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.

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>American Chestnut</th>
<th>Northern Red Oak</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Height (cm)</td>
<td>174 ± 20.8</td>
<td>160 ± 12.7</td>
<td>0.739</td>
</tr>
<tr>
<td>Ground Line Diameter (cm)</td>
<td>191 ± 20.2</td>
<td>181 ± 10.4</td>
<td>0.474</td>
</tr>
<tr>
<td>Canopy Expansion (%)</td>
<td>37 ± 5.8</td>
<td>37 ± 4.5</td>
<td>0.997</td>
</tr>
<tr>
<td>D1 to Live Crown (cm)</td>
<td>78 ± 4.3</td>
<td>65 ± 3.2</td>
<td>0.008</td>
</tr>
<tr>
<td>First-order Lateral Branches</td>
<td>31 ± 2.2</td>
<td>16 ± 1.1</td>
<td>0.787</td>
</tr>
<tr>
<td>Crown Projection Area (m²)</td>
<td>13 ± 0.64</td>
<td>8.0 ± 0.27</td>
<td>0.025</td>
</tr>
<tr>
<td>Total Leaf Area (m²)</td>
<td>2.14 ± 0.65</td>
<td>1.44 ± 0.27</td>
<td>0.235</td>
</tr>
<tr>
<td>Specific Leaf Area (mm²)</td>
<td>37 ± 4</td>
<td>36 ± 2.3</td>
<td>0.826</td>
</tr>
<tr>
<td>Leaf Anisochronicity</td>
<td>2.15 ± 9.65</td>
<td>1.27 ± 9.62</td>
<td>0.008</td>
</tr>
</tbody>
</table>

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

Methods

- American chestnut (28) and red oak (46) were selected from a large 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 cm). 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).

Equation Form

Total Biomass: \[ y = \sum_{i=1}^{4} \beta_i \mathrm{GL} \mathrm{DM}_i \]

where:
- \( i \) for foliage biomass
- \( 2 \) for branch biomass
- \( 3 \) for stem biomass
- \( 4 \) for root biomass

Figure 2. Excavation of root mass commenced by hand, though on some larger trees trenches were dug adjacent to roots with a Bobcat backhoe attachment.

Results

Major findings:

- American chestnut allocated more resources to foliage 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.

- We hope this will aid in the design of management strategies which favor chestnut based on its inherent ecological characteristics.

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

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.

Conclusions

- American chestnut was more acclimated to low-light understory conditions than red oak (Bazzaz and Grace 1997).
- Chestnut invests heavily in branch structures to display foliage. In shaded understory locations chestnut will remain responsive to release.
- Chestnut may benefit in aviculature 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 5. Weighing foliage samples after drying.

Figure 6. Estimated biomass allocation by ground line diameter to structural groups in American chestnut and northern red oak.

Figure 7. Foliage recovery and stem harvest.

Figure 8. Shoot to root ratio of American chestnut and northern red oak.

Figure 9. Chemical flooding and procrastinating root lament.

Acknowledgements

- Field and lab assistance: Justin Amennault, Johanna Deepeez, Kyle Earnshaw and Michael Loesch-Fries
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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.

Related Projects

- Determining optimum light environment to favor American chestnut over competing hardwoods.

Literature Cited


