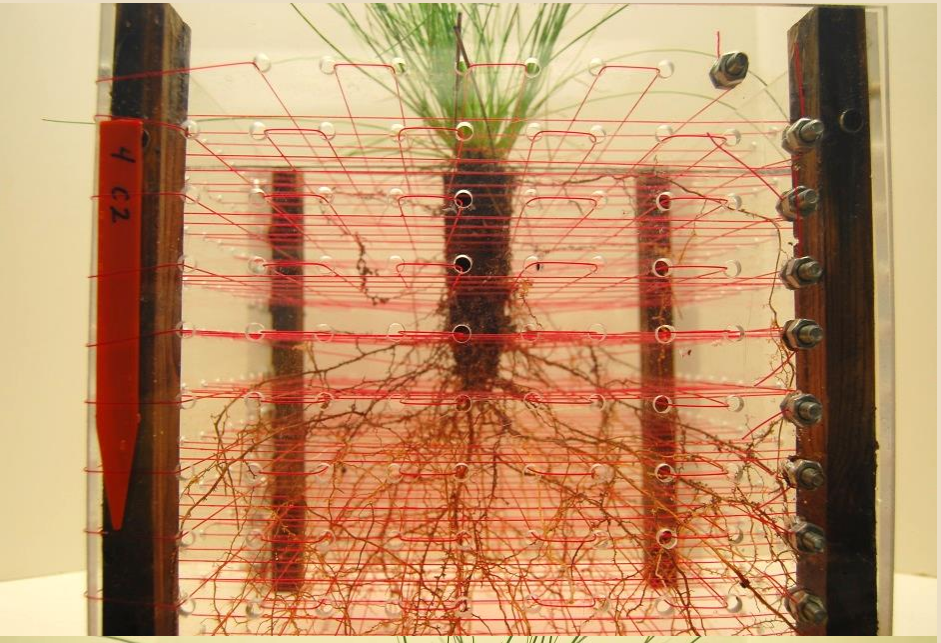


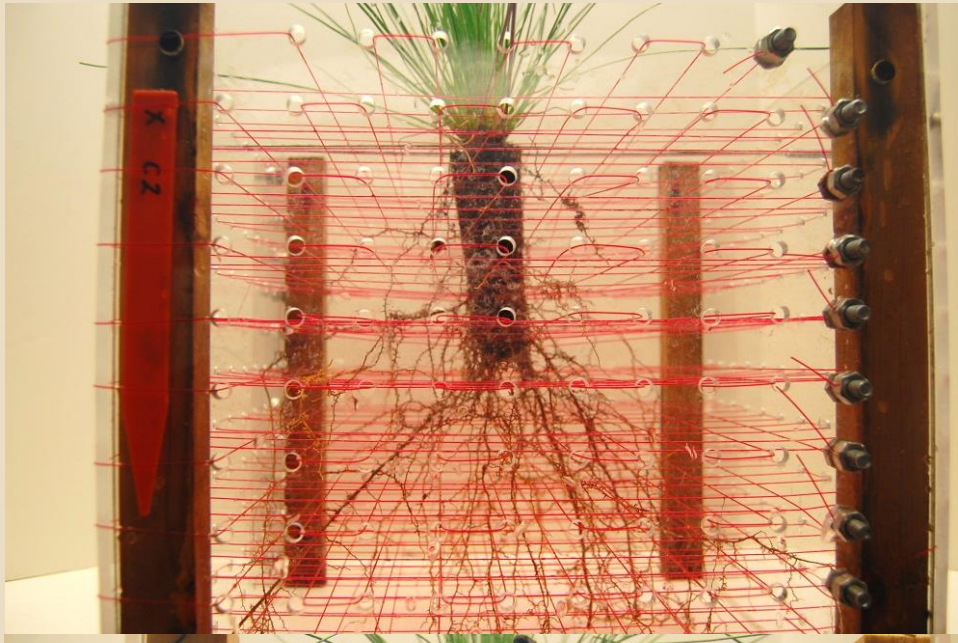


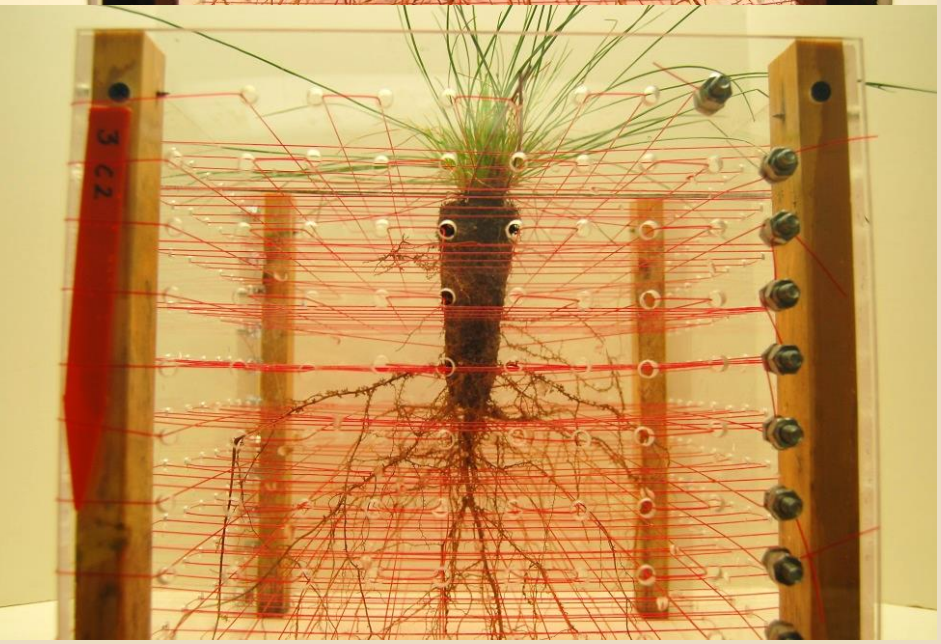


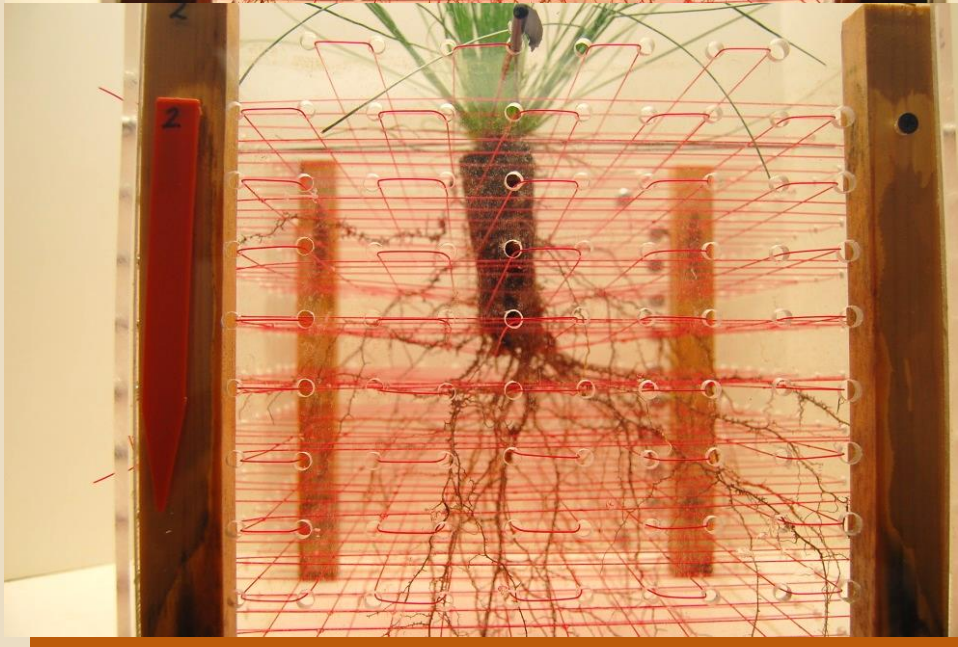


C2 - Longleaf

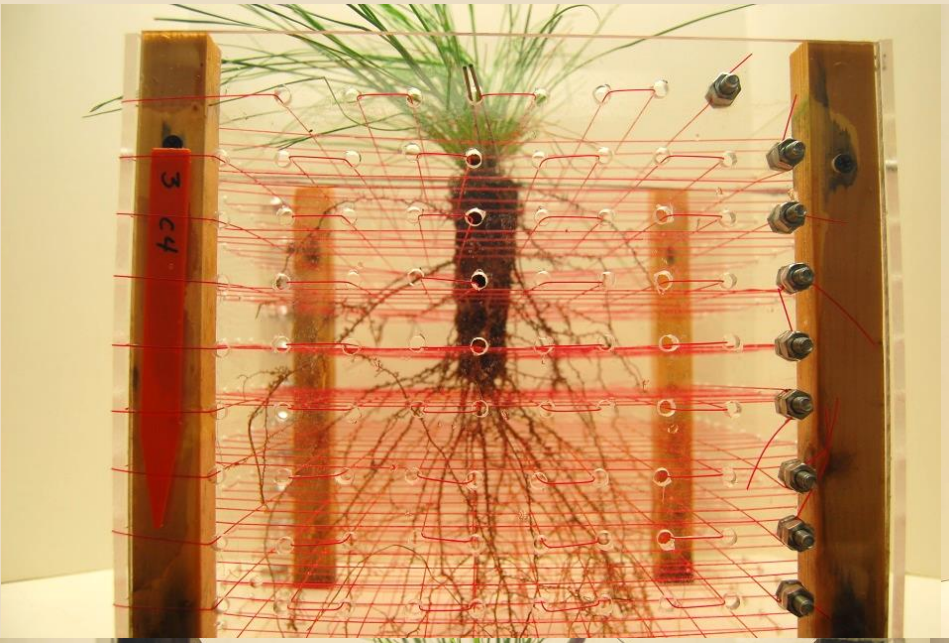


