On the early competitiveness of American chestnut (*Castanea dentata* [Marsh.] Borhk.) in mixed plantations

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Abstract

American chestnut (*Castanea dentata* (Marsh.) once represented up to 40-50% of the forest canopy throughout eastern deciduous forests. The introduction of the fungal pathogen *Cryphonectria parasitica* (Murr.) Barr. all but eliminated American chestnut throughout its native range. This once economically and ecologically important species now exists as sprouts incapable of reaching reproductive maturity. A blight-resistant hybrid form of American chestnut is likely to be incorporated into restoration programs in the near future. This study examined early (five growing seasons) morphological and physiological competitive aspects of American chestnut grown in a plantation setting with northern red oak (*Quercus rubra* L.) and black cherry (*Prunus serotina* Ehrh.) in West Lafayette, Indiana, USA. Species were randomized within all possible combinations of mixtures. Mixtures were randomized within three spacings (1×1 m, 2×2 m, and 3×3 m), and spacings were randomized within each of three blocks. Despite an initial advantage in height, American chestnut exhibited the lowest relative height growth in the 2×2 and 3×3 m spacings. This resulted in lower total heights of 35-65 cm (2×2 m) and 46-52 cm (3×3 m) compared to the other two species five years after planting. Relative height growth, as well as final absolute heights, were comparable among species in the 1×1 m spacing. Black cherry exhibited 2-3 times greater relative ground-line diameter (GLD) growth than oak and chestnut at all spacings. Linear regressions showed that growth was generally proportional to net photosynthesis (*A*), with 49-89% of total variation in relative height and GLD growth explained by *A* among species. Increases in *A* likely resulted from increases in leaf [N]. While black cherry had the most aggressive growth, northern red oak and American chestnut performed acceptably, especially in the 1×1 m spacing. American chestnut had the poorest stem form overall, but fared better in the 1×1 m spacing where the crown competition factor was highest. Hence, an intermediate spacing between 1×1 m and 2×2 m could be helpful in maintaining chestnut's growth and stem form. Mixture effects reflected individual species traits rather than true mixture effects due to the short monitoring period. Overall, our short-term findings suggest black cherry and northern red oak generally fared better than American chestnut despite its reputation for rapid and aggressive growth. Further monitoring will be carried out to determine if these trends continue.

Introduction

Blight resistant American chestnut has the potential to become an important tree species for forest restoration. Contemporary research suggests that American chestnut seems to be adapted to a wide range of site conditions and light environments, and is reported to be a fast growing species with desirable timber (Jacobs 2007). Thus, for economical and ecological reasons it should be an attractive tree species for many private landowners in eastern North America. However, relatively little is known regarding the silvical characteristics of chestnut in field settings. Even less is known about the response of American chestnut in mixed plantation settings, which has been identified as an important tool for forest restoration as they may meet a wide variety of social, economical and environmental objectives in comparison with monocultures (Paquette and Messier 2010).

The aim of this study was to gain further knowledge regarding factors that influence the growth and competitiveness of American chestnut grown with associated fine hardwood species such as northern red oak (*Quercus rubra* L.) and black cherry (*Prunus serotina* Ehrh.), in an effort to ensure successful outplanting of chestnut in the future. **Specific objectives include (*i*) evaluating the relative competitiveness of American chestnut under varying spacings and species mixtures; (*ii*) examine ecophysiological responses of American chestnut seedlings under varying spacings and species mixtures.**

Materials and Methods

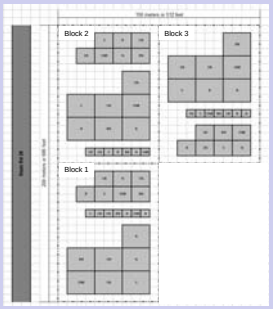

Figure 1. General layout of the chestnut study (B = Black cherry, C = American chestnut, and N = Northern red oak).

- Established spring 2007 at Martell Forest, West Lafayette, IN
- Planted at three spacings (1×1 m, 2×2 m, and 3×3 m), in all seven possible species combinations, replicated in three blocks (Figure 1)
- Each plot consists of 30 seedlings, plus one guard row
- Measured height, ground line diameter (GLD) and crown width annually for five years
- Net photosynthesis (*A*, μmol CO_2 m^{-2} s^{-1}), transpiration (*E*, mol H_2O m^{-2} s^{-1}), stomatal conductance (*g*, mmol H_2O m^{-2} s^{-1}), predawn leaf water potential (leaf Ψ_{pd}), and foliar [N] were measured in 2009 and 2010 (not presented here)

Results

Table 1. Mean (± SE, n=36) survival by species and measurement year (2007-2011). For each year, means not followed by the same letter are significantly different ($P < 0.05$).

Species	Survival (%)									
	2007		2008		2009		2010		2011	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Black cherry	96.9a	0.9	91.6a	2.5	90.7a	2.5	90.1a	2.7	87.6a	3.0
Northern red oak	98.5a	0.7	98.4a	0.6	97.9b	0.7	97.5b	0.8	98.2b	0.6
American chestnut	96.6a	0.8	93.1a	2.0	89.1a	3.2	88.7a	2.6	88.3a	2.4

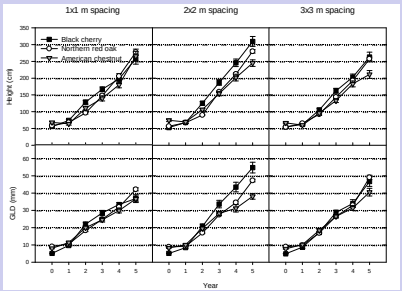

Figure 3. Mean (± SE, n=12) height and ground line diameter (GLD) of black cherry, northern red oak, and American chestnut for the first five years after planting at three different spacings: 1×1 m, 2×2 m, and 3×3 m between seedlings. The plantation was established in 2007 (year = 0) and re-measured at the end of each growing season from 2007 to 2011 .

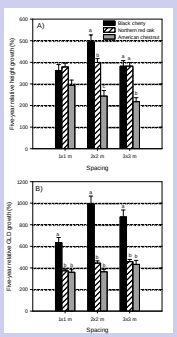

Figure 2. Relative height (A) and ground line diameter (GLD; B) growth in black cherry, northern red oak, and American chestnut for the first five years after planting at three different spacings: 1×1 m, 2×2 m, and 3×3 m between seedlings. For each spacing, means (± SE, n=12) not followed by the same letter are significantly different ($P < 0.05$).

Table 2. Mean (± SE, n=9) crown competition factor (CCF) in 2009, 2010, and 2011 by mixture. Species combinations include black cherry (*Prunus serotina*, B), American chestnut (*Castanea dentata*, C), and northern red oak (*Quercus rubra*, N) in pure plots or in mixtures.

Mixture	CCF by measurement year					
	2009		2010		2011	
	Mean	SE	Mean	SE	Mean	SE
Black cherry (B)	76	23	79	18	84	19
Northern red oak (N)	38	12	36	8	66	16
American chestnut (C)	47	15	37	11	72	23
BC	71	22	64	18	90	28
BN	63	19	65	16	84	21
NC	43	16	40	11	82	24
NBC	57	13	57	14	84	19

Conclusions

- Survival rates were relatively high, and similar across species
- Black cherry was the most aggressive competitor, and tended to increase CCF
- American chestnut performed best in the 1×1 m spacing, but exhibited lower relative and absolute height growth in the wider spacings
- Mixture effects were not significant at this point in plantation development, though may become more pronounced as CCF surpasses 100
- This study provides valuable insight on the relative performance of American chestnut in mixed-plantation settings

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