EFFECTS OF THREE GROUND COVER TREATMENTS ON INITIAL OAK ESTABLISHMENT ON A RECLAIMED MINESITE[1]

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Abstract. There is an increasing desire by land managers to reestablish hardwood forests on reclaimed coal mine sites in the southern Appalachians. Oaks are particularly important for both timber value and wildlife use, however the establishment of planted oak seedlings may be hindered by the competitive nature of groundcover that is typically planted on these sites. In 2004, nine experimental plots were established. Three plots were located in an area that had been reclaimed approximately 30 years ago and had a dense cover of legumes and grasses. Six plots were located in a newly reclaimed area where mixed sandstone and siltstone were placed with minimal compaction in the upper 4 feet of substrate. These plots were seeded with annual rye and birdsfoot trefoil, with 3 plots having a sparse cover of rye at the time oak seedlings were planted (rye), and 3 plots with bare soil initially, seeded one month after oak planting (bare soil). Eight one-year-old seedlings of chestnut oak (*Quercus montana*), scarlet oak (*Q. coccinea*) and white oak (*Q. alba*) were planted on a 2x2 m spacing within each plot, and bud flushing, growth, seedling condition, and survival were monitored over 2 growing seasons. First-year survival for all treatments and species was greater than 84%. Results suggest that ground cover has an influence on oak establishment through both direct competitive effects and indirect effects on soil properties.

Additional Key Words: reforestation, Quercus, competition

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[1] Paper was presented at the 2006 Billings Land Reclamation Symposium, June 4-8, 2006, Billings MT and jointly published by BLRS and ASMR, R.I. Barnhisel (ed.) 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2006 pp 848-855

DOI: 10.21000/JASMR06010848

http://dx.doi.org/10.21000/JASMR0601848

Introduction

Many older mine sites in the Southern Appalachians had loosely dumped tailings that were left to recover naturally and now support productive hardwood forests typical of this region. After the Surface Mining Control and Reclamation Act (SMCRA) of 1977 was put in place, regulators and new state and federal regulations heavily emphasized "short-term hydrologic impacts, sediment control, surface stability, and complete ground cover" (Burger 1999). The inception of regulations with these new emphases stimulated coal operators to grade and heavily compact spoil materials to increase their stability, and plant dense stands of grasses and legumes requiring heavy fertilization in order to check soil erosion (Burger 1999). These new practices allowed coal operators to successfully comply with the new regulations, but they also resulted in planning that did not incorporate productive forest as a future land cover, or soil conditions that resulted in reforestation failures when trees were planted. New research shows that tree establishment is possible if mine tailings materials are placed with minimal compaction (Burger and Torbert, 1999). In fact, 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). Recent tests are promising and interest in re-establishing tree species is high, but cultural, technical and regulatory barriers to reforestation remain.

The Appalachian Regional Reforestation Initiative (ARRI) was established in Dec. 2004 and is a cooperative effort between the Office of Surface Mining and the states in the Appalachian coal region with the goal of removing these barriers to reforestation. New guidelines for reclaiming coal-mined land to support forested land uses have recently been published (Burger et al., 2005) and recommend the practitioner "use ground covers that are compatible with growing trees". Past reclamation practices have established several non-native species in this region, some of which (e.g., *Lespedeza bicolor* and *Festuca arundinacea*) have been very successful in colonizing reclaimed sites and have proven to be aggressive competitors of tree seedlings (Zipper, 2004). Current recommendations for sowing ground cover in areas planned for afforestation call for a mixture containing birdsfoot trefoil (*Lotus corniculatus* L.), *Lespedeza* sp., perennial ryegrass (*Lolium perrene* L.), foxtail millet (*Setaria italica* L.) and redtop (*Agrostis alba* L.), with a total seeding rate of 26 to 41 pounds per acre (Kentucky Department of Fish and Wildlife Resources, et al., 1995). The required stocking density of trees on reclamation sites planned for forest uses is a minimum of 300 stems per acre, a standard set by the Natural Resources and Environmental Protection Cabinet in 1995.

The primary objective of this research was to determine the effects of ground covers differing in density and composition on the growth and survival of oak seedlings planted on a reclaimed mine site. An additional objective was to quantify microsite conditions associated with each type of ground cover in order to provide insight into the mechanisms underlying the performance of planted seedlings.

