SECOND YEAR SURVIVAL OF COMMERCIAL HARDWOODS ON RECLAIMED MINESOILS IN WEST VIRGINIA[1]

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Abstract. Due to increasing environmental pressure, the state of West Virginia has proposed legislative changes for acceptable post-mining land use for surface mined lands. Current legislation in West Virginia has emphasized the development of commercial forestry as the only post-mining land use on mountaintop surface mines that seek an AOC variance. In the spring of 2001, a research study was initiated in north central West Virginia to examine the establishment and sustainability of commercial hardwood forests on reclaimed surface mine land. Research involved the planting of commercial hardwood species [red oak (*Quercus rubra* L.), black cherry (*Prunus serotina* Ehrh.), black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), and yellow-poplar (*Liriodendron tulipifera* L.)] into north- and south-facing aspects, ripped and unripped minesoils, mowed and unmowed groundcover, and direct seeded and 1-0 planted seedlings. First year results were reported last year, which showed extremely high survival for planted trees (>95% for all species). Black cherry and red oak seedlings were damaged by rodents toward the end of the first growing season (2001). Results after the second growing season showed that all planted species experienced additional mortality (survival varied between 80 to 99%). Differences in tree survival among treatments became significant by the end of the second growing season. Higher tree survival was found in ripped plots (88%) vs. unripped plots (75%) and in unmowed plots (85%) vs. mowed plots (79%) in 2002. These differences in survival during the second year were most pronounced on south-facing aspects. Tree establishment from planted seeds increased during the second growing season (2002) for some species, but declined for others. During the first year, 31% of black walnut seeds germinated and established, and this number increased to 40% as additional seedlings emerged the second year. During the first year, 30% of red oak seeds germinated, but survival was only 6% after the second growing season. It appears that red oak seedlings (from seed) could not compete with the groundcover. Mortality of seeded oaks was greater in the unripped and mowed plots. The other species (black cherry, white ash, and yellow-poplar) exhibited very low germination and establishment from seeds (4%, 1%, and 0% respectively).

Additional Key Words: black cherry, black walnut, red oak, reforestation, tree planting, tree seeds, tree seedlings, white ash, yellow-poplar.

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Introduction

Large mountaintop removal surface mines in southern West Virginia have recently been limited to commercial forestry as a post-mining land use when a variance from putting the mountain back to approximate original contour (AOC) is obtained. Most of the West Virginia landscape (around 75%) is forested and, with the prevailing climate, almost all land in this region (both mined and unmined land) will naturally revert to forestland if left undisturbed. In fact, the climate and soil/geology of the central Appalachians is conducive to some of the best hardwood forest growth in the world. Hardwood timber prices are at record levels and with the continued reduction in timber harvests from federally-owned forestlands, coupled with increasing demand, hardwood timber values are projected to continue upward into the future.

Since the late 1970s, most surface mined land in West Virginia has been reclaimed to either pasture/hayland or wildlife habitat as the post-mining land use (Plass, 1982). Reasons for this were threefold. First, the landowner could receive a faster economic return or benefit from the land by grazing animals or producing hay. Second, reclamation for these land uses was usually easier and less expensive, and the company could normally get their reclamation bonds returned more quickly. Third, water quality was generally of higher quality from pasture/hayland areas immediately after reclamation compared to reforested sites (Boyce, 1999). However, problems associated with the agronomic land uses include lack of a high long-term economic return, low plant community diversity, continued high maintenance and treatment costs, and eventual collapse of the plant community and potential reversion to barren, eroded landscapes. With current regulations, these large tracts of reclaimed surface mined lands are being developed to a more long-term environmentally-stable and economically-beneficial post-mining land use through the establishment of commercially valuable trees.

There are several advantages of commercial forestland as a post-mining land use (Burger and Torbert, 1992). First, forests provide long-term site stabilization, which can enhance soil and water conservation. Second, trees inhibit the establishment and proliferation of weedy and undesirable plant species from invading the site. Third, productive wildlife habitat is promoted as a by-product. Fourth, most timber sales at maturity provide a favorable economic return. In addition, some states provide tax incentives through reduced property taxes for managed timberland.

