NATIVE HIGH VALUE TREE RECLAMATION ON SURFACE MINED SPOILS IN EASTERN KENTUCKY

William R. Thomas, Matthew H. Pelkki, and James M. Ringe[1]

Abstract—Grading standards on reclaimed coal mines as outlined in PL 95-87, the Surface Mining Control and Reclamation Act of 1977, have resulted in spoil compaction that severely limits tree root penetration. This leads to high tree seedling mortality. A field study was established on surface mined lands in eastern Kentucky to study the effects of two levels of compaction (no compaction and compacted) and two soil amendments (bark mulch and barn straw mulch) on three native high value tree species: white ash (*Fraxinus americana*), yellow-poplar (*Liriodendron tulipifera*), and northern red oak (*Quercus rubra*). Bark mulch seemed to have little effect on seedling vigor and survivorship and the barn straw seemed to lower both vigor and survivorship. Bulk densities for each compaction level were significantly different. Results are based on one year of data, in the future we hope to answer the question, will the uncompacted plots result in higher vigor and survivorship than the compacted plots, and that is our hypothesis.

INTRODUCTION

Coal mining has disturbed over 2.4 million ha in the United States since 1930 and the majority of that land was originally forested in Appalachia (Zeleznik and Skousen 1996). Often the best post mining land use is to return the lands to forests as quickly as possible. There is much interest in reclaiming mined lands with high value trees, especially if economical methods can be found. Reclamation costs could be significantly reduced if a method is developed to successfully establish trees and grasses (Larson and Vimmerstedt 1990).

In order to achieve productive forests on post mined lands, reclamation techniques that ensure good tree survivability and growth must be adopted (Campbell 1997). One of the key problems in establishing a productive forest on previously surfaced mined lands is excessive compaction, which leads to high tree seedling mortality. Chaney et al. (1995) believe that the initial condition of mined sites reconstructed under specifications of PL 95-87 result in a growth media that is less than optimal for high-value species of hardwood trees.

Reclamation research in the midwest has shown that pre-federal law mining sites resulted in some of the most productive areas in the region for the growth of tree seedlings (Ashby et al., 1978). A study by Burger and Torbert (1992) has shown that when mine spoil is loosely dumped without grading and planted with various species of trees, survival is higher than that on graded mine spoil. The problem of soil compaction has been approached in two ways: (1) prevent or minimize occurrence of the problem and (2) ameliorate the problem once it has happened (Sweigard, 1990). The former is preferable to the later because it conserves resources.

The two objectives of this study were to 1) investigate the effects of two levels of compaction on seedling survival of three native high value tree species, and 2) investigate the influence of two soil amendments on seedling survival of three native high value tree species. This paper reports first-year results and serves as baseline data for an ongoing study.

METHODS AND MATERIALS

Study Area

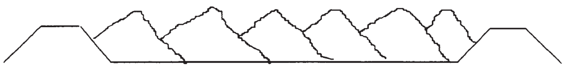
The study was conducted on a surface mine in eastern Perry County, Kentucky (37° 24' N, 83° 8' W). This mine is located in Kentucky's eastern coalfield in the Cumberland Plateau physiographic region. Climate is temperate humid continental with average annual precipitation of 117 cm, and an average monthly precipitation of 10 cm, which ranges from 6-12 cm. Average temperature is 13°, 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).

Plot Construction

Six enclosed 1 ha plots, approximately 70 m wide and 155 m long, were constructed (Figure 1). Two of the plots (#7 and #8) were constructed in time for the 1996 planting season. Due to construction delays the remaining four plots were not ready until the 1997 planting season. Bulldozers were used to create the borders of the plots, which were required for a hydrologic study, earth moving equipment was then used to loose dump the spoil material in consecutive piles until the entire plot was filled. Three of the plots (#2,#3,#4) were left in the loose condition and represented the no compaction treatment. The other three plots (#7,#8,#9) were driven over repeatedly with a bulldozer and represented the compacted treatment, these compacted plots were constructed to industry compaction levels. When reestablishing forests in this region it is important to ensure adequate ground cover for erosion

[1] Research Assistant, and Associate Professors, University of Kentucky, Department of Forestry, 205 Thomas Poe Cooper Building, Lexington, KY 40546, respectively.