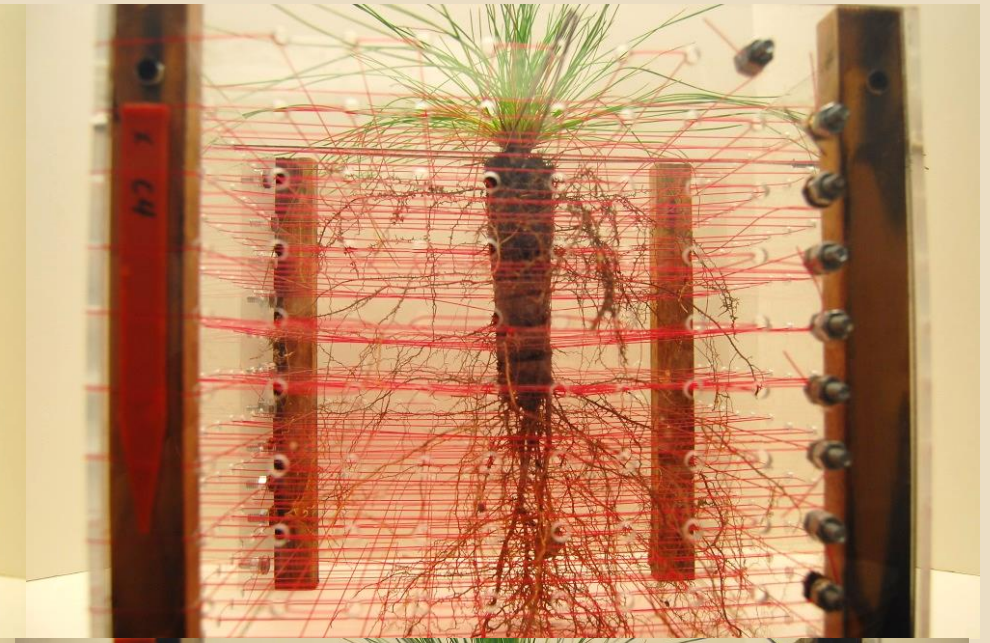


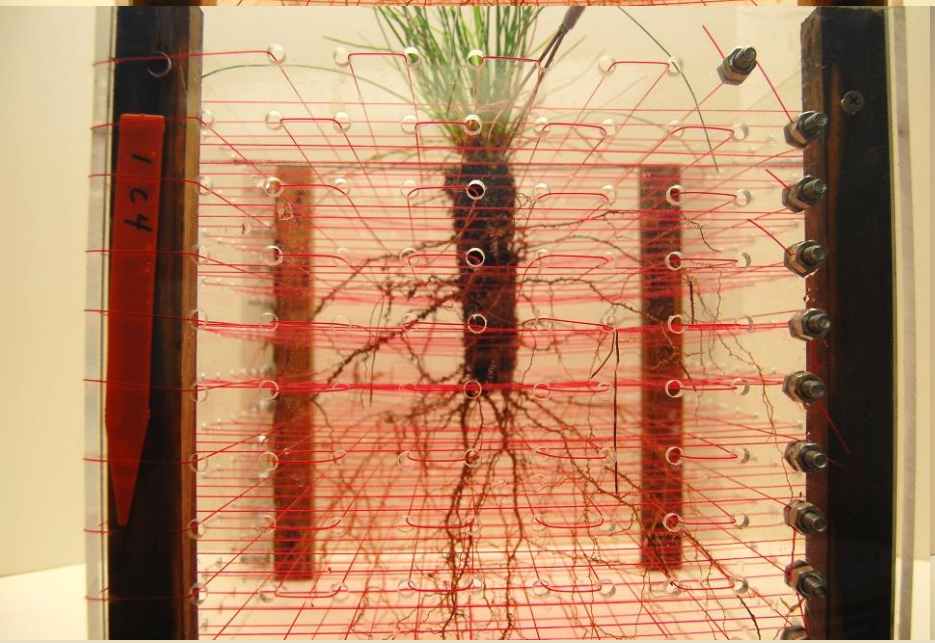


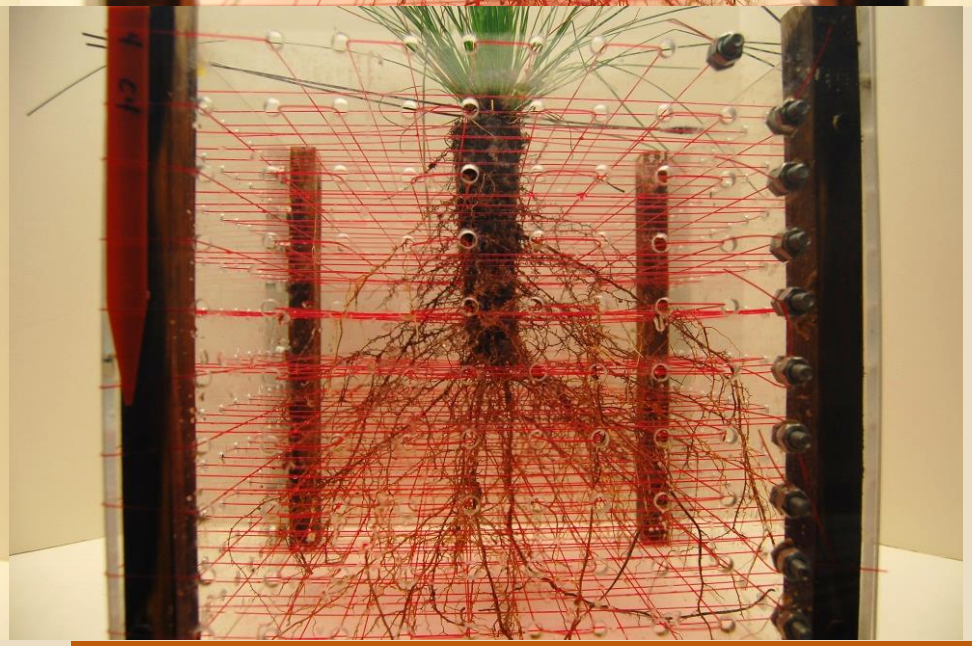


C4 - Longleaf

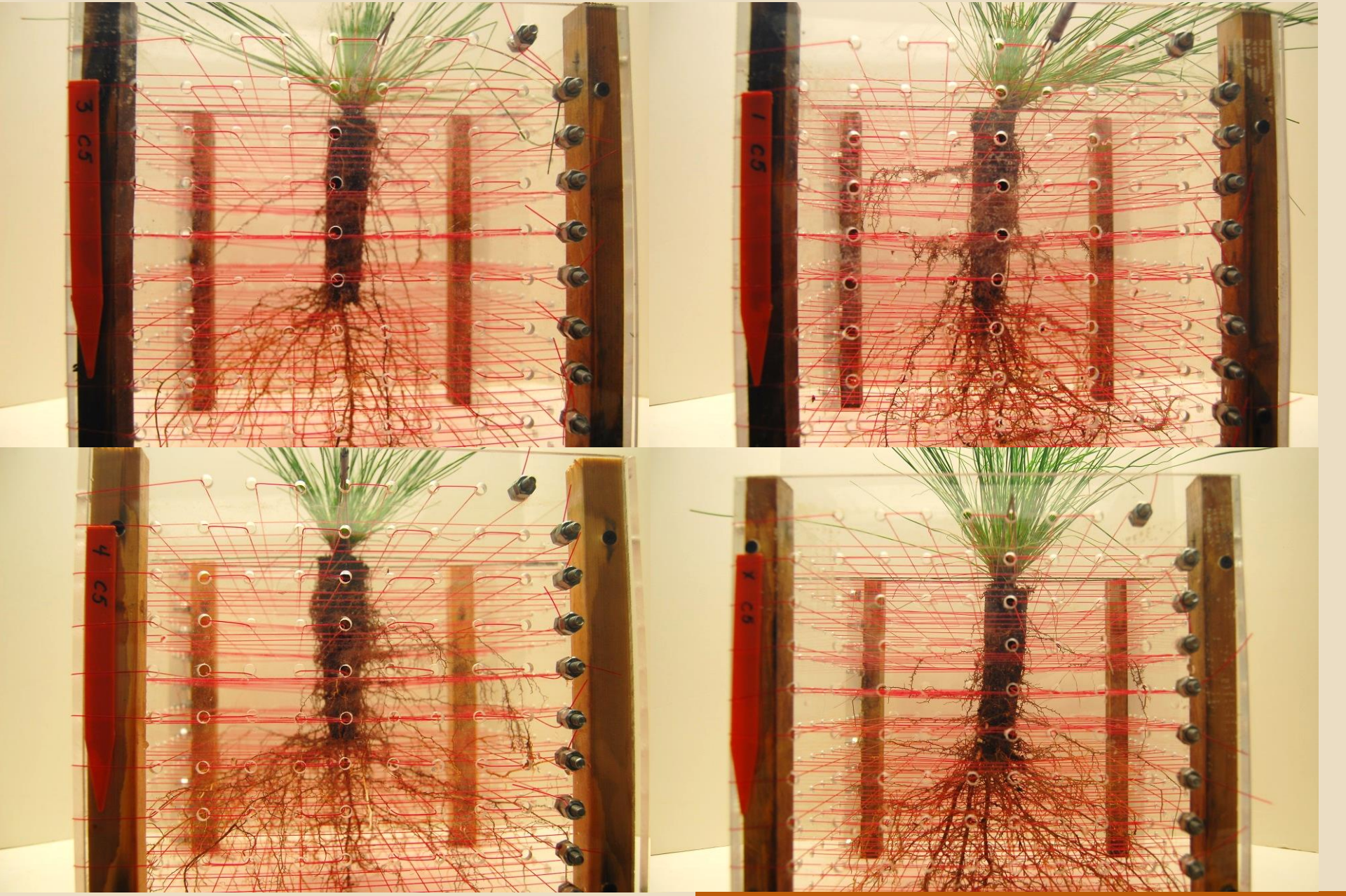