Previous research studies have revealed some problems with establishing commercial hardwood timber species on reclaimed surface mine lands. First, soil properties may not be conducive to the establishment of commercial hardwoods. For example, pH of the minesoil may be too low, causing high concentrations of acid cations like aluminum in the soil, which can hinder tree growth (Bramble and Ashley, 1955; Davidson, 1979; Limstrom, 1960). On the other hand, high minesoil pH may also hinder the growth of trees since most hardwood species are adapted to slightly acid soil conditions, and competing forage species are more adapted to these high pH soil conditions (Skousen et al., 1994). Compaction, resulting from regrading the topsoil to make it smooth for planting, also restricts root growth and retards the establishment and growth of trees (Burger, 1999; Larson and Vimmerstedt, 1983; Torbert et al., 2000). Coarse texture and a high percentage of rock fragments, which are common in minesoils, may limit the amount of plant available water (Bramble and Ashley, 1955; Potter et al., 1951).

These soil problems can be largely alleviated by re-spreading native topsoil or several feet of native brown sandstone, which underlies the soil, onto the surface after re-grading. This material is weathered with a slightly acid pH, has adequate supplies of nutrients, has soil material and rocks of suitable size to hold enough water for the growth of trees, and should be only rough graded on the surface to limit the amount of compaction (Burger and Torbert, 1992).

Aspect of the site has received some attention for tree establishment. Haynes (1983) found sparser plant communities on drier, south-facing aspects, while northern aspects had more vigorous plant communities, which was related to improved moisture conditions. As a result, recommendations for tree planting suggest that trees adapted to drier site conditions [pines (*Pinus spp*.), black locust *(Robinia pseudo-acacia* L.), and red oak] be established on southern and western aspects. Trees adapted to wetter and cooler climates [black walnut, black cherry, yellow-poplar, cottonwood (*Populus deltoides* Marsh.), green ash (*Fraxinus pennsylvanica* Marsh.), white ash, sweet gum (*Liquidambar styraciflua* L.)] should be planted on northern and eastern aspects.

A primary cause of poor success with establishment of hardwood trees on surface mines is the mortality that comes with poor tree planting techniques and poor seedling condition (Vogel, 1981). Tree planters should be experienced and be required to plant the trees in a fashion that will maximize their opportunity for survival. In many cases, tree planters have no incentive for following correct procedures, nor are they held responsible for getting a live tree in the ground. Studies have found that a few species of trees in some instances had better survival by direct seeding than by planted seedlings (Boyce and Merz, 1959; Plass, 1974). But most studies document that the majority of planted seedlings are superior to direct seeding for tree establishment (Finn, 1958; Limstrom and Merz, 1949, Vogel, 1981).

Tree establishment on surface mines is also hindered by the seeded ground cover. Trees planted into introduced aggressive forages [especially tall fescue (*Festuca arundinacea* L.) and sericea lespedeza (*Lespedeza cuneata* L.)] are often overtopped by the grasses or legumes, and are unable to break free through the coverage (Burger and Torbert, 1992; Torbert et al, 1995). The seedlings are pinned to the ground and have little chance for survival. If it is known that trees are to be planted, a tree-compatible ground cover should be seeded that will be less competitive with trees. The last major obstacle to tree establishment comes from rodent and deer (and other wildlife species) damage, and this damage is often closely related to the amount and type of ground cover (Brown, 1962; Deitschman, 1950; Limstrom and Merz, 1960). Part of this problem may be reduced by planting a tree-compatible ground cover, which does not produce as thick of a ground cover needed by voles (*Microtus* spp.) and other rodents. The tree compatible ground cover should be slow growing, sprawling or low growing, not alleopathic, and not present competition to trees (Burger and Torbert, 1992). In our region, whitetail deer damage is often very great. Deer will simply walk down the rows of planted tree seedlings and browse the leaves and tops.

A local surface mining company was required to establish a commercial hardwood forest on a recently reclaimed surface mine near Morgantown, West Virginia. Before going large scale, the company contracted researchers at West Virginia University to plant commercial hardwood trees on a 0.5-ha area and to monitor tree survival. We planted and seeded five hardwood species onto north- and south-facing aspects, into ripped and unripped plots, and into mowed and unmowed plots. The objective of this study was to determine survival of these trees in these various treatments.

Materials and Methods

A one-year-old reclaimed site near Morgantown, West Virginia was selected for this reforestation study. The site had been surface mined for the Waynesburg seam of coal (Pennsylvanian System, Monongahela Group) during 1997 to 2000, and the overburden was composed of 75% sandstone and 25% shale and mudstone. After backfilling and re-grading, a 15-cm layer of fluidized bed combustion ash (FBC) was applied to the surface. This ash was supplied by the Morgantown Energy Associates FBC power plant, and the ash had a pH of 12, and a calcium oxide content of about 20%. The ash was placed on the backfill as a liming agent, and was used also to retard the movement of water downward into the backfill, since it has a tendency to set up as a weak cement upon wetting. Application of FBC ash is a standard practice on Waynesburg surface mines in this area. Not only does it solve the problem of ash disposal, but also alkalinity generated by the FBC ash aids in preventing acid mine drainage problems from these minesoils. After the FBC ash was placed in this 15-cm layer, then bulldozers re-spread 15 to 30 cm of topsoil, which had been removed and stored before mining. The area was fertilized with 275 kg/ha of 10-20-10 fertilizer, and seeded with tall fescue, orchardgrass (*Dactylis glomerata* L.), birdsfoot trefoil *(Lotus corniculata* L.), and annual winter wheat (*Triticum aestivum* L.). The grasses and legumes formed a consistently thick ground cover.

