THE INFLUENCE OF DIFFERENT GROUND COVER TREATMENTS ON THE GROWTH AND SURVIVAL OF TREE SEEDLINGS ON REMINED SITES IN EASTERN TENNESSEE[1]

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Abstract: There is growing interest in the reforestation of surface mined lands for various land uses including forest products and wildlife habitat. These objectives can be met by planting native tree species and seeding a ground cover to control erosion. However, many ground covers compete aggressively with tree seedlings in this region, preventing establishment. A research project was designed with two main objectives; to investigate the competitive effects of different ground cover species on the growth and survival of tree seedlings, and to identify the relationship between the growth and function of tree seedlings and microsite variables. Five tree species, native to the eastern hardwood forest surrounding the mine site, were planted in 2005: yellow poplar (*Liriodendron tulipifera* L.), sugar maple (*Acer saccharum* Marsh.), northern red oak (*Quercus rubra* L.), eastern redbud (*Cercis canadensis* L.), and Virginia pine (*Pinus virginiana* Mill.). Five different ground cover treatments were applied to the planted area. Two mixes consisted of native warm season grasses (NWSG), two standard reclamation mixes, and one control. Growth and survival, seedling transpiration, soil respiration, and groundcover biomass were analyzed. At each seedling, light measurements and percent herbaceous cover based on the Braun-Blanquet scale were collected. Seedling survival was related to size at planting, and to the density of ground cover. Survival was highest in moderate amounts of cover, although root collar diameter growth decreased with increasing cover in redbud and pine. Tree seedling growth and survival tended to be greatest in the native warm season grass treatments.

Additional Key Words: reclamation, native warm season grasses (NWSG), soil respiration, transpiration, photosynthetically active radiation (PAR), percent herbaceous cover, reforestation, surface mining.

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Introduction

There is growing interest in the reforestation of surface mined lands for various land uses including forest products (Burger and Zipper, 2002; Burger and Torbert, 1999; Gorman et al., 2001). Property owners are becoming increasingly aware of the potential to return their land to a forest system. When forestry is the post mining land use, federal regulations require the prevention of excessive surface compaction, which can be completed by minimal pass grading of the surface. Reduction in the number of passes with heavy equipment has been shown to reduce compaction of the minesoil (Daniels and Zipper, 1988) creating better media for tree seedling development.

Planting a diverse mix of native trees can help to decrease erosion losses from the site and decrease the amount of time needed for the forest to recover and establish a new dynamic ecosystem similar to what was once present on site. In many situations, post mining reclamation consisted of revegetating with non-native herbaceous covers such as annual rye (*Lotus corniculatus*) and birdsfoot trefoil (*Lolium multiflorum*) to ensure bond release from the agency. However, there is considerable debate about the ability of these non-native species to add to the health of the ecosystem over the long term (Holl, 2002), and it is not known exactly how these species influence forest succession. New recommendations for the planting of trees on surface mines calls for the use of non-competitive native ground cover (Burger et al., 2005a), but species and seeding rates have not yet been identified for this region. Native warm-season grasses can establish well on mine reclamation sites (Ashby et al., 1989), and provide habitat for quail, a declining species in the southeast (Wear and Greis, 2002). Once established, these grasses provide good erosion control due to their extensive root systems, while their bunching growth habit allows the invasion of native woody and herbaceous species. However, little is known about their competitive effects on tree establishment.

This experiment to assess the competitive effects of ground cover on seedling growth and survival was established in 2005. The first study objective was to examine the relationships between five different native and non-native herbaceous cover treatments and the growth and survival of five species of planted tree seedlings over two growing seasons. The second objective of the study was to identify the relationship between microsite conditions and tree seedling growth and function.

Methods

Physical description

The research plots are located within the New River watershed in western Anderson County, in East Tennessee (36º08' N 84º21' W, elev. 800 m). The study site is located on the Photorevised 1979 Duncan Flats, Tennessee USGS 7.5 minute quadrangle map. This site is characterized by steep slopes (25 – 50%) with a north-northwest aspect. Contour mining was the method employed; this was done by using surface and auger mining operations to extract the coal. The old coal bench near the top of the mountain was excavated to mine coal deeper into the mountain, a process called re-mining, that extracted an estimated 377,000 tons of coal from this 125 acre (50 ha) surface mine. Approximately 78% of the study site was previously mined (pre- and post-SMCRA) and topsoil was not salvaged during these operations. The re-mining was completed in 2004. The mine operators used Caterpillar bulldozers to reclaim the approved alternate topsoil material by minimal pass grading which was intended to leave the area rough and loosely compacted as recommended in the new reforestation guidelines (Burger et al., 2005a). The area was then seeded with ground cover to meet the permit requirements of 80% for bond release. The permit defines the post-mining land use of this site to be undeveloped land and wildlife habitat.

Vegetation

The forest cover surrounding the study site is classified as Oak-Hickory. This site is in a classic southeastern mixed mesophytic hardwood forest. The Southeast has the greatest variety of native plant communities, native plant species, and rare and endemic native plants in the United States (Owen, 2002). Anderson County, Tennessee has a significantly diverse native vascular plant collection including more than 832 different species (University of Tennessee Herbarium, 2006). Data collected from above the mined area indicate that the native forest structure was not compromised by past mining operations (Jordan Marshall, personal communication, 2004).

Experimental design

Five tree species, yellow poplar (*Liriodendron tulipifera*), sugar maple (*Acer saccharum*), northern red oak (*Quercus rubra*), eastern redbud (*Cercis canadensis*), and Virginia pine (*Pinus virginiana*), native to the eastern hardwood forest surrounding the mine site, were planted on April 15, 2005. Twelve-hundred 1-0 bareroot tree seedlings were randomly assigned to planting spots to ensure representative distributions across replications. Sites were selected along the overburden slope which appeared to have the least amount of grading. Four rectangular blocks measuring 210 ft (64 m) X 65ft (19.8 m) were delineated above the road. Each block was approximately 0.32 ac (0.13 ha), and was divided into 5 rectangular plots of equal size. Within each block, 300 randomly assigned seedlings were planted in rows on 6ft (1.8 m) spacing.