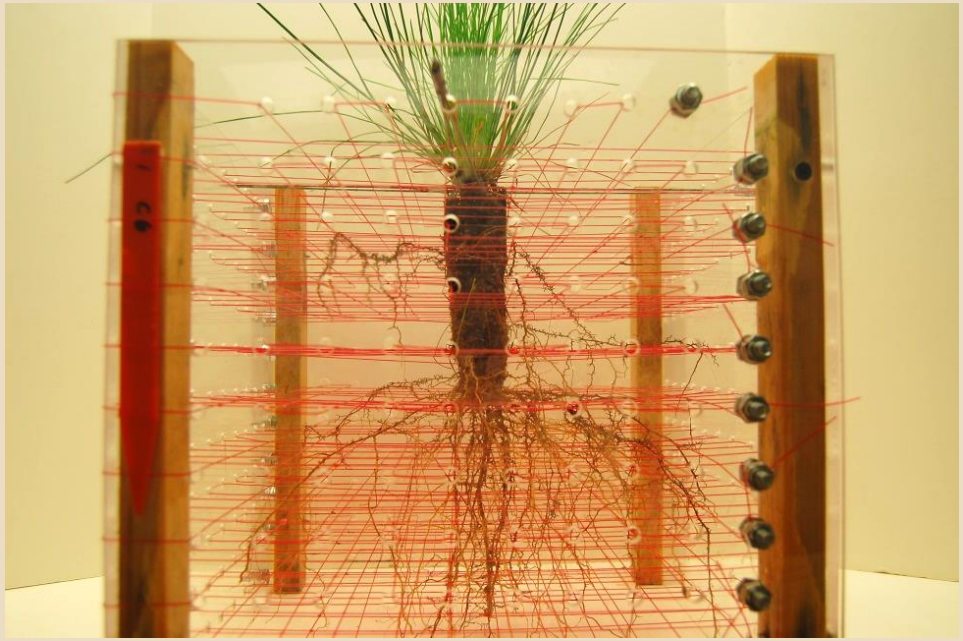


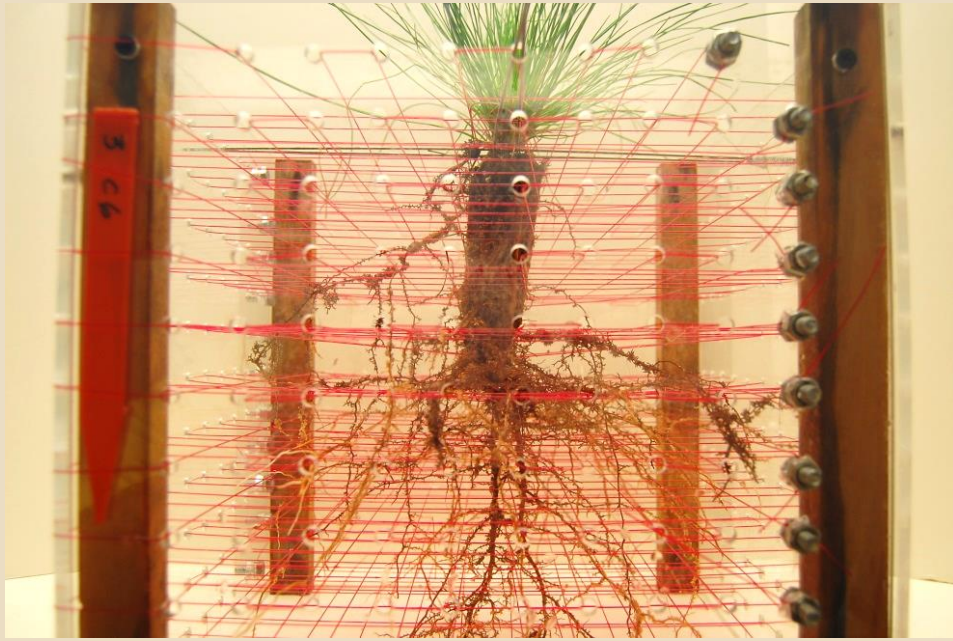


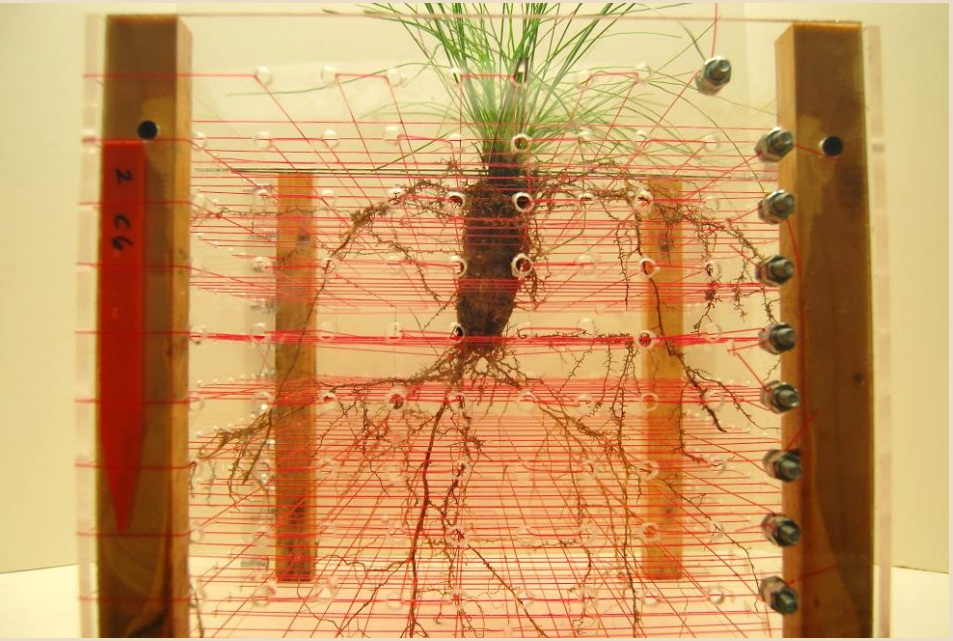
C5 - Longleaf

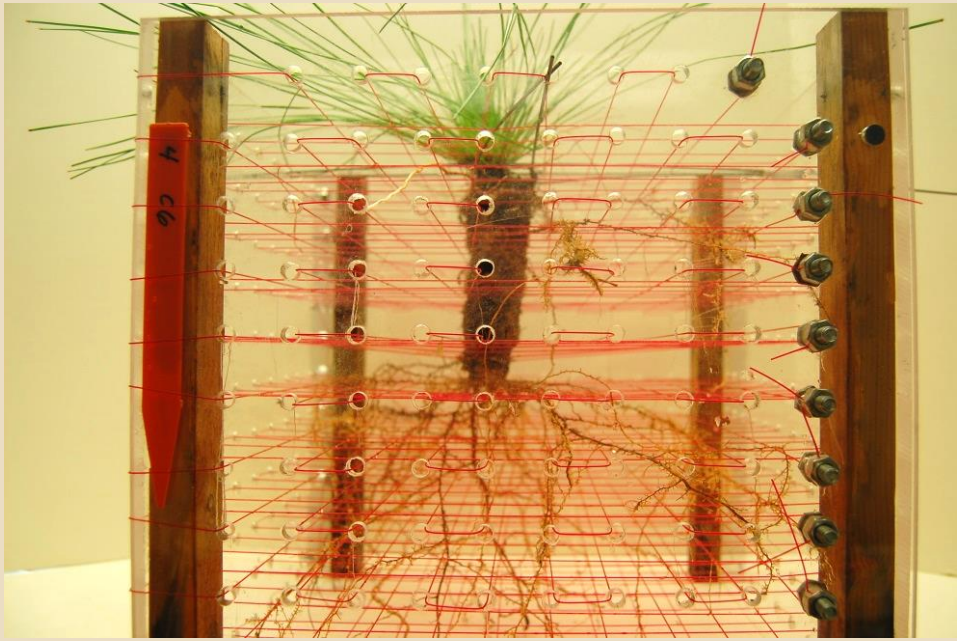


C6 - Longleaf

