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Growth and Survival of Hardwoods and Pine Interplanted with European Alder

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Abstract

European black alder is recommended for planting on many surface mine spoils in the eastern United States. It grows rapidly on a range of spoil types and contributes to soil enrichment by fixing nitrogen and providing a leaf fall rich in nutrients.

This study evaluated the effect of alder on the survival and growth of five hardwood and five pine species.

After 10 growing seasons, the alder had had little effect on the survival of the interplanted species, but their height and diameter growth were greater in association with alder. Foliar analyses showed that the interplanted species had used nitrogen fixed by the alder.

EUROPEAN black alder *(Alnus glutinosa)* is recommended for planting on many surface mine spoils in the eastern United States (*Funk and Dale 1961, Lowry et al. 1962*). It grows rapidly, reaching heights of 20 to 30 feet in 10 years on favorable sites. The alders contribute to soil enrichment by fixing nitrogen and by depositing a leaf litter rich in essential plant nutrients. These characteristics suggest alder as a nurse crop for hardwoods and coniferous trees.

Finn *(1953)* documented advantages and disadvantages of using black locust *(Robinia pseudoacacia)* as a nurse crop. He concluded that the growth of many species was increased by planting them with locusts. Foliar analysis indicated that the locust was a source of nitrogen for the interplanted species. But the wide-spreading crown and prolific root sprouts of the locust often suppressed or killed slow developing interplanted tree seedlings. This will not be as severe a problem with alder as it has a narrow, columnar crown and does not sprout from the roots.

This study was made to compare the survival and growth of five hardwoods and five pine species planted with and without an alder nurse crop. The conclusions, based on 10 years of observation, indicate that alder is a desirable nurse crop.

THE STUDY

The study was established near London, Kentucky, on Lily coal seam spoils. Elevation of the site is about 1,500 feet. One or two contour cuts were made to recover the coal. The spoil was piled on the outside of the cut with no leveling before planting (fig. 1). The strongly to very strongly acid surface spoil, ranging in pH from 3.5 to 5.5, is a mixture of shale and sandstone. There were also occasional patches of toxic spoil with a pH below 3.5.

Three blocks were established on spoils with similar surface characteristics. Each block was divided into two plots (fig. 2). On one plot, five hardwoods and give species of pine were planted. Each 20-tree row was assigned to one of the following species in random order:

Figure 1.—The study area at the time of planting. The spoil was piled on the outside of the cut with no leveling before planting.

Figure 2.—A block 6 years after planting. The plot planted with alder is on the left; that planted without alder, on the right.

Yellow-poplar	(*Liriodendron tulipifera* L.)
Sweetgum	(*Liquidambar styraciflua* L.)
Sycamore	(*Plantanus occidentalis* L.)
White ash	(*Fraxinus americana* L.)
Cottonwood	(*Populus deltoides* Bartr.)
Shortleaf pine	(*Pinus echinata* Mill.)
Virginia pine	(*Pinus virginiana* Mill.)
Pitch pine	(*Pinus rigida* Mill.)
Eastern white pine	(*Pinus strobus* L.)
Loblolly pine	(*Pinus taeda* L.)

On the second plot, the same species were planted in 20-tree rows alternating with rows of European alder. All species on both plots were spaced 7 x 7 feet. As the experimental design required, the plots with alders were twice the size of the plots without alders.

Measurements

Survival was determined at the end of the first, third, fifth, and tenth growing seasons. Total height of the hardwoods and pines was measured to the nearest tenth of a foot at the end of the third, fifth, and tenth growing seasons. Dale *(1963)* summarized the results of measurements at the end of three growing seasons. Alders were not measured during the study period.

During August of the tenth growing season, leaf samples were collected from each of the test species. Where enough trees had survived, 50 trees of each species were sampled, 25 of those grown with an alder nurse crop and 25 of those grown without it. The trees sampled were chosen from all living trees on the three blocks proportionally. Where less than 25 trees had survived, all living trees were sampled. Leaves or needles were collected from the upper half of the crown on the south or west side. Leaves with obvious insect or disease damage were discarded. Each sample was oven dried and ground in a Wylie mill. A commercial laboratory measured all foliar nutrients except nitrogen; we used the Kjeldahl method to measure foliar nitrogen.