For this study, we selected five different ground cover mixes for seeding into treatments. Any vegetation that had established within the treatment plots was cut manually, and then treated with a glyphosate herbicide (Roundup PRO, Scotts Miracle-Gro Co., Marysville, OH) prior to seeding treatment mixes. Hand broadcast seeding of the treatments was completed on June 7 and 8, 2005. The first mix was "Mesic prairie mix" (*Shooting Star Nursery*, Georgetown, KY) which contains 19 native wildflower/forb species (30% of mix), and four native warm season grass species; little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum natans*), and switchgrass (*Panicum virgatum*). This mix was seeded at the recommend rate of 8 pounds per acre (lbs ac^{-1}) (9 kilograms per hectare (kg ha^{-1})) of pure live seed (PLS). The second seed treatment was based on warm season grasses that are relatively short in stature at maturity and native to the area; little bluestem (*Schizachyrium scoparium*), side oats grama (*Bouteloua curtipendula*), and eastern gamagrass (*Tripsacum dactyloides*). This treatment was seeded at 8 lbs ac^{-1} (9 kg ha^{-1}) PLS also. Treatment three had birdsfoot trefoil seeded at 4 lbs ac^{-1} (4.5 kg ha^{-1}) and annual rye seeded at 15 lbs ac^{-1} (16.8 kg ha^{-1}). Treatment four also had two species in the mix, perennial rye (*Lolium perenne*) and creeping red fescue (*Festuca rubra*), both seeded at 10 lbs ac^{-1} (11.2 kg ha^{-1}). The fifth treatment was the control with no additional herbaceous vegetation seeded.

Sampling Methods

Herbaceous Cover. In May and August 2005 and 2006, percent cover of the herbaceous vegetation was measured and recorded around each seedling. A circular area around each seedling with a radius of 1.6 ft (0.5 m) was inspected to attain the amount of herbaceous cover. Using a sampling scale based on a 25% range developed by Braun-Blanquet (1932), a cover class number to quantify the amount of herbaceous vegetation was assigned to each seedling (Table 1).

Table 1. Herbaceous percent cover classes, based on Braun-Blanquet (1932) cover classes for small sample areas.

Cover classes	0	1	2	3	4
Percent Cover	0-1%	1-25%	25-50%	50-75%	75-100%

Light. Photosynthetically active radiation (PAR) was measured during the summer of 2006 around solar noon (±1 hr) using a Decagon Accupar Ceptometer (Decagon Devices, Pullman, WA). Sampling for PAR results in a quantitative index of the level of light reaching a seedling in the presence of herbaceous competition. PAR measurements were recorded at 2 in, 10 in, and 40 in (5 cm, 25 cm, and 1 m) above the ground level at the seedling. Each measurement occurred within 2 in (6 cm) of the seedling stem along the south side of the seedling avoiding shading by the seedling leaves. A second stand alone unit was set in full sun exposure recording measurements every 30 seconds for the duration of the plot sampling time in order to calculate percent full PAR (Barwatt, 2004). Measurements of PAR were only taken during the second growing season as the cover was not considered influential during the first season of growth.

Growth and survival. Initial height and root collar diameter (RCD) were measured on every seedling in May of the first growing season (2005), in December of 2005, and in November of 2006. Seedling survival, time of leaf flushing, signs of severe insect damage, evidence of deer browsing, and overall plant conditions were monitored on a bi-monthly basis during the 2005 and 2006 seasons. The timing of seedling flushing was used to determine if the seedlings were stressed due to transplanting. Any seedlings that did not flush or show any signs of survival during the first season were considered to be killed by transplant stress. Seedlings were monitored monthly during each growing season (May – Sept.), with erosion and injury due to browsing being recorded. This information was used to help determine the causes of mortality of each individual. Individuals counted as living at the end of the growing season, but not living the following May were considered as winter mortality.

Physiological Data. Seedling transpiration rates were measured in 2005 and again in 2006 between 7:45 am and 10:00 am July 25 to July 29. Readings were recorded using a Li-Cor LI-1600 Steady State Porometer with fixed aperture head (Li-Cor Biosciences, Lincoln, NE), on the uppermost fully-expanded leaf. A total of 60 seedlings of a single species (3 individuals per treatment per block) were measured per day.

Soil respiration measures the CO_2 efflux rate of the soil in a dynamic chamber on the soil surface. This was done using the Licor LI-6400 Portable Photosynthesis System with a soil respiration chamber attachment (Li-Cor Biosciences, Lincoln, NE). The respiration measurements were recorded near 20 randomly selected sugar maple seedlings each day (1 seedling per treatment within each of the four blocks), between 10:00 am and 2:00 pm, July 25 to July 29 in both years of the study. Studies have shown that the highest mean rate of CO_2 efflux occurs in July (Ponder, 2005). Measurements were taken by placing the chamber edge 2 in (6 cm) from the stem of the maple seedlings, on an area devoid of vegetation.

Statistical Analysis. The SPSS program, version 14.0 (SPSS Inc., 2005, Chicago, IL), was used for all statistical analysis. For this study, all main effects were tested using ANOVA models, which were considered significant at an alpha ≤ 0.05. Where significant main effect interactions were found, ANOVA was run on each species separately. Post hoc tests of statistically significant relationships were conducted using Duncan's multiple range tests to determine the significant differences between group means (StatSoft, Inc., 2006).

Results

Cover

Cover class distribution surrounding each seedling changed noticeably between the first and second growing season. In the first year, almost 70% of the seedlings were growing within 1-25% cover; this was reduced to 20% in the second growing season. During the first season only 5% of the seedlings were growing in cover above 50%. While in the second season over 30% of the seedlings were growing in cover above 50%. There was an increase in seedlings surrounded by 0-1% cover in the second season.

There were significantly different amounts of cover surrounding the seedlings within treatments ($p < 0.000$). The annual rye/birdsfoot trefoil treatment had significantly greater cover around the seedlings than all other treatments (Fig. 1).

