EFFECTS OF SEEDLING SIZE AND GROUND COVER ON THE FIRST-YEAR SURVIVAL OF PLANTED PINE AND HARDWOODS OVER AN EXTREME DROUGHT[1]

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Abstract: Poor growth and survival has been noted in tree seedlings planted into an existing ground cover. Such observations are ascribed to competition between root systems of ground cover and trees for water and nutrients. During drought, competition for water becomes intense and could result in mortality. Seedlings of shortleaf pine, green ash, northern red oak, and shagbark hickory were planted on twelve plots on a loosely graded ridge-top in eastern Tennessee that had been reclaimed and planted with native warm season grasses in 2006. Plots were planted in spring of 2007 with pine alone, hardwoods (ash, oak and hickory) alone, or alternating pine and hardwood seedlings. Planting was followed by an extreme and extended drought. In December of 2007, survival of shortleaf pine averaged 35%, while northern red oak averaged 95%, green ash 87%, and hickory 88%. Seedling size at time of planting was related to the probability of survival, with larger seedlings showing low mortality rates. Survival was greater on the northwestern facing slope, while seedlings on the southeastern slope had the greatest growth. Cover of native grasses at the time of planting ranged from 8 to 44%, but there was no clear relationship between ground cover density and seedling survival.

Additional Key Words: competition, *Quercus*, *Carya*, *Pinus*, *Fraxinus*

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Introduction

New guidelines for reclaiming coal-mined land to support forested land uses (Burger et al., 2005) recommend the placement of surface material with minimal compaction and the use of ground covers that are compatible with growing trees. Good survival rates have been documented on sites reclaimed using this Forestry Reclamation Approach (Emerson and Skousen, 2007), and forest productivity on these sites has the potential to exceed that of the undisturbed forest, as the growth rate of many tree species is related to soil depth (Burns and Honkala, 1990). However, herbaceous competition has been identified as a significant factor influencing tree survival and growth (Hughes et al., 1992; Ashby, 1992; Burger and Zipper, 2002).

Past reclamation practices have often utilized non-native ground cover species, some of which have been very successful in colonizing reclaimed sites but have also proven to be aggressive competitors of tree seedlings. Native species are preferable to exotic species in order to fulfill several of the long-term goals of reforestation, and compatibility between groundcover species and trees is also important for long-term success. Previous studies have shown that the survival of planted hardwood seedlings was greater in native warm season grass treatments than in ground cover mixes containing fescue (Rizza et al., 2007), and was greater in areas of moderate ground cover establishment. Only a small proportion of seedling mortality in that study could be explained by erosion, planting stress, or herbivory, and while the cause of mortality could not be determined, the largest proportion of mortality over the first two years of growth occurred over the summer months. Although ground cover competes with tree seedlings for moisture and nutrients, it also performs beneficial functions such as moderating temperature and evaporation at the soil surface, increasing the soil water holding capacity, retaining nutrients on the site, and promoting the re-establishment of nutrient cycling. Therefore, while moderate levels of ground cover are beneficial to forest establishment, they may also be detrimental when soil moisture or nutrient levels are below a certain level.

On the steep slopes of reclaimed minesites in Tennessee, the rapid establishment of ground cover is necessary to control erosion. A better understanding of competitive interactions, and the conditions under which seedlings compete with herbaceous native ground covers for water or nutrients, will allow for selection of trees and groundcovers that maximize establishment success on these sites. This experiment was designed to investigate the interactions between trees and ground cover, and later, the interaction between individual trees in pine or hardwood plots, or mixed pine/hardwood blocks, planted into an established native warm season grass ground cover on a reclaimed mine site. Plots were established to test the hypotheses that 1) seedlings that were larger at the time of planting would have a greater probability of survival, 2) seedlings planted on a slope with a northwestern aspect and lower on slopes would have better growth and a greater probability of survival than those on the southeast-facing slope and closer to the top of the ridge, and 3) the establishment of root systems and soil respiration would be greatest in mixed pine/hardwood plots. The third hypothesis will be tested with a long-term study, and not addressed in this paper. In the summer following planting, an extreme drought provided an excellent opportunity to assess the importance of water relations in competitive interactions, and to determine which seedling characteristics conferred an advantage to the seedlings with respect to drought tolerance under extremely competitive conditions. As a result, we tested the statistical hypothesis that a greater ground cover density at the time of planting would result in reduced probability of survival for planted seedlings.

