TREE GROWTH AND NATURAL REGENERATION ON THREE LOOSE-GRADED SURFACE MINE SPOIL TYPES IN KENTUCKY: PRELIMINARY FINDINGS[1]

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Abstract: Reforestation research on mined lands has shown that loosely graded topsoil, weathered sandstone and/or other non-toxic topsoil substitutes are suitable growing media for establishing native forests in Appalachia. Reclamation practitioners however, have expressed confusion as to what constitutes the best available material other than topsoil. Six research plots were established on a surface mine for the purpose of evaluating the influence of three different loose-graded spoil types on tree performance. The three spoil types are: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) mixed weathered and un-weathered sandstones, and shale material (mine-run spoil). The total area of each plot is approximately 4,050 square meters (one acre). Four species of tree seedlings were planted into the spoils. Growth and survival of the planted trees were evaluated for two years. As an indicator of natural succession potential, percent ground cover of volunteer vegetation on the three spoil types was also evaluated. Preliminary observations indicated that by the second year (2006) after planting, the gray plots had an overall higher average survival (96%) than the mixed (84.5%) and brown plots (83%). The brown sandstone plots however, showed significantly more growth in height and diameter than the gray and mixed plots. Ground cover from natural regeneration was found to be 42.3 percent on the brown plots (40 different species), 2.6 percent on the mixed plots (21 different species), and less than 1 percent on the gray plots (6 different species).

Additional Key Words: tree performance, compacted spoil.

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Introduction

Since the implementation of the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) in May of 1978, many opportunities have been lost for the reforestation of surface mines in the eastern United States. Soil scientists and foresters have reported that excessive compaction of spoil material in the backfilling and grading process is the biggest impediment to the establishment of productive forests as a post-mining land use (Ashby et al., 1984; Burger et al., 1997; Graves et al., 2000).

In the 1950's and 1960's, a regulatory requirement of surface mining performed in the gently rolling terrain of the Midwestern states was referred to as "strike-off" reclamation. This requirement consisted of making one or two bulldozer passes down the length of each parallel ridge of soil, pushing it into the parallel valleys on both sides. If viewed from the air, the result of "strike-off" reclamation would look like the rough surface of a giant washboard. Trees were then planted at the rate of 1500 to 2000 per hectare into this loosely graded spoil bank. The growth of those trees in this non-compacted spoil over the past 40 to 50 years has been very good relative to typical mine spoils (Ashby, 2006).

Stability of mine sites was a prominent concern among regulators and mine operators in the years immediately following the implementation of SMCRA. These concerns resulted in the highly compacted and consequently unproductive spoils of the early post-SMCRA era. However, there is nothing in the regulations that requires mine sites to be overly compacted as long as stability is achieved. Mostly cultural barriers and not regulatory barriers have contributed to the failure of reforestation efforts under the federal law over the past 29 years. Efforts are being made to change the perception that the federal law and regulations impede effective reforestation techniques and interfere with bond release (OSMRE, 2006).

Drawing on the recommendations generated by surface mine reclamation research over the past 40 years, the United States Department of Interior's Office of Surface Mining Reclamation and Enforcement (OSM) and the seven state regulatory authorities in the Appalachian Region advocate the following forestry reclamation techniques: (1) Create a suitable rooting medium for good tree growth that is no less than 1.2 meters deep and comprised of topsoil, weathered sandstone and/or the best available material; (2) Loosely grade the topsoil or topsoil substitutes placed on the surface to create a non-compacted growth medium; (3) Use native and non-competitive ground covers that are compatible with growing trees; (4) Plant two types of trees – early succession species for wildlife and soil stability, and commercially valuable crop trees; and, (5) Use proper tree planting techniques (OSMRE, 2006).

These five recommendations are extensively supported by research with the exception of the first recommendation involving the selection of a suitable spoil type as the rooting medium. Mine soil development from different rock types is complex, and different rock types can have vastly different physical and chemical properties. The wording, "best available material" is ambiguous and has generated significant controversy and confusion. Clear definitions of good forest mine soils based on mine soil analyses and tree growth responses are needed.

Researchers have reported on the attributes of loose-graded brown weathered sandstone spoil compared to un-weathered fine-textured rocks (Torbert et al., 1990). Other studies have identified certain types of loose-graded mixed un-weathered sandstone and shale (mine run) spoil as being highly productive (Conrad et al., 2002; Angel et al., 2006). A recent study compared the response of three native hardwoods to weathered and un-weathered sandstone materials in a greenhouse study (Showalter et al., 2006); however, no operational-scale side-by-side comparisons of these two spoil types have been made on the same mine site. Although these studies do not conflict in regards to their findings, they show that several different mine spoils may serve as topsoil substitutes suitable for tree growth while others are unsuitable. The economic considerations implied by each of these studies are significant and may prompt coal operators to favor one spoil type over another regardless of suitability for trees. Mine spoil suitability for trees must be established so coal operators and regulators can make informed cost-benefit decisions. Furthermore, several gaps exist in the scientific literature concerning the selection of a suitable spoil type as the rooting medium.