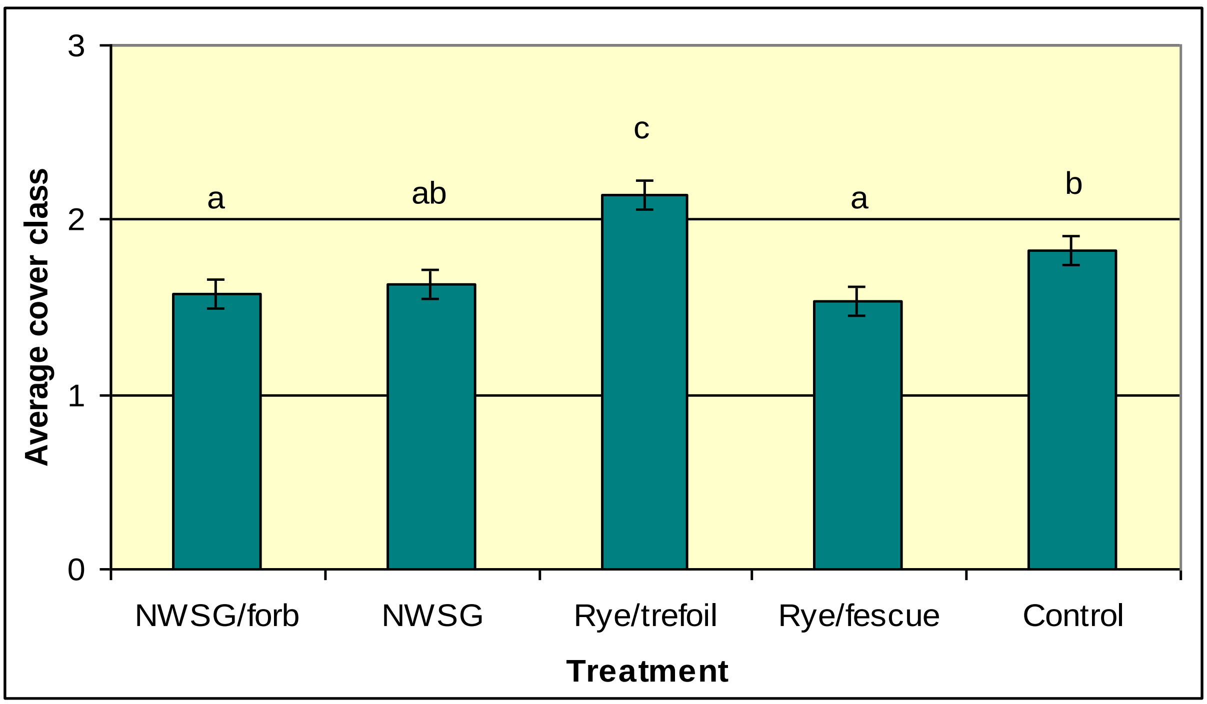

Figure 1. Mean herbaceous cover class differences by treatment for all seedlings. Herbaceous cover class zero is 0-1% cover, class one is 1-25%, class two is 25-50%, class three is 50-75% and class four is 75-100%. Bars represent standard error. (Means with the same letters are not significantly different at $\alpha = 0.05$ using Duncan's technique.)

Light

Increased cover resulted in decreased PAR levels (Fig. 2) at the 5 cm level (p = 0.001). There were no significant differences between treatments or between cover classes when PAR was measured at 25 cm and 1 m above the ground.

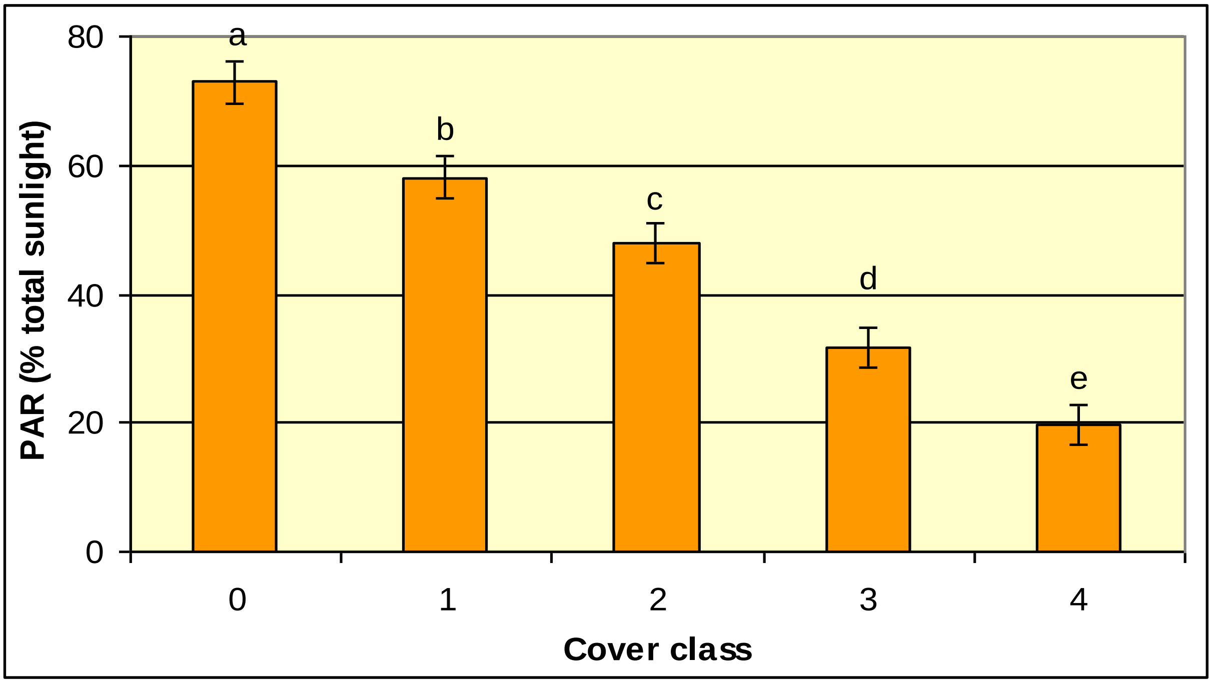

Figure 2. PAR sampled at 5 cm above the ground surface by herbaceous cover class. Herbaceous cover class zero is 0-1% cover, class one is 1-25%, class two is 25-50%, class three is 50-75% and class four is 75-100%. Bars represent standard error. (Means with the same letters are not significantly different at $\alpha = 0.05$ using Duncan's technique.)

