SURVIVAL OF COMMERCIAL HARDWOODS ON RECLAIMED MINESOILS IN WEST VIRGINIA: 6TH YEAR RESULTS[1]

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Abstract. Recent changes to West Virginia coal mining regulations emphasize commercial forestry as a preferred post-mining land use on surface mined areas. In the spring of 2001, a study was initiated in northern West Virginia to examine the establishment and growth of commercial hardwood trees on a reclaimed surface mined site. We planted seeds and 1-0 seedlings of five 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 treatment combinations of north- and south-facing aspects, ripped and unripped minesoils, and mowed and un-mowed groundcover. First and 2nd year results showed extremely high survival of planted seedlings (>95% for all species) and seedling establishment from seeds was about 16% for black walnut and <5% for the other species. By the 6th year, black cherry survival averaged 37% for seedlings and 4% for seeds across treatments, red oak was 46% and 2%, yellow poplar was 66% and 0%, black walnut was 81% and 36%, and white ash was 99% and 1%. Average height of trees was greatest with white ash (89 cm), followed by black walnut (65 cm) and yellow poplar (67 cm), then by red oak (45 cm) and black cherry (40 cm). Seedling and seed survival was best on north, ripped, and un-mowed plots.

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

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Introduction

About 78% of West Virginia is forested and, with the prevailing climate, almost all land in this region will naturally revert to forestland if disturbed by fire, farming, or mining. 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.

Early reclamation during the 1940s to 1970s usually involved planting of conifers and some hardwood tree species on surface mined land to replace the forest which had been removed (Ashby, 2006; Brown, 1962; Limstrom, 1960). Reforestation was chosen because the land had been originally forested and reforested sites provided long-term site stabilization, wildlife habitat, and future economic value when trees are harvested (Torbert and Burger, 1992). But since the late 1970s with the passage of a national surface mining law, most surface mined land in West Virginia has been reclaimed to either pasture/hayland or wildlife habitat post-mining land uses (Plass, 1982). The reasons for this switch related to: 1) less expense to the mining company, 2) quick economic returns to landowners by grazing and haying systems, 3) predictable bond release because the consistent ground cover gave good erosion control and water quality, and 4) better land stability compared to pre-law mined landforms where no grading was performed (Boyce, 1999). Reclamation to pasture or hay land is good if the site is maintained with fertilizer, lime, and forage removal. But problems develop if these maintenance practices are neglected and the plant community can quickly collapse and revert to a barren, eroded landscape of weedy and undesirable species. Trees will return eventually, but a long time must pass as the site succeeds through a series of unproductive plant communities until valuable hardwood species ultimately invade back onto the site and the canopy closes (Gorman et al., 2001; Potter et al., 1951; Zeleznik and Skousen, 1994).

Reforestation of mined lands has gradually emerged during the early 2000s as a preferred post-mining land use option, even before current regulatory requirements. There are several obstacles to reforestation. First, poor survival and growth of hardwood species has occurred especially when tree seedlings are planted into heavy herbaceous ground cover (Holl, 2002; Torbert and Burger, 2000; Burger and Torbert, 1990). Survival and growth of trees is often weather dependent and less predictable compared to forage species. Replanting of trees is expensive and reclamation success relies on height growth of the trees. Losing a year or two of tree growth because of poor weather or browsing by animals can delay the release of money held in reclamation bonds.

Another problem is related to the requirements for topsoiling and the compaction that may result from the placement and grading of this material to form a smooth surface (Ashby, 1997; Torbert and Burger, 1990; Rolf, 1994). Several studies have shown rapid weathering of blasted rock materials ("substitute" topsoil) when placed on the surface for revegetation and the fast development of soil horizons (Roberts et al., 1988; Sencindiver and Ammons, 2000; Haering et al., 2004; Haering et al., 1997). Substitute topsoils made from unweathered material have a slightly alkaline pH, variable sized particles and rocks which hold adequate supplies of nutrients and enough water for tree growth (Burger and Torbert, 1992). Recent regulations require replacement of native topsoil and weathered brown sandstone material to a depth of 1.2 to 1.5 m rather than unweathered substitute topsoil.

