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PINE SEEDLINGS RESPOND TO LIMING OF ACID STRIP-MINE SPOIL

Abstract.—A greenhouse trial was made to determine the effect of three rates of liming on the growth of five species of pine seedlings in an extremely acid strip-mine spoil. Liming at the rate of 5 tons per acre-foot significantly increased the growth of four of the species. Tissue analysis indicated the growth rate may be related to a reduction in the concentration of the metallic ions of manganese, iron, copper, and zinc.

Extremely acid strip-mine spoils present a difficult reforestation problem. A few species of trees and shrubs may survive on spoils with pH values between 3.5 and 4.0, but growth is generally very slow. Below pH 3.5, few species will survive. Therefore, species selection is not the complete answer to this revegetation problem. Spoil treatment to modify the acid condition appears necessary.

Since liming is a widely accepted treatment for acid agricultural soils, lime appears to be a logical material to use. However, there is little information about herbaceous response to liming acid strip-mine spoils and even less about the use of lime with tree and shrub species. Therefore, a greenhouse test was made to determine the effect of three rates of liming on the growth of five pine species in an extremely acid strip-mine spoil.

Methods

We used the following species of pine: loblolly (*Pinus taeda* L.), shortleaf (*Pinus echinata* Mill.), pitch (*Pinus rigida* Mill.), Virginia (*Pinus virginiana* Mill.), and a hybrid of pitch and loblolly pine grown from seed produced by the Republic of South Korea that is considered to be very acid-tolerant. Seedlings for each species were 1-0 stock of similar size and condition.

The treatments, equivalent to 2, 5, and 10 tons of lime per acre-foot of soil, were compared with an untreated check. The purpose was to bracket the extremes and have two intermediate treatments.

The spoil was a coarse mixture of sandstone and shale; it had a pH of about 3.4. Before potting, the spoil was sieved through a screen of ½-inch mesh, thoroughly mixed, and then treated with hydrated lime as required by the assigned treatment. Round containers, 12 inches in diameter and 12 inches deep, were lined with black polyethylene and filled with 35 pounds of spoil. Each pot was then brought to 20 percent moisture by weight and allowed to stand 1 week before planting.

One seedling of each species was planted in each of the four treatments. Before potting, top length, root length, and total green weight of each seedling were measured.

We placed the pots in a greenhouse for 6 months, adding distilled water weekly to bring the spoil to 20 percent moisture by weight. The weight of water added was recorded.

Before the first fall frost, the pots were moved outdoors to a lath house. Distilled water was added when the spoil surface appeared dry. After 3 months outdoors and exposure to several freezes, the pots were brought inside and placed on a light table. The light source consisted of 40-watt cool white fluorescent and 200-watt incandescent bulbs; light intensities ranged from 800 foot-candles at the top of the pots to 1,200 foot-candles at the tip of the tallest seedling. Day length was set at 16 hours. Distilled water was added at weekly intervals.

The study was terminated at the end of this second growth period (about 4 months). We determined pH and specific conductance on spoil samples from the top and bottom of each pot. Specific conductance was determined to document changes in total soluble salt concentration of the soil solution resulting directly or indirectly from the application of lime. After the spoil was washed from the roots, each seedling was remeasured. The new needles, old needles, stem, and roots of each seedling were separately oven-dried and ground in a Wiley mill for tissue analysis. Tissue nutrient concentrations for elements except nitrogen were determined spectrographically at a commercial laboratory; nitrogen was determined by the Kjeldahl method in our laboratory.