Materials and Methods

The site is located on Zeb mountain (36º30’19”N 84º16’54”W), near Elk Valley, TN. The regional climate is moderate with annual precipitation of 135cm/yr. Coal was removed from the site by cross-ridge mining, in which overburden is removed from the crest of the ridge to access the coal, then replaced to approximate the original contour of the site. Following coal extraction, the upper 1.5m to 2m of material was placed with minimal grading to create a low compaction substrate suitable for trees. Material ranges from 60:40 to 30:70 sand:shale mix, with a pH of 6.8-7.5. The experimental site is located on the top of the reclaimed ridge at an elevation of 762m. The site is nearly 100m higher than surrounding ridge-tops, is subject to a high degree of exposure to wind and solar radiation, and is replenished with soil moisture solely through precipitation.

Six 10m x 24m plots were delineated on the SE side of the ridge, and six on the NW side. Of these, three were located on the upper slope, and three on the lower portion of the slope. Three planting treatments of hardwood, pine, and hardwood/pine mix were randomly assigned to the three plots on the upper southeast facing slope, to the three plots on the lower southeast facing slope, three plots on the upper northwest facing slope, and the three plots on the lower northwest facing slope. Material placement was completed in the fall of 2005, and the site was seeded shortly thereafter with 6.7kg/ha annual rye (*Lolium multiflorum*), 3.4kg/ha Indian grass (*Sorghastrum nutans*), 0.2kg/ha switchgrass (*Panicum virgatum*), 3.4kg/ha big bluestem (*Andropogon gerardii*), 7.8kg/ha little bluestem (*Schizachyrium scoparium*), 2.2kg/ha Korean lespedeza (*Lespedeza stipulacea*) and 6.8 kg/ha birdsfoot trefoil (*Lotus corniculatus*). Fiber mulch was applied at a rate of 1690 kg/ha, and lime (Liquid Lime Plus, PlantWise Biostimulant Company, Louisville, KY) was applied at a rate of 2242 kg/ha. By the time seedlings were planted in May 2007, there was a well-established cover of native warm-season grasses. Little to no lespedeza or trefoil was apparent. Herbaceous ground cover was quantified on each plot by the line-intercept method, on two transects across the plot diagonals. Cover was then expressed as a percentage of total transect length, and the two transects were averaged to obtain mean cover for each plot. Ground cover was measured at the time of tree planting, and again in Aug. 2007. On a single day in Aug., between the hours of 11:00 and 14:00, volumetric soil moisture of the upper 15cm of soil was measured (Trase Mini TDR, Soilmoisture Equipment Corp. Santa Barbara, CA) and temperatures at the soil surface and at a depth of 6cm were measured using a systematic sampling method designed to reduce time-of-day influence on treatment means.

Table 1. Height and root collar diameter of seedlings at the time of planting.

		Initial height (cm)			Initial RCD (mm)		
	Number	Mean	Max.	Min.	Mean	Max.	Min.
Pine	539	20.4	76.5	5.0	4.3	10.2	0.6
oak	247	53.7	62.3	7.4	6.2	14.2	2.2
oak (high quality)	97	81.7	161.2	13.5	8.9	16.6	3.0
hickory	95	24.9	62.0	10.1	6.5	13.4	2.1
green ash	96	53.3	105.3	21.5	7.0	18.9	2.3

One year old (1-0) shortleaf pine (*Pinus echinata*), pignut hickory (*Carya glabra*), northern red oak (*Quercus rubra*) and green ash (*Fraxinus pennsylvanica*) seedlings were obtained from the Tennessee Division of Foresty State Nursery (Table 1). Additional high- quality northern red oak seedlings were supplied by the Tennessee Tree Improvement Program at the University of Tennessee. Ninety seedlings were planted on a 1.5m x 1.5m spacing within each treatment plot. Hardwood species were randomly placed within the hardwood plots. In the mixed pine/hardwood plots, hardwoods and pine were planted in an alternating pattern, with the species of hardwood randomized. Measurements of height and root collar diameter were collected at the time of planting (May 2007), and again in Dec. of the same year. Mortality was also recorded at this time, using a firmly rooted stem with an apparently healthy bud as the criteria for recording a seedling as living. Precipitation over the May – Aug. 2007 period was the lowest recorded from the year 1895 to 2008 (NOAA, 2008) (Table 2).

