SUCCESSFUL REFORESTATION BY USE OF LARGE-SIZED AND HIGH-QUALITY NATIVE HARDWOOD PLANTING STOCKS[1]

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Abstract. - - The extent of area reclaimed to postmining forest land has rapidly declined since enactment of Public Law 95-87. Compacted growth media, herbaceous plant competition, and increased costs of reforestation operations have discouraged many coal operators from choosing forest land as a feasible postmining land use. A demonstration area was established to test the ability of large-sized (2.5 to 4.0 feet in height) seedlings to establish on a topsoiled site that had a 90% or better ground cover. A site dominated by redtop (Agrostis alba L.), alfalfa, (Medicago sativa L.), and red clover (Trifolium pratense L.) was sprayed with Paraquat (1, 1'-dimethyl-4, 4' bipyridinium) in 18-inch wide strips to suppress the vegetation. The following spring the sprayed strips were ripped with a standard agricultural subsoiler. Following ripping, large-sized seedlings of green ash (Fraxinus pennsylvania Marsh.), sweetgum (Liquidambar styraciflua L.), staghorn sumac (Rhus typhina L.), Shumard oak (Quercus shumardii Buckl.), sawtooth oak (Quercus acutissima Carr.), and bur oak (Quercus macrocarpa Michx.) were hand-planted into the ripped strips. First-year survival rates were 95, 98, 82, 95, 97, and 85 percent for green ash, sweetgum, sumac, Shumard oak, sawtooth oak, and bur oak, respectively. Overall survival rate for all species of large-sized seedling was 94 percent. This high level of success, based upon first-year survival, is attributed to a combination of herbaceous vegetation suppression, rapid development of an effective root system due to ripping, and the large-sized seedlings' ability to overtop the surrounding herbaceous vegetation.

Additional Key Words: Surface-mine Reclamation; Native Hardwoods; Successful Reforestation Method; Kentucky; Vegetation Suppression; Mine Soil Ripping; Tree Survival

Introduction

The majority of lands that will be surfaced-mined within the south, the northeast, and the central lakes region of the United States exhibit some variant of a forest land pre-mining land use. Current regulatory requirements dictate that surface-mined lands be returned to approximate original contour. Forest land, or some variant of forest land (wildlife habitat, recreational, etc.), will possibly be the highest land use capability that can safely be established on steep slope sites. Since the passage of Public Law 95-87, ever decreasing acreages are being committed to forest land postmining use. Regulations associated with this law require extensive grading, topsoiling, and vigorously growing herbaceous vegetation that will protect replaced topsoil from erosion and prevent sedimentation to off-site receiving waters.

Earlier researchers (Riley, 1973, Limstrom, 1960 and 1964; and Coleman 1951) have demonstrated that excessive grading of mined land will lead to decreased survival and productivity and poor growth form. Vogel (1981) states that tree growth can be adversely affected for as long as 30 years after planting if mine soils high in silt and clay (a common condition for topsoiled mine soils) have been severely compacted. However, Vogel (1981)

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states that severe compaction can be treated by deep ripping prior to tree establishment.

Once the mine soil has been adequately prepared, in relation to abatement of severe compaction, competition from herbaceous vegetation is the next major obstacle that must be overcome when successfully establishing trees on mined land. Vegetation scalping or use of herbicides are the most common methods now utilized for lessening competition effects of the herbaceous vegetation. Trees are then planted into the approximate centers of the scalped and/or chemically-treated strip. These types of operations are generally much more expensive to perform, therefore a coal operator may file for a land use change and leave the area for "pasture/hayland" use rather than having to go to this extra expense and effort to establish trees.

Another detriment to practical considerations of establishing forest land is that of stocking rates. In some instances regulatory authorities have required tree stocking rates as high as 1200 to 1400 stems per acre to satisfy requirements for bond release. For most forest land variant uses (particularly forest land established to desirable timber species as future investments for saw timber), required stocking rates are excessive. For both a mixed forest and a "tree farm" type forest, a final established stand of 400 to 500 trees is more than adequate to promote self pruning, good form, and optimal growth rates (Finkbinder, 1981). In addition, if management practices such as thinning, fertilizing, and limb pruning are performed for the first 5 to 10 years after establishment, the stocking rates should be further reduced (Williamson, 1985).