Results

Spoil chemical properties.—Analysis of the spoil showed a progressive increase in pH with increasing amounts of lime. There was no significant difference in pH between the top and bottom of the pots. The pH of the treatments at the top of the pots were as follows:

Treatment	*pH*
Check	3.5
2 tons lime/acre	3.9
5 tons lime/acre	6.6
10 tons lime/acre	7.6

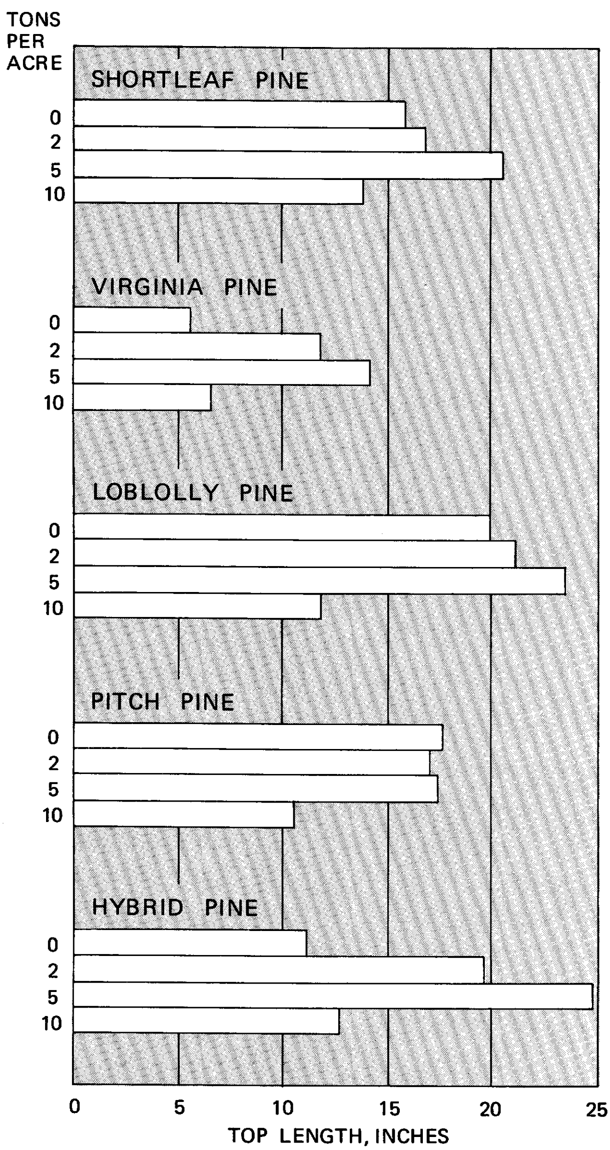

Figure 1.—Top length by species and treatment.

There was a significant increase in specific conductance in the pots with 2- and 5-ton treatments. A significant difference in specific conductance between the top and the bottom of individual pots was found only in the check. The bottom of the check pot had a specific conductance of 0.8 millimhos/cm. and the top was 1.3 millimhos/cm. The specific conductance at the top of the pots were as follows:

Treatment	*Specific conductance (millimhos/cm.)*
Check	1.3
2 tons lime/acre	1.7
5 tons lime/acre	1.6
10 tons lime/acre	1.2

Seedling size and growth.—Although only one seedling of each species was used with each level of liming, the consistency in response for all species, except pitch pine, is encouraging.

Differences in top length, root length, and total green weight, at the time of potting and after the second growth period, were used to compute growth. Average top length was the greatest on the 5-ton-per-acre treatment for all species except pitch pine (fig. 1). The top lengths on the 10-ton-per-acre treatment were as short or shorter than all other treatments for shortleaf, loblolly, and pitch pine.

For Virginia and loblolly pines, liming effect on root depth was similar to that on top growth (fig. 2). For the pitch x loblolly pine hybrid, root length increased with each lime increment; the reverse was true for shortleaf pine. Root length of pitch pine was erratic.

Green weights were less after the 10-ton treatment than after either the 2- or 5-ton treatments (fig. 3). Virginia pine and the hybrid responded dramatically to the 2- and 5-ton treatments while modest gains were made by loblolly and shortleaf. The green weight of pitch pine decreased with each increase in lime.

Water use.—We computed average weekly water use during the first 5-month growth period for each species under each treatment and found that from greatest to least water use, the treatments ranked as follows: 5 tons per acre, 2 tons per acre, check, and 10 tons per acre. Since each seedling was of similar size when potted, the differences in water use probably were related to growth response.

Nutrient content of plant tissue.—We first compared the concentrations of each of 12 nutrients in the roots, stems, new needles,[1] and old

[1] Those needles that developed during the second growth period.

