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PLANTING TRIALS OF AMERICAN CHESTNUT IN CENTRAL APPALACHIAN MOUNTAINS

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Abstract**:** Field planting methods for American chestnut were examined in three separate trials to develop guidelines for the anticipated establishment of blight-resistant hybrid American chestnut into Appalachian forests. A direct-seed tree shelter test examined the effect on height growth of using five-foot tall tree shelters, vented or unvented, and no tree shelter treatments. A containerized/nursery stock test examined the effect on height growth of two nursery stocks (1-1 and 1-0) and greenhouse raised containerized stock in two container sizes (40 and 10 cu. in.) where half of each of the containerized stocks were given a 2.5-foot tree shelter. The direct-seed tree shelter test and the containerized/nursery stock test were located adjacent to each other at two sites. In addition, a site evaluation test examined the suitability of planting American chestnut at seven forest sites that formerly supported chestnut. In the absence of deer browsing, 5-foot tree shelters, vented or unvented, and 2.5-foot tree shelters, had no significant advantage over unsheltered treatments for seedling height after three field seasons. However, tree shelters were absolutely critical where deer browsing was frequent. 1-0 nursery stock did not grow significantly better than older 1-1 stock beyond the first field season, indicating that the extra year in the nursery was not necessary. Container size had no significant effect on growth rate. Planted seedlings competed well when natural regeneration was reset to ground level mechanically. Height and survival were unacceptably low for successful regeneration in all site evaluation trials, probably because of our inexperience in direct-seeding this species and intentionally casual approach to controlling competition and access by deer.

Keywords: direct-seed / container stock / nursery stock / tree shelter / regeneration / browse / transplant / seedlings / reforestation / restoration

INTRODUCTION

Field planting methods for American chestnut were examined to develop guidelines for the anticipated establishment of blight-resistant hybrid American chestnut into Appalachian forests. Much of what is known about American chestnut silviculture and regeneration ecology is derived from observations and studies that were carried out before the blight and the advent of forestry research as we now know it. Prior to the blight (*Cryphonectria parasitica*), American chestnut was found on gentle to steep slopes in mixtures with pines, oaks, and other hardwoods. The species avoided limestone-derived soils or bottoms with wet, cold, or shallow soils (Buckhout 1896, Zon 1904). Much of the reproduction was of coppice origin as most nuts were consumed by wild animals, livestock, and man (Buckhout 1896, Zon 1904). Seedlings that were able to germinate grew rapidly and formed long, vigorous, and wide spreading root systems similar to oak (Toumey and Korstian 1931). Regeneration was likely favored by widespread clearcutting and wildfires as chestnut was not as shade tolerant compared with beech, maple, and other potential competitors (Toumey and Korstian 1931).

Based on the authors' experience with oak, a relative of chestnut, trials were established to examine planting methods previously used for oak with the assumption that the results would be similar. Three trials were performed: 1) a direct-seed tree shelter test, 2) a containerized/nursery stock test, and 3) a site evaluation test.

STUDY ONE

Protection from white-tailed deer (*Odocoileus virginianus*) is essential to establishing healthy forest seedlings in many parts of central Appalachia. When valuable disease-resistant American chestnut genotypes become available as planting stock for restoration, extraordinary protection measures such as use of fencing or tree shelters will be warranted. Tree shelters are relatively effective in protecting seedlings from deer until the tree grows above the deer browse line. The shelters also purportedly provide favorable growing conditions by moderating environmental extremes. However, shelters reduce light intensity, physically limit display of leaves to sunlight, and can increase temperatures around the seedling. Tree shelters often induce seedlings to grow faster in height than in diameter, and the resulting trees are typically spindly and susceptible of falling over if not supported. Shelters can have warmer internal temperatures compared to ambient conditions, which can accelerate bud break in the spring or delay hardening-off in the fall rendering trees susceptible to frost damage or winter injury. To prevent this, Tree Pro (West Lafayette, Indiana), a manufacturer of tree shelters, produces a vented shelter designed to maintain cooler temperatures and thus allow the seedling to acclimate more normally in autumn.