Materials and Methods

The experimental site is in the Cumberland Mountains in eastern Tennessee (36º08' N 84º21' W) at an elevation of 853 m on a 450 ha site reclaimed after surface mining of coal. The regional climate is moderate with annual precipitation of 135 cm/yr. The site was surrounded by mature hardwood forest typical of the Southern Appalachian region. In this region, coal is removed from horizontal seams located near the upper slopes of mountains capped by layers of siltstone and sandstone. Typically, the siltstone and sandstone overburden is partially removed by blasting and subsequent excavation to expose the horizontal coal seam along the appropriate contour, which creates a horizontal bench and vertical highwall. As a result, this method of surface mining is commonly referred to as contour mining. The site studied was first mined in the 1970's, and a large proportion of this area was mined again in 2003. Portions of the site reclaimed in the 1970's appear typical of post-SMCRA sites with a dense cover of grasses and lespedeza species and very few woody species. *Lespedeza bicolor*, *Lespedeza cuneata*, orchard grass (*Dactylis glomerata*), and Timothy (*Phleum pratense*), were among the prominent components of the plant community. Three plots were selected within the area reclaimed in the 1970's, and are referred to as "old-field" plots. Areas reclaimed in the late fall of 2003 had overburden materials replaced in a manner such as to reduce soil compaction, and were seeded with 45 kg/ha annual rye, 17 kg/ha orchard grass, 3.4 kg/ha red clover, 12.4 kg/ha Kobe lespedeza and 6.8 kg/ha birdsfoot trefoil. Fiber mulch was applied at a rate of 1690 kg/ha. The substrate is comprised of approximately 70% shale and 30% sandstone. The amount of topsoil available for reclamation was negligible. In keeping with reclamation standards, the overburden substrate was replaced in a fashion that covered up as much of the highwall as possible, and approximated the pre-mining slope of the mountain. In March of 2004, annual rye formed a tall, sparse cover over parts of the site (rye), while other parts of the site remained bare (bare) and it was assumed that seeding had failed. Three plots were established within the rye area, and three within the bare area. All old-field, rye, and bare plots were generally located along the same contour, and had a northeast aspect.

On May 26 and 27, 2004, eight seedlings each of chestnut oak (*Quercus montana*) , white oak (*Quercus alba*) and scarlet oak (*Quercus coccinea*) were planted in random order on a 2x2 m spacing within each plot. All seedlings were one year old at the time of planting (1-0) and were obtained from the North Carolina Forest Service State Nursery. The height and root collar diameter of each seedling was measured at the time of planting. The date of resumption of growth, indicated by expansion of the terminal bud (flushing), was recorded. Plants were monitored weekly during the period of bud flushing in 2004 and 2005. Browsing and survival were monitored monthly during the growing season. Root collar diameter and height were measured at the end of each growing season.

Soil samples from the upper, mid, and lower slope sections of each plot were obtained at the time of planting. Soil was analyzed for relative moisture content, field capacity, pH, salinity and particle size distribution. Percent volumetric soil moisture to a depth of 15 cm was measured with a portable Trase Time Domain Reflectometry (TDR) probe (Soilmoisture Corp., Goleta, CA). Soil moisture measurements were taken on June 24 and July 20, 2004 in all plots at 9 systematically placed sample points between seedling sampling locations in each plot. Three sample points were located along each of the upper, middle, and lower slope positions within each plot. Soil density was also measured at each of the soil moisture sampling points on the same dates with a Lange penetrometer (Lange Penetrometers, Gulf Shores, AL).

Photosynthetically Active Radiation (PAR) was measured at the 9 systematically placed sample points on July 20, 2004 with a Decagon Accupar Ceptometer (Decagon Devices, Pullman, WA). At each sample point, PAR measurements were taken 20, 50, and 100 cm above the ground. Measurements in all plots were taken within an hour of solar noon under clear skies.

Transpiration rates were measured with a steady state porometer (Licor Inc., Lincoln, NE) on the uppermost fully expanded leaf of each sampled seedling. Four seedlings per species per plot were measured on a single day in Aug. 11, 2004, between the hours of 11:30 and 14:30.

Groundcover vegetation was sampled along four 5m linear transects located along random azimuths in the old-field area. The amount of the transect tape intersected by each groundcover species was tallied for subsequent determination of percent cover.

Results and Discussion

In August of 2004, PAR levels at 20 cm above the ground in the old field and rye treatments were approximately 35% lower than in the bare treatment (Fig. 1). This difference was likely due to the greater density of vegetation less than 50 cm tall in the old field and rye treatments than in the bare treatment, and would have resulted in less PAR received by the seedlings planted, at least in the case of seedlings in the shorter height classes. Mean PAR values at 50 and 100 cm above the ground were much more comparable between treatments (Fig. 1), although mean PAR at 100 cm was significantly greater in the old field treatment than in the other treatments. Significantly greater PAR values at 100 cm in the old field treatment were unexpected as this treatment had the greatest abundance of tall vegetation such as *Lespedeza bicolor*.

