Continued Monitoring of American Chestnut Restoration Sites on Surface Mined Land in Kentucky – Final Report

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Narrative: The use of reclaimed surface mines for chestnut reestablishment has gained considerable attention as OSMRE continues to promote the Forestry Reclamation Approach (FRA). Numerous reasons for planting chestnuts on fresh mine spoils have been presented by the University of Kentucky and include: high survival and growth for native hardwoods on loose-dumped mine spoils, light and soil chemical characteristics that are similar to higher elevation and ridgetop positions where chestnuts were dominant, loose mine spoils are initially devoid of vegetative competition, and fresh mine spoils may initially be devoid of pathogenic microbial communities such as Phytophthora, which have hindered TACF's breeding and restoration efforts elsewhere. Also, the Appalachian coal region falls almost entirely within the natural distribution of American chestnut. If loose mine spoils prove conducive to chestnut survival and growth, then the establishment and dispersal from founder populations of blight resistant hybrids throughout the range of the Appalachian coal region would aid TACF's goal of restoring the chestnut throughout its range (French et al., 2007).

In Kentucky, research to evaluate the suitability of loose mine spoils in the Appalachian coal region for chestnut establishment began in 2006. Pure American chestnuts, Chinese chestnuts and various TACF backcross seedlings were tested at the Bent Mountain Mine (Appalachian Fuels) in Pike County, Kentucky and other locations in Kentucky and West Virginia to serve as proxies for the true-breeding blight resistant backcrosses. We planted container-grown seedlings into differing types of spoil material to determine which parent material fosters the best growth and survival. Studies are also underway to evaluate the influence of spoil type on the presence of pathogens such as Phytophthora. Silvicultural methods that may optimize chestnut growth and survival are also being examined by my group. Forest establishment techniques such as the use of tree shelters to deter seed predation and herbivory, the use of bare root versus containerized seedling establishment and use of technologies for controlling herbaceous competition are being examined. Thus far, survival and growth have been good and some very interesting information pertaining to spoil suitability, Phytophthora viability, and reforestation techniques in mine spoils have been generated from these studies. Funding for this project allowed for continued monitoring of these sites and development of useful information for TACF, OSM, and citizens of Appalachia pertaining to the return of the mixed mesophytic forest that once dominated these lands and its dominant species – the American Chestnut.

The Bent Mountain Study

Since late 2003, the University of Kentucky has been engaged in the on-going installation of a reforestation research complex on an active mountaintop removal operation located on Bent Mountain on Brushy Fork near the community of Meta in Pike County, Kentucky (latitude N 37° 35′ 49″, longitude W 82° 24′ 19″) (Figure 1).

Figure 1. Aerial photograph of the surface mine and reforestation research complex at Bent Mountain in Pike County, Kentucky taken in October 2007.

The operator of the mountaintop removal operation is Appalachian Fuels. This mine is located in Kentucky's eastern coalfield in the Cumberland Plateau physiographic region and is predominately forested. Climate is temperate humid continental with average annual precipitation of 114 cm, and an average monthly precipitation of 10 cm, which ranges from 6-12 cm. Average temperature is 13° Celsius, with a mean daily maximum and minimum of 31° and 18° in July and 8° and -4° in January (Hill, 1976). The mine is within the Hazard Coal Reserve District as delineated by the U.S. Geological Survey (Huddle et al., 1963). Ultisols are the predominant soil order in the area (USDA, 1998). The soil series at the study site is Dekalb, which are typically on upper side slopes and ridges (Hayes, 1982).

The geologic unit that is affected by surface mining in the Bent Mountain area is the Lower and Middle Pennsylvanian (Carboniferous, 318.1-306.5 Ma) Breathitt Formation. The formation consists of interbedded sandstone, siltstone, shale and coal. Sandstone, shale and siltstone, in that order, are the most abundant rock types. In general, the sandstone is light gray, massive, fine to medium grained, and weathers to a yellowish or reddish brown. The shale is dominantly medium gray, silty, and contains siderite nodules (Wolcott and Jenkins, 1966). Strata exposed in the area rise 3 degrees southeast due to the Pine Mountain Fault, located to the southeast. To the northwest the same strata and coal seams may be 60 meters lower due to the overthrust. The formation contains over seven coal seams that are being mined.

Spoil Placement and Planting:

Research plots were established in March 2008 on Bent Mountain for the purpose of evaluating chestnut performance on end-dumped spoil. The spoil was predominately brown weathered sandstone. Spoil was dumped out of the end of the dump trucks ("end-dumped") into piles that average about 3.5 m in height. The piles were placed in parallel rows in such a way that they closely abutted one another across a 4-acre site. The tops of the spoil piles were then "struck-off" with one pass of a bulldozer (Caterpillar D9, straight blade) down the length of each parallel ridge of spoil, pushing it into the parallel valleys on both sides. The one pass with the bulldozer cut the piles down in elevation by about 1 m, which resulted in the final average height of the piles to be about 2.5 meters. Spoil placement conformed to specifications in Reclamation Advisory Memorandum Number 124 (RAM 124) issued by the Kentucky regulatory authority (KDSMRE, 1997) and OSMs Forest Reclamation Advisory #2 (Burger et al., 2006).

