ODC 232.33 : 174.7 Pinus spp. : 114.456 : 181.32

Factors Affecting the Establishment of DIRECT-SEEDED PINE ON SURFACE-MINE SPOILS

by William T. Plass

USDA FOREST SERVICE RESEARCH PAPER NE-290
1974

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082
WARREN T. DOOLITTLE, DIRECTOR

The Author

WILLIAM T. PLASS, a research forester, received his bachelor of science degree in forestry from Iowa State University in 1948, and his master of science degree in silviculture from the University of Missouri in 1959. He joined the USDA Forest Service in 1948, and worked with the Central States Forest Experiment Station before transferring to the Northeastern Forest Experiment Station in 1966.

MANUSCRIPT RECEIVED FOR PUBLICATION 7 SEPTEMBER 1973

Factors Affecting the Establishment of
DIRECT-SEEDED PINE ON SURFACE-MINE SPOILS

Abstract

In a greenhouse study the emergence, survival, and growth of seven species of pine were related to chemical and textural characteristics of 12 Kentucky spoils. The results identify three factors that may affect the establishment of direct-seeded pine on surface-mine spoils. First, fine-textured spoil material may restrict seedling emergence. Coarse-textured sandstones and hard shales may provide a better seedbed. Second, species vary in their response to chemical and physical characteristics of the spoil material. Loblolly and longleaf pine were adapted to a wide range of spoils. The growth of shortleaf and white pine was reduced on extremely acid spoils.

Finally, the growth of loblolly pine was greatest where the percentage of phosphorus in the whole plant was greatest.

DIRECT SEEDING of pine is an appealing but as yet unreliable alternative method of spoil bank reforestation in the Appalachian region. Field trials have been made, but the results were not encouraging (*1, 2*).

On natural soils in the southern pine region, direct seeding on many sites is considered as reliable as planting. Guidelines for species selection, seed treatment, and site preparation are available (*3, 4*). Some of this information may apply to Appalachian surface-mine spoils. Additional information is needed to predict the effect of specific spoil characteristics on seedling establishment and growth.

The objective of this greenhouse study was to relate the emergence, survival, and growth of seven species of pine to chemical and textural characteristics of 12 spoils. The spoil characteristics considered are often used to identify those suitable for plant growth.

WHAT WE DID

Material from six eastern and six western Kentucky spoils was selected. These were mixtures of sandstones and shales in varying proportions. The pH of each spoil was determined in a laboratory with a standard line-operated pH meter and a 1:1 soil to distilled water solution. Spoil pH ranged from 2.5 to 8.4 (table 1). Plant-available phosphorus was determined on leachate extracted with Bray No. 1 solution. Available phosphorus ranged from 0.7 to 27.3 ppm.

Each of the 12 spoils was assigned to a redwood box measuring 11 by 18 inches, and 4½ inches deep. Before filling with spoil, each box was lined with black polyethylene. A ½-inch layer of perlite was placed at the bottom of each box to provide internal drainage. Next, a 1-inch layer of spoil was added. This spoil had been sieved through a ½-inch mesh screen. Seventy plant bands, measuring 1½ inches square and 3 inches deep, were placed in each box and half-filled with similar spoil. Half of the plant bands in each box were then filled with fine-textured material that passed a 20-mesh screen. The remainder of the bands in each box were filled with the coarse material that did not pass the 20-mesh screen. After each box was filled, it was brought to approximately 20 percent moisture by weight with distilled water.

Seven species of pine were sown. These represented northern and southern species that are recommended for spoil bank planting. The species were shortleaf pine (*Pinus echinata* Mill.), loblolly pine (*Pinus taeda* L.), Virginia pine (*Pinus virginiana* Mill.), longleaf pine (*Pinus palustris* Mill.), pitch pine (*Pinus rigida* Mill.), red pine (*Pinus resinosa* Ait.), and white pine (*Pinus strobus* L.).

