To the Graduate Council:

I am submitting herewith a thesis written by Gary Hugh Irwin entitled "Minisite Preparation for Strip Mine Reclamation." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

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MINISITE PREPARATION FOR STRIP MINE RECLAMATION

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gary Hugh Irwin

March 1981

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DEDICATION

This work is dedicated to my parents George Hugh Irwin and Virginia Louise Irwin. Throughout my life they have shared countless learning experiences with me through extensive travel. They have provided me with fascinating and challenging reading material. Their encouragement in me of a love for nature and a respect for knowledge is greatly responsible for skills which were essential in performing this research.

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ABSTRACT

Pinus Virginiana Mill. and Pinus rigida Mill. were planted during the period between June 22 and July 5, 1977 on two reclaimed strip mined areas. Tubelings of both species inoculated with Pisolithus tinctorius (Pers.) Coker and Couch were planted in (1) undisturbed spoil and in (2) minisites to which amendments had been added and the spoil tumbled. Treatment and control were replicated in plots on both a bare area and an area seeded to grass. Seedling counts made 2 months, 8 months, and 14 months after planting revealed for both species that:

1. Survival on grassed plots was better with minisite preparation than with no preparation.
2. Survival on bare control plots was greater than on grassed control plots.
3. Survival on bare minisite plots was equal to survival on grassed minisite plots.
4. Frost heave was greater on control plots than on minisite plots.
5. Frost heave was greater on bare plots than on grassed plots.

Treatment strategies utilized in the experiment, (1) seedling containerization, (2) inoculation with Pisolithus tinctorius, (3) minisite preparation, (4) species selection, and (5) grass cover manipulation, can extend the ability to increase survival and

growth of tree plantings on strip mines. Such planting operations could extend practical planting times and decrease the need for replantings.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION AND OBJECTIVES.	1
II.	MATERIALS AND METHODS.	3
	Study Areas.	3
	Seedling Preparation	4
	Minisite Treatment	6
	Other Treatments	6
	Outplanting.	7
	Experimental Design.	7
	Data Collection.	7
	Spoil Analyses	9
	Foliage Analyses	9
	Statistical Analyses	9
III.	RESULTS.	10
	Minisite vs Control.	10
	Survival	10
	Frost heave.	14
	Growth	16
	Bare Area vs Grassed Area.	21
	Survival	21
	Growth	25
	Chemical analyses.	29
IV.	DISCUSSION	35
	Basic Treatments	35
	Minisite Treatment	36
	Competing Vegetation	36
	Species Reaction	37
V.	CONCLUSION	38
LITERATURE CITED		39
VITA		41

LIST OF TABLES

TABLE		PAGE
1.	Plots Established for Minisite Preparation Study on Massingale Mountain, Campbell County, Tennessee, June 22-July 5, 1977.	8
2.	Monthly Precipitation (Inches) for 1977, 1978, and 30 Year Average for Clinch Subdivision Above Norris (Near Study Areas).	11
3.	Survival (%) by Treatment of Pitch and Virginia Pines on Bare Area	12
4.	Survival (%) by Treatment of Pitch and Virginia Pines on Grassed Area.	13
5.	Frost Heave (%) by Treatment of Pitch and Virginia Pines in March 1978.	15
6.	Height Means (cm) of Minisite vs Control Pines in October 1978.	17
7.	Basal Diameter Means (cm) of Minisite vs Control Pines in October 1978.	19
8.	Biomass (Grams Dry Weight) of Minisite vs Control Pines in October 1978.	20
9.	Survival (%) of Pitch Pine Tubelings on Bare and Grassed Areas Following July 1977 Outplanting	22
10.	Survival (%) of Virginia Pine Tubelings on Bare and Grassed Areas Following July 1977 Outplanting	23
11.	Frost Heave (%) of Bare Area vs Grassed Area Pines in March 1978.	24
12.	Height Means (cm) of Bare Area vs Grassed Area Pines in October 1978.	26
13.	Basal Diameter Means (cm) of Bare Area vs Grassed Area Pines in October 1978	27
14.	Biomass (Grams Dry Weight) of Bare Area vs Grassed Area Pines in October 1978	28

TABLE PAGE

15. Chemical Analyses of Soil from Selected Sites on the Experimental Areas before Outplanting 30

16. Chemical Analyses of Spoil from Selected Bare Area Plots after Two Growing Seasons 31

17. Chemical Analyses of Foliage from Selected Bare Area Plots after Two Growing Seasons 34

CHAPTER I

INTRODUCTION AND OBJECTIVES

The dwindling of petroleum reserves, coupled with continued high levels of energy consumption, has intensified the search for new energy supplies and has brought about a re-examination of old supplies. Coal reserves in the U.S. are vast. Known supplies total in excess of 196 billion tons, enough to last 300 years at the present rate of consumption (Garrett, 1981).