Table 2. Total monthly precipitation and departure from normal (DPNP) (NCDC, 2008)

2007	Precip. (mm)	DPNP (mm)
May	250	-264
June	151	-313
July	479	-37
Aug.	107	-232
Sept.	247	-128
Oct.	286	-16
Nov.	521	35
Dec.	384	-158

Logistic regression was used to test the influence of seedling height and root collar diameter at the time of planting, and position on the slope (top to bottom, by row) on the probability of seedling survival. For the purpose of visual presentation, data were split into three groups of approximately equal size based on initial height, with the split at the nearest integer value. Differences between groups were not tested statistically. A T-test was used to test for the effects of aspect, and linear regression was used to test for the effects of initial ground cover percentage on seedling survival. All statistical analyses used SPSS (SPSS Inc., Chicago, IL) software. Regression analyses used one-tailed tests, and two-tailed tests were used for comparisons of aspect. Results were considered significant at $p \leq 0.05$.

Results and Discussion

For all species, initial seedling size was a significant factor in survival, with larger seedlings having a greater probability of survival over the first growing season (Fig. 1). This held true when considering seedlings overall, as well as for individual species. For both pine and oak, the relationship between survival and initial size was significant for root collar diameter, but not for seedling height. In ash and hickory, initial height was the significant factor influencing survival, although similar trends for increasing survival with increasing height and diameter were found for all hardwoods. Numerous studies have documented increased survival with increasing size at planting, under less rigorous conditions. While most species followed the expected patterns of