Establishment Plots:

Thirty plots were established on the end-dumped site at Bent Mountain in 2008. Each plot was 10 x 10-m in size and planted with 25 chestnuts. Five chestnut genotypes were used in the study: American, Chinese, B1-F3, B2-F3, and B3-F2. Each species was examined with and without the use of tree shelters to examine whether or not seed predation was problematic on these sites (Figure 2). Treatments were randomly assigned to a plot location and were replicated three times. As such, 150 chestnuts were required for each genotype giving a total of 750 nuts for the study.

At each planting location a ≈ 3" deep hole was prepared using a dibble or shovel. A teabag of fertilizer (Treessentials, Duluth, MN) was placed in the bottom of the hole and covered with 1-2 inches of planting mix (Scotts® general potting medium). The teabag was a 10 gram biodegradable planting packet containing a blend of: 16.00% Total Nitrogen, 6.00% Available Phosphoric Acid, 8.00% Soluble Potash and trace elements consisting of 6.92% Combined Sulfur, 0.52% Zinc, 0.54% Iron, 0.54% Magnesium, 0.26% Copper, 0.05% Boron, and 0.56% Manganese.

Each chestnut was placed on the planting mix, roots down, and covered with an additional inch of planting mix. Chestnuts on sheltered plots were protected with 2-foot tubex® shelters that are anchored to the ground with white oak stakes, following the manufacturer's instructions.

Plot Designation

Type	Shelter	No-Shelter
Chinese	1, 13, 28	20, 14, 30
American	2, 5, 25	8, 12, 23
B1F3	10, 17, 24	9, 22, 27
B2F3	7, 11, 19	15, 16, 29
B3F2	4, 21, 26	3, 6, 18

Figure 2. Randomly assigned treatment designation for the 2008 study.

Survival and Growth Measurements:

Tree height was recorded in August of each year. Notes were also taken in regards to plant health (vigor, dieback, herbivory). Percent survival was calculated by comparing the number of trees alive in the following year with the number of nuts planted in 2008. Species and shelter effects on seedling height were determined using analysis of variance for a factorial completely randomized design with PROC GLIMMIX (SAS, 1999). Survival data of the seedlings were analyzed with repeated measures logistic regression models (PROC GENMOD). The models included all main effects and two-way interactions, with survival as the dependent variable, and treatments as the independent variables. Probabilities of seedling survival were calculated by back transformation of the least-squares mean (LSM) from the logistical models $(e^{LSM})/(1 + e^{LSM})$. A Chi-square analysis (a = 0.05) was used given that data were not normally distributed due to the reduced sample size associated with herbivory in the unsheltered plots.

Results:

Germination was calculated as the percentage of seeds which sprouted, and ranged from 77-84 percent for all five genotypes when sheltered and 1-12 percent when not sheltered (Table 1). There were no main effects of genotype for germination percentage, but there was a significant shelter effect (Table 1). The data by revealed no genotype effects within sheltered or unsheltered chestnuts, but all five types had a significant shelter effect (p = <0.0001).

Survival was calculated as the percentage of chestnuts planted which had not died by the end of the growing season, including those which did not germinate (Table 1), and was lower for all genotypes when compared to germination. There was a significant shelter effect on all genotypes (<0.0001), but no main effect across all chestnuts types. Among sheltered trees the pure American chestnut had the lowest survival (54%), while all other types were similar (64 to 74%). Among plots where chestnuts were not sheltered, there were no differences among genotypes in survival rates, which ranged from 1-10 percent.

When height (cm) was measured, the differences between genotypes became clearer. Like germination and survival, there was a significant main effect of sheltering the trees. The B1F3 line had significantly more height growth than the other backcrosses and pure American lines. Chinese chestnut heights were similar to all other lines examined Mean heights ranged from 60 to 73 cm among sheltered, and 16 to 33 cm among unsheltered chestnuts.

Table 1: Mean height, percent germination, and percent survival of the five chestnut genotypes after **2008 growing season.** *

Genotypes	Germination		Survival		Height**	
	Shelter	No Shelter	Shelter	No Shelter	Shelter	No Shelter
	---------------%		---------------%		-------cm	-------
American	82 ± 10	12 ± 13	54^{b} ± 8	10 ± 11	**60^{b} ± 19**	**24 ± 17**
B1F3	77 ± 6	6 ± 8	69^{a} ± 6	5 ± 6	**73^{a} ± 18**	**27 ± 15**
B2F3	77 ± 15	1 ± 2	64^{a} ± 18	1 ± 2	**60^{b} ± 18**	**33 ± x**
B3F2	84 ± 12	6 ± 2	65^{a} ± 2	4 ± 4	**63^{b} ± 16**	**16 ± 9**
Chinese	78 ± 9	6 ± 11	74^{a} ± 10	6 ± 11	**66^{ab} ± 19**	**26 ± 8**
	---------- p values ----------					
Genotype	0.6862		0.8274		**0.8011**	
Shelter	<0.0001		<0.0001		**<0.0001**	
Interaction	0.9625		0.2887		**0.5747**	