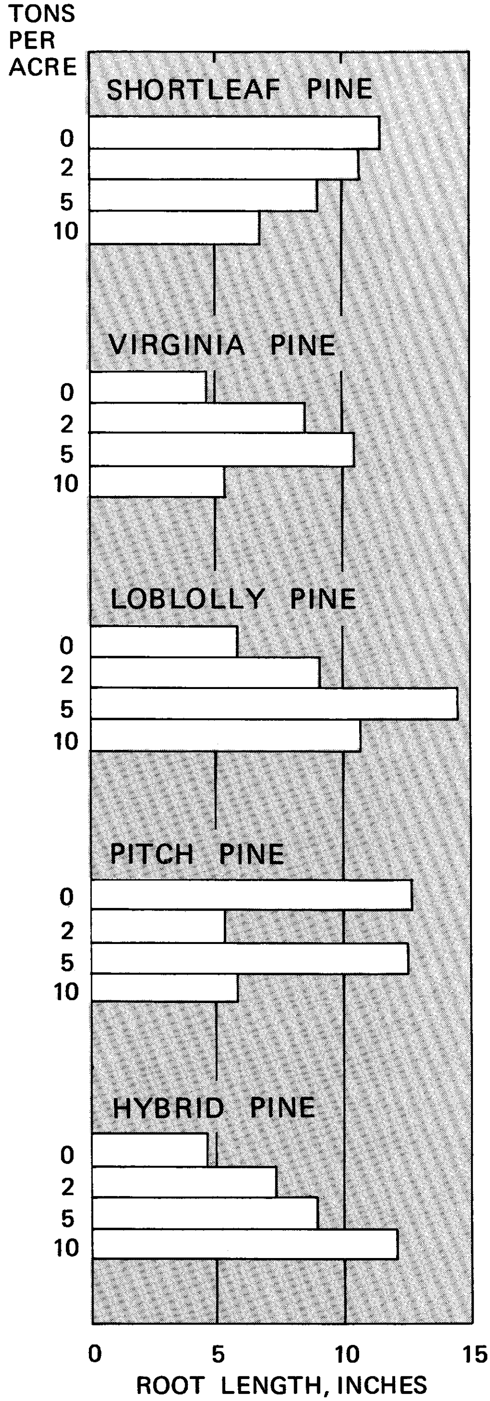

Figure 2.—Root length by species and treatment.

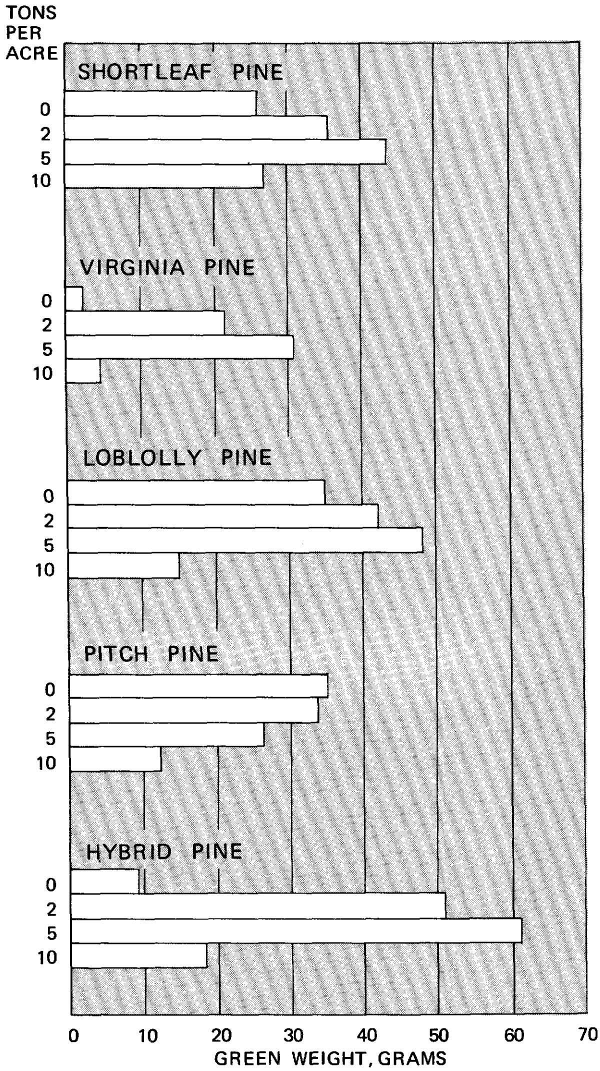

Figure 3.—Green weight of seedlings by species and treatment.