Germination tests were run on one lot of 100 seeds of each species. The results at the end of 30 days were compared with the emergence in the spoil material. Emergence occurred when the hypocotyl arch broke through the surface of the spoil.

Table 1.—*The pH and plant-available phosphorus by spoils*

Number	Location	pH	Available phosphorus
			(ppm)
1	Western Kentucky	8.4	0.7
2	Western Kentucky	7.8	1.6
3	Western Kentucky	6.9	5.9
4	Eastern Kentucky	5.3	2.6
5	Eastern Kentucky	4.8	3.9
6	Eastern Kentucky	4.8	4.1
7	Eastern Kentucky	4.7	22.1
8	Western Kentucky	4.7	27.3
9	Eastern Kentucky	4.0	4.6
10	Eastern Kentucky	3.8	2.9
11	Western Kentucky	3.6	6.2
12	Western Kentucky	2.5	1.1

Ten plant bands in each box were assigned to each species. Half of these had been filled with fine-textured spoil, and the remainder with coarse-textured spoil. Ten seeds were placed in each plant band, and covered to a depth equal to the thickness of the seed.

Emergence and mortality were recorded for each plant band every 2 or 3 days. At the end of 120 days, the study was terminated. The spoil was washed from the roots, and each seedling was measured. Top length was measured to the nearest tenth of an inch from the root collar to the top of the terminal bud for all species except longleaf pine. Needle length was measured for longleaf pine due to its characteristic short stem development during the first growing season. Root length for all species was measured from the root collar to the tip of the longest primary root.

All loblolly pine seedlings on 10 of the spoils were oven dried and ground in a Wylie mill. This tissue, a composite of needles, stems, and roots, was analyzed spectrographically at a commercial laboratory to determine the concentration of the following nutrients: phosphorus, potassium, calcium, magnesium, manganese, iron aluminum, copper, zinc, boron, molybdenum, and sodium.

RESULTS

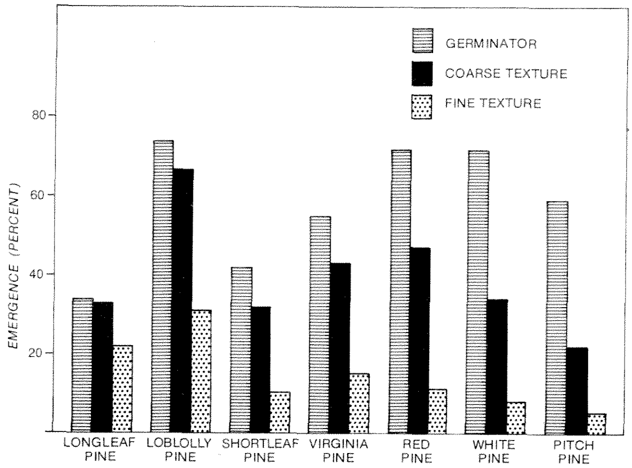
The success of direct seeding can be evaluated at three stages in seedling development: emergence, survival, and growth. Each of these in turn depends on different factors. In evaluating the results from this study, we considered species, spoil pH, and spoil texture. Species variations reflect inherent characteristics of the seed that may be difficult to manipulate. Spoil pH and spoil texture are external factors subject to modification by spoil treatments.

Emergence

The emergence of all species was strongly influenced by the extremes in spoil texture. For all species, emergence was significantly reduced in the fine material (fig. 1).

Spoil pH influenced emergence only on the extremely acid number 12 spoil. On this spoil, the species emerging were longleaf, loblolly,

Figure 1.—A comparison of germinator results with the percentage emergence at the end of 45 days on all spoils by species and spoil texture.



