EARLY TREE AND GROUND COVER ESTABLISHMENT AS AFFECTED BY SEEDING AND FERTILIZATION RATES IN TENNESSEE[1]

D. S. Buckley[2] and J. A. Franklin

Abstract: Planted ground covers can compete strongly with planted tree seedlings, hindering reforestation efforts. Fertilization increases the growth of ground cover, but its effects on hardwood tree seedlings and competitive interactions between trees and ground cover species are unclear. A 3x3 factorial experiment with 3 levels of broadcast water-soluble fertilizer and 3 seeding rates was established in 2006 to test for differences in tree seedling growth and survival, and for differences in ground cover establishment and composition. The ground cover was applied by hydroseeding a mixture of native warm-season grasses, annual rye and Korean lespedeza, along with lime, mulch and tackifier. Bare-root, 1-0 tree seedlings of scarlet oak, white oak, black walnut and mockernut hickory, along with mockernut hickory seed were planted on an 2.4 x 2.4m spacing. Tree growth and survival, and ground cover establishment have been monitored, and the effect of seeding and fertilization rate evaluated. Generally, seeding rate had little effect, while increased fertilization rate was associated with increased percent cover of forbs. However, there was high variability between blocks, with substantially greater ground cover on the block immediately below intact forest. At the highest seeding rate, fertilization significantly increased cover of legumes. First year survival of white and scarlet oak was greater than 90%. Survival of direct seeded and planted 1-0 mockernut hickory seedlings was similar after one year. Continued monitoring of longer term survival and growth of trees is planned.

Additional Key Words: hardwoods, warm-season grass, forestry, native species

---

[1] Paper was presented at the 2008 National Meeting of the American Society of Mining and Reclamation, Richmond, VA, ***New Opportunities to Apply Our Science*** June 14-19, 2008. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

[2] David S. Buckley, Associate Professor, and Jennifer A. Franklin, Assistant Professor, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN, 37996

Proceedings America Society of Mining and Reclamation, 2008 pp 180-191
DOI: 10.21000/JASMR08010180

http://dx.doi.org/10.21000/JASMR08010180

Introduction

New reclamation practices and standards under SMCRA resulted in greater safety and reduced negative environmental impacts, but also seemed to be associated with reduced survival and productivity of planted trees, hindering reforestion in the eastern US. These problems stimulated research on potential causes and techniques for increasing the success of reforestation efforts under SMCRA (e.g., Burger et al., 1998; Burger and Zipper, 2002; Conrad et al., 2002; Skousen and Zipper, 1997). The current Forestry Reclamation Approach (FRA) was developed based on these reforestation principles, and is currently being promoted through the Appalachian Regional Reforestion Initiative (ARRI). The FRA recommends the placement of a minimum of four feet (1.2 m) of suitable medium for tree growth with minimal compaction, and seeding with non-competitive native ground covers (Burger et al., 2005; Sweigard et al., 2007).

On steep slopes, the rapid establishment of dense ground cover is used to control erosion. However, the deeply rooted forest vegetation on steep slopes is critical for long-term slope stability by limiting surface erosion, reducing sediment yield, and reducing the risk of mass slope failures by increasing soil shear strength and maintaining favorable hydrology (Abe and Ziemer, 1991; Wilkinson et al., 2002; Norris, 2005; Van Beek et al., 2005). Herbaceous competition has been identified as one of the most significant factors influencing tree survival and growth (Hughes et al., 1992; Ashby, 1992). Tree survival on reclaimed minesites has been found to increase with decreasing ground cover (Bagley and Shaffer, 1992; Rizza et al., 2007; Skousen and King, 2004). However, ground cover at levels below 50%, and the use of native warm-season grasses may be beneficial to planted tree seedlings (Franklin and Buckley, 2006; Rizza et al., 2007). Ground cover moderates temperature and evaporation at the soil surface, increases the soil water holding capacity, and retains nutrients on the site.

