

HERBACEOUS GROUND COVER EFFECTS ON NATIVE HARDWOODS PLANTED ON MINED LAND¹

J. A. Burger², D. O. Mitchem, C. E. Zipper, and R. Williams

Abstract. There is increasing interest among eastern U. S. landowners and coal operators in restoring mined land to native hardwood forests. Establishing a mix of native hardwood tree species simultaneously with erosion control ground covers is difficult. The purpose of this study was to test the response of hardwood species to three levels of ground cover control using an herbicide. Treatments were *control* (90% ground cover), *spot spray* around trees (50% cover), and *broadcast spray* (10% cover). Survival of oak species was generally greater when spot sprayed, but survival of ash, maple, poplar and white pine was unaffected. Tree biomass of most species was greater on spot sprayed plots. Trees on broadcast sprayed plots were damaged by herbicide drift rendering this treatment less effective. Overall stocking on spot sprayed plots was 67%, which met the stocking performance standard when 700 trees/acre were planted. A Forestland Reclamation Approach, which includes ground cover management, is needed for successful native hardwood reforestation.

Additional Key Words: reforestation, herbicides, tree planting, reclamation

¹ Paper was presented at the 2005 National Meeting of the American Society of Surface Mining and Reclamation, June 19-23, 2005. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

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Proceedings America Society of Mining and Reclamation, 2005 pp 136-146

DOI: 10.21000/JASMR05010136

<https://doi.org/10.21000/JASMR05010136>

Introduction

During a 40-year period prior to the implementation of the Surface Mining Control and Reclamation Act (SMCRA), native hardwood trees were often planted on surface mine spoils in the Appalachian and Midwestern Coalfield Regions. Most trees were planted directly into the loose, cast overburden and suffered little competition from other vegetation. The quality of the spoils was highly variable, but when conditions were right most species grew well and some exceeded the growth of trees on adjacent non-mined sites (Ashby 1987; Rodrigue, 2002). With the implementation of the SMCRA in 1978, the condition of reclaimed surface mines changed dramatically. Surface mines are larger and deeper, and mountain top removal allows mining of multiple coal seams. Unweathered overburden from deep in the geologic profile usually becomes the plant growth medium on the surface. Federal and state laws require that most mined sites be returned to approximate original contour, and that all reclaimed surfaces be seeded with erosion-control ground covers as soon as practicable. Post-SMCRA mine spoils are often heavily graded and compacted, especially on gentle slopes and flat areas. Vigorously growing, dense groundcovers are commonly sown or hydroseeded for erosion control.

Except for several early-successional woody species such as black locust, autumn olive, Virginia pine, and white pine, few native tree species survived and grew normally under these new conditions (Ashby and Kolar, 1998). The unweathered mine spoils had very different physical and chemical properties compared to native soils, and they were usually heavily compacted as the new landscape took shape. The erosion control ground cover, often consisting of hardy and aggressive species such as tall fescue and sericia lespedeza, quickly overtopped planted seedlings causing poor survival and growth. As a result, during a 20-year period between 1980 and 2000, most coal operators created grasslands, wildlife habitat (grasslands with a mix of woody wildlife food plants), or unmanaged forest (ground cover grasses with a mix of black locust, pine species, and woody shrubs) rather than attempting return of the land to its original use, which in most cases was native hardwood forest. The majority of these new grasslands have been abandoned to natural succession and most are covered with thickets of autumn olive, black locust and a number of other early-successional species, many of them non-native, invasive, and of no commercial value. In the past 5 years interest in restoring the native forest on mined land has resurged as landowners realize they need to put the land to productive use for economic reasons. In most cases, the native forest is the most logical post-mining land use given historic timber markets in the region.

Given the past difficulty establishing native hardwoods on mined land, in part due to competitive ground cover, the purpose of this study was (1) to determine if a mix of commercially-valuable, native hardwood species would meet the reclamation performance standards required by Virginia's reclamation regulations for "commercial forestry"; (2) to determine if, and to what extent, tree survival and growth would respond to spot spraying versus broadcast spraying of herbaceous ground cover; and (3) to estimate the practicality and cost of applying herbicide treatments in lieu of other approaches to meet tree stocking standards for performance bond release.