* Mean height, germination percent, survival percent ± standard deviation

** Least sig. differences (α = 0.05) of sheltered species represented by superscripts.

Between 2009 and 2012 survival in the sheltered plots showed slight declines (5 – 27% reduction) in all genotypes except American which exhibited a dramatic reduction of 52% (Tables 2-5). Survival in the unsheltered plots was < 10% for all genotypes. By 2012 survival ranged from a high of 7% for Chinese to complete mortality for the B3F2 genotype. Throughout the 2009-2012 monitoring period seedling heights of the various genotypes in the sheltered treatments increased by an average of 28 cm per year with B2F3 exhibiting the least height growth (22 cm) and Chinese showing the most (32 cm). However, by the end of 2012 there was no significant difference in height for any of the sheltered genotypes. The unsheltered plants that germinated and survived did exhibit some height growth over the study period, but it was statistically lower than that observed for the sheltered treatments for each year of the project. Survival and height of the unsheltered trees showed irregular patterns as several trees experienced dieback and resprouted the following year (Figures 3 and 4).

Table 2: Mean height, percent germination, and percent survival of the five chestnut genotypes after **2009 growing season.** *

	Survival (%)		Height (cm)**	
Genotypes	Shelter	No Shelter	Shelter	No Shelter
American	$50^{b} \pm 10$	6 ± 4	**$97^{b} \pm 25$**	**76 ± 34**
B1F3	$69^{a} \pm 6$	2 ± 2	**$107^{a} \pm 24$**	**60 ± x**
B2F3	$58^{a} \pm 15$	0 ± 0	**$102^{ab} \pm 24$**	**0 ± 0**
B3F2	$60^{ab} \pm 4$	2 ± 4	**$104^{ab} \pm 20$**	**32 ± 12**
Chinese	$68^{a} \pm 13$	6 ± 11	**$108^{a} \pm 25$**	**61 ± 23**
p values				
Genotype	0.6178		**0.4788**	
Shelter	<0.0001		**0.0001**	
Interaction	0.2228		**0.1021**	

* Mean height, germination percent, survival percent ± standard deviation
** Least sig. differences (α = 0.05) of sheltered species represented by superscripts.

Table 3: Mean height, percent germination, and percent survival of the five chestnut genotypes after **2010 growing season.** *

Genotypes	Survival (%) Shelter	Survival (%) No Shelter	Height (cm)** Shelter	Height (cm)** No Shelter
American	$42^{b} \pm 20$	6 ± 5	**$129^{b} \pm 29$**	**93 ± 25**
B1F3	$65^{ab} \pm 5$	0 ± 0	**$137^{ab} \pm 27$**	**0 ± 0**
B2F3	$57^{ab} \pm 16$	0 ± 0	**$129^{b} \pm 32$**	**0 ± 0**
B3F2	$57^{ab} \pm 2$	1 ± x	**$135^{ab} \pm 28$**	**59 ± x**
Chinese	$72^{b} \pm 10$	8 ± 14	**$148^{a} \pm 44$**	**75 ± 30**
<u>p values</u>				
Genotype	0.3534		**0.6157**	
Shelter	< 0.0001		**<0.0001**	
Interaction	0.0591		**0.2039**	

* Mean height, germination percent, survival percent ± standard deviation
** Least sig. differences (α = 0.05) of sheltered species represented by superscripts.

Table 4: Mean height, percent germination, and percent survival of the five chestnut genotypes after **2011 growing season.** *

Genotypes	Survival (%) Shelter	Survival (%) No Shelter	Height (cm)** Shelter	Height (cm)** No Shelter
American	$28^{b} \pm 17$	8 ± 7	**$167^{a} \pm 27$**	**105 ± 35**
B1F3	$59^{ab} \pm 13$	0 ± 0	**$159^{ab} \pm 33$**	**0 ± 0**
B2F3	$52^{ab} \pm 13$	0 ± 0	**$144^{b} \pm 36$**	**0 ± 0**
B3F2	$48^{ab} \pm 7$	1 ± x	**$161^{ab} \pm 37$**	**59 ± x**
Chinese	$71^{a} \pm 20$	8 ± 14	**$174^{a} \pm 48$**	**94 ± 45**
<u>p values</u>				
Genotype	0.4251		**0. 2160**	
Shelter	< 0.0001		**<0.0001**	
Interaction	0.6636		**0.5645**	

* Mean height, germination percent, survival percent ± standard deviation
** Least sig. differences (α = 0.05) of sheltered species represented by superscripts.

Table 5: Mean height, percent germination, and percent survival of the five chestnut genotypes after **2012 growing season.** *

Genotypes	Survival (%) Shelter	Survival (%) No Shelter	Height (cm)** Shelter	Height (cm)** No Shelter
American	$26^{b} \pm 15$	5 ± 6	**183 ± 45**	**106 ± 46**
B1F3	$60^{ab} \pm 7$	1 ± x	**174 ± 46**	**100.0 ± x**
B2F3	$54^{ab} \pm 18$	1 ± x	**150 ± 46**	**130 ± x**
B3F2	$41^{ab} \pm 8$	0 ± 0	**178 ± 58**	**0 ± 0**
Chinese	$70^{a} \pm 14$	7 ± 11	**196 ± 63**	**115 ± 30**
p values				
Genotype	0.2648		**0.9489**	
Shelter	< 0.0001		**0.0034**	
Interaction	0.1118		**0.7799**	

* Mean height, germination percent, survival percent ± standard deviation
** Least sig. differences (α = 0.05) of sheltered species represented by superscripts.