Fertilization increases the growth of ground cover, and is usually applied at the time of planting to support the rapid and dense growth of an annual crop for the purpose of erosion control. The use of less aggressive species along with reduced seeding or fertilization rate may be required to obtain levels of ground cover between 25% and 50% that are desirable for reforestation. Native ground cover species generally have lower fertility requirements than agronomic species. Upland hardwood tree species of the Appalachians are also adapted to low-nutrient soils that are common in this region. Nutrient requirements of hardwood tree seedlings are not well known however and how competitive interactions between trees and ground cover species may change across gradients in nutrient availability are unclear. The purpose of this study was to determine the optimum seeding and fertilization rate for the establishment of tree seedlings in a native warm-season grass ground cover. We applied 10:20:20 N:P:K at 0, 224, and 448 kg/ha, and seeded ground cover at 5.9, 29.7, and 59.4 kg/ha. Our working hypothesis is that reducing seeding and fertilization rates to 50% of the currently recommended rate will result in desirable levels of ground cover, while having a minimal effect on the establishment of planted tree seedlings.

Materials and Methods

The site is located on Zeb mountain (36º29'35"N 84º17'06"W), near Elk Valley, TN, at an elevation of 600m. The regional climate is moderate with annual precipitation of 135cm/yr. The site is surrounded by mature hardwood forest typical of the Southern Appalachian region. Coal was extracted by contour mining, and overburden of siltstone and sandstone replaced to the approximate original contour with slopes of 20-45%. The amount of topsoil available for reclamation was negligible, and overburden was used as a topsoil substitute. The upper 1.5m to 2m of material was placed with minimal grading to create a low compaction substrate suitable for trees as recommended by the forestry reclamation approach (FRA).

Three 31.7m x 190m plots were placed side-by-side on an east-facing slope. Two plots on the upper portion of the slope were place side-by-side separated by a 10m buffer strip, and the third was on the lower portion of the slope. Upper and lower slopes were separated by a haul road with a drainage channel on the inner side, providing a hydrologic separation between the upper and lower plots. Each plot was divided along the length of the slope into nine 34m x 17m sub-plots, to which fertilizer x ground cover treatments were randomly assigned.

Hickory (*Carya alba*) seed was collected in Sept. 2005 from 4 plots in Anderson County, TN, float tested to remove empty seed, and stored at 4°C until planting. Germination rate was tested in the greenhouse, and found to be 80% ($\pm$5%). Thirty-six seedlings of white oak (*Quercus alba*), 8 scarlet oak (*Quercus coccinea*), 10 black walnut (*Juglans nigra*), 15 mockernut hickory, and 9 mockernut hickory seed were planted in random order on a 2.4m x 2.4m spacing within each treatment plot. White oak and scarlet oak seedlings grown from local seed sources were provided by the University of Tennessee Tree Improvement Program, while mockernut hickory and black walnut seedlings were obtained from the North Carolina State Forest Nursery. Bare-root seedlings were planted between Apr. 28 and May 4, 2006. All seedlings were one-year old at the time of planting (1-0). Seeds were planted at a depth of 6-10cm. No tree seedlings were planted within a 5m buffer strip where sub-plots met, or within 2.5m of the plot boundary on the upper and lower edges.

Figure 1. Application of seeding rate and fertilization treatments by hydroseeding. The 17m wide blue band being seeded is one sub-plot; two more completed sub-plots are visible on the left.

Treatments were applied by hydroseeder on May 9, 2006 (Fig. 1). The tank of the hydroseeder was flushed prior to treatment application, and before each new tank mixture. Treatments consisted of three levels of fertilization, applied as a water-soluble 10:20:20 N:P:K (from urea, ammonium phosphate and soluble potash), and three seeding rates in a full factorial experiment (Table 1). The seeding mix (100%) consisted of 6.7 kg/ha annual rye (*Lolium multiflorum*), 3.4 kg/ha Indian grass (*Sorghastrum nutans*), 0.2 kg/ha switchgrass (*Panicum virgatum*), 3.4 kg/ha big bluestem (*Andropogon gerardii*), 7.8kg/ha little bluestem (*Schizachyrium scoparium*), 2.2 kg/ha Korean lespedeza (*Lespedeza stipulacea*) and 6.8 kg/ha birdsfoot trefoil (*Lotus corniculatus*). Annual rye is a widely distributed introduced grass that is used to provide rapid vegetative cover, but does not persist past the first growing season. Indian grass, switchgrass, big bluestem and little bluestem are native and widely distributed in the US east of the Rocky Mountains, grow in upright bunches, and are adapted to drought and to a wide range of soil conditions. All grow to a height of approximately 1 m, with the exception of big bluestem, which averages 2 m in height. Indian grass is tolerant of nutrient-poor soils, while little bluestem is found primarily on fertile soils. Korean lespedeza and birdsfoot trefoil are introduced legumes planted widely in the eastern US to enrich soils by fixing nitrogen. Fiber mulch was applied at a rate of 1690 kg/ha, and lime (Liquid Lime Plus, Plant-Wise Biostimulant Company, Louisville, KY) was applied at a rate of 224 kg/ha to all plots. The treatment mix was applied in a 17m wide vertical strip from the top to the bottom of the slope, and an accuracy of about 1m at the edge of the sub-plots was possible.

