# The Combined Effects of Fertilization and Relative Water Limitation on Needle Water Potential, Shoot Hydraulic Parameters and Root Distribution in 13-year-old Loblolly Pine (Pinus taeda L.)

Edward Russell, MS[1]; John Seiler, PhD[1]; Christopher Maier, PhD[2]; Quinn Thomas, PhD[1]; Erik Nilsen, PhD[1]
[1][Virginia Polytechnic and State University], [2][USFS]

## ABSTRACT

*A 2x2 factorial randomized complete block experiment in the piedmont region of Virginia was established to investigate the possible interactive effects of throughfall reduction and fertilizer application in a stand of Loblolly pine. Factor levels were no throughfall reduction versus ~30% reduction, and the addition or omission of a one-time, complete fertilizer application. Three years after treatments were imposed, soil cores were collected for characterization of root density under and between exclusion troughs, pre-dawn and mid-day needle water potential was measured in early and late summer of 2015, and 1-2 year old terminal shoots were collected for characterization of physical and hydraulic properties. Root densities were significantly lower under the troughs, there was significantly less fine root mass under the troughs, and the proportion of roots present as <2mm was higher under the troughs. Needle water potentials were affected strongly by throughfall exclusion, and were not made significantly more negative by fertilizer in addition to throughfall exclusion. Additionally, although not statistically significant at α = 0.05, drought lowered the daily range of needle water potential by making pre-dawn potentials more negative. Specific needle area was significantly increased by fertilizer addition only. Shoot hydraulic properties, namely needle area-specific (Kl) and sapwood area-specific (Ks) conductivities were significantly affected by the interaction between fertilizer and throughfall exclusion. Fertilizer only lowered Kl in the absence of throughfall exclusion. Fertilizer lowered Ks with or without throughfall exclusion, but much more so without it. Values of the ratio of Ks:Kl, (which is needle area:sapwood area) were also significantly affected by the interaction between factors. These findings, coupled with the lack of significantly more negative mid-day needle water potentials suggests that the use of fertilizer under current exclusion conditions did not imperil the experimental trees. The changes in hydraulic conductivities partially explain decreases in transpiration seen in the fertilized trees. Further work will characterize root hydraulic properties, and the effects on water use efficiency of fixed partial rootzone drying utilizing a split pot greenhouse study.*

## BACKGROUND

- The experimental site is an upland site in the Piedmont physiographic region of VA
- The trees are 13 year old, mid-rotation Loblolly pine
- The soil at the site is fine, shallow and acidic, mainly Spear's Mountain and Littlejoe soil series consisting mostly of low CEC 1:1 clay with ~ 10cm O-A horizon
- A hardpan layer is present approximately 1 meter below the surface
- The site was planted in 2003 at 1200 stems per hectare, by 2011 density was ~790 stems/ha
- Understory vegetation was removed both mechanically and chemically
- The experimental design is a $2^2$ factorial randomized complete block design with fertilizer and throughfall as treatment factors first imposed April 2012
- Throughfall exclusion removes ~30% of natural throughfall
- The fertilizer treatment consisted of 224 kg N $ha^{-1}$, 27 kg P $ha^{-1}$, 52kg K $ha^{-1}$, and 1.12 kg $ha^{-1}$ micronutrient mix (6% S, 5% Bn, 2% Cu, 6% Mn and 5% Zn), all applied in April 2012

## HYPOTHESES

- Fertilizer treatment will not significantly lower needle water potentials
- Fertilizer will lower needle and sapwood area specific conductivities, but less so under throughfall exclusion
- The FPRD treatment in the greenhouse study will reduce transpiration, and the effect will lessen over time
- Root density will be greater outside of the exclusion areas
- There will be a higher density of fine roots (< 2mm) away from the exclusion troughs