As coal prices have risen, more areas have been economically opened to mining. Strip mined coal represents more than half of the nation's total production and this proportion is expected to increase in the future. Unfortunately, the destructive potential of strip mining is great. All vegetation and overburden must be removed down to the coal. Soil and overburden were formerly disposed of in the most expedient manner, usually being dumped downhill. Recent laws require miners to return the overburden after coal removal and to shape the overburden to the contour of the mountain. Although top soil is also saved and placed on top of the overburden, it is frequently of low quality. Speed in establishing vegetation on such areas is vital, as mud and toxic wastes wash from the area to pollute streams and kill vegetation and animal life for miles downstream. Revegetation, although mandated by law, is often difficult.

The objective of the experiment reported here was to test a revegetation strategy for establishing trees on strip mined sites.

The experiment involved the use of several procedures and methods incorporated into a single treatment. While these methods have been tested and demonstrated of value in revegetation, they have not until now been tested together as a unit. The goal in the experiment was to combine these methods in a practical, economical procedure that could be adapted to reclamation efforts on strip mined lands.

CHAPTER II

MATERIALS AND METHODS

Study Areas

The areas selected were in the Cumberland Mountains near Caryville, Tennessee, on land owned by Koppers Co. and mined by Long Pit Mining Co. under contract with the Tennessee Valley Authority. The study areas were located in the Block Quadrangle at 36°17'30" latitude and 84°18'45" longitude on the Pleasant Garden Ridge of Massengale Mountain at approximately 2,900 feet elevation (Luther, 1967).

Natural vegetation of the study areas was characteristic of higher elevations of the Cumberland Mountains. The tree cover was dominated by *Quercus* and *Carya* with lesser components of *Acer*, *Liriodendron*, *Robinia*, and other mesophytic genera. Trees were generally small and of poor quality for lumber due to shallow soil, frequent fires, and repeated "high grading" of the area for lumber.

One area used in the study had been the point of a ridge. After the removal of coal, it was an almost completely flat bench. Arrangements were made to forego the usual grass seeding of this site in order to test the effects of grass on tree survival and growth. This area, which will be referred to as the "bare area," constituted a control in judging the effects of vegetation on trees of the other area.

The other area, higher on the ridge, was characterized by steep slope on both sides of the ridge. Plots were located on the

southeast slope, which had been mulched and seeded with grass according to usual reclamation procedures. This site will be referred to as the "grassed site."

While being different in some factors, the two areas chosen for this study were similar in many respects. The two areas had been a part of the same ridge and were located within several hundred feet of each other. Both areas were reclaimed by standards which require that the original surface soil be replaced as the surface layer. Although crumb structure, micro-organisms, and organic matter had been destroyed in the surface soil, some beneficial qualities remained such as the presence of small particles for water holding and buffering capacity. Depth of the surface soil following reclamation was quite variable, being as thin as 2 inches in some places.

Seedling Preparation

Virginia pine (Pinus virginiana Mill.) and pitch pine (Pinus rigida Mill.) were chosen for study. Virginia pine in good condition was found on old strip mined areas near the study area. Pitch pine had not been tested on strip mines but is known to be tolerant of low quality sites (Fowells, 1965). Neither species produces high quality wood, but both offered the possibility of quick establishment and growth.

Seedlings were grown at The University of Tennessee, Knoxville, under the direction of U.S. Forest Service personnel in Athens, Georgia. Westvaco provided seeds of improved stock from their orchard near Ivy, Virginia. They were germinated in flats in a

mixture of one-half sand and one-half peat moss. Before branching occurred, seedlings were transplanted into Hillson-sized rootrainers manufactured by Spencer-Lemaire Ltd., Edmonton, Alberta, Canada. The value of rootrainers in the survival and growth of outplanted seedlings has been well demonstrated (Tinus, Stein, and Balmer, 1974). The rootrainer medium consisted of milled pine bark, vermiculite, and sewage sludge in the ratio of 4:1:1. This mixture was wetted with water containing a wetting agent.

All seedlings and medium were inoculated with a spore infusion of Pisolithus tinctorius (Pers.) Coker and Couch, hereinafter referred to as Pt. This fungus, in a mycorrhizal association, has proved very beneficial when pines are planted on drastically disturbed sites (Marx and Bryan, 1975). Although all pines have mycorrhizal associations, these are usually formed by other fungi, e.g., Thelephora terristris Ehrh. ex Fr., which are of benefit on more fertile sites, but which seem to have less value on harsh sites. Pt must be specifically introduced to the roots. The mycelium mixed into the growing medium has proven to be the best method (Marx, 1975). However, mycelium was not available to us at the time of the experiment, so we resorted to inoculation with spores. The spores were dispersed across the top of the planted rootrainers and immediately watered into the media.