Table 1. Fertilization and seeding rate treatments applied to plots, as a percent of standard application rates, and in kg/ha.

Treatment	-------Fertilizer-------		------Seeding Rate-----	
	%	kg ha^{-1}	%	kg ha^{-1}
1a	0	0	10	5.9
2a	0	0	50	29.7
3a	0	0	100	59.4
1b	50	224	10	5.9
2b	50	224	50	29.7
3b	50	224	100	59.4
1c	100	448	10	5.9
2c	100	448	50	29.7
3c	100	448	100	59.4

In early August of 2006 and in mid-July of 2007, groundcover vegetation was sampled along two 20m transects that ran diagonally through the center of each plot. The amount of the transect tape intersected by each groundcover type was tallied for subsequent determination of percent cover. Groundcovers were classified as either grasses (which included sedges), legumes (which included all types of clover as well as lespedeza), or non-leguminous forbs which consisted of all other species. Tree survival was recorded in June of 2007. Seedlings that had failed to produce new growth, and seed locations without a visible shoot were counted as dead.

A general linear model was used to test for differences in the percentage of cover of each ground cover type, with respect to seeding rate and fertilization rate (SPSS 15.0, SPSS Inc., Chicago, IL). Tree survival was tested against fertilization rate only. To meet assumptions of equal variance, data were log-transformed prior to analysis. Where significant main effects were found, differences were compared using a Duncan post-hoc. All results were considered significant at the $p \leq 0.05$ level.

Results and Discussion

The development of ground cover over the first year was slow, with cover on all plots less than 10% at the end of the first growing season. Unusually dry weather following seeding resulted in the failure of annual rye in the first year. May and June precipitation was half that of normal values (11.4cm vs. 22.1cm average), and likely suppressed vegetative development in the first year. Although seeding was completed at an optimal time of year for the establishment of native warm-season grasses (Panciera and Jung, 1983), no grasses were visible until late fall. By July of the second growing season, ground cover on the plots ranged from 1% to 75%, with an average of 21% across all plots. There was no significant effect of seeding rate on the amount of ground cover, although cover tended to be lowest at the lowest seeding rate (Fig. 2).

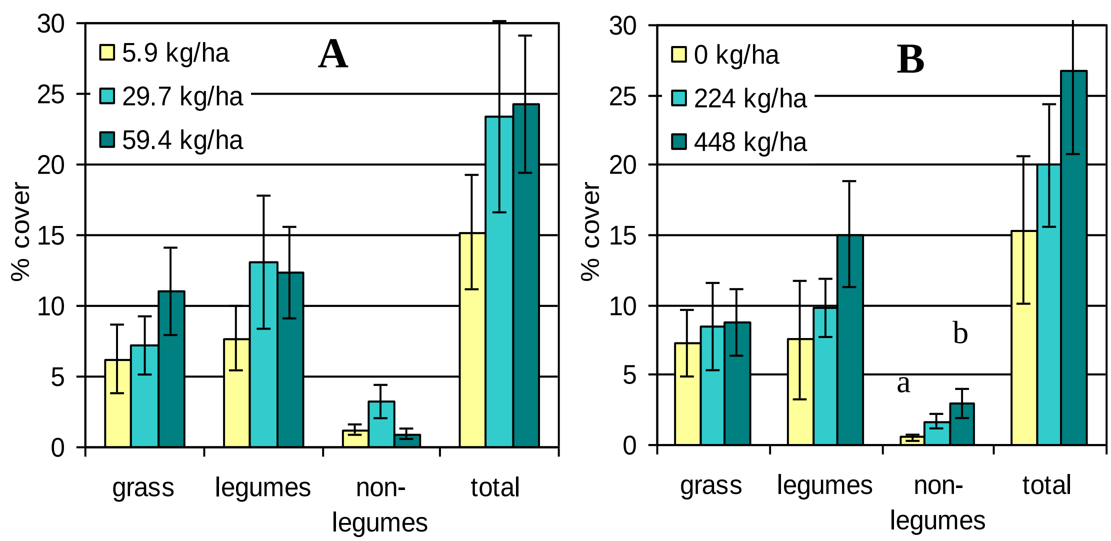

Figure 2. Mean ground cover of grasses, legumes and non-leguminous forbs in July of the second growing season in response to three seeding rates (A) and three levels of fertilization (B). Bars represent $\pm$ 1 standard error. Different letters indicate a significant difference between treatments at the 0.05 level.

