INITIAL TRANSPIRATION AND GROWTH OF NATIVE HARDWOOD SEEDLINGS PLANTED ON STEEP RECLAIMED MINE SITES[1]

Adam D. Klobucar[2], Elizabeth A. Aubuchon, Jennifer A. Franklin, and David S. Buckley

Abstract. Interactions between herbaceous groundcover and tree species planted on steep slopes of coal mine sites can be complex. Planted groundcovers can compete strongly for resources, hindering the growth of tree seedlings. Northern red oak, shagbark hickory, black cherry, and American chestnut were planted within four different groundcover treatments (alfalfa, switchgrass, goldenrod, and bare ground) on three different reclaimed sites in eastern Tennessee. Transpiration and growth of tree seedlings and soil moisture measurements were taken to document and explain tree performance, and to investigate the degree of competition between the different groundcover and tree species. Tree seedling growth performance did not differ between groundcover treatments during the first growing season. Additional first-year results suggest that slope position had a significant effect on transpiration of shagbark hickory in July ($p=0.0036$) and on transpiration in American chestnut seedlings in September ($p<0.0001$). Soil moisture at 15 cm below the surface had a weak linear relationship with July transpiration in black cherry ($p=0.0385$). It was also found that shagbark hickory height growth ($p=0.0207$), northern red oak height growth ($p=0.0081$), and northern red oak root collar diameter growth ($p=0.0105$) had linear relationships with September transpiration measurements.

Additional Key Words: soil moisture, tree performance, slope positions, northern red oak, shagbark hickory, black cherry, American chestnut, alfalfa, switchgrass, goldenrod.

---

[1] Paper was presented at the 2011 National Meeting of the American Society of Mining and Reclamation, Bismarck, ND ***Reclamation: Sciences Leading to Success*** June 11 - 16, 2011. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Adam D. Klobucar and Elizabeth A. Aubuchon are Graduate Research Assistants and Jennifer A. Franklin and David S. Buckley are Associate Professors within the University of Tennessee Institute of Agriculture, Department of Forestry, Wildlife and Fisheries, Knoxville, TN 37996.

Proceedings America Society of Mining and Reclamation, 2005 pp 326-335
DOI: 10.21000/JASMR05010326 <-this is incorrect.

http://dx.doi.org/10.21000/JASMR11010326

Introduction

In the Appalachian Region, initial efforts to reclaim and revegetate surface mines following the passage of the 1977 Surface Mining Control and Reclamation Act (SMCRA) involved the seeding of herbaceous groundcovers such as tall fescue (*Festuca arundinacea*) and serecia lespedeza (*Lespedeza cuneata)*. These plants were successful in controlling surface erosion, but often reduced the survival and growth of interplanted tree seedlings when reforestation was a post-mining management goal. Tracking in and compaction following the replacement of overburden materials were additional key components of these early post-SMCRA reclamation efforts. These measures improved the stability of steep, reclaimed slopes, but resulted in a very poor rooting medium for trees. The Forestry Reclamation Approach (FRA), which is recommended by the Appalachian Regional Reforestation Initiative (ARRI), was developed to address these problems (Burger et al., 2005). The FRA involves minimal compaction of the top 1.2 m of topsoil or topsoil substitute and the planting of only those herbaceous groundcovers that are compatible with tree growth and survival.

The number of herbaceous groundcover species that could be used to reduce surface erosion is quite large, but the compatibility of many of these species with interplanted tree seedlings has yet to be tested. Optimum groundcover species would be effective in minimizing surface erosion and the formation of rills that can occur on steep (20-45%) slopes, while having minimal competitive effects on co-occurring tree seedlings. A replicated field study designed to investigate the utility of three potentially tree-compatible groundcover species (switchgrass (*Panicum virgatum*), Grey goldenrod (*Solidago nemoralis*), and alfalfa (*Medicago sativa*)) having different rooting characteristics was established on three mine sites in eastern Tennessee in the spring of 2009. Four native hardwood tree species (northern red oak (*Quercus rubra*), American chestnut (*Castanea dentata*), black cherry (*Prunus serotina*), and shagbark hickory (*Carya ovata*)) were interplanted with these groundcover species. Annual ryegrass (*Lolium multiflorum*) was also planted on the sites to provide a fast-growing, but temporary groundcover.