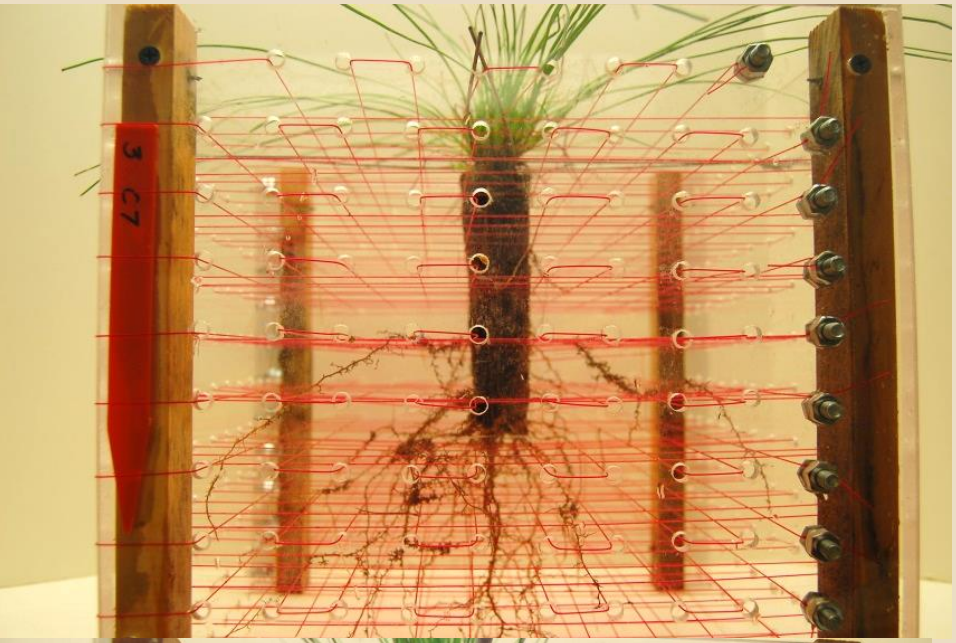


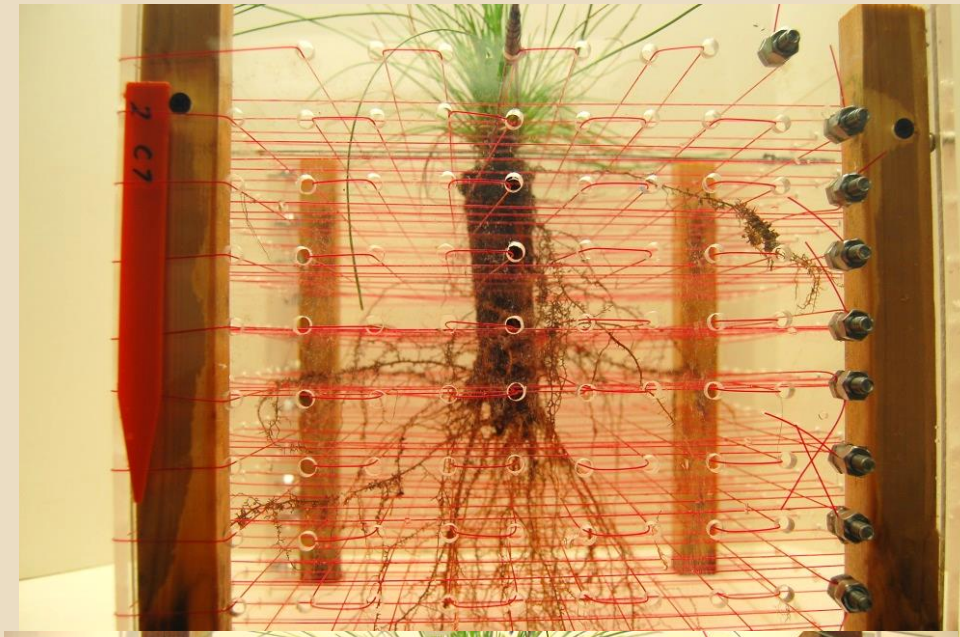


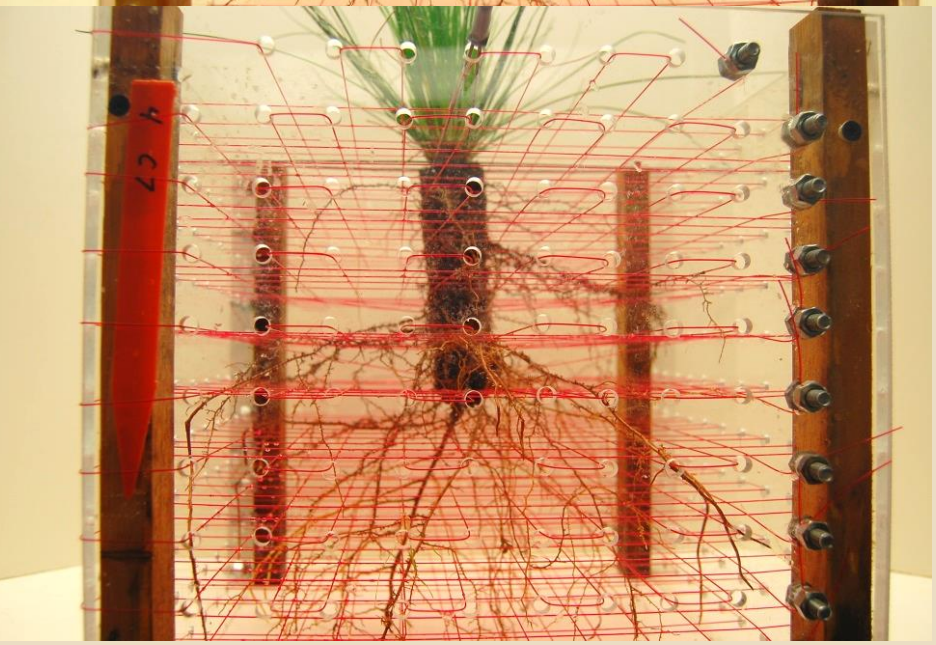


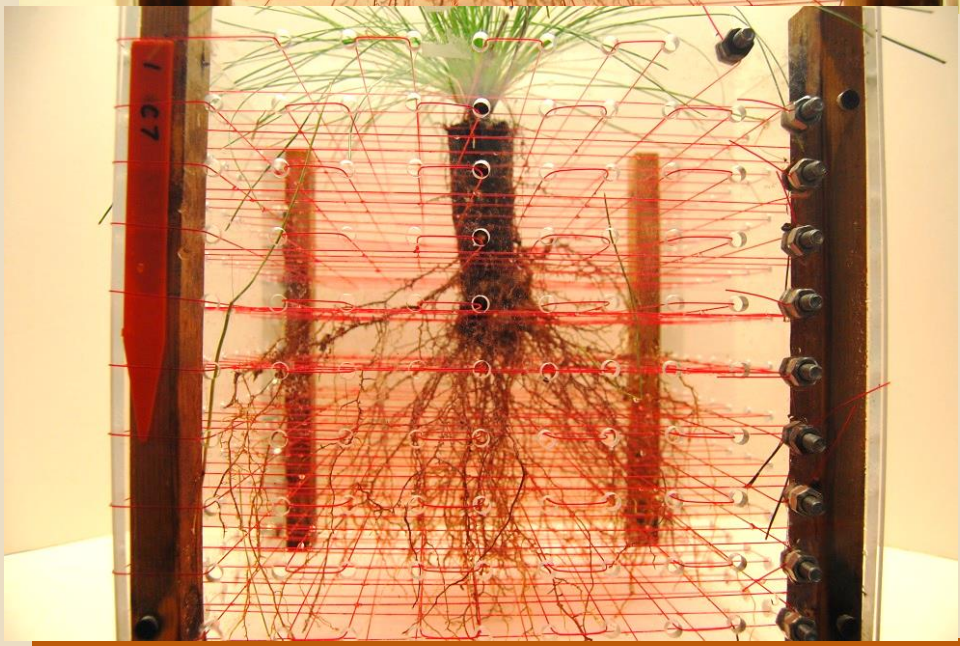


C7 - Longleaf





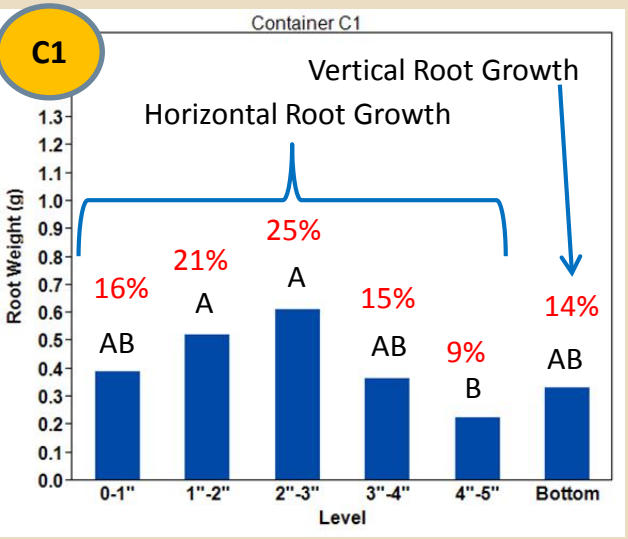


