REVEGETATION OF ABANDONED MINE LANDS IN PENNSYLVANIA WITH CONTAINERIZED SEEDLINGS AND SOIL AMENDMENTS[1]

by

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Abstract. In 1977, a study was initiated in central Pennsylvania on the feasibility of revegetating barren abandoned mine lands with containerized red pine (*Pinus resinosa*) seedlings in combination with various soil amendments and herbaceous seed mixes. The sites selected had low nutrient availability, high acidity (pH 3.0 to 3.3), and high exchangeable Al. Vegetation was lacking even though tree seedlings had been planted following completion of mining in 1968-69. Variables tested were location (3 sites), soil amendment (none, lime, lime + fertilizer, lime + fertilizer + mulch), seeding mix (none, deertongue grass + birdsfoot trefoil, KY-31 tall fescue + birdsfoot trefoil), and seedling type (2 + 0 bare-root seedlings, Japanese paperpot seedlings). There were 144 plots with 20 trees per plot. In 1989, 12 growing seasons following planting, over-all survival was 71.5%. The only significant differences in survival involved seedling type; bare-root seedlings had significantly higher survival than Japanese paperpot seedlings at one location (Renovo), but not at the other two. There were significant differences in tree height among amendments, with mean heights of 3.0, 3.7, 4.4, and 4.4 m for no amendment, lime, lime + fertilizer, and lime + fertilizer + mulch, respectively. No other variables and no interactions were significant with respect to tree height. Supplemental studies in subsequent years showed that: (1) other types of containers had survival and height growth rates similar to those of the bare-root and Japanese paperpots in the main study; and (2) survival was high after 10 years for all plantings done during three consecutive years.

Additional Key Words: *Pinus resinosa* Ait., reclamation, bare-root seedlings, herbaceous seed mixes, survival, tree height.

Introduction

In 1977, the Surface Mining Control and Reclamation Act was passed to regulate surface mining and reclamation of mine lands in the U.S. Title IV of the act specified funds for the reclamation of abandoned mine land through a levy on each ton of coal mined. This provision was of special importance to Pennsylvania where an estimated 159,000 acres had been abandoned and were in need of some reclamation activity (Grim and Hill 1974). It was apparent the funds generated from the tax on coal produced would not be nearly enough to reclaim all of the abandoned mine land according to the standards in the federal law. Therefore, a priority system was established which provided for complete reclamation only on those sites posing a threat to public safety and welfare. Less emphasis and money were allocated for sites with environmental problems (e.g. those that were barren and/or producing acid mine drainage).

A vegetative cover would reduce environmental problems associated with these low-priority abandoned mine lands. Erosion would be reduced, aesthetics would be improved, food and habitat for wildlife would be created, and possibly wood products would eventually be produced. Therefore, inexpensive methods to produce or generate some vegetative cover needed to be developed. This was the overall objective of a series of studies begun in 1977 in the bituminous region of

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Pennsylvania. The underlying considerations of the studies and justification for them are:

1. Species. The choice was red pine (Pinus resinosa), since it performs well on a variety of mine sites in Pennsylvania. Including other species in the study would increase its complexity and cost and probably yield little information in addition to that obtained in past species trials on abandoned mine lands, such as that by Horn and Ward (1969).

2. Seedling type. Almost all of the red pine seedlings previously planted on mine lands had been two-year-old seedlings raised in conventional nursery beds and planted in a bare-root condition. However, in various parts of North America, use of containerized seedlings was growing in popularity. The qualities possessed by such seedlings (Tinus 1974) might enable them to survive and grow better than the bare-root stock when planted on adverse sites. Therefore several types of container-grown seedlings as well as bare-root nursery stock were considered for use in the study.

3. Soil amendment. Abandoned mine lands in Pennsylvania are characterized by high acidity, low available nutrients, and, in many cases, toxic levels of aluminum. They are low in soil-moisture capacity and are often subject to high surface temperatures. Therefore, various combinations of lime, fertilizer, and mulch were included in the study.

4. Herbaceous seed mixes. Planted tree seedlings provide negligible cover for several years following planting. In order to achieve a more immediate vegetative cover, it is necessary to apply an herbaceous seed mix, preferably containing at least one legume species. Cool-season grasses have usually been used, although there are indications that warm season grasses are less competitive with newly established tree seedlings and, once established, provide a longer-lasting cover. Therefore a mix containing a cool-season grass, KY-31 tall fescue (Festuca arundinacea), was compared to one containing a warm-season grass, deertongue grass (Panicum clandestinum). Each contained a legume, birdsfoot trefoil (Lotus corniculatus).