Competition and several other factors such as sunlight, precipitation, nutrients, and topographic position can affect tree seedling growth and survival (Kozlowski et al., 1991). Competitive effects of groundcover and other plant species can include reduced soil moisture, reduced plant growth (Harmer et al., 2003) and reduced transpiration (Davis et al., 1999).

Consequently, competitive interactions between the planted tree seedlings and the different groundcover species were a predominant focus in this study.

Objectives

The first long-term objective of this study was to assess the performance of different tree species planted within different groundcovers and the second long-term objective was to determine the influence of different groundcover species on resource availability. Here we briefly report first-year effects of the different groundcover treatments on tree seedling performance, and present results for tree seedling transpiration obtained during the first growing season, which provide indications of seedling physiological status and soil moisture availability.

Methods

Three field study sites within reclaimed areas associated with active coal mining operations were selected: 1) King Mountain (36º37’N 83º56’W elevation: 594 meters), which is located in Claiborne County, Tennessee and is on a west-facing slope (287º azimuth); 2) Zeb Mountain (36º30’N 84º16’W elevation: 701 meters), which is located in Campbell County, Tennessee and is on a southeast-facing slope (151º azimuth); and 3) Windrock Mountain (36º07’N 84º19’W elevation: 859 meters), which is located in Anderson County, Tennessee and is on a west-facing slope (290º azimuth). Each study site contained steep slopes, as defined by the Office of Surface Mining. Material was placed on all slopes using the FRA that is recommended by ARRI.

Each study site was subdivided into 4 plots, and each plot was randomly selected to receive either one of the groundcovers (switchgrass, goldenrod, or alfalfa), or no groundcover. Tree seedlings were established in columns perpendicular to the slope and spaced 2 m apart (Fig. 1). Shagbark hickory, northern red oak, and an alternating mixture of black cherry and American chestnut seedlings were each systematically planted within 3 of the 9 columns within all plots (Fig. 1). All groundcover species and tree seedlings were planted in March 2009.

Total shoot height and root collar diameter were measured on all tree seedlings prior to out-planting. These variables were measured to provide baseline values for subsequent measurements and calculations of annual height and diameter growth. Measurements of shoot height, root collar diameter growth, and survival were taken in the field at the conclusion of the 2009 growing season.