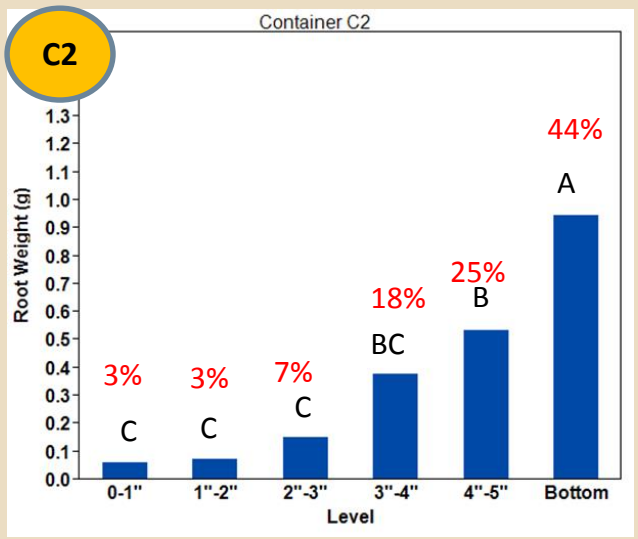


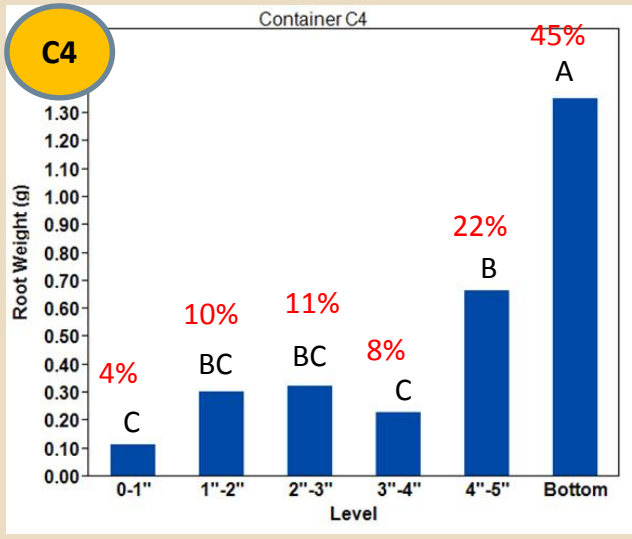
Plugs after media washed out

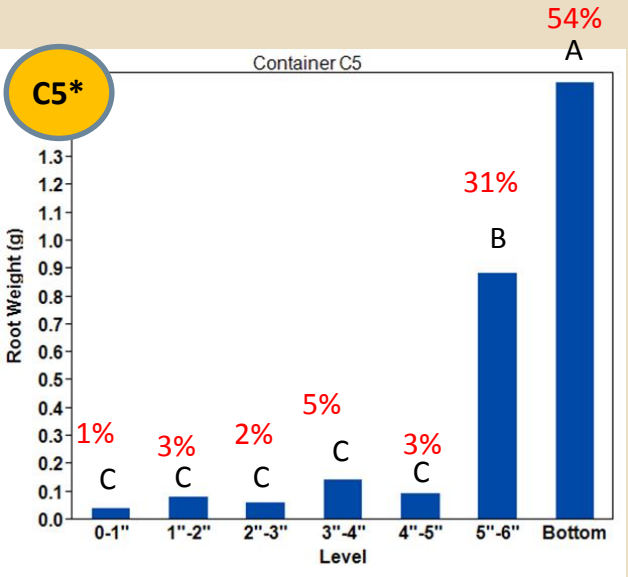
Comparison of copper treated (left) and hard plastic (right) root system after media is washed out

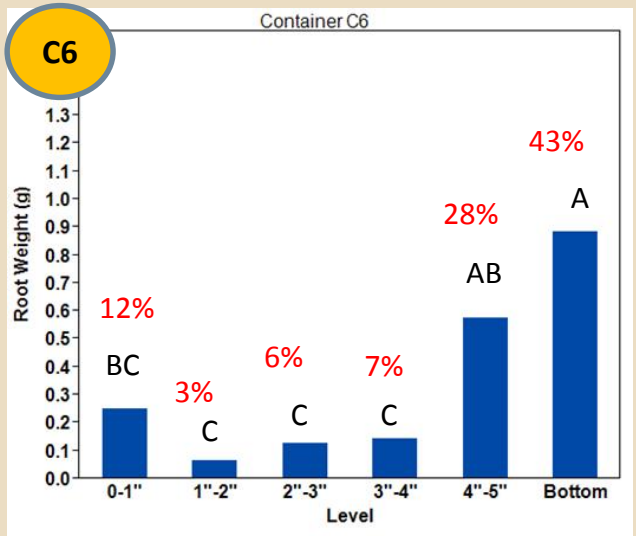
Longleaf Pine

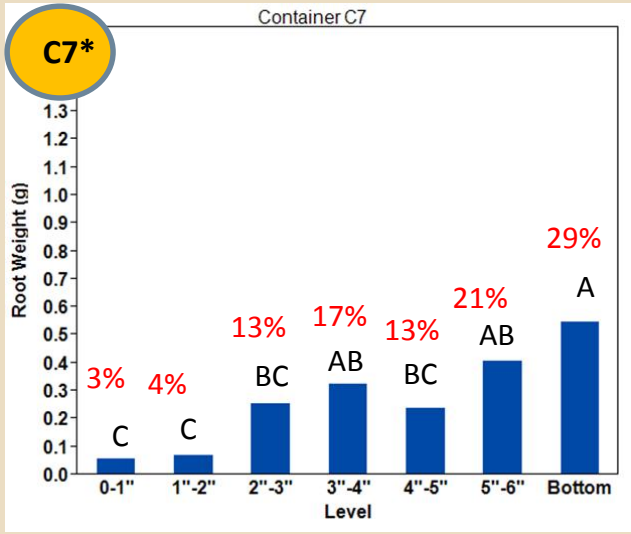












Where are the first 50% of the longleaf pine roots?