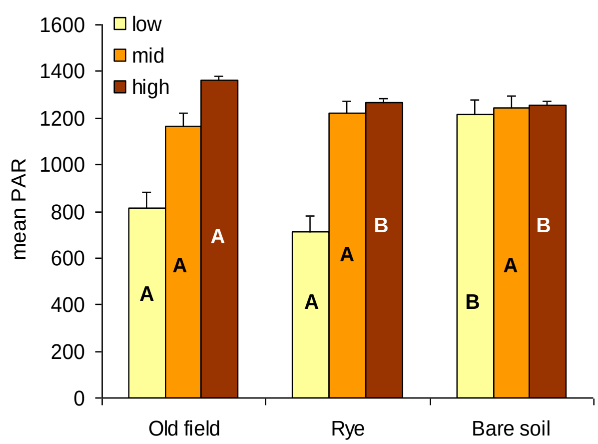

Figure. 1 Mean photosynthetically active radiation (PAR) at 20 cm (low) 50 cm (mid) and 100 cm (high) above ground level. Bars represent standard error. Different letters represent significant differences between treatments for a given height at P$\leq$0.05.

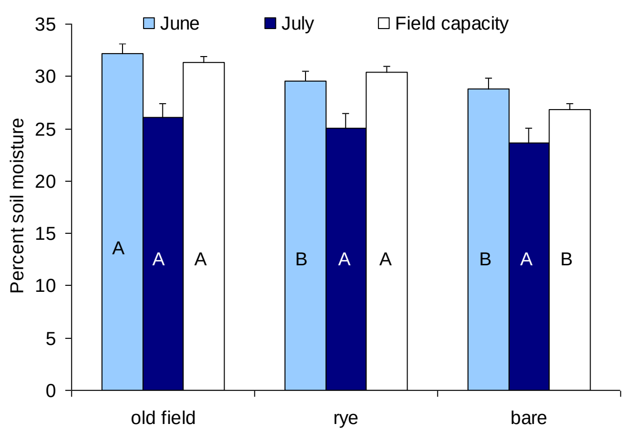

Figure. 2 Mean soil moisture and field capacity in old field, rye and bare soil treatments. Bars represent standard error. Different letters represent differences between treatments for a given species at P$\leq$0.05.

Percent soil moisture to 15 cm depth was significantly greater in the old field treatment than in the rye and bare soil plots in the June measurement, and significantly greater in the old field and rye treatments than in the bare treatment when soils were at field capacity (Fig. 2). The presence of groundcover vegetation can have multiple potential effects on soil moisture, including depletion of soil moisture through transpiration and conservation of soil moisture by reducing losses to evaporation from the soil surface. The results for soil moisture suggest that potential negative impacts of transpiration on soil moisture were overridden by the positive impacts of vegetation in shading the soil and reducing evaporation. It is also possible that the greater period for soil development in the old field treatment could have influenced the patterns observed in soil moisture. The substrate in the newly reclaimed rye and bare treatment areas was somewhat alkaline at a pH of 7.9 $\pm$ 0.15, and pH in the old field treatment was significantly lower at 7.5 $\pm$ 0.15. No consistent differences in soil density were found between treatments (data not shown).

Survival of oak seedlings was 84% in Oct. of 2004, and 61% in Jan. of 2005, and did not differ significantly between treatments. By spring of 2005 both rye and bare ground treatments had a dense cover of clover that may have had a competitive effect during the second growing season. Survival rates of red oak (*Quercus rubra*) planted into grasses and ferns were found to have similar survival rates of 58% after 4 years (George et al., 1991). Deer browsing and rodent girdling in 2004 resulted in much of the mortality recorded in 2005. Approximately 8% of seedlings showed evidence of deer browsing, while 14% were partially or fully girdled by rodents across all treatments and species.

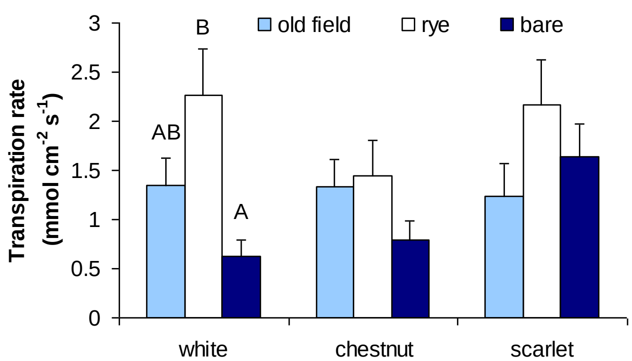

Figure. 3 Mid-day transpiration rates of oak seedlings planted in three ground cover treatments. Bars represent standard error.