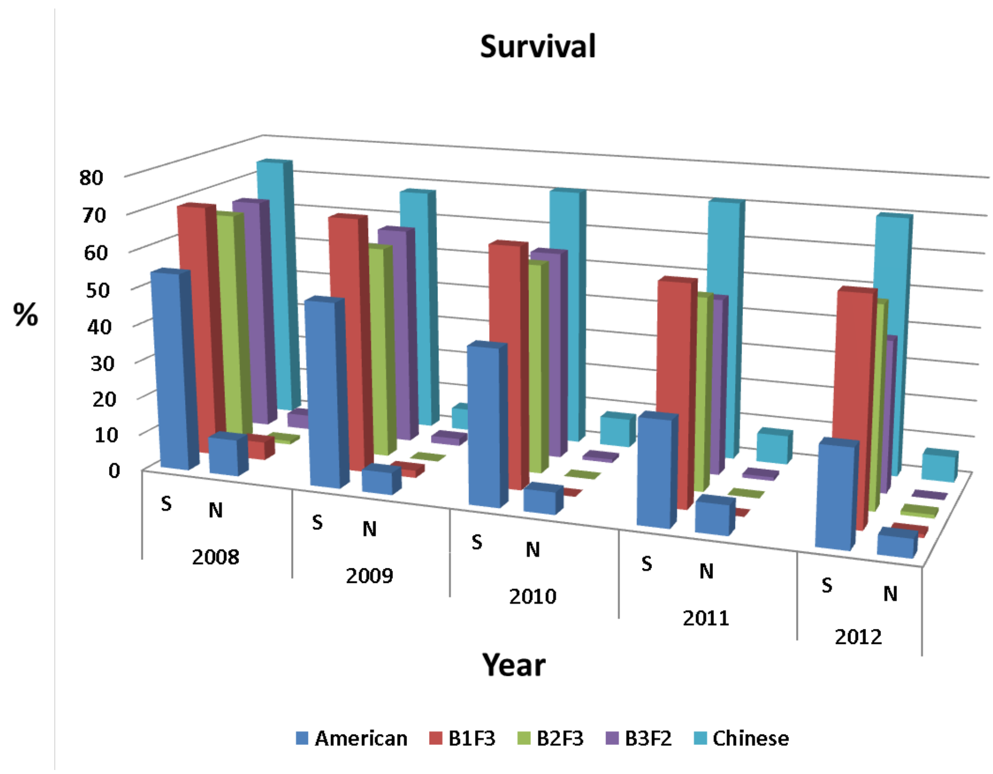


Figure 3. Survival of chestnut genotypes in sheltered (S) and unsheltered treatments (N) at the Bent Mountain surface mine in Pike County, KY.

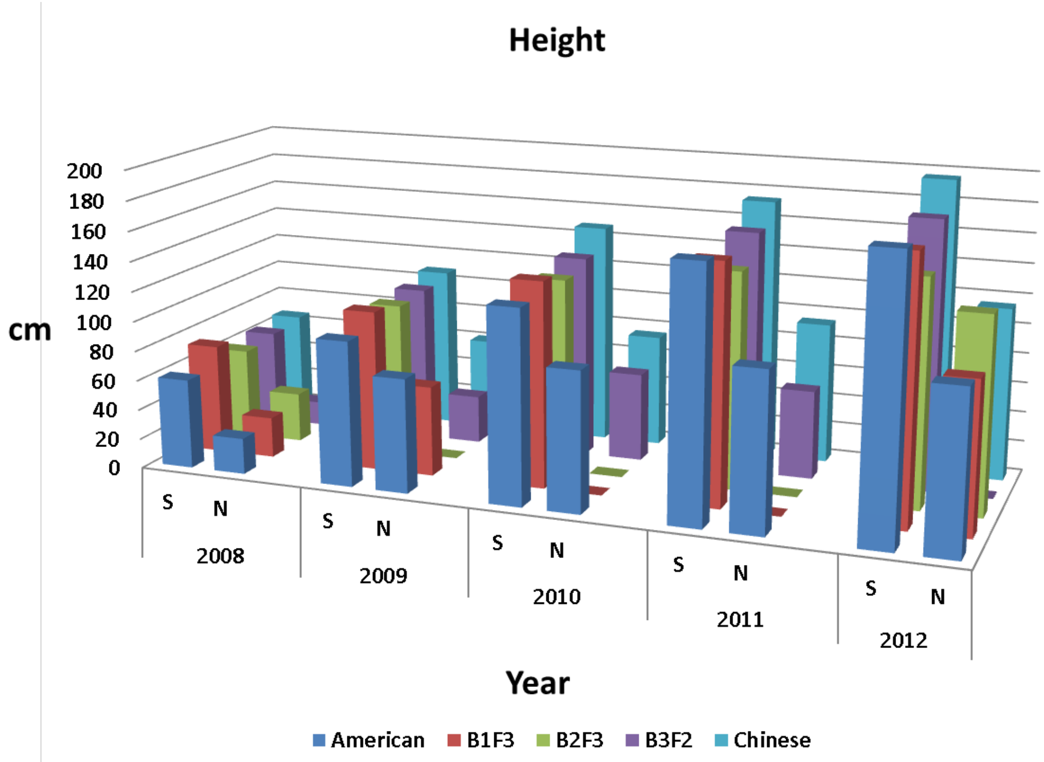


Figure 4. Height of chestnut genotypes in sheltered (S) and unsheltered treatments (N) at the Bent Mountain surface mine in Pike County, KY.