Survival

Seedling survival at the end of the second growing season was related to seedling root collar diameter at time of planting for sugar maple (p = 0.049), northern red oak (p = 0.005), eastern redbud (p = 0.027), and Virginia pine (p = 0.001). Yellow-poplar seedlings with larger RCD at planting did not have significantly better survival in this study (p = 0.222).

Across all treatments, the five species of trees planted for this project had significantly different rates of survival. Sugar maple had significantly better survival through the first two seasons of growth than did any of the other species (Fig. 3). The survival of the yellow-poplar was significantly lower than all other species.

There were no significant differences in overall species survival between treatments. However, there were trends suggesting better survival of four tree species in the two NWSG treatments than in the non-native treatments (Fig. 4). Yellow-poplar survival was below 30% over all treatments and was the only species which did not demonstrate higher survival rates in the two native warm season grass treatments.

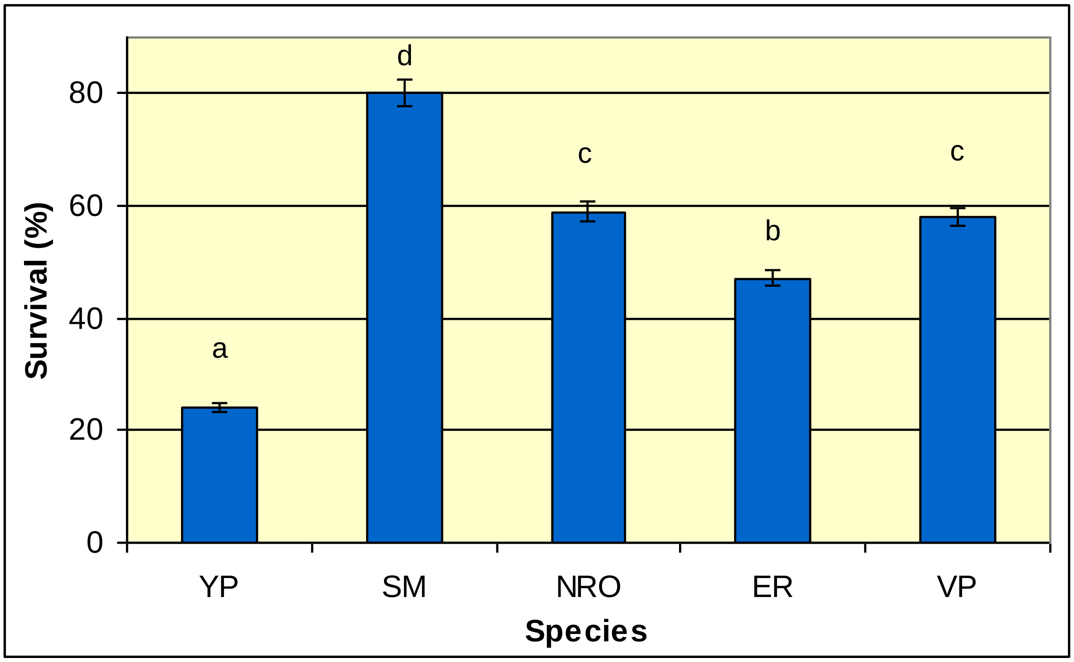

Figure 3. Percent survival of the five species of seedlings planted in this project over two full growing seasons. Bars represent standard error. (Means with the same letters are not significantly different at $\alpha = 0.05$ using Duncan's technique.) YP = yellow-poplar, SM = sugar maple, NRO = northern red oak, ER = eastern redbud, VP = Virginia pine.

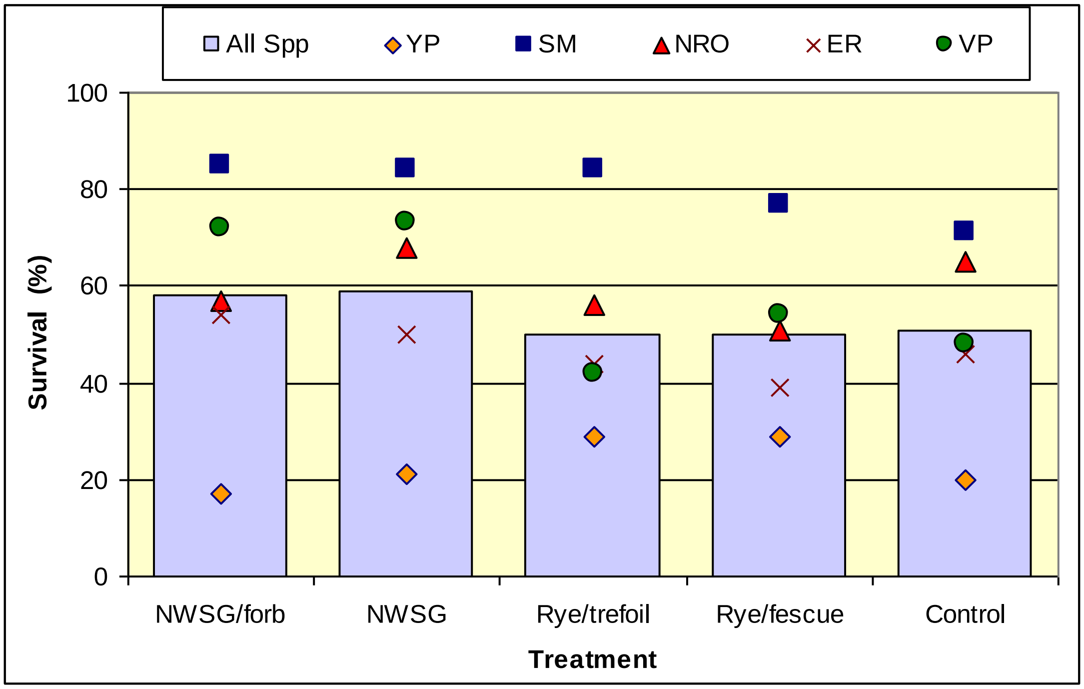

Figure 4. Overall seedling survival (bars) and each tree species (symbols) survival within each herbaceous treatment. YP = yellow-poplar, SM = sugar maple, NRO = northern red oak, ER = eastern redbud, VP = Virginia pine.