Methods and Procedures

In the spring of 2002, a 10-acre reclaimed mine site in Wise County, Virginia, owned by Penn Virginia Resource Partners Corp. and mined by Red River Coal Company, was planted to a

mix of hardwood and pine species by Williams Forestry, Inc. The topsoil substitute consisted of a loosely graded mix of sandstone and shale taken from above the Taggart coal seam. These mine spoils commonly have a neutral pH and high level of fertility. During the summer prior to tree planting, the site had been reclaimed and seeded with a standard ground cover mix consisting of orchard grass, timothy, redbud, birdsfoot trefoil, and red clover, which achieved 90 to 100% ground cover.

A random mix of commercially-valuable native hardwood species, including white ash, red oak, white oak, chestnut oak, sugar maple, and tulip poplar was planted on 8 x 8 foot spacing at a rate of 600 trees/acre, 100 trees/acre of each species. An additional 75 wildlife/nurse trees/acre were planted in the mix, including 25 trees/acre each of crab apple, bristly locust, and silky dogwood. Although a commercial hardwood stand was intended, 25 trees/acre of white pine were planted to serve as a growth-rate indicator through time and to provide winter cover for wildlife; white pine is counted as a crop tree. Therefore, 625 crop trees and 75 wildlife trees/acre were planted for a target planting rate of 700 woody stems/acre. An average expected survival rate of 70% would leave 420 crop trees and 52 wildlife trees/acre (420/52) to meet the 400 crop and 40 wildlife trees/acre (400/40) required for bond release in Virginia.

Blocks of three 1/3-acre comparison plots were marked off wherein three herbicide treatments were applied: (1) *control*, no herbicide was applied; (2) *spot spray*, a 1-yard diameter circle around the stem of each tree; and (3) *broadcast spray*, direct spray across the entire plot area. The block layout was repeated three times within the planted area for a total of nine plots. RoundUp Ready (41% active ingredient) at a rate of 2 oz/gal was sprayed twice each year for three years. Herbaceous ground cover averaged 90, 50, and 10% for the control, spot, and broadcast treatments, respectively. The photo in Fig. 1 shows one of the three treatment blocks.

In October of each year, a tree count was made by species, and the height and ground-line stem diameter of each tree were measured. For a general estimate of growth, a biomass volume index was calculated by multiplying the tree height by the square of the stem diameter (d^2h). The effects of the three treatments on tree survival, height, and biomass volume were tested using a one-way ANOVA for a randomized block design, and Fisher's LSD test was used to separate mean treatment values ($P < 0.10$) (SAS, 2001).

Results and Discussion

Stocking

The original tree count average by treatment is shown in Table 1. There were slightly fewer trees planted than the target of 700 trees/acre. The total average tree count by treatment was 687, 663, and 680 trees/acre in the control, spot, and broadcast plots, respectively. After three years, the total tree count was 420, 436, and 393 trees/acre in the control, spot, and broadcast treated areas, for overall survival rates of 61, 67, and 58%, respectively. Required stocking rates for "commercial forestry" in Virginia are 400 crop trees and 40 wildlife trees/acre (400/40). The count after three years was 351/69, 394/42, and 358/35 trees/acre for the control, spot, and broadcast plots, respectively. The spot-sprayed plots had an overall survival rate of 67%, which nearly met the target of 400 crop trees/acre. Had the planned 700 trees/acre been planted instead of the 663 actually planted, the performance standard of 400 would have been met at this rate of survival. With survival rates of only 61 and 58%, respectively, the control and broadcast treatments did not meet the crop tree performance standard.