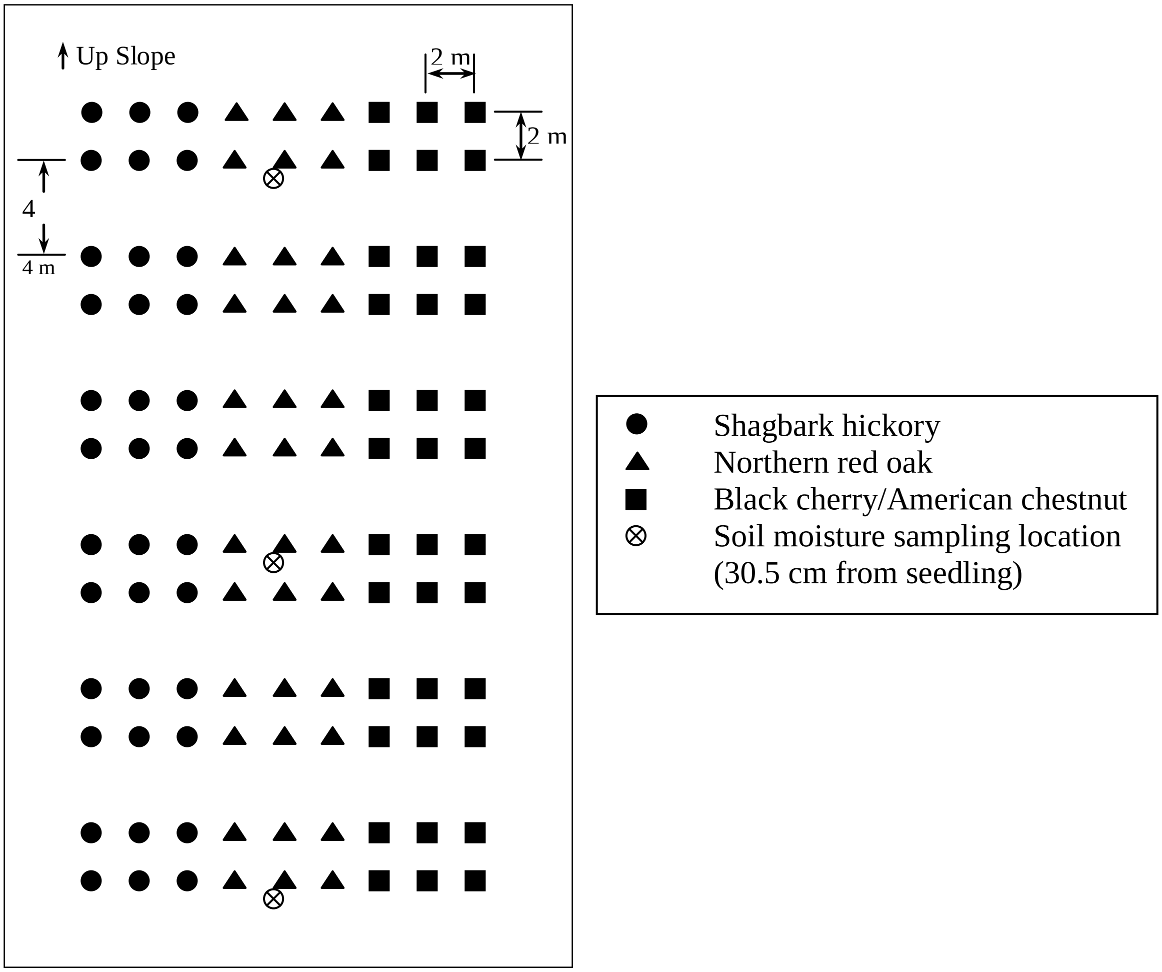

Figure 1. Seedling planting and soil moisture sampling locations within one subplot receiving a given groundcover treatment.

Vegetation was sampled around the planted tree seedlings on randomly selected rows within 1 m^2 square quadrats. Percent cover of planted groundcover species and unplanted herbaceous volunteers were recorded in July and September 2009, along with the maximum height of the groundcover and volunteer species to determine establishment and growth of groundcover species, and their potential effects on seedling growth and survival.

Prior to planting, soil moisture sampling tubes were installed at 3 different locations (upper, lower, and middle portion of the slope) on each plot (Fig. 1). These tubes were approximately 91 cm long and 2.5 cm wide. Soil moisture was measured bimonthly at depths of 15, 23, 30, 46, 61, and 76 cm below the surface of the soil (Fig. 2) using an Aquapro soil moisture probe (Aquapro Sensors, Ducor, CA 93218). Foliar transpiration of a subsample of seedlings was measured using a Li-Cor LI-1600 Steady State Porometer (Li-Cor, Inc., Lincoln, NE). Measurements were obtained on the upper-most fully expanded leaf of each sampled seedling. Seedlings in six randomly selected rows in each plot were measured in July and September 2009 (Fig. 3).

Figure 2. Soil moisture measurement.

Figure 3. Transpiration measurement.

All statistical analyses were carried out using SAS/STAT® software (version 9.2, SAS Institute Inc., Cary, NC) with $\propto = 0.5$. Differences in tree seedling performance and soil moisture between groundcover treatments were analyzed with 1-way ANOVA using models appropriate for a randomized complete block design ($y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$; where μ is the overall mean, τ_i is the i^{th} treatment effect, β_j is the j^{th} block effect, and ϵ_{ij} is the random error).