In 1997, a planting of direct-seeded American chestnut was established at Stone Valley (SV), The Pennsylvania State University's Experimental Forest in Huntingdon County, Pennsylvania. The test was designed to measure the effect on height growth of vented and unvented, five-foot-tall tree shelters (Tree Pro) vs. no tree shelter. For tree shelter treatments, American chestnut seed (obtained from Philip Lunde, Galesville, Wisconsin) was planted 1 inch below the soil surface and a vented or unvented tree shelter was erected over the planting spot. Shelters were pressed into the soil 1 in. Seeds for the unsheltered treatment were planted only within a seed protector, a 6 in. long piece of pre-split 1 in. diameter PVC pipe inserted into the ground to inhibit seed predation by small mammals. Fifty American chestnut seeds were planted for each treatment in a randomized complete block design. The study was established in a recent shelterwood harvest area (50 percent basal area removed) and a six-strand electric fence was erected around the entire site to provide protection from deer. Fortunately, this area has a very low deer population, and the need for protection from deer was minimal. Nonetheless, fencing allowed for a comparison of the shelters' effects on chestnut seedling growth without potential confounding from the effects of deer browsing. Native chestnut sprouts occur immediately next to the study area, so the site may be considered suitable for this species.

As anticipated, seedlings were significantly taller ($P<0.05$) in shelters compared to those left unsheltered for the first two years, but there was no statistical difference in height between the types of shelter in any year. Trees with no shelter began to catch up during the third growing season, to the point that there was no significant difference between treatments, but their mean height was still lower by about one foot compared to the sheltered treatments. Over the next three years, unsheltered trees became substantially taller than sheltered seedlings, although not significantly so, by nearly one, two, and three feet for each respective year. Certainly had there been deer pressure at this site unsheltered trees would have had much more difficulty in getting established and growing beyond the deer-browse line. After seven years of growth, the average heights are 21.1, 17.7, and 15.1 feet for unsheltered, vented-shelter, and unvented-shelter trees, respectively, and the tallest tree is 29.2 feet (unsheltered). This confirms the excellent suitability of this site for chestnut growth, not to mention the rather startling potential of this species to grow well in forest plantations. Blight is beginning to appear in the plantation.

A replicate test was begun in 1998 at the SV site and at a site in Tuscarora State Forest (TSF), about 70 miles south in Perry County, Pennsylvania. However, bears continually ravaged the SV planting by tearing apart the shelters, and data collection was discontinued in 2002 because the plantation was too disrupted to provide meaningful results. Fortunately, the bears concentrated their efforts in this replicate and did minimal damage to the adjacent 1997 trial. The TSF site differed primarily in the amount of sunlight reaching the trees, as this plantation was established in a clearcut (rather than a shelterwood). This site also had an electrified fence, but the fence was largely ineffective and there was very heavy deer browsing on vegetation within the fence.

As in the 1997 SV test, initial heights at TSF were greater with tree shelters than without, and there was no significant difference in mean height between shelter types until after the fifth growing season when the trees had grown well above the tops of the shelters and trees in vented shelters were taller. In sharp contrast to the SV test, trees without shelters at TSF have never grown past competing vegetation or above the height of deer because of continual deer browsing. After six years of growth, the average heights are 2.2, 14.8, and 12.9 feet for unsheltered, vented-shelter, and unvented-shelter trees, respectively. The sheltered treatments are on par with parallel treatment means at SV of the same age.

The results of this study show that shelters do not benefit, and may even retard, the growth of American chestnut in forest plantations in the absence of deer pressure . Where deer were abundant, five-foot tree shelters were far more advantageous than no protection. No significant difference in growth was detected between trees in vented as opposed to unvented tree shelters.

STUDY TWO

While direct seeding will likely be the most efficient and cost-effective planting method for reestablishing chestnut into the central Appalachian forests, planting seedlings ensures higher survival rates per seed and permits greater control over final tree placement. Transplanted seedlings may also be competitively superior against the understory vegetation often encountered on forest sites.

Evaluations of the performance of containerized and nursery stock were performed at the SV and TSF sites adjacent to the previously mentioned direct-seeded, tree-shelter studies. The purpose of this study was to compare the growth of seedlings grown in two sizes of containers and raised in a greenhouse for three months (mid-February thru mid-May) and seedlings that had been grown under standard forest nursery conditions at a nearby Bureau of Forestry nursery for one or two years. The large and small containers measured 10 inches in length by 2.5 inches in diameter (40 cu. in.) and 8.25 inches in length by 1.5 inches in diameter (10 cu. in.), respectively. One hundred of each type of containerized stock was planted at each site, half of which also had a 2.5-foot shelter for limited deer protection. The nursery stock consisted of 20 each of 1-0 and 1-1 (one year in seedbed, one year in transplant bed) stock at each site. All seeds were obtained from the same source as the previous study. Each site was established in a completely randomized design in early- to mid-May of 1999. Existing vegetation was cleared to the ground with a brush cutter in an effort to reset competition. An auger with a 4-inch bit was used to plant the seedlings.