This paper provides preliminary results after two years of tree growth and natural regeneration on loose-graded brown weathered sandstone spoil, gray un-weathered sandstone spoil, and mixed sandstone/shale material (mine-run spoil) on a surface mine in eastern Kentucky. This is part of a larger multi-year study that is designed to evaluate the influence of surface mineralogy (or geology) of differing types of loose-graded spoil on reforestation success and water quality and quantity attributes.

Methods

Study area

The University of Kentucky has been engaged in the on-going installation of a reforestation research complex since late 2003 on an active mountaintop removal operation located on Bent Mountain on Brushy Fork near the community of Meta in Pike County, Kentucky (latitude N 37° 35′ 49″, longitude W 82° 24′ 19″). The operator of the mountaintop removal operation is Appalachian Fuels. This mine is located in Kentucky's eastern coalfield in the Cumberland Plateau physiographic region and is predominately forested. Climate is temperate humid continental with average annual precipitation of 114 cm, and an average monthly precipitation of 10 cm, which ranges from 6-12 cm. Average temperature is 13° Celsius, with a mean daily maximum and minimum of 31° and 18° in July and 8° and -4° in January (Hill, 1976). The mine is within the Hazard Coal Reserve District as delineated by the U.S. Geological Survey (Huddle et al., 1963). Ultisols are the predominant soil order in the area (USDA, 1998). The soil series at the study site is Dekalb, which are typically on upper side slopes and ridges (Hayes, 1982).

Research plots

Six research plots were established in March 2005 on Bent Mountain for the purpose of evaluating tree performance on three loose-graded spoil types: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) mixed brown weathered sandstone, gray un-weathered sandstone, and shale material (mine-run spoil). The predominant color in the brown weathered sandstone spoil type is "light yellowish brown" (10YR 6/4). The gray un-weathered sandstone, the predominant color is predominantly "light gray" (10YR 7/1). The third spoil type composed of mixed brown/gray sandstones and shale material is mottled one-third each of the above colors and one-third "gray" (2.5YR 5/) (Munsell, 1975). The three spoil types will henceforth be referred to as "brown", "gray", and "mixed". A small amount of coarse woody debris and root propagules were observed in the brown plots soon after installation, but not in the gray and mixed plots. No effort was made to quantify the woody debris and root propagules.

The three loose-graded spoil types are the three treatments in this experiment and the three treatments are randomly assigned to the six plots. The three treatments are installed in square plots that measure about 63 meters on each side. The total area of each plot is approximately 4,050 square meters (one acre). The three treatments are replicated twice, creating a total of six plots or experimental units. The six plots are physically separated and isolated from each other by a 2.5-meter buffer zone where no loose spoil was dumped.

The brown, gray, and mixed spoil types were "end-dumped" by large dump trucks in piles six to twelve feet deep that were placed in parallel rows in such a way that they closely abut one another across each of the six plots. The capacity of the dump trucks was 134 metric tons (57 bank cubic meters) per load. The spoil piles were then "struck-off" with one pass of a small bulldozer (D-5) down the length of each parallel ridge of spoil, pushing it into the parallel valleys on both sides. The spoil was dumped in the six plots and struck-off as specified in Reclamation Advisory Memorandum Number 124 (RAM 124) issued by the Kentucky regulatory authority (KDSMRE, 1997). The final grade configuration of the spoil resembles many natural forest sites in the area with a hummocky micro-topography that is characterized by small mounds, depressions, rocks, and boulders, which create a surface more amenable to recruitment, establishment, and survival of diverse, native forest species, both flora and fauna.

Because of the hummocky micro-topography and little relief of the six plots, controlling on-site erosion and off-site sedimentation with the usual mix of reclamation grasses and legumes was not necessary. Some on-site soil movement has been observed over the past two years. That is, the humps from the rough end-dumping and grading have settled into the depressions and the site is beginning to level out naturally without compaction from machinery. No grasses or legumes were seeded since it was anticipated that soil movement would be contained within the six plots. Four species of tree seedlings were planted on a 1.8 meter by 2.4 meter (6 foot by 8 foot) spacing into the loosely graded spoil of the six plots on April 2, 2005. The four species were white oak *(Quercus alba)*, red oak *(Quercus rubra)*, yellow-poplar *(Liriodendron tulipifera)*, and green ash *(Fraxinus pennsylvanica)*.