Discussion:

After a five year monitoring period, the utility of using tree shelters for direct seeded chestnuts on loose-dumped spoil was clearly demonstrated. The unsheltered seed was likely predated by rodents. By 2012 the differing chestnut genotypes in the sheltered treatments exhibited some variability with regards to survival, but all three backcrosses were statistically similar to that of the Chinese which had the highest survival rate. The American genotype exhibited the lowest survival rates. Although there were some differences with respect to survival, the live saplings on the site in 2012 exhibited similar heights regardless of genotype, suggesting that the growth medium was suitable for all chestnut varieties and that mine spoils could be useful in future restoration efforts..

Small mammals are an important part of terrestrial ecosystems and drive a variety of ecosystem processes. Small mammals serve as prey for a variety of mammalian, avian, and reptilian predators (Mindell, 1978; Yearsley and Samuel, 1980). As such, their return to post-mining landscapes should be an important biodiversity consideration for reclamation. However, small mammals can also negatively modify plant community composition and species distribution through foraging and burrowing (Hole, 1981; Siege, 1988). Their roles as seed predators, herbivores, detritivores, and seed dispersers have been shown to affect plant distribution and succession on surface mine lands (Chamblin 2002). Bramble and Sharp (1949) observed seed predation by White-footed Mice

(*Peromyscus leucopus)* causing failed Northern Red Oak (*Quercus rubra*) establishment on Pennsylvania surface mines. More recently, a study showed that White-footed Mice and other small mammals prefer loose-dumped reforested landscapes over those reclaimed using traditional approaches due to the abundance of crevices formed between large rocks (Larkin et al., 2008).

The benefits of shelters on our site were obvious, with shelters being significant for all chestnut types for germination, survival, and height. Nuts could not be found within many of the unsheltered holes, which support the hypothesis that mice and other wildlife are foraging on the nuts (West et al., 1999; Strange and Shea, 1998; Conner et al., 2000; Dubois et al., 2000). Although the long-term viability of chestnuts on this site cannot be evaluated at this time, it is clear that the use of shelters is essential if direct seeding methods are to be utilized in future planting efforts.

The Legacy Mineland Study

The use of surface mines for American chestnut reestablishment is gaining acceptance as numerous successful reforestation projects, following the Forestry Reclamation Approach (FRA), have been demonstrated on mine lands across Appalachia. American chestnut (*Castanea dentata*) was formerly the most important hardwood species throughout the forests of eastern North America, but introduction of an exotic fungal blight (*Cryphonectria parasitica*) in the early 20th century decimated C. dentata populations. The American Chestnut Foundation has been working to develop blight-resistant chestnut backcrosses that may soon be available for widespread distribution. To ensure a successful reintroduction, information on site requirements, establishment, and growth of American chestnut is needed. Surface mine spoils in the Appalachian coal region have been suggested as potential sites for the establishment of founder populations of blight-resistant chestnut hybrids which may then act as reservoirs for chestnut dispersal into surrounding forests.

Numerous reasons for planting chestnuts on fresh mine spoils have been presented and include: high survival and growth on loose-dumped mine spoils, light and soil chemical characteristics that are similar to higher elevation and ridgetop positions where chestnuts were dominant, loose mine spoils are initially devoid of vegetative competition, and fresh mine spoils may initially be devoid of pathogenic microbial communities such as Phytophthora, which have hindered restoration efforts elsewhere. Also, the Appalachian coal region falls almost entirely within the natural distribution of American chestnut (Barton et al., 2010). Even though initial success has been demonstrated on fresh spoil FRA sites (see above Bent Mountain Study), little information exists on the success of chestnuts on post-bond release sites that were reclaimed as grasslands. Further, information on the effect of competition (herbaceous and herbivory) is limited. As such, a study was initiated with the following objectives:

1. *Evaluate the suitability of American chestnuts on ripped post-bond release mine sites*
2. *Examine the use of tree shelters for preventing herbivory (browse)*
3. *Examine the use of weed mats for controlling herbaceous competition*

4. *Evaluate the influence of shelters and mats on chestnut growth and survival*

Three post-bond mine lands in eastern Kentucky (Whitley, Perry and Morgan Counties) that were reclaimed as hay land pastures were dozer ripped and planted with bare-root 15/16 backcross chestnuts in 2010 (Figures 5 and 6). At each site, 25 chestnuts were planted in each of twelve plots that contained the following treatments (n=3): (1) control; (2) weed mats; (3) tree shelters; and (4) tree shelters plus weed mats (Figure 7). Seedling height and diameter were measure after planting and repeated again in 2011 and 2012. Herbaceous biomass and browse were assessed after the first and second year (2010 and 2011).

