PERFORMANCE OF THREE PINE SPECIES AFTER ELEVEN YEARS ON PRE- AND POST-LAW MINED SITES IN VIRGINIA[1]

by

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Abstract. A reforestation experiment to test the growth and value of three pine species was established on two surface-mined sites in the Appalachian coalfields of Virginia. One site was mined just prior to enactment of the 1977 Surface Mining Control and Reclamation Act (SMCRA), and one site was mined and reclaimed to its approximate original contour in accordance with post-SMCRA regulations. Three pine species (*Pinus taeda, P. virginiana,* and *P. strobus)* were planted on each site in 1981. A fertilization and an herbaceous weed control treatment were tested. Half the plots were fertilized with a 21-g fertilizer tablet at time of planting and a broadcast application of 50 kg/ha N as ammonium nitrate prior to the fourth growing season. Each plot was split to accommodate an herbaceous weed control treatment during the first three years. After 11 years, all three tree species grew very well on the pre-law bench site, but were less productive on the post-law AOC site. The fastest-growing species was loblolly pine, which averaged 22 feet tall. Aggressive herbaceous ground covers commonly established on surface-mined land to reduce erosion were successfully controlled by herbicides, resulting in a significant improvement in survival and growth of all tree species. Fertilization had little effect on tree growth and was not as beneficial for tree establishment as the herbicide treatment. The good performance of these commercial tree species in this study demonstrates that good forest management opportunities exist for the owners of surface-mined land.

Additional Key Words: reforestation, SMCRA, reclamation

Introduction

In 1977, Congress passed the Surface Mining Control and Reclamation Act (SMCRA). This law had a tremendous effect on coal surface mining and reclamation in the Appalachian coalfields. Prior to 1977, contour mining was common; coal operators would push soil and overburden rock over the side of the mountain to reach the coal seams. After the coal was removed, a flat "bench" and "highwall" remained, with "outslopes" consisting of loose soil and rock. The outslopes and bench were commonly seeded with grasses and black locust (*Robinia pseudoacacia*), and several rows of white pine (*Pinus strobus*) were planted along the edge of the bench. Revegetation was designed to minimize soil erosion and sediment in streams; there was little or no thought given to reforestation for commercial forestry purposes. Disturbed lands were essentially written off as wasteland with no commercial value. Therefore, the productive potential of these mined lands for forest production is largely unknown.

One of the important requirements of SMCRA is that land be returned to its "approximate original contour" (AOC); coal operators must now reconstruct the slopes by replacing overburden on the bench and covering the highwall. Another important requirement is that land must be reclaimed to a level of productivity at least equal to that which existed before mining. Although some land can be used for hayland/pasture, residential, or industrial uses, most of the surface-mined land in the Appalachians is too steep or remotely located to realistically be used for anything other than timber production. Hence, timber production is an important post-mining land use in the Appalachian Mountains. For these landowners, it is not sufficient to merely plant trees, but trees must grow well enough to warrant timber management activities. However, little was known about the productivity and feasibility of mined land for commercial forestry purposes.

In 1980, a study was established to evaluate the performance of three pine species on two types of surface-mined sites, a pre-SMCRA bench and a post-SMCRA reclaimed AOC slope, and to evaluate the effect of chemical weed control and fertilization on tree establishment and growth. The purpose of this paper is to report the performance of the three species 11 years after establishment, after the stands had fully closed. Particular emphasis was placed on relative productivity of pre-law and post-law mined sites and how tree growth on these sites compared with undisturbed sites.

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Methods

The two sites chosen for this study were a pre-SMCRA bench site and a post-SMCRA return-to-contour site. Hereafter, these site types will be called pre-law and post-law, respectively. The pre-law bench site is characteristic of the condition of surface-mined lands prior to passage of SMCRA and the post-law AOC site is characteristic of lands mined after passage of this law. Both sites are located in Wise County, Virginia.

Eighteen 20 m by 20 m (0.1-acre) experimental plots were installed on two benches at elevations between 790 and 825 m; both had less than 2% slope. One bench was mined in 1977 and hydroseeded in 1978. The second bench was mined in 1978 and hydroseeded in 1979. Nine plots were placed on each bench. Coal company records indicate that both benches were hydroseeded with a combination of Kentucky-31 tall fescue (*Festuca arundinaceae* Schreb.), red clover (*Trifolium pratense* L.), ladino clover (*Trifolium repens* L.), annual rye (*Lolium multiflorum* Lam.), and redtop (*Argostis alba* L.), with 409 kg/ha of 16-27-14 fertilizer. Prior to establishing the study plots, the ground cover was dominated by tall fescue and Sericea lespedeza (*Lespedeza cuneata*). Because the site had an established ground cover, it was disc-harrowed with a heavy-duty forestry harrow in February 1981 and again in April 1981.