<u>Data collection</u>

Tree-survival, tree-growth, and soils data are collected each year from the reclamation plots. Dry bulk density was measured in the field using a duel-probe nuclear density probe. Multiple soil samples (8 per plot) were collected from the upper 15 cm of each plot during the first growing season. Samples were analyzed for cation exchange capacity (CEC), total exchangeable bases (TEB): total recoverable soil elements (Ca, Mg, Fe), particle size, and pH (1:1). Extractable bases and CEC were analyzed using the 1 M ammonium acetate (NH_4OAc), pH 7.0 (Buchner funnel) (5B1) (5A1b) methods respectively (NRCS, 1996). Elemental analyses were done on an ICP-OES (Varian-Vista-Pro-CCD Simultaneous) after extraction using the HNO_3-HCl microwave-based digestion method [U.S. Environmental Protection Agency (USEPA), 1996, method 200.2]. Quality assurance-quality control protocols were followed for all analytical procedures as outlined in USEPA (1994) method 6020. Particle size analysis was performed using the pipette method (NRCS, 1996). Soil pH was measured in a 1:1 soil-water suspension with a HI 991301 Hanna pH meter and probe.

Independent t-tests assuming unequal variance were used to compare survival, height and diameter means of seedlings growing on the differing spoil types. Statistical significance was established were $P < 0.05$ in all cases.

Preliminary Results

Bulk density measurements taken in 2005 at three difference depths (5, 15 and 30.5 cm) in the three spoil types show very close values (Table 1).

Table 1. Bulk density at 5, 15 and 30.5 cm depths by spoil type at the Bent Mountain surface mine in Pike County, Kentucky.

Treatment	Bulk Density (g cm$^{3\ -1}$)		
	5 cm	15 cm	30.5 cm
Brown	1.48	1.71	1.82
Gray	1.51	1.72	1.82
Mixed	1.49	1.70	1.82

The average bulk density for all depths in all three types of spoil was 1.67 g cm$^{3\ -1}$ which is the same as the average bulk density measurements taken over a four year period in the strike-off research plots at the University of Kentucky's Starfire reforestation research complex in Perry County, Kentucky (Angel et al., 2006). The data at Starfire definitively show that strike-off and loose-dump techniques improve seedling height and survival and that even a small amount of traffic (i.e., one or two passes per the strike-off method) may result in enough compaction to significantly reduce survival and growth in some species, such as yellow poplar *(Liriodendron tulipifera)* and white pine *(Pinus strobus)*.

Initial spoil physicochemical results reveal that the brown sandstone plots contain higher clay content, CEC and % moisture over that of the gray sandstone, while the mixed sandstones and shale plots exhibited intermediate values (Table 2). The brown sandstone plots were slightly acidic (pH = 6.0) and contained the highest Fe concentration. The gray sandstone plots and mixed plots were slightly alkaline (pH = 8.0 and 8.3, respectively) and exhibited high Ca concentrations, possibly indicative of the presence of carbonates within the spoil. X-ray diffraction of the spoil material indicated the presence of quartz and clay minerals in all plots and the presence of siderite ($FeCO_3$) in the mixed and gray plots. Additional characterizations are planned to further characterize the mineralogy of these spoils.

Table 2. Mean (n = 16) spoil physicochemical properties from the upper 15 cm at the Bent Mountain surface mine in Pike County, Kentucky.

Parameter	Brown	Gray	Mixed
pH (1:1)	6.0	8.0	8.3
CEC (cmol kg^{-1})	8.2	2.5	3.3
Total Ca (mg kg^{-1})	780	3,901	2,613
Total Mg (mg kg^{-1})	2,291	2,844	2,422
Total Fe (mg kg^{-1})	20,825	16,797	17,951
Sand (%)	60.8	77.7	73.9
Clay (%)	11.9	6.5	7.7
Moisture (%)	7.1	3.6	4.2

Figures 1 – 5 show the mean tree height in cm by spoil type for all species combined and for each species individually after the first year (2005) and the second year (2006) of growth. In the 2006 bars for Fig. 1 – 5, means with the same letter are not significantly different at the p = 0.05 confidence level. No letters are shown in the 2005 bars for Fig. 1 – 5 since the height measurements taken in 2005 reflect less than one year of growth and no statistical comparisons were made.

By the summer of 2006 the brown spoil showed significantly more growth for each of the four individual species and for all species combined than the gray and mixed spoil. Significant differences in mean tree height also were observed between the gray and mixed spoils for all species except for yellow poplar. The second best growth in mean tree height was observed in the mixed spoil for all species combined and for each species individually. The mean tree height in the gray spoil for all species combined and for each species individually was the lowest of the three spoil types. Due to die back and herbivory, the mean tree heights as measured in 2005 and 2006 showed a decreased for white oak on the gray and mixed spoil (Fig. 2) and for red oak on the gray spoil (Fig. 3). The tree species that preformed the best in terms of height growth on all three spoil types was yellow poplar (Fig. 4).