After inoculation, seedlings were housed in a greenhouse using standard lighting and watering schedules. Initially, fertilizer was applied every week; the length of time between fertilizing was gradually increased to two weeks. Two weeks before outplanting, seedlings were moved outside under partial shade to acclimate to field conditions.

Minisite Treatment

The minisite treatment was made as follows:

1. A 20 cm wide hole was drilled 60 cm deep with an auger.
2. Loosened spoil was excavated, placed in a cement mixer, and tumbled.
3. While the spoil was being tumbled the following materials were added:
   a. lime[1] to neutralize active and reserve acidity
   b. prescribed nutrients phosphorus, potassium, and nitrate[2] to bring the spoil to a higher level of fertility
   c. pine bark for organic matter
   d. sewage sludge for organic matter and nutrients
   e. vermiculite to loosen the spoil
4. When thoroughly mixed, the amended spoil was returned to the hole.

Other Treatments

Except for the minisite treatment, preparations of control plots were similar to preparations of minisite plots. Spacing of seedling sites was 1 meter by 2 meters. On control plots, grass was scalped from the seedling sites prior to planting. The scalped area was approximately equal to the area of the hole opening drilled for

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[1]Ca was added to the minisite spoil at the rate of 50,000 pounds per acre.

[2]P, K, and N were added to the minisite spoil at the following rates: P--20 pounds per acre; K--100 pounds per acre; N--100 pounds per acre.

the minisites. Scalping of the sites was performed to eliminate competing vegetation from the control sites, just as the drilling of holes eliminated vegetation from the minisites. However, it was observed in the first and second seasons that grass encroached more swiftly on control sites than on minisites.

Outplanting

Preparation and outplanting were performed during the week of July 1, 1977. Treatment assignments are shown in Table 1. Holes for minisite seedlings were made with planting bars in the prepared sites. Holes for the control seedlings were made in the unprepared spoil with heavy iron bars because the spoil was much too hard for ordinary dibbles. All seedlings were planted using standard procedures. Seedlings were selected at random from the stock of containerized seedlings. After seedlings were planted, they were irrigated one time.

Experimental Design

The experimental design was a randomized block with four replications of each species in each block. A replication of each species consisted of a control plot and a treatment plot. One block was in the grassed area, and one block was in the bare area. Treatment assignment is shown in Table 1.

Data Collection

Survival data were recorded in October 1977, March 1978, and October 1978. Frost heave data were also taken in March 1978. In October 1978 data on three measures of growth were taken: (1) height from ground level, (2) base diameter, and (3) above ground biomass.

Table 1. Plots Established for Minisite Preparation Study on Massingale Mountain, Campbell County, Tennessee, June 22-July 5, 1977.

Plot No.[a]	Treatment[b]	Plot No.[a]	Treatment[b]
17	Va - 0	33	Va - 1
18	Pp - 0	34	Va - 0
19	Pp - 1	35	Pp - 0
20	Va - 1	36	Pp - 1
21	Va - 1	37	Va - 1
22	Pp - 0	38	Pp - 1
23	Pp - 1	39	Pp - 0
24	Va - 0	40	Va - 0
25	Pp - 0	41	Pp - 1
26	Va - 1	42	Va - 1
27	Va - 0	43	Va - 0
28	Pp - 1	44	Pp - 0
29	Va - 0	45	Pp - 1
30	Pp - 1	46	Va - 0
31	Pp - 0	47	Pp - 0
32	Va - 1	48	Va - 1

[a]Plot Nos. 17-32, bare area; plot nos. 33-48, grassed area.

[b]Va = Pinus Virginiana, Pp = Pinus rigida; 0 = no treatment - control, 1 = minisite treatment.

A random sampling of two rows per plot was sacrificed for biomass analysis. Trees were cut at ground level. These plants were then dried at 105° C until there was no further weight loss.

Spoil Analyses

Before the grassed area was seeded with grass and before trees were planted, soil samples were taken from both areas. At each sample site, samples were taken from the 0-2 cm depth, the 10-15 cm depth, and the 30-35 cm depth. Samples were analyzed for pH, P, K, Ca, Mn, An, and Mg by the Georgia Extension Service, Athens, Georgia.

Soil samples were also taken at the end of the second growing season. These samples were taken from the minisite cylinder and from the control soil (immediately adjacent to the plant) in two replications on the bare area. The samples were sent to A&L Laboratories of Memphis to be analyzed for organic matter, organic ENR, P (weak and strong Bray), K, Mg, cation exchange capacity, base saturation, Ca, pH, H, and nitrate.

Foliage Analyses

The foliage was stripped from the plants after being dried and weighed for biomass determination and was sent to A&L Labs to be analyzed for N, P, K, Mg, Ca, Na, Fe, Al, Mn, B, Cu, and Zn.