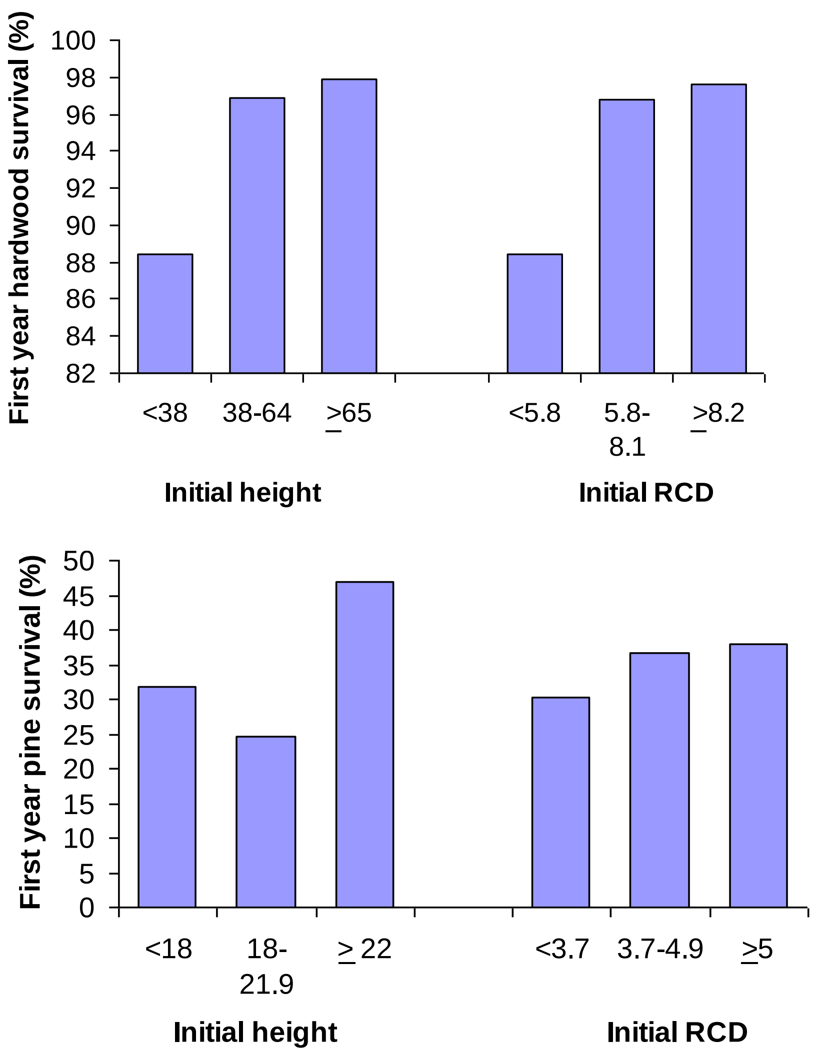

Figure 1. First year survival of three size classes of height (cm) and root collar diameter (RCD, in mm) of planted 1-0 pine (top) and hardwood (bottom) seedlings under extreme drought conditions.

survival under the extreme drought conditions of this study, pine of intermediate size had lower survival rates than those that were larger or smaller (Fig. 1). Larger conifers can be more susceptible to planting stress than smaller seedlings if dry conditions follow planting (Rose et al., 1993), but those with larger root systems in good contact with moist soil at greater depth also have better root growth in the weeks following planting (Hinds and Long, 1986). Root collar diameter may be a better predictor of survival by indicating a larger root system, or greater root:shoot ratio. However, it is important to note that in addition to seedling size, factors such as cultural conditions, genetics, and soil characteristics may influence root growth potential (Grossnickle, 2005), thereby affecting establishment under adverse conditions. Because dormant hardwoods have less transpirational water loss that would contribute to planting stress, root:shoot ratio may be a less important factor in influencing survival, leading to a clearer relationship between overall size and survival. Oak seedlings of greater initial root collar diameter have been found to have better survival over an 11-year period over a variety of conditions (Weigel, 1999), though none as adverse as those of the current study.

Despite a particularly harsh site and growing season, survival of hardwood seedlings over the first growing season was greater than 80% on most plots (Fig. 2). Aspect was a significant factor in seedling growth and survival. Survival of shortleaf pine (less than 40 % overall) was much lower than that of hardwoods, and significantly lower on the SE aspect. While shortleaf is known to occur across a wide range of sites, growth is generally better on moist soils and in areas of moderately high precipitation (Lawson, 1990). Soil temperature was significantly different between aspects, and potentially detrimental surface temperatures as high as 50°C were recorded on the southeastern aspect. Greater increases in RCD were recorded on the southeastern-facing slope, and could also be related to soil temperature. The southeastern-facing slope also had a lower initial ground cover density that could have influenced RCD increases, although the data suggest this may not be the case.

At the time seedlings were planted, the average amount of ground covered by existing native warm-season grasses was significantly higher on the NW slope than on the SE slope (Table 3). Ground cover values ranged from 4 to 44%, with the majority of plots being in the 10 to 30% range. Due to the relatively late growing season and clumped growth habit of these grasses, measurements made in May mainly reflected the diameter of clumps of the previous years growth, and the stand of grass appeared to be well-stocked across most of the site. The cover of