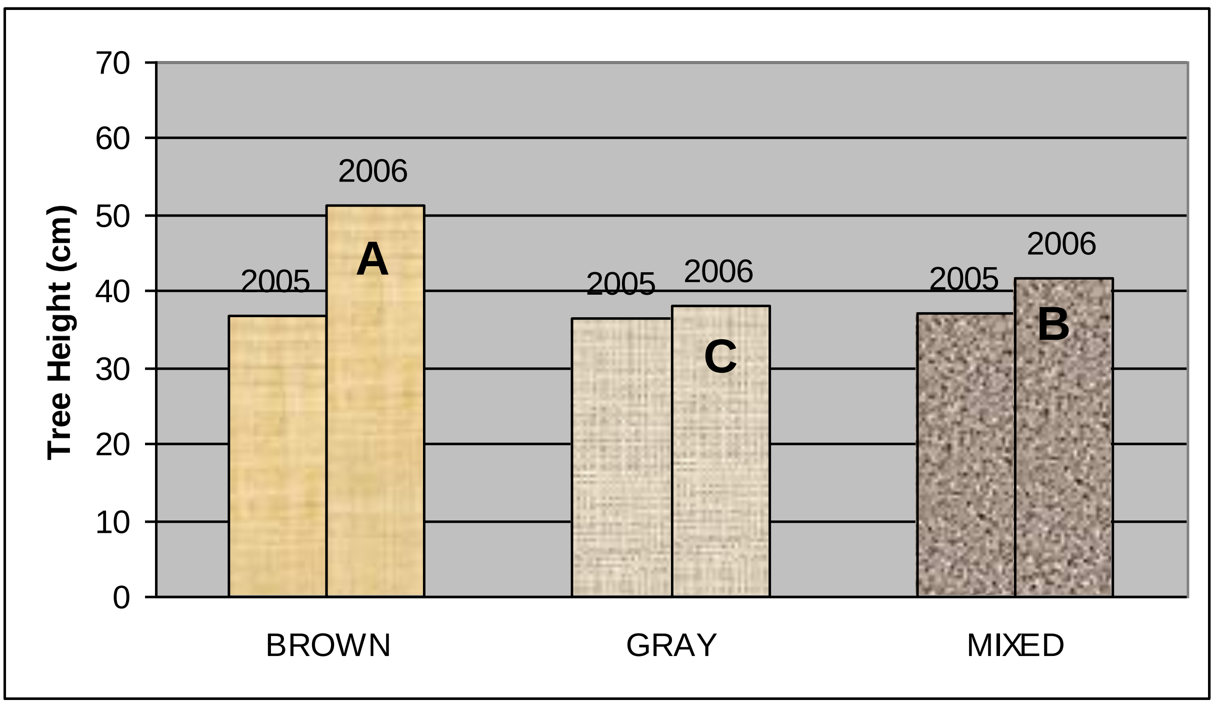

Figure 1. Mean tree height in cm by spoil type for all species combined for first year (2005) and second year (2006). Letters apply to differences in means among spoil types for only 2006. Means with the same letter are not significantly different at the p = 0.05 confidence level.

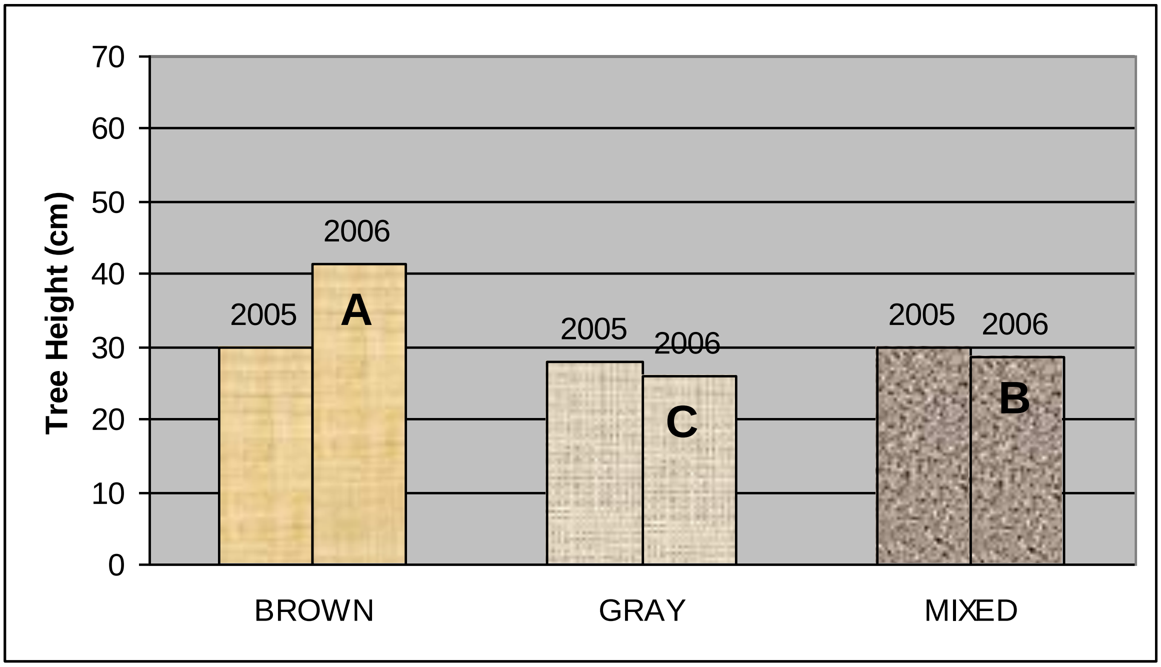

Figure 2. Mean tree height in cm by spoil type for white oak for first year (2005) and second year (2006). Letters apply to differences in means among spoil types for only 2006. Means with the same letter are not significantly different at the p = 0.05 confidence level.