Uncompacted, loose soil material, regardless of its weathered or unweathered condition, has also been shown to be a preferred rooting media for trees (Ashby, 2006; McFee et al., 1981). In many cases, operators and regulators have been conditioned to expect smooth, compacted, lawn-like reclamation with a consistent cover of grasses and legumes. The rough-graded, sparsely-covered reclamation required for tree planting is considered equivalent to no reclamation for many individuals who are inclined toward pasture and hay land post-mining land uses.

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 anticipated 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 allelopathic, 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 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 0.8-ha area and to monitor tree survival and growth. We planted and seeded five hardwood species onto north- and south-facing aspects, into ripped and unripped plots, and into mowed and un-mowed plots. The objective of this study was to determine survival and growth of these trees in these various treatment combinations.

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 to approximate original contour, 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 the ash also was used to retard the movement of water downward into the backfill because the ash forms a weak cement upon wetting. Application of FBC ash is a standard practice on Waynesburg surface mines in this area because it not only solves the problem of ash disposal, but it also prevents acid mine drainage formation due to the alkalinity of the ash and its sealing capacity. After FBC ash placement, bulldozers re-spread and compacted 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 (*Festuca arundinacea* Schreb.), 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 0.8-ha section of the reclaimed land (39°39’30”N, 80°03’00”W) with both a north- and a south-facing aspect was selected for our study. Elevation of the site was 372 m (1220 feet above sea level) and slope on each aspect was about 15%. Before the experiment was established, both the north- and south-facing sites were mowed with a brush hog to reduce the height of ground cover.

On each site (North or South aspect), the tree planting experiment consisted of a split block design. After the initial mowing (Fig. 1) and after tree planting, one half of each aspect (considered a block) was mowed every month from May through September for the 1st 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 15-20 cm before mowing to 5 cm after mowing. Mowing was discontinued after the 1st 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 exposed trees to increased deer and rodent predation.

Within each block (mowing treatment) on both sites, 16 plots of 20m x 6m were established where half was ripped and half was not. The ripping treatment (Fig. 2) consisted of a single-blade ripper attached to a bulldozer that ripped the minesoil to a depth of one meter along the contour. This treatment was meant to reduce minesoil compaction and to break up the potential hardened layer of ash beneath the topsoil, but it also broke up the consistently thick ground cover and reduced competition by disturbing the surface.

Figure 1. Mowing treatment during 1st year.

Figure 2. Ripping treatment along the contour.

Within each plot (8 per ripping treatment), seedlings of the five species of trees were planted on half of the plot and the other half was planted with tree seeds (Fig. 3). Hardwood seedlings of yellow-poplar, black cherry, white ash, black walnut, and red oak were planted alternatively at 1-m spacing with mattocks. Seeds of these same tree species were buried at the same spacing along the other half of each row. Seedlings and seeds were planted alternatively to provide a mixed hardwood stand. Each plot had 30 planted trees and 30 planted seeds (5 tree species x 6 replications). For each treatment combination (e.g., South-Mowed-Ripped plots), 240 trees and 240 seeds were planted. Including all treatment combinations, 1920 total trees were planted and 1920 seeds were planted (768 per species; 384 trees planted and 384 seeds buried). Site preparation and planting occurred in April 2001.

Tree survival was determined 6 months after planting (1st year-September 2001), after 2 growing seasons (2nd year-September 2002), after 5 growing seasons (5th year-August 2005), and after 6 growing seasons (6th year-August 2006). The reason for mortality of each seedling was also determined (either rodent/deer damage or die back). Germination and establishment of tree seeds were determined by looking at each individual location where a seed had been planted (Fig. 4). 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 block sub-treatments.

Figure 3. Planting tree seedlings in ripped plots. Figure 4. South-facing aspect after 1st year.

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 (EC) (Rhoades, 1982), texture (Gee and Bauder, 1986), and % coarse fragments (>2mm by weight).