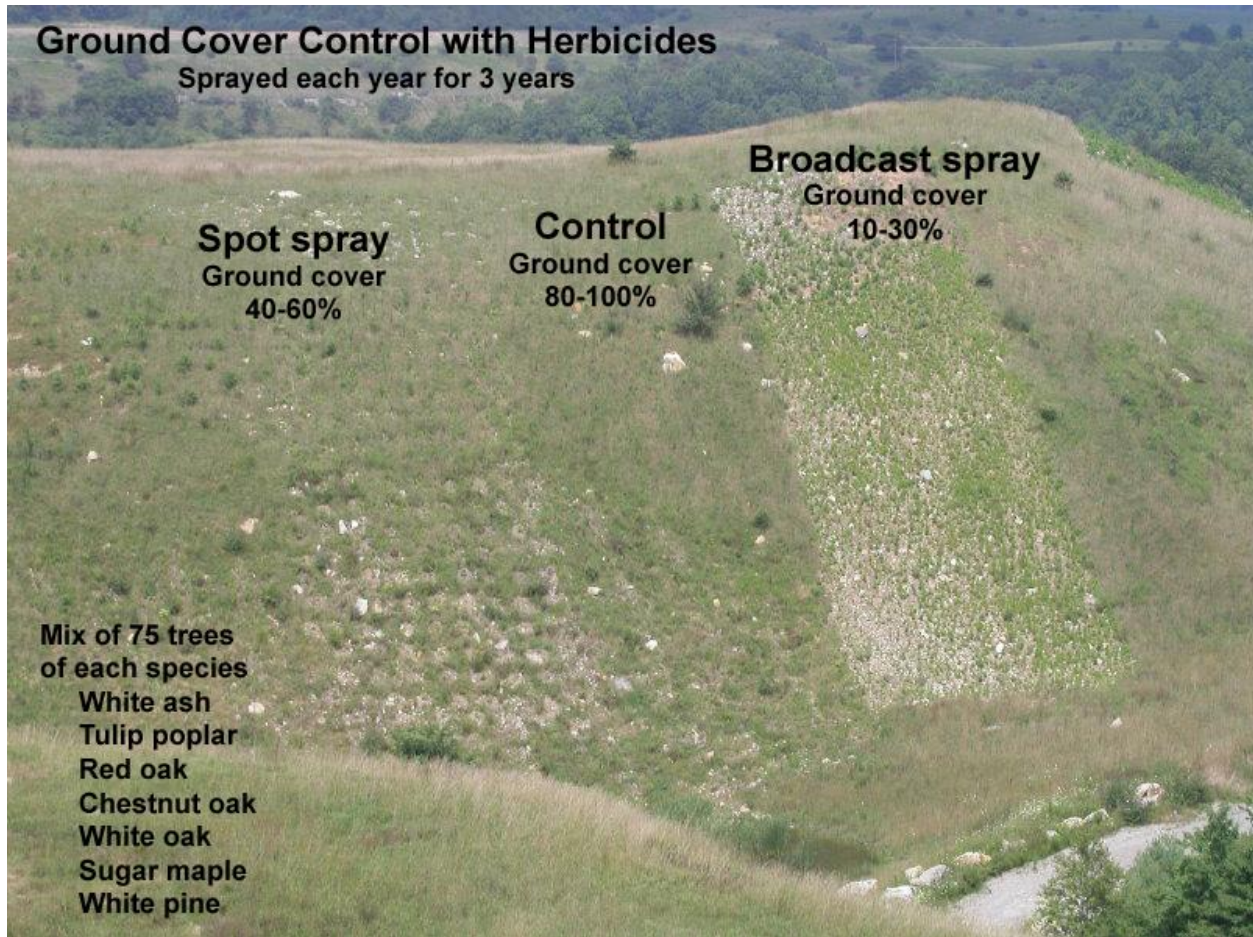


Figure 1. Photo overview of one block showing, from left to right, spot, control and broadcast treatments.