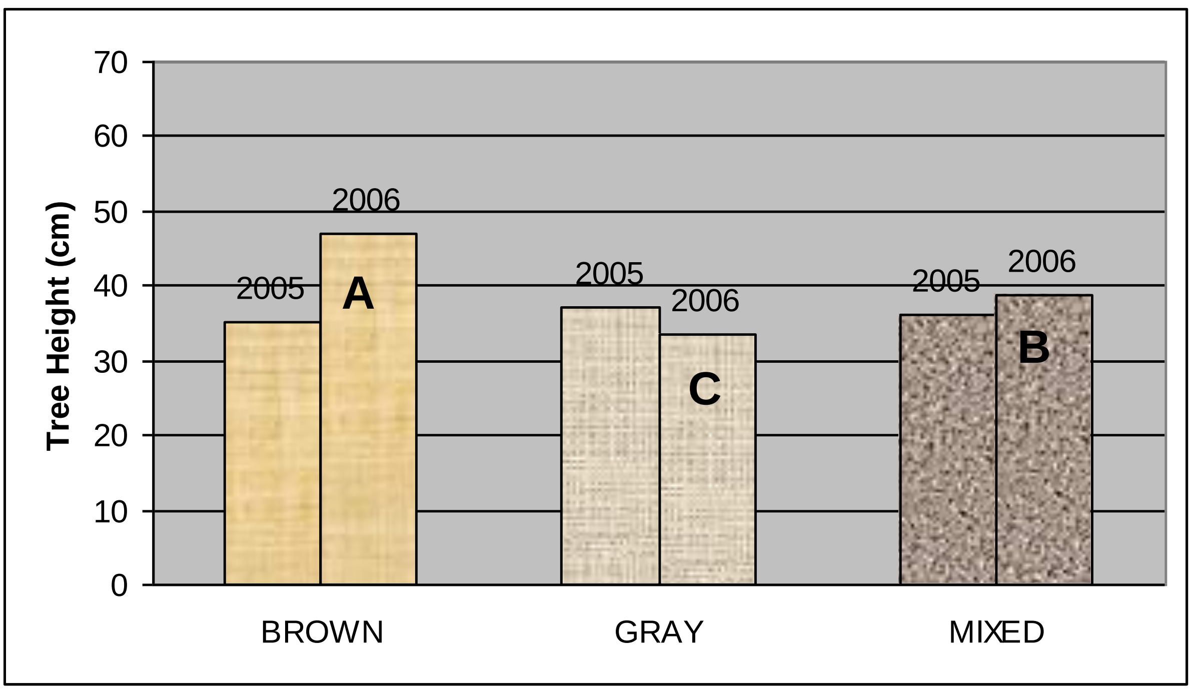

Figure 3. Mean tree height in cm by spoil type for red oak for first year (2005) and second year (2006). Letters apply to differences in means among spoil types for only 2006. Means with the same letter are not significantly different at the p = 0.05 confidence level.