Statistical Analyses

An analysis of variance procedure was performed on survival data. T-tests were performed on height, diameter, biomass, soil chemicals, and foliage chemicals. Level of significance was set at .05 and .10 as indicated.

CHAPTER III

RESULTS

When considering the results of this experiment, it should be emphasized that planting of the seedlings occurred during midsummer of a summer with typically severe moisture stress (Table 2). Yet survival was high, especially on the bare area. Aside from the testing of the minisite treatment, these results provide confirmation of the effectiveness of two procedures used in the experiment; namely, (1) inoculation with Pt and (2) propagation of seedlings in rootrainers. As pointed out in the methods section, these procedures were used on all seedlings because of their demonstrated efficacy on strip-mined and other harsh sites.

A. Minisite vs Control

Survival

There was no significant difference in survival between control and minisite treatments on the bare area (Table 3). However, there was a significant difference between control and minisite treatments on the grassed area (Table 4). It is hypothesized that the minisite preparation was of benefit on the grassed area while not on the bare area because of different water relationships. The grassed area had a thick growth of grass; the bare area had few plants except experimental pines. The greater number of plants would be expected to create greater moisture stresses for pines on the

Table 2. Monthly Precipitation (Inches) for 1977, 1978, and 30 Year Average for Clinch Subdivision Above Norris (Near Study Areas).

Month	Precipitation		
	1977	1978	30 Year Average
Jan.	2.08	5.84	4.24
Feb.	1.51	1.26	4.27
March	4.08	3.71	4.79
April	8.68	2.77	3.66
May	1.90	5.35	3.81
June	6.16	3.31	3.96
July	4.23	5.24	5.07
August	4.67	5.61	3.98
Sept.	3.38	1.89	3.06
Oct.	6.83	1.15	2.44
Nov.	7.36	4.05	3.46
Dec.	3.22	6.61	4.07
Annual	54.10	46.79	46.81

Sources: Tennessee Valley Authority, 1977, Precipitation in Tennessee River Basin, Annual 1977. TVA, Division of Water Management, Data Services Branch. Report No. 0-243-A77; Tennessee Valley Authority, 1978, Precipitation in Tennessee River Basin, Annual 1978. TVA, Division of Water Management, Data Services Branch. Report No. 0-243-A78.

Table 3. Survival (%) by Treatment of Pitch and Virginia Pines on Bare Area.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	October 1977		
Pitch	98.5	95.4	N.S.[a]
Virginia	98.5	93.0	N.S.
	March 1978		
Pitch	92.9	95.4	N.S.
Virginia	92.3	91.5	N.S.
	October 1978		
Pitch	87.2	81.6	N.S.
Virginia	87.8	82.9	N.S.

[a]Not significant at the .05 level.

Table 4. Survival (%) by Treatment of Pitch and Virginia Pines on Grassed Area.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	October 1977		
Pitch	85.7	45.7	.05
Virginia	89.8	60.7	.05
	March 1978		
Pitch	84.2	40.8	.05
Virginia	80.6	53.1	.05
	October 1978		
Pitch	77.0	41.3	.05
Virginia	79.1	45.9	.05

grassed area. The vermiculite and organic matter added in the minisite treatment was expected to increase the water holding capacity of the spoil. The creation of better water relationships in the grassed minisites enabled minisite trees to survive better than control trees. However, on the bare area, where water was probably not as critical a factor, survival was as good for controls as for minisites, implying that the chemical amelioration was not a significant factor in early (first two seasons) survival.

Frost Heave

Table 5 reveals a much greater frost heave of control than of minisite plants on the bare area. Spoil contained in the minisites was loosened and made more compressible when vermiculite and pine bark were tumbled with it. Planting holes punched into the minisites had relatively soft walls. Planting holes punched into the control sites had very hard walls. Thus, it is hypothesized that the hard walls of the control planting holes formed a container in which water could collect and freeze, thereby heaving the pines. The soft walls of the minisite planting holes allowed freer percolation of water, preventing the formation of pockets in which water could freeze. Also the addition of vermiculite and pine bark to the minisite spoil would have increased its water holding capacity. With a raised saturation point the spoil would have been less prone to form water pockets.

While over 50 percent of the bare controls of both pitch and Virginia pines frost heaved the first winter after planting, few of

Table 5. Frost Heave (%) by Treatment of Pitch and Virginia Pines in March 1978.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	Bare Area		
Pitch	8.2	69.4	.05
Virginia	6.1	53.1	.05
	Grassed Area		
Pitch	0.0	1.0	N.S.[a]
Virginia	0.0	3.6	N.S.