Survival

White and chestnut oak survival was highest on spot-sprayed plots, followed by broadcast-sprayed plots (Fig. 2). White oak survival was 59, 88, and 74% for the control, spot and broadcast treatments, respectively, and 43, 68, and 65%, respectively, for the chestnut oak. The herbicide treatments had no effect on survival of the remaining species. White ash and red oak survived well regardless of treatment, meeting the goal of 70%, an expected survival rate for hardwoods on mined land. When released from ground cover competition using herbicides, chestnut and white oaks also met the survival goal of 70%. Tulip poplar, sugar maple, and white pine all had survival rates below 50%, and controlling the ground cover had no apparent effect on their survival. The differences in survival among species concur with those reported by Vogel (1973), Washburn et al. (1993), Chaney et al. (1995), Ashby and Kolar (1998), and Kost et al. (1998), and they concur with many anecdotal field observations. That is, white ash survives well across a range of sites, while oaks are more site-specific and do best on loose, uncompacted, moderately acid spoils (Burger et al. 2002). Tulip poplar and sugar maple are especially site-sensitive and typically survive at rates below 50% regardless of site quality (Auch et al. 2005).

White pine usually survives well in competitive environments on moderately acid sites, and its poor survival in this case can be attributed to alkaline mine soils in which it is trying to grow.

Table 1. Stocking by species after planting and after three years.

Treatment	White Ash	Sugar Maple	Yellow Poplar	Chestnut Oak	White Oak	N. Red Oak	Crab-apple	White Pine	Silky Dogwood	Bristly Locust	Mean Stocking
	----- Original Stocking after Planting (trees/acre) -----										
Control	100	99	95	94	84	102	28	27	32	26	687
Spot Spray	84	92	94	86	78	108	31	33	28	29	663
Whole Plot	83	99	99	104	91	106	23	24	25	26	680
Species Means	89	97	96	95	84	105	27	28	28	27	
----- Stocking after 3 Years (trees/acre) -----											
Control	93	42	41	43	51	72	23	9	32	14	420
Spot Spray	76	52	45	58	68	84	9	11	27	6	436
Whole Plot	73	43	22	68	67	75	5	10	24	6	393
Species Means	81	46	36	56	62	77	12	10	28	9	

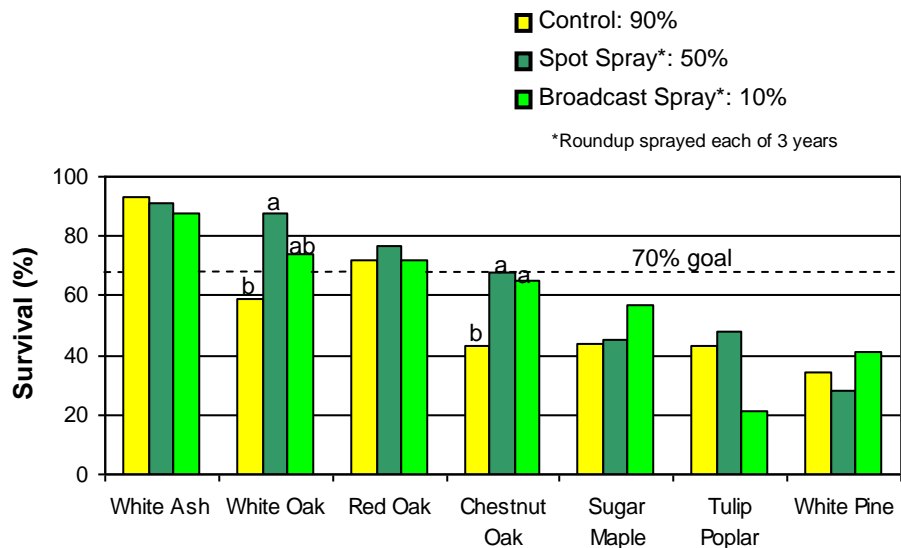


Figure 2. Ground cover effect on tree survival after three years.