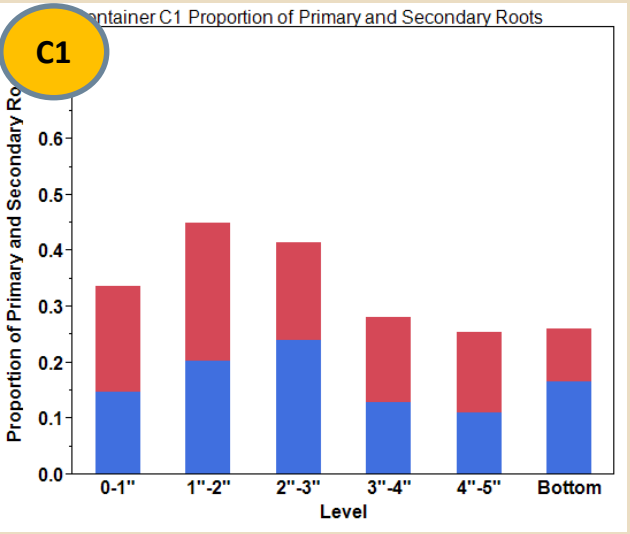
Level	C1	C2	C4	C6	Level	C5	C7
0-1"					0-1"		
1"-2"					1"-2"		
2"-3"					2"-3"		
3"-4"					3"-4"		
4"-5"					4"-5"		
Bottom					5"-6"		
					Bottom		

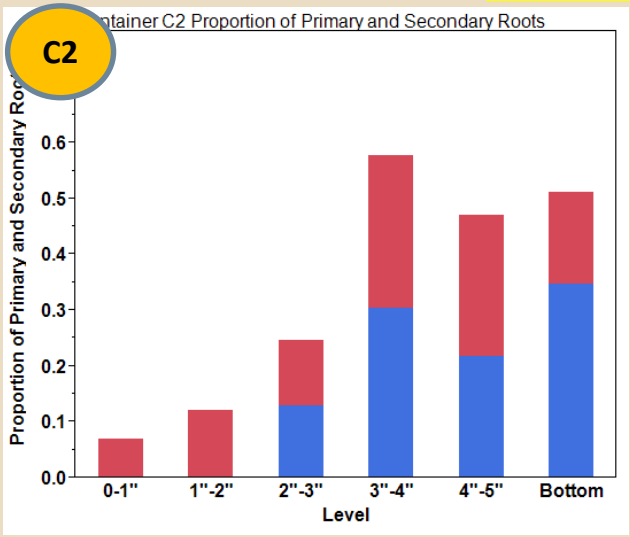
Average number of roots and root weight (plus taproot) after 5 months - Longleaf

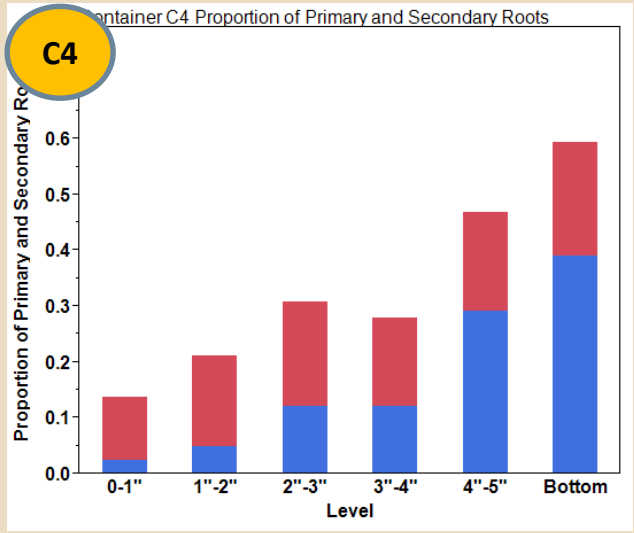
Container	Average total number of roots	Average weight of roots (g) (total)
C1	36 B	5.6 BC
C2	54 AB	5.7 BC
C4	50 AB	7.3 AB
C5*	64 A	8.3 A
C6	30 B	5.4 C
C7*	54 AB	6.0 BC