[a]Not significant at the .05 level.

them were dead at the March 1978 and October 1978 survival counts. First, it should be pointed out that frost heave occurred in a wide spectrum of severity, from almost complete expulsion from the ground to very minor heaving. Secondly, Table 2, page 11, shows that the spring and summer of 1978 were moist, with precipitation well distributed over the growing season. Thus, the frost heaved seedlings were not stressed severely for moisture. There was no difference in frost heave between minisite and control on the grassed area.

Growth

Three measures of growth were used: tree height, stem diameter, and dry biomass of the stem and leaves. Measurements were made in October 1978, at the end of two growing seasons. Height and diameter of every tree were measured, but only a selected sample was sacrificed for biomass determinations.

Because of the mid-summer planting, there was little growth during the first season. The seedlings had come from the relatively mild conditions of the greenhouse to the harsh conditions of the strip mine sites; the stress of surviving took precedence over biomass storage. Observation during the second season revealed that growth occurred mostly during the spring when moisture was more plentiful and before the stresses of summer heat and drought.

Height. For Virginia pine there was no difference (P=.10) in height between minisites and controls for either the bare area or the grassed area (Table 6). Pitch pine on the bare area was taller (P=.10) on minisites than on controls. Pitch pine on the grassed area

Table 6. Height Means (cm) of Minisite vs Control Pines in October 1978.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	Bare Area		
Pitch	28.88	23.00	.10
Virginia	30.96	29.59	N.S.[a]
	Grassed Area		
Pitch	36.93	28.52	.05
Virginia	28.12	32.47	N.S.

[a]Not significant at the .10 level.

was taller (P=.05) on minisites than on controls. This result is explained if we assume that the minisite treatment had its major early benefit to height growth in improved water relationships. The benefit to pitch pine minisite plants on the bare area could be explained as due to (1) chemical amelioration or (2) lack of frost heave.

Basal diameter. There were no significant differences in basal diameter between minisite and control for either species on either area (Table 7).

Biomass. Pitch pine had numerically greater biomass on minisite than on control plots (Table 8). This difference did not register as significant with a t-test even though the numerical difference was quite large. The lack of sensitivity may be due to the small number of samples, variation in the numbers sampled because of missing plants, and wide variations in the biomass values. Field observation also substantiated that the minisite plants were physically larger than control plants (for pitch pine). Because this difference occurred on the bare area as well as on the grassed area, there is indication that (1) chemical amelioration or (2) lack of frost heave benefited biomass growth of pitch pine. However, the opposite relationship is observed in the case of Virginia pine. As in other growth measures, Virginia pine seems to have thrived better on control plots than on minisite plots. The reason or reasons for this are not known. Being a pioneer species, Virginia pine may thrive better on mineral soil, organic matter inhibiting growth in some

Table 7. Basal Diameter Means (cm) of Minisite vs Control Pines in October 1978.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	Bare Area		
Pitch	0.928	0.783	N.S.[a]
Virginia	0.893	0.860	N.S.
	Grassed Area		
Pitch	0.695	0.530	N.S.
Virginia	0.483	0.568	N.S.

[a]Not significant at the .10 level.

Table 8. Biomass (Grams Dry Weight) of Minisite vs Control Pines in October 1978.

Pine Species	Site Preparation Method		Statistical Significance of Differences
	Minisite	Control	
	Bare Area		
Pitch	24.13	19.30	N.S.[a]
Virginia	30.03	37.87	N.S.
	Grassed Area		
Pitch	20.31	11.24	N.S.
Virginia	8.23	14.69	N.S.

[a]Not significant at the .10 level.

manner. However, pitch pine is also a pioneer species, and it clearly grew better on minisites.

B. Bare Area vs Grassed Area

Survival

Plants on control plots showed significantly greater survival (P=.05) on the bare area as compared to the grassed area for both Pitch pine and Virginia pine (Tables 9 and 10). However, there were no such differences between areas in the case of minisite plots, the one exception occurring in the case of Virginia pine in the earliest survival count. The difference between minisite-bare area and minisite-grassed area disappeared in later survival counts. The lack of competing vegetation on the bare area obviously conferred advantage, while the dense grass competed for moisture and light with the seedlings on the grassed area. Evidently, the minisite treatment suppressed differences between the bare area and the grassed area. Grass soon encroached on control seedlings. Although minisites on the grassed area were slower to be encroached upon by grass, as the experiment progressed, minisites as well as controls were in heavy competition with grass. This result implies that the minisite conferred an early competitive advantage to the seedlings. This effect on the grassed area was still apparent after two growing seasons.

Frost heave. It is apparent from Table 11 that frost heave occurred more frequently on bare controls than on grassed controls. Surrounding vegetation, while competing with the seedlings, also evidently mitigated the effects of frost heave. Reasons for this

Table 9. Survival (%) of Pitch Pine Tubelings on Bare and Grassed Areas Following July 1977 Outplanting.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
	October 1977		
Minisite	98.5	85.7	N.S.[a]
Control	95.4	45.7	.05
	March 1978		
Minisite	92.9	84.2	N.S.
Control	95.4	40.8 (45.7)[b]	.05
	October 1978		
Minisite	87.2	77.0	N.S.
Control	81.6	41.3[b]	.05

[a]Not significant at .05 level.