Main Study

Procedures

In 1976, three study sites were selected in various parts of the bituminous region of Pennsylvania (Figure 1). All three sites had previously been planted with tree species, but for one reason or another, survival was nil. The sites, named for the closest large town, were:

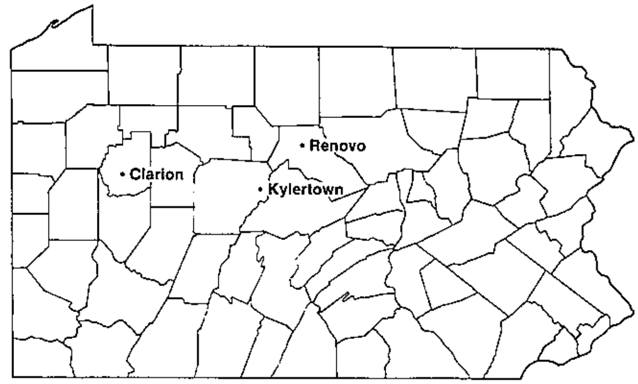

Fig. 1. Location of abandoned mine land study sites.

1. Kylertown. Approximately 10.5 km north-northwest of Kylertown; Lower Kittanning seam; mining completed in 1969; average pH 3.3.

2. Clarion. Approximately 14.5 km southwest of Clarion; Upper and Lower Kittanning seams; mining completed in 1968; averaged pH 3.2.

3. Renovo. Approximately 7.2 km northwest of Renovo; Lower Kittanning seam; mining completed in 1968; average pH 3.0.

A randomized complete block design with split plots provided a factorial experiment at each location. There were two replications, each containing four major plots, with six split plots in each major plot. The major plot factor was amendment (control, lime, lime + fertilizer, lime + fertilizer + mulch). The split plots contained all possible combinations of two factors, seeding mix (control, KY-31 tall fescue + birdsfoot trefoil, deertongue grass + birdsfoot trefoil) and seedling type (2 + 0 bare-root nursery stock, seedlings grown in Japanese paperpots (Hodemaker 1974), with individual containers of 3.8 cm in diameter by 15 cm in length, in the greenhouse for an extended growing season). Each split plot contained 20 trees planted on a 7-ft x 7-ft (2.1 m x 2.1 m) spacing.

The study was originally designed to include two additional types of containers, the Tinus Spencer-Lemaire book planter (Spencer 1974) and multi-seedling pots, a relatively new concept in container technology. The multi-seedling pots had a top diameter of 18.5 cm and a height of 19.0 cm. Each had a maximum of 12 seedlings per container. The seedlings are bare-rooted just before planting in the field; thus, they have similarities to both nursery-grown stock and conventional containerized seedlings. However, the Spencer-Lemaire and multi-seedling pot seedlings were of very poor quality at the time of planting. They were small, chlorotic, and low in vigor.

Within 8 weeks following planting, 71.5% of the Spencer-Lemaire seedlings and 99.4% of the multi-seedling pot seedlings were dead. Data from these types of containers have therefore been omitted from the statistical analyses.

Spoil samples were taken in late summer and early fall 1976 and analyzed for texture, pH, lime requirement, available P, exchangeable K, Mg, Ca, Al, and Mn, and specific conductivity.

Ground agricultural limestone was applied in accordance with the soil test recommendations in March 1977 at the following rates: Kylertown and Clarion, 4 t/acre (9.0 mt/ha); and Renovo, 5 t/acre (11.2 mt/ha). All plots, including controls, were scarified by disking or ripping following application of the lime.

Tree seedlings were planted during the period of April 1 through 3, 1987. Because of a heavy rain on April 2, the spoils were at or near field capacity during or soon after planting. Herbaceous seed and fertilizer were broadcast applied in mid-April. Each mix contained 10 lb/acre (11.2 kg/ha) of birdsfoot trefoil and 20 lb/acre (22.4 kg/ha) of a grass--either KY-31 tall fescue or "Tioga" deertongue grass. An 8-32-10 fertilizer, with 70% of the N in a slow-release form (sulfur-coated urea), was applied at a rate of 600 lb/acre (670 kg/ha). About one week later, hay mulch was applied by hand at a rate of 2 t/acre (4.5 mt/ha) and tacked down with an asphalt emulsion. Details on the study sites, soil analyses, and plot and treatment are available in Goodman (1978).