All 1-way ANOVAs were carried out with the General Linear Models (GLM) Procedure, and the Univariate Procedure was used to generate normal probability plots and statistics for checking normality and other assumptions underlying ANOVA. Inspection of the results for the Univariate Procedure run with each 1-way ANOVA revealed that no data transformations were necessary. Pairwise comparisons of treatment means were conducted with Tukey's HSD. As there were no significant differences in seedling performance or soil moisture between groundcover treatments, transpiration measurements were pooled across groundcover treatments prior to investigating the effects of slope position (upper, middle, and lower) on the transpiration of tree seedlings with 1-way ANOVA. Relationships between transpiration and seedling growth and between soil moisture and transpiration were investigated with simple linear regression.

Simple linear regressions were completed using the Regression Procedure, and residual plots and the Univariate Procedure were used to investigate linearity and other assumptions underlying simple linear regression. No transformations on X or Y were warranted based on the results of these diagnostic procedures. Standard errors reported along with the treatment means presented were calculated with the STDERR function within the Means Procedure.

Results and Discussion

With respect to the long-term objectives, no significant differences in the growth performance of any of the planted tree species or soil moisture were found between the different groundcover treatments during the 2009 growing season. Further, no significant regression relationships were found between the growth performance of tree seedlings in 2009 and either soil moisture or percent cover of groundcover species. Germination, establishment, and development of the planted groundcover species were very slow during the 2009 growing season, which likely contributed to the lack of significant groundcover treatment effects.

Significant differences in the transpiration of some tree species occurred across slope positions. In July 2009, mean foliar transpiration of shagbark hickory was approximately 1 µg cm-^{2}s-^{1} greater at lower slope positions than at the middle and upper slope positions (Fig. 4), and the differences were significant ($p = 0.0036$).

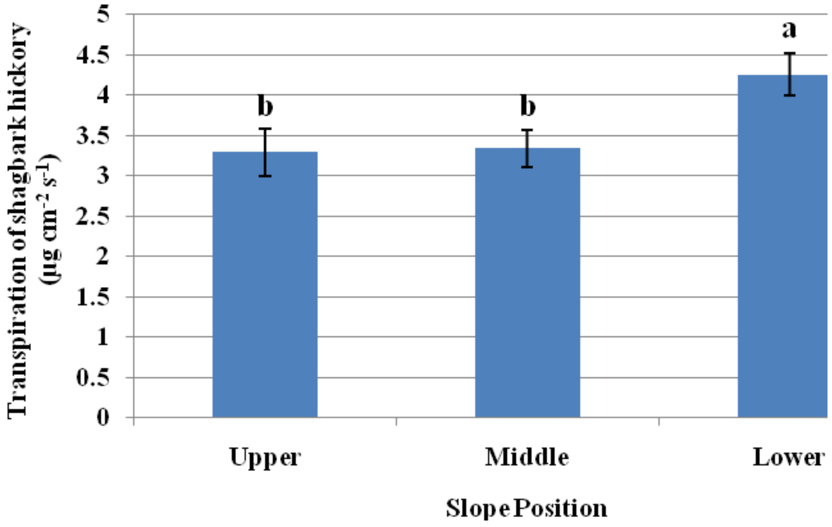

Figure 4. Effect of slope position on foliar transpiration of shagbark hickory in July 2009. Means with the same letter are not significantly different. Error bars represent 1 standard error.

Foliar transpiration of American chestnut in September also differed ($p < .0001$) between slope positions and on average, transpiration of American chestnut was approximately 1 µg cm^2 s^{-1} greater at upper slope positions than at the middle and lower slope positions (Fig. 5).