Growth

By the end of the third growing season, four of the six hardwood crop trees – white ash, white oak, red oak, and sugar maple – grew significantly taller when ground cover was eliminated in spots around the trees (Fig. 3). Although broadcast spraying reduced total ground cover in the plots to about 10%, average tree height was generally less than the height of spot-sprayed trees, except for white ash. This difference was due largely to herbicide drift when broadcast spraying. When walking on steep, rocky slopes with a backpack sprayer, it is very difficult to locate small seedlings in and under herbaceous weeds and grass to avoid damaging them with herbicide. The taller white ash stood well above the ground cover out of harm's way, so broadcast spraying can be more effective when there is less risk of damaging the trees. When trees are small, spot spraying is safer because the applicator locates each tree before spraying and directs the spray away from the tree. Greater total tree biomass of white ash, estimated by a volume index (d^2h) as shown in Fig. 4, shows that trees in broadcast sprayed plots would grow best if ground cover could be controlled without damaging the trees. The biomass of white ash growing in broadcast sprayed plots was nearly twice that in spot sprayed plots. This dramatic growth response of early-successional hardwoods, when free of herbaceous competition, was reported by other researchers working on mined land reforestation (Vogel, 1973). In most cases, however, spot spraying, which leaves 50% ground cover, may be the more prudent treatment, as it reduces the risk of excessive soil erosion.

Tree Growth Over Time

Ground cover control is more critical for some species than others due to each species' growth habit. A generalization is that early-successional pioneer species like white ash and white pine have a progressive shoot-growth habit; that is, their shoots extend incrementally each year after planting. Many mid- to late-successional species like the oaks and sugar maple have a habit of extending their root systems first at the expense of shoot growth, often dying back to their root collar and re-sprouting again in the spring. The photos in Fig. 5 show a healthy white oak and a sugar maple with shoot dieback. Dieback can recur from one to four years, especially in difficult environments, before significant shoot growth occurs. This habit was evident in the growth of sugar maple and white oak, where both species experienced some dieback the second year, which is reflected by a lower second-year height compared to first-year height (Fig. 6). However, by the third year, both species extended their shoots, but only in the spot-sprayed plots. Planting older, containerized stock (e.g., 3-0 stock) with large root systems reduces dieback, but older stock is more expensive and much more difficult to plant in mine spoils.

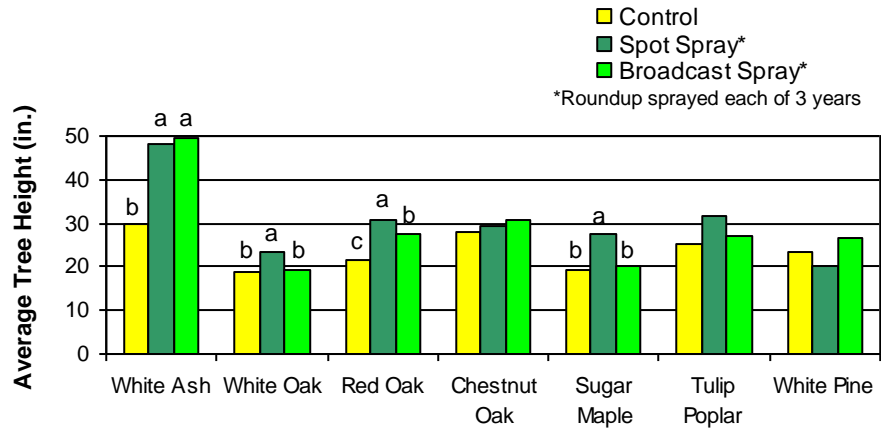


Figure 3. Ground cover effect on tree height after three years.