All planting stock transplanted well at both sites with better than 90 percent survival across all treatments and sites after two years in the field. More individuals began to die in the third year as other limiting factors (*e.g.*, deer pressure and competing vegetation) became increasingly severe.

At SV, heights of the 1-1 and 1-0 nursery-grown seedlings were significantly greater than those of younger, containerized seedlings after the first year in the field. There was no significant difference in height between 1-1 and 1-0 seedlings after two years in the field, which means that the extra year of growth in the nursery was not of practical advantage. The extra resources of the nursery-grown seedlings (initially larger root and shoot systems) were still providing a height advantage to those seedlings compared to the younger, containerized material through five field seasons. The only exception was the large-container / no-shelter treatment, which was not significantly shorter than seedlings grown from 1-0 nursery stock after the fifth year; mean heights after five growing seasons were 9.4, 8.2, and 6.5 feet for 1-1, 1-0, and large-container / no-shelter treatments, respectively.

Containerized stock at SV was fairly consistent in height across treatments through three field seasons, but by the end of the fourth season, seedlings grown without shelters began to outgrow their sheltered counterparts. The height advantage of unsheltered seedlings was statistically significant by age five. These results precisely mirror those of Study 1 with 5-foot tree shelters. After five years of growth, there was no significant height difference between seedlings started in different-sized containers and planted without shelters, but percentage survival was slightly higher with the seedlings that were started in the larger container (86 vs. 78 percent). In general, container-grown seedlings at SV have lagged in growth about a year behind the one-year-older 1-0 nursery stock, but not quite two years behind the two-years-older 1-1 stock.

At TSF the story was again vastly different due to significant deer pressure. While the nursery stock held height advantages over containerized material after the first growing season, 1-1 and 1-0 stock exhibited only meager growth in following years. Because all 1-1 and 1-0 seedlings were unprotected by shelters, the deer were able to continually browse new growth, and those seedling treatments have essentially failed at TSF. After five growing seasons, survival was only 40 and 45 percent for 1-0 and 1-1 nursery stock treatments, respectively.

Seedlings started in containers and provided with tree shelters have done better at TSF. Sheltered stock started in large containers have been taller than seedlings in other treatments since sometime in the second growing season, although sheltered seedlings started in small containers began to catch up by age five. However, with few exceptions, seedlings have never grown much beyond the height of the shelter itself (2.5 feet), and the mean height of all seedlings in shelters was only 3.3 feet after five field seasons. In addition to the deer pressure, these seedlings had to contend with an abundant cohort of yellow-poplar seedlings that became established simultaneously with the installation of this study. Yellow-poplar is a famously competitive species on good sites, but some of the chestnut seedlings that managed to escape the deer are competing fairly well with the yellow-poplar, typically just behind them in height. We will continue to watch these with great interest.

Overall, this study shows that transplanting of both nursery and greenhouse-grown, containerized stock can be accomplished with great success, but only if deer browsing is not a factor. In the absence of browsing, planted American chestnut seedlings can compete well with surrounding natural regeneration through five field seasons if that regeneration is reset mechanically at the time of field planting. If deer browsing is not a factor, seedlings grow better without tree shelters than with. There appears to be no advantage to using 1-1 nursery stock, which is costly to produce and difficult to plant compared to 1-0 nursery stock.

STUDY THREE

In our latest phase of experimental chestnut plantings, we are examining the suitability for American chestnut of a range of native and relatively undisturbed forest sites by attempting direct-seeded establishment of chestnut plantations. The Pennsylvania Chapter of the American Chestnut Foundation provided seed for this study. Seven sites were established with 50 seeds each in 2001 and this was replicated in 2002. The sites vary in soil type, elevation, aspect, competing ground vegetation, and undoubtedly other important respects. All plantations were established in fenced areas that had recently been harvested, or in areas that were fenced to encourage regeneration where little vegetation existed due to over-browsing by deer.

Two of the sites were located approximately 80 miles south of State College, PA, in Tuscarora State Forest. "Eby Ridge" has a Hazleton extremely stony, sandy loam soil that consists of a deep, well-drained, strongly acid soil that formed under sandstone residuum. It sits on a south-facing slope at 1237 ft. It had little competing ground vegetation after the first year of establishment, but the 2001 trial later developed considerable hardwood competition. "Dead End Road" consists of the same soil type, but sits on the east side of a ridge top at 2026 ft. and has considerable competition with a thick carpet of *Vaccinium*. While this site is fenced, it still has a considerable presence of deer.