A section of the reclaimed land that had both a north- and a south-facing aspect was selected for our study. Slope on each aspect was about 15%. Initially, we planned to include comparisons of low-competition ground cover to high-competition (standard reclamation forage species) ground cover using fresh, unreclaimed minesoils. Due to timing and site constraints, this was not possible, and we had to use the 1-year-old reclaimed site with its already established ground cover. Before the experiment was established, both the north- and south-facing sites were mowed with a tractor and brush hog to reduce the height of ground cover, which was sheltering an established rodent population.

On each site (aspect), the tree planting experiment consisted of a split block design. After the initial brush hogging and after tree planting, one half of each site (block) was mowed every month (May through September) for the first year (2001) in an attempt to reduce ground cover competition, while the other half was not mowed after the initial mowing. Mowing was done with a walk-behind, rotary brush hog mower between tree rows to within 3 to 5 cm of tree seedling stems. The ground cover varied in height from 15 cm before mowing to 5 cm after mowing. Mowing was discontinued after the first year (2001) because of apparent negative effects on tree survival. Mowing actually produced denser grass/legume growth resulting in increased ground cover competition. Mowing also appeared to expose trees to increased deer predation.

Within each block (mowing treatment), plots were established for ripped and unripped treatments. The ripped treatment consisted of a single-blade ripper attached to a bulldozer, which ripped the minesoil to a depth of one meter. This treatment was meant to reduce minesoil compaction and to break up the potential hardened layer of ash beneath the topsoil, but it also reduced competition from the ground cover forage species by disturbing the surface. Ripping was done along the contour.

Within each plot (ripping treatment), subplots were established with tree seedlings being planted on half of the subplot and the other half being seeded with tree seeds. Hardwood seedlings of yellow-poplar, black cherry, white ash, black walnut, and red oak were alternately planted at 1-m spacing with a mattock. Seeds of these same tree species were direct seeded at the same spacing along the other half of each row. There were three rows in each plot (two meters between rows), with six replications per species. Seedlings and seeds were planted alternatively to provide a mixed hardwood stand. Each plot received five seedlings or seeds with six replications, equating to 30, planted trees per plot). Plot size was 10 meters (five species either planted or seeded at 1-m spacing) by six meters (three rows at 2-m spacing), with a 2-m buffer zone between each plot for a total area of 0.21 ha per site (aspect).

In summary, each site (aspect) and block (mowing treatment) had four treatment combinations or plots (ripped vs. unripped, and planting of tree seedlings vs. tree seeds). Each plot was replicated four times for a total of 32 plots per site with 30 trees within each plot (960 trees per site). So, including both north- and south-facing sites, 1,920 total trees (384 per species; 192 planted and 192 seeded) were placed into the ground of which 960 were planted and 960 were seeded. Site preparation and planting occurred in April 2001.

Hardwood tree survival was determined in October 2001 (about six months after planting) and in October 2002 (after 2 growing seasons). The reason for mortality of each seedling was also determined (either rodent/deer damage or die back) during this period. Germination and establishment of tree seeds was determined by looking at each individual location where a seed had been planted. Bulk soil samples of the topsoil layer and the FBC ash layer were collected at three randomly determined points on each aspect. Soil characterization included pH (McLean, 1982), electrical conductivity (Rhoades, 1982), texture (Gee and Bauder, 1986), and % coarse fragments (>2mm by weight). The data for tree survival was analyzed as a split block design with aspect as the main blocks and with ripping and mowing as split plot sub-treatments.

Results and Discussion

There were no significant differences in the measured soil properties between north and south aspects, so the average values for all minesoil samples are shown in Table 1. Soil pH was slightly acid (6.1) in the topsoil. Slightly to moderately acid soil pH is preferable for tree establishment since acidic conditions reduce competition from forages. Soil pH was much higher (8.7) in the FBC ash layer (Table 1). High pH in the ash layer may reduce the availability of soil phosphorus and other micronutrients in that zone. Soluble salts, as measured by electrical conductivity, were low in the topsoil, while soluble salts were much higher in the FBC ash layer (Table 1). Most agronomic crops are unaffected by EC values of 2 or less (Jurinak et al., 1987), but reductions in yield are often noticeable with EC values of 4 or greater (Sobek et al., 2000). As mentioned, most hardwood trees prefer moderately acid conditions, and prefer EC values less than 4 dS/m (Sobek et al., 2000).