There were significant differences in the overall survival of the planted seedlings within the herbaceous cover classes (Fig. 5). Except for Virginia pine, the moderate cover classes had the highest survival rates. Northern red oak survival was significantly different between herbaceous cover classes (*p* = 0.029). Survival was highest for northern red oak in 25 to 50% herbaceous cover. Survival was lowest when there was 0-1% cover present around the seedlings. Eastern redbud also had significantly different survival rates between cover classes (*p* < 0.000). Survival was significantly higher in the 25 to 50% cover than in other cover classes. There were no significant differences in survival between the cover classes for yellow-poplar, sugar maple, or Virginia pine.

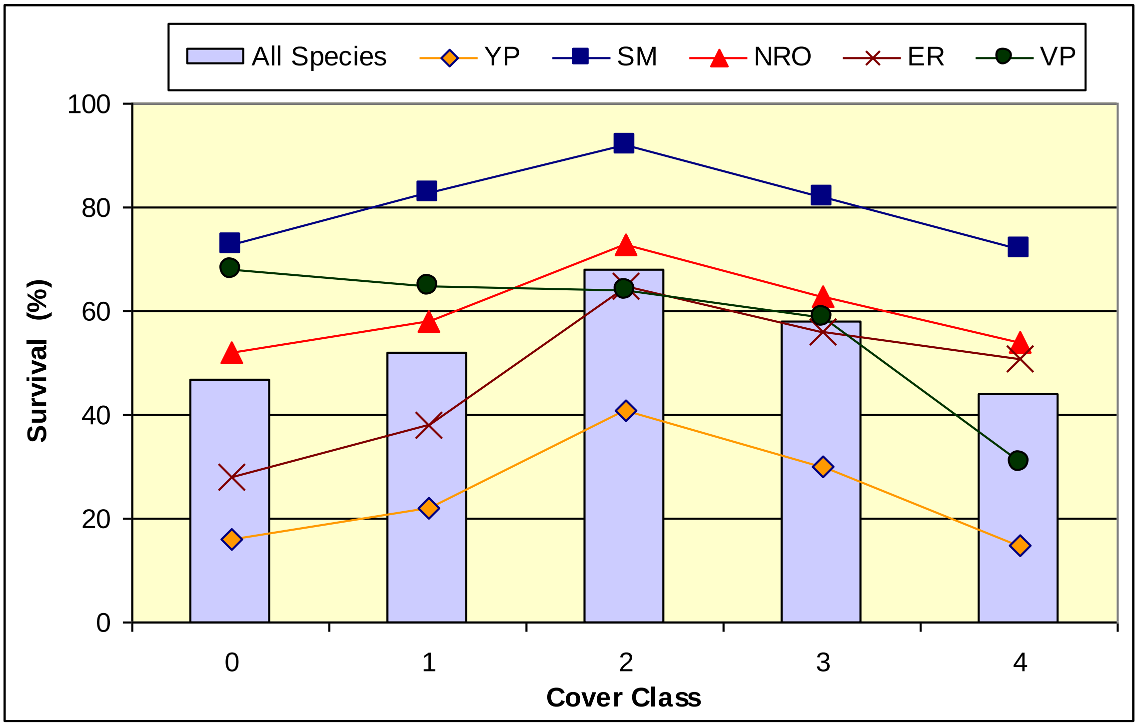

Figure 5. Overall species (bars) and each species (symbols) survival within each herbaceous cover class. YP = yellow-poplar, SM = sugar maple, NRO = northern red oak, ER = eastern redbud, VP = Virginia pine. Cover class 1 = 0-1%, 2 = 1-25%, 2 = 25-50%, 3 = 50-75%, 4 = 75-100%.

<u>Causes of Mortality</u>

Initial planting stress on the bare root seedlings accounted for an average of 12% of the overall mortality per species, with sugar maple and Virginia pine having the least mortality from transplanting stress (Fig. 6). Deer browsing accounted for just over 8% of the overall mortality on this site. Virginia pine had the highest mortality related to browsing. Field observations determined that 85 Virginia pine seedlings were browsed during the second growing season, which was a significant (*p* = 0.001) increase from the 27 browsed during the first season. In contrast, northern red oak (65 browsed) and eastern redbud (58 browsed) were browsed significantly less during the second season of growth (2 browsed, p = 0.002 and 8 browsed, p = 0.007, respectively). Erosion channel development caused an average of 9% of the mortality per species on the study site. The greatest contributor to the death of seedlings was winter mortality over the first winter following planting, which averaged 23.5% of the total mortality. However, the cause of more than half of the total mortality could not be identified.