Citation for proceedings: Stringer, Jeffrey W.; Loftis, David L., eds. 1999. Proceedings, 12th central hardwood forest conference; 1999 February 28-March 1-2; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 293 p. [Peer-reviewed paper].



Uncompacted Plots #2,#3,#4)

Compacted Plots 7,#8,#9)

Figure 1—Cross-sectional diagram of plots. Plots are 70 m wide and 155 m long, borders of plots are 2-3 m high.

control; however if inappropriate herbaceous species are chosen, tree seedling survival will be reduced due to excessive competition. All plots were seeded with a slow establishing non-aggressive mixture of grasses and legumes. The grass and legume mixture consisted of annual rye (*Secale cereale*), perennial rye (*Lolium perenne*), orchard grass (*Dactylis glomerata*), birdsfoot trefoil (*Lotus corniculatus*), and Appalow lespedeza (*Serecia lespedeza*, var. Appalow) at the following rates of application 33.61 kg/ha for the annual rye and 5.61 kg/ha for each of the other species. Bark mulch was applied to two plots (#3,#8) at the rate of 125 ton/ha. Barn straw mulch was applied to two plots (#4,#7) at the rate of 125 ton/ha. The remaining plots (#2,#9) received no soil amendments.

Tree Species Selection

Tree species selection for our project was based on species that are native to the area, had documented performance in land reclamation, and a potential commercial value. White ash was chosen because it is a high value native tree species that has shown high survivability on surfaced mined lands (Zeleznik and Skousen 1996, Medvick 1969). Yellow-poplar was chosen because it is native to the area, very fast growing, and there is a rapidly growing market for this species. Northern red oak was chosen because it is a native species that has a high value.

Planting and Measuring of Tree Seedlings

Twenty-one subplots were established inside each of the plots. These subplots were 20 m x 20 m and one corner was permanently marked with rebar and metal tags identifying subplot number and species planted within the subplot. Each of the three species were randomly allotted to three subplots within each plot. The remaining twelve subplots in each plot were allotted to four other tree species not included in this study. Tree seedlings (1-0) were purchased from the Kentucky Division of Forestry's tree nursery in Morgan County, Kentucky. Tree seedlings were planted on a 1.8 m x 1.8 m spacing, yielding 121 trees per subplot. Two of the plots (#7,#8) were planted in the spring of 1996 and the remaining plots were planted in the spring of 1997. All tree seedlings were planted by professional tree planters. Annual measurements were made from the end of July through mid August. Total height of each tree was recorded to the nearest cm. In addition to total height, each tree was assigned a vigor class. Vigor classes were developed by the authors and consisted of five classes: 0-tree was dead, 1-tree was nearly dead, 2-intermediate/ stressed, 3-vigorous with one or two signs of stress, and 4-vigorous with no signs of stress. Signs of stress included chlorotic, withered, or misshapen foliage. Tree survival percentages were calculated by dividing the number of live tree seedlings measured in each plot by the number of trees originally planted in the plots. In addition to survivorship percentages, vigor rankings were characterized by the mode and mean of each plot.

Bulk Density

Bulk density is defined as the mass of a unit volume of soil (Brady 1990). There is a direct relation between bulk density and compaction level of the mine spoil. Bulk density was measured by a technique developed by Muller and Hamilton (1992). This technique consists of excavating a hole (approx. 1000 cm^3) in the mine spoil and carefully saving and weighing all material. The hole is then filled with expanding polyurethane foam, which can be obtained from most home improvement or building stores, cardboard is then secured on top of the hole to ensure that the foam fills all crevices in the hole. Curing of the foam takes 8 hrs, and after curing the foam is removed from the hole. Loose debris is then washed from the foam, and any foam that was not actually in the hole is removed. Spoil material was sieved using a 2mm sieve, weights of the sieved spoil material and the spoil material that would not pass through the 2mm sieve were recorded. This reveals the rock fragment content of the spoil material. Volume of the hole is then determined by displacing water with the foam. Seven subplots were randomly selected within each plot and sampled for their bulk density. To test for significant differences among compaction levels, a general linear model procedure with least significant difference t-tests of the SAS System (1996) was used.