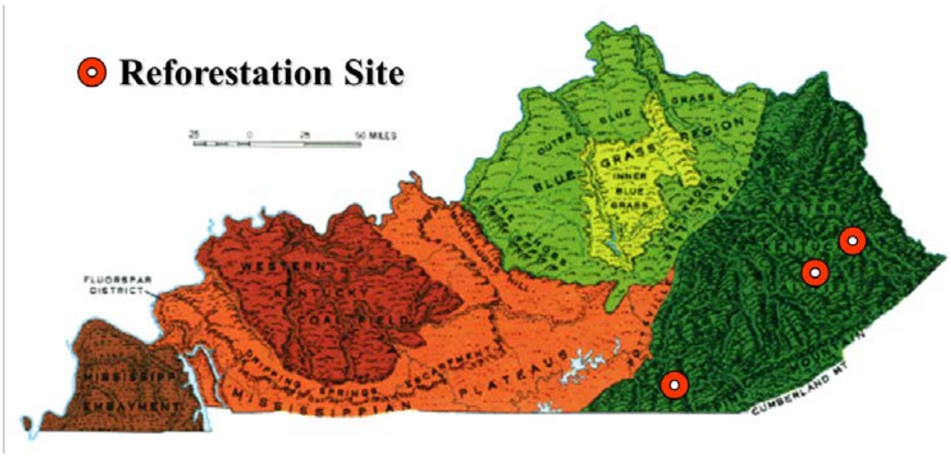


Figure 5. Location of chestnut planting sites in Whitley, Perry, and Morgan Counties (left to right) Kentucky.

Figure 6. Ripping of compacted grassland mine soil.

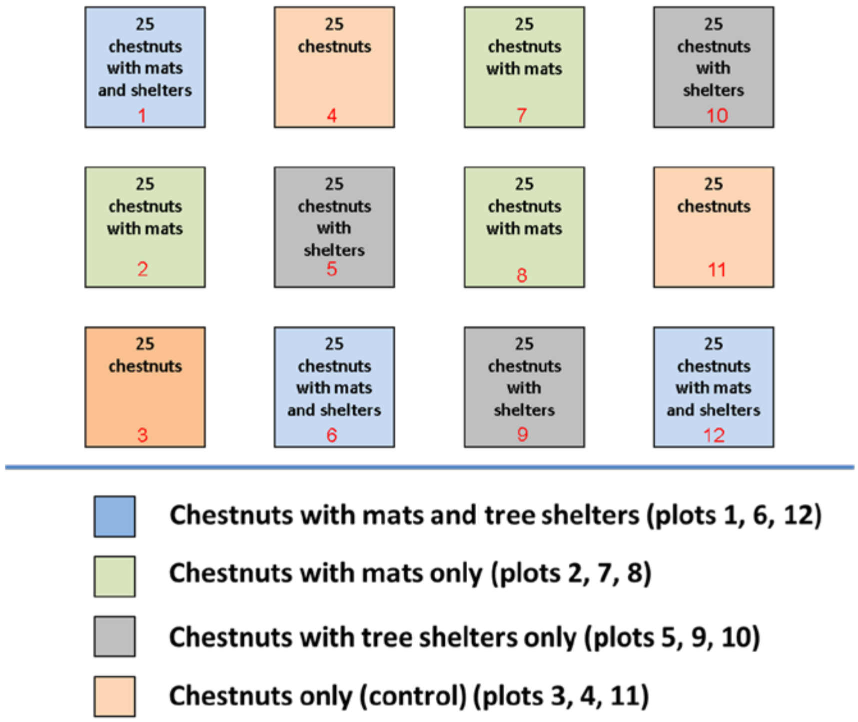
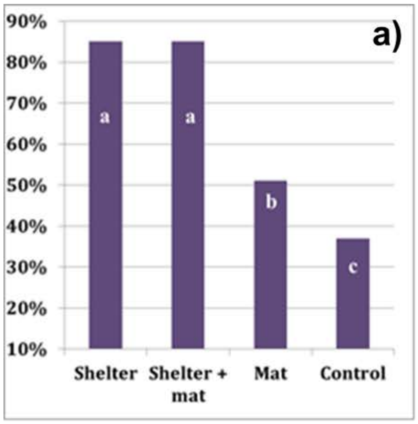


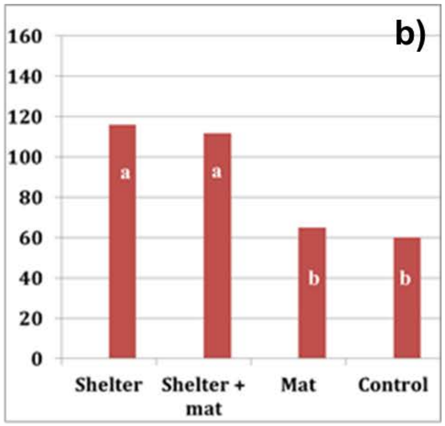
Figure 7. Experimental design for post bond release ripping study. Design was replicated at each site within eastern Kentucky.