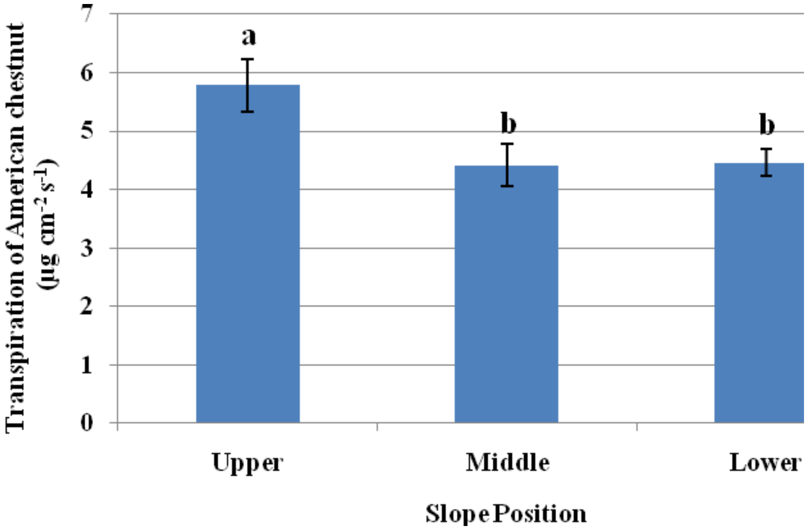

Figure 5. Effect of slope position on foliar transpiration of American chestnut in September 2009. Significance and error bars as in Fig. 4.

Height growth of northern red oak was found to be weakly related ($p=0.0081$) to foliar transpiration in September (Fig. 6), and root collar diameter growth in northern red oak was also found to be weakly related ($p=0.0105$) to transpiration in September (Fig. 7).

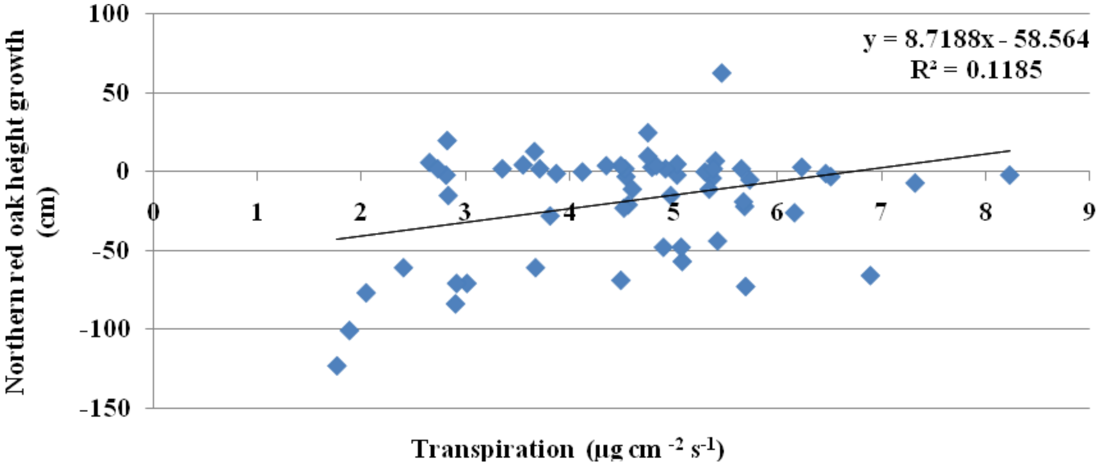

Figure 6. Linear relationship between northern red oak height growth and foliar transpiration in September 2009.