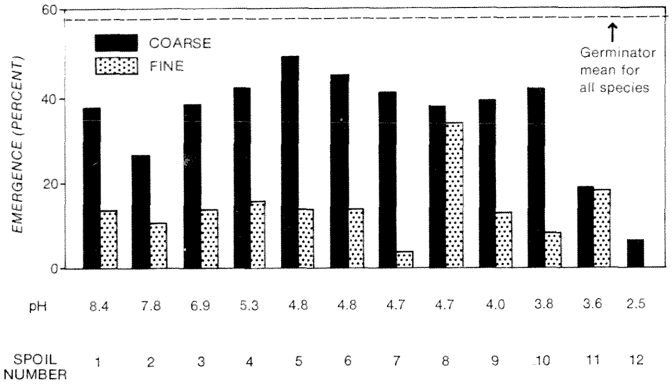
shortleaf, and Virginia pine. All seedlings were weak, and died soon after emergence.

A factor contributing to the low emergence was soil crusting. Penetrometer tests after 1 day of drying indicated that forces of the magnitude of more than a ton per square foot were required to break through the crust. This may be particularly important for pine since germination is epigeous. The hypocotyl arch could experience difficulty in breaking through this hard material.

In the coarse-textured material, the emergence of longleaf and loblolly compared favorably with results in a germinator. Moderate differences between spoil and germinator occurred for shortleaf and Virginia pine, and large differences for white, red, and pitch pine. It is not known if the seed failed to germinate in the spoil, or if it germinated but did not emerge.

There were significant differences in seedling emergence between coarse- and fine-textured materials for 9 of the 12 spoils (fig. 2). These spoils ranged in pH from 3.8 to 8.4. Spoil texture did not affect emergence on spoils 8 and 11. On spoil 12, with a pH of 2.5, emergence was observed on the coarse-textured material, but not on the fine-textured material. Van Lear (5) has shown toxic ion concentration is greater on fine-textured spoil than on coarse-textured materials.

Figure 2.—Average percentage emergence at the end of 45 days for all species by spoil and spoil texture.



Survival

Textural classes did not significantly affect survival. White pine had the highest overall survival: 89 percent on the coarse material and 95 percent on the fine material (fig. 3). Red pine had the lowest survival: 65 percent on the coarse material and 40 percent on the fine material.

Survival for all emerging seedlings was similar on 9 of the 12 spoils (fig. 4). These varied widely in pH. Significantly lower survival occurred on spoils 11, 1, and 12 which had pH values of 3.6, 8.4, and 2.5, respectively.

Figure 3.—Percentage survival by species and spoil texture for all spoils.

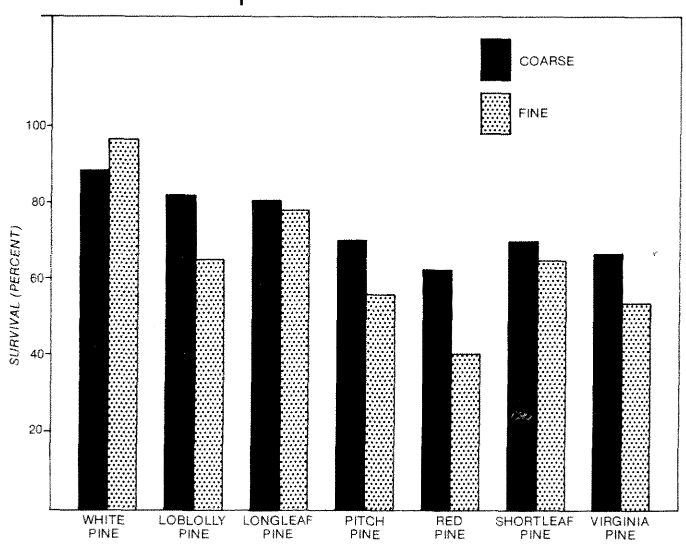
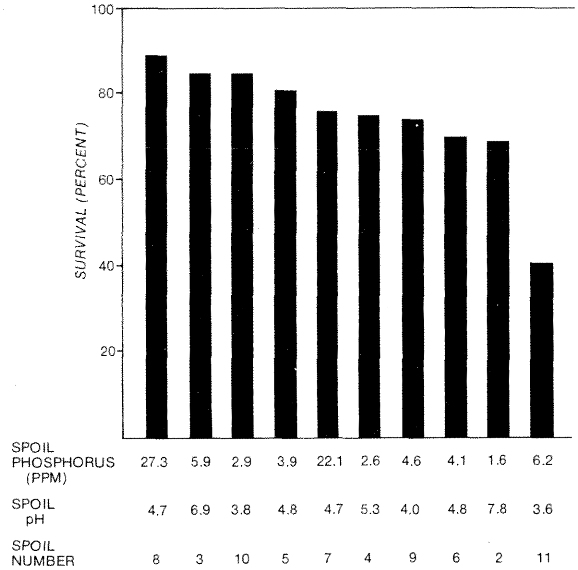