Results:

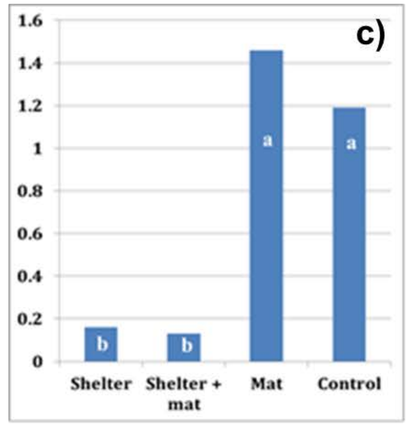
After two growing seasons, mean seedling survival was significantly higher in the shelter (85%) and shelter + mat (85%) treatments than the mat (51%) and control (37%) treatments (Figure 8a). Mean seedling height was also greater in the two shelter treatments (116 and 112 cm for shelter and shelter + mat, respectively) than the mat (65 cm) and control (60 cm) treatments (Figure 8b). Browse was moderate to heavy on the non-sheltered seedlings, while essentially absent on the sheltered plots (Figure 8c). Variation amongst sites existed, but was not radically different across the counties (Table 6). Perry County exhibited both the highest survival in sheltered plots and lowest in the non-sheltered treatments after two growing seasons.



Survival (%)



Height (cm)



Browse: 0 = none; 1 = light; 2 = moderate; 3= heavy; 4=severe.

Figure 8. Influence of shelter and mat treatments on mean American chestnut seedling survival a), height b), and browse c) in eastern Kentucky after two growing seasons.

Table 6. Year two (2011) seedling height, survival and level of browse by site and treatment.

Treatment	Height (cm)	Browse	Survival (%)
		Whitley County	
Shelter	126	0.30	65
Shelter + Mat	105	0.18	81
Mat	60	1.57	59
Control	67	1.31	52
		Perry County	
Shelter	111	0.06	99
Shelter + Mat	131	0.09	96
Mat	63	1.72	19
Control	44	1.25	8
		Morgan County	
Shelter	110	0.12	91
Shelter + Mat	100	0.09	79
Mat	71	1.07	76
Control	69	1.00	51

After 3 growing seasons, mean seedling survival had declined in all treatments but was still significantly higher in the shelter (65%) and shelter + mat (60%) than in the mat (40%) and control (27%) treatments (Figure 9a). Mean seedling height growth was limited between years 2 and 3 of the study (<20 cm for all treatments), but height was still greater in the two shelter treatments (124 and 127 cm for shelter and shelter + mat, respectively) than in the mat (67 cm) and control (78 cm) treatments (Figure 9b). Browse remained moderate on the non-sheltered seedlings, while low on the sheltered plots (Table 7).

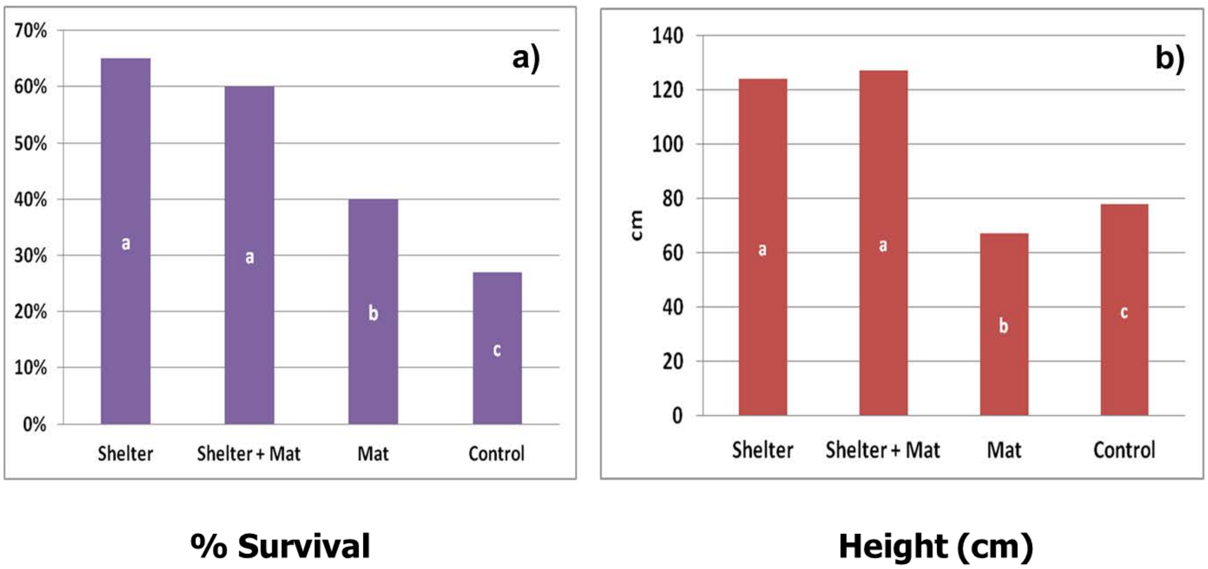


Figure 9. Influence of shelter and mat treatments on mean American chestnut seedling survival a), and height b) in eastern Kentucky after three growing seasons.

Variation amongst sites grew considerably with respect to seedling survival during the third growing season (Table 7). Perry County continued to exhibit both the highest survival in sheltered plots and lowest in the non-sheltered treatments after two growing seasons. Survival dropped across the board in Whitley County (32-37%) and treatments seemed to have little effect, possibly because browse pressure was low. Although browse seemed to influence both survival and height in Perry County, the effect was only noticeable on height in the Whitley and Morgan County sites.