Spoil Analysis

Characterization of the spoil materials chemical properties were obtained through spoil analysis. A composite sample was taken from five systematic sub-samples on each subplot. Care was taken to ensure that no soil amendments were included in the spoil analysis. Samples were submitted for analysis of ten parameters, which included organic matter, phosphorus, potassium, calcium, magnesium, pH, nitrate nitrogen, soluble salts, water holding capacity , and total nitrogen. There were a total of nine composite samples from each plot; results of spoil analysis were averaged for each plot.

RESULTS AND DISCUSSION

Because tree seedlings age varied, analysis was limited to reporting percentages and averages. Northern red oak preformed well on all plots (Table 1) except for plot #8 which was compacted and had barn straw added, this plot is also one year older. White ash preformed equally well on the uncompacted and compacted spoils; however yellow-poplar did better on the plots that were one year old as compared to the two year old plots. Mortality was highest on plots #7 and #8, where the seedlings were 1 year older than in the other plots. The big question is, how will the

Table 1—Tree survival on surface mined lands in eastern Kentucky, treated with two levels of compaction and two soil amendments

Plot	White ash	Yellow-poplar	Northern red oak
	Pct survival		
Measured in 1st growing season only			
2 Uncompacted/no mulch	89	90	93
3 Uncompacted/bark mulch	92	95	100
4 Uncompacted/barn straw	99	94	97
9 Compacted/no mulch	95	98	100
Measured in 2nd growing season only			
7 Compacted/barn straw	82	15	52
8 Compacted/bark mulch	97	41	96

one year old tree seedlings do next year, and will the compacted plots look similar to the uncompacted plots?

Compaction levels as characterized by bulk densities were significantly different at p=.05 (Table 2). Overall bulk density was 1.4 Mg/m^3 on the uncompacted spoils and 2.3 Mg/m^3 on the compacted spoils. Bulk density within the uncompacted plots was not different at the p=.05 level of significance, within the compacted level. Plots #7 and #8 were not different from each other. Rock fragment content ranged from 50.3 percent to 54.5 percent on the uncompacted plots and from 55.9 percent to 71.1 percent on the compacted plots (Table 3).

Nine composite samples were submitted for analysis of spoil chemical properties of each plot. Composite samples results were then averaged for the entire plot. Table 4 reports the average spoil characteristics of each plot.

Plot #7 had the lowest mean vigor (1.18) of all the plots; however it is evident that vigor was lowest on the 2 year old seedlings as compared to the 1 year old seedlings. White ash preformed better on the one year old plot (Table 5). Yellow-poplar performed much better on the one year old plots than on the two year old plots (Table 6). The same pattern held true for northern red oak (Table 7) with performance better on the one year old plots as compared to the two year old plots. Overall vigor of the tree seedlings was highest on the one year old plots (Table 8).

Plots that were treated with soil amendments had lower overall vigor for all species than those plots left untreated. Plots treated with bark mulch fared better than those treated with the barn straw mulch. The barn straw mulch plots seem to support a much hardier ground cover than the bark mulch plots. This could have caused increased competition on the tree seedlings from the ground cover species.

Table 2—Bulk density (Mg/m^3) values on uncompacted and compacted plots on surface mined lands in eastern Kentucky

Plot	Bulk density
	*Mg/m^3**
Uncompacted	
2	1.5^a
3	1.3^a
4	1.4^a
Overall mean**	1.4^1
Compacted	
7	2.1^a
8	2.0^a
9	2.7^b
Overall mean**	2.3^2

*Bulk density values within a compaction level followed by the same letter are not significantly different at P=.05.
**Overall means for a compaction level followed by the same number are not significantly different at P=.05.