Spoil samples were collected in the spring and fall of the tenth growing season. Thirty samples were collected at random on each plot. The pH was determined from a 1:2 mixture of soil and distilled water with a line pH meter. Total soluble salts were measured electrically with a conductivity meter from a 1.2 mixture of soil and distilled water.

The litter from three 1-foot-square quadrats on each plot was collected, air dried, and weighed to measure litter accumulations with and without alder. These samples were collected at the midpoint between two rows of trees.

RESULTS

Spoil characteristics and litter accumulation 10 years after planting

We compared spoil characteristics and litter accumulation to determine whether alders caused significant changes in the chemistry of the surface spoil during the 10-year study period.

In the spring of the tenth growing season, the pH of the spoils under alders was significantly lower than that of spoils without alders (table 1). A similar analysis in the fall of the same year showed no significant difference in pH between spoils with alders and those without. Spoil pH was lower in the fall than in the spring, both with and without alders.

This may be the result of soil moisture trends and biological factors that influence the formation of acid. The cool weather in the spring reduces microbiological activity in the soil and the frequent rains leach out residual acidity. During the summer and fall, increased temperature accelerates the biological formation of acid. Wetting and drying cycles bring the acidity to the surface by capillary action.

Variations in soluble salt concentrations were similar to pH variations. Salt concentrations were higher under the alders. They were higher in the fall than in the spring. This suggests that the alder cover crop contributes to acidity and to soluble salt concentrations.

There was about twice as much litter on the plots interplanted with alders. Average accumulation under the alders was 27.5 tons per acre, oven-dry weight. On plots without alders, the average was 12.8 tons per acre. Much of the difference is attributed to alder leaf fall.

Survival

Seedlings often die during the first growing season because of their condition when planted or the way they were planted. Site conditions may cause a consistent attrition from year to year. The alders could affect survival when they overtop the interplanted species. In this planting, the trees were overtopped during the fifth or sixth growing seasons (fig. 3). Since the objective of this study was to determine the effects of alder on interplanted species, comparisons of survival during the last 5 years of the study are important.

More cottonwoods and loblolly pines died under the alder nurse crop between the fifth and tenth growing seasons (table 2). The alders overtopped the tallest interplanted species by 5 to 10 feet, and suppression probably caused much of the mortality in these two intolerant species. The survival of the other eight species was not affected by the alder cover crop.

Height and diameter growth

The height growth of 6 of the 10 species was significantly greater under the alder nurse crop 5 years after establishment (table 3). Sycamore, sweetgum, and white ash showed the greatest response to alders. Cottonwood, pitch pine, yellow-poplar, and white pine grew as well without an alder nurse crop.

After 10 years' growth, all species except loblolly pine were significantly taller where they had been planted with alders. Growth differences between trees planted with and without alders were less for cottonwoods than for the other seven species. Cottonwoods and loblolly pines also showed increased mortality when planted with alders. The greatest growth

Table 1.—Mean pH and total soluble salts 10 years after planting

Measurement	Season	Plot 1 W[a]	Plot 1 WO	Plot 2 W	Plot 2 WO	Plot 3 W	Plot 3 WO	Plot average W	Plot average WO
pH	Spring	4.0	4.6	5.1	5.1	4.6	4.9	4.6	4.9
	Fall	4.1	4.3	4.8	4.9	4.6	4.6	4.5	4.6
Total soluble salts (mmhos/cm)	Spring	.093	.063	.061	.051	.088	.062	.081	.059
	Fall	.201	.140	.114	.089	.166	.133	.165	.115

[a] W: with alder; WO: without alder.

Figure 3.—Alders overtopped the seedlings in this planting in the fourth and fifth growing seasons. The top picture shows 3-year-old white pines interplanted between alders. Below is the same spot during the sixth year.