Data on tree seedling survival and growth have been collected at various time since planting. Our paper deals primarily with the most recent data collection, made in spring 1989, 12 years following plot establishment. These data were analyzed using conventional analysis of variance techniques for randomized blocks with split plots.

Results and Discussion

Chemical properties of the minesoils before treatment are given in Table 1. The values did not vary greatly among locations and were similar to those reported by Beyer and Hutnik (1969) and Horn and Ward (1969) for the same seams, but in other locations in Pennsylvania. The spoils were coarse in texture, indicating possible problems with water stress, high surface temperatures, and low nutrient availability. The pH values were low and available Al was high, indicating a potential for toxicity.

In spite of the adverse conditions existing on the untreated spoil, differences in mean survival among amendments were not significant after the first growing season (Goodman 1978) nor after the twelfth. However, there was a difference in pattern of survival with time (Table 2). Mortality has occurred between every measurement date on the untreated control plots. In contrast, mortality on those receiving soil amendments leveled off after the first few growing seasons. Survival decreased by 12 percentage points between the first and twelfth seasons for the untreated control, but only 5, 4, and 1 percentage points for the lime, lime + fertilizer, and lime + fertilizer + mulch treatments, respectively. Evidently, some of the trees which initially survived on the untreated controls were too weak to withstand subsequent environmental stresses, which were more severe on the control plots than on treated plots. The treatments resulted in an increase in nutrient availability and a decrease in toxicity problems (Goodman 1978). Also, the herbaceous cover increased as additional soil amendments were applied, thereby making the microclimate more suitable for tree survival and growth.

In the analysis of variance for the 1989 survival data, only container type and the container by location interaction were significant. Bare-root nursery stock had an overall mean survival of 75% compared to 68% for the Japanese paperpots (Table 3). However, the Renovo plots were almost completely responsible for this difference. There, the mean survival for bare-root stock was 75%, well above the 55% survival for Japanese paperpots. In fact, the Renovo plots planted with Japanese paperpots and receiving no amendment were the only ones with a mean survival of less than 50%.

Table 1. Selected chemical characteristics of minesoils at study sites (from Goodman 1978).

Site	pH	Bray No. 1 P	Exchangeable Cations K	Mg	Ca	Mn	Al	Specific Conductivity
		kg/ha	- - - - - - me/100 g				- - - - - -	mmhos/cm
Kylertown	3.3	0.96	0.077	0.47	0.23	0.088	2.95	0.45
Clarion	3.2	2.41	0.078	1.12	0.89	0.066	3.35	0.76
Renovo	3.0	0.74	0.085	0.61	0.69	0.012	2.95	0.62

Table 2. Mean survival of red pine trees by date and amendment.

Date	Soil Amendment*				
	None	L	L+F	L+F+M	Mean
	%	%	%	%	%
May, 1977	91	86	88	84	87
Aug, 1977	76	76	78	77	77
May, 1978	72	74	76	76	74
Aug, 1978	70	72	74	76	72
Aug, 1979	69	72	74	76	72
Dec, 1980	67	71	74	76	72
May, 1989	64	71	74	76	71

* L = lime; F = fertilizer; M = mulch.

Possibly the lower pH and available P levels at Renovo (Table 1) as compared to the other locations were responsible for the lower survival rate of Japanese paperpot seedlings. If so, this would indicate that containerized seedlings may be less resistant to environmental stresses than bare-root stock. This needs to be verified in other studies before any changes in planting recommendations are made.

The seed-mix treatments were very similar with respect to both mean survival (71, 73, and 70%) and mean height (3.8, 3.9, and 3.8 m) for the control, KY-31 tall fescue + birdsfoot trefoil, and deertongue grass + birdsfoot trefoil, respectively. Furthermore, the analyses of variance revealed no significant interactions involving seed mix. Consequently, data for the different seed-mix treatments were combined in Table 2. The lack of a seed-mix effect on tree survival and growth is not surprising since the lime + fertilizer + mulch treatment had, at the end of the first growing season following planting, the best mean cover, which was only 32%. Such a sparse cover would provide little competition to the established tree seedlings.

The mean tree height for all plots combined was 3.9 m (Table 3). In 1981, four growing seasons following planting, the mean tree height was only 0.5 m, indicating that the annual height growth in recent years has been considerably better than in the early years.