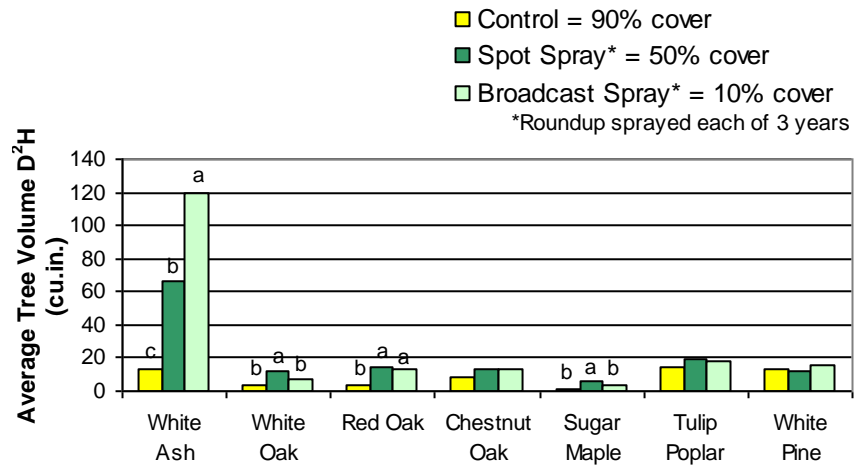


Figure 4. Ground cover effect on tree volume after three years.



Figure 5. Photos show a spot-sprayed white oak (left) and a spot-sprayed sugar maple (right).