Results and Discussion

Soil Properties

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, while soil pH was alkaline (8.7) in the FBC ash layer. Soluble salts, as measured by EC, were low in the topsoil and much higher in the FBC ash layer. Most agronomic crops are unaffected by EC values of 2 dS m^{-1} or less (Jurinak et al., 1987), but reductions in yield are often noticeable with EC values of 4 dS m^{-1} or greater (Sobek et al., 2000). Most hardwood trees prefer moderately acid conditions, and prefer EC values less than 2 dS m^{-1} (Rodrigue and Burger, 2004).

The topsoil had a clay loam texture with an average of 13% coarse fragments >2mm in size (Table 1), similar to values for native topsoil in the area. The FBC ash layer had a sandy loam texture. During sampling, it was evident that the FBC ash layer was continuously cemented. The ripping treatment 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 tree roots growing in the topsoil had probably not been influenced greatly by the cemented ash layer about 15 to 30 cm below the topsoil during these early stages of growth, but root restrictions will certainly occur over time. We also anticipate that the fragments of cemented ash will degrade into silt-sized particles over time.

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

Horizon	pH	EC ($dS\ m^{-1}$)	Sand (%)	Silt (%)	Clay (%)	Texture	Coarse Frags (%)
Topsoil	6.1 ± 0.3	0.2 ± 0.04	29 ± 0.4	34 ± 0.3	37 ± 0.4	Clay loam	13 ± 2.3
FBC Ash	8.7 ± 0.2	2.3 ± 0.07	54 ± 1.5	42 ± 1.3	4 ± 0.2	Sandy loam	52 ± 3.6

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

Tree Species Survival

Black Cherry. Black cherry is valuable furniture wood and is currently in high demand and brings a consistently high timber price ($1.20/Bd. Ft.). It is found throughout the eastern USA and grows best on slightly acidic and moist sites (Hicks, 1998). Black cherry associates with many upland tree species such as the oaks, poplar, hickories, and maples. It is known as an early successional species and invades quickly onto disturbed sites. Black cherry seedlings are susceptible to deer and rodent damage (Brown, 1962).

Overall survival of black cherry was very good (79-91%) during the first two years of the study (Table 2). Rainfall was above average during the first two years. Mortality of trees during the 3rd to the 6th years increased, so that survival after the 6th year averaged 37% across all treatments.

Table 2. Average percent survival of planted seedlings for Black Cherry with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Black Cherry Seedlings				
Treatments	1st	2nd	5th	6th
	(--------------------%------------------)			
South	92	84	43	39
North	90	76	35	35
Ripped	96	85	**48**	**45**
Unripped	86	73	**31**	**29**
Mowed	92	80	**32**	**30**
Un-mowed	91	78	**46**	**44**
Average	91	79	39	37

[1]Values within years for a specific treatment that are bolded are significantly different at the 0.05 level.

Survival of black cherry was not significantly different between north- and south-facing aspects. By the 5th year, ripping significantly increased survival, which is probably due to the tree roots having a channel of loosened soil in which to grow and the channels also capturing water and directing it to the roots. Surprisingly, un-mowed plots had better black cherry survival than mowed plots. We noticed during the 1st year of the study that mowing increased the competitiveness of the groundcover and made the tree seedlings more accessible to deer and rodents. We, therefore, discontinued mowing after the 1st year and the effect of mowing on black cherry mortality is now evident. We observed that every one of the black cherry seedlings were browsed by deer and the damage from girdling and browsing may have taken several years before the trees died. Black cherry survival decreased from 91% after the 1st year to 37% after the 6th year.

Black cherry seeds showed no establishment during the 1st year, but that increased to as high as 6% in some plots during the 2nd to 6th years (Table 3). The few seedlings we observed from seeding make it difficult to distinguish any treatment effects or trends.

Table 3. Average percent survival of planted seeds for Black Cherry with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Black Cherry Seeds				
Treatments	1st	2nd	5th	6th
	(-------------------%-------------------)			
South	0	4	4	4
North	0	3	5	3
Ripped	0	3	3	1
Unripped	0	4	6	6
Mowed	0	1	5	5
Unmowed	0	6	4	4
Average	0	3	4	4

Red Oak. Red oak is one of the fastest growing oaks native to North America. Its wood is widely used for lumber and veneer, and the tree is important to wildlife. Red oak is found throughout Appalachia and grows best on deep, well-drained soils on north and northeastern aspects. It grows with a variety of other oaks, hickories, maples, and poplar. It produces large, heavy seeds for reproduction, but also is capable of stump sprouting. Compared with the other commercially-valuable timber species in this region, red oak has the most consistent and sustained growth.