Finally, seedling availability is often a limiting factor when one plans to perform larger scale reforestation projects. Within the past few years "coniferous" reforestation projects utilizing container-grown stock has become popular. Containerized seedlings are more apt to survive, and planting seasons can be greatly extended by using containerized stock as opposed to bare-root stock. Production of container stock can barely meet demand, so in some cases the cost may be prohibitive. Hardwoods are normally established as bare-root seedlings, but adequate numbers of hardwood stock of acceptable quality and size are difficult to obtain. State-operated nursery facilities normally can provide limited numbers of desirable species, but due to demand pressure it is provided as 1-0 stock. For hardwoods, larger and older stock are usually more desirable because of their increased ability to compete with herbaceous vegetation and to better resist damage by wild animals (rodents, deer, etc.). High quality and large-sized seedlings are available but they are extremely expensive.

Upon reviewing the preceding information, it is no wonder that coal operators are discouraged from establishing forest land variant uses. Despite these difficulties Peabody Coal Company is actively involved with reforestation, and a majority of reclaimed properties of Peabody Coal Company's Eastern Division is committed to postmining forest variants ranging from commercial forests to mixed forest for wildlife habitat enhancement.

During 1983, a project was initiated at Gibraltar mine to demonstrate various methods of planting, vegetation suppression, herbaceous vegetation selection, woody plant selection, planting times, densities, size of planting stock, source of stock, etc. From these various operations we hope to establish the most economical, but yet reliable and acceptable, methods of reforestation for a variety of specific forest land variants. This is not bona-fide research in a pure sense, because all treatments are not replicated and differences exist, in slope, aspect, herbaceous mixtures, planting times, etc. are variable for the many different combinations of treatments utilized. The intent of this paper is to present initial results of planting trials utilizing large-sized planting stock with relatively intense treatments directed toward site preparation and herbaceous vegetation control. Results will be compared to those obtained from "state nursery" stock, but statistical comparisons cannot be made due to differences in slope and aspect.

Methods

The study site is at Gibraltar Mine near Central City, Kentucky. The area had been surface-mined for coal during 1981. The spoil was generated from mining No. 9 coal by dragline. During the spring of 1983 the area was graded to approximate the original contour, with an average slope gradient of about 14 percent and this site has a southern aspect. After grading, topsoil was replaced with a scraper to a depth of approximately eight inches. The topsoil was the surface horizon of mainly Sadler silt loam (Glossic Fragiudalf; fine-silty, mixed messic) which had an organic matter content of approximately 1.0 percent. During the fall of 1983, the replaced topsoil was limed at a rate of 6 tons per acre, and the lime was incorporated with a chisel plow. This tillage operation also reduced any topsoil compaction that may have occurred during the topsoil replacement operations.

Following lime incorporation, the area was seeded to perennial herbaceous vegetation. The seeding mixture consisted of redtop, alfalfa, and red clover at rates of 15, 10, and 5 pounds per acre, respectively, applied by broadcast with a hydroseeder. After seeding, the area was fertilized by broadcasting from a spreader truck. Fertilizers applied were 450 and 200 pounds per acre of di-ammonium phosphate and muriate of potash, respectively. Wheat straw mulch was then applied with a straw blower at a rate of 1.0 tons per acre. The mulch was anchored by making one pass with a straw crimper.

Herbaceous vegetation establishment by the above method was very successful and by late spring of 1984 it had attained a ground cover of greater than 90 percent had been attained. During mid-July (after seed set of redtop), the area was mowed with an eight-foot tractor-drawn rotary mower to suppress vegetation height. The cutting height of the mower was set at approximately 4 inches to minimize damage to the vegetation.

During August of 1984, "tree rows" were established by spraying Paraquat in 18-inch wide strips with a boom sprayer which had been modified by attaching sheet metal skirts that directed the spray into its desired width. The individual rows were approximately 11 feet apart. This would allow enough room for agricultural machinery to operate between the tree rows if mowing, or even renovation, of the herbaceous vegetation was necessary. The rate of application was approximately 1.5 pints per acre (actual whole area basis), and no other pre- or post-emergence herbicides were applied. The sprayed strips were then subsoiled with a standard agricultural subsoiler operated at a depth of approximately 24 inches, and the area was left to overwinter.