Another 18 plots were located on a post-law AOC site at an elevation of 580-625 m with an average slope of 40% and a westerly aspect. The slope was mined and reclaimed to its approximate original contour in 1979. It was hydroseeded in 1981 with Kentucky-31 fescue, redtop, ladino clover, annual rye, and annual lespedeza (*L. stipulacea*) with 560 kg/ha of 10-20-20 fertilizer. The ground cover was about 10 cm tall when trees were planted.

Tree seedlings were grown in containers from seed in a greenhouse. Stratified seeds of each pine species were planted in Spencer-Lemaire Rootrainers (Hillson model, 150 cm3/cavity; Spencer-Lemaire Industries, Ltd., Edmonton, Canada) containing a 1:1 v/v steam-sterilized peat-vermiculite mixture. Seedlings were grown in the greenhouse from January through May 1981. The trees were not subjected to a period of dormancy before field planting. Trees were planted in early June 1981 on a 1.5 x 2.5 m spacing.

Three species and two fertilizer treatments were factorially assigned and replicated three times on each site type. The three pine species were loblolly pine (*P. taeda* L.), white pine, and Virginia pine (*P. virginiana* Mill.). The fertilizer treatments consisted of a control treatment and a treatment in which seedlings were planted with a 21-g slow-release fertilizer tablet (20-10-15) placed 10 cm deep within 10-15 cm of the seedling, and in April, 1984, prior to the fourth growing season, 56 kg N/ha as ammonium nitrate was broadcast-applied to these plots.

Each plot was split in half to accommodate an herbicide treatment. Herbaceous weed control consisted of spraying glyphosate at a rate of 0.62 kg a.i./ha 16 days prior to planting the trees and again during September 1981. Seedlings were protected with paper bags during the second application. Prior to the third growing season, sulfometuron methyl was broadcast at the rate of 0.22 kg a.i./ha.

Tree heights and diameters were measured after the first, second, third, fifth, and eleventh growing seasons. The study was analyzed by ANOVA as a split-plot randomized block design with species and fertilizer treatment factorially arranged and replicated three times within each site type. Each plot was split to accommodate the herbicide treatment. Treatment effects were considered significant if the level of probability for random occurrence was less than 0.05.

Results and Discussion

Comparison of Tree Species

Eastern white pine is the most frequently planted commercial tree on Virginia minesoils. White pine is native to the region, and it can grow very well on minesoils. In Virginia, approximately 90% of surface-mined land is replanted with a mixture of tree species that almost always includes white pine. Virginia pine is also a native species, although it is seldom planted. Loblolly pine is not native to the Central Appalachian coalfields, although it is planted occasionally.

In this study, loblolly pine had the best survival and growth through age 11 (Table 1). The average height for loblolly pine (6.9 m) was twice that of white pine (3.4 m). Loblolly pine also had the best average survival rate (80%). Virginia pine also survived and grew much better than white pine, but not quite as well as loblolly pine. Despite the fact that loblolly pine is not native to the mountains, there was no indication that it suffered from the several severe winter storms that occurred during the course of this study. Older stands of loblolly pine in the general region attest that the species is capable of tolerating the climate.

Table 1. Comparison of survival and growth of 3 tree species after 11 years on a pre-law bench and a post-law AOC site.

	Pre-SMCRA Bench Site			Post-SMCRA AOC Site		
Species	Survival (%)	Ht. (m)	Diam. (cm)	Survival (%)	Ht. (m)	Diam. (cm)
Loblolly pine	77 a	7.0 a	11.2 a	82 a	6.7 a	8.9 a
Virginia pine	63 ab	5.6 b	9.7 b	81 a	5.3 b	7.4 a
White pine	45 b	3.7 c	5.3 c	63 b	3.1 c	3.6 b

The relative survival of the three species is not necessarily indicative of how well these species would compare for operationally-planted seedlings, since the seedlings used in this study were containerized. The seedlings had not been through a dormancy stage before they were planted. Thus, white pine, which has a determinant growth habit, was essentially finished with its annual growth by the time of field planting, and did not resume growth until the following year. On the other hand, both loblolly and Virginia pine continued to grow rapidly after field planting. Furthermore, white pine seedlings are usually two years old when field-planted as bare-root stock, whereas loblolly and Virginia pine are planted as one-year-old seedlings. Accounting for the age difference in seedlings that are routinely planted and the growth habit differences among these species, there is effectively a two-year time lag between performance of white pine in this study and the performance that might be expected from bare-root seedlings.

For the purposes of comparing the productivity of these reclaimed sites with the productivity of other land, site index was calculated for loblolly pine and white pine, the two main timber species. For loblolly pine, SI_{25} was estimated from the average height of the tallest 25% of the trees in each plot, 8.1 m. From site index curves for loblolly pine (Amateis and Burkhart 1985), a height of 8.1 m at age 11 corresponds to a SI_{25} of about 17.1 m. This is a moderate level of productivity similar to much of the land in the southern Piedmont where loblolly pine is commercially managed.