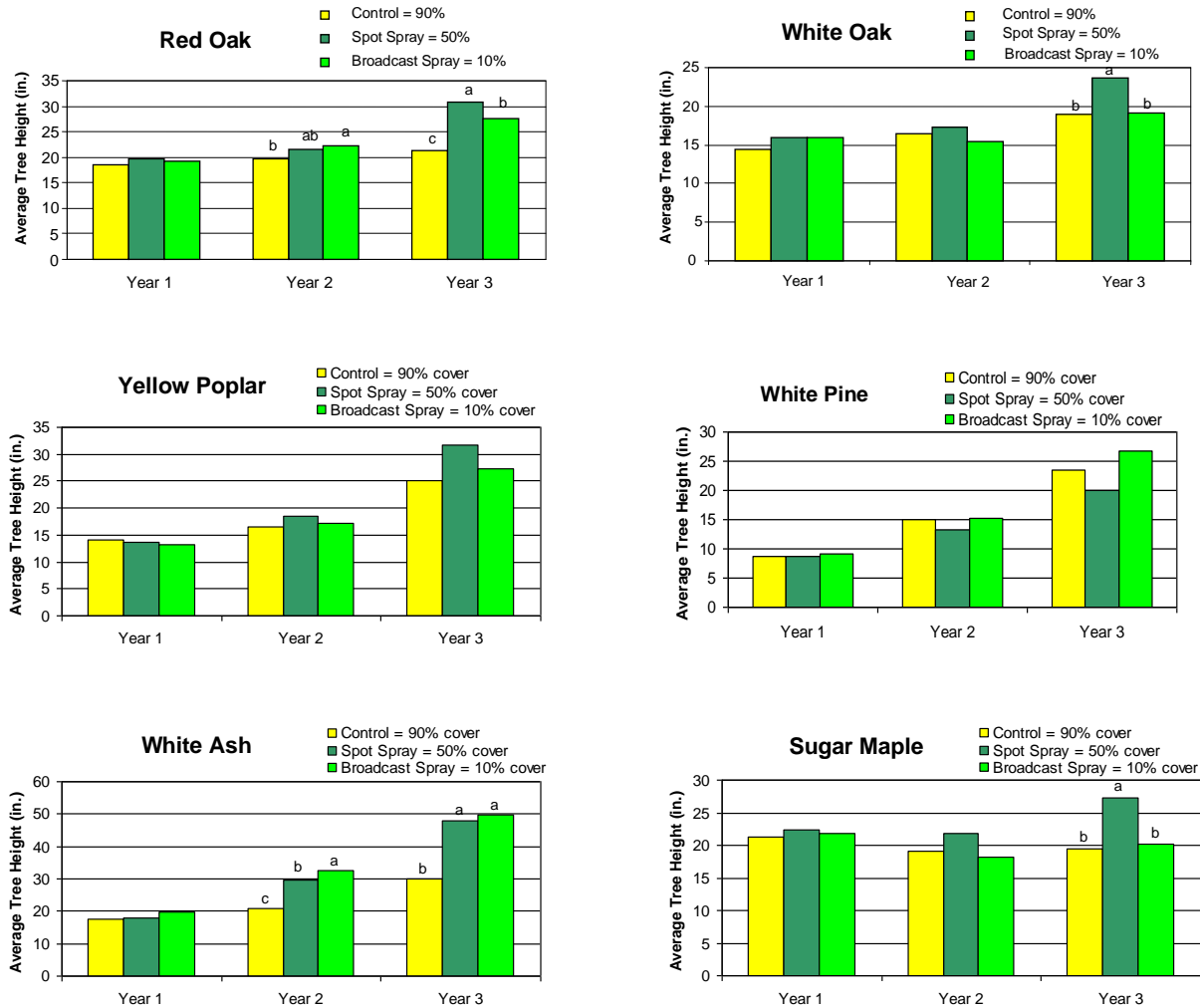


Figure 6. Tree height growth patterns over time by species. Some species exhibited progressive growth (e.g., white ash, red oak), while others experienced dieback (e.g., sugar maple, white oak).

Management Implications

Landowners are very interested in restoring their mined land to diverse, commercially-valuable native hardwood species. The results of this study suggest this is possible provided that site-sensitive species survive the difficult conditions of reclaimed mined land, including the competitive herbaceous ground cover used for erosion control. The use of herbicides to reduce ground cover competitiveness increased the survival and growth of most species, especially when ground cover was spot sprayed around the trees. Tree survival on spot-sprayed plots was 67%, which was just adequate for meeting bond release stocking standards. Without spraying, survival was 61%, which fell short of the minimum requirement. Therefore, herbicides can be a useful management tool to increase survival and growth of planted hardwoods; however, it is an expensive practice. Considering chemical costs and applicators needing to work on difficult

terrain in uncertain weather, a single application will cost \$70 to \$100/acre, a cost that mine operators would be reluctant to pay if they had other options.

An alternative way of achieving successful reforestation of native hardwoods is to adopt a Forestland Reclamation Approach outlined by Torbert and Burger (2000) and by Burger and Zipper (2002). The Forestland Reclamation Approach requires coal operators and inspectors to think and do differently compared to how they normally reclaim land for grassland, wildlife, or unmanaged forest. The Forestland Reclamation Approach requires (1) selecting topsoil substitutes specifically for trees, (2) rough-grading surfaces to leave 4 feet of spoil material uncompacted, (3) a tree-compatible ground cover that is less competitive than standard grassland mixes, (4) a reduced rate and a change in the composition of applied fertilizer to high phosphorus and low nitrogen, and (5) a professional tree planting contractor who specializes in planting hardwoods on mined land and who guarantees his work.

The use of tree-compatible ground covers during reclamation can allow seedlings to survive at rates exceeding the 70% that is necessary to achieve regulatory compliance without the expense of follow-up herbicide treatment. Furthermore, our experience indicates that sowing tree-compatible groundcovers at reduced rates often allows invasion by woody vegetation from adjacent forests. The results of this study suggest that sowing ground cover at reduced rates achieving 50 to 70% cover, instead of 90% currently required by Virginia's regulations, would also greatly improve the likelihood of hardwood reforestation success. Non-compacted mine soils have higher infiltration rates and erode less than graded soils. When using the Forestland Reclamation Approach, less ground cover is needed to prevent erosion and protect water quality, and in the process, diverse mixes of trees are able to survive and grow at rates that will create an economically viable forest (Fig. 7).



Figure 7. Planting native hardwoods on sites prepared using the Forestland Reclamation Approach (FRA) greatly increases reforestation success.

Acknowledgments

We greatly appreciate the help and support of the Powell River Project, Red River Coal Company, and Penn Virginia Resource Partners Corp.

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