Red oak survival was significantly greater on north-facing aspects by the 5th year, as one might expect (Table 4). There was no significant difference for survival between ripping and mowing treatments. Overall survival was 47% after 6 years.

Table 4. Average percent survival of planted seedlings for Red Oak with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Red Oak Seedlings				
Treatments	1st	2nd	5th	6th
	(---------------------%---------------------)			
South	98	87	**41**	**36**
North	99	93	**64**	**57**
Ripped	99	94	58	53
Unripped	98	86	47	42
Mowed	99	87	47	44
Unmowed	98	93	56	50
Average	99	90	52	47

[1]Values within years for a specific treatment that are bolded are significantly different at the 0.05 level.

The number of red oak seedlings from seeds declined from 16% after the 1st year to 4% after the 2nd year (Table 5). It is possible that the red oak seedlings could not compete with the grass/legume ground cover or were damaged from deer browsing or rodent predation. Red oak mortality tended to be slightly higher in the south aspect, which might suggest that moisture conditions may have influenced survival.

Table 5. Average percent survival of planted seeds for Red Oak with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Red Oak Seeds				
Treatments	1st	2nd	5th	6th
	(---------------------%-------------------)			
South	14	3	1	1
North	17	4	5	3
Ripped	14	5	3	2
Unripped	17	1	3	2
Mowed	15	1	2	1
Unmowed	16	5	4	3
Average	16	4	3	2

Yellow Poplar. Yellow poplar is the most significant individual species with the greatest volume (except for the oaks taken as a whole) in the mesophytic region of the Eastern Deciduous Forest (Hicks, 1998). Yellow poplar is a fast-growing species generally found on the best sites with deep, well-drained soils, and on north and northeast-facing aspects. It produces wood that is usable for a wide variety of products from composites and structural timber to furniture. It is an important wildlife species, and the large flowers are an important source of nectar for bees. Yellow poplar will invade and grow quickly on disturbed areas. When growing on lower quality sites, it is shorter-lived and can be overtaken or outgrown by red oak.

Yellow poplar survival averaged greater than 90% during the first two years of the study, but that number declined to 68% after the 6th season (Table 6). Not surprisingly, survival was significantly higher on the north-facing aspect. It also survived better in ripped and un-mowed plots. The south, unripped, and mowed treatment plots had only 10% yellow poplar survival (interaction data not shown). The drier south aspect, the unripped plots where no channels were available for water capture and root extension, and the mowed treatment with increased ground cover competition really decreased survival of yellow poplar seedlings.

Table 6. Average percent survival of planted seedlings for Yellow Poplar with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Yellow Poplar Seedlings				
Treatments	1st	2nd	5th	6th
	(----------------------	%	----------------------	)
South	95	84	**52**	**48**
North	100	97	**85**	**88**
Ripped	100	97	**77**	**79**
Unripped	96	84	**59**	**56**
Mowed	96	85	**52**	**51**
Unmowed	98	96	**86**	**84**
Average	97	90	68	68

[1]Values within years for a specific treatment that are bolded are significantly different at the 0.05 level.

An unexpected result was that not one of the seeds of yellow poplar emerged in our plots (Table 7). Seeds of yellow poplar are winged and occur in cone-like aggregates, with good seed crops being produced almost every year (Hicks, 1998). Seeds are viable for up to 20 years in the leaf litter. Perhaps seedlings of yellow poplar will emerge in subsequent years as climatic and soil conditions provide an opportunity for seed germination and establishment.