Increased fertilization rate at the time of planting resulted in small increases in percent cover for all ground cover types in the second growing season (Fig. 2B). This response was statistically significant for the non-leguminous forb component. Because only grasses and legumes were seeded, this component is comprised of species that volunteered into the site. Although it made up less than 5% of total vegetation, this component contributes to species diversity, and will be monitored as vegetative development progresses. Fertilization increased the cover of legumes, and this effect was significant only at the highest seeding rate. While legumes are generally tolerant of low-nutrient soils, liming and low levels of fertilization are recommended for good establishment (Skousen and Zipper, 1997). Fertilization is generally not recommended for warm-season grasses at the time of seeding as it promotes the growth of competitive species. However, fertilization had no effect on the initial establishment of native-warm season grasses, and the low levels of other ground covers were unlikely to limit grass establishment. While a grass cover of 5-10% may appear low, a density of approximately one plant per square foot that is adequate to produce a fully stocked stand of warm-season grasses at an age of two to three years. These species often produce sparse foliage initially, while developing extensive root systems.

Figure 3. Ground cover in July of the second growing season varied greatly between plots and treatment sub-plots, both in species composition and in percent cover which ranged from 1% to 75%. Two treatments on plot 2 are shown, and plot 1 is seen at the far end of the slope.

There was a marked difference in ground cover vegetation development between the three plots, with plot 1, closest to intact forest, having nearly three times the ground cover of the other plots by July of the second growing season (Fig. 4). Within this plot, fertilization rate appears to have had a much greater effect on ground cover development (Fig. 5), although this cannot be analyzed statistically. Plot 1 was located on the slope directly below a portion of intact forest, and had a slightly concave topography. Of the three plots, this was the only one with a substantial area above that could act as a water catchment, and observations and limited gravimetric soil moisture measurements suggest greater water availability on this plot.

Figure 4. Percentage of grass, legume, and non-leguminous forb cover on 3 plots in July of the second growing season. The mean of all treatments is shown.

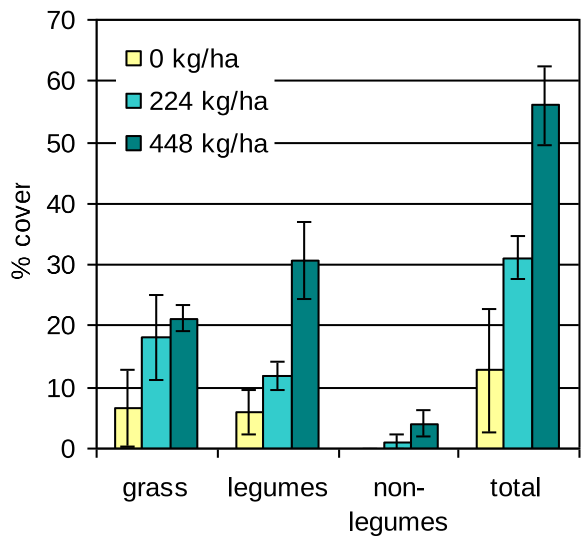

Figure 5. Plot 1 mean ground cover of grasses, legumes and non-leguminous forbs in July of the second growing season with three levels of fertilization.

Across all plots, fertilization effects may appear over a longer time period, when periods of good growing conditions allow for the utilization of resources, as was found in a 10-year study of vegetative development on fertilized vs. unfertilized minespoils in Germany (Jochimsen, 2001). Fertilization has also been found to have long-term effects through improvements in soil properties (Shukla et al., 2004).

After one year, survival of white and scarlet oak was greater than 90%, while survival of both planted and direct seeded hickory was similar after one year, and below 40%. Due to the low levels of ground cover in the first year, competition with ground cover species was not likely a factor in first-year tree seedling survival. Fertilization rate did not significantly affect seedling survival in the first year (Fig. 6). The effect of microsite has also been found to be of greater importance than fertilization in the growth and survival of conifers on a reclaimed minesite in this area (Buckner and Kring, 1967). Because nursery-grown seedlings often contain high levels of stored nutrients, deficiency symptoms may not appear for several years. However growth and survival of planted hardwoods after 18 years on an un-amended acidic minesite in Kentucky suggests that competition rather than fertility limited forest development (Wade et al. 1985). Growth and survival of these seedlings will continue to be monitored.