Over all oak species, transpiration rates were significantly higher in the rye treatment than in the old field or bare ground (Fig. 3). Within species, differences in transpiration were significant for white oak alone where mean transpiration rates in rye cover were three times that of bare ground. The light cover of rye likely provided enough shade during the heat of the day to reduce evaporative losses and allow stomata to remain open. Bare soil had both a low soil water holding capacity and high light exposure which led to stomatal closure during mid-day. White oak, thought to be a more mesic oak species (Johnson, 1990; McQuilkin, 1990; Rogers, 1990), was the most sensitive to these different site conditions. The transpiration rate of Quercus robur seedlings has been found to not only decrease with soil moisture, but also with the availability of nutrients (Wellander and Ottosson, 2000). This effect may be responsible for the lower transpiration rates we observed in the old field treatment where dense ground cover competes for nutrients with the oak seedlings.

The date of bud flushing did not vary significantly with treatment. A substantial amount of dieback occurred during the first growing season as indicated by negative values for height growth and root collar diameter (Fig. 4 and Fig. 5). Of the three oak species, scarlet oak is the least tolerant of shading and most tolerant of dry soils (Johnson, 1990; McQuilkin, 1990; Rogers, 1990). This is the only species to have shown dieback over the 2005 growing season, and this occurred only in the old field sites suggesting it may not be able to persist under this heavy competition. Chestnut oak showed substantial height growth in both rye and old field sites, but root collar diameter growth was significantly lower in the old field than in the rye treatment suggesting it was negatively impacted by heavy root competition.

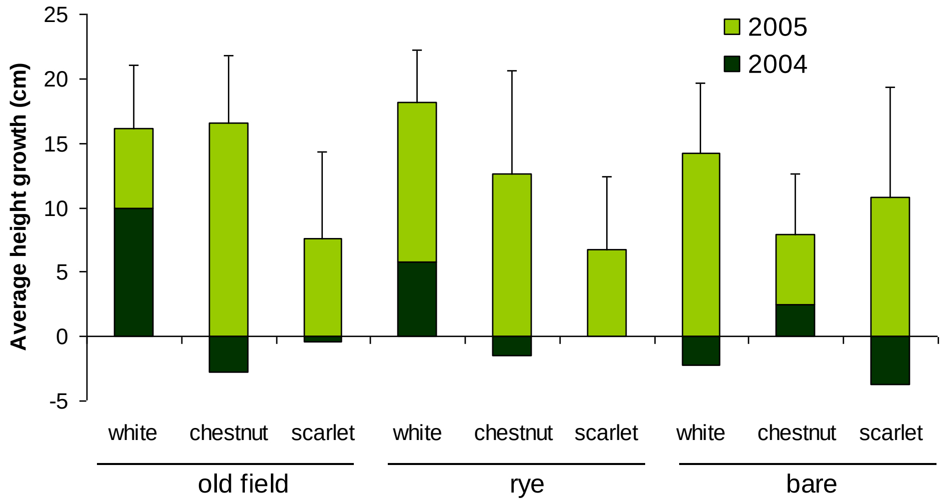

Figure. 4 Average height growth over the 2004 and 2005 growing seasons of oak seedlings planted on old field, rye and bare sites. Bars represent standard error.