Table 7. Average percent survival of planted seeds for Yellow Poplar with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Yellow Poplar Seeds				
Treatments	1st	2nd	5th	6th
	(---------------------%-------------------)			
South	0	0	0	0
North	0	0	0	0
Ripped	0	0	0	0
Unripped	0	0	0	0
Mowed	0	0	0	0
Unmowed	0	0	0	0
Average	0	0	0	0

<u>Black Walnut.</u> Black walnut is the most valuable of the native hardwoods in North America (Hicks, 1998) giving values of $1.40/Bd. Ft. The dark-colored wood is valued for furniture and gun stocks, and the nuts are valued food for humans and wildlife. It is widely distributed throughout the eastern USA, but is usually found as scattered individuals throughout the mesophytic forests. Black walnut is a site-demanding species and requires deep, well-drained soils of near neutral pH for best growth. It reproduces by seed, which are large and heavy, and it produces a toxic substance that is antagonistic to competing vegetation (allelopathy).

Black walnut showed similarly high survival rates of 96 to 98% during the first two years after transplanting (Table 8). By the 6th year, walnut survival was still above 80%. Survival did not appear to depend on any treatment. We were surprised that black walnut did so well on these sites, but others have reported good survival with this species on surface mined land (Anderson et al., 1989; Ashby and Kolar, 1977).

In discussing our favorable black walnut survival results with other foresters in the region, several mentioned that survival of this tree after planting into minesoils is quite unpredictable and some were surprised at our results. These foresters also explained that long-term productivity of this species is much more questionable than other tree species. Many foresters have witnessed the crash of this species when planted in minesoils due to insufficient availability of moisture and nutrients for this high-demanding species. Black walnut is not planted frequently on mined lands because of the large root system of 1-0 planting stock and the effort needed to open a sufficiently large hole for the root system. Therefore, despite our findings and the favorable findings of others, high numbers and widespread planting of black walnut should be approached with caution based on the experiences of past planting trials.

Table 8. Average percent survival of planted seedlings for Black Walnut with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Black Walnut Seedlings				
Treatments	1st	2nd	5th	6th
	(-----------------------%----------------------- -)			
South	98	96	87	81
North	98	95	81	80
Ripped	99	95	86	83
Unripped	97	96	82	76
Mowed	99	96	85	79
Unmowed	97	95	82	83
Average	98	96	84	81

An average of 16% of black walnut seeds germinated during the 1st year, and this number increased to an average of about 35% across all treatments (Table 9). It will be interesting to see if additional tree seedlings will emerge from seeds, and to compare the incremental height growth of trees from seedlings versus those from seed. Seed establishment was significantly greater in ripped plots during the 5th and 6th years. Black walnut seedling survival and establishment from seeds were excellent in this study.

Table 9. Average percent survival of planted seeds for Black Walnut with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

Black Walnut Seeds				
Treatments	1st	2nd	5th	6th
	(--------------------%------------------ -)			
South	17	14	32	31
North	14	20	41	40
Ripped	22	22	**44**	**43**
Unripped	10	14	**28**	**27**
Mowed	13	15	26	25
Unmowed	20	19	47	46

Average	16	17	36	35

[1]Values within years for a specific treatment that are bolded are significantly different at the 0.05 level.

White Ash. White ash is distributed throughout the eastern USA, and is used for tool handles, baseball bats, and furniture. It is a site-demanding species that requires moist and fertile conditions (Hicks, 1998; Schlesinger, 1990), is a relatively fast-growing species, and is frequently associated with yellow poplar, black cherry, red maple, and red oak. White ash generally functions as an exploitive species, taking advantage of sites that are temporarily enriched due to disturbance. Seedlings of white ash may take up to 15 years to reach a 5-ft height, but once the root systems are established, white ash trees can outgrow their competitors. Seeds are winged and light in weight and spread easily from the parent tree, but good seed production varies with a 2 to 3-year periodicity (Hicks, 1998). The Emerald ash borer (*Agrilus planipennis* Fairmaire, an exotic beetle) threatens to destroy white ash trees in the eastern USA, and widespread planting of ashes is being re-evaluated in spite of their high survival after planting. In fact, tree planters on surface mines in West Virginia are reducing white ash to 10% of the planting composition mix.