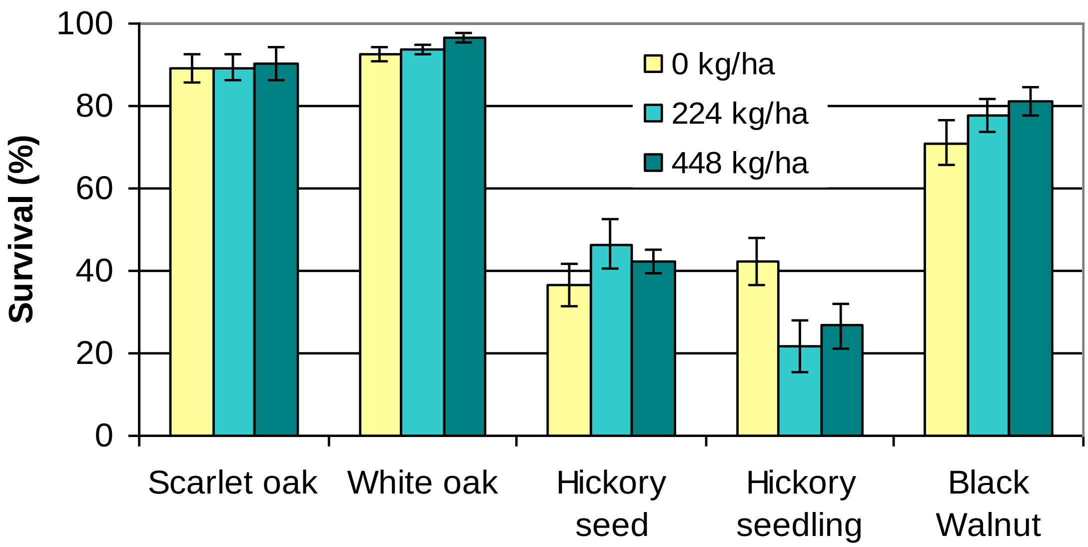

Figure 6. First year survival of planted tree seedlings and seed at 3 levels of fertilization, applied as 10:20:20 at the time of planting.

Overall, seeding rate had very little effect on the percent cover of ground cover species after two growing seasons. Based on the early results for fertilization, it appears little can be gained by investing in fertilization during the establishment of warm-season grasses. This supports general recommendations that advise against fertilization during initial establishment of warm-season grasses in agricultural and other applications to limit weedy competitors (Harper et al., 2004). Results of fertilization, however, did differ between plots which highlights the potentially important influence of microsite conditions on our ability to control cover through the manipulation of seeding and fertilization rates. At the end of the second year, the degree of development of ground cover species suggests that intense competition between planted trees and ground cover species was unlikely. However, it is important to note the failure of the annual cover crop, and that substantially higher ground cover could result from high seeding and fertilization rates, especially on good sites and with optimal weather conditions. Continued monitoring of ground cover and tree development will be necessary to capture long-term effects of fertilization and seeding rates, and is planned.

Acknowledgements

Funding for this project was provided by National Coal Corp. The authors wish to thank Terry Ayres of National Coal for assistance with site selection and preparation, Victor Davis of the Knoxville Field Office of OSM for assistance with site selection and permit requirements, and Bill Johnston for facilitating plot establishment and treatments. We would also like to thank Bay Outdoors Inc. for hydroseeding treatments, and Stuart Wilson, Sharon Jean-Philippe, Aamir Saleem, and Stephane Jeckel for technical assistance.

Literature cited

Abe, K. and R. R. Ziemer. 1991. Effect of tree roots on a shear zone: modeling reinforced shear stress. Canadian Journal of Forest Research 21:1012-1219. http://dx.doi.org/10.1139/x91-139.

Ashby, C. W. 1992. Update of ongoing research. pp 739-755. *In*: The 9th annual meeting of the American Society for Surface Mining and reclamation. June 14-19. Duluth, MN.
https://doi.org/10.21000/JASMR92010739

Bagley, F. L., and S. Shaffer. 1992. Reforestation of surface-mined land in Maryland. pp 616-623. *In*: 9th annual meeting of the American Society for Surface Mining and Reclamation. June 14-19. Duluth, MN.
https://doi.org/10.21000/JASMR92010616

Buckner, E. R. and J. S. Kring. 1967. A Crop for mine spoils? KTG Journal 7(1). Keep Tennessee Green Association, Sewanee, TN.