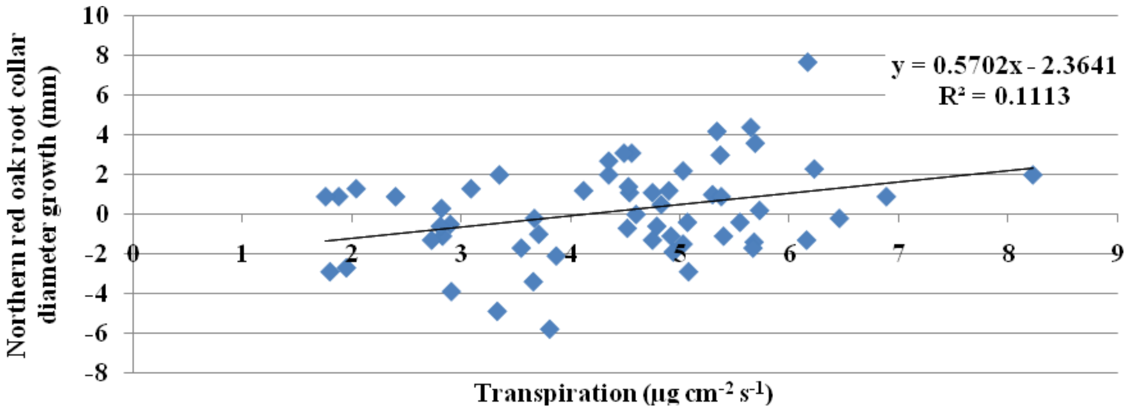

Figure 7. Linear relationship between northern red oak root collar diameter growth and foliar transpiration in September 2009.

Height growth of shagbark hickory had a very weak, but significant (p=0.0207) relationship with transpiration in September 2009 (Fig. 8).

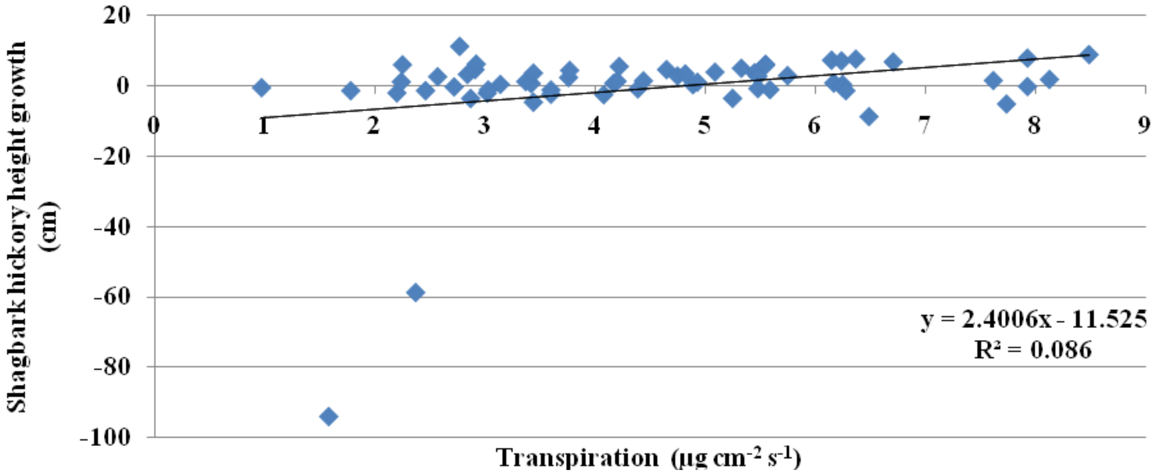

Figure 8. Linear relationship between shagbark hickory height growth and foliar transpiration in September 2009.

Soil moisture at 15 cm below the surface had a very weak, but significant (p = 0.0385) negative linear relationship with July foliar transpiration measurements for black cherry (Fig. 9).

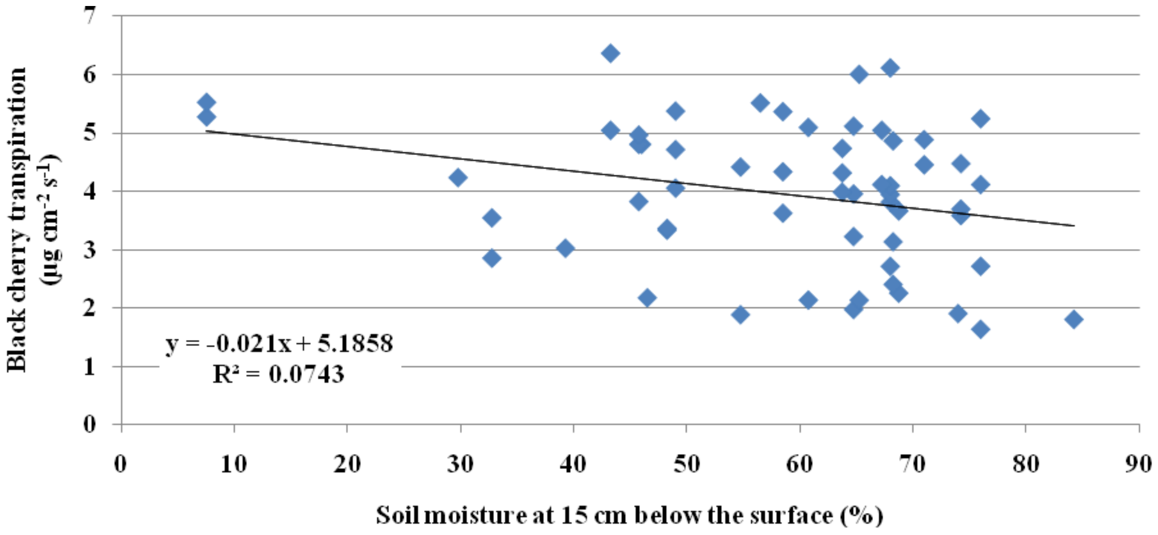

Figure 9. Linear relationship between black cherry July 2009 transpiration and soil moisture.

The sparseness of groundcover on the project sites may explain the lack of significant effects of the type or percent cover of groundcover species on tree seedling growth performance during the first growing season. The groundcover species evaluated in this project were considered to be tree-compatible groundcovers because they tend to be sparse the first year and increase in density during subsequent years. This developmental pattern can allow planted tree seedlings to rapidly emerge above the groundcover, thereby increasing their survival (Burger and Zipper 2002). The significant differences found in seedling transpiration between slope positions combined with the significant relationships between seedling growth and transpiration suggest that slope position may also be an important determinant of seedling performance on steep slopes, and that a given slope position could either mitigate or intensify the competitive effects of a co-occurring groundcover species. Longer-term monitoring of tree seedling performance and effects of the groundcovers is planned. As the development of the groundcovers progresses, more definitive results will become available for interpreting effects of different groundcover species on tree seedling performance and resource availability.

Acknowledgements

We would like to thank the U.S. Department of Interior, Office of Surface Mining for providing the funding for this work; National Coal Co., Premium Coal Co., and Mountainside

Coal Co. for providing study sites and logistical support; and Chris Miller, John Johnson, and other members of the UT Tree Physiology Lab for providing valuable assistance in the field.

Literature Cited

Burger, J. A., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. Appalachian Regional Reforestation Initiative Forest Reclamation Advisory No. 2.

Burger, J. A. and C.E. Zipper. 2002. How to Restore Forests on Surface Mined Lands. Virginia Tech Cooperative Extension Publication No. 460-123.

Davis, M. A., K. J. Wrage, P. B. Reich, M. G. Tjoelker, T. Schaeffer, and C. Muermann. 1999. Survival, growth, and photosynthesis of tree seedlings competing with herbaceous vegetation along a water-light-nitrogen gradient. Plant Ecology 145: 341–350. http://dx.doi.org/10.1023/A:1009802211896.

Harmer, R. and M. Robertson. 2003. Seedling root growth of six broadleaf species grown in competition with grass under irrigated nursery conditions. Ann. For. Sci. 60: 601-608. http://dx.doi.org/10.1051/forest:2003052

Kozlowski, T. T., P. J. Kramer, and S. G. Pallardy. 1991. The Physiological Ecology of Woody Plants. Academic Press, San Diego, CA.