Table 2.—Percent survival by species at the end of the first, fifth, and tenth growing seasons

Species	Growing season First		Fifth		Tenth	
	W [a]	WO	W	WO	W	WO
Hardwoods:						
Sycamore	32	55	30	53	30	53
Sweetgum	48	68	47	67	47	65
White ash	85	97	85	93	85	92
Cottonwood	68	48	60	40	48	40
Yellow-poplar	52	77	48	68	48	67
Softwoods:						
Virginia pine	93	93	93	93	93	92
Shortleaf pine	73	78	73	75	73	75
Loblolly pine	52	50	50	43	35	42
Pitch pine	88	95	87	93	87	93
White pine	85	88	83	80	83	78

[a] W: with alder; WO: without alder.

Table 3.—Average total height at the end of the fifth and tenth growing seasons (in feet)

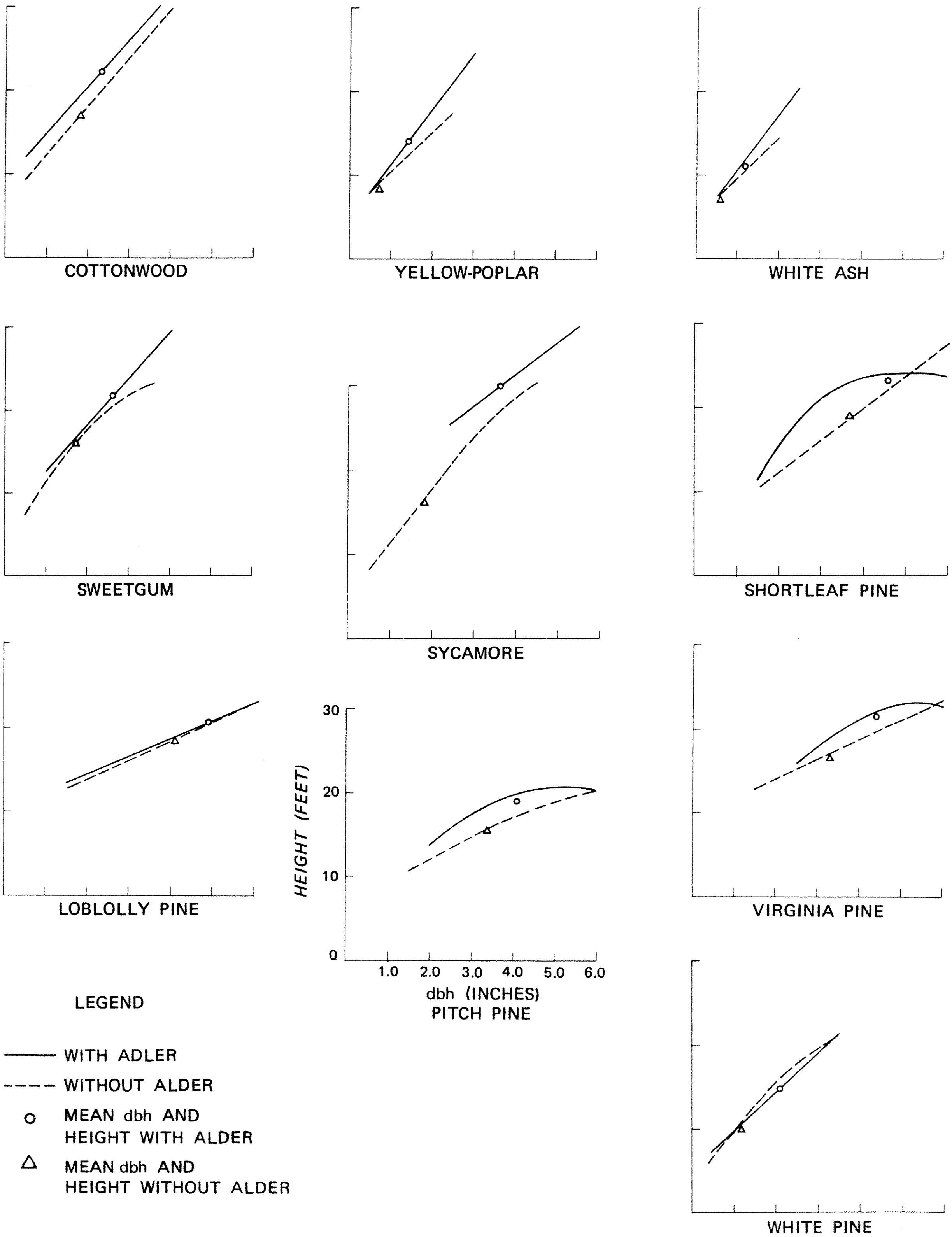
Species	After 5 growing seasons			After 10 growing seasons		
	With alder	Without alder	Diff.	With alder	Without alder	Diff.
Sycamore	12.4	8.1	4.3**	30.0	16.3	13.7**
Sweetgum	8.7	6.7	2.0**	21.6	15.3	6.3**
White ash	7.4	5.9	1.5**	11.1	7.6	3.5**
Virginia pine	8.1	6.7	1.4**	21.5	16.8	4.7**
Shortleaf pine	9.2	7.9	1.3**	23.2	18.6	4.6**
Loblolly pine	10.2	8.8	1.4**	20.7	18.6	2.1
Cottonwood	10.1	9.0	.9	22.1	17.1	5.0*
Pitch pine	6.7	6.0	.7	18.8	15.5	3.3**
Yellow-poplar	4.8	4.3	.5	14.1	8.1	6.0**
White pine	2.8	2.7	.1	14.8	10.0	4.8**