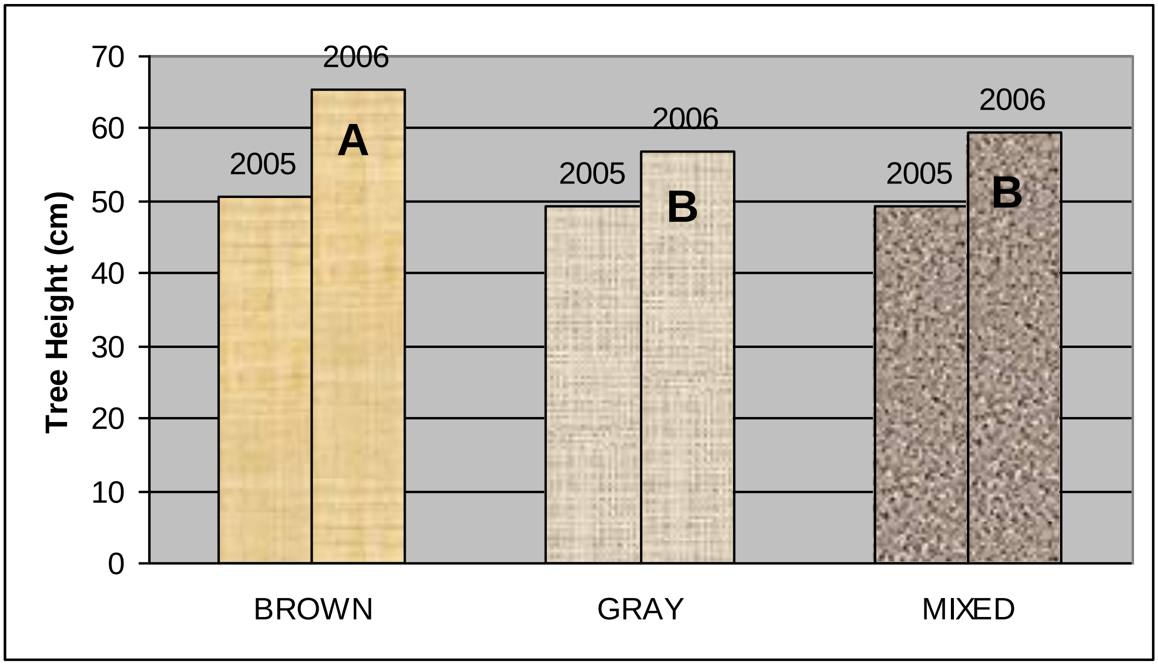

Figure 4. Mean tree height in cm by spoil type for yellow poplar for first year (2005) and second year (2006). Letters apply to differences in means among spoil types for only 2006. Means with the same letter are not significantly different at the p = 0.05 confidence level.

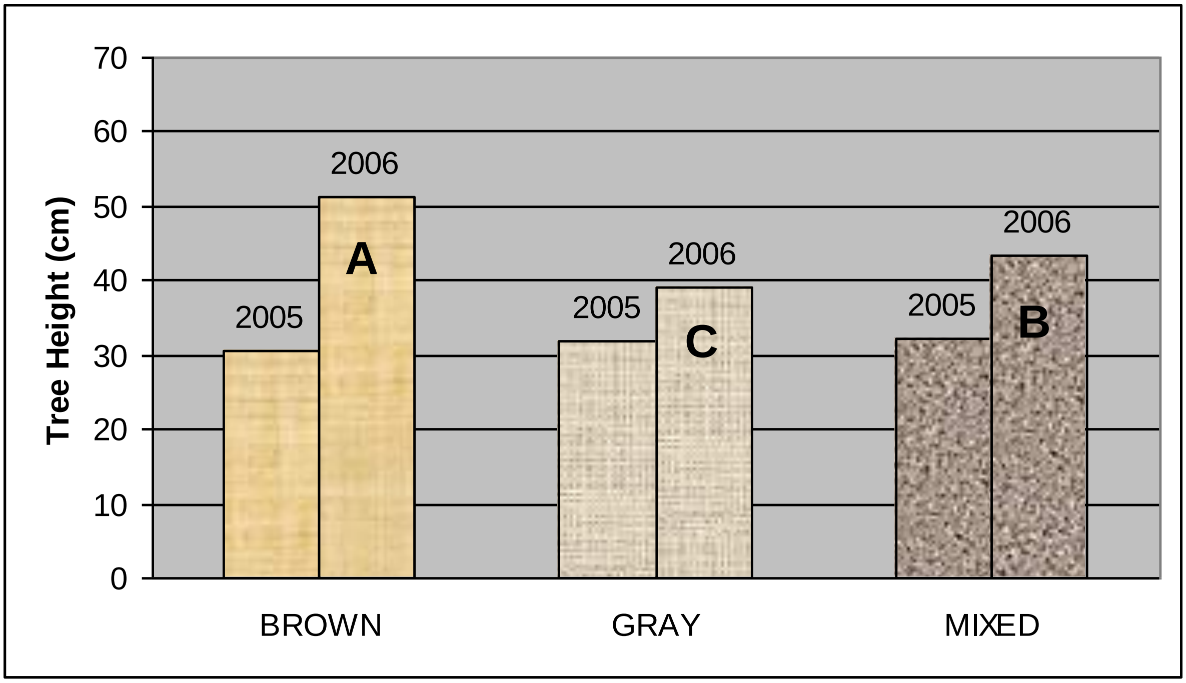

Figure 5. Mean tree height in cm by spoil type for green ash for first year (2005) and second year (2006). Letters apply to differences in means among spoil types for only 2006. Means with the same letter are not significantly different at the p = 0.05 confidence level.

Table 3 shows the percent tree survival and mean stem diameter at ground level by spoil type for all species combined and individual species after the second year (2006) of growth. By the summer of 2006, the gray spoil showed significantly better survival than the brown and mixed spoil for all species combined. No significant differences were observed in the survival between the brown spoil and the mixed spoil for all species combined and each of the individual species with the exception of white oak. Across all spoil types, green ash survived the best (mean = 94.7%), followed by white oak (mean = 92.7%), and then by red oak (mean = 88.9%). The species that had the least survival across all three spoil types after two years was yellow poplar (mean = 74.6%).