needles[2] of trees grown in the check pot to determine which part had the highest concentration.[3] The new needles had the highest concentration of potassium. Magnesium, manganese, and boron concentrations were highest in the old needles. Highest amounts of calcium, iron, copper, aluminum, and molybdenum were found in the roots. There was no significant difference between plant parts in the concentrations of phosphate or zinc, but their concentrations were assumed highest in the new

[2] Those needles on the seedling when potted or that developed during the first growth period.
[3] Statistically significant at the 1-percent level.

Table 1.—*Average nutrient content of tissue with the highest nutrient concentration for all species, by treatment*

Nutrient	At tons of lime per acre— 0	2	5	10	Differences between treatments were:
	Pct.	*Pct.*	*Pct.*	*Pct.*	
Nitrogen	1.56	1.22	1.36	1.43	Not determined.[1]
Phosphorus	.15	.15	.12	.09	Significant.[2]
Potassium	.53	.60	.59	.73	Not significant.
Calcium	1.28	.90	2.10	2.78	Highly significant.[3]
Magnesium	.33	.26	.18	.13	Highly significant.
	Ppm.	*Ppm.*	*Ppm.*	*Ppm.*	
Iron	1,998	1,150	818	871	Highly significant.
Manganese	750	798	421	218	Highly significant.
Aluminum	3,129	2,996	2,868	2,728	Not significant.
Copper	43	29	20	24	Highly significant.
Zinc	76	62	36	37	Highly significant.
Boron	38	44	38	21	Highly significant.
Molybdenum	5.06	4.22	2.82	3.22	Significant.

[1] Insufficient data.
[2] Statistically significant at the 5 percent level.
[3] Statistically significant at the 1 percent level.

needles and roots, respectively. There was insufficient data to statistically determine the highest concentration of nitrogen, but it was assumed to be in the new needles.

We compared nutrient content by treatment using values from the plant part with the highest concentration. Phosphorus, magnesium, molybdenum, zinc, copper, and boron decreased with increasing amounts of lime (table 1). Calcium was low on the check and 2-ton treatments, but increased with the 5- and 10-ton treatments. Concentrations of iron and manganese were reduced after the 5- and 10-ton treatments. Liming had no effect on the concentration in plant tissues of potassium, aluminum, or nitrogen.

Conclusions

We found that, under greenhouse conditions, liming at the rate of 5 tons per acre-foot can significantly improve the growth of loblolly, shortleaf, Virginia, and a hybrid of pitch-loblolly pine. Liming did not increase the growth of pitch pine. It was also apparent that 10 tons of lime per acre-foot reduced the growth of all species below that obtained with lesser amounts of lime.

Tissue analysis pointed out significant differences in nutrient content between treatments. In the tissues of the unlimed plants, all nutrients except calcium were as high or higher than those in the plants growing in the limed spoil. Growth, however, was best after the 5-ton-per-acre liming treatment. One explanation for the slow growth on the unlimed spoil could be toxic amounts of some elements. Since the 5-ton-per-acre treatment reduced the concentration of manganese, iron, copper, and zinc by almost half, it appears that one or more of these elements could have contributed to the reduction in growth.

Growth after the 10-ton-per-acre treatment was always less than after the other treatments. Also, the concentration of all elements except calcium, potassium, aluminum, and nitrogen was significantly reduced by this treatment. Therefore, heavy liming appears to have interfered with the absorption of essential nutrients.

The results indicate that liming can influence the growth of some pine species on extremely acid spoils; field research will be necessary to determine rates of application and duration of effect on extremely acid sites.

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