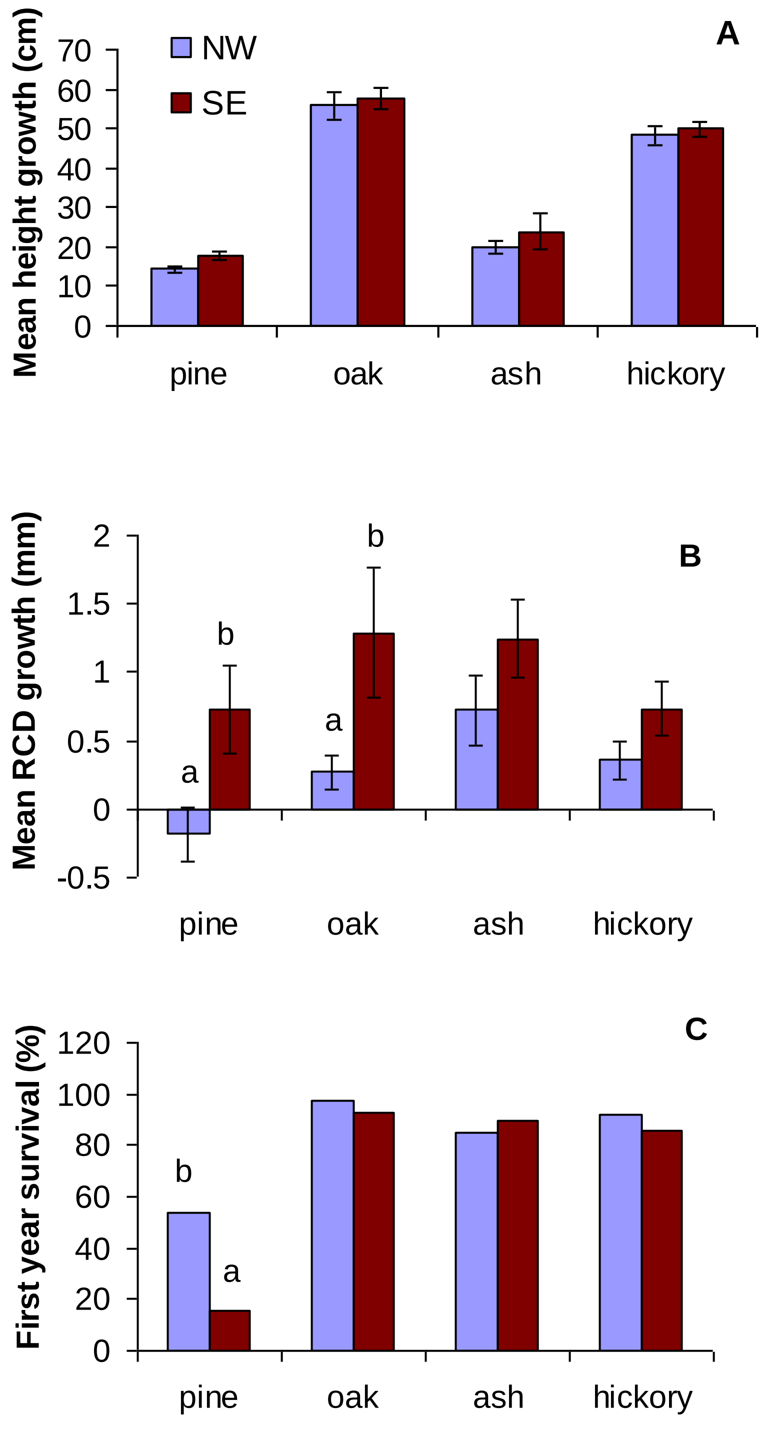

Figure 2. Mean increase in height (A) and root collar diameter (B), and survival from May-Dec of 1-0 seedlings planted on a northwestern and southeastern aspect. Bars indicate standard error. Different letters indicate a significant difference between aspects.

grasses would be expected to increase over the growing season, however grass cover remained nearly constant in most plots, and actually decreased in all plots having an initial cover density of greater than 15% (data not shown) suggesting competition between grasses. Competition for soil moisture between trees and herbaceous ground cover was expected to be intense over the summer following planting as both are actively growing during summer months. However, no significant relationship was found between seedling survival and the density of ground cover at the time of planting. There were also no significant interactions between size of seedlings at the time of planting, ground cover density, and the probability of survival, although other studies have found that larger seedlings have a greater ability to grow under conditions of competition (Jobidon et al., 1997). Furthermore, a low density of ground cover is unlikely to explain the lack of a competitive effect, as there was evidence of competition between grasses. Native warm season grass treatments have been found to be less competitive with tree seedlings than non-native ground covers under weather more typical of this area (Rizza et al., 2006), although the reason remains unknown. The competitive interaction between these species deserves further investigation to determine whether roots occupy different spatial zones, or utilize water resources at different times.

Table 3. Mean (± SE) ground cover at the time of planting, in August of the same year, soil moisture, and soil temperature, measured on a single day in Aug. 2007 on the northwestern and southeastern aspects. An asterisk indicates a significant difference between aspects.

	NW aspect		SE aspect	
Initial ground cover	27.2	±5.8	11.9	±1.9 *
August ground cover	16.7	±3.8	12.8	±2.5
Soil moisture %	10.9	±1.5	8.5	±0.8
Soil surface temperature (degrees C)	37.2	±1.1	45.0	±1.4 *
Soil temperature at 6cm depth (degrees C)	27.3	±0.3	30.2	±0.7 *

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