White ash had the best survival among the five species. No trees died the 1st or 2nd years and only one tree (on the un-mowed north aspect) out of the original 384 died during the 3rd to 5th year (Table 10). One additional white ash tree died during the 6th year. White ash has shown good survival on other sites (Zeleznik and Skousen, 1996) and often survives better than any other planted tree species. White ash was the most noticeable of the trees on our site, but it also was browsed heavily (Fig. 5 and 6). Sadly, foresters predict an almost complete demise of this tree during the next two decades.

Figure 5. Tree growth after the 6th year.

Figure 6. Browsing of trees by deer.

Germination and establishment of white ash seeds was very low with only 2% of the seeds establishing by the 6th year (Table 11).

Table 10. Average percent survival of planted seedlings for White Ash with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

White Ash Seedlings				
Treatments	1st	2nd	5th	6th
	(---------------------	%	-------------------	)
South	100	100	99	99
North	100	100	100	100
Ripped	100	100	99	99
Unripped	100	100	100	100
Mowed	100	100	99	99
Unmowed	100	100	100	100
Average	100	100	100	100

Table 11. Average percent survival of planted seeds for White Ash with various treatments on a surface mine in West Virginia during 1st (2001), 2nd (2002), 5th (2005), and 6th (2006) growing seasons.

White Ash Seeds				
Treatments	1st	2nd	5th	6th
	(---------------------	%	-------------------	-)
South	0	1	1	1
North	0	0	3	2
Ripped	0	1	1	1
Unripped	0	0	3	2
Mowed	0	0	2	1
Unmowed	0	1	2	2
Average	0	1	2	2

Height Growth

On average, height of these five trees was greatest in ripped plots on the north aspect, while the shortest trees were on the unripped plots of the south aspect (Table 12). Black cherry and red oak were the shortest of all the trees, while white ash showed the greatest height. We expect that incremental height growth will continue to increase during the next several years now that roots have had 6 years to become established.

Table 12. Average height of seedlings of 5 tree species for the 5th and 6th growing season.

	North				South				Totals	
	Ripped		Unripped		Ripped		Unripped			
Species	5th	6th	5th	6th	5th	6th	5th	6th	5th	6th
Black Cherry	52	53	29	30	42	40	34	37	39	40
Black Walnut	69	79	72	66	56	61	48	53	61	65
Red Oak	47	53	35	43	51	48	30	34	41	45
Yellow Poplar	81	82	67	86	58	56	40	45	62	67
White Ash	88	102	82	85	83	92	74	77	82	89
Average	67	74	57	62	58	59	45	49		

Summary and Conclusions

Survival was nearly 100% for white ash during the first 6 years after planting seedlings. Planting of white ash seeds showed about 2% establishment. Black walnut had about 81% seedling survival. Seeds of black walnut had an overall 35% survival, with seeds in ripped and un-mowed plots giving significantly better survival. Yellow poplar was the only tree that showed significantly better survival in north, ripped, and un-mowed plots, with an average survival across all treatments of 68%. No yellow poplar seeds germinated and established. Red oak survival was 47% overall, and seedlings survived better on north vs. south aspects. Sixteen percent of red oak seeds established after the 1st year but survival of seeds declined to 2% after the 6th year. Black cherry showed 37% seedling survival and had significantly better survival on ripped and un-mowed plots. About 4% of the seeds established after the 6th year.

In general, the north-facing, ripped, and un-mowed plots gave greater survival than south, unripped, and mowed plots. Northern aspects probably improved moisture conditions and provided cooler temperatures than southern aspect. Ripping generally resulted in increased survival for all species. Higher survival on ripped plots was probably due to improved conditions for plant rooting and more available moisture resulting from increased infiltration and collection of water in the ripped soils. In general, mowing resulted in lower tree survival due to creating a denser vegetation cover, increasing moisture and nutrient competition. Mowing also made the seedlings more susceptible to herbivores.

Direct seeding was only successful with the large-seeded black walnut. Black walnut had about 35% survival of planted seeds after the 6th growing season. Average height of trees was greatest with white ash (89 cm), followed by black walnut (65 cm) and yellow poplar (67 cm), then by red oak (45 cm) and black cherry (40 cm).

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