## METHODS

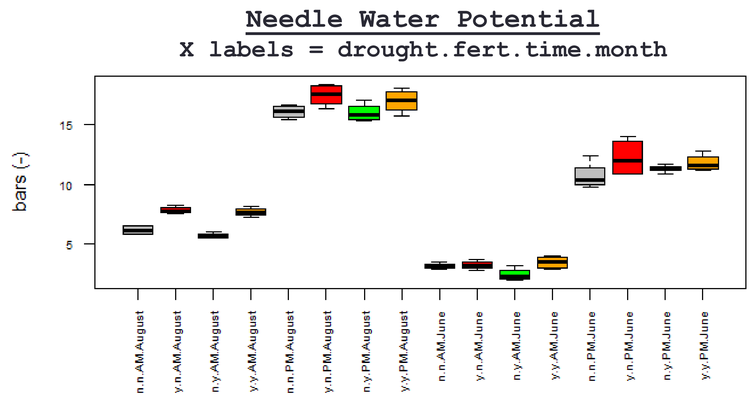
- Soil samples to characterize root density were collected to 15 cm depth randomly under and between exclusion troughs for a total of 32 individual samples
- Analysis of root samples was carried out with WINRhizo image analysis system (Regent Instruments Inc., Quebec City, Quebec, Canada)
- Two terminal shoot samples were taken from mid-canopy from each of the 16 experimental units, for a total of 32 samples
- Hydraulic properties and SLA were characterized per the method of Sperry et al. 1988
- Needle water potential measurements were made for two samples per experimental unit per time (pre-dawn and mid-day), per sampling month (July and August 2015) for a total of 128 samples
- Needle water potentials were measured using a pressure chamber per the methods of Scholander et al. 1965
- All data manipulation and analysis was carried out using R (R Foundation for Statistical Computing, Vienna, Austria)
- Psuedoreplication was addressed either by simple averaging or by the employment of hierarchical modeling using the R package lme4 per the methods of Bates et al. 2015, dependent upon desired model inference
- Effects of partial rootzone drying will be characterized using a greenhouse study using split pots to effect treatment, and thermal dissipation sap flux probes to measure transpiration

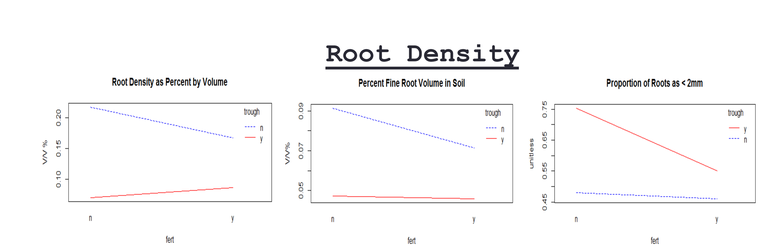
Clockwise from upper left: a scanned root sample, a pressure chamber, measuring steady state hydraulic conductance, and establishing a greenhouse split pot study to characterize effect of troughs with a control

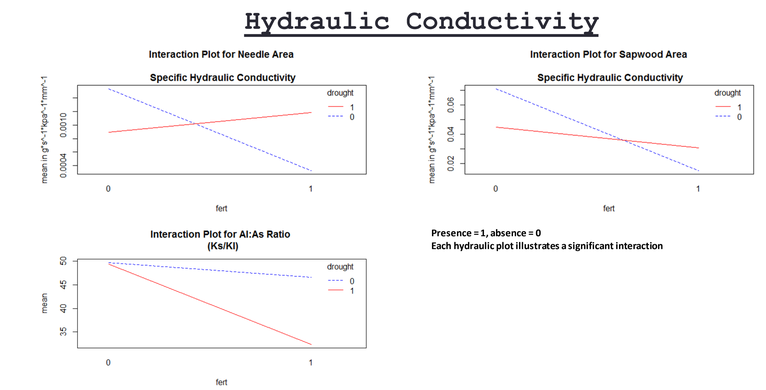
## RESULTS

- Fertilizer did not significantly lower needle water potentials (pre-dawn or mid-day), while throughfall exclusion did, particularly under late season water limitation
- Root density was significantly higher between exclusion troughs, fine roots occupied a significantly larger portion of the soil volume between troughs compared to under troughs, and the proportion of total roots as fine was larger under the troughs (p = ~0.067)
- Fertilizer significantly lowered Ks, Kl, and needle area:sapwood area (Al:As = Ks:Kl) dependent on throughfall exclusion factor level. Also, specific leaf area was significantly higher under fertilization

## RESULTS cont.




## CONCLUSIONS

- **Needle water potentials suggest that fertilizer application did not result in any significant moisture stress under the experimental conditions. This could be due, in part, to the high rainfall during the experimental period. This result supports the assertion that fertilization is not likely to endanger trees.**
- **The findings from characterization of terminal shoot hydraulic properties propose one potential component of the mechanism behind decreases in needle-level stomatal conductance observed in response to fertilization under non-water limiting conditions (unpublished data)**
- **The use of throughfall exclusion troughs to simulate reduced rainfall has resulted in significant redistribution of roots and changes to the proportion of fine roots. It is very likely that there are physiological effects of the banding of soil moisture that are confounded with the simulation of reduced rainfall. The current greenhouse study allows for an appropriate control treatment to test this hypothesis**

WORKS CITED:
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