Table 3. Second year (2006) percent tree survival and mean stem diameter at ground level by spoil type for all species combined and individual species at the Bent Mountain surface mine in Pike County, Kentucky. Values within rows with the same letter for percent survival and stem diameter are not significantly different at $p = 0.05$ level.

	Percent Survival			Stem Diameter (mm)		
	Brown	**Gray**	**Mixed**	**Brown**	**Gray**	**Mixed**
All species	83 (b)	96 (a)	85 (b)	10.57 (a)	7.26 (c)	7.92 (b)
White Oak	81 (b)	100*	98 (a)	9.07 (a)	5.74 (c)	6.38 (b)
Red Oak	86 (a)	100*	81 (a)	9.83 (a)	6.93 (c)	7.82 (b)
Yellow Poplar	70 (b)	85 (a)	69 (b)	12.60 (a)	9.19 (b)	9.58 (b)
Green Ash	93 (a)	96 (a)	95 (a)	10.72 (a)	7.44 (c)	8.18 (b)

*Statistical differences are not shown for those groups where 100% survival was achieved.

The relative values for mean stem diameter for each of the four species and all species combined across the three spoil types reflected approximately the same trends observed for the relative values for mean height across the three spoil types. If we had created charts for mean stem diameter, the relative heights of the bars representing the three spoil types would have looked very similar to the three bars in the charts we created for mean tree height. The t-tests comparing stem diameters between the three spoil types returned results that were identical to the results comparing tree height between the three spoil types.

Natural Regeneration

To avoid a competitive effect of an herbaceous cover on the trees no grasses or legumes were seeded on the six plots. However, after the start of the second growing season, it was obvious that volunteer species were beginning to colonize two of the six plots. In July of the 2006 growing season, the Rennie-Farmer inventory system (Farmer et al., 1981) for evaluating revegetation on reclaimed surface mines was conducted on all six loose-graded research plots to provide an estimate of ground cover and to tabulate the composition of volunteer species. The sampling techniques for estimating ground cover provided by this methodology use a 90 percent statistical confidence interval (i.e., one-sided test with a 0.10 alpha error). The average percent ground cover of the volunteer vegetation on the three spoil types into the second growing season were found to be 42.3% on the brown spoil, 2.6% on the mixed spoil and less than 1% on the gray spoil. The brown spoil was found to contain 40 different species, whereas 6 different species were observed on the gray spoil and 21 different species were found on the mixed spoil. The majority of the volunteer vegetation on the brown spoil was composed of three species: *Tussilago farfara* (Coltsfoot), *Chenopodium album* (Lambsquarter), and *Phytolacca americana* (Pokeweed). A list of the volunteer species per soil type is presented in Table 4.

It is suspected that the primary source of the volunteer vegetation on the brown plots was the coarse woody debris and root propagules that were observed in the brown plots soon after installation. No coarse woody debris or root propagules were observed in the gray and mixed plots. However, it is uncertain how much of the volunteer vegetation was in place when the spoil was end-dumped or how much was blown in by the wind or carried in by birds and other animals. An analysis of the influence of the physicochemical properties of the three different spoil types on tree growth and natural regeneration is beyond the scope of this paper. This research is part of a larger multi-year study that was designed to evaluate the influence of surface lithology of these three types of loose-graded spoil on reforestation success and water quality, quantity, movement, utilization, and evapotranspiration by the growing trees.

Summary

Preliminary observations indicate that by the second year (2006) after planting, the gray spoil had an overall higher average survival (96%) than the mixed spoil (85%), and the brown spoil (83%). The brown spoil however, showed significantly more growth in height and diameter than the gray and mixed spoil. Perhaps the more important observation that could be used at this time to predict productivity potential on the three spoil types is the amount of ground cover established through natural regeneration. Volunteer vegetation was found to cover 42.3% of the brown plots, 2.6% of the mixed plots, and less than 1% of the gray plots. After two growing seasons, the volunteer vegetation on the whole experiment was composed of a total of 45 different species, with 40 of these found on the brown spoil, 6 on the gray spoil, and 21 on the mixed spoil. On the brown spoil, the following three species made up the majority of the composition: *Tussilago farfara* (Coltsfoot), *Chenopodium album* (Lambsquarter), and *Phytolacca americana* (Pokeweed).

Table 4. Naturally regenerated species per spoil type.