Figure 4.—Percentage survival by spoils for all cies and both spoil textures.



Growth

On spoils where environmental conditions may be severe, or where there is a high risk of loss due to erosion, it seems reasonable to expect the largest seedlings to have the best chance of survival. This assumption considers the entire plant, since root development may be even more important than top growth.

Seedling growth differed between species, and varied with the chemical properties of the spoil. The effects of texture could not be evaluated since the roots of all species penetrated to depths below the surface textural extremes.

Loblolly and longleaf pine grew well on all spoils (table 2). Both species showed a tendency toward slower growth on spoils having a pH of 5.0 or higher. Longleaf pine needle length and loblolly pine root growth were significantly less on these spoils.

White pine, which characteristically makes slow initial growth, grew very slowly on all spoils and had the shortest mean root length of all species. Top and root growth were sig-

Table 2.—*Top and root growth for each species by spoil pH classes*

pH Class	Species						
	White pine	Red pine	Pitch pine	Virginia pine	Shortleaf pine	Loblolly pine	Longleaf pine
				(Inches)			
Top Growth:							
4.0 or less	1.4	1.4	1.8	2.6	2.1	4.1	11.7[a]
4.1 - 5.0	2.2	1.7	2.1	2.4	2.8	4.0	12.9[a]
5.1 or more	1.9	1.5	2.1	2.5	2.2	3.6	9.8[a]
Root Growth:							
4.0 or less	4.0	5.6	7.9	11.4	6.8	11.8	21.1
4.1 - 5.0	6.5	9.6	8.8	11.6	10.4	14.3	25.4
5.1 or more	5.9	9.2	9.2	10.2	8.2	9.8	23.7

[a]Needle length.

Table 3.—*Mean whole plant tissue analysis of loblolly pine seedlings from spoils supporting the best and poorest top growth*

Nutrient	A: Best growth[a]	B: Poorest growth[b]	$\frac{A-B}{B}$
Phosphorus, % O.D. Wt.	.180	.087	+ 107
Potassium, % O.D. Wt.	.853	.900	– 5
Calcium, % O.D. Wt.	.390	.633	– 38
Magnesium, % O.D. Wt.	.220	.253	– 13
Manganese, ppm	531.0	373.3	+ 42
Iron, ppm	1001.3	859.3	+ 17
Copper, ppm	19.0	23.0	– 17
Aluminum, ppm	2423.0	2204.0	+ 10
Zinc, ppm	69.0	86.3	– 20
Boron, ppm	20.7	19.3	+ 7
Molybdenum, ppm	1.883	2.017	– 7
Sodium, ppm	11.7	13.0	– 10

[a]Spoils: 5, 7, and 9
[b]Spoils: 3, 6, 10

Table 4.—*Mean whole plant tissue analysis of loblolly pine seedlings from spoils supporting the best and poorest root growth*

Nutrient	A: Best growth[a]	B: Poorest growth[b]	$\frac{A-B}{B}$
Phosphorus, % O.D. Wt.	.267	.087	+ 207
Potassium, % O.D. Wt.	.903	.863	+ 5
Calcium, % O.D. Wt.	.435	.383	+ 14
Magnesium, % O.D. Wt.	.210	.340	– 38
Manganese, ppm	617.7	510.3	+ 21
Iron, ppm	1372.0	1177.7	+ 16
Copper, ppm	20.0	30.7	– 35
Aluminum, ppm	2297.3	2213.0	+ 4
Zinc, ppm	73.7	63.0	+ 17
Boron, ppm	27.7	21.7	+ 28
Molybdenum, ppm	1.977	1.823	+ 8
Sodium, ppm	12.3	9.3	+ 43

[a]Spoils: 7, 8, and 9
[b]Spoils: 4, 10, and 11

nificantly reduced on spoils with a pH of 4.0 or less.