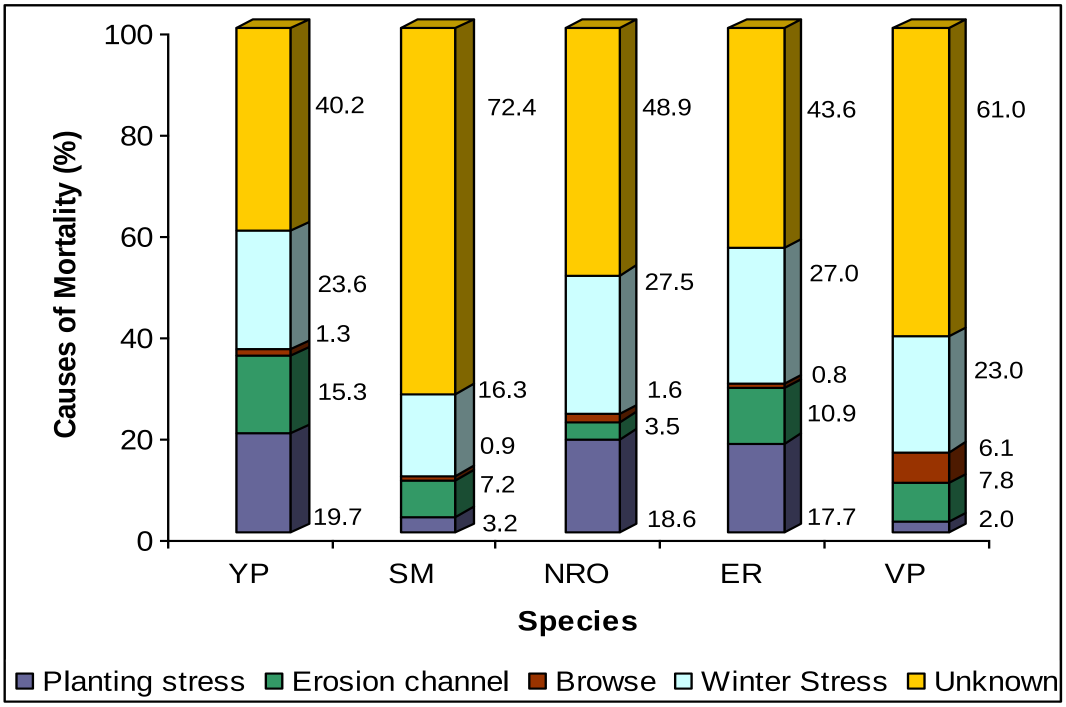

Figure 6. Percentage of seedling mortality explained by four main experimental observations including planting stress, erosion channel development, browsing, and winter mortality. Values in figure are percent mortality by species.

Growth

Root collar diameter (RCD) growth differed significantly between species during the second season. There were no significant differences in RCD or height growth of the seedlings between treatments or herbaceous cover classes during the first year of the study. During the second growing season there were treatment and cover effects on seedling RCD growth (Fig. 7). Yellow-poplar (p = 0.825) and northern red oak (p = 0.098) did not differ significantly in RCD growth, while sugar maple (p = 0.040), eastern redbud (p = 0.006), and Virginia pine (p = 0.010) growth was significantly different between treatments (Fig. 7). Seedlings growing in the native warm season grass and forb treatments tended to have the greatest diameter growth between treatments, and those within the annual rye/birdsfoot trefoil treatment had the least growth. Root collar diameter growth was also influenced by the amount of cover surrounding each seedling (Fig. 8). Northern red oak (p = 0.023) and Virginia pine (p = 0.007) RCD growth was significantly different within the cover classes. Seedling height growth did not show any significant differences with respect to treatments or herbaceous cover class in either year of this study (Data not shown).

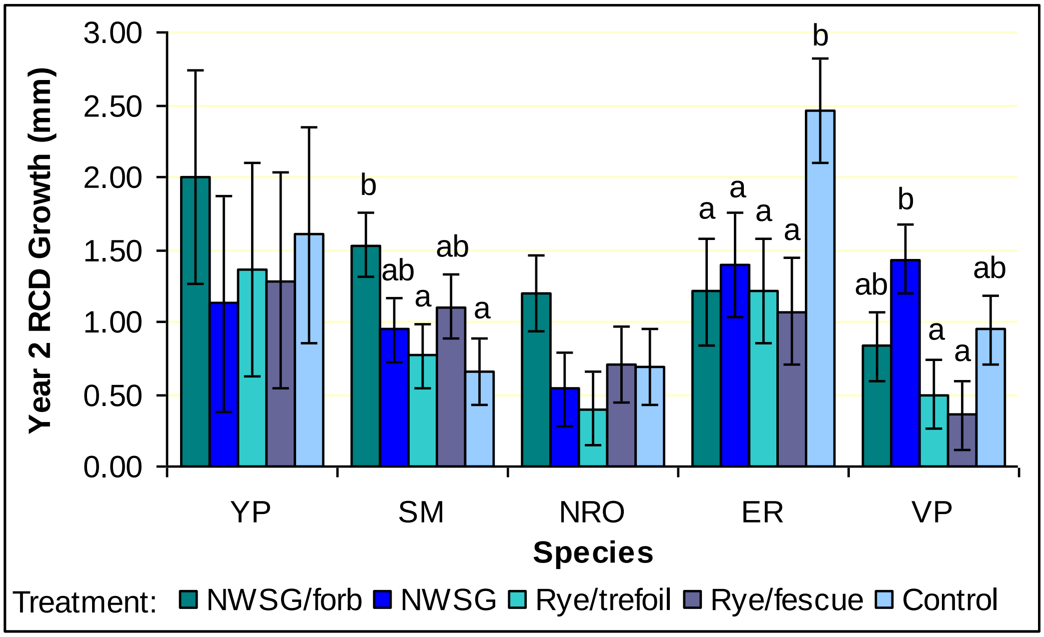

Figure 7. Seedling root collar diameter (RCD) growth in millimeters during the second growing season for each species within the five treatments. Bars represent standard error. Different letters represent significant differences between treatments within a species. YP = yellow-poplar, SM = sugar maple, NRO = northern red oak, ER = eastern redbud, VP = Virginia pine.

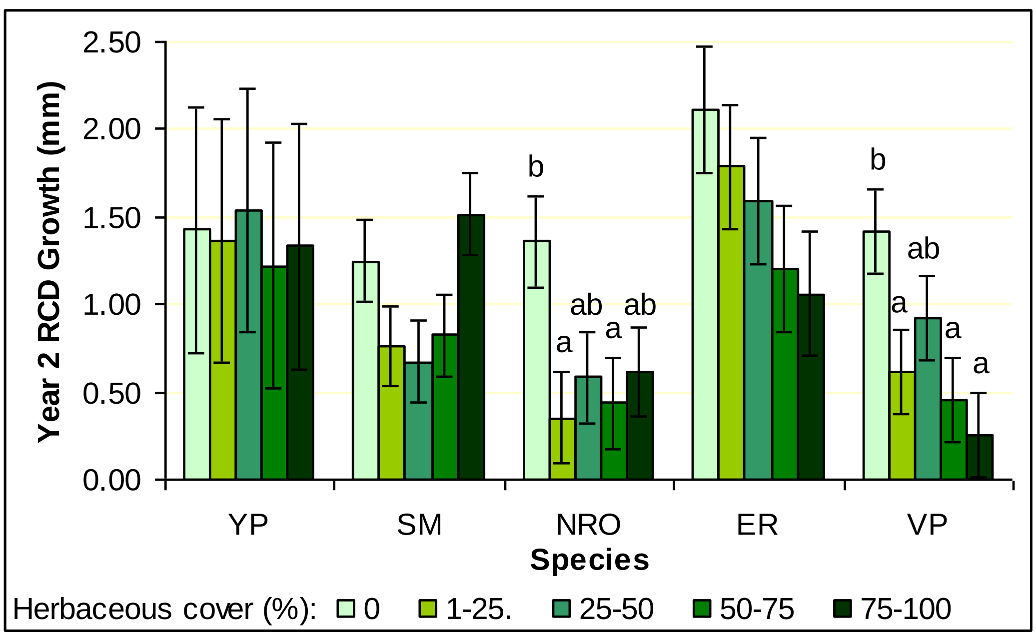

Figure 8. Seeding root collar diameter (RCD) growth during the second growing season for each species within each cover class. Bars represent standard error. Different letters represent significant differences between treatments within a species. YP = yellow-poplar, SM = sugar maple, NRO = northern red oak, ER = eastern redbud, VP = Virginia pine.

