Above and Belowground Biomass Allocation Patterns in American Chestnut and Northern Red Oak

Ethan Belair and Mike Saunders
Purdue University, Department of Forestry and Natural Resources
Hardwood Tree Improvement and Regeneration Center

Introduction

Efforts to restore American chestnut would benefit from improved understanding of how chestnut interacts with its environment and how its adaptations compare to other common hardwood species. Historically, chestnut occurred in oak stands prone to frequent disturbance, though the mechanisms leading to this association are unclear. We evaluated **biomass partitioning in chestnut and red oak saplings** to better understand these species' ecological **adaptations to disturbance**. We hope this will aid in the design of management strategies which favor chestnut based on its inherent ecological characteristics.

Figure 1. Excavation of roots was completed primarily by hand, though on some larger trees, trenches were dug adjacent to roots with a Bobcat backhoe attachment.

Results

Table 1. Mean ± standard error for morphological characteristics of American chestnut and northern red oak, and p-values for comparison between species. All comparisons are across the range of ground line diameters observed.

	American chestnut	Red oak	p-value
Total Height (cm)	174.4 ± 20.1	167 ± 12.7	0.759
Ground Line Diameter (cm)	1.91 ± 0.20	1.81 ± 0.16	0.674
Canopy openness (%)	**17.1 ± 1.1**	**27.4 ± 3.5**	**0.007**
Ht to Live Crown (cm)	**51.1 ± 4.3**	**65.6 ± 3.2**	**0.009**
First-order Lateral Branches	11.1 ± 1.2	10.5 ± 1.1	0.707
Crown Projection Area (m^2)	**1.18 ± 0.30**	**0.42 ± 0.07**	**0.021**
Total leaf Area (m^2)	2.14 ± 0.51	1.44 ± 0.27	0.225
Specific Leaf Area (m^2/kg)	**37.7 ± 1.4**	**30.5 ± 2.9**	**0.026**
Leaf Area Index	**2.11 ± 0.13**	**4.27 ± 0.62**	**0.001**

Figure 3. Chestnut's preferential allocation to foliage allows it to reproduce at a young age, when planted in full sunlight.

Major findings:

- American **chestnut allocated more resources to foliage and branches** than red oak.
- **Oak allocated more resources to root structures** than chestnut.
- American **chestnut had more efficient canopy structure** than red oak, with greater crown projection area, higher specific leaf area, less layering of foliage, and more low-lying branches.
- Neither species showed notable allocation changes under different light environments.
- Both species tended to shift allocation from foliage to branches as ground line diameter increased.

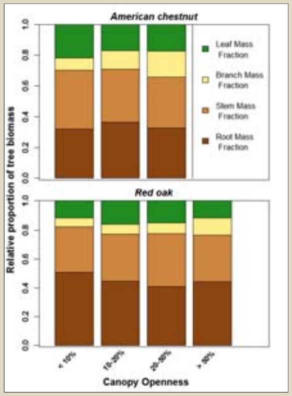

Figure 4. Observed biomass allocation by canopy openness class to structural groups in American chestnut and northern red oak. There were no chestnut sampled in the highest light class.

Table 2. Mean ± standard error for fractional biomass allocation of American chestnut and northern red oak, and p-values for comparison between species. All comparisons are across the range of ground line diameters observed.

Response	American chestnut	Red oak	p-value
Canopy openness	**17.1 ± 1.1**	**27.4 ± 3.5**	**0.007**
LMF	**0.174 ± 0.006**	**0.148 ± 0.005**	**0.002**
BMF	**0.135 ± 0.011**	**0.077 ± 0.005**	**< 0.001**
SMF	0.344 ± 0.013	0.337 ± 0.009	0.641
RMF	**0.347 ± 0.015**	**0.438 ± 0.010**	**< 0.001**
Shoot:Root	**1.499 ± 0.110**	**0.985 ± 0.043**	**< 0.001**

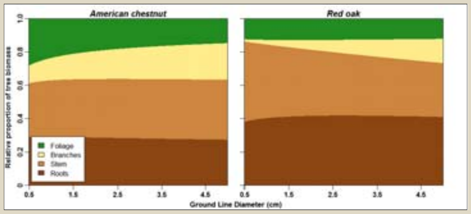

Figure 5. Estimated biomass allocation by ground line diameter to structural groups in American chestnut and northern red oak.

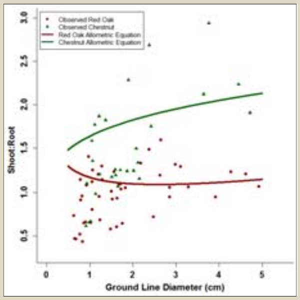

Figure 6. Shoot to root ratio of American chestnut and northern red oak. Lines represent shoot:root derived from NSUR allometric equations; points represent observed shoot:root of samples.

Methods

- American chestnut (28) and red oak (46) were selected from a larger pool to provide a range of stem volumes.
- Samples ranged from 0.5 - 5.0 cm ground line diameter.
- Saplings planted on three Purdue University properties in 2007 and 2009 were destructively sampled in 2013.
- Leaf area measured on a subsample of foliage.
- Biomass was split into four functional groups: foliage, branches, stem and coarse roots (>2 mm).
- All samples dried to a constant mass and weighed.
- Weights used to fit **additive biomass equations** (Parresol 2001) using nonlinear seemingly unrelated regressions in SAS 9.3 (SAS 2011).
- Additional analyses in R 2.15 (R Core Team 2012).

Figure 2. Many chestnuts had extremely fibrous root systems, with numerous lateral roots descending up to 3 m below ground.

Equation Form

Total Biomass: $$\hat{y} = \sum_{i=1}^{4} \beta_{i0} GLD^{\beta_{i1}}$$

where:
$i = 1$ for foliage biomass
$i = 2$ for branch biomass
$i = 3$ for stem biomass
$i = 4$ for root biomass

Figure 7. Weighing foliage samples after drying.

Conclusions

- American chestnut was **more acclimated to low-light understory conditions** than red oak (Bazzaz and Grace 1997).
- Chestnut invested heavily in branch structures to display foliage. In shaded understory locations **chestnut will remain responsive to release**.
- Chestnut may benefit in silvicultural systems that create diffuse shade, giving them an advantage over less shade-tolerant species.
- Treatments which reduce competition may **minimize chestnut mortality during restoration**, which is especially important given the low availability of growing stock.
- **Red oak invested heavily in roots**, an adaptation that benefits individuals on nutrient-poor or **disturbance-prone sites**.
- Red oak may be ill-adapted to rich, mesic sites in the absence of frequent disturbance.

Figure 8. Chestnut following leaf removal and preceding stem harvest.

Literature Cited

Bazzaz, F.A. and J Grace. 1997. Plant resource allocation. Physiological ecology series. San Diego, CA: Academic Press.

Parresol, B.R. 2001. Additivity of nonlinear biomass equations. Canadian Journal of Forest Research 31: 865-878.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

SAS. 2011. SAS/STAT 9.3 User's Guide, 1st Edition. SAS Institute, Cary, NC.

Acknowledgements

- Field and lab assistance: Justin Arseneault, Johanna Desprez, Kyle Earnshaw and Michael Loesch-Fries
- All former and current members of the Saunders lab
- Purdue College of Agriculture Mission Oriented Grant

Related Projects

- Measuring concentrations of nonstructural carbohydrates in chestnut and oak to evaluate how they effect individual response to disturbance.
- Quantifying the response of chestnut and oak saplings to surface fire topkill, and how that response is altered by light regime.
- Determining optimum light environment to favor American chestnut over competing hardwoods.