The greatest top and root growth for all species occurred on spoils with a pH between 4.1 and 5.0. Virginia pine was the species least affected by the chemistry of the spoil.

Tissue Analysis of Loblolly Pine

Composite samples of the needles, stem, and roots of loblolly pine seedlings were analyzed to relate growth to tissue analysis. Separate samples were collected for loblolly pine growing on 10 spoils. The analyses of seedlings from spoils supporting the best top growth were compared to analyses of seedlings from three spoils with the poorest top growth. Similar comparisons were made for seedlings from spoils supporting the best and poorest root growth.

In all comparisons, high tissue phosphorus was consistently related to better top and root growth (tables 3 and 4). Tissue of the larger seedlings had 2 to 3 times more phosphorus than the tissue of the small seedlings. Zarger considered phosphorus deficiency the primary limitation to tree growth on surface mine spoils (*6*).

Iron, manganese, copper, and boron were higher in seedlings growth on the spoils supporting better growth. Magnesium and copper were higher in seedlings making the poorest growth. There was no consistency for the other nutrients.

CONCLUSIONS

Several preliminary conclusions can be drawn from this data.

1. Spoils with a high percentage of fine-textured material probably should be avoided. Surface crusting of fine particles may interfere with emergence. Coarse-textured sandstones and hard shales appear to offer better seedbed conditions.

2. Species selection is important. For the seven species tested, longleaf and loblolly pine appear to offer the best opportunities for success. The inherent slow growth of white pine and its even slower growth on acid spoils could contribute to high mortality under field conditions.

3. Root growth was more responsive to the chemistry of the spoil than top growth, and it could be a critical factor in seedling survival. Sites with coarse-textured spoil with a pH between 4.1 and 5.0 may offer the best chance of success. Adequate available phosphorus is required for greatest root and top growth.

LITERATURE CITED

(1) Zarger, T. G., J. A. Curry, and J. C. Allen. (In Press). SEEDING OF PINE ON COAL SPOIL BANKS IN THE TENNESSEE VALLEY. *In* Proc. Int. Symp. on Ecology and Revegetation of Drastically Disturbed Areas. Gordon and Breach Science Publishers, London.

(2) Thor, Eyvind, and James S. Kring. 1964. PLANTING AND SEEDING OF LOBLOLLY PINE ON STEEP SPOIL BANKS. J. For. 62(8): 575-576.

(3) Derr, Harold J., and William F. Mann, Jr. 1971. DIRECT-SEEDING PINES IN THE SOUTH. USDA Agric. Handb. 391. 66 p.

(4) Russell, T. E., and A. L. Mignery. 1968. DIRECT SEEDING PINE IN TENNESSEE'S HIGHLANDS. USDA Forest Serv. Res. Pap. SO-31. 22 p.

(5) Van Lear, David H. 1971. EFFECTS OF SPOIL TEXTURE ON GROWTH OF K-31 TALL FESCUE. USDA Forest Serv. Res. Note NE-141. 7 p.

(6) Zarger, T. G., G. W. Bengston, J. C. Allen, and D. A. Mays. (In Press). USE OF FERTILIZERS TO SPEED PINE ESTABLISHMENT ON RECLAIMED COAL MINE SPOIL IN NORTHEASTERN ALABAMA, II. FIELD EXPERIMENTS. *In* Proc. Int. Symp. on Ecology and Revegetation of Drastically Disturbed Areas. Gordon and Breach Science Publishers, London.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.