* 1 extra level of plug

Proportion of Primary and Secondary Roots by Level

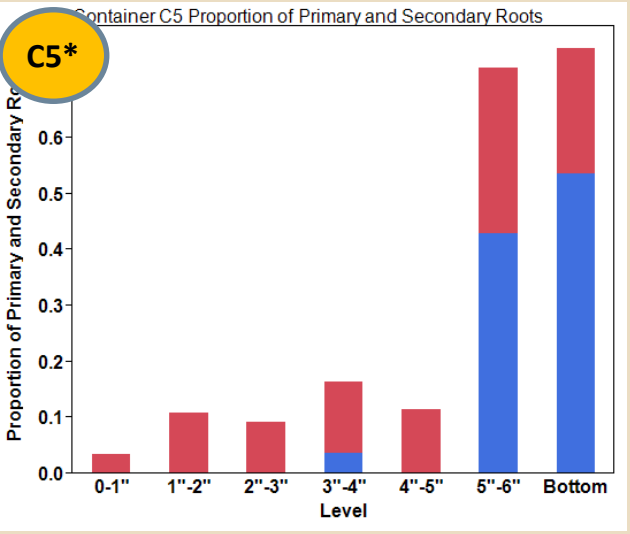


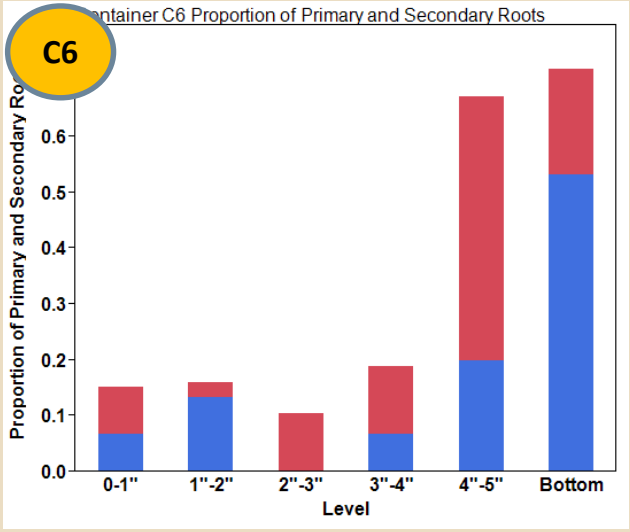


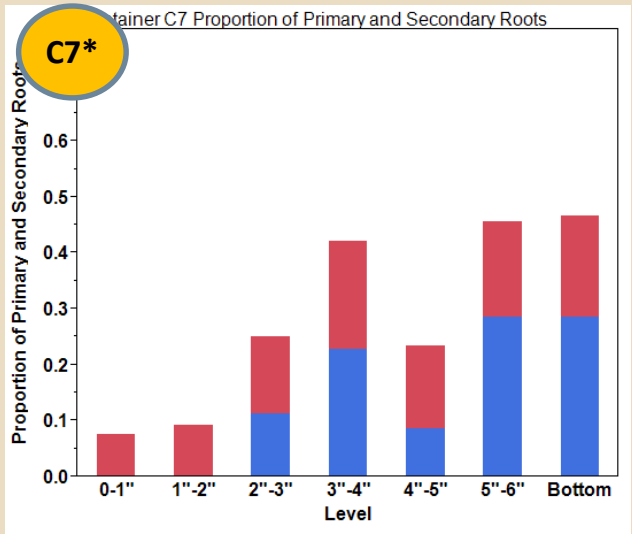


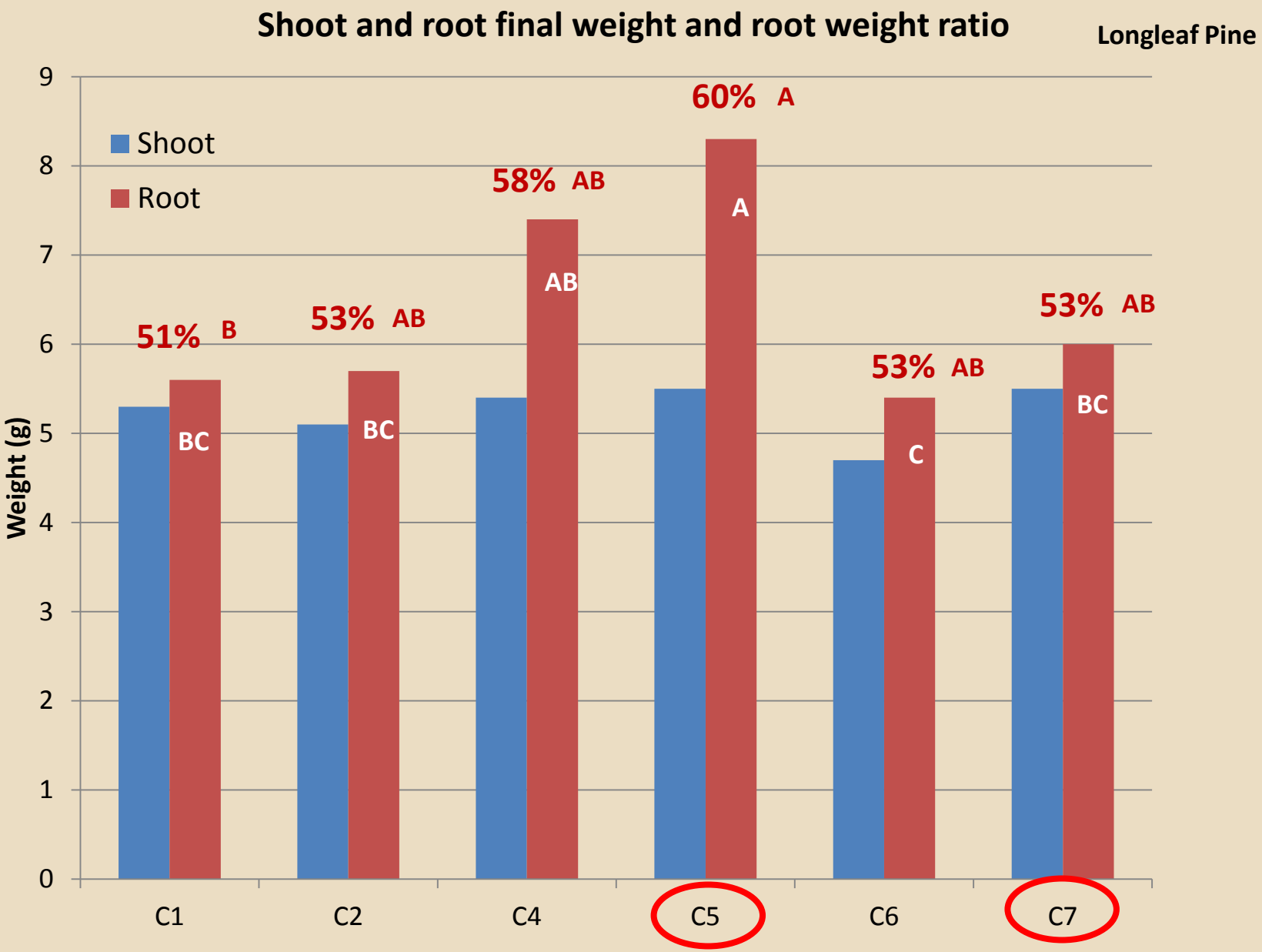
=Proportion of primary roots >2.0 mm

=Proportion of secondary roots <2.0 mm








Shoot and root final weight and root weight ratio
Longleaf Pine
Shoot
Root
Weight (g)
0
1
2
3
4
5
6
7
8
9
51% B
53% AB
58% AB
60% A
53% AB
53% AB
BC
BC
AB
A
C
BC
C1
C2
C4
C5
C6
C7

More Points to Ponder….

- In the south we use relatively few types of container set compared to NW
- The evolution of container sets used in the south is relatively recent
  - Consolidation of single cells to ~45 cells/tray to 125 cells /tray
  - Shift from polystyrene to hard plastic containers
  - Modification of cavity (internal and external) to encourage side root pruning either chemically or with addition of side air holes

More Points to Ponder….

- Over same time period (5 months) loblolly formed more roots than longleaf pine and about the same root mass
- Container type appears to have more of an effect on root morphology in longleaf than loblolly pine
- Roots in the mid section of “long” containers are lacking. This may be due to low oxygen levels or high moisture. These container sets may improve their root architecture with the addition of side air pruning holes.

More Points to Ponder….

- For Longleaf,
  - Hard Plastic Containers (and non-cooper treated polystyrene containers): lateral roots develop at all levels of the cavity but are directed downward with internal cavity ribs.
  - Copper-treated Polystyrene Containers: Lateral roots that develop within the cavity are chemically pruned when they reach the cell wall and do not appear to be forced downward.

More Points to Ponder….

– The root architecture of loblolly and longleaf pine grown in container C2 were similar. The same with container C6

More Points to Ponder….

- When examining toppling in the field. We need to look for a correlation with seedling age at time of extraction from the container and container type.
- This study illustrates the natural inclination of lateral roots to grow out of the plug unimpeded. In the field, the direction of lateral root growth is determined by soil conditions and presence of rocks and debris.

- Barry Brooks and Nina Payne for assembling and string the boxes
- Eric Stuewe, Jol Hodgson, Lewis Taylor Farms, International Forest Company for supplying containers for study
- Peter Germishuizen, LTF Farms, for initial idea for box study
- National Science Foundation (CAFS) for funding