"Deep Hollow" is located approximately 40 miles east of State College in Bald Eagle State Forest. The soil type is delineated as Dystrochrepts bouldery great group, but it appears very similar in texture and stoniness to Hazleton. In fact, this site bears a very strong resemblance to Eby Ridge in most regards. Deep Hollow sits on a south-facing slope at 1302 ft. and had only a small amount of competing *Vaccinium* on the 2001 trial, but a greater density on the 2002 trial.

Four sites are located within Rothrock State Forest south of State College. "Galbraith Gap" has a Laidig extremely stony loam soil that consists of a deep, well-drained, strongly acid soil that formed under sandstone and siltstone alluvium. It sits on a south-facing slope at 1930 ft. and has a thick carpet of *Vaccinium*. Here again, although this is a fenced area, there is a considerable presence of deer. "Pine Swamp Road" has a Hazleton-DeKalb soil type very similar to the Hazleton series. It sits on an east-facing slope at 1442 ft. and has a thick carpet of hay-scented fern. "Owl Gap" has a Buchanan extremely stony loam soil that consists of a very deep, moderately well-drained, slowly permeable, very strongly acid soil. Buchanan series soils formed in colluvium on mountain footslopes, sideslopes, and in valleys that were weathered from acid sandstone, quartzite, siltstone, and shale. It sits on a north-facing slope at 1403 ft. and has a thick carpet of hay-scented fern. "Spruce Mountain" also has a Buchanan soil type. It sits on a south-facing slope at 1593 ft. and has some competition with grasses, forbs, and regenerating sassafras and red maple.

All sites were mechanically cleared before planting with a brush cutter to reset competing vegetation. Radicles had emerged from most seeds while in storage and were cut back to facilitate planting in seed protectors (described above) that were used for protection against small mammals. The competition described above was present at the time of data collection in late September 2001 and was similar through 2003.

<u>2001 Trial</u>

After three years in the field, seedlings at Owl Gap were tallest (20.0 inches) and had the best survival (66 percent) compared to the other sites. Spruce Mountain was second best in height (17.4 inches), but ranked last in survival (26 percent). Eby Ridge and Deep Hollow were close behind in height (15.4 and 15.0 inches, respectively), but had lower survival (38 and 47 percent, respectively). The rapid reemergence and density of the hay-scented fern at Pine Swamp Road seemed to be too much for the chestnut seedlings to develop much height (7.5 inches) while survival slowly declined to 46%. Finally, the intensity of deer browsing at Dead End Road and Galbraith Gap made the growth and survival of any edible plant almost impossible, so work at these two sites was discontinued. However, growth was unacceptably poor at *all* sites, and even the best survival rate (66 percent) is borderline by our standards of a successful forest plantation.

2002 Trial

Owl Gap, Eby Ridge, and Spruce Mountain had the tallest trees (20.0, 18.7, and 14.0 inches) at the end of the second year. Mean seedling height at Deep Hollow was substantially less (9.4 inches), and the seedlings under the dense hay-scented fern cover at Pine Swamp Road reached a mean height of only 5.5 inches. Mean heights after two years in the field in this trial were similar to mean heights after three years in the field in the 2001 trial, but no site is exhibiting the growth that chestnut is capable of. Survival at all sites was unacceptably poor, with Owl Gap having the highest at only 48 percent.

These trials are still in their infancy, and our methods need to be refined until we can get better survival and more acceptable early height growth. Other than deer browsing, competing vegetation appeared to be one of the greatest factors affecting height at all sites, and resetting it mechanically back to the ground level apparently did not give direct-seeded chestnut sufficient early advantage for successful establishment. These plantations would have been failures if the goal had been to restore American chestnut to these sites. Plans to continue these studies with additional trials utilizing chemical control of competition and planted seedlings are underway.

CONCLUSIONS

After examining several planting methods we still believe direct seeding will be the most efficient and economical method of reestablishing American chestnut when large numbers of seed become available, if competition and deer browsing can be adequately controlled or avoided, as these appear to be absolutely critical factors when planting chestnut from seed. The growth and survival of seedlings at SV in Study 1 demonstrate the remarkably vigorous potential of American chestnut in forest plantations, but the failures at TSF and in Study 3 show that this potential is fragile if conditions are not right. With a small amount of seed or available land area, one may well chose to use either bareroot or containerized nursery stock to ensure greater survival. We found 1-0 nursery stock to be just as good as 1-1, thus there is no real need for the extra year at the nursery. Containerized material had an excellent success rate but was costly to produce.

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