Table 3—Average rock fragment content of spoil material on surface mined lands in eastern Kentucky

Plot	Avg. weight of spoil material <2mm	Avg. weight of spoil material >2mm	Average rock fragment
	g		*Pct*
2	852.92	864.22	50.3
3	1194	1431.3	54.5
4	1088	1267.4	53.8
7	890.09	1884.64	67.9
8	655.3	1613	71.1
9	707.92	898.85	55.9

Table 4—Average spoil characteristics of plots on surface mined lands in eastern Kentucky

	Plot					
	Uncompacted			Compacted		
Parameter	2	3	4	7	8	9
Organic matter (%)	1.8	2.0	3.2	4.0	4.7	2.8
Phosphorus (ppm)	0.0	0.0	0.0	0.3	0.3	0.3
Potassium (ppm)	4	6	13	14	11	11
Calcium (ppm)	56	46	79	48	60	80
Magnesium (ppm)	23	19	30	25	26	48
pH	5.9	5.2	5.8	6.9	7.5	6.9
Nitrate nitrogen (ppm)	25	4	7	11	35	38
Soluble salts (mmhos/cm)	0.4	0.4	0.6	0.4	0.5	0.7
Water holding capacity(%)	9.8	9.5	10.6	13.6	13.8	12.7
Total nitrogen (lb/acre)	624	653	1166	2034	1574	1107

Table 5—Vigor of white ash seedlings planted on surface mined lands in eastern Kentucky

Plot	N	Mode	Mean
Measured in 1st growing season only			
2 Uncompacted/no mulch	323	2	2.39
3 Uncompacted/bark mulch	333	2	2.24
4 Uncompacted/barn straw	375	2	2.24
9 Compacted/no mulch	345	3	2.49
Measured in 2nd growing season only			
7 Compacted/barn straw	364	2	1.69
8 Compacted/bark mulch	357	2	2.09

Note: vigor consisted of five classes: 0-dead, 1-nearly dead, 2-intermediate/stressed, 3-vigorous, slight stress present, 4-vigorous with no signs of stress.

Table 6—Vigor of yellow-poplar seedlings planted on surface mined lands in eastern Kentucky

Plot	N	Mode	Mean
Measured in 1st growing season only			
2 Uncompacted/no mulch	326	2	2.24
3 Uncompacted/bark mulch	346	2	2.14
4 Uncompacted/barn straw	340	2	2.13
9 Compacted/no mulch	355	2	2.25
Measured in 2nd growing season only			
7 Compacted/barn straw	363	0	0.32
8 Compacted/bark mulch	363	2	1.38

Note: vigor consisted of five classes: 0-dead, 1-nearly dead, 2-intermediate/stressed, 3-vigorous, slight stress present, 4-vigorous with no signs of stress.

CONCLUSION

This study reports first year data on establishment of native high-value tree seedlings on surface mined lands in eastern Kentucky. Current law requires mine operators to grade the surface to the approximate original contour which results in the soil being compacted to the point where seedling survival is severely hindered. Due to the fact that tree seedlings age varied we are unable to compare the compacted plots and uncompacted plots treated with soil amendments, and the two plots that had no soil amendments (compacted & uncompacted) had similar vigor and survivorship. The real question is will, once data has been collected for several years, the uncompacted plots result in higher vigor and survivorship than the compacted plots, and that is our hypothesis. If forestry is the post mining land use then bond release does not occur until five years after the last reclamation activity. Bark mulch seemed to have little effect on seedling vigor and survivorship and the barn straw seemed to lower both vigor and survivorship. In the future we hope to demonstrate that seedling survival will be least successful on compacted plots suggesting that a viable alternative to current reclamation practices exists; avoiding compaction by