Soil amendments have had a significant impact on tree height (Table 3). Trees on plots receiving both lime and fertilizer were almost 50% taller than those on untreated plots. Trees on plots receiving lime only were intermediate in height.

During the first year, when height growth averaged only 3.6 cm, there were very small differences among amendments (Goodman 1978). Mean height growth doubled in the second year, with trees on limed and fertilized plots having more than twice the height growth of those on the untreated control. Over the next few years, height growth continued to increase, and the limed and fertilized plots maintained their two-to-one advantage over the control plots with respect to height growth. Although annual height growth was not measured in 1989, it appears from visual observations that the trees are still benefiting from the lime and fertilizer treatment.

By the end of the first growing season following planting, mean herbaceous cover was 0% in the non-amended control plots, less than 5% in the lime, 21% in the lime + fertilizer, and 32% in the lime + fertilizer + mulch plots (Goodman 1978). These values were very similar to those of Vandevender and Sencindiver (1982) for acid mine spoils in West Virginia treated with various combinations of lime and fertilizers.

The fescue mix had a better mean cover (33%) than the deertongue mix (20%). There was some natural invasion on the lime + fertilizer and lime + fertilizer + mulch plots by both herbaceous and woody species. In 1989, these plots contained considerable numbers of trees, mainly aspen (Populus spp.) at the Clarion and Kylertown sites and black locust (Robinia pseudoacacia) at Renovo. This aspect of the study will be covered more fully in a subsequent paper.

Supplemental Studies

The almost complete failure of the multi-seedling pot phase provided an opportunity for two supplemental studies. The objectives were: (1) to determine how representative 1977 was with respect to seedling survival and subsequent height growth on non-amended sites; and (2) to determine how types of container systems other than Japanese paperpots would perform in comparison to 2 + 0 nursery-grown seedlings planted in a bareroot condition.

Annual Variability Study

This study was conducted at the Kylertown and Clarion sites on the control and lime split plots that had initially been planted with seedlings from multi-seedling pots. Vegetative cover on these covers was less than 5%. Twenty nursery-grown 2 + 0 red pine seedlings were planted in each split plot in the springs of 1978 and 1979 to complement those planted in 1977. Thus there was a total of 480 seedlings in 24 split plots.

Mean survival of these plantings in 1989 was 76% for the 1977 planting, 82% for the 1978 planting, and 90% for the 1979 planting. This high survival for three consecutive years even on untreated plots indicates that many abandoned mine

Table 3. Mean survival and height in spring 1989 of red pine trees for each location, amendment, and container type*.

Location	Amendment**	Mean Survival			Mean tree height		
		BR***	JPP***	All	BR***	JPP***	All
		%	%	%	m	m	m
Kylertown	None	78	74	76	2.8	2.8	2.8
	L	88	80	84	3.3	3.3	3.4
	L+F	87	79	83	4.3	4.1	4.2
	L+F+M	84	80	82	4.4	4.4	4.4
	All	84	78	81	3.7	3.7	3.7
Clarion	None	54	78	66	3.4	3.5	3.4
	L	60	57	58	3.5	4.0	3.7
	L+F	82	66	74	4.6	4.4	4.5
	L+F+M	70	82	76	4.3	4.6	4.5
	All	67	71	69	4.0	4.1	4.0
Renovo	None	60	42	51	2.4	3.3	2.8
	L	80	61	70	3.5	4.1	3.8
	L+F	74	58	66	4.5	4.4	4.4
	L+F+M	83	58	71	4.2	4.4	4.3
	All	74	55	65	3.7	4.1	3.9
All	None	64	65	64	2.8	3.2	3.0
	L	76	66	71	3.5	3.3	3.7
	L+F	81	68	74	4.5	4.3	4.4
	L+F+M	79	73	76	4.3	4.4	4.4
	All	75	68	71	3.8	4.0	3.9

* Value for different seed mixes have been combined for simplicity.
** L = lime; F = fertilizer; M = mulch.
*** BR = bare-root nursery stock; JPP = Japanese paperpot.

lands in Pennsylvania can be successfully revegetated using conventional nursery-grown seedlings of species adapted to the site, such as red pine. However, spring weather conditions during the 1977-1979 period were generally favorable for seedling establishment. Droughts did occur during the spring of 1977, but the seedlings had been planted when soil conditions were near optimum.

As expected, tree height varied significantly with year of planting. However, mean height per year is nearly the same for the three different years. Results with respect to location and to application of lime were similar to those found in the main study.