The topsoil had a clay loam texture with an average of 13% coarse fragments >2mm in size (Table 1). The 13% coarse fragment content in the topsoil layer is much lower than the average minesoil of this age. Clayey textures are intermediate in "plant available" water holding capacity.

The FBC ash layer had a sandy loam texture. Since soil texture samples were not pre-treated to remove carbonate aggregating/cementing agents, reported values for sand and silt in FBC ash may be falsely elevated. During sampling, it was evident that the FBC ash layer was continuously cemented. The sampling process resulted in the break up of the ash layer into coarse fragments and the coarse texture and cementation of the FBC ash layer would justify classifying this as a restrictive zone for plant rooting and water uptake. The trees were growing in the topsoil and their roots had probably not been influenced greatly by the cemented ash layer about 15 to 30 cm below the topsoil.

Table 1. Soil characterization of topsoil and FBC ash layers of our reclaimed surface mine in northern West Virginia.

Horizon	pH	EC (dS/m)	Sand (%)	Silt (%)	Clay (%)	Texture	Coarse Frags (%)
Topsoil	6.1 ± .3	0.2 ± .04	29 ± .4	34 ± .3	37 ± .4	Clay loam	13 ± 2.3
FBC Ash	8.7 ± .2	2.3 ± .07	54 ± 1.5	42 ± 1.3	4 ± .2	Sandy loam	52 ± 3.6

*FBC ash samples were not pre-treated for removal of carbonate aggregating/cementing agents into <2mm particles.

Overall, survival of planted trees was exceptionally good for these five species at this site during the first (2001) growing season (Table 2). Rainfall was above average during April to June, with more droughty conditions during July to September of both years (2001 and 2002). White ash had the best survival among the five species, with no mortality the first year and only one tree out of the original 192 dying the second year. White ash has shown good survival on other sites (Zeleznik and Skousen, 1996), and often survives better than any other planted tree species. Black walnut showed similar high survival rates of 92 to 99%. Red oak and yellow-poplar survival was significantly higher (<0.05) on the north aspect than the south aspect. Northern red oak and yellow-poplar are known to prefer mesic sites since it is normally found in moist coves and on north- and east-facing slopes in native forests in this region. The south-facing aspect had higher levels of solar radiation with higher temperatures, thereby providing less moisture in the soil. The lowest survival of red oak and yellow-poplar was found in the mowed plots on the south aspect where the dense ground cover increased competition for available moisture. Black cherry survival was the poorest in our study, averaging 68 to 89%. Most of the mortality for this species was due to rodent damage (data not shown).

On the north aspect (Table 2), survival was significantly lower for black cherry in unmowed plots. The higher vegetation on unmowed plots provided increased cover for rodents on this site. Almost all the tree mortality on the north aspect was associated with rodent damage (data not shown). When hardwoods are to be planted during reclamation, grain forages such as annual wheat, rye (*Secale cereale* L.), or oats (*Avena sativa* L.) should not be used in the seeded ground cover mix. These grain crops provide quick cover and food for a buildup of rodent populations. Invariably as these grain species die back, the rodents turn to the tree seedlings as a food source.

Table 2. Average percent survival of planted species on two aspects and with two mowing treatments on a surface mine in West Virginia during 2001 and 2002.

Species	North Aspect				South Aspect			
	Mowed		Unmowed		Mowed		Unmowed	
	2001	2002	2001	2002	2001	2002	2001	2002
	--------------------------%----------------------------							
Black Cherry	95a	78c	86b	68d	90ab	83bc	96a	89ab
Red Oak	100a	92b	97ab	94b	97ab	81c	98ab	92b
Yellow-poplar	99a	94b	100a	99a	92b	75c	94b	93b
Black Walnut	99a	97a	97a	92b	98a	95ab	97a	97a
White Ash	100	100	100	99	100	100	100	100

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

Total seedling survival was higher ($p<0.05$) in ripped plots on both sites, and seemed especially noticeable on the south aspect (Table 3). Ripping caused disturbance in the topsoil layer, forming a loosened soil zone with reduced bulk density and enhanced water infiltration. Ripping also broke up the hardened ash layer beneath the topsoil. The ash layer could have acted as a restrictive zone, similar to a fragipan, which would impede plant root growth and water movement. Over time with increasing tree and root growth, we believe the effects of ripping will become more evident on the survival and growth of these trees. The striking difference in average survival between ripped and unripped plots on the south aspect further suggests that plant rooting depth and the amount of available water are likely factors contributing to the higher mortality on the south-facing slope.