[b]October 1978 survival was greater than March 1978 survival because some plants counted as missing at the earlier date were found alive at the later date. Even if a maximum survival of 45.7% is assumed for March 1978, significance would remain the same. Pitch pine frequently sprouts from roots even though it is dead above ground.

Table 10. Survival (%) of Virginia Pine Tubelings on Bare and Grassed Areas Following July 1977 Outplanting.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
	October 1977		
Minisite	98.5	89.8	.05
Control	93.0	60.7	.05
	March 1978		
Minisite	92.3	80.6	N.S.[a]
Control	91.5	53.1	.05
	October 1978		
Minisite	87.8	79.1	N.S.
Control	82.9	45.9	.05

[a]Not significant at the .05 level.

Table 11. Frost Heave (%) of Bare Area vs Grassed Area Pines in March 1978.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
	Pitch Pine		
Minisite	8.2	0.0	N.S.[a]
Control	69.4	1.0	.05
	Virginia Pine		
Minisite	6.1	0.0	N.S.
Control	53.1	3.6	.05

[a]Not significant at .05 level.

could be (1) less soil moisture due to greater evapotranspiration from the grassed area, (2) greater mechanical compressibility in the soil containing networks of grass roots, (3) insulation and wind blockage of the soil by the grass, and (4) failure of planting holes to trap water due to grass root networks. The actual role of these factors could not be judged by the experiment.

Growth

Height and basal diameter. Pitch pine on the grassed area was taller (P=.10) than pitch pine on the bare area for both minisites and controls (Table 12). However, both species showed greater basal diameter (P=.10) on the bare area than on the grassed area (Table 13). The data indicate that the growth pattern of seedlings on the two sites differed. Bare area seedlings tended to increase more in stem diameter; grassed area seedlings tended to increase more in stem height. This difference might have been due to the greater competition for light in the grassed site. Another possibility is that the difference was due to stimulation of stem diameter growth by wind action on the unshielded bare area seedlings.

Biomass. Both pine species had greater biomass on the bare area than on the grassed area (Table 14). The fact that the difference did not register as significant on the t-test is probably because of the low number of samples, variation in the numbers sampled because of missing plants, and wide variation in the biomass values. However, observation of the plants substantiated that there did seem to be a

Table 12. Height Means (cm) of Bare Area vs Grassed Area Pines in October 1978.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
	Pitch Pine		
Minisite	28.88	36.93	.10
Control	23.00	28.52	.10
	Virginia Pine		
Minisite	30.95	28.12	N.S.[a]
Control	29.59	32.47	N.S.

[a]Not significant at the .10 level.

Table 13. Basal Diameter Means (cm) of Bare Area vs Grassed Area Pines in October 1978.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
		Pitch Pine	
Minisite	0.928	0.695	.05
Control	0.783	0.530	.10
		Virginia Pine	
Minisite	0.893	0.483	.05
Control	0.860	0.568	N.S.[a]

[a]Not significant at the .10 level.

Table 14. Biomass (Grams Dry Weight) of Bare Area vs Grassed Area Pines in October 1978.

Site Preparation Method	Area		Statistical Significance of Differences
	Bare Area	Grassed Area	
	Pitch Pine		
Minisite	24.13	20.30	N.S.[a]
Control	19.30	11.24	N.S.
	Virginia Pine		
Minisite	30.03	8.23	.10
Control	37.87	14.69	N.S.

[a]Not significant at the .10 level.

difference in biomass between bare and grassed areas. Due to the absence of competition for water and light on the bare area, this difference would be expected.

Chemical Analyses

While there were differences between levels at sample points, these differences did not follow a pattern (Table 15). Nutrients increased as well as decreased with depth, depending on the sample location. This irregularity might be expected from the degree of mixing the spoil and soil is subjected to in the movement and replacement of the material. The second grassed sample should not be considered typical as it was near a "hot spot" that later showed up in the area. These "hot spots" were areas of extreme toxicity where subsequently most or all of the vegetation died. "Hot spots" occurred on both the grassed and the bare area and were characterized by oily, dark soil as time progressed. From the extremely low pH, this appears to be such a place that was inadvertently sampled. The grassed site appears to be higher in the nutrients P, K, Ca, and Mg. If we can discount the very low pH of the second grassed sample as characteristic of a "hot spot" rather than of the whole grassed area, the pH of the two areas appears close to each other.