Trees were planted during March of 1985. Individual rows were planted to a single species. Trees were planted at a spacing of approximately 11 feet apart within rows. An 11 by 11 spacing yields an initial stocking rate of approximately 360 trees per acre. Bare-root stock of six species was utilized. Green ash, sweetgum, staghorn sumac, Shumard oak, sawtooth oak, and bur oak were hand-planted by dibble bar into the pre-sprayed and ripped strips. No other treatments pertaining to fertility or further vegetation supression were utilized.

Results and Discussion

The growing season experienced during the spring and summer was average, and no abnormal extended periods of "wet or dry" or "warm or cold" weather occurred. Survival counts were made during October of 1985. Trees were classified into three groups as to whether they were living or dead or whether or not re-sprouting had occurred. A re-sprout was considered to be a special category of living trees, but they were included when total survival was determined. Results of survival following the first growing season are given in Table 1. and Table 2. Data given in the first table are given numerically, whereas those given in the latter are expressed as a percent.

Table 1. Survival of large-sized stock approximately 6 months after planting.

	- - - - - - Total Number - - - - - - -				
Species	Planted	Living	Dead	Re-sprout	Survival
Green Ash	733	571*	37**	125	696***
Sweetgum	434	401	10	23	424
Sumac	166	129	35	2	131
Shumard oak	95	88	5	2	90
Sawtooth oak	97	94	3	0	94
Bur oak	99	83	15	1	84

* Living stem where entire crown contains living leaves.
** No part of stem or crown is alive, also contains missing and deer damaged trees.
***Total survival - Number living plus re-sprouted.

Table 2. Percent survival of large-sized stock approximately 6 months after planting.

	- - - - Total Number - - - - - - -			
Species	Living	Dead	Re-sprout	Survival
	- - - - - - - - % - - - - - - - - - -			
Green Ash	77.9	5.0	17.1	95.0
Sweetgum	92.4	2.3	5.3	97.7
Sumac	77.7	21.1	1.2	78.9
Shumard oak	92.6	5.3	2.1	94.7
Sawtooth oak	96.9	3.1	0.0	96.9
Bur oak	83.8	15.2	1.0	84.8
Total	84.1	6.5	9.4	93.5

Sweetgum showed the highest overall survival rate at 97.7 percent, while staghorn sumac showed the lowest survival rate at 78.9. Even this lowest survival rate is acceptable from a practical standpoint of reforestation. Green ash had a very high survival rate (95 percent), but 17.1 of all living plants of this species was from re-sprouts. Whether or not a significant number of re-sprouts will survive the following years to allow the plant to attain a defined crown is yet to be determined.

Survival was very good for all of the oak species. In general, the oaks contained a lesser percentage of re-sprouts than the other species tested. Considering all species, we attained an overall survival rate of 93.5 percent, with only 9.4 percent of the total amount of living trees occurring as re-sprouts. Although this data is preliminary and long-term survival rates cannot be determined until the trees have gone through several growing seasons, there were no obvious indications of severe stress, because the majority of seedlings planted overtopped the adjacent herbaceous vegetation. We attributed this characteristic as to why the plantings were highly successful.

No other comparison data was collected pertaining to relative root vigor of the established seedlings, however, a limited number of trees were randomly excavated for observation. The root systems were vigorous and highly branched. The roots were well developed within the "rip mark" established by the subsoiler down to a depth of 24 inches, and were highly branched within this approximately 2 to 3 inch wide area.

As was stated earlier, direct comparisons (from a statistical standpoint) were not made between the large-sized stock and "state-provided" stock because of differences in slope, aspect and species used. However, for comparison purposes we determined survival rates of "state-supplied" stock, using the same methods, in an area adjacent to that where these large-sized seedlings were established. However, only three species were used in this study, which included green ash, sycamore, and northern red oak, and their survival rates were 68, 60, and 54%, respectively. These rates of survival are fair, but were obviously not equal to those attained by use of the large-sized planting stock. The smaller-sized state stock contained higher percentages of missing trees, which indicates mortality occurred fairly quickly after planting and/or there was more severe damage from rodents.

One cannot adequately discuss this topic without making a brief mention pertaining to cost. As stated earlier, increased revegetation costs and high rates required for stocking are the major limitations as to why reforestation land uses are not being used as often as possible by coal operators in lieu of other land uses. The large-sized stock is expensive (180 to 300 dollars per thousand, depending upon species) as compared to stock furnished by state nurseries (35 to 50 dollars per thousand). In addition, the site preparation (mowing, spraying, ripping, etc.) is relatively more expensive.

For this specific set of circumstances described in this study, it was determined that site preparation costs (mowing ripping, and spraying) were approximately $75.50 per acre. When all costs were considered, it was determined that the cost of establishing a large-sized seedling was 68 cents per tree as compared to 23 cents per tree for state-furnished stock. Table 3 has been constructed so that a direct comparison for estimating total cost of tree establishment can be made comparing large-sized stock to state furnished stock at various planting rates.

As one can readily see, planting large-sized seedlings can be expensive when large stocking rates and/or acerages are planted, as this costs about 3 times more per tree. However, we contend that when one considers the survival rates of the large-sized stock averaged 30 percent greater than state stock trees, and one would need to either plant twice the number of state-stock trees or have the added costs of replanting, large-sized trees may not be that much more expensive. Another factor to consider is that of species selection. If one is desiring to establish a forest land use for future saw timber resources, the higher stocking rates will not be needed if one uses tree pruning, however, the cost of this operation may be equal to planting at a more dense stand and thus allow natural pruning to occur.

Table 3. Comparison of cost of establishing various numbers of large-sized stock to state-furnished stock.

Stocking Rate	State Stock	Large-sized Stock
(stems/acre)	(at 23¢/tree)	(at 68¢/tree)
100	23.00	68.00
200	46.00	136.00
300	69.00	204.00
400	92.00	272.00
500	115.00	340.00
600	138.00	408.00
700	161.00	476.00
800	184.00	544.00
900	207.00	612.00
1000	230.00	680.00

The current management system at Peabody Coal Company involves an initial stocking rate of approximately 360 trees per acre, with an anticipated survival of approximately 300 per acre. When these trees reach 2" DBH, they are scheduled to be thinned to approximately 150 trees per acre for a 30-year saw timber rotation. Of the 150 trees remaining, it is estimated that approximately 75 will be marketable. Therefore, we are contending that perhaps the more commonly-used high stocking rates are not needed nor desired. The cost of stocking this required initial density will be approximately $250.00, as compared with about $150 per acre using present techniques. We believe it will be more economically sound to plant seedlings of good form that have a greater than 90 percent chance of survival. It should be noted that this initial stocking rate will not be sufficient to meet required densities for vegetation bond release; therefore, in the future, following completion of our experiment, additional relatively inexpensive state stock will be planted alongside the large-sized stock. In future plantings, nurse trees such as black locust, European alder, etc. will be planted between the rows of large-sized stock in order to meet the required densities. Following bond release, these trees will probably be removed when thinning operations described above are performed. It is hoped that rule changes can eventually be attained that will allow much lower initial stocking rates when large-sized and high-quality seedlings are utilized. We believe that a stocking rate of approximately 150 trees per acre would be more realistic for a bond release requirement when desirable timber species are used in reclamation.

Summary

Establishing trees to this relatively low density could have some disadvantages. The wider spacings will decrease the potential saw timber value because of excessive branching. In addition, the increased sunlight to the herbaceous cover could hamper natural understory development. On the other hand, there are some obvious advantages to establishing trees to a relatively lower density. First, there would be reduced competition among the trees themselves and well-formed crowns would be produced. Second, the wider spacing will extend the life of grasses and legumes in the understory and perhaps provide for a longer and more stable erosion control. Third, and most important, we believe that by using our method more of the presently forested land that will be surface mined will be returned to forests rather than using some other land use variant. Even at the high costs associated with this type of reforestation operation, about $100 per acre more, the 150 trees that result will have a significant value as compared to those species commonly being used in present reclamation.

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