** Significant at 1% level
* Significant at 5% level

Table 4.—Average dbh and height with and without alder nurse crop

Species	dbh		Height	
	With alder	Without alder	With alder	Without alder
	Inches		*Feet*	
Yellow-poplar	1.4	0.7	14.1	8.1
Cottonwood	2.3	1.9	22.1	17.1
Sweetgum	2.6	1.7	21.6	15.3
White ash	1.2	.6	11.1	7.6
Sycamore	3.6	1.8	30.0	16.3
Virginia pine	4.4	3.3	21.5	16.8
White pine	2.1	1.2	14.8	10.0
Pitch pine	4.1	3.4	18.8	15.5
Shortleaf pine	4.6	3.7	23.2	18.6
Loblolly pine	4.9	4.1	20.7	18.6

Figure 4.—Diameter-to-height curves for the 10 species studied.



in response to alders was shown by sycamore, sweetgum, and yellow-poplar.

The average diameter of all species was greater under the alder nurse crop (table 4). Differences in diameter between trees grown with and without alders ranged from 1.8 inches for sycamore to 0.4 inch for cottonwood. Virginia, shortleaf, and loblolly pine averaged about 1.0 inch greater in diameter when grown with alders. This indicates that for many species a merchantable crop could be realized at an earlier age if the trees were interplanted with alders.

The percentage of stems over 4.0 inches dbh provides additional information on the acceleration of diameter growth by an alder nurse crop. Sixty to 80 percent of the stems of Virginia, pitch, shortleaf, and loblolly pine planted with alders were 4.0 inches dbh or larger at 10 years of age. This compares with 25 to 50 percent without alders. Diameter growth of hardwoods was slower. A few sycamores, sweetguns, and cottonwoods had stems 4.0 inches dbh or larger.

Relationship between height and diameter

Regression analyses were used to construct curves to show the relationship between diameter and height for each species with and without alder. In general the relationship between diameter and height was a straight line for hardwoods. Interplanting with alder did not affect this relationship. The pine species showed wide variation in the shape of the diameter-to-height curves. This variance occurred between species and within species, between trees planted with and without an alder nurse crop.

Without alder, cottonwood, yellow-poplar, and white ash had a linear relationship between diameter and height (fig. 4). There were significant differences between the curves for each species. The sweetgum and sycamore data showed a curvilinear relationship described by a quadratic curve. This suggests that these two species may be affected by site characteristics that cause a slowing in height growth for the larger diameter trees. An analysis of covariance showed no significant difference between the sweetgum and sycamore curves. Grouping the data for these two species resulted in a quadratic curve with a correlation coefficient of 0.94. Independently, the correlation coefficients were: sweetgum 0.91 and sycamore 0.94.