For white pine, SI_{50} was calculated using Beck's (1974) three-year growth intercept method. This method for estimating site index of young trees is based on the amount of height growth that occurs during a three-year period after the trees have reached the free-to-grow point above the herbaceous cover. Beck's procedure calls for beginning the height growth measurement near breast height. Estimates of site index for young trees based on height and age may underestimate the productivity of surface-mined land, where aggressive ground covers can reduce tree height during the early years. On average, the dominant white pines grew 2.3 m during this three-year period, which corresponds to a site index of 35 m. Doolittle (1958) reported that the average level of productivity for white pine on natural soils in the southern Appalachians was 25 m for age 50. Thus, it appears that white pine productivity on these sites was better than average for natural soils in the region. These estimates of site index for loblolly pine and white pine indicate that in the long run white pine may be more productive, even though early growth of loblolly pine was better.

Comparison of Pre-Law Bench vs. Post-Law AOC Sites

This study provides a unique opportunity to compare the productivity of pre-SMCRA and post-SMCRA reclamation sites. Results of this study can be used to judge the effects of post-law reclamation on forest productivity.

Throughout the course of this study, trees were larger on the pre-law bench than on the post-law AOC site. Aside from the difference in slope steepness and soil depth, the main difference between the sites was the rock type of the topsoil substitute (Table 2). The post-law AOC site had a greater proportion of siltstone, which is reflected in the soil texture and pH. The silt plus clay fraction of the post-law AOC site was 75% compared to 50% on the pre-law bench site. This causes poorer drainage and aeration. These pine species are adapted to a soil pH between 4.5 and 5.5. When the study was established in 1981, both sites had similar levels of soil nutrients.

Table 2. Selected soil properties of a pre-SMCRA[1] bench site and a post-SMCRA AOC site at time of establishment[2].

Soil Property	Pre-SMCRA Bench Site	Post-SMCRA AOC Site
Coarse fragments (%)	43	49
Sand[3] (%)	51	24
Silt (%)	28	41
Clay (%)	21	35
Bulk density (g cm^{-1})	1.4	1.3
Organic matter (%)	1.8	1.2
pH	6.1	5.5
Total nitrogen (μmol g^{-1})	51.1	55.9
Phosphorus[4] (μmol g^{-1})	0.20	0.24
Potassium[5] (μmol g^{-1})	2.05	2.58
Calcium (μmol g^{-1})	14.37	15.22
Magnesium (μmol g^{-1})	10.50	17.73

[1] Pre-SMCRA: reclaimed prior to enactment of the 1977 Surface Mining Control and Reclamation Act.
[2] Data from Schoenholtz et al. 1984.
[3] Sand, silt, and clay values are percentages of fine earth fraction (< 2mm diameter).
[4] Phosphorus extracted with sodium bicarbonate.
[5] Cations extracted with ammonium acetate.

The initial effects of site differences may have diminished. For the most part, the greater rate of growth that occurred on the pre-law bench during the first five years has ceased, and trees have recently been growing at approximately the same rate on the post-law site. At age 5, the average height for trees (all species averaged together) on the pre-law site was 40 cm taller than for trees on the post-law site. At age 11, the average height was 42 cm taller, essentially the same. It remains to be seen if this trend holds as the stands approach harvestable age.

Site index estimates for loblolly pine were about the same across sites. Both sites had an average SI_{25} of 17 m. On the other hand, estimated SI_{50} for white pine was much higher on the pre-law site than on the post-law bench site. Only two white pine plots on the post-law AOC site, however, had trees that were tall enough to make a site index estimate, and both of these plots were fertilized. The average three-year height growth for these trees was 2.8 m, with a corresponding site index estimate of 41 m. On all other white pine post-law AOC plots, no tree had grown above dbh height for three or more years, and thus it was not possible to use Beck's method to estimate site index. On the pre-law bench site, all white pine plots had trees tall enough for these measurements. Trees in the fertilized pre-law plots grew 2.2 m with a site index estimate of 34 m, while trees in the unfertilized plots grew 2.1 m with a site index estimate of 33 m.

We believe all pine species could grow better on most post-law sites in the long run if weathered sandstone overburden is used rather than siltstone overburden. Minesoil on benches is inherently shallow due to the underlying bedrock. Since the post-law sites are constructed by replacing overburden on top of the bench, the depth to bedrock can be very deep, and this could have a beneficial effect on long-term growth. However, many post-law sites, including this one, have undesirable siltstone surfaces which could reduce long-term forest productivity due to poor soil drainage, aeration, and unsuitable chemistry.