The analyses of the soil samples taken at the end of two growing seasons showed no significant differences between minisite and controls (Table 16). However, cation exchange capacity and calcium both were much greater for minisites than for controls. The sample these results were based on was very limited. These values may

Table 15. Chemical Analyses[a] of Spoil from Selected Sites on the Experimental Areas before Outplanting.

Area	Site	Depth (cm)	Factor or Element				
			pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Grassed Area	1	2	4.5	60	242	187	92
		10-15	4.6	52	171	532	201
		30-35	5.1	120	168	1270	379
	2	2	2.6	52	14	960	615
		10-15	2.3	8	15	723	625
		30-35	2.3	8	14	786	535
Bare Area	3	2	4.0	< 4	68	15	7
		10-15	4.3	< 4	24	6	1
		30-35	4.1	< 4	31	21	4
	4	2	4.8	< 4	132	111	39
		10-15	4.8	< 4	105	63	37
		30-35	4.7	< 4	106	92	34

[a]Analyses performed by the University of Georgia, Athens, Georgia.

Table 16. Chemical Analyses[a] of Spoil from Selected Bare Area Plots after Two Growing Seasons.

Item	Unit	Treatment[b]	Pitch Pine Value	Pitch Pine Significance	Virginia Pine Value	Virginia Pine Significance
Organic matter	%	0	2.70	N.S.[c]	2.65	N.S.
		1	2.70		3.40	
Organic ENR	lbs/Acre	0	98.00	N.S.	97.00	N.S.
		1	98.00		112.00	
P (Weak Bray)	ppm	0	2.00	N.S.	3.50	N.S.
		1	4.50		3.50	
P (Strong Bray)	ppm	0	4.50	N.S.	5.00	N.S.
		1	11.50		5.50	
K	ppm	0	56.50	N.S.	54.50	N.S.
		1	47.50		75.00	
Mg	ppm	0	27.50	N.S.	40.00	N.S.
			35.00		40.00	
CEC	Meq/100g	0	1.95	N.S.	3.50	N.S.
		1	14.40		7.90	
Base Saturation						
K	%	0	7.40	N.S.	4.20	N.S.
		1	3.60		2.70	
Mg	%	0	11.70	N.S.	9.80	N.S.
		1	4.60		5.15	
Ca	%	0	25.65	N.S.	19.05	N.S.
		1	33.55		56.95	

Table 16 (Continued)

Item	Unit	Treatment	Pitch Pine Value	Pitch Pine Significance	Virginia Pine Value	Virginia Pine Significance
(Base Saturation)						
H	%	0	53.95	N.S.	67.10	N.S.
		1	58.60		35.05	
Ca	ppm	0	100.00	N.S.	125.00	N.S.
		1	675.00		950.00	
pH Soil	-	0	4.60	N.S.	4.25	N.S.
		1	4.20		5.20	
pH Buff	-	0	6.90	N.S.	6.70	N.S.
		1	6.75		6.65	
H	Meq/100g	0	1.05	N.S.	2.40	N.S.
		1	10.60		2.60	
Nitrate	ppm	0	5.50	N.S.	5.50	N.S.
		1	5.00		6.00	

[a]Analyses performed by A&L Laboratories of Memphis, Tennessee.

[b]0 = no treatment - control, 1 = minisite treatment.

[c]Not significant at the .10 level.

reflect true contrasts between the sites, or they may be artifacts of the variable chemistry of the strip mine.

Foliage samples showed no significant difference between minisite and control in almost all factors (Table 17). The exceptions occurred with zinc and calcium in the case of Virginia pine. There was more zinc and calcium in foliage of plants on minisites than of plants on controls. Curiously, there was less nitrogen in Virginia minisite plants than in controls. Again, the small sampling used for these analyses makes reliability of statistical analysis low and interpretation difficult.

Table 17. Chemical Analyses[a] of Foliage from Selected Bare Area Plots after Two Growing Seasons.

Item	Unit	Treatment[b]	Pitch Pine Value	Pitch Pine Significance	Virginia Pine Value	Virginia Pine Significance
N	%	0	1.873	N.S.[c]	2.343	.10
		1	1.943		1.723	
P	%	0	0.153	N.S.	0.155	N.S.
		1	0.170		0.180	
K	%	0	0.550	N.S.	0.588	N.S.
		1	0.648		0.678	
Mg	%	0	0.085	N.S.	0.085	N.S.
			0.103		0.083	
Ca	%	0	0.283	N.S.	0.243	.10
		1	0.320		0.498	
Na	%	0	0.010	N.S.	0.010	N.S.
		1	0.010		0.010	
Fe	ppm	0	293.750	N.S.	443.000	N.S.
		1	588.750		227.000	
Al	ppm	0	920.000	N.S.	1147.500	N.S.
		1	1062.500		1292.500	
Mn	ppm	0	930.000	N.S.	521.250	N.S.
		1	620.000		396.000	
B	ppm	0	15.000	N.S.	14.500	N.S.
		1	14.000		23.000	
Cu	ppm	0	6.250	N.S.	6.750	N.S.
		1	6.500		5.500	
Zn	ppm	0	55.750	N.S.	27.500	.10
		1	54.250		39.500	

[a]Analyses performed by A&L Laboratories of Memphis, Tennessee.