Container Comparison Study

This supplemental study, located only at the Kylertown site, consisted of two parts: (1) planting of five different seedling types on a non-seeded split plot within each of the main soil amendment plots; and (2) planting of the same five seedling types on the various herbaceous seed mix split plots within two of the main soil amendment plots (lime + fertilizer and lime + fertilizer + mulch).

The seedling types were: (1) 2 + 0 nursery-grown seedlings; (2) multi-seedling pot seedings; (3) Tinus Spencer-Lemaire book container seedlings; (4) Colorado container seedlings; and (5) tarpaper container seedlings. The first three were the same as those involved in the main study. The Colorado container is a styroblock with 30 cavities each 5 x 5 x 19 cm in size. The tarpaper container is made by folding and stapling a sheet of asphalt-based roofing paper to form a container 5 x 5 cm in cross-section and 18 cm in length. Its advantages and disadvantages are discussed by Strachan (1974).

In both trials, a row of four trees of each seedling type were planted in each split plot in the spring of 1978. Survival and tree height data were collected in the spring of 1989 and analyzed by analysis of variance techniques.

Mean survival was good for all seedling types in both trials (Table 4)

Table 4. 1989 mean survival and tree height for supplemental studies of seedling types.

Seedling Type	Amendment trial Survival	Amendment trial Tree Height	Seed mix trial Survival	Seed mix trial Tree Height
	%	m	%	m
Nursery bare root	91	3.3	83	4.0
Multi-seedling pot	91	3.1	88	3.8
Spencer-Lemaire book	88	3.3	83	3.7
Colorado styroblock	91	3.3	92	4.0
Tarpaper	94	3.1	83	3.8

and did not vary significantly from one another. Within each trial, mean tree heights were also uniform among seedling types. Survival was much better than reported by Davidson and Sowa (1974) in earlier trials with container-grown seedlings on acid mine spoils in Pennsylvania. However, the container types we used were less susceptible to frost heaving, a major problem in their study.

The results with respect to soil amendment for all five container types and two replications combined were:

Amendment	Mean Survival	Mean Height
	%	m
None	78	2.5
Lime	100	3.0
Lime+fertilizer	92	3.8
Lime+fertilizer+mulch	92	3.8

Mean survival for the non-amended plots was significantly less than for the treated plots. Mean heights increased with each additional amendment, with the exception of the mulch application. These patterns were similar to those found in the main study and confirmed the need for lime and fertilizer use in mine land reclamation as emphasized by Mays and Bengtson (1978).

One difference between the main study and the supplemental study was the difference in mean survival between the lime + fertilizer and lime + fertilizer + mulch treatments. Survival was greater for the lime + fertilizer + mulch treatment in the main study but less in the supplemental study. The probable cause was that the supplemental study planting was made after a vegetative cover, albeit sparse, had been established. As shown below, there seems to be an inverse relationship between mean survival and percent cover.

Amendment	Seed Mix	Aug. 1977 Mean Cover	Mean 1989 Survival
		%	%
L+F	None	0	92
L+F	Deertongue	14	95
L+F	Fescue	21	85
L+F+M	None	0	92
L+F+M	Deertongue	23	80
L+F+M	Fescue	37	70

Conclusions

1. Many of the abandoned mine lands in Pennsylvania can be revegetated by merely planting species adapted to the site, such as red pine.

2. Application of lime and fertilizer, however, will increase tree growth substantially for at least a decade following planting. Long-term survival may also be increased.

3. On abandoned mine lands, application of lime and fertilizer will probably be required to obtain an herbaceous cover. Even then, the cover will likely be sparse. The application will also promote natural invasion of the sites by woody and herbaceous species and result in greater biotic diversity.

4. The competition for water and nutrients, and possibly allelopathic effects, resulting from an established vegetative cover, even a sparse one, on abandoned mine lands may result in decreased survival of newly planted seedlings.

5. The performance of containerized seedlings on abandoned mine lands in Pennsylvania is similar to that of conventional nursery-grown stock planted in a bare-root condition. No one type of container provides substantially better survival and growth than the others. The choice of seedling type for planting on abandoned mine lands in Pennsylvania therefore depends on factors such as availability, cost, ease of planting, and care needed during planting. These factors were not investigated in our study.

6. Seedling quality is probably more important than seedling type in the successful establishment of trees on abandoned mine lands.

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