Burger, J., D. Graves, P. Angel, V. Davis, and C. Zipper. 2005. The Forestry Reclamation Approach. U.S. Office of Surface Mining. Forest Reclamation Advisory Number 2. 4 p.

Burger, J. A., D. L. Kelting, and C. Zipper. 1998. Maximizing the value of forest on reclaimed mined land. Virginia Cooperative Extension Publication Number 460-128. Virginia Polytechnic Institute and State University. Blacksburg, VA.

Burger, J. A., and C. E. Zipper. 2002. How to restore forests on surface-mined land. Virginia Cooperative Extension Publication Number 460-123. Virginia Polytechnic Institute and State University. Blacksburg, VA.

Conrad, P. W., R. J. Sweigard, D. H. Graves, J. M. Ringe, and M. H. Pelkki. 2002. Impacts of spoil conditions on reforestation of surface mined land. Mining Engineering 54:39-46.

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/JASMR06010848

Harper, C. A., G. E. Bates, M. J. Gudlin, and M. P. Hansbrough. 2004. A landowners guide to native warm-season grasses in the Mid-South. University of Tennessee Extension Publication 1746.

Hughes, G. H., G. L. Storm, and B. E. Washburn. 1992. Establishment of native hardwoods on mined lands revegetated under current regulations. pp. 601-606. *In*: 9th annual meeting of the American Society for Surface Mining and Reclamation. June 14-19. Duluth, MN.
https://doi.org/10.21000/JASMR92010601

Jochimsen, M. E. 2001. Vegetation development and species assemblages in a long-term reclamation project on minespoil. Ecological Engineering 17: 187-198. http://dx.doi.org/10.1016/S0925-8574(00)00158-0.

Norris, J. E. 2005. Root reinforcement by hawthorn and oak roots on a highway cut-slope in southern England. Plant and Soil 278:43-53. http://dx.doi.org/10.1007/s11104-005-1301-0

Panciera, M. T. and G. A. Jung. 1983. Switchgrass establishment by conservation tillage: planting date response of two varieties. J. of Soil and Water Conservation 39: 68-70.

Rizza, J., D. S. Buckley, and J .A. Franklin, 2007, Influence of different ground cover treatments on the growth and survival of tree seedlings on remined sites in eastern Tennessee ,Proceedings America Society of Mining and Reclamation, 2007 pp 633-677 http://dx.doi.org/10.21000/jasmr070106637

Shukla, M. K., R. Lal, J. Underwood, and M. Ebinger. 2004. Physical and hydrological characteristics of reclaimed minesoils in southeastern Ohio. Soil Science Society of America J. 68: 1352-1359. http://dx.doi.org/10.2136/sssaj2004.1352.

Skousen, Jeff, and Jim King. 2004. Tree survival on mountaintop mines in southern West Virginia. West Virginia University Extension Service.

Skousen, J., and C. E. Zipper. 1997. Revegetation Species and Practices. Virginia Cooperative Extension Publication Number 460-122. Virginia Polytechnic Institute and State University. Blacksburg, VA.

Sweigard, R., J. Burger, C. Zipper, J. Skousen, C. Barton, and P. Angel. 2007. Low Compaction Grading to Enhance Reforestation Success on Coal Surface Mines. U.S. Office of Surface Mining. Forest Reclamation Advisory Number 3. 6 p.

Van Beek, L. P. H., J. Wint, L. H. Cammeraat, and J. P. Edwards. 2005. Observation and simulation of root reinforcement on abandoned Mediterranean slopes. Plant and Soil 278:55-74. http://dx.doi.org/10.1007/s11104-005-7247-4

Wade, G. L., R. L. Thompson, and W. G. Vogel. 1985. Success of trees and shrubs in an 18-year-old planting on mine spoil. USDA Forest Service, Northeastern Forest Experiment Station, Research Paper NE-567.

Wilkinson, P. L., M. G. Anderson, and D. M. Lloyd. 2002. An integrated hydrological model for rain-induced landslide prediction. Earth Surface Processes and Landforms 27:1285-1297. http://dx.doi.org/10.1002/esp.409.