[b]0 = no treatment - central, 1 = minisite treatment.

[c]Not significant at the .10 level.

CHAPTER IV

DISCUSSION

A. Basic Treatments

One of the most important implications of this experiment is that seedlings can be planted at a season of year generally considered very unfavorable for survival with the expectation of respectable survival rates. Overall survival was in excess of 70 percent. Without the use of containerized seedlings, these results probably would not have been possible. The ability of the seedling root mass to buffer against the stresses of water deficiencies, frost heave, and toxic chemicals helps account for the high survival in this experiment.

Also of demonstrated benefit for pine plantings on strip mined areas is root inoculation with Pisolithus tinctorius. Although an attempt was made to inoculate seedlings with Pt spores, the method of inoculation was less than successful. This failure unwittingly provided a comparison between the experimental plots, which had poor inoculation, and adjacent Forest Service plots, which had good inoculation. The success of their inoculation was demonstrated by the large number of Pt basidiocarps that fruited in the late summer of 1978 on the Forest Service plots. Even though the Forest Service added no amendments nor made site preparations, their plants showed greater survival and vigor than both our controls and treatments after two growing seasons.

B. Minisite Treatment

The minisite treatment might be considered an extension of the containerized seedling concept, the minisite cylinder offering many of the same benefits as the root mass of the containerized seedling. The chief benefit of the minisite treatment was in the improved water relations it conferred. On the grassed site, where water stress was an important factor, the minisite treatment dramatically improved survival for both pine species and also improved growth of pitch pine. The aspect of treatment responsible for this improvement seems to be the addition of pine bark and vermiculite and their tumbling with the spoil. This process should have improved soil structure, increased aeration, increased water holding capacity, and promoted percolation. In addition, the loose texture resulting from this process practically eliminated frost heaving. Lack of frost heave, or perhaps chemical amelioration, contributed to improved growth of minisite pitch pines on the bare site. Thus under the proper circumstances the minisite treatment was of benefit in both survival and growth.

C. Competing Vegetation

The problems of erosion, as well as reclamation laws that require immediate revegetation, preclude leaving bare areas on strip mines. However, the opportunity to compare the response of pines on a bare area to the response on a grassed area was valuable. Survival and growth on the bare site were better than on the grassed site. This was predictable because of moisture stress due to the abundance of transpiring plants on the grassed site. However, much

of this advantage was duplicated by the minisite treatment. Survival of minisite seedlings on the grassed area was equal (P=.05) to survival of minisite seedlings on the bare area. Growth of pitch pine on grassed minisites, although not as great as for the bare area, was greater than grassed controls. Thus minisite treatment holds the potential of easing the effects of grass competition, while taking advantage of the erosion control that grass offers. It should be possible to reduce the rate at which grass seed is applied to reclaimed areas without encouraging erosion. This reduction would more effectively allow pine seedlings to become established and grow above the grass without becoming suppressed.

D. Species Reaction

The two species of pine used in the experiment reacted differently to the experimental situations. Pitch pine responded well in both survival and growth to the minisite treatment. Virginia pine responded well in survival to minisite treatment. However, the minisite treatment did not improve growth for Virginia pine as it did for pitch pine. The results of the experiment indicate that pitch pine would be a better choice than Virginia pine to use in conjunction with minisite treatment.

CHAPTER V

CONCLUSIONS

Strategies utilized in this experiment offer the opportunity to greatly extend the available planting times, as well as to increase the success rate of tree plantings on strip mined land. Without these methods, tree planting is best confined to two or three months of the year. Extending this time may allow areas to be planted with less delay; increasing survival could make unnecessary the repeat plantings sometimes required to establish tree cover. While planting operations utilizing minisite treatment, Pt inoculation, and containerized seedlings are more expensive in time and money than conventional planting operations, they also promise to be more flexible for management purposes.

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VITA

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In September 1975 he began study at The University of Tennessee, Knoxville, for a Master's degree. In September 1976 he accepted a research assistantship in the Forestry Department to study strip mine reforestation.

In September 1980 he and his wife, the former Beth Csorgo of Murfreesboro, Tennessee, accepted the position of houseparents at Columbus Home, a temporary home for abused and neglected children, where he is presently employed.

The author is active in conservation issues of eastern Tennessee. He has been active in efforts to preserve areas of Cherokee National Forest as wilderness, and has been working in citizen participation phases of the Cherokee National Forest Land Management Plan. He presently is secretary of the Harvey Broome Group of the Sierra Club.