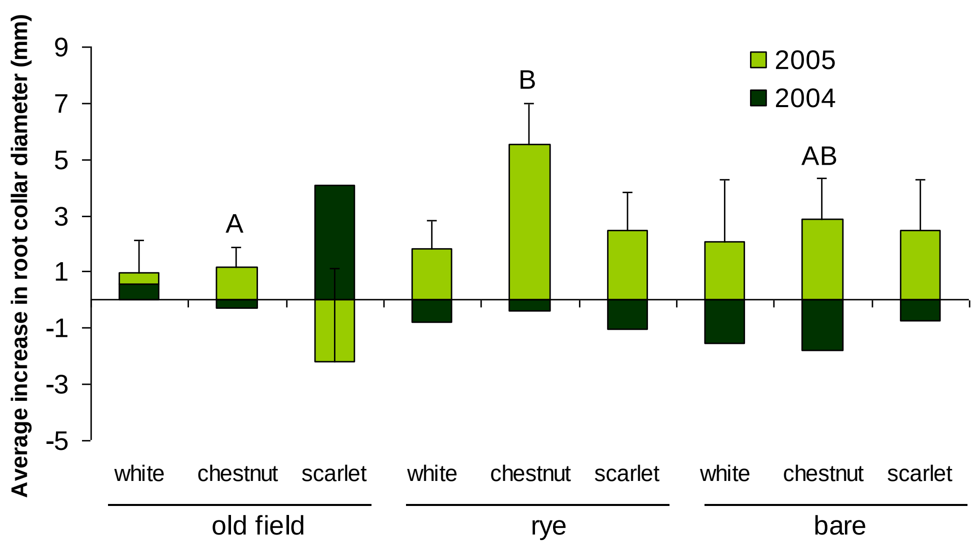

Figure. 5 Average root collar diameter growth over the 2004 and 2005 growing seasons of oak seedlings planted on old field, rye and bare sites. Bars represent standard error.

We conclude that the light cover provided by the rye treatment provided the best conditions for oak seedling growth overall. This treatment appears to have provided the best balance between the positive effects of the vegetation on water relations and the negative effects of competition.

Acknowledgements

This study was funded by National Coal Corp. The authors wish to thank Bill Johnson of National Coal and Victor Davis from the U.S. Office of Surface Mining for their support of this project. We also thank Jordan Marshall, Brien Ostby, John Rizza and Scott Faw for technical support.

Literature Cited

Burger, J.A. 1999. Academic research perspective on experiences, trends, constraints, and needs related to reforestation of mined land. P. 63-74 *in* Proceedings of a technical interactive forum on enhancement of reforestation at surface coal mines (23-24 March, 1999, Fort Mitchell, KY). (Accessible on the USDI, Office of Surface Mining, Mid-Continent Region web page located at www.mcrcc.osmre.gov/tree/)

Burger, J.A., D. Graves, P. Angel and V. Davis. 2005. Appalachian Regional Reforestation Initiative (ARRI) Forest Reclamation Advisory, Number 2. U.S. Office of Surface Mining. 4p. available at http://arri.osmre.gov/

Burger, J.A., and J.L. Torbert. 1999. Status of reforestation Technology: The Appalachian Region. P. 95-108 *in* Proceedings of a technical interactive forum on enhancement of reforestation at surface coal mines (23-24 March, 1999, Fort Mitchell, KY). (Accessible on the USDI, Office of Surface Mining, Mid-Continent Region web page located at www.mcrcc.osmre.gov/tree/)

Burns, R.M., and B.H. Honkala (eds.). 1990. Silvics of North America. Volume II, Hardwoods. USDA Forest Service Agriculture Handbook 654.

George, D.W., T.W. Bowersox and L.H. McCormick. 1991. Effectiveness of electric deer fences to protect planted seedlings in Pennsylvania. In: Proceedings, 8th central hardwood conference, Gen. Tech. Rep. NE-148. U.S. Department of Agriculture, Forest Service: 395-401.

Johnson, P.S. 1990. Scarlet Oak. *In*: Silvics of North America. Volume II, Hardwoods. Burns, R.M., and B.H. Honkala (eds.). USDA Forest Service Agriculture Handbook 654: 625-630.

Kentucky Department of Fish and Wildlife Resources, Kentucky Department of Natural Resources Division of Forestry, and Kentucky Department for Surface Mining Reclamation and Enforcement, 1995. Plant species, distribution patterns, seeding rates and planting arrangements of revegetation of mined lands. Technical reclamation memorandum #21.

McQuilkin, R.A. 1990. Chestnut oak. *In*: Silvics of North America. Volume II, Hardwoods. Burns, R.M., and B.H. Honkala (eds.). USDA Forest Service Agriculture Handbook 654: 721-726.

Rogers, R. 1990. White Oak. *In*: Silvics of North America. Volume II, Hardwoods. Burns, R.M., and B.H. Honkala (eds.). USDA Forest Service Agriculture Handbook 654: 605-613.

Wellander, N.T. and B. Ottosson. 2000. The influence of low light, drought and fertilization on transpiration and growth in young seedlings of Quercus robur L. For. Ecol. Mgmt. 127: 139-151. http://dx.doi.org/10.1016/S0378-1127(99)00126-7.

Zipper, C. 2005. Powell River project: Reforestation and forestry land uses of reclaimed mined land. (Field tour, Aug. 11, 2005). Virginia Polytechnic Institute, Blacksburg, VA. Pp. 20-22.