Physiological Measurements

No significant differences in transpiration rate between treatments or between species occurred during the two years of this study. However, when analyzed across treatments with respect to cover, during the second year sugar maple seedlings had significantly higher transpiration rates when surrounded by cover above 50%, and northern red oak seedlings had significantly higher transpiration rates when surrounded by cover less than 25% (data not shown). Considerable variation was present in the mean transpiration rates for all species in both years.

Soil respiration rates, sampled around sugar maple seedlings, were not significantly different within treatments, herbaceous cover class, or year. There was considerable variation in the respiration rates, which ranged from 1.04 to 20.03 mmol CO_2 $m^{-2}s^{-1}$ and 1.13 to 20.10 mmol CO_2 $m^{-2}s^{-1}$ in 2005 and 2006, respectively, and we were not able to explain this variation with any of the variables measured.

Discussion

These results suggest that seedling establishment and growth are influenced by the surrounding herbaceous cover. While species were affected differently, direct species comparisons are difficult due to dissimilar physiological characteristics, which dictate their growth rates. Species react differently to planting stress, competition for light, water and nutrients, and even browsing and erosion. Yellow-poplar seedlings characteristically grow quickly to remain above vegetation competing for light. On the other hand, northern red oak seedlings expend more energy on the accumulation of below ground roots compared to above ground shoot growth (Sander, 1990; Ashby, 1995), making early growth responses difficult to measure.

Seedling size at the time of planting also differed greatly between species, and to a lesser extent between individuals within a species. While many researchers have suggested that increased seedling size corresponds to greater survival after out-planting, other studies have reported no correlation between size and survival rates for many species (Boerner and Brinkman, 1996). In this study there was a significant positive relationship between initial seedling size and survival rate in four of the five species studied. In contrast to Deirauf and Garner (1996), yellow-poplar was the only species that did not have greater survival rates for larger seedlings. Because mortality was so high for this species, the ability to detect such a relationship was greatly reduced. Approximately 60% of the mortality was explained; together planting stress and winter mortality accounted for 43% of yellow-poplar mortality. These seedlings did have higher survival rates in the moderate cover class, suggesting that although yellow-poplar is considered an early-successional species, they were particularly sensitive to stresses associated with exposure on this site.

Northern red oak and sugar maple had greater survival rates, and similar responses to ground cover. The main influence on the survival of these seedlings was winter mortality. Winter mortality rates can differ significantly by species, planting site, and from year to year (Fenner, 1987). These are mid-successional species, and are thought to be relatively tolerant of competition. Both species had greater survival rates when surrounded by moderate amounts of groundcover, and higher transpiration rates in the second year when surrounded by higher amounts of groundcover. This suggests improved water relations at moderate amounts of ground cover, as has been reported previously for three species of oaks on this site (Franklin and

Buckley, 2006). However, there were no detectable differences in root function, as none of the sampled variables were able to explain the variation in soil respiration rates around the sugar maple seedlings. Other research has demonstrated the difficulties in predicting soil respiration responses in the complex eastern deciduous forest (Edwards and Norby, 1999).

Grasses have been shown to compete with trees for water and nutrients in a number of ecosystems. Burger et al. (2005b) reported that herbicide control obtaining 40–60% ground cover was most advantageous for overall survival rates on reclaimed sites in Virginia. Results of a previous study (Ashby et al., 1989) supported the use of warm-season grasses for revegetation of mined sites, but warned that their size and competitive ability may limit tree growth. Although the growth of northern red oak and sugar maple was high in the absence of cover, there was no apparent growth response to increasing amounts of cover. They also showed the greatest growth in the native warm season grass treatments.

Eastern redbud and Virginia pine typically grow best in environments with high light and low competition. While redbud survival was highest at intermediate cover classes, survival of Virginia pine decreased with increasing cover. Eastern redbud seedlings had only 47% survival overall. However, these seedlings were very small at the time of planting, and our results suggest that planting larger seedlings would help to increase their survival. The root collar diameter growth of both species decreased with increasing ground cover, suggesting that diameter growth of these species is relatively intolerant of competition. Both species had some foliage near ground level, where light levels were reduced by ground cover. However the importance of light levels in affecting growth and survival of these species on this site is questionable. Although PAR did decline with increased cover, this was only present at the 5 cm level and all seedlings had foliage above the 5 cm level during the second growing season. Competition for water and nutrients could have potentially reduced seedling growth rates.

Significant research has been conducted on restoring native warm season grasses in the western United States for grassland and prairie ecosystems. The clumping effect of these grasses enables invasion of native herbaceous and woody species (Barnes and Washburn, 2000). This research demonstrates that these native grasses can also be utilized for forestry reclamation on drastically disturbed sites, and that these may promote the survival of tree seedlings. However the exact mechanisms which create beneficial growing conditions for the outplanted seedlings are not clear at this time.

Recorded causes of mortality appeared to be independent of treatments over the duration of this study. Erosion channels developed thought the study area as well as the surrounding reclaimed area. These channels extended from top to bottom of the reclaimed slope, were as small as a few inches deep to several feet in depth, and in some areas accounted for the mortality of entire rows of seedlings. Deer browsing was another detrimental impact on the seedlings. During the first season, the herbaceous cover of the site was minimal and the seedlings were the only vegetation present in certain areas. Many of the seedlings were browsed by white tailed deer, which removed as much as half of the seedlings' above ground biomass. Much of this browsing occurred in the latter part of the season and could explain the high level of mortality during the first winter.