Table 3. Average percent survival of planted seedlings on two aspects with two ripping treatments on a surface mine in West Virginia during 2001 and 2002.

Species	North Aspect				South Aspect			
	Ripped		Unripped		Ripped		Unripped	
	2001	2002	2001	2002	2001	2002	2001	2002
	----------------------------%-----------------------------							
Black Cherry	95a	78c	86b	68d	98a	93ab	86b	79c
Red Oak	97ab	95b	100a	91c	100a	93bc	95b	80d
Yellow-poplar	100a	98a	99a	95a	99a	95a	96a	73b
Black Walnut	98ab	92b	98ab	97ab	100a	98ab	95b	94b
White Ash	100	99	100	100	100	100	100	100

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

Only tree species with large seeds (black walnut and red oak) produced significant numbers of surviving tree seedlings on the seeded plots (Tables 4 and 5). Viability (cut test) was high (>95%) for all seeds at planting time. Large seeds of black walnut and red oak had enough reserve energy to germinate and compete with the existing vegetation during the first growing season. Black walnut, black cherry, and white ash increased in number of trees established in 2002 as some seeds apparently germinated during the second growing season (Tables 4 and 5).

Table 4. Average percent survival of trees from planted seeds on two aspects with two mowing treatments on a surface mine in West Virginia.

Species	North Aspect				South Aspect			
	Mowed		Unmowed		Mowed		Unmowed	
	2001	2002	2001	2002	2001	2002	2001	2002
	----------------------------------%----------------------------------							
Black Cherry	0	0	0	3b	0	1b	0	10a
Red Oak	18a	1d	16a	6c	11b	1d	16a	4c
Yellow-poplar	0	0	0	0	0	0	0	0
Black Walnut	17b	22a	20ab	25a	8c	10c	19ab	22a
White Ash	0	0	0	0	0	0	0	2a

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

The number of red oak seedlings (from seeds) declined during the same period from 30% growing in 2001 to only 6% surviving at the end of the 2002 growing season. It appeared that red oak trees germinated from seeds could not compete with the grass/legume ground cover. Red oak mortality was highest in the unripped plots and mowed plots where competition for available moisture was greatest. Survival of seeded trees in relation to treatments was similar to planted seedlings. For example, the plots that were mowed on south-facing aspects showed significantly lower survival than on other plots (Table 4). Ripping significantly helped the survival of most tree species, especially with black walnut seeds (Table 5). Black walnut is a tap-rooted species, and it is apparent that ripping aided in the establishment of this species, since survival was almost 1.5 to 2 times greater in ripped vs. unripped plots.

Table 5. Average percent survival of trees from planted seeds on two aspects with two ripping treatments on a surface mine in West Virginia.

Species	North Aspect		South Aspect	
	Ripped	Unripped	Ripped	Unripped

	2001	2002	2001	2002	2001	2002	2001	2002
	----------------------------------%----------------------------------							
Black Cherry	0	2b	0	1b	0	9a	0	2b
Red Oak	15ab	7c	19a	0d	13b	3d	15ab	2d
Yellow-poplar	0	0	0	0	0	0	0	0
Black Walnut	27a	31a	9c	16b	16b	18b	11c	15b
White Ash	0	0	0	0	0	2a	0	0

[1]Values within rows for each species with a different letter are significantly different at the 0.05 level. If no letters are shown, there was no significant difference for survival among treatments for that tree species.

Summary and Conclusions

Overall, survival was very good for all planted seedlings. Survival varied among species with white ash experiencing almost no mortality, while black cherry experienced the highest mortality mostly as a result of rodent damage. Mowing had mixed effects depending on individual species and aspect. In general, mowing resulted in lower tree survival due to denser vegetation cover, which increased moisture competition. Ripping generally resulted in increased survival for all species, but especially so on the south aspect. Higher survival on ripped plots was probably due to improved conditions for plant rooting and more available moisture resulting from increased infiltration. Direct seeding was only successful with the large-seeded black walnut. Black walnut had 40% survival of planted seeds after the second growing season (2002). Even though the percent survival of black walnut was lower with direct seeding compared to transplanting, the savings in planting costs may possibly justify its use in establishing this species. Low establishment from seeds could be easily offset by planting more tree seeds.

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