Species	Common Name	Type†	Native‡	Spoil Type		
				Brown	**Gray**	**Mixed**
Acer rubrum	Red maple	T	Yes	+	+	+
Ageratina altissima	White snakeroot	H	Yes	+	-	-
Ailanthus altissima	Tree of heaven	T	No	+	-	+
Chenopodium album	Lambsquarter	H	No	21%*	+	+
Conyza canadensis	Horseweed	H	Yes	1%	-	-
Cyperus esculentus	Yellow nutsedge	G	Yes	+	-	-
Dactylis glomerata	Orchardgrass	G	No	+	-	-
Danthonia spicata	Poverty oat grass	G	Yes	+	-	-
Daucus carota	Wild carrot	H	No	1%	-	-
Digitaria sp.	Crabgrass	G	**	<1%	-	-
Echinochloa crus-galli	Barnyard grass	G	No	<1%	-	17%
Erechtites hieraciifolia	Fireweed	H	Yes	<1%	-	8%
Erigeron annuus	Annual fleabane	H	Yes	+	-	-
Festuca arundinacea	Kentucky 31 fescue	G	No	-	-	+
Gnaphalium purpureum	Purple cudweed	H	Yes	+	-	-
Ipomoea sp.	Morning glory	H	**	<1%	-	-
Lactuca saligna	Willow-leaf lettuce	H	No	2%	-	+
Lactuca serriola	Prickly lettuce	H	No	1%	-	+
Lamiaceae	Mint family	**	**	-	-	+
Lespedeza cuneata	Sericea lespedeza	H	No	1%	+	+
Lespedeza striata	Kobe lespedeza	H	No	-	-	+
Lotus corniculatus	Birdsfoot trefoil	H	No	+	-	-
Melilotus officinalis	Yellow sweetclover	H	No	+	-	-
Microstegium vimineum	Japanese stiltgrass	G	No	-	-	+
Oxalis sp.	Sorrel	H	**	-	-	+
Panicum capillare	Witchgrass	G	Yes	+	-	-
Parthenocissus quinquefolia	Virginia creeper	V	Yes	+	+	-
Paulownia tomentosa	Royal Paulownia	T	No	+	-	+
Phytolacca americana	Pokeweed	H	Yes	15%	+	+
Pinus virginiana	Virginia pine	T	Yes	+	-	-
Plantago major	Common plantain	H	No	+	-	+
Platanus occidentalis	American sycamore	T	Yes	+	-	-
Polygonum caespitosum	Oriental ladysthumb	H	No	<1%	-	-
Populus deltoides	Eastern Cottonwood	T	Yes	+	-	-
Robinia pseudoacacia	Black locust	T	Yes	+	-	-
Rubus sp.	Blackberry	**	**	<1%	-	+
Solanum ptycanthum	E. black nightshade	H	No	2%	-	+
Sonchus asper	Prickly sow thistle	H	No	<1%	-	-
Trifolium pretense	Red clover	H	No	+	-	-
Trifolium repens	Ladino clover	H	No	+	-	6%
Tussilago farfara	Coltsfoot	H	No	51%	+	69%
Ulmus alata	Winged elm	T	Yes	+	-	+
Verbascum thapsus	Wooly mullein	H	No	2%	-	-
Viola sp.	Violet	H	Yes	<1%	-	-
Vitis sp.	Wild grape	V	Yes	+	-	-
Total number of species	**45**			**40**	**6**	**21**
% cover				**42.3%**	**<1%**	**2.6%**

†H = herbs; G = grass, sedge or rush; T = trees and shrubs; V = woody vine; + = species observed on indicated spoil type but not detected by Rennie-Farmer inventory system; - = species not observed on indicated spoil type.
*Percentages reflect amount of naturally regenerated cover on indicated spoil type attributed to indicated species.
‡Native species status taken from Jones (2005).
**Not enough information to determine status.

Regulatory Implications

In August 2006, the US Federal Register published a rule issued by OSM that is designed to remove an impediment to planting trees by revising the revegetation success standards for forestry post-mining land uses in Tennessee (Federal Register, 2006). For several decades, researchers from across the country have reported that ground cover competition has a significant impact on survival and development of trees seedlings. Dense ground covers compete with trees for moisture, nutrients, sunlight, and space and provide a habitat for animals that eat tree seedlings. Trees planted with dense ground cover either die or, if they survive, will exhibit only stunted growth. The current ground cover success standard in Tennessee for areas where trees are to be planted requires 80% of a reclaimed mine site to be covered with ground cover vegetation before it is considered successfully revegetated. Researchers have determined that revegetation levels of this magnitude are far too high to allow for successful tree survival and growth. They have also demonstrated that planting tree seedlings in loose or lightly graded material, including rough and rocky spoil with little or no groundcover, will produce survival and growth rates that exceed tree growth on un-mined lands. Because of the reduced grading and compaction, infiltration is also increased, while storm runoff and sedimentation are decreased. These factors will lead to reduced erosion. These important research discoveries have provided the impetus for OSM to change the Tennessee revegetation regulations. The proposed rule would require a standard that is specifically geared to the unique characteristics of each mine site and to the proposed postmining land use. In any case, the amount of revegetation must be sufficient to control erosion on the mine site. The preliminary observations made at Bent Mountain regarding the amount of volunteer vegetation imply that spoil type can be a unique characteristic of a mine site in the consideration of how much initial herbaceous ground cover to seed with planted tree seedlings. Less initial seeding may be required if it can be anticipated that a specific type of spoil material will be inherently receptive to volunteer vegetation.

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