Table 7—Vigor of northern red oak seedlings planted on surface mined lands in eastern Kentucky

Plot	N	Mode	Mean
Measured in 1st growing season only			
2 Uncompacted/no mulch	338	2	2.32
3 Uncompacted/bark mulch	363	2	2.23
4 Uncompacted/barn straw	353	2	2.22
9 Compacted/no mulch	363	2	2.08
Measured in 2nd growing season only			
7 Compacted/barn straw	363	0	1.05
8 Compacted/bark mulch	362	2	1.93

Note: vigor consisted of five classes: 0-dead, 1-nearly dead, 2-intermediate/stressed, 3-vigorous, slight stress present, 4-vigorous with no signs of stress.

Table 8—Vigor of white ash, yellow-poplar, and northern red oak tree seedlings planted on surface mined lands in eastern Kentucky

Plot	N	Mode	Mean
Measured in 1st growing season only			
2 Uncompacted/no mulch	987	2	2.32
3 Uncompacted/bark mulch	1042	2	2.20
4 Uncompacted/barn straw	1068	2	2.20
9 Compacted/no mulch	1063	2	2.27
Measured in 2nd growing season only			
7 Compacted/barn straw	1090	0	1.18
8 Compacted/bark mulch	1082	2	1.80

Note: vigor consisted of five classes: 0-dead, 1-nearly dead, 2-intermediate/stressed, 3-vigorous, slight stress present, 4-vigorous with no signs of stress.

minimizing grading. This will result in reclamation that is not only cheaper but will allow quicker establishment of productive forest lands. A limitation of this type of reclamation is that it requires relatively flat land, and while appropriate for mountaintop removal is of limited use on contour mines.

REFERENCES

Ashby, C.W.; Kolar, C.A.; Guerke, M.L. [and others]. 1978. Our reclamation future with trees, coal extraction and utilization. Research Center, Southern Illinois at Carbondale. 101 p.

Brady, N.C. 1990. The nature and property of soils. New York: Macmillan. 103 p.

Burger, J.A.; Torbert, J.L. 1992. Restoring forests on surface-mined lands. Publ.: 460-123. Virginia Cooperative Extension Service; Virginia Polytechnic Institute and State University. 16 p.

Campbell, C. 1997. Reforestation initiative. Reclam. Advis. Memo. 124. Frankfort, KY: Kentucky Department for Surface Mining Reclamation and Enforcement. 11 p.

Chaney, W.R.; Pope, P.E.; Byrnes, W.R. 1995. Tree survival and growth on land reclaimed in accord with Public Law 95-87. Journal of Environmental Quality 24: 630.

Hill, J.D. 1976. Climate of Kentucky. Kentucky Agric. Exper. Stn. Prog. Rep. 221.

Huddle, J.W.; Lyons, F.J.; Smith, H.L.; Ferm, J.C. 1963. Coal reserves of eastern Kentucky. U.S. Geol. Surv. Bull. 1120. 147 p.

Larson, M.M.; Vimmerstedt, J.P. 1990. Effects of mine soil and seeded herbaceous species on survival of planted trees. Internat. J. of Sur. Min. and Recla. 4: 53.

Medvick, C. 1969. Selecting plant species for revegetating surface coal mined lands in Indiana, a forty-year record. Mid-West Coal Producers Institute. [As presented in Papers on Reclamation Hutnik]. 1440: 65.

Muller, R.N.; Hamilton, M.E. 1992. A simple, effective method for determining the bulk density of stony soils. Commun. Soil Sci. Plant Anal. 23(3&4): 313-319.

SAS Institute Inc. 1996. The SAS system for windows. Version 6.12. Cary, NC.

Sweigard, R.J. 1990. Reclamation of surface-mined lands for agricultural use. Internat. J. of Sur. Min. and Recla. 4: 131.

Zeleznik, J.D.; Skousen, J.G. 1996. Survival of three tree species on old reclaimed surface mines in Ohio. Journal of Environmental Quality. 25: 1429.