When planted with alder all hardwood species showed a linear relationship between diameter and height. An analysis of covariance indicated that data for cottonwood and sycamore could be grouped. The resulting correlation coefficient was 0.89. Before grouping, the correlation coefficients were: cottonwood, 0.91 and sycamore, 0.68. The correlation coefficients for the other species with alder were as follows: white ash, 0.91; yellow-poplar, 0.83; and sweetgum, 0.91.

The relationship between diameter and height was also linear for shortleaf pine, loblolly pine, and Virginia pine growing without an alder nurse crop. There was no significant difference between the curves for Virginia pine and loblolly pine. The correlation coefficients for these species were: Virginia pine, 0.73; shortleaf pine, 0.90; and loblolly pine, 0.82.

Pitch pine and white pine had a quadratic curvilinear relationship between diameter and height when growing without an alder nurse crop. An analysis of covariance showed no significant difference between the curves. The coefficient of correlation was 0.96 for white pine and 0.86 for pitch pine.

When planted with an alder nurse crop, white pine and loblolly pine showed a linear relationship between diameter and height. The correlation coefficients were 0.96 for white pine and 0.72 for loblolly pine. The alder nurse crop modified the diameter-to-height curve for white pine from curvilinear to linear. This is an expression of white pine's tolerance to shading by the alder and an improvement in site factors affecting height growth.

Shortleaf pine, pitch pine, and Virginia pine all displayed a quadratic curvilinear relationship between diameter and height. By analysis of covariance there was no significant difference between the curves. The correlation coefficients were: shortleaf pine, 0.65; Virginia pine, 0.95; and pitch pine, 0.61. The change from linear to curvilinear relationship for shortleaf and Virginia pine when planted with alder suggests the alder may be suppressing height growth. It is possible that wider spacing between these two species of pine and the alder would minimize suppression by the alder.

Foliar analysis

The spoil analyses show that alders reduce pH and increase the concentration of soluble salts. It is also known that alders fix atmospheric nitrogen under favorable conditions. These facts show that alder can alter the chemical and nutrient regimes on a planting site. Foliar analyses were used to identify nutrient differences between species growing with and without alders.

Comparisons of foliar nitrogen showed that nitrogen fixed by the alders is available to interplanted species. All species had higher foliar nitrogen when grown with alders (table 5).

The hardwood foliage had higher concentrations of iron, cobalt, molybdenum, and barium when grown with alder. Concentrations of phosphorus and calcium were lower in the foliage of hardwoods growing with alder.

Nitrogen was the only nutrient found in higher concentrations in the foliage of pines growing with alders. Manganese, strontium, and silicon were lower in pines growing with alder.

Variation in foliar nutrients between species is illustrated by the concentrations of foliar macronutrients. Sweetgum, white ash, and yellow-poplar had significantly higher foliar nitrogen with alder (table 6). Cottonwood had higher foliar magnesium with alder. Variations for the other macronutrients in the hardwood species were either not significant or the foliar nutrient levels were significantly higher without alder.

White pine growing with alder had significantly higher nitrogen, potassium, and calcium. Shortleaf pine had significantly higher nitrogen (table 7). The remaining variations between pines growing with and without alder were either not significant or significantly higher without alder.

Volunteer Virginia pines, similar in size to those on the study plots, grew on an adjacent old field. The old field foliage was higher in

Table 5.—Average concentrations of foliar nutrients with and without alder nurse crop

Foliar nutrient	Hardwoods		Pine	
	With alder	Without alder	With alder	Without alder
Nitrogen, percent	1.17	1.03	1.01	.82
Phosphorus, percent	.27	.38	.19	.18
Potassium, percent	1.10	1.09	.85	.83
Calcium, percent	.84	.96	.27	.30
Magnesium, percent	.51	.47	.08	.10
Manganese, ppm.	514	502	651	721
Iron, ppm.	66	53	51	51
Boron, ppm.	33	39	14	17
Copper, ppm	11	9	4	3
Zinc, ppm.	37	33	32	31
Aluminum, ