Session 4

CASE STUDIES OF REFORESTATION IN MINING RECLAMATION: SUCCESS AND FAILURE

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Montana: Site Adapted Container Grown Woody Plants for Mine Reclamation
Len Ballak, Bitterroot Restoration Inc., Corvallis, Montana

The Arid and Semiarid West
Vernon Pfannenstiel, Peabody Coal Company, Flagstaff, Arizona

Texas Utilities' Commitment to Reforestation
Sid Stroud, Texas Utilities, Dallas, Texas

Successful Forestry Reclamation in Louisiana/Mississippi
Marty Walker, North American Coal Corporation, Ackerman, Mississippi

Successful Tree Planting Techniques for Drastically Disturbed Lands: A Case Study of the Propagation and Planting of Container-Grown Oak and Nut Trees in Missouri

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Illinois/Indiana
Chris Liebering, Liebering and Sons Reforestation, Lamar, Indiana

American Electric Power Company Reforestation History on Reclaimed Mined Lands
Gary Kaster, AEP Land Management, McConnellsville, Ohio

Mycorrhizal Fungi and Trees—A Successful Reforestation Alternative for Mine Land Reclamation
Charles E. Cordell, Plant Health Care, Asheville, North Carolina

Kentucky Reforestation Case Study
Dan Williamson, Kentucky Reclamation Association, Madisonville, Kentucky

Forest Productivity of Reclaimed Mined Land: A Landowner's Perspective
Timothy Probert, Pocahontas Land Company, Bluefield, West Virginia

PACIFIC NORTHWEST

Glen Waugh[1]
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Background

Most of what I will be talking about relates to the Centralia Coal Mine in southwestern Washington. This mine started in 1971 and has about 14,500 permitted acres. It produces marginal quality coal that is burned by an adjacent power plant. It does do fairly high quality reclamation. The area was forestry premining and most of the reclaimed land is returned to forestry. Forestry is big business in this area. They have currently reclaimed about 3,000 acres. They have a lot of acres exposed at one time because of the low coal quality. They have about 20 years experience with tree planting. The overburden that is used for subsoil is a weathered sandstone.

Sewage Sludge Application

Early on the company used sewage sludge to amend the topsoil. The sludge was injected to a depth of 3 feet on the reclaimed area which also had the advantage of breaking up compaction at depth. When the company changed hands in 1991, the new company ceased the sludge application because of potential liability issues and because the sludge resulted in a ground cover that was too dense for good results with the tree planting. Herbicides had to be used to kill the grass prior to tree planting, and the dense cover encouraged rodents that would girdle the new trees.

Control of Surface Water Runoff

The biggest problem for this mine site is the control of water runoff. They use very large rock lined drainage channels to convey the water off the site. The drainages can provide some very good riparian habitat on the mine site. They will usually plant willows in the drainage channels.

Revegetation Plan

The revegetation plan calls for establishing an herbaceous ground cover for about two years. Then they herbicide strips in the ground cover in order to plant the trees. They do not have any problems with acidic toxic spoil material. They will then break up the compaction in these strips by ripping it at depth. They have had their best success by planting douglas fir on the tops of the furrows left by the ripping. On areas that have received topsoil, they plant douglas fir. On areas without topsoil, they plant red alder. They leave open areas and edge areas within the tree stands to improve the area for wildlife. The seedlings used are a genetically improved commercial stock from the Weyerhouser Nursery. Their key to survival is to have hardy planting stock with a good root system. They prune the roots to about 6 inches in length prior to planting. The trees are harvestable at about 18 inches in diameter when they are 45 to 50 years of age. The stocking requirements were established by the Department of Forestry at 190 trees per acre. They have found by planting the trees on a 10 foot by 10 foot spacing that they get the best results. They commercially thin the stand for pulp wood at about 15 to 20 years.

Wildlife Enhancement

In order to create diversity in the vegetation, they create open areas and establish riparian areas with alder, willow, and cat tails. They end up with a lot of open water areas surrounded by wetlands. They have a resident elk herd that has caused problems by girdling trees. After extensive studies by the Department of Wildlife, they have come up with a limited hunting program managed by a local sportsman club. They now have a handicapped hunting

program for people who are wheelchair bound, on crutches, and even blind. They also work with Ducks Unlimited because of the water fowl that use the area. They have worked with the Boy Scouts who use the site for Eagle projects to build nesting boxes, bird houses, and other wildlife habitat enhancements.

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MONTANA: SITE ADAPTED CONTAINER GROWN WOODY PLANTS FOR MINE RECLAMATION

Len Ballak[1]
Bitterroot Restoration Inc.
Corvallis, Montana

Introduction

Beginning in 1986, Bitterroot Restoration Inc. has done a lot of mine land reclamation all over the country from wetlands to arid regions. We grow our own native plant seedlings in a nursery. We also do our own seeding and outplanting.

Concerning planting trees and shrubs in the West, they are not easily established. It also can be expensive and difficult to get appropriate planting materials. Competition with herbaceous species can be a difficult problem. The postmining substrate also may be very different from what was found in the premining condition. We also have a problem with the reduced levels of soil microoganisms. Another big problem can be periodic droughts or other extreme weather conditions.

Methods for Improving the Odds for Success

In order to obtain the best results, we have to control all controllable variables. This includes site preparation by minimizing compaction and retention of organic materials in the rooting zone. You also have to be careful with fertilizers so that you do not create a problem with excessive herbaceous competition. You need to create micro-sites and not end up with the uniform compacted sites found with highway site reconstruction techniques. You need to contour the sites in order to enhance site diversity.

We can control seed sources. We need to produce site adapted planting stock. This is the type of problem where you may plant nonsite adapted species and not be aware of the problems for many years until the climatic conditions occur for which the stock is not adapted.

Another thing you can control is plant material. In the West, wild dug plants can be successful. These are site adapted and inexpensive if available close by. They also bring the right soil microoganisms with them. You also can use cuttings of woody species. Success is limited to a few species, and you may limit your genetic diversity. Bare root plantings are inexpensive and may work well in areas where there is sufficient moisture. Bare root plantings are, however, very limited to the time that is best for planting. Containerized planting stock increases the time that planting can be done and still result in a successful planting. Usually we can produce site adapted planting stock from seed for containerized planting within a year of seed collection. We can control species selection. You need to carefully examine whether or not you should be planting climax species when the early successional species may be more adapted to the site. You need to have a good program for seed collection, handling, and storage. You can control planting standards by having the appropriate size of planting materials, root to shot ratio, making sure that the plants are dormant.

You also can control the most appropriate mycorhizzal inoculation in the nursery. We are set up to collect root portions from the site and culture the site specific microoganisms for the nursery stock. Inoculation is not infection and that is what you need. In order to ensure infection, we are committed to checking all of our seed stock to determine that they have been appropriately infected with the right microorganisms. We tested the effectiveness of our inoculation efforts by dividing one planting effort in thirds. One third used site adapted microorganisms, one used a commercial inoculant, and the last third was not inoculated. On the difficult to establish species like Chokecherry, we had a 98 percent survival rate with the site adapted innoculate, and about 45 percent with the

commercial and noninoculated trees. On the easier to establish species like rose, both the side adapted and commercial inoculated trees had a 98 percent survival and the noninoculated trees even had a 90 percent survival.

Planting quality can be controlled. We use hoedads for planting because planting bars often compact the sides of the hole. This can result in frost heaving during fall plantings. You also can use tree protectors to protect them from browsers and environmental extremes. The only way you can get better is to find out how you did. When you set up a project, you also need to set up standards and methods for determining success.

Field Results

The first field project I would like to discuss is from northwest Colorado. We planted chokecherry, service berry, aspen, and some gambel oak. Our main problems at this site are competition from herbaceous vegetation, summer drought, and browse damage. In order to improve our success, we have not seeded the planting areas, used pre-emergent herbicides, and planting in shallower soils. We have only had mixed success at this site. In order to combat the summer drought problem, we inoculate all of the seedlings with site adapted microorganisms.

On the Big Sky Coal Mine in eastern Montana, we plant ponderosa pine, juniper, and several shrubs. The main problems are poor survival from drought years and competition from herbaceous vegetation and some loss from browsing. In order to improve our success, we have modified the planting mix and switched from machine planting to hand planting in order to take advantage of microsites. We have had both successes and failures.

At the Basin Creek Mine at 10,000 feet on the continental divide in Montana, the problem we have here is called "Red Belt." When the wind comes up and the ground is still frozen, the tree will not be able to obtain moisture and will dry out and die. An extremely windy site, you can not plant in the spring because the snow stays on the ground so long that by the time it all melts it is too late to plant. We have adapted to this with fall plantings. We did a lot of planting close to rocks and logs in order to take advantage of natural wind breaks. We also have tried tree protectors. We also have come up with a strategy to do summer plantings in July on north facing slopes and are getting 70 to 80 percent survival. This was the way we were able to get our conifers established.

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THE ARID AND SEMIARID WEST

Vernon Pfannenstiel[1]
Peabody Coal Co.
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Introduction

What I will be talking about should reflect on what the major coal operators are doing to establish woody plants in the states of New Mexico, Arizona, Montana, and Colorado. I am used to working in many areas that only get nine to ten inches of precipitation per year. Our Black Mesa Mine in Arizona is in a 9 inch precipitation zone where it is extremely difficult to establish woody species. It would be a stretch to use the term "reforestation" in the West. We do not plant large contiguous areas to woody plants and then not in high densities.

Natural Vegetative Communities and Mining in the West

In eastern Montana, the natural vegetation is dominated by ponderosa pine and juniper. These species tend to predominate on sandstone outcrops and colluvial slopes. The mining usually occurs in the alluvial valley, up the side drainages, and on the benches. Most of the mining does not occur in areas with heavy stands of trees.

In Wyoming, the natural vegetation is dominated by shrub grasslands with occasional ponderosa pine on scoria ridges. Riparian tree communities are more important in this environment. Many of these communities are maintained by specific soil and geologic conditions that do not exist after mining such as perched water tables and bedrock sandstone subsoils.

In Arizona, New Mexico, and Utah, mining occurs in pinyon and juniper communities on the rocky slopes and hill sides.

SMCRA requires us to reestablish many of these tree and shrub communities, but most of the land use is grazing. We establish woody plants is small blocks for wildlife and community and biological diversity. There are no commercial forestry plantings.

Tree Planting Efforts

We tended to pick our trees for the earliest industry plantings from tree lists and windbreak lists. We planted both native and introduced species. These early plantings were too ambitious and did not take an ecosystem approach. We did not know why or how these species existed where they did. We also tried to plant trees on soils that were better suited to shrub grasslands because of their heavy soil texture. Our early results were poor with few survivors. Over the years we have emphasized more native tree plantings.

Our current technology is based on being able to control the factors that will give us the best results. In order to get better results, we now collect native adapted seed sources to develop our planting stock. Our sites are subject to extreme variations in climatic conditions. At Black Mesa, we have had as high as 15 inches of precipitation and as low as 3 inches. Of course, you never know when you are going to get the extreme conditions. If you do a fall planting just before a 3 inch precipitation year you can bet you will be replanting. We usually partner with a good nursery who has developed the appropriate cultural practices to improve our chances for success. Infection of planting stock with appropriate mycorrizhae is critical to most plantings. Microsite selection is crucial to success in woody establishment. We tend to stick to north facing slopes. We do not do irrigation. We try to plant into soils that came from native tree sites and use direct haul soils as much as possible in order to quickly reestablish the soil ecosystem. If we are lucky, we may even get some volunteer regeneration of species. I like to keep the

herbaceous cover competition down to the minimum and do not think that a little erosion is a problem. We seed with a low competition native species for our herbaceous cover.

I have found that on some sites we are able to keep out the noxious annual weeds like kochia, russian thistle, and cheat grass by planting native annuals such as rocky mountain bee plant and annual sunflower. The large leaves of the sunflower also shade the site and reduce the soil temperature.

We have gone mostly to hand plantings of woody stock in order to take advantage of microsites and plant on areas that are too rough and rocky to machine plant. We have to fence the areas to control livestock and wildlife. We are starting to plant pinyon seedlings around our sagebrush because we noted that this seemed to be happening in the natural environment. These planting have been quite successful. We are establishing islands of woody species with direct transplant of some trees and shrubs.

In Montana, we have planted about 275,000 ponderosa pine and 1,300,000 rocky mountain juniper on a 900 acre site with about a 20 to 30 percent survival. In Colorado, we planted about 400,000 to 500,000 seedlings of tall shrubs and aspen. Of that we planted about 20,000 aspen with less than 10 percent survival; service berry had 20 to 60 percent survival; choke cherry 10 to 50 percent; and gambel oak 10 to 30 percent.

In Arizona and New Mexico we planted nearly 200,000 pinyon seedlings with 20 to 25 percent survival. We have planted about 10,000 transplants with a tree spade with about 75 percent survival. In addition we have planted several thousand gambel's oak.

Future Efforts

We will be planting more trees in the future but we will be working hard on our research and development that will emphasize an ecosystem approach to improve the odds for survival. We need to reconsider some of the regulatory requirements such as the need for some areas to have less herbaceous cover and the nine inch rill and gully rule may not always be appropriate. We need to continue cooperative efforts between the industry and the regulatory community.

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[1] Vern Pfannenstiel, Environmental Scientist, Peabody Western Coal Company, Kayenta, Arizona. Pfannenstiel graduated from Colorado State University in 1978 with a BS in rangeland ecology and a minor in mined land reclamation. Following graduation he spent 3 years with the Soil Conservation Service in Colorado and Idaho. For the past 18 years he has worked as an environmental scientist for Peabody Coal Company and Peabody Western Coal Company in Arizona, Colorado, Montana, and Wyoming. He has extensive experience in baseline vegetation studies, permitting, and reclamation planning and implementation. In particular, his efforts have been directed towards reestablishing native species, including woody plants, on reclaimed lands. He received the ASSMR Special Award in 1996 for these efforts and led a team at the Black Mesa Mining Complex that received the 1998 Excellence in Surface Mining Reclamation Award from OSM for revegetation with native and culturally significant plants.

TEXAS UTILITIES' COMMITMENT TO REFORESTATION

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Abstract

Texas Utilities Company (TU) operates three surface coal mines in east Texas where, since 1971, it has mined and reclaimed over 44,000 acres and currently mines about 1,800 acres annually, of which 72 percent is returned to forest uses. Reforestation efforts began in 1975 as wildlife corridors in pastureland. As of December 1998, TU has planted 12.7 million trees on reclaimed soils to establish 21,000 acres of commercial forestland and wildlife habitat. Annual planting efforts include 26 different tree species and result in normal survival rates of 75 to 90 percent.

Constant improvement in the reforestation program is maintained through a continued approach of applying findings from research and field trials. Keys to reforestation success at TU mines have been found to include: (1) soil quality; (2) quality control that begins at the seed source; (3) advance planning and ordering of seedlings; (4) cold storage facilities at or near the mine site; and (5) planting techniques. The most significant key to success was finding a companion plant as a ground cover that provided effective erosion control, but minimized competition with seedlings for moisture and nutrients. Resolution of ground cover concerns was found in use of cool season annuals, and in use of herbicides to control competition from established forage grasses. Other challenges to making a successful reforestation program include standards for erosion control and ground cover performance.

TU views mine reclamation as a unique opportunity for establishing productive forestland and a commitment to the future supply of woodlands for environmental, economic, and wildlife benefits.

Introduction

Texas Utilities Company (TU) provides electric and natural gas utility services for one-third of the population of Texas. Approximately 42 percent of the electric service provided our customers in Texas is fueled by coal principally from TU mines. The purpose of this paper is to review TU's experiences (both successes and failures) in mine reforestation and present our commitment to fostering increased use of reforestation as a reclamation method.

Texas Utilities Mining Company (or TUMCO) conducts Texas Utilities' surface mining operations. TUMCO is a wholly owned subsidiary of Texas Utilities and operates three surface mines in east Texas where, since 1971, we've mined over 603 million tons of coal, and currently mine 29 million tons annually. As of December 1998, TU has mined and reclaimed over 44,000 acres; over half of which is reclaimed to forestland. Out of the total acres reclaimed, 42 percent has received Phase III bond release, 20 percent has received Phase I and II release, and 23 percent more is in the five-year extended responsibility period. Currently, about 1,800 acres are mined annually, of which 72 percent is being returned to forest uses of commercial forestland and wildlife habitat. Other minor postmine land uses are pastureland and water resources. With seedling survivals that range between 75 and 90 percent on normal years, TU considers its reforestation program to be very successful, yet on a constant improvement trend. This improvement is maintained by applying the same approach that TU has used to develop the program beginning in 1971: through research and field trials and then application of findings.

The early TU reclamation program emphasized pastureland. This would remain the dominant postmine land use for 20 years. Until 1973, little was known about mine reforestation in our region. Studies completed that year demonstrated the potential for reforestation success on TU mine soils and helped in developing reforestation program goals that included:

- Diversity (both in species and land use),
- Fully stocked stands with minimal replanting,
- Use of native or locally adapted species,
- Sustainability of the forest cover,
- Soil stability,
- Low Maintenance, and
- Low Cost.

These goals have been achieved. Through long-range planning TU now has several sources and adequate supply of seedlings. Where once only half a dozen species were planted, now TU plants 26 different species including 12 varieties of oaks. Where once only meager survivals resulted, now there are fully stocked stands at the end of the critical first two years. The established stands are sustaining growth at or better than premine forests with natural regeneration occurring. Forested sites have remained stable, with substantially less maintenance. And, planting and management of these forests are being accomplished at less cost than for our pastureland over the five-year period of extended responsibility.

Since 1975, 12.7 million trees have been planted on TU reclaimed sites. During this time reclamation personnel resolved many of the problems that were impacting success. While many of these problems are common to other regions, it is unlikely that the solutions are applicable to all other regions. TU found that for its region and mine sites:

- Selected overburden materials provided superior productivity over native soils.
  TU's use of the dragline side-cast method allows placement of selected stratigraphic materials in the near surface of spoil as a topsoil substitute. The most common postmine soil is loamy textured with high productivity potential for forage grasses, crops, or forests. These soils often meet prime farmland criteria as set forth by the NRCS.
- Use of low ground pressure track equipment for soil reconstruction prevented development of the dense soils that existed prior to mining.
- Localized or regional nurseries should be used.
- Improved genetic material should be used if possible.
  TU plans seedling orders at least two years in advance with nurseries to ensure that cultural practices used by nurseries will result in seedlings that meet the height, root collar diameter, and root-to-crown ratio that has been determined to enhance survival and growth.
- Bare-root and plug seedlings provided more rapid and consistent success than direct seeding.
- On site cold storage and proper handling and protection of seedlings is critical.
  Each mine has a cold storage facility on-site, which is essential for holding such a large quantity of seedlings while planting is ongoing. Cold storage allows the mine to extend the planting season by maintaining dormancy of the seedling until it is planted.
- Machine planting was more economical and provided better quality control during planting.
  One automatic machine planter can enable TU to plant 10,000 seedlings a day. TU mines may have up to 12 planters operating on days of good ground conditions. Some areas still require hand- planting, and the program should be flexible to continue under various seasonal conditions.
- Minimize fertilization to levels ensuring vigor.
  Fertility is another key to success. Over fertilization in the first two years, while it may favor ground cover, could prove fatal in extended periods of low rainfall and high temperatures. TU has found that utilizing residual nutrients from ground cover establishment is normally sufficient to ensure initial seedling survival and health. Light applications of a balanced fertilizer (a maximum of 50# N annually) over the next one or two years aid in seedling vigor as organic matter begins to contribute to the nutrient cycle. Another approach is use of fertilizer tablets at planting. The tree gets the benefit of the slow release fertilizer and micronutrients without overstimulation of the ground cover.

Many of these problems were simple adjustments of cultural practices to fit the circumstances. Others required extensive studies and field trials. But above all, the most difficult obstacle was to find a ground cover or companion plant that: (1) has the height to protect the seedling from wind and sun desiccation, yet will not shade the

seedling out; (2) keeps soil temperatures down in the summer but does not compete with the seedling for water or nutrients; and (3) has a cover that does all this while having adequate root mass and cover to prevent 9-inch rills.

With annual rainfall averaging 40+ inches, often in intense events, erosion on native soils is commonplace. So, numerous field trials were conducted on ground covers and maintenance practices that would balance erosion control with seedling survival. TU found two approaches to be most dependable:

1. Utilize cool season annuals (such as wheat, oats, or rye) as ground cover. Seedlings are planted in the established cover, which provides the needed erosion control without moisture competition after the plant matures. The wheat stubble is left standing throughout the summer, and native grasses and legumes are inter-seeded; however, sometimes a more aggressive ground cover is required.

2. When planting in a ground cover of established forage grasses, band-spraying of herbicides can be used to kill competition to the seedling while leaving soil stabilizing cover in place. This is not the preferred approach, but it has been cost effective for converting pastureland to trees and on more erosive sites.

The greater success in seedling survival has been with the cool season annuals as ground cover; yet, while this method provides the needed survival, the site is still more prone to erosion over the first two years than if it were planted in forage grasses. The cost of erosion repair may significantly impact the economic benefits of reforestation. Again, quality control in use of field cold storage and proper handling to prevent exposure of roots until planted is critical, as is the planting of the seedling at the proper depth and root posture. Since there is no control for the timeliness of rainfall, proper techniques could give the seedling the needed advantage that means survival during extended dry periods.

Yes, reforestation can be successful; however, surface mining regulations do present factors that have negatively influenced the success of reforestation, yet, this is often due more to the interpretation of those regulations rather than the intent. These factors may dramatically impact the cost of reforestation and influence operators to utilize other vegetative types for reclamation purposes. TU and several mining companies in Texas favor reforestation for our region, and encourage other operators in Texas to do the same. Some operators consider there to be too much uncertainty in reforestation and choose other cover types that prove to be more straightforward in ensuring compliance, demonstrating success, and achieving bond release. Reforestation can work; but the extent of focus on erosion control and success validation procedures effectively favor monocultures and continue to discourage reforestation. Instead, operators and regulators should rely on the long-term watershed benefits that forest cover types offer.

Although the federal program has recognized the certainty of erosion as a natural process, Texas, among other state programs, still uses the 9-inch rill standard that has often been interpreted to restrict operators to total pre-vention of 9-inch rills. Operators are forced to make decisions that minimize the short-term risk of erosion, and that usually leads to an aggressive grass as a ground cover (which is a barrier to reforestation success). States' rulemaking initiatives to adopt federal language found in 816.95(b) will help to encourage other companies to re-forest mined land and aid others in reducing unnecessary costs of reforestation. The fact is, in erosive soils, trees present better long-term watershed management, but a higher short-term risk to compliance. Absolute prevention of erosion is a great goal, but in our circumstance, not practical, natural, or realistic. Further improvements may be realized through reducing the extent of final grading once the target postmine grade has been reached. Forestland does not need the smooth surface of a pasture or meadow, yet many operators and regulators alike still approach all final grading with a pastureland mentality.

Flexibility in ground cover success standards is also important. A significant component to long-term ground cover, stability and watershed benefits is the litter naturally resulting from the canopy. All such litter should count toward ground cover performance. In addition, percent ground cover standards should be reviewed to seek increased flexibility to speed establishment of trees. Ground cover standards also should allow for annuals to be counted in the permanent plant community. A hardy ground cover is needed that may include perennials or annuals, but likely a combination of the two. Finally, consideration should be given to establishing a shorter

extended responsibility term specific to forestland. This could help encourage reforestation by allowing release sooner after seedling establishment.

TU strongly supports the recent initiative to identify regulatory barriers to reforestation and develop action steps to encourage use of reforestation, but the regulatory authority and operators alike should also recognize that the post-mine level of reforestation land uses should be appropriate for local and regional environmental and economic needs. The supply of timber in the South is currently being consumed at a greater pace than growth on privately owned lands. TU views mine reclamation as an opportunity for establishing healthy, well managed forests with excellent wildlife value and economic return.

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[1] Sid Stroud, Environmental Waste Manager, Texas Utilities Services, Dallas, Texas. Sid Stroud has been involved in mine reforestation since 1975. He has been directly involved in the research, program development, and operational aspects of Texas Utilities' mine reforestation efforts, which now include over 21,000 reforested acres from planting of 12.7 million seedlings. Prior to September 1998, Sid was reclamation manager for Texas Util-ities, where he was responsible for developing and managing the reclamation, land-use, and bond release pro-grams for the company's 105,000 permitted mine acres. He is a graduate of Stephen F. Austin State University, College of Forestry in 1978.

SUCCESSFUL FORESTRY RECLAMATION IN LOUISIANA/MISSISSIPPI

Marty Walker[1]
North American Coal Corp.
Ackerman, Mississippi

Introduction

The two projects I will be speaking on are joint ventures between the North American Coal Corp. and Phillips Coal Corp. North American Coal Corp. has received ten awards for reclamation excellence from the Office of Surface Mining.

Oxbow Mine, Louisiana

The Oxbow Mine is located near Coushatta, Louisiana. It disturbs about 100 acres per year to produce about 750,000 tons of lignite for the Dolet Hills power plant. It is located in the Red River floodplain and receives about 46 inches of precipitation annually. The mine site had a hill within the permit area that lends itself to reforestation with loblolly pine. The floodplain itself will be reforested with bottom land hardwoods. Topsoil substitution has been approved for this site. We do an extensive overburden analysis comparison between the overburden materials and the existing unmined soil materials. The undisturbed soil series is made up primarily of the moreland clay (92.9 percent) and has a site index for yellow poplar of about 80 for a 50 year growth period. Currently, we have reclaimed and revegetated about 305 acres of which about 228 have been returned to a forest land use.

Our method of reclamation is to cast the overburden by dragline, grade the overburden with dozers, and establish a permanent cover crop consisting of bermuda grass. We plant our trees and then over spray with an herbicide. We are moving away from the over spray method because of potential damage to the tree seedlings. The tree species we are currently planting include loblolly pine, bald cypress, nutall oak, shumard oak, sawtooth oak, bitter pecan, and wild plum. We have had some problems obtaining good planting stock of the hardwoods and shrubs. Now we have several vendors that are growing the high quality hardwood stock that we need, especially for wildlife plantings. We plant the pine on a 6 by 10 foot spacing (726 seedlings per acre) and the hardwoods on an 8 by 10 foot spacing (544 seedlings per acre). We have had a 90 percent survival on our pine plantings.

Our biggest challenges have been related to controlling aggressive herbaceous vegetation, especially with a legume called hairy vetch. It is very hard to keep this plant out, as is comes in the mulching materials. Because we use graded overburden materials, we do not have a lot of problems with compaction. We have also experienced poor seedling vigor in the early years of establishment. The high pH of the overburden material (7.0 and higher) negatively impacts the early vigor of the loblolly pine. At about year three, the new trees seem to get over this low vigor phase and begin to do well.

Red Hills Mine, Mississippi

The status of our Mississippi lignite mine is that although we will not produce coal until 2000, we have planted 250 overcup oak, 750 shumard oak, and 750 willow oak on diversions necessary for water control at the mine site. This mine is located in the Red Hills of east central Mississippi and will generate 3.3 million tons of lignite on 125 acres per year for the Choctaw power plant. It receives about 56 inches of precipitation per year. Most of the soils are associated with the hilly topography and have a B horizon with a clay content of 35 to 55 percent. By selectively handling the overburden material, we can achieve a better plant growth medium than existed prior to mining. Yellow poplar has a very high site index of 110 and loblolly pine has a site index in the low 80s. About 73 percent of the county is in commercial forest land.
The reclamation plan calls for a truck/shovel haul back. We will then establish a grass cover followed by tree

planting. Special techniques we will employ include the use of a chisel plow to rip the soil on a 9 foot spacing and band apply Roundup herbicide in July. This rip fills back in during the fall rains and the Roundup controls the herbaceous vegetation. We plant the trees into the ripped row in mid-December. This allows us to avoid the over spray damage to seedlings we experienced with other methods. We will plant the pine on a spacing of 6 by 9 feet (807 seedlings per acre) and the hardwoods on a 14 by 14 foot spacing (222 seedlings per acre). The pine will be planted on the upland sites and the hardwoods in the drainages and wetter wildlife sites. The postmining land use will be 90 percent forest land use.

Quality planting stock is becoming difficult to obtain because there currently is a very high demand as many private landowners are replanting areas that have been recently harvested. We have a lot of damage from rodents girdling the trees.

Recommendations

We recommend that we could encourage tree planting by keeping revegetation and soil monitoring simple and reduce the length of the extended responsibility period for forest and wildlife land uses. We will discourage tree planting with complex monitoring procedures that require expensive consultants in order to determine vegetation success.

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SUCCESSFUL TREE PLANTING TECHNIQUES FOR DRASTICALLY DISTURBED LANDS: A CASE STUDY OF THE PROPAGATION AND PLANTING OF CONTAINER-GROWN OAK AND NUT TREES IN MISSOURI

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Abstract

Successful tree seedling establishment on drastically disturbed lands is contingent on seven major variables: (1) selection of proper native species; (2) purchase of the best quality planting stock; (3) correct handling of planting stock; (4) correct planting techniques; (5) effective control of competing vegetation; (6) proper soil conditions and preparation; and (7) weather. Exotic species should not be planted to avoid past mistakes such as kudzu, japanese honeysuckle, sericia lespedeza, and chestnut blight. A major concern of reclamation specialists and ecosystem res-torationists is obtaining high-quality plant materials with the correct provenance. Ecosystem restorationists, rec-lamation specialists, park managers, and private landowners can easily and cheaply propagate native oak or other hardwood species from local parent stock using Whitcomb bottomless containers. Proper seed collection, storage and preparation techniques as well as propagation methods are critical for seedling growth and development into quality air-pruned planting stock. Air-pruned seedlings of local provenance can be outplanted in the fall after one growing season with little transplanting shock while developing extensive root systems prior to soil freezing in winter. Establishment success of container-grown seedlings greatly exceeds that of spring-planted, bare-root seedlings. Fall-planted, container-grown seedlings have a decided advantage since their roots continue to grow throughout the fall and much of the winter, enabling them to better withstand summer drought and weedy competitors. Container-grown seedlings also allow a five- to six-month planting season compared to bare-root seedlings' four to six weeks. Since propagation costs are minimal, planters who grow their own save money on the planting stock. Because the quality is higher, home-grown seedlings have greater establishment success, saving labor, time, and money. With better survival rates, far fewer trees need be planted as compared to bare-root seedlings.

Introduction

Many hard-earned lessons learned by reclamation specialists are frequently ignored or forgotten by their successors. Successful tree planting is dependent upon a few simple techniques. Trees are effective in reclamation because mining can create deep, nontoxic mine soils that are often more productive than many adjacent forest soils. AML and SMCRA Title V mine lands can become important commercial and recreational forest resources with proper planning and management.

Trees produce large amounts of organic matter in mine soils that promote nutrient cycling, particularly that of nitrogen and phosphorus. Tree roots break up compaction by creating root channels. Large tap-rooted species such as bur oak (*Quercus macrocarpa*), swamp white oak (*Quercus bicolor*), and baldcypress (*Taxodium distichum*) are particularly effective (Ashby and Vogel, 1993). Tree root systems stabilize the reclamation site by reducing erosion and sedimentation. Certain trees species tolerate high acidity and low fertility, typical soil conditions found on many mine sites. Trees are extremely important for wildlife habitat. In midwest farm country, mine lands may be the only “dense” timber in the landscape.

Early reclamation efforts of mine lands in the East and Midwest centered on afforestation. Early tree planting efforts in the East and Midwest were based on observation of woody invasion and natural succession of trees on aban-

doned mine spoils (Croxton, 1928). Clark (1954) found that tree planting success on mine lands depends on soil chemistry, soil texture, water-holding capacity, and effects of erosion and sedimentation. This assumes planting materials and methods are uniformly good and that compaction is not a problem.

Ashby and Vogel in their excellent reference *Tree Planting on Mined Lands in the Midwest: A Handbook* (1993) argue that there are seven major environmental factors and physical characteristics in tree planting success: (1) climate (macro- and micro-climate); (2) soil physical factors (texture, organic matter, coarse fragments, surface roughness, compaction, and drainage); (3) soil chemical factors (reaction or pH, toxic elements and soil infertility, particularly of nitrogen and phosphorus); (4) competition with herbaceous groundcovers; (5) lack of soil organisms; (6) mammals and birds; and (7) fire.

Vogel (1987) writes that the reclamation specialist ***can control*** six factors that influence planting success: (1) quality of planting stock; (2) care of planting stock; (3) method of planting; (4) time of planting; (5) competition from herbaceous vegetation; and (6) soil compaction. Vogel also argues that following proper establishment techniques is as important as selecting the appropriate plant species.

Reclamation specialists must combine these environmental factors and physical characteristics with correct administrative and technical procedures. Hence, successful tree establishment on drastically disturbed lands such as coal mine sites is contingent upon seven major variables: ***(1) selection of proper native species; (2) purchase of the best quality planting stock; (3) correct handling of planting stock; (4) correct planting techniques; (5) effective control of competing vegetation; (6) proper soil condition and preparation; and (7) weather.***

These variables are omnipresent, regardless of unique regional conditions. It does not matter whether the reclamation specialist is planting gamble oak (*Quercus gambelii*) under 15 inches of annual precipitation in Utah or northern red oak (*Quercus rubra*) with 45 inches in Pennsylvania. The utilization of specific establishment techniques largely depends on the reclamation budget. However, the reclamation specialist must be aware that the most expensive parts of tree establishment are buying the planting stock and paying the planter. Without proper establishment techniques, the very best stock, planted with the best care, may be nothing more than food for soil decom-posers.

Forest restoration is becoming increasingly important in reclamation of eastern mine lands. High hardwood lumber prices and the new demand for wood chips for paper production has awakened the realization that the demand for hardwoods is increasing at a time when coal mining, among other competing developments in the East, is removing forests at an ever increasing rate. In the Midwest, the demand for hardwood also is increasing, putting greater demand on slower growing oak forests. Forested mine lands could play a role in easing this demand for hardwood while providing recreation and improving wildlife habitat and water quality. Tree planting on mine lands is very important because many high value tree species such as black walnut (*Juglans nigra*), pecan (*Carya illinoensis*), and oaks (*Quercus spp*.) may not easily or quickly colonize these areas because natural seed transport is limited unless a seed source is close by.

Black walnut can be effectively grown on high quality, uncompacted mine spoil with limited herbaceous competition (Ashby and Kolar, 1998). North America's most valuable hardwood can achieve very high growth rates, often exceeding growth on native soils. The lack of high quality native soil sites limits production of high quality timber due to black walnut's exacting edaphic and ecological demands. Property owners may find a large return in nuts and timber from black walnut on high mine soils.

The author has propagated approximately 1,500 container-grown oak and nut tree seedlings per year since 1990, outplanting on abandoned mine lands and old fields in central and western Missouri. Seedlings grown in the Whitcomb bottomless containers result in the taproot being "air-pruned." The taproot grows through the bottom of the container and is exposed to the air. The apical meristem desiccates and die which stimulates lateral root development throughout the container. Once planted, a lateral root establishes a new taproot or multiple laterals that form codominant, branched main roots (Whitcomb, 1988). First-year establishment success for container-grown seedlings is approximately twice the success of bare-root seedlings in side-by-side field trials in Missouri. White *et al* (1970) planting hardwoods and McDonald (1991) using pines and douglas-fir, confirm higher establishment success rates for container-grown seedlings in native soils.

Greatest mortality of container-grown seedlings in Missouri resulted largely from excessive competing vegetation and rodent damage in winter. It was not obvious than any container-grown seedlings were lost due to moisture stress. Bare-rooted seedlings were usually lost in the initial flush of growth or in midsummer due to moisture stress. Tap-rooted hardwoods such as oak, hickory, and walnut responded well to air-pruning, which resulted from using bottomless containers. In many oak plantings, the tops of seedlings die back in midsummer but later sprout back from adventitious buds located at the root collar. This is a common survival mechanism of most oak species (Olson and Boyce, 1971; Dixon, *et al*. 1984; Merz and Boyce, 1956; and Liming and Johnston, 1944). Seedlings were propagated in the author's backyard, placed upon a raised, welded hog or cattle panel, with four-inch squares, and protected from squirrels by a wood frame and chicken wire. Bare-root seedlings were purchased from the Forrest Keeling Nursery in Elsberry, Missouri and from the Missouri Department of Conservation George O. White State Forest Nursery.

Discussion

Selection of native species is important for reclamation success, particularly for ecosystem functioning. The Surface Mining Control and Reclamation Act, Section 515(b)(19) requires Title V reclamation to create "...a ***diverse***, effective, and permanent vegetative cover of the same seasonal variety ***native*** to the area affected and capable of ***self-regeneration*** and ***plant succession*** at least equal in extent to the natural vegetation of the area..." Reclamation in this country has not often achieved this goal, largely because of the next clause, which reads "...except that ***introduced species*** may be used in the revegetation process where desirable and necessary to achieve the postmining land use plan." (SMCRA, 1993) (italics are the author's). The use of trees for reclamation must function as a part of the natural ecosystem of the region. The reclamation specialist must work with these natural processes rather than against them. Native cover crops that promote native tree seedling establishment also tend to promote natural succession. Although Title IV (AML) is not required to adhere to Section 515, AML programs should set goals to enhance and restore diversity and ecosystem functioning of reclamation sites, rather than create more low-quality pasture composed solely of alien monocultures.

Many mine soils are extremely productive for hardwoods. Burger and Torbert (no date) report that reforestation efforts at the Powell River Project in southwestern Virginia indicate that "... restored forests on mine lands can be equally or more productive than the forests that were removed." Deep, uncompacted mine spoils can lead to the development of extremely productive forest soils. The author has observed excellent growth of black walnut; pecan; white, red, and bur oaks; and even drought sensitive tulip poplar *(Liriodendron tulipifera*) on 30 year old, uncompacted, neutral pH mine soils in western Missouri, 250 miles west of its native range in the Ozarks. Tulip poplar has thrived in protected mesic sites on mine lands. Typically, tulip poplar will not survive in this region on native soils without supplemental watering in the summer.

The author has observed nut trees growing on uncompacted, high quality mine soils producing abundant seed crop, often producing in years when trees growing in native soils do not. While limited to mere observation of pecan, black walnut, and various oak species, it is deductive to assume that deep rooting and high water availability during critical points in the development of nuts may lead to greater nut production during favorable years and important smaller yields in "off years." This may help smooth the typical boom and bust years that are hard on wildlife and nut growers' pocketbooks.

Native tree species are often adapted to the environmental conditions of the reclamation site (Limstrom, 1963). Many native species in the humid East and Midwest are tolerant of acidic natural soil conditions; therefore, these species may be effective since they tolerate acidic mine soil conditions as well. Observing natural invasion and succession of native species on acidic AML spoils may provide clues for species selection. The reclamation specialist can purchase such seedlings from regional nurseries specializing in or growing large selections of native species. Seeds or propagules can be collected from specimens growing on the mine site, grown by the specialist as described in the case study, and planted on the reclamation site. The reclamation specialist should avoid planting native species that are overly aggressive. Black locust (*Robinia psuedoacacia*) is native to the East and is com-

monly used as a nurse crop. It has sometimes proven to be overly aggressive and persistent in mine lands, slowing natural succession and limiting species diversity due to its dense shade and ability to spread by root sprouts. Plass (1977) found that the exotic black alder (*Alnus glutinosa*), grown as a nurse crop, can be effective in enriching mine soils, but can overtop desired species of hardwoods and conifers, limiting their establishment success. Species such as black locust and black alder should have limited use in reclamation plantings, unless the reclamation specialist is prepared to remove these species once the soil is properly developed and replant with more desirable species (Seidel and Brinkman, 1962).

The disastrous ecological effects of aggressive exotic and naturalized plant species on native plant communities is well-documented. Kudzu (*Pueraria lobata*) and japanese honeysuckle (*Lonerica japonica*) are two examples of "conservation" species that have escaped from mine and roadside stabilization plantings and pose significant threats to adjacent native plant communities. Other exotic pests have been introduced by accident by importing infected wood products, plant materials, and other commodities. Chestnut blight, dutch elm disease, and the gypsy moth are three of the best known and well-documented examples of pathogens and pests that were inadvertently introduced into North America. Reclamation specialists must avoid the desire of quick and easy plant establishment by using exotics, and focus on the long-term effects of reclamation and ecosystem functioning. Many exotic plants delay native plant invasion and natural succession of drastically disturbed lands.

Purchase of or propagation of quality planting stock is obviously important. This includes selecting materials propagated from stock adapted to local conditions and climate (Limstrom, 1963). The reclamation specialist should purchase planting stock or collect seed from trees growing within the correct climatic zone. Authorities specify that seed provenance (the place of seed origin) be a certain number of miles north or south and east or west of the planting site. Elevation also should be considered in mountain regions. The best rule is to select stock that can tolerate the planting site's minimum low temperature and survive the region's usual drought conditions. These can be determined from meteorological data. Drought effects on drastically disturbed lands may be of much greater duration and intensity than on a region's native soils.

The stock should be healthy, showing little damage to roots or shoots, and have no mold, offensive smell, or dry roots. Planting stock is expensive. Poor-quality stock has little chance for survival and should be returned for replacement or credit. The reclamation specialist can propagate stock in-house. Using container-grown stock greatly improves seedling establishment. Seed can be selected by the reclamation specialist from plants that are from local sources and adapted and growing under similar environmental conditions. Seed collected from plants growing on drastically disturbed lands may have a "genetic" advantage under these conditions and may prove effective in reclamation success. The container-grown case study emphasizes these points.

Typically, bare-root seedlings with larger calipers (the diameter of the seedling at its root-collar) have much greater establishment success than smaller ones. Vogel (1987) recommends that most conifers and hardwoods have a minimum caliper diameter of 0.1 to 0.15 inches (2.5 to 4mm). Thompson and Schultz (1995) suggest that nurseries should focus on root system development and grade seedlings on root system classification rather than shoot growth. Survival, height, and diameter growth of red oak seedlings was significantly greater in Iowa when the seedlings had ten or more first-order lateral roots.

Bare-root seedlings are grown in nursery beds from one to several years. They are removed (called "lifting") from the beds while dormant and sold or transplanted to a different bed for further growth. Nursery stock is sold based on the age and number of times the seedling has been transplanted. For example, seedlings grown in a bed for one season and sold are 1-0 stock. Seedlings grown two years with one lift and transplanted to a bed for the second season growing are 2-1 stock. The first number refers to seedling age, while the second refers to the number of times lifted and transplanted. Lifting cuts the deep roots of tap-rooted species which stimulates lateral root growth. This is physiologically similar to the air-pruning treatment described in the container-grown seedling case study. Both stimulate lateral root development. Improper lifting can result in shock to the seedling, leading to delayed growth or even death.

Correct handling of planting stock is crucial to establishment success. The reclamation specialist should inspect the nursery prior to purchasing stock to ensure the material is handled correctly. Seedlings should be free of defects, correctly sized and graded, and properly stored, packaged, and shipped. Nurseries that cannot meet these high standards should be avoided. No matter how good the nursery, some material may be shipped that does not meet these quality standards. A good nursery will accept the return of defective material and replace it or credit it to a future purchase. Nurseries that refuse returns should not be used.

Once the stock is delivered, it should be protected from drying winds, freezing or hot temperatures, and direct sunlight. Stock can be covered in the field by straw, tarps, or reflective heat blankets. The best protection is in a cool, dry barn, garage, or other structure. Stock should be planted quickly following its shipment from the nursery. Bare-root stock should be inspected for defects once the bundles are opened. Roots should be protected from drying with moist, shredded papers, peat moss or other water-absorbent materials. Water-absorbent gels can be used to keep the roots moist while planting.

One issue that always arises is that of pruning. Most experienced tree planters agree that the root-to-shoot ratio should be maintained around 1:1. Conifers should never have leaders pruned. Most hardwood species can be root-pruned to facilitate planting, only if the pruning is less than one/three the total root area. Root pruning of hardwoods may require shoot pruning to maintain the 1:1 ratio. Shoots should be pruned slightly above a live lateral bud to allow it to develop into a terminal shoot.

Correct planting techniques are simple but often overlooked. Toumey and Korstian (1931) write, "The chief aim in [tree] planting should be to interrupt growth to the least possible degree consistent with economy." The establishment success of container-grown seedlings illustrates this point. Seedlings should be planted with shoots near vertical, in a hole that is large enough to accept the roots easily without bending or twisting, and with the soil tamped gently around the roots without excessive compaction. Bare-root seedlings must be planted with the root collar at or slightly below the soil line. Bare-root seedlings must be planted after the last heavy spring frost date to minimize the potential of frost-heaving. Any deviation from these rules should not be tolerated.

Mechanical planting is a cheap alternative to hand planting. Both methods require similar correct handling and planting procedures for success. Mechanical planting is only as good as the efforts of the planting contractor and his or her equipment. Select a proven type of mechanical planter and an effective operator. Consult with state and federal foresters about the types of machines available and the operator's credentials in a region before issuing a contract. As with hand planting, find contractors who do good work.

Rugged terrain and rocky soils limit the use of mechanical planters. Wet soil conditions are not conducive to effective planting. Mechanical planters increase compaction on wet soils. Mechanical planting is quicker than hand-planting. This can be important when there are many acres to plant and the planting window is short.

Inspect the trees following planting. Place a guarantee clause in the tree planting contract to compel the contractor to perform correctly. Require performance bonds and reference checks. Good tree planters want these contract conditions because they can compete with and outbid the marginal operators.

Effective control of competing vegetation often is overlooked prior to tree planting. Dense ground cover is desirable to prevent erosion and sedimentation on a reclamation site; however, it may increase rodent populations that can destroy tree seedlings. It also may enhance browsing by deer and rabbits. Established herbaceous ground covers typically can out-compete tree seedlings, particularly during the first growing season. Water is usually the most limiting factor in tree-seedling establishment on mine lands (Munshower, 1994; Ashby and Vogel, 1993; Limstrom, 1960; Vogel, 1980; and Clark, 1954). The extensive root systems of herbaceous plants out-compete young seedling roots for water and nutrients as the seedlings overcome transplant shock and summer droughts. Competing herbaceous plants can overtop tree seedlings, reducing photosynthesis and cause shoot die-back and sometimes complete mortality.

Researchers suggest that competition for sunlight can be the chief limiting factor for successful establishment when water is not limiting (Holch, 1931; Toumey, 1929; Carvell and Tryon, 1961). The container-grown case study supports this belief. Anderson, *et al.* (1989) believes that vegetation must be controlled for the first four years following planting to ensure successful establishment. This time period may be excessive in the Midwest for some tree species, although growth will certainly be affected by the extra competition in the seedlings' early years.

Aggressive alleleopathic species, such as tall fescue (*Festuca arundinacea*), should not be used as a cover species in areas to be planted in trees. Less competitive and aggressive species such as redtop (*Agrostis alba*), timothy (*Phleum pratense*), or perennial ryegrass (*Lolium perenne*) should be planted at rates of two to four pounds of pure live seed per acre. A low-growing legume such as white clover (*Trifolium repens*) or common lespedeza (*Lespedeza striata*) can be planted at low seeding rates to add nitrogen. Adapt cover crop selections to local conditions.

Competing vegetation can be removed by "scalping." This can be done mechanically, by discing, rototilling, or drag bucket, or manually by using hoes, mattocks, or shovels. Vegetation is "scalped," leaving bare soil to receive the planted seedlings. This process can be expensive and time and labor intensive but very effective. Applying herbicides in strips or spotting is less expensive than physical scalping and very effective for vegetation control, but the environmental and human health and safety issues must be considered. All chemical applications must be performed according to label directions. Never apply chemicals in standing water.

The reclamation specialist must not scalp vegetation in such a fashion as to permit erosion. Always disc or apply herbicides along the contour, leaving swales, ditches, and channels undisturbed and well-vegetated.

Most hardwood seedlings need only one year of scalping to become established. Although less aggressive annual weeds quickly invade the scalped areas, they typically pose little threat to healthy seedlings in the second season. If tall annual weeds overtop seedlings in the first season, a clipping with a sickle bar or a hydraulic arm mower set high enough to miss the seedling is effective. The mowed material can be raked or thrown at the base of the seedling to function as an organic mulch.

Tree shelters, ground cover control blankets, and mulches also can be very effective, but can be extremely costly and labor intensive (Ashby, 1995; Smith, 1993). Tree shelters are particularly effective in protecting seedlings from animal browsing and from spot herbicide applications. Kjelgren, *et al.* (1994) found that tree shelters with or without deep-ripping, greatly improved survival of white oak seedlings on a reclaimed dragline mine in Illinois. Birds often use the shelters for perches, sometimes breaking young shoots. Paper wasps and mud daubers build nests inside the tubes that can pose a hazard to inspectors.

Proper soil conditions and soil preparation are the foundations of successful tree establishment. Certain basic edaphic or soil conditions must be present before trees can be successfully established. Mine soils tend to be low in organic matter, nitrogen, and phosphorus. Water infiltration is slow and water-holding capacity is low in graded mine soils due to compaction. Compacted mine soils accentuates the effects of soil acidity on plants and decreases water availability. Some mine soils contain acid-forming or toxicity-forming materials that impede seedling establishment.

Reclamation is a soil-building process. In natural systems, drastically disturbed lands undergo a succession of living organisms that may take decades or even centuries for successful colonization to occur. The foundation of natural succession is the development of a biological system with the plant community being the most visible portion. However, before this plant community can be expressed, a soil biological system must be developed that creates environmental conditions that allow those plants to complete their life cycles. Plants are most susceptible to harsh environmental conditions and disturbance just after germination. Many plants produce abundant seeds because most seedlings will die. The environmental changes of the microsite that result from a developing soil biological system enable many young seedlings to survive this early establishment period (Blake, 1935; Daubenmire, 1959).

Reclamation attempts to telescope this multiseasonal development of a diverse and complex soil biological system into a few short years. Often, on drastically disturbed lands reclamation specialists attempt to create a stable soil system in one season. Reclamation failures give testimony to our lack of understanding of natural processes. Bradshaw (1987) writes that ecosystem restoration "....is a considerable intellectual challenge requiring that we not only understand the nature of the ecosystem itself, but also the nature of the damage and how to repair it...*land restoration is an acid test of our ecological understanding*." The goal should be to develop a sustainable soil biological system even if it takes several years. Unless topsoil is imported with its biological system intact, it will take time to develop such a system. In most instances, topsoil should not be "borrowed" because it is never returned, and this practice only increases the amount of disturbance.

Low pH can greatly affect seedling establishment. Acid-forming materials present in many mine spoils can lower spoil pH far below what is acceptable for most tree species. As the pH drops, metals such as aluminum, manganese, and iron increases in solution. Aluminum is especially toxic to plant root growth (Berg and Vogel, 1973). As a general rule, do not plant trees on mine soils with a surface pH of 5.0 or less. Before planting, amend acidic mine soils with neutralizing material such as agricultural lime, or use organic matter to buffer the acidity and raise the pH. Otherwise, plant trees in less acidic microsites such as protected slopes and depressions and let natural succession finish the job in later years. Natural invasion patterns can provide clues to the location of these micro-sites. Field pH determination using hydrion papers is effective in verifying these microsites.

Mine soil fertility can be improved by growing nitrogen-fixing cover crops such as legumes. Plants create soil organic matter that promotes nutrient cycling and soil microbial activity. Virtually all plant-available nitrogen and phosphorus in soils are derived from the decomposition of organic matter by microbes (Brady, 1996). Organic matter increases water-holding capacity, increases cation exchange capacity, buffers soil pH, lowers bulk density, and promotes the development of a diverse, soil microbial population. These factors greatly improve the success of seedling establishment. Green manure cover crops can be disced into graded mine spoils to improve soil fertility and organic matter levels. Organic matter can improve soil pH and buffer the exchangeable acidity, improving revegetation and seeding establishment success (Berg and Vogel, 1973; Brady, 1996).

Over time, mine soils tend to stabilize pH and nutrient cycling converging towards values that are more typical of regional native soils (Davidson, *et al*., 1988). Acidic "hot spots" or "greasy spots" are common AML problems. Incorporating organic matter and lime can accelerate plant and microbial colonization which, in turn, decreases soil pH, improves soil buffering, and increases nitrogen and phosphorus accumulation and availability. Planting calcium-enriching species such as dogwoods that accumulate calcium in their leaves results in less acidic and more fertile mine soils. Pines tend to accumulate high levels of aluminum in their needles as a way to prevent physiological damage to plant tissue. The needles acidify the soil litter layer limiting plant and microbial colonization which, in turn, limits nitrogen and phosphorus cycling and ecological succession and diversity on mine lands.

Low soil fertility also can be addressed by liming and chemical fertilization. While cheap and effective, chemical fertilizers can pose environmental hazards if improperly used and impede the development of native plants adapted to low fertility levels often associated with mine soils. The reclamation specialist must look at the long-term goals of reclamation to determine the proper course of action.

Water is the most limiting factor in tree or shrub establishment (Gjerstad *et al.*, 1984; Munshower, 1994; Ashby and Vogel, 1993; Limstrum, 1960; Vogel, 1980; Clark, 1954). Excessive compaction of clay-dominated mine soils caused by heavy earth-moving equipment decreases mine soil water-holding capacity. Tree seedling roots have difficulty penetrating compacted mine soils. The effects of drought are accentuated in compacted mine soils, and often result in transplanted seedlings dying because their root systems are not extensive or deep. Compaction also impedes the infiltration of water into the mine soil. In wet periods, this can result in waterlogged or anaerobic conditions that can kill seedlings or severely damage their root systems (Clark, 1954; Munshower, 1994; Ashby, 1993). Czapowskyj (1970) found that grading sandy or rocky, coarse-textured mine spoils improves tree seedlings' performance in Pennsylvania by reducing the slopes and thereby increasing water infiltration into the spoil. This result may be limited to extremely coarse textured spoils and cannot be considered typical of most spoil conditions

in the Midwest. Grading clay-rich mine soils can result in compaction and ponding of water.

Deep ripping by ripper bars, subsoilers, V-shank rippers, or rome plows pulled by bulldozers is often effective in breaking up compaction, increasing water infiltration, and increasing penetration of tree roots. Ripping down 24 to 48 inches greatly improves seedling establishment rates. A second pass, angled on a 60 degree bias rather than perpendicular to the first, seems to be most effective in breaking up compacted spoil. In 1995, ripping costs ranged from $100 to $200 per acre, to a depth of 24 to 36 inches on 20-foot centers. Tree planting costs can total $200 to $300 per acre. Ripping increased first season bare-root survival rates from 30% to 40% to 60% to 80% for an investment of $100 to $200 per acre, resulting in a total tree-planting cost ranging from $300 to $500 per acre. Ripping may be the critical factor in stand survival in a drought year. Ripping increases surface roughness which promotes water retention in microhollows. Ripping slows near-surface wind velocities, reduces erosion, and slows evapotranspiration (Ashby and Vogel, 1993). Torbert and Burger (1996) found that minimal grading and surface roughness such as that left by ripping greatly improved tree growth and minimized erosion by increasing infiltration. Ripping also removes competing vegetation from the planting rows. Anecdotal evidence suggests that ripping may increase rodent predation of seedlings by providing habitat and easier access to roots (Ashby, 1992). While this may be locally devastating, heavy rodent predation may only be cyclical, tied to vole and other rodent population cycles. These factors tend to promote tree establishment. Additional plantings required to replace dead stock may almost double the cost of tree planting to $400 to $600 per acre. Does it not make sense to spend a few more dollars up front to ensure higher establishment rates and minimize replacement costs by ripping and scalping?

Weather can be the most crucial factor in tree-planting success. As mentioned earlier, water is usually the most limiting factor in tree-seedling establishment. All the best soil preparation, high-quality planting stock, and proper planting methods can go for naught if it does not rain. Munshower (1994) suggests planting trees and shrubs just prior to the period of maximum precipitation. Even so, droughts like that of 1980 and 1988, or even a pronounced spring drought during the first season, can destroy a tree planting. Like a farmer, the reclamation specialist must be an optimist, believing that the weather will be favorable and that the best laid plans and the expense will not be in vain. However, when the weather is not favorable, the reclamation specialist must accept failure, adapt to new conditions and revise plans, but never give up. In the arid West, optimal establishment years are few, and the native plant community ecology studies provide evidence that most seedlings are established in those optimal years (Munshower, 1996). Although, optimal establishment years are more frequent in the humid East and Midwest (Daubenmire, 1959), failures do occur and can play a major role in reclamation success.

Methods/Container-Grown Case Study

Qualitative observation of establishment success of container-grown seedlings since 1990 suggests a first-season survival rate of 90 percent for air-pruned bur oak and pecan grown in half-gallon bottomless containers. This compares to 35 percent survival of two-year-old bare-root stock grown at either a local commercial nursery or the state forest nursery. These were side-by-side plot trials of seedlings planted in prepared rows of prairie soils in Conservation Reserve Program (CRP) crop fields in western Missouri. Additonal test plots were established in neutral graded mine spoils and in a grassy old field. Rows were set along the contour at 15-foot centers, disced, and planted by hand. Container-grown seedlings were planted in the fall, and bare-root seedlings were planted in the spring. Success rates were slightly higher in very fine sandy loam soils mapped as Bates loam (2 to 5 percent slopes, fine-loamy, siliceous, thermic Typic Argiudolls), compared to silty clay soils mapped as Kenoma (2 to 5 percent slopes, fine, montmorillinitic, thermic Vertic Argiudolls) (USDA, 1995). Competition became intense in

midsummer as late-season weeds such as common and giant ragweed, giant foxtail, cocklebur, and beggar ticks germinated from the old-field seedbank. The rows were mowed in July to prevent shading of the seedlings.

A second test plot was established on rough-graded, neutral mine spoils, (silty clay texture with 15 percent shale channers, 5 percent sandstone pebbles, and few sandstone cobbles) in western Missouri. Establishment success in the first season was approximately 75 percent for container-grown bur oak and pecan, compared to 30 percent for

bare-root seedlings. Compaction was minimal since all grading was performed by a D-3 dozer knocking the tops off the spoil ridges, pushing the fill into the valleys between ridges. Wind-disseminated species, particularly broomsedge, slowly colonized the plots, competing with the seedlings. Adjacent mine lands were heavily vegetated, enabling deer to browse the plot undisturbed. Japanese honeysuckle invaded the mine spoil plots from outside by rapidly spreading vines.

A third test plot was established in central Missouri on loess-derived forest soils that had been cleared in the 19th century, then farmed and planted to tall fescue in recent decades. In places, much of the A horizon had been eroded and mixed by plowing into the E horizon. The soils were classified by the author as eroded Winfield silt loam (fine-silty mixed, mesic, Typic Hapludalfs) (USDA, 1994). Fescue sod was removed with a heavy hoe around each seedling to reduce competition at the time of establishment. Spraying could be as effective, but must be done while the seedlings are dormant. First-year survival rates for container-grown bur and northern red oak were 90 percent compared to 35 percent for bare-root. Mortality was high during the first winter due to a large population of voles (*Microtus* spp.). The author suspects the rodent predation is due to the greater nutritional content of container-grown seedlings compared to natural seedlings in the grass pasture. Cattle were removed from the pasture prior to planting, and the vole population exploded afterward.

Moisture was excessive at all sites during the period of fall 1992 to summer 1995. There was a pronounced water deficit in the summer of 1990 and in 1995, resulting in correspondingly lower establishment rates. Prolonged soil saturation resulted in anaerobic conditions in upland soils due to excessive rain throughout the summer of 1993. Many seedlings were observed to have suffered extensive root rot, killing the seedlings outright or indirectly by winter kill. Success rates were high in the well-drained Bates loam during the wet period. Appendix I outlines successful oak seedling propagation techniques.

Conclusion

The container-grown seedling methodology outlined in the case study has proven successful in small-scale establishment of deep taprooted hardwoods that are extremely difficult or impossible to transplant. Species without prominent taproots such as birch, ash, and maple receive no advantage from air-pruning as compared to traditional containers. All species of oaks, walnuts, and hickories, including pecan, responded well to air-pruning via bottomless containers. Baldcypress, hackberry, tulip poplar, kentucky coffeetree, persimmon, and basswood are effectively grown and out-planted using the air-pruned method (Lovelace, 1996). Many later-successional species planted to enrich the mine land ecosystem are prevented or are limited in their natural ability to invade drastically disturbed lands due to the distance from the site to a seed source (Ashby *et al*., 1980). Out-planted container-grown seedlings are more readily established with an intact root system as compared to bare-root. Growth and development of the air-pruned root system are rapid, enabling the seedlings to more readily survive harsh competition for water and nutrients in the first growing system than bare-root seedlings. Fall planting accentuates this difference. Container-grown seedlings continue to send out roots until the soil approaches freezing temperatures, which in Missouri are from late December to February. Some of the lateral roots enlarge and grow downward, developing into a multistemmed taproot system. Container-grown seedlings have a much greater planting window than bare-root in the East and Midwest, since their roots are continually growing which reduces or eliminates transplanting shock (Tinus and Owston, 1984). Bare-root seedlings can only be planted while dormant in the spring, allowing little time to establish an effective root system that can compete against annual weeds and survive during summer drought.

Ashby (1980) found that natural succession processes on drastically disturbed lands mimic classic old-field succession. Often desirable oak and nut seed trees are not near mine lands in the Midwest, therefore cannot colonize mine lands. With the bottomless container method, hard-to-find oak and nut seedlings can be propagated from seed collected from local parent stock that are adapted to the unique growing conditions of the planting area. High-quality, container-grown, air-pruned, seedlings can be used to enhance the biological diversity and wildlife habitat of drastically disturbed lands. In 1998, the author collected 272 and 178 viable acorns from two five-year-old bur oak seedlings (Quercus macrocarpa) grown with the methodology described in this paper. Future observations are needed to

determine if the container-grown methodology somehow promotes early seed production. Planting long-lived oaks and hickories passes a legacy from one generation to another that outlasts many day-to-day labors.

Successful tree-seedling establishment largely depends on the seven variables listed in the introduction of this paper. Water remains the chief limiting factor in seedling establishment. Compaction is the chief culprit in limiting tree root development, in water infiltration, and in water-holding capacity of mine soils. Soil chemistry plays a major role in establishment success since many weathering by-products of mine spoils are salts that absorb water and disperse clay particles, which further limits plant available water. Acid-forming materials directly affect root growth. Low pH solubilizes metals in soils, especially aluminum which is extremely toxic to plant roots. Low organic matter in mine soils results in low nutrient levels, particularly nitrogen and phosphorus, poor nutrient cycling, and low soil microbial populations.

These conditions can be overcome by adequate analysis of soil conditions and soil preparation. Soil preparation includes liming, ripping, scalping, and fertilizing, or the use of green manure crops. Purchase good planting stock of locally adapted native species, especially if the mine soils are acidic. The stock must be correctly handled and planted. Once all this is done, establishment is largely up to nature. If weather conditions are favorable, the stand should be successfully established in the critical first season. However, the reclamation specialist must be patient and be able to withstand the pressure of supervisors, regulators, landowners, and the general public, who may not understand that tree-planting success takes time. Finally, practioners must get out of the office and observe what works and adapt their efforts to local conditions.

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APPENDIX I
OAK PROPAGATION TECHNIQUES

Fall/Winter

1. Collect acorns that have proper color and no weevil holes, cracks, or other surface blemishes. Do not collect green seeds. Acorns with caps still affixed should be discarded. Larger acorns tend to produce larger seedlings. Whether this difference is a short-term or long-term effect is not clear. However, it is obvious that a larger transplanted seedling has greater survival rates (Downs and McQuilkin, 1944, McComb, 1934 and Korstian, 1929).
2. Acorns should be floated in water. Those that float should be discarded since they tend to be dead or damaged. Acorns that sink should be collected and allowed to dry to the touch on newspapers in a cool, dark location. Most acorns desiccate quickly, resulting in a serious reduction in viability. Sound acorns typically have a germination rate of 75 to 90 percent. For successful germination, white oak (*Leucobalanus*) group acorns must have a moisture content above 30 to 50 percent, with a minimum of 20 to 30 percent for the red oak (*Erythobalanus*) group (USDA, 1948). Bur oak acorns should have their caps removed for the float test.
3. Collect dried acorns into one-gallon sealable plastic bags, preferably freezer-type bags.
4. Place acorn-filled bags in a refrigerator set at 34EF to overwinter. Periodically, check and remove acorns damaged by weevil larvae and mold.

5. Hickory nuts, pecans, walnuts, and hazelnuts require moist stratification for proper germination. They should be stored in a moist mixture of half sand and half ground peat. Storage containers with airtight lids should be used. Place storage containers in a cool, unheated location to overwinter. Floating cannot be used to remove dead or damaged nuts. Check periodically to maintain moisture level. Do not saturate the mixture because the nuts can rot.

Spring

1. In mid-March, check *Leucobalanus* (white oak group) acorns for the emergence of the radicle (first root) from the acorn tip.
2. Plant acorns in Whitcomb bottomless containers (also called milk cartons) that are resting off the ground

after the threat of a hard freeze (around 25EF) is over. Flats with welded wire bottoms can be built to hold the containers. Acorns should be carefully planted once the radicle has emerged. The radicle should be planted with the growing tip pointed downward. Radicles planted upward cause the roots to spiral or bind. Planting can continue until the middle of June, although growth may be less than in earlier stock. *Erythobalanus* (red oak group) acorns germinate more slowly than *Leucobalanus*. Do not wait for radicle emergence to plant.

3. The potting mix that has yielded the best growth and development for the author is two parts topsoil (silt loam, very fine sandy loam or silty clay loam is preferred), two parts ground peat (commercial quality with no sticks or stems), and one part composted manure (available at nurseries and discount stores in 40-pound plastic bags). Soil compaction or dense, tight potting mix can delay radicle emergence or even damage the radicle itself. Therefore, it is imperative to have a loose potting mixture (Korstian, 1927, and Connell, 1961). White (1970) found that using soil alone in the potting mix greatly reduces seedling growth. Using topsoil from oak-hickory regions inoculates the seedling roots with mycorrhizal fungi. Although there is always a risk of introducing pathogens or pests from the topsoil, the benefits of my-corrhizal inoculation outweigh the risk (Dixon et al, 1984). The peat reduces total weight and improves the soil mix structure. Organic matter in the potting mix greatly improves seedling root development and improves water-holding capacity. This is particularly important for oak, hickory, pecan, and walnut seedlings (Lovelace, 1996). Manure in the mix provides slow-release nutrients.
4. Cover the plastic container bottoms with one layer of newspaper to initially contain the soil mix. The bottomless nature of the containers allows the taproot to grow downward until it penetrates beyond the container. At this point, the exposed root meristem dies, hence the term “air-pruned.” This prevents the root spiraling and girdling common in container-grown oaks and hickories. The air-pruned taproot stimulates the growth of lateral roots, which fill the container by the end of summer. Species with strong taproot tendencies reestablish this growth pattern once outplanted (Lovelace, 1992).
5. Periodically inspect stratified hickory, pecan, and walnut seeds. Nuts that have opened or have emerging radicles should be planted immediately.
6. Protect planted containers left outdoors from squirrels. They will wipe out an entire planting within hours once they smell the nuts. Downs and McQuilkin (1944) found rodents, particularly deer mice, *Peromyscus maniculatus*, to be more damaging to dropped acorns in the forest than squirrels or chipmunks. Whether that is true in the backyard remains to be seen.
7. Do not plant defective, weevily, discolored, or excessively moldy acorns. By June 1, do not plant hickory nuts, pecans, or walnuts that have not split open for radicle emergence. Throw these to the squirrels since it is unlikely they will germinate.
8. Planted containers should have a 1/8- to 1/4-inch-thick surface layer of shredded bark or coarse sawdust. This provides a protective mulch that reduces evaporative losses and inhibits puddling and compaction of the soil surface. The mulch layer can save the seedlings from desiccation on a windy August day. This also mimics the natural revegetation process by simulating forest floor litter. Korstian (1927), Barrett (1931), McComb (1934), and Corvell (1961) all emphasize the importance of a protective organic layer for effective seed germination and seeding establishment. This remains true for outside grown, container-grown seedlings.

Summer

1. Keep the soil mix moist but not saturated during the entire growing season. Too much water causes the seeds and roots to rot. Once the secondary leaves emerge, transpiration becomes rapid and water in the plastic containers can be quickly depleted. Weeds should be pulled from the container soil.
2. In July and August, check the seedlings every day for moisture stress. Water as needed.
3. Insects usually are not a problem, but mold and mildew can cause leaf problems during a wet spring. Insect pests can be crushed by hand. Spraying should be done only as a last resort.

4. Transplant early, well-developed seedlings by late July into one-gallon, two gallon, or five-gallon plastic pots for further flushes of growth. Only air-pruned seedlings should be transplanted into the plastic pots to prevent root spiraling and binding. Potted seedlings must be outplanted in the first fall season to prevent root spiraling and binding.
5. White oak, chinkapin oak, and post oak seedlings tend to be small and slowly established in the first season. Initially, plant acorns in six-inch grow tubes and transplant to half-gallon milk carton containers by August. These seedlings will be too small to plant in the coming fall and should be stored overwinter for another growing season before planting.
6. Inspect all seedlings to ensure air-pruning has occurred. If not, prune the taproot with hand shears.
7. Seedlings grow best in full sun from the east in the morning, with light shade from midday to evening. Try to find a hedge row or large tree, and locate seedlings on its east side. Allow the canopy to shade the seedlings by midday. Deep shade is not desirable.

Fall

1. Outplant healthy, vigorous seedlings as soon as daytime temperatures begin to drop into the low 80s and the fall showers begin.
2. Scalp overly competitive grasses by hoeing or spraying around the planted seedling. Make a two- to three-foot-diameter clearing around each seedling. Plastic tree tubes can greatly increase survival and growth of transplants, but cost must be considered.

3. Discard seedlings that are too weak, spindly or short. It is too much work to plant container-grown stock that will not survive.
4. Store small, slowly established white, chinkapin, and post oaks for the winter in a cool, dark, moist place such as a root cellar or earth-contact basement. They should have undergone a good freeze to slow or stop shoot biologic activity prior to storage. Roots continue to grow in winter until the soil temperature approaches freezing.
5. Seedlings can be planted successfully until early December if properly mulched and located in a protected location. Frost-heaving can be a concern for unmulched seedlings or plantings located in exposed areas susceptible to frost-heaving. Good fall establishment enables the seedling to send out deep roots in preparation for summer drought and competition for moisture and nutrients. The result is that container-grown seedlings give the planter five to six months to plant stock as compared to the one-month bare-root seedling planting window.
6. Store extra seedlings overwinter for a spring planting. These can be planted from mid-February to the end of April.
7. **Select the correct native species and adapt to local conditions.**

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ILLINOIS/INDIANA

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Introduction

I would like to review a few common sense theories. The future is now and it is our turn. It is our turn to lead. It is our turn to create meaning for all of those around us. We must dispel the idea that trees will not grow on re-claimed land. In Indiana, we are planting nearly a million trees a year on reclaimed mine land. We are con-sistently achieving bond release and a significant growth rate. These successes came from the result of many people working together. It came from people like you and me sharing our ideas and experimenting with what we learned. The results we get when working together is greater that the sum of what we can each do individually. Often we act as a catalyst to motivate each other. Many times there needs to be a change in how companies com-municate in order to get things done. Many times a bottom up approach will find solutions to our problems. It gives employees a sense of ownership in a project that will encourage us to become proactive rather than reactive. As our nation increases in complexity, demands for clean air, water, and a better environment also will increase. We have no choice but to meet the challenge. Future generations depend on what we will do today.

Tree Planting Recommendations

What is the physical make up of a successful tree planting project? The following is an outline, in order of importance, of what I have found to be required to successfully establish trees on a reclaimed mine site, realizing that it is the sum of these factors that produces good results.

- **Seedling Quality.** The seedling must have a large, healthy, fibrous root and as large a diameter of stem, within reason, as possible. There must be a desirable root to shoot ratio. This type of seedling is being consistently produced by the Indiana State Nursery. Many tree planting contractors would prefer to plant smaller seedlings because it is easier, especially with hand-planting. Availability of a sufficient quantity of good seedlings is a problem in Indiana. Some species of trees do not respond well to planting on reclaimed mine sites in Indiana. These would include tulip poplar, eastern red cedar, and some of the shrubs for wildlife plantings. Sometimes you are compelled to use what is available because there are not sufficient quantities of the most desirable species.
- **Seedling Care After Leaving the Nursery.** They should be refrigerated as soon as they leave the nursery and until they are in the ground. It is crucial to have a good working relationship with the nursery.
- **Soil Conditions.** Soil conditions are more critical for mechanical planting than for hand-planting. These conditions are less critical early in the season but become more so as the season progresses and temperatures rise. Late in the season, wet soils will compact quickly after drying out in the sun. In this condition, good soil to root contact is impossible. I have found that I get the best results with mechanical planting by waiting for good soil conditions later in the season, rather than planting too wet too early. If I am hand-planting, then it is best to plant as early as possible.
- **Weed Control.** The improper selection and overuse of herbicides has destroyed many seedlings. By mistake, we learned that the application of one third the rate of some herbicides gave us satisfactory weed control and no problems with seedling damage from the herbicide. Different species and varieties of tree seedlings have dif-ferent tolerance levels to herbicides, which compounds our problems. Research at Purdue has shown that a successful application of the correct herbicide to control herbaceous cover for the young tree seedling invari-ably results in superior tree growth. “Milestone” appears to be the forest herbicide of the future. It is environ-mentally friendly and friendly to the tree seedlings as well. More research is needed to get better forest friendly products on the market.
- **Seedling Placement.** The mechanical equipment used to plant tree seedlings is expensive. Field conditions that prevent the use of mechanical equipment include rocks, wood, steep inclines, and washouts that cause excessive wear and breakdowns to this equipment. We started with a 4 inch planting shoe to accommodate the

largest seedling root possible, but found we could not get proper closure around the root with that large of a shoe. We soon changed to a 2.5 inch shoe and installed sod cutters on our press wheel in order to get better root to soil contact. This made a noticeable difference in our survival rate. We also cut some of our machines down and converted them to a heavy duty three point hitch machine for better maneuverability. One of our machines is a split axle planter with a crawler tractor for steeper slopes and hard to plant areas. We will install dual wheels on our four wheel drive tractors this spring. When we first started machine planting we tried to plant at root collar depth. We soon found that we had to plant much deeper. We spray the seedlings with a pollimer and water mix in order to retain as much of the nursery soil on the roots as possible. Our higher cost of planting reflects our higher capital investment cost. I have found it is better to do a good job the first time rather than risk replanting. This proves to be more economical for our clients. Because there are so many uncontrollable variables that could affect tree survival, we do not guarantee tree survival. Instead, we do everything possible to ensure that the seedlings are planted right the first time. In order to ensure a given number of healthy seedlings per acre, you must plant a higher number originally in order to cover expected mortality of a certain percentage of the seedlings. Replanting is very difficult because of the patchy nature of surviving seedlings. Replanting efforts must be done by hand, which often results in just delayed mortality as hand-planting on reclaimed lands have a much lower survival rate. Our six years of hand-planting efforts has had limited success.

- **Follow up.** Some follow up is necessary. Keeping the centers of the rows clean to conserve moisture and preventing excessive rodent damage and animal browse may be of benefit. This could reduce the possibility of replanting. Grass control is more crucial than broad leaf control. Unfortunately, the decaying vegetation that you mowed early in the season provides hiding places for rodents and highlights the tree rows for browsing animals. Each mine site is different and specific methods need to address the specific requirements of each site. It is important to inspect the site regularly to determine management needs.

Summary

The things that make tree planting efforts most likely to succeed are: (1) seedling quality; (2) seedling care; (3) soil conditions; (4) tree friendly herbicides and weed control; (5) seedling placement; (6) follow up; and, most of all, (7) developing a good attitude about tree planting. Our planet will respond graciously, preventing the detrimental repeat of history experienced by ancient civilizations and more recent developing nations.

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- Tom Wallace Forestry Award,
- Area Six Conservation Award,
- 1983 Indiana Logger of the Year Award,
- 1985 Statewide Outstanding Tree Farmer of the Year Award, and
- the 1998 Vance Pat Wiram Award.

AMERICAN ELECTRIC POWER COMPANY REFORESTATION HISTORY ON RECLAIMED MINED LANDS

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Introduction

American Electric Power Company is one of the largest investor owned electric utilities in the United States. Its business is generating, transmitting, and distributing electricity and providing related services to seven million people throughout portions of seven mideastern states. In providing this service, extensive land reserves have been acquired by the company to support the company's generation plants, coal mining operations, coal transportation facilities, and transmission and distribution facilities. The company owns a total of 311,000 acres, the bulk of which is fuel related, surface or underground coal reserves. Ninety-five percent of American Electric Power's electric generation is fossil fuel based. In 1996, AEP burned 52 million tons of coal from surface and deep mines in eight states. Approximately 15 percent was produced by AEP's affiliated coal companies in Ohio and West Virginia.

As a consequence, American Electric Power Company has a long history and extensive experience in reforestation on reclaimed mined lands. One of the first land-oriented programs the company entered into was its tree planting or reforestation program. This began in 1946 with the planting of raw spoil banks on the company's Philo I and II strip mine ownership south of Zanesville, to return the mined land to a productive capacity. Not only was it the first planting of mixed hardwoods on strip-mined banks, but its success served as the basic building block in the company's continued policy to return mined lands to a productive capacity through the planting of trees.

When the company's mining operations expanded into the Cumberland coalfields, this reforestation commitment continued. Even though this planting was required to achieve compliance under the old reclamation laws, it has always been a sincere effort to reforest with the best species available to achieve the establishment of commercially viable, mixed-hardwood plantations. In addition, when old agricultural fields were abandoned due to marginal agricultural productivity, they were also planted to trees, predominantly mixed pine.

When the new reclamation law was enacted in 1972, the establishment of grass as a vegetative cover was required to achieve compliance. Although this diminished the extent of the company's tree planting program, efforts to establish forest plantations on the new grasslands continued, using both chemical and physical means of vegetative control to establish trees. In addition, several research studies were conducted to identify the best techniques and species to use on post-SMCRA sites.

In 1995, AEP made a commitment with the Department of Energy under its Climate Challenge Program, to plant 15 million trees on 20,000 acres of company land by the year 2000. This project will reforest 11,000 acres of reclaimed grassland areas that are no longer under bond. During the period 1996 to 1998, a total of 9,741,406 trees were planted on 12,131 acres.

The sum total of these efforts has resulted in the creation of 40,428 acres of mixed-hardwood and mixed-pine plantations involving 50 million tree seedlings.

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MYCORRHIZAL FUNGI AND TREES—A SUCCESSFUL REFORESTATION ALTERNATIVE FOR MINE LAND RECLAMATION

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Abstract

Successful consistent revegetation of drastically disturbed mine sites (i.e., acid coal spoils and mineral waste dumps) throughout the United States and several foreign countries has been achieved by using the biological "tools"—mycorrhizal fungus inoculated tree seedlings, native shrubs, and grass species. These trees and shrubs are custom-grown in bareroot and container nurseries with selected mycorrhizal fungi and grasses, and forbs are inoculated in the field at the time of planting. On disturbed sites, specific mycorrhizal fungi such as *Pisolithus tinctorius* (PT) or VAM provide significant benefits to the plant symbionts through increased water and nutrient absorption, decreased toxic materials absorption, and overall plant stress reduction.

One of the best examples of the practical application of this symbiotic mycorrhizal fungus-host tree technology is in Ohio. During the past 18 years, the Ohio Division of Mine Land Reclamation—Abandoned Mined Lands (AML) program has utilized the combination of the PT fungus and selected tree species in a successful reforestation project to significantly improve the effectiveness and reduce the cost of AML reclamation projects. Since 1982, over 5 million PT-inoculated pine and oak seedlings have been planted on over 3,000 acres of unreclaimed AML sites. Tree survival has averaged over 85 percent in the PT-inoculated tree plantings with less than 5 percent tree failures as compared with less than 50 percent survival and over 75 percent failures in previous plantings with the same noninoculated tree species. From 1982 to 1998, the Ohio AML reforestation project with PT-inoculated trees has cost approximately $970,000 or $300/acre. In 1998, approximately 340,000 PT-inoculated seedlings were planted on 242 acres at a cost of $195,000 or $805/acre. This represents an approximate 87 percent cost reduction as compared with conventional mineland reclamation methods ($6,000/acre). The PT seedling inoc-ulation cost is only $35/acre or about 4 to 12 percent of the reforestation cost which is relatively minute when compared to the consistent tree survival and early growth benefits obtained on these highly disturbed stressful sites. Interest in the application of this natural environmentally friendly technology to mineland reclamation programs throughout the United States and several foreign countries is expanding. This "total natural systems approach" to successful mineland revegetation is available through a team of scientific and business experts offered by Plant Health Care—Reclamation, Inc.

Introduction

Vast areas of the United States have been rendered nonproductive by over 175 years of intensive, uncontrolled surface and subsurface mining (5). Millions of acres of abandoned mined lands (AML) in the United States along with additional millions in several foreign countries (Asia, Europe, Africa, and South America) are in urgent need of reclamation. The 1990 Abandoned Mined Lands Inventory revealed that it would cost over $3 billion just to eliminate health and safety hazards on AML in the United States. An additional $57.8 billion would be required to reclaim environmental problem AML sites assigned third priority by the Surface Mining Control and Reclamation Act of 1977 (SMCRA). One northcentral state, Ohio, alone contains 200,000 acres of abandoned strip mines. Using conventional AML reclamation techniques (grading, resoiling, fertilizing, and revegetating), the cost of

reclaiming these sites is estimated to be $1.5 billion. Problems associated with abandoned mineland include subsidence, acid or toxic drainage, landslides, sedimentation and flooding, loss of productivity, hazardous impoundments, visual pollution, and abandoned equipment (5). Mining for natural resources also generates a variety of waste materials that differ significantly in their biological, chemical, and physical characteristics. Factors such as soil pH, organic matter, composition, fertility, moisture, temperature, and microbial composition profoundly influence successful plant (trees, shrubs, and grasses) establishment and growth on these mineland sites (19).

Increasing public awareness and intensified environmental legislation have regulated the mining industry to assure effective reclamation on mined lands. Since the enactment of SMCRA in 1997 (Public Law 95–87), active strip mine reclamation has focused on intensive soil grading, replacing topsoil, and establishing a dense herbaceous cover to quickly control erosion, thus assuring prompt bond release. Although reforestation may not be the se-lected alternative in the reclamation of active mine land operations, it is receiving considerable interest as a viable reclamation "tool" in AML programs. Reforestation, of course, is neither new nor innovative; however, it deserves renewed interest and consideration for mine land reclamation applications. Tree planting on mined land is an excellent reclamation alternative that was deemphasized during the time period in which alternative objectives, regulations, and policies were developed following the enactment of environmental laws in the 1970's (3). With today's technology, the land can be shaped to its former contour; the soil can be replaced to its approximate previous configuration; and acidic coal spoils and other mine wastes can be capped and sealed away from the environment. However, even with the most intensive procedures to improve soil fertility and structure, efforts to restore previously existing vegetation have all too often failed. Establishment of trees has been especially difficult, often requiring repeated plantings to offset recurrent mortality (8,13).

Mycorrhizae and Mined Sites

The feeder roots of most plant species (trees, shrubs, forbs, flowers, and grasses) are infected by specialized fungi that form beneficial associations called mycorrhizae (fungus roots). The most widespread symbiotic (mutually beneficial) association on plant roots is mycorrhizae. These structures greatly increase root absorption efficiency and are vital to the survival and growth of both the host tree and the fungus. Compared to nonmycorrhizal roots, those roots colonized by mycorrhizal fungi have increased water and nutrient absorptive capacity, nutrient fixation, resistance to root pathogens, and longevity. As the main interface between seedling and soil, mycorrhizae are a key measure of root system quality.

Mycorrhizae are of two primary biological types: endomycorrhizae (which penetrate host cells) and ectomycorrhizae (which grow between the root cells and cover the root surface with a mantle of fungus hyphae).

Endomycorrhizae is the most widespread type and comprises three groups–ericaceous, orchidaceous, and vesicular-arbuscular (VAM) mycorrhizae. The endomycorrhizae also are predominantly found on hardwood tree species along with some conifers. VAM occur on more plant species than all other types of mycorrhizae combined. Over 90 percent of the 300,000 species of vascular plants in the world form VAM in natural soils.

Ectomycorrhizae occur on about ten percent of the world flora, and are predominantly found on conifer species along with some hardwoods (oak, birch, beech, chestnut, hickory, and eucalyptus). Numerous fungi form ectomycorrhizae. In North America alone, at least 2,100 species of fungi form ectomycorrhizae with forest trees. The vast majority of plants in natural environments have mycorrhizae; it is the rule in nature. Therefore, a primary prerequisite of successful mine land reclamation with trees, shrubs, forbs, flowers, and grasses is the most compatible combination involving the mycorrhizal fungi, plant host species, and the soil and environmental conditions on the mine site.

One ectomycorrhizal fungus, *Pisolithus tinctorius* (Pt) has been widely used to improve mine land reclamation tree planting success. Acid coal spoils, kaolin spoils, mineral mine wastes, borrow pits, and other severely disturbed sites have been successfully forested with tree seedlings having Pt ecomycorrhizae. Although the fungus does not directly affect the quality of the mined site, it modifies the tree root system so that it can tolerate adverse soil conditions, such as low pH (3.0), high temperatures, low fertility, mineral toxicity, and drought, that usually kill other ectomycorrhizal fungi along with their host trees (4, 5). Pt offers a practical, economical, effective alter-native

to intensive mine land reclamation, particularly on AML projects.

There is a large body of published scientific research showing the practical significance of the Pt ectomycorrhizae and specific VAM fungi to revegetation of mined lands and other adverse sites in the United States and other parts of the world. Most of these field research and demonstrations were done on very acid coal mined lands in the eastern United States that also were droughty with high summer soil temperatures and contained high amounts of Al, S, Mn, and Fe (11). Other research and field demonstrations have been done on kaolin, phosphate, and mineral mines; impoverished eroded soils; and borrow pit sites (10). The results from all sites have been similar. After several years, seedlings with Pt ectomycorrhizae or with selected VAM had significantly greater survival and growth and contained less heavy metals in their foliage than seedlings with ectomycorrhizae or VAM formed by other species of naturally occurring mycorrhizae fungi, (7,12).

Nursery Inoculations and Seeding Production

During the past 20 years, operational programs have been developed for the practical and effective inoculation of bareroot and container nursery seedings with Pt inocula for mine land reclamation programs. Pt was selected for its demonstrated benefits to a variety of host trees and for its adaptability to adverse soil conditions, ease of manipulation, and wide geographic and tree host range. Many conifer and some hardwood tree species on a variety of nursery sites have been artificially inoculated with Pt inocula. Effective Pt vegetative inoculum has consistently improved the quality of bareroot and container nursery seedlings along with subsequent benefits to mined land reclamation and forestation (Figure 1) (15,17). Results obtained from thirty-four bare-root nursery inoculations conducted during the three-year period, 1978 to 1980, showed that Pt inoculated southern pine seedlings had a 17 percent increase in fresh weight, a 21 percent increase in ectomycorrhizal development, and a 27 percent decrease in the percent of cull seedlings at seedling harvesting date (Figure 2). Seedlings are the most responsive when at least half or more of their ectomycorrhizae are Pt ectomycorrhizae (Pt index > 50).

Procedures for operational nursery use vary among the different commercial Pt inocula types. With any of the mycelium and spore inocula, the biological requirements of a second living organism are added to that of the seedling. Consequently, special precautions are necessary for the Pt inoculum during shipping, storage, and handling, along with certain aspects of seedling production, lifting, handling, and field planting. For successful Pt inoculation in bare-root seedbeds, populations of pathogenic and saprophytic fungi and native ectomycorrhizal fungi that may already be established in the soil must be reduced by spring soil fumigation. Prior to sowing, vegetative inoculum can be broadcast on the soil surface and incorporated into the fumigated seedbeds or it can be machine-applied with greater effectiveness and efficiency (Figure 3). For container-grown seedlings, vegetative or spore inoculum can be incorporated into the growing medium before filling the containers. Spores also can be sprayed or drenched onto container media for containerized seedlings and onto seedbeds in bare-root nurseries following seed germination and seedling emergence.

In the VAM program, bare-root and container nursery inoculations are continuing, using a multiple-fungal species VAM “cocktail” inoculum on selected hardwood tree seedling, native shrub species, native flowers, and grasses for mine land and forestation applications. Results of VAM inoculations on several hardwood seedling species in several eastern U. S. bare-root nurseries, on selected native shrubs in a western U.S. container nursery, on native shrubs in a western U.S. container nursery, and on native grasses/flowers on a copper mine site in the western United States have all been positive. Research on the consistent positive effects of VAM on eastern hardwood tree species also has been published (9). A variety of ecto and endomycorrhizal fungus species and inocula types targeted for specific applications such as mine land reclamation are presently commercially available from PHC Reclamation, Inc.

Guidelines for MycorTree™ seedling production are designed to maintain healthy root systems with abundant specific mycorrhizae. Development and retention of lateral and feeder roots and mycorrhizae must be considered from seed sowing through seedling harvest and field planting. Nurserymen, field foresters, reclamation specialists, and tree planters must remain aware of the two biological components—the tree seedling and its complement of mycorrhizal fungi.

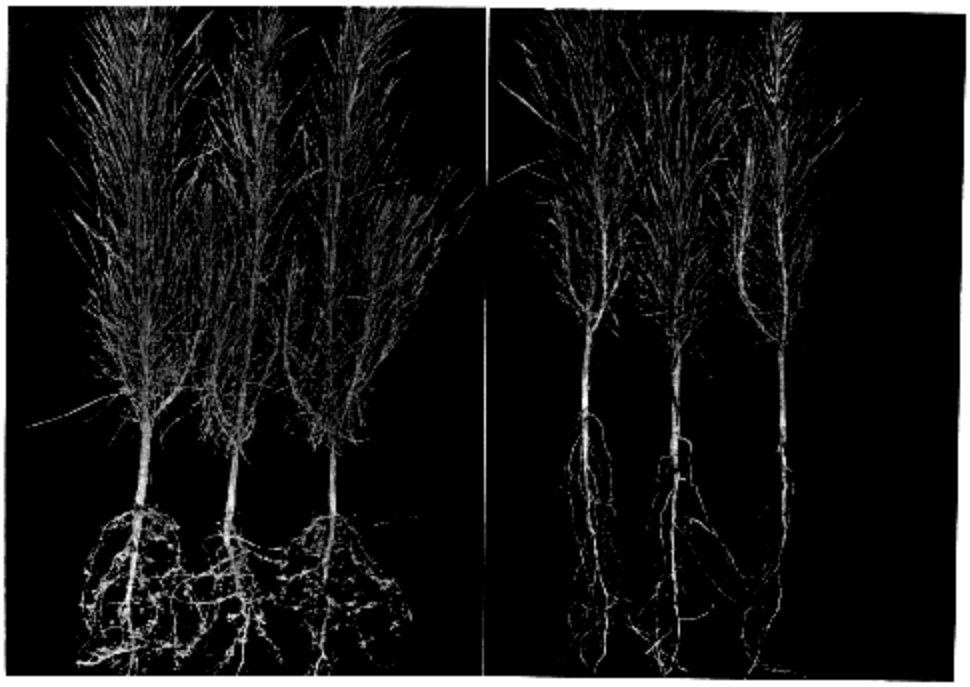

Figure 1. 1-0 loblolly pine seedlings with Pt ectomycorrhizae (left) and with only naturally occurring ectomycorrhizal fungi (right).

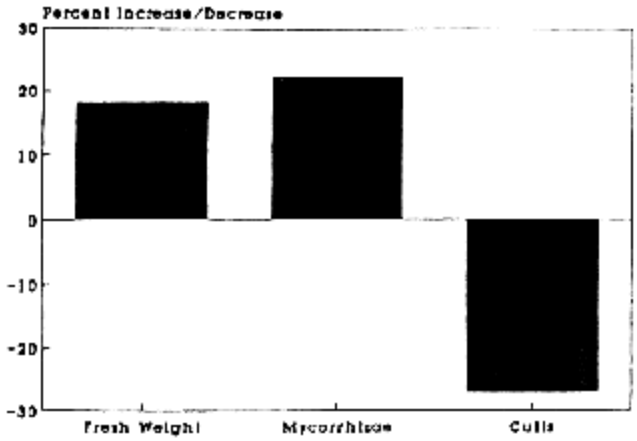

Figure 2. Effects of Pt inoculation with vegetative inoculum on seedling fresh weight, ectomycorrhizal development, and nursery cull reduction in 34 bareroot nursery studies.

Figure 3. Applicator for mycorrhizal fungus inoculations in bare-root nurseries.

Mycorrhizal fungi generally have similar moisture, fertility, and pH requirements as their host plants, but tolerance to extreme or adverse conditions varies among fungus species. Nursery soil and cultural factors that significantly affect mycorrhizal development include pH, drainage and moisture, fertility, fumigation, pesticides, cover crops, shading, seedling spacing and density, and root pruning. Soil and water pH values and water quality are three of the most limiting factors affecting the development of mycorrhizae in most bare-root and container nurseries. Soil fertility and irrigation should be based on the requirements of the seedling. Excessively high levels of phosphorus and nitrogen (particularly in VAM inoculations) along with excessive irrigation (particularly in containers and poorly drained seedbeds) should be avoided. Certain pesticides are particularly detrimental to specific ectomycorrhizae such as Pt, and they must not be used in conjunction with inoculations. Precautions also are warranted when using artificial shade on seedbeds or in greenhouses. Minimum threshold light quantities are required for adequate photosynthate production and subsequent mycorrhizal development. When day length is short, the amount of natural light in greenhouses is often inadequate and must be supplemented with artificial lighting. Proper seedling spacing and density along with custom-applied root pruning practices in bare-root nurseries contribute to high-quality seedlings with maximum lateral roots and mycorrhizae development. These traits are associated with desirable height and basal diameter characteristics (5).

Seedling harvesting, handling, storage, and planting practices also may have significant effects on the retention of lateral roots and mycorrhizae. Ectomycorrhizae are delicate structures and special care must be taken during all stages of seedling handling to retain the feeder root system and mycorrhizae. Feeder roots and their associated mycorrhizae can be ripped off and left behind in seedling beds during harvesting, desiccated in storage, or deliberately cut off prior to field planting. To maintain seedling quality, conventional nursery practices may

require modification to minimize damage to feeder roots and mycorrhizae. Stripping of feeder roots has severe negative impacts on seedling field performance (16). During transfer of seedlings from the field to the packing room, and at all other times when seedlings are subject to direct environmental exposures such as wind and direct sunlight, special care is required to avoid drying of the feeder roots and mycorrhizae.

The seedling packing procedure and packing materials also may have significant effects on the ability of the seedling to endure storage, maintain root system quality, and survive field planting. Cold storage is vital to slow seedling respiration and maintain quality particularly for extended storage periods. Numerous studies have documented the effects of storage time on seedling quality. For most tree species and their associated mycorrhizae, proper storage for two to six weeks at 36EF is not detrimental (5).

Successful Mine land Reclamation

Seedlings with Pt ectomycorrhizae have been repeatedly used for successful reclamation of acid coal spoils, mineral mine wastes, kaolin wastes, borrow pits, and other disturbed sites throughout the United States and in several foreign countries. Positive field responses follow successful Pt nursery inoculations, use of suitable mine land reclamation techniques and procedures, and favorable mine land spoil and environmental factors.

Extensive reclamation research has been conducted on custom-grown seedlings with Pt ectomycorrhizae on disturbed and adverse sites of various types in the eastern United States. In 1966, Shramm made the initial observations and report of the widespread association of Pt with pines growing naturally on harsh mine land coal spoils in Pennsylvania (20). Reviews by Marx (11) and Cordell *et al*. (4) discussed improvements in survival and growth of seedlings with ectomycorrhizae on these sites. Maximum benefits were obtained on the coal spoils having higher temperatures, lower pH, and greater moisture stress.

Foliar analyses of seedlings with Pt ectomycorrhizae from mined sites show increases in macronutrients and reduced levels of potentially toxic microelements. Marx and Artman (13) found significantly more N and less S, Fe, Mn, and Al in seedlings with Pt than those with natural ectomycorrhizae on acid coal spoils in Kentucky. On mine spoils in Tennessee and Alabama, Berry (1) measured significantly lower levels of Mn in needles of Pt seedlings than in needles of control seedlings.

Consequently, these and other field planting results strongly suggest the ability of Pt and other selected species of ecto and endomycorrhizal fungi to mediate adverse factors on mine land sites. Research has shown that root systems with abundant ecto or endomycorrhizae also are apparently more effective and efficient in extracting water and essential nutrients from soil during periods of extreme water stress than root systems with either fewer or less adaptable mycorrhizae. In southern Ohio, virginia, eastern white, and loblolly x pitch pines and northern red oak (*Quercus rubra L.*) seedlings with Pt ectomycorrhizae have exhibited significant increases in tree survival and reforestation success when compared with standard nursery seedlings (Table 1) (17).

Table 1. Tree survival and reforestation success following use of Pt pine and hardwood seedlings in 356 reforestation plantings on abandoned mine lands in southern Ohio, 1982 to 1998.

Seedling Treatment	Average Survival %	Planting Success %
Pt-inoculated	85	95+
Noninoculated [1/]	<50	<25

[1/] Reforestation planting efforts using standard nursery seedlings prior to the Pt program

The great diversity of mine land and other severely disturbed sites to planted seedlings with specific mycorrhizae have revealed a number of factors that influence the success or failure of reclamation. Field results continue to demonstrate dramatic increases in survival and growth of MycorTree™ seedlings on sites with adverse pH (acid or alkaline), excessive levels of phytotoxic elements, prolonged moisture stress, high surface temperatures, and low nutrient availability. Exceptions may occur on severely compacted and/or high bulk density soils where increased MycorTree™ survival may be followed by a slowing of growth. Compacted and/or high bulk density soil conditions are most effectively mitigated by subsoiling or deep ripping prior to planting (2). Some ectomycorrhizal fungi, such as Pt, develop well and provide significant tree survival and growth benefits on porous, course, droughty sites but reduced benefits on poorly drained high bulk density soils .

Case Studies

Ohio Abandoned mine land Reforestation Program. One of the best examples of the practical application of this fungal technology is in Ohio. After reviewing the successful results of the field research and demonstration program, the Ohio Division of Mine Land Reclamation established the following criteria in 1982 for the use of tree seedlings with Pt ectomycorrhizae in their abandoned mined land reforestation program (3):

1. The strip-mined sites, gob piles, or industrial mineral sites must have been abandoned since 1972, with no present potential for full-scale reclamation.
2. The sites must presently be barren, eroded, and without adequate stabilizing vegetation.
3. The remaining potential of the site is nonexistent with no full-scale reclamation efforts (grading, topsoiling, fertilizing, and seeding) either proposed or likely to occur on the site.
4. The target sites also must have a history of off-site damage such as sedimentation that has resulted from the site's present condition.

During the past 18 years, the goals and priorities of the Ohio reforestation program have evolved into planting Pt pine and hardwood seedlings to provide a low-cost, low-maintenance, effective reclamation alternative for mined areas that contribute minor quantities of sediment to streams, degrade aesthetics, lack adequate ground cover, and are not eligible for traditional reclamation techniques under federal abandoned mine land guidelines (3). Reclamation plans also must be developed far enough in advance (one to two years) to allow adequate time for seedling production and for administrative planning and decision making.

Since its inception in 1982, the Ohio Abandoned Mine lands Reforestation Program has planted over 5 million PT-inoculated pine and oak seedlings on over 3,000 acres of unreclaimed AML sites (Figure 4). The typical site is barren, eroded with a mixture of bench slopes and out slopes of 2:1 or steeper terrain. Over 95% out of 350 plus sites have been hand-planted by local contractors. The sites also are highly acidic (pH 2.9-3.4), and no soil amendments (ie., lime, fertilizer, or water irrigation) are used. Tree survival has averaged over 85 % in the PT-inoculated tree plantings with less than 5% tree failures as compared with less than 50% survival and over 75% failures in previous plantings with the same noninoculated tree species (17). From 1982 to 1998, the Ohio AML reforestation project with PT-inoculated trees has cost approximately $900,000 or $300/acre. In 1998, approximately 340,000 PT-inoculated seedlings were planted on 242 acres at a cost of $195,000 or $805.00/acre. This represents an approximate 87% cost reduction as compared with conventional mine land reclamation methods ($6,000/acre). The Pt seedling inoculation cost is only $35.00/acre ($.02/seedling) or about 4% of the reforestation cost, which is relatively minute when compared to the consistent tree survival and early growth benefits obtained on these highly disturbed stressful sites.

Utah Copper Mine Site. This Utah copper mine has been active for over 100 years and has disrupted more than 20,000 acres of land. The disturbed areas have extensive erosion, sedimentation of drainages, dust hazards, and little or no satisfactory vegetation. The waste dump slopes are 1.5H:1.0V or steeper with highly acidic conditions. There also are numerous borrow areas with gravelly conditions and several large areas of mill tailings. There is little suitable topsoil readily available and subsoils range from poor to unsuitable quality. This high altitude mining site has low precipitation with freezing winter and hot summer temperatures.

Figure 4. Abandoned mine land (AML) Paxton Site – Perry Co., Ohio, Preplant- 1985 (top photo) and reforested with eastern white and virginia pines – 1991 (bottom photo). The spoil pH is 2.8 with available phosphorus at less than 5 ppm. Tree measurements in 1992 showed a survival of 98%, average basal diameter of 2 inches and average height of 9.5 feet.

The primary reclamation objectives on the mine waste dumps were to mitigate the production of acidic water, stabilize the dumps, mitigate soil erosion and dust, establish vegetation, and return the dumps to wildlife habitat use. The reclamation objectives for the borrow and mill tailings areas were to establish vegetation, eliminate dust hazards, mitigate soil erosion, and return the land to beneficial use (17).

The PHC-Reclamation, Inc. approach to revegetation of this mining area was to use the natural systems solution. It involved the selection of site-suitable plant species based on results from initial test plots. The best combination of site, plant species, and specific mycorrhizal fungi were identified and used in conjunction with other my-corrhizal fungi to provide suitable survival and growth benefits to tree and shrub seedlings and to grasses, forbs, and shrubs started from seed on site. Biosolids were used as a soil amendment to improve the initial adverse physical, chemical, and plant nutrient problems of some of the low quality soils (14).

Unique reclamation equipment for VAM fungal inoculation, seeding, and erosion mitigation also was developed. VAM fungal spores and beneficial bacteria in pelletized form were developed for easy and controlled field inoculation.

A container-grown tree and shrub seedling production program was established in a local tree nursery that included protocols for custom inoculation of trees and shrubs with specific ectomycorrhizal or VAM fungi and bacteria. The ectomycorrhizal fungi included Pt and a similar puffball-producing fungus, *Scleroderma cepa,* isolated from an eastern coal mined site. The VAM fungi included a species isolated from sagebrush growing on undisturbed native soil near the mine site and, also, a “cocktail” of several selected VAM fungal species isolated from other plant species in different physiographic locations.

The results have been very positive. The client's objectives have been met and compliance has been achieved with regulatory agencies. Several thousand custom seedlings have been grown in the nursery and planted on the reclaimed areas. Survival and growth rates of preinoculated trees and shrub seedlings and the grasses, flowers, and shrubs inoculated at seeding, are significantly better than the noninoculated plants.

By using the natural PHC Reclamation, Inc. biological approach to solve their revegetation problems, the client has experienced a reduction in costs ranging from 40 to 80 percent depending on the type of area being reclaimed. Savings in both short-term project reclamation work and long-term maintenance are included. Typically, reclamation and revegetation establishment costs, minus recontouring, were reduced from a range of $8,000 to $13,000 per acre to less than $1,000 (without soil placement) to $5,000 per acre (with soil placement).

Conclusions

Consistent research and field demonstration results obtained during the past two decades clearly demonstrate the benefits of utilizing selected ecto and endomycorrhizal fungi for the custom production and/or field inoculation of MycorTree™ seedlings, native shrubs, forbs, flowers, and grasses for application in mine land reclamation programs. Reforestation with selected MycorTree™ pine and hardwood seedlings is presently receiving widespread interest as a viable alternative in abandoned mine land reclamation programs in the eastern United States. Positive results have been obtained from the environmental extremes occurring in the moist East to the arid West of the United States. Major scientific breakthroughs in recent years have led to the commercial production of a variety of MycorTree™ products and their practical application in tree seedling nurseries, forestation, and mine land reclamation sites. Advanced technology discoveries also have revealed the role of a “total intergrated package” in successful mine land reclamation programs. The package includes consideration of site factors such as pH, toxicity, and compaction. Adopting remediation practices such as subsoiling and soil amendments, using of unique reclamation site seeding/inoculating equipment, and selecting the most compatible plant species and mycorrhizal fungi for the planting site are combined in a holistic approach to effective practical mine land reclamation.

This “natural systems environmentally friendly approach” to successful mine land revegetation is available through a team of scientific and business experts offered by PHC Reclamation, Inc. Reclamation costs vary considerably depending on the products and services requested by the client and the location and complexity of the mine site.

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KENTUCKY REFORESTATION CASE STUDY

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Introduction

Achieving a postmining land use of forest land is possible under the accepted interpretation of Public Law 95-87. However, as a forester, site index, tree quality, and species composition will be significantly different than the forest that originally occupied a mining site or what was attainable on ungraded or limited graded sites. What we have come to accept as forest land is a shrubby conglomerate of good surviving species with little or no foreseeable economic value.

Historically speaking it was obvious to operators that tree failures, which began with grading and revegetation requirements in the mid 1960s, combined with the great success of grass and legume systems in the 1970s, all spelled the demise of tree planting with the inception of Public Law 95-87. Revegetation to stop erosion on long compacted slopes was the primary concern.

While most operators in western Kentucky began wholesale use of the pasture/hayland postmining land use, Peabody Coal Company made a concerted effort to retain the forest land use. Nearly all the "tail-gate" research I am about to discuss was done on Peabody Coal Company lands. Together with my colleague, Brent Gray of Peabody Coal, we have tried and are still trying different methods to produce a productive forest.

History of Reforestation Efforts

Beginning in 1977 and later in 1980 when I joined Brent, the most compelling puzzle was the stark differences between the old nongraded sites and the current law. The old sites contained vigorous stands of quality hardwoods and pine. Post grading sites were characterized by stunted, irregularly stocked areas of autumn olive, black locust, black alder, bicolor lespedeza, and others. Higher quality species disappeared or existed only as resprouts. Although we were aware of the concern over grass competition and compaction, many of the areas we inherited were already seeded to tall fescue and alfalfa. Initially, site preparation was of less concern than planting stock quality and planting care. We were certain that if we addressed these issues, we could recreate the impressive stands on prelaw sites. We also expanded the species composition to include many oaks and other commercial hardwoods. Strict guidelines were imposed on our stockmen and tree planters. We also had an outside planting contractor come in so we could compare his work with our normal crews. As a rule, most trees were surviving very well through the spring and early summer. By the end of the summer, stocking rates were dropping drastically.

In the early 1980s, tree planting was on a relatively small scale (about 250,000 trees per season). It was generally accepted that a site would have to be replanted two to three times before stocking rates would be high enough for possible bond release. As tree acres increased in the 1980s (1.4 million trees in 1987), it became quite costly to keep replanting. In an effort to determine when trees were dying and what was causing mortality, we set up inventory plots at several mine sites in 1990. Plots were inventoried monthly. The results showed that we were losing most of our seedlings in August when our normal drought occurs. This was true not only of first year trees, but also for second and third year trees. By late winter rodents also were girdling surviving trees.

Seeing that our "quality" tree efforts were producing only limited increases in seedling survival, we started experimenting with herbicide applications. We made use of a wide variety of both pre and postemergent herbicides to control herbaceous vegetation. We have had mixed success with herbicides: application is another added cost; caution has to be used as to application rates; and in-house modifications need to be made to develop a sprayer that works in a specific situation. For example, in our rolling hill situation, we were forced to eliminate multirow boom

sprayers because of uneven application. We feel that herbicide application is an absolute must in western Kentucky

regardless of what type of permanent ground cover is used. I should mention that we also tried scalping grass competition and had very poor results. I don't recommend scalping.

By the mid 1980s, we began to realize that compaction was a more serious problem than we anticipated. Our first ripping experiment was done at Gibraltar Mine in Muhlenberg County, Kentucky. A thirteen-acre site was selected. In 1983 the site was revegetated to a tree compatible ground cover, strip sprayed, and ripped with a single shank ripper to a depth of 12" to 18". The site was hand-planted with high quality 3' to 4' bare-rooted seedlings from International Paper. This area developed into our best example of post-SMCRA tree planting. However, a similar site less than a quarter mile away was totally devastated by voles. We are finding that single shank ripping creates a vole tunnel. We now use multishanked rippers that shatter a three-foot wide zone. We feel that the lateral loosening of the soil greatly benefits tree growth.

We don't know how long the ripping effect will last. We may be only widening the problem we observed with single shank ripping. We excavated thirteen-year-old trees in our Gibraltar study and found the root system following the ripper crevice much like a phone cable. We are concerned about the stability of the trees.

This is a rather simplified discussion on the depth of our ripping experiments. Use of large dozers/tractors pulling large multishanked rippers are costly to operate, pull up many rocks, and require a very large capital investment. Although we haven't done any serious comparisons of row ripping versus block ripping over a period of time, block ripping may be more beneficial to a site. It is our opinion that ripping not only increases survival but greatly increases initial growth.

Over the years we have changed our permanent ground cover species to be more tree friendly. The particular mixes are not important. There are publications full of the perfect mix. What we have found is that on a typical site in western Kentucky, any grass legume ground cover is detrimental to tree survival. We feel that herbicides are critical in the reduction of ground cover. Permanent ground cover is not only physically competitive to trees but it is a natural habitat for voles. Voles have devastated hundreds of acres of our tree planting. To get a better understanding of how many voles were actually on our sites we set up three vole traps at Ken Mine in Ohio County, Kentucky, and checked them regularly for thirteen months. A trap consists of two fifty-foot long pieces of three-foot metal flashing arranged in a cross pattern. A five-gallon bucket is set at ground level at the end of the pieces of flashing. We captured eighty-five voles and forty-one white-footed mice.

In an effort to delay the establishment of permanent ground cover to see what influences this had on tree survival, we selected an area at Alston Mine in Ohio County, Kentucky. The area was roughly two hundred acres in size. A sorghum sudan grass cover crop was seeded on the area in the spring of 1988. The cover crop was allowed to winterkill. Trees were planted in the spring of 1989. After planting the site was aerially seeded. The planting was generally a success, however, voles damaged some sections and spot replanting was done in 1990. Although this method produced a successful planting, rodent damage is a tremendous problem and is as important a factor as compaction and grass/legume competition.

Stocking Rates

The original stocking rates that we had to deal with was 450 trees an acre for forest land. This was a crucial problem early on with operators shifting away from forest land postmining land use. After countless discussions with state and federal regulators, it still took nearly fifteen years for someone to realize this stocking level was way above timber industry standards. The stocking levels in Kentucky have dropped to 300 trees per acre, but I don't know if it will have any effect at this time.

Species Selection

We have tried dozens of various species over the years. Our main objective was to try to find hard mast (oak) and pine that would survive. We gave up a long time ago on species such as black walnut, yellow poplar, and northern red oak. Pines are continuing to be a problem.

We have determined over the years for our situation that willow oak and bur oak have the best survival of all the oak

species that we have tried. Green ash will survive; however, it rarely becomes a tree of good form. Sycamore, autumn olive, and silky dogwood are still the main stays and show the best survival. Virginia and loblolly pine have very spotty survival.

Direct Seeding

In conjunction with Jim Powell, the first experiments we started were direct seeding of tree species in an effort to stave off tree planting and be able to get a better species selection as well as extending our planting window. We established an extensive plot area of both large mast and light seeded species at Sinclair Mine in Muhlenberg County, Kentucky. These areas used various grass species ground covers as well as no vegetation. The success rate was so low that we abandoned the plots. The experiment was replicated at Gibraltar Mine in Muhlenberg County, Kentucky with the same results.

We gave chestnut oak and bur oak some more attention a few years later in our reforestation planting and have had mixed results. One year the tree crews direct seeded 10,000 pounds of chestnut oak alone. We also had some success hydroseeding eastern red cedar on final impoundment slopes. It is our conclusion that direct seeding has a very limited niche in the climate, soils, and ground cover requirements of western Kentucky and should not be used as the primary method of reforestation.

Topsoil vs. Spoil

It is fairly obvious that even very acid spoils in Western Kentucky will support good tree growth if left uncompacted. But, in 1990, we felt compelled to set up a side by side comparison of graded spoil versus graded spoil with six inches of replaced topsoil. The area had been in woodland before mining and is located at Ken Mine in Ohio County, Kentucky. Both the spoil and the topsoil were slightly acid and fairly normal. The areas were revegetated with the same grass/legume mix and were treated the same as far as discing, fertilizing, liming, etc. Loblolly and virginia pine as well as various hardwoods and shrubs were planted in subplots. Planting was done on a 4 X 4 spacing or 2,722 trees per acre. The entire eight-acre experimental area was planted by a crew of three experienced planters and a great deal of care was taken to keep the seedlings in good condition.

The results were inconclusive. Neither treatment was clearly superior for tree establishment. It can be assumed that replacing what was considered topsoil in this area was much more costly than no replacement. The most puzzling problem from this experiment was the continued mortality for the planted trees and shrubs.

Hoedad vs. Dibble Bar

There has been much discussion that the hoedad is an inferior tool for tree planting. Most contract planters use the hoedad because of the speed of planting. Traditionally our in-house crews have and still use the dibble bar.

We set up an experiment in at Ken Mine in Ohio County, Kentucky in 1997 on a site that had a topsoil variance. The experiment consisted of comparing hoedad, dibble bar, and shovel planting. The area was strip sprayed and every other row was ripped with a multi-shanked ripper. Virginia pine, bur oak, and sawtooth oak were used in the experiment. No root pruning was allowed. Results showed that the hoedad planting was more successful than the dibble bar or shovel for the first year of survival. The ripped rows were far more successful than the unripped rows for each of the planting tools. From our experience and from examining sites in other states, we feel that unsupervised contractors combined with heavy root pruning may be more detrimental than the type of planting tool used.

Tree Spade

In the early 1980s, we had access to a forty-four inch Vermeer tree spade. We set up some experimental areas to see if we could get large trees to act as bird roosts and possibly encourage natural regeneration. Also we hoped that these trees would be close to seed production age. This experiment was extremely expensive and was soon abandoned. The trees we planted survived but growth had been retarded.

Tree Source

Over the years we have tried seedlings from a broad spectrum of nurseries. Pine survival is a serious problem for us. In our experience we have found a slightly higher survival for container pine versus bare root pine. We also have noticed that bare-root seedlings from the major timber companies have a slight to moderate increased survival and growth rate over state nursery trees.

Conclusion

After 20 years, over 17 million trees, and millions of dollars, it is our conclusion that soil or spoil compaction due to the current interpretation of grading in western Kentucky is by far the most detrimental problem in developing a healthy, profitable forest land postmining land use for future generations to enjoy. We can only hope that we can now reproduce the forests that we have enjoyed that were planted in the 1940s to 1960s.

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FOREST PRODUCTIVITY OF RECLAIMED MINED LAND: A LANDOWNER'S PERSPECTIVE

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Introduction

Since 1977, Public Law 95-87 drastically altered surface mining and reclamation practices. One important aspect of this law is the attention that it gives to future land use opportunities of reclaimed land. The intent of the law is to ensure that surface mined land is reclaimed to a condition capable of supporting a productive land use. As a result, coal companies must specify a postmining land use for which the land will be reclaimed. Furthermore, productivity standards were established for various land uses and coal companies must post a performance bond that can only be returned if the performance criteria for the specified land uses are achieved. Theoretically, re-claimed sites which satisfy bond release criteria after five years and have been successfully reclaimed are capable of being used for the intended postmining land use.

In the central Appalachian region of Kentucky, West Virginia, and Virginia, where prime farmland and economic development opportunities for mined land are scarce, the most practical land-use choices are hayland/pasture, wildlife habitat, or forest land. Since 1977, most of the mountainous mined land in Kentucky, Virginia, and West Virginia has been reclaimed as hayland/pasture or wildlife habitat, which is less expensive to reclaim than forest land since there are no tree planting costs. This method of reclamation has been encouraged by many land holding companies to help their coal lessees meet the requirements of regulations in the reclamation laws and at the same time keep the mining companies from absorbing extra reclamation costs. This has resulted in many acres of land producing grass, shrubs, and legumes, but few trees.

Forestry is the most logical and economical land use for large tracts of reclaimed land in the Appalachians. Most of this land was forested before mining and, whether by design or through natural succession, this land will ulti-mately return to a forested condition. The author of this paper is involved in forest management for Pocahontas Land Corporation (PLC), a large landholding company, which owns thousands of acres of surface mined land. Pocahontas would like to manage its reclaimed mined land for commercial forests, where it is economically fea-sible to do so. Timber production is often the only economically feasible land use for large tracts of steep and remote mined land. Furthermore, the economic returns on productive forest land can be very good; however, the key term is **"productive forest land."** Unfortunately, in recent years, as landowner interest in managed forest land has increased, it has become increasingly apparent that current reclamation and regulatory practices limit the creation of productive forest land.

Each year numerous photographs of award winning reclamation projects are published in various trade magazines. In all cases, these photos depict smoothly contoured surfaces with lush ground cover. For landowners with a long-term interest in timber production, these award winning reclamation projects represent lost opportunities. The presence of the tall and lush vegetation indicates that no trees are present and probably will not be established until several years after bond release. If trees have been established, they will be severely impacted by thick ground cover competing for sunlight, nutrients, and moisture. For each year the site is used to grow forage species, an additional year will be required if the site is converted to a commercial forest. The smoothly contoured surfaces of award winning reclamation projects indicate compacted surface soils that are not capable of supporting good tree growth once trees are established. The combination of delayed tree establishment and reduced growth rates will drastically reduce landowners' opportunities to derive future economic benefits from reclaimed mined land. From the landowner's perspective, these award winning reclamation projects are areas where the long-term land use opportunities are sacrificed for immediate cosmetic enhancement, but landowners simply have not had a practical

and workable alternative. It is very difficult to require mine operators to employ a postmine land use that would add costs to reclamation operations and increase risk of not obtaining bond release within the specified five-year period.

In 1986, Pocahontas Land Corporation began a cooperative research project with Virginia Tech to examine some of the problems associated with tree establishment on reclaimed surface mine lands, including compaction. The results of this study showed that good tree growth could be attained by creating a "quality" site prior to tree planting. A set of guidelines was developed that coal companies could follow to establish more productive forests, and at the same time create adequate ground cover to satisfy current reclamation laws. With this information Pocahontas has encouraged its coal lessees to apply for forest land as the postmine land use when possible.

Case Studies

The purpose of this paper is to bring your attention to the impact surface mine reclamation has on site productivity and returns on investment. The data used in the case studies is based on two research projects conducted on lands of PLC. The first study contrasts the impact of site productivity and management decisions on the economic returns and timber production. The first scenario represents a common situation in the central Appalachians; land is reclaimed as hayland/pasture or wildlife habitat, and the landowner decides to plant trees after release of the reclamation bonds. Trees grow poorly as a result of compaction and harvest value is low. Some trees are lost to the competing ground cover in the year after planting. In the second scenario, the postmining land use is forest land and the coal company specifically reclaims the land to maximize forest productivity. Although this type of reclamation is not widespread, it is feasible.

A second study, established in eastern Kentucky in 1990, shows that forest productivity and landowner's return on investment was maximized by selecting an oxidized sandstone spoil, avoiding compaction by eliminating the "tracking in" procedure, and using a tree-compatible ground cover to control erosion while allowing seedling establishment. In this study, site productivity, tree growth, and value are compared using three degrees of soil compaction, all other factors being equal.

Assumptions for each of the reclamation scenarios with respect to tree planting, grading costs, forest productivity, timber yields, and harvest values are as follows:

Case 1
Hayland/Pasture Reclamation Scenario

- Land is reclaimed as hayland pasture in year 1 and bond is released in year 5.
- After bond release, landowner plants 454 white pines at year 5 on an 8' x 12' spacing at a cost of $0.30/seedling ($136.20/a)
- Site index of the land is 60; compaction caused by intensive grading practices during reclamation limits productivity, only product produced is pulpwood.
- 65 percent reach harvest (295 trees)

Pulpwood

- After 30 years, trees have been growing for 25 years.
- At year 30, there will be an estimated tons/a of pulpwood.
- The stumpage price will be $2.00/ton; the average diameter of the trees will be 8 inches and average weight will be 0.125 tons giving the stand a weight of 36.9 tons/a; these trees can only be used for pulpwood, mine props, or other low value products.
- The timber harvest value will be 36.9 tons/a x $2.00/ton = **$73.80/a**.
- Land management cost and land tax cost the landowner $1.50/a annually.
- Rate of return to the landowner = **Negative 4.11 Percent**.

Forest Land Reclamation Scenario

Pulpwood

- Land is reclaimed as forest land in year 1 and bond is released in year 5.
- As part of the commercial woodland postmine land use, the coal company plants 454 white pines per acre at year 1 at a cost of $0.30/seedling ($136.20/a)
- Site index of the land is 100; the coal company is careful to avoid compaction; minimal grading on level areas, short slopes, and gentle slopes; "tracking in" before seeding is eliminated on all but steepest slopes, and with low growing groundcover, seedling survival has increased to 90 percent.
- Reduced grading costs saves coal company $225/a (3 hrs. of D-7 @ $75/hr.) which more than offsets the cost of planting trees.
- At year 17 the pines are thinned and pulpwood is removed leaving half the trees with a spacing of 12' x 16' with 202 left to grow into saw timber, pulpwood harvest generates .08/tree or 16.2 tons/a.
- Income generated at age 17 is 16.2 tons x $2.00/a = **$32.40/a**.

Saw Timber

- At year 30, trees have been growing for 30 years, and 203 trees will be harvested as small saw timber having a diameter of 14 inches and a volume of 50 board feet Doyle Scale.
- There will be 10,150 board feet of merchantable timber.
- The stumpage price will be $50/MBF; and the harvest value will be 10.15 MBF/a x $50/MBF = **$507.50/a**.

Pulpwood

- At year 30, there will be 37.56 tons/a of additional pulpwood harvested from topwood.
- The stumpage price will be $2.00/ton.
- Pulpwood value will be 37.56 tons/a x $2/ton = $75.12/a.
- Total value at harvest will be $507.50/a + 75.12/a = $582.62/a.
- The total income from this property for the 30 years was $615.02; costs associated with owning the land were $1.50/a for management and land tax.
- The rate of return for the landowner for this investment was **16.08 percent**. (See Table 1.)
- The coal company's cost of planting trees ($136.20/a) is offset by the savings resulting from less grading ($225/a); the net **savings to the coal company is $88.80/a**.

Case 2

In our second study, the effect that compaction, spoil type, and groundcover had on rates of return of yellow poplar was investigated. Yellow poplar was targeted because it is a relatively fast growing species like white pine, and the saw timber is worth twice as much to the landowner at harvest time. (See Table 2.)

Site index 60

- Heavily tracked site yields only pulpwood at harvest time; survival rate is 50 percent.
- As part of the commercial woodland postmine land use, the coal company plants 454 white pines per acre at year 1 at a cost of $0.40/seedling ($181.60/a).
- At year 30, 227 trees/a are harvested yielding an average of 64.24 tons/a for a value of $128.48/a.
- Taxes and management costs are $1.50 annually. Pulpwood price is $2/ ton. Yellow poplar saw timber price is $115/MBF.
- **The rate of return for site index 60 is a negative 2.20 percent**.

Site index 80

- Moderately tracked site yields pulpwood at a thinning in year 20, and saw timber and pulpwood in year 30;

survival rate is 80 percent.

- The coal company plants 454 trees for a cost of $181.60/a. Taxes and management costs are $1.50 annually.
- At year 20, 182 trees/a are harvested in a thinning operation yielding an average of 22.75 tons/a for a value of $45.50/a.
- At year 30, 181 trees/a are harvested for saw timber, and the topwood is sold as pulpwood. Yellow poplar saw timber averages 13"dbh and yields 65 board feet Doyle Scale for a total saw timber yield of 11,765 board feet/a for a value of $1,352.97/a. Pulpwood yield is 22.62 tons/a for a value of $45.24/a.
- **Total revenue generated for site index 80 is $1,443.72. Rate of return is 7.14 percent**.

Site index 100

- Minimal compaction yields pulpwood at a thinning in year 17, and saw timber and pulpwood harvest in year 30; survival rate is 90 percent.
- The coal company plants 454 trees for a cost of $181.60/a. Taxes and management costs are $1.50 annually.
- At year 17, 288 trees/a are harvested in a thinning operation yielding an average of 36 tons/a for a value of $72/a.
- At year 30, 166 trees/a are harvested for saw timber, and the topwood is sold as pulpwood. Yellow poplar saw timber averages 16"dbh and yields 140 board feet Doyle Scale for a total saw timber yield of 23,240 board feet/a for a value of $2,672.60/a. Pulpwood yield is 29.05 tons/a for a value of $58.10/a.
- **Total revenue generated for site index 100 is $2,802.70. Rate of return is 9.8 percent**.

An additional comparison was made showing the effects soil compaction mediation has on site quality and return on investment. By ripping up a compacted site an additional cost of $155/a is incurred to the landowner. A good site is created after ripping the ground, but the cost reduces the landowners rate of return to **7.52 percent.** If the site was created properly at the time of soil placement, the return on investment would have been **9.8 percent,** and if the coal operator and landowner were sharing the cost of tree establishment the rate of return could have been **12.34 percent.** (See Table 3.)

Advantages to Landowners

These scenarios are plausible representations of typical and potential reclamation practices. Although specific cost and revenue values will vary from case to case, the relative comparison will remain valid. The timber yield and harvest value will always be greater when land is carefully reclaimed to maximize forestry land-use opportunities. When site productivity is damaged by compaction (as indicated in the hayland/pasture scenario), long-term tree growth may not be sufficient to justify the cost of tree planting. Under these conditions, the land is essentially useless to the landowner; taxes and management costs will have to be paid on the land even though timber cannot be profitably grown, and other land-use opportunities are limited. In most cases, the landowner will have trouble selling the land since there is little demand for large tracts of isolated, unproductive tracts.

Advantages to Coal Companies

This paper deals with the situation where the landowner and coal company are separate entities. Although this paper concentrates on the advantages of forest land reclamation to the landowner, the author recognizes that coal companies cannot be expected to incur additional reclamation costs to maximize future economic opportunities for the landowner. Fortunately, coal companies can save money by using reclamation practices that will maximize forest productivity. The cost of planting trees will be offset by savings associated with reduced grading and the use of a tree compatible ground cover. In many cases, coal companies will be able to achieve bond release with forest land more quickly than other postmining land use plans. Experience has shown that careful planting in a loose, uncompacted mine soil in the absence of dense herbaceous vegetation will result in good tree establishment and rapid growth, which will result in release of reclamation bonds in five years. Often, bond release is delayed on grass and legumes type reclamation and the coal company incurs additional costs for gully repair and reseeding. Even when forage production is adequate to satisfy bond release requirements for hayland/pasture, the process of documenting productivity via biomass sampling can be more expensive than documenting ground cover and tree

stocking levels for bond release on forest land.

Advantages for Environment

A fundamental purpose of PL 95-87 is to provide environmental protection. Some reclamation inspectors have argued that attempts to increase forest productivity by reducing grading activities and using less competitive ground covers will result in more erosion and environmental degradation. To the contrary, long-term environmental protection will be enhanced by practices which promote the development of a healthy forest ecosystem. The root system of a fully stocked, healthy forest will stabilize slopes. The litter layer which develops beneath the closed canopy of a healthy forest increases water infiltration into the soil and reduces soil erodibility to virtually zero. Regional biodiversity in the central Appalachians can be increased by establishing a mix of coniferous and hardwood species since this region is typically dominated by deciduous species such as oak, hickory, red maple, and yellow poplar. In some parts of the Appalachians the establishment of pine forests will increase wildlife populations by providing a much needed source of visual and thermal cover for winter protection, while the oaks and hickories will provide hard mast.

Conclusion

The author of this paper is involved in forest management for a company with vast landholdings in the central Appalachian coal fields. This landowner believes that long-term forestry land-use opportunities of surface mined land are still being sacrificed for short-term cosmetic benefits. The reclamation community should recognize the long-term implications of reclamation practices and understand that reclamation must be land-use specific. Productive forests can be created at the time of reclamation which would benefit both the coal operator and landowner. Hopefully someday soon, landowners will economically harvest trees from surface mined lands that were once reclaimed to roughly graded, uncompacted mine spoil which greatly resembles the natural state of the land before mining as Public Law 95-87 intended.

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