Table 7. Year three (2012) seedling height, survival and level of browse by site and treatment.

Treatment	Survival (%)	Browse	Height (cm)
		Whitley County	
Shelter	33	0.28	138
Shelter + Mat	37	0.28	135
Mat	32	0.28	77
Control	33	0.88	104
		Perry County	
Shelter	98	0.07	111
Shelter + Mat	96	0.08	129
Mat	0.19	1.71	64
Control	0.08	1.83	67
		Morgan County	
Shelter	65	0.44	122
Shelter + Mat	47	0.66	117
Mat	71	1.45	65
Control	41	1.48	63

Discussion:

Reclaimed post-bond release surface mines provided an opportunity to examine the growth and survival of advanced backcross American chestnuts. Although early findings were promising, limited growth and high sapling mortality by 2012 at some sites may be attributed to browse and aggressive competition or due to stress from excessive heat and a prolonged drought that occurred during the summer of 2012. Seedling survival differed among the three sites. Perry County had the overall highest survival, notably in the two shelter treatments. Whitley County had the lowest survival, likely due to the very aggressive and competitive grasses at this site. Browse was highest in the control treatments among all 3 of the counties. Overall, browse was considered light to moderate. Whitley Co exhibited the overall greatest tree height, particularly in the shelter only treatment. The studies aim to evaluate the use of mats and shelters for maximizing reforestation success were mixed. The use of mats alone provided little benefit over that of the control and appeared to add little benefit when used in combination with shelters over what the shelter alone provided. As such, forest managers should consider all costs associated purchasing and installing these materials before implementing them in a field project. Shelters, on the other hand clearly show benefit with regard to seedling height and in some cases survivorship and are recommend in areas where browse pressure is high.

Published Works and Presentations:

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Angel, H, C.D. Barton and P. Angel. Third year survival and height growth of American chestnut on post-bond release surface mines in eastern Kentucky. 2013 National Meeting of the American Society of Mining and Reclamation, Laramie, WY Reclamation Across Industries, June 1 – 6, 2013.

Angel, H, C.D. Barton and P. Angel. Influence of weed mats and tree shelters on survival and height growth of American chestnut on post-bond release surface mines in eastern Kentucky. 2012 National Meeting of the American Society of Mining and Reclamation, Tupelo, MS Sustainable Reclamation June 8 - 15, 2012.

Barton C.D. Restoring Ecosystem Services on Surface Mines in Appalachia. Centre College Convocation; Danville, KY. October 18, 2011. (Chestnut work included)

Barton C.D. Restoring Ecosystem Services on Surface Mines in Appalachia. Midwest Ground Water Conference; Lexington, KY. September 20, 2011. (Chestnut work included)

Barton C.D. Green Forests Work for Appalachia. Presentation to Executive Staff of the Appalachian Regional Commission; Prestonsburg, KY. September 7, 2011. (Chestnut work included)
Barton C.D. Restoring Ecosystem Services on Surface Mines in Appalachia. USEPA Brownfields Conference; Philadelphia, PA. April 5, 2011. (Chestnut work included)

Barton C.D. Central Appalachia in Transition and the Need for Economic Revitalization. 2011 Good Jobs, Green Jobs National Conference; Washington, DC. Feb. 8-10, 2011. (Chestnut work included)

Barton C.D. Restoring Ecosystem Services on Surface Mnes in Appalachia. 2010 ASA-CSSA-SSSA Annual Meeting; Long Beach, CA. Nov. 1-4 (Chestnut work included)

Barton C.D., D. Graves, C. Agouridis, R. Warner, J. Stringer and P. Angel. Reforestation of Surface Mines in Appalachia. 17th Central Hardwood Forest Conference. Lexington, KY. April 5-7, 2010 (invited keynote presentation)

Barton C.D., C. Agouridis, R. Warner and P. Angel. Reforestation of Surface Mines in Appalachia. Forum on Coal in Kentucky. Lexington, KY. November 5, 2009 (invited)

Barton C.D. Green Forest Works for Appalachia. United Nations Environmental Programme – Billion Tree Campaign Press Conference. New York, NY. Sept. 21, 2009 (invited)

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Adank, K.M., C.D. Barton, M.E. French and P. DeSa. Occurrence of Phytopthora on Reforested Loose-Graded spoils in Eastern Kentucky. 2008 National Meeting of the American Society of Mining and Reclamation, Richmond, VA, New Opportunities to Apply Our Science. June 14-19, 2008.

Awards:

• American Society of Mine Reclamation, 3rd Place Student Poster Presentation; Received by Hannah Angel, 2013.

• American Society of Mine Reclamation, 1st Place Student Poster Presentation; Received by Hannah Angel, 2012.

• American Society of Mine Reclamation, 3rd Place Oral Presentation; Received by Michael French, 2007.

Media Coverage of Program (Selected):

The Lane Report

New Greenhouse Sprouts Learning Opportunities. June 20, 2012.

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Habitat Restoration at Flight 93 Memorial Site; US Fish and Wildlife; May 2012.
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Flight 93 Memorial Tree Planting; University of Kentucky, College of Agriculture; May 2012.
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