Herbicide Effects

Numerous researchers and practitioners throughout the country have experienced problems trying to establish tree seedlings in aggressive ground covers established during reclamation. Tall ground cover species can overtop seedlings and block light, compete for soil moisture and nutrients, become entangled with seedlings, bend them to the ground during the winter, and provide cover for rodents that feed on the bark. One way to reduce herbaceous competition is to provide a clear area around seedlings with herbicides.

Herbicide effects on survival and growth were statistically greater for all species on the post-law AOC site, but the effect was less on the pre-law bench site (Table 3). The ground cover during the first few years of this study was more aggressive on the post-law AOC site than on the pre-law bench site. Without weed control, many trees on the post-law AOC site were overtopped and died. Others remained suppressed for several years. The effect of weed control on the post-law AOC site does not appear to be diminishing with time, even though there are no residual effects of herbicide on ground cover. At age 11, all plots except a few white pine plots had a closed canopy, and the herbaceous ground cover was virtually eliminated. At age 5, the average tree height on the post-law AOC site was 66 cm greater on the herbicide-treated plots than on the control plots. At age 11, the difference in tree height increased to 158 cm. On the pre-law bench site, the beneficial effect of weed control has declined. Whereas average tree height for herbicide plots was 34 cm taller than that for control plots at age 5, average tree height was only 27 cm taller at age 11.

Fertilizer Effects

Fertilizer tablets were used at the time of planting to selectively provide nutrients to the tree without stimulating the ground cover. An additional band application of ammonium nitrate was applied prior to the fourth growing season. In general, fertilization improved survival and growth on both sites, but statistically significant effects did not occur for any species (Table 3). On both sites, height response to fertilizer at age 11 was greater than effects measured at age 5. On the post-law AOC site, fertilized trees averaged 47 cm taller than control trees at age 5 and 124 cm taller at age 11. On the pre-law bench site, the difference was 37 cm at age 5 and 93 cm at age 11. On the pre-law bench site, the response to fertilizer was greater than the response to herbicide, whereas the opposite occurred on the post-law AOC site.

Table 3. Effect of weed control and fertilizer treatments[1] on 11-year survival, height, and diameter of three pine species on a pre-SMCRA[2] bench site and a post-SMCRA AOC site.

	Pre-SMCRA Bench Site			Post-SMCRA AOC Site		
Treatment	Survival (%)	Height (m)	Diameter (cm)	Survival (%)	Height (m)	Diameter (cm)
			LOBLOLLY PINE			
Control	75 b	6.5	10.9	72	6.3	8.6
Fertilized	90 a	7.5	11.2	82	7.1	9.1
Control	78	6.8	10.9	60 b	5.7 b	7.9 b
Herbicide	87	7.2	11.4	93 a	7.7 a	10.2 a
			VIRGINIA PINE			
Control	72	5.3	9.4	52	4.7	6.9
Fertilized	95	6.1	9.9	81	6.2	8.4
Control	85	5.5	9.4	44 b	4.7 b	6.6 b
Herbicide	78	5.8	9.9	83 a	5.9 a	8.4 a
			WHITE PINE			
Control	75 b	6.5	10.9	26	2.3	2.5
Fertilized	90 a	7.5	11.2	65	3.8	4.6
Control	78	6.8	10.9	33 b	2.3 b	2.3 b
Herbicide	87	7.2	11.4	58 a	3.8 a	4.8 a

1 Treatment effects determined by ANOVA with a significance level of 0.05.
2 Pre-SMCRA: reclaimed prior to enactment of the 1977 Surface Mining Control and Reclamation Act.

Summary

For some landowners, forest management may be the best and perhaps the only practical post-mining land use, especially for steep tracts of land that include hundreds of acres. Reclamation can be more than stabilizing a disturbed ecosystem; it can be an opportunity to establish an economically-viable forest enterprise. This study shows that commercial pine species can grow at rates equivalent to those on undisturbed soils. Controlling ground cover on reclaimed sites is needed for tree establishment, especially on older reclaimed sites where the ground cover is well established. The application of herbicides for three years as exercised in this study may not be practical on an operational basis, but a single application during the year of establishment, or the use of a less competitive, tree-compatible ground cover, would produce similar results (Burger and Torbert, 1992). Fertilizer seemed to improve tree survival and growth, but its use was not essential for tree establishment.

Overall, we believe landowners are missing a valuable forestry opportunity by not establishing productive forests on mined land. Land is essentially being abandoned after mining and reclamation. The land will eventually become forested through natural succession, but it will be several hundred years before it will become a commercially-valuable forest. Alternatively, our study shows that commercial forests, growing at rates similar to those on undisturbed sites, can be established on both pre- and post-SMCRA sites using conventional silvicultural techniques. Furthermore, post-law reclamation could be greatly improved for forestry if weathered sandstone overburden materials were placed on the surface and left uncompacted, and if non-competitive ground covers were used for erosion control.

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