Conclusion

Current surface mining permits in Tennessee require seedling survival to be greater than 60% at the time of bond release. We would not recommend planting yellow-poplar on these sites due to the poor performance of planted seedlings, and its ability to invade from the surrounding forest as noted on these sites. Survival of sugar maple, northern red oak and Virginia pine were acceptable for bond release. The survival of all species can likely be improved by planting seedlings with larger root collar diameters. Results by cover class suggest that reducing ground cover seeding application rate is most desirable. These data support recent OSM revisions in Tennessee that allow reduced ground cover, stating herbaceous cover should be limited to that necessary to control erosion where forestry is the post-mining land use (Tennessee Federal Regulatory Program; Final Rule 30, CFR Part 942, Federal Register, March 2, 2007, 9615-9637). All tree species had better survival when growing in moderate amounts of herbaceous ground cover, although root collar diameter growth generally decreased with increasing cover. Tree survival was generally highest in native warm-season grass treatments, although we were unable to determine the mechanisms underlying this observation with the methods employed.

Acknowledgements

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References

Ashby, W. C. 1995. Oak seedling root and shoot growth on restored topsoil. Tree Planters' Notes. 46: 56-57.

Ashby, W. C, K. P. Hannigan, and D. A. Kost. 1989. Coal mine reclamation with grasses and legumes in southern Illinois. J. Soil and Water Conserv. 44: 79-83.

Barnes, T. G. and B. E. Washburn. 2000. Native warm season grasses for erosion control? You gotta be kidding! Erosion Control. Volume 7: Number 8. Accessed March, 2006. Received: http://www.forester.net/ec_0011_native.html

Barwatt, B. A. 2004. Maximizing Northern Red Oak (*Quercus rubra*) Seedling Growth to Sustain Oak-Dominated Ecosystems in East Tennessee. University of Tennessee. 136 p. Thesis.

Boerner, R. E. J. and J. A. Brinkman. 1996. Ten years of tree seedling establishment and mortality in an Ohio deciduous forest complex. Bull. Torr. Bot. 123: 309-317. http://dx.doi.org/10.2307/2996780.

Braun-Blanquet, J. 1932. Plant Sociology: The Study of Plant Communities. New York, McGraw-Hill, 439 p.; (Translated and edited by G.D. Fuller and H.C. Conrad).

Burger, J.A., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005a. The Appalachian Reforestation Initiative. U.S. Office of Surface Mining. Forestry Reclamation Advisory Number 2. 4pp.

Burger, J.A., D.O. Mitchem, C.E. Zipper, and R. Williams. 2005b, Herbaceous ground cover effects on native hardwoods planted on mined land, Proceedings America Society of Mining and Reclamation, 2005 pp 136-146. http://dx.doi.org/10.21000/JASMR05010136.

Burger, J.A. and J.L. Torbert. 1999. Status of reforestation technology: The Appalachian Region. pp 95-108. In: Vories, K. and D. Throgmorton (eds.). Proc. of Enhancement of reforestation at surface coal mines: Technical Interactive Forum. March 23-24. Fort Mitchell, Kentucky.

Burger, J.A. and C.E. Zipper. 2002. How to Restore Forests on Surface-Mined Land Virginia Coop. Ext. Pub. 460-123.

Daniels, W.L. and C.E. Zipper. 1988. Improving coal surface mine reclamation in the central Appalachian region. p.139-162. In: J.C. Cairns (ed.) Rehabilitating damaged ecosystems. Vol. 1. CRC Press, Boca Raton, FL.

Dierauf, T. A. and J. W. Garner. 1996. Effect of initial root collar diameter on survival and growth of yellow-poplar seedlings over 17 years. USFS Tree Planter's Notes 47: 30-33.

Edwards, N. T. and R. J. Norby. 1999. Below-ground respiratory responses of sugar maple and red maple saplings to atmospheric CO2 enrichment and elevated air temperature. Plant and Soil. 206: 85-97. http://dx.doi.org/10.1023/A:1004319109772

Fenner, M. 1987. Seedlings. New Phytol. 106: 35-47. http://dx.doi.org/10.1111/j.1469-8137.1987.tb04681.x.

Franklin, J.A. and D.S. Buckley, 2006, Effects of three ground cover treatments on initial oak Franklin, J.A. and D.S. Buckley, 2006, Effects of three ground cover treatments on initial oak establishment on a reclaimed minesite, Proceedings America Society of Mining and Reclamation, 2006 pp 848-855 http://dx.doi.org/10.21000/JASMR06010848855

Gorman, J., J. Skousen, J. Sencindiver, and P. Ziemkiewicz. 2001. Forest productivity and minesoil development under a white pine plantation versus natural vegetation after 30 years. *In*: Proc. of the 2001 National Meeting of the American Society of Surface Mining and Holl, K. D. 2002. Long-term vegetation recovery on reclaimed coal surface mines in the eastern USA. J. Applied Ecol. 39: 960-970. http://dx.doi.org/10.1046/j.1365-2664.2002.00767.x.

Owen, W. 2002. The History of Native Plant Communities in the South. Wear, David N.; Greis, John G., eds. 2002. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.

Ponder, F. 2005. Effect of soil compaction and biomass removal on soil CO2 efflux in a Missouri forest. Comm. Soil Sci. and Plant Anal. 36: 1301-1311. http://dx.doi.org/10.1081/CSS-200056935.

Sander, I. L. 1990. *Quercus rubra* L. Northern red oak. Burns, Russell M., and Barbara H. Honkala, tech. coords. Silvics of North America: 1. Conifers; 2. Hardwoods. Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 p.

StatSoft, Inc. 2006. Electronic Statistics Textbook. Tulsa, OK: StatSoft. Received August, 2006. Available: http://www.statsoft.com/textbook/stathome.html

University of Tennessee Herbarium. 2006. County Collection Diversity Map of Tennessee. Accessed April 5, 2006. Received: http://tenn.bio.utk.edu/vascular/diversi.htm

Wear, D. N. and J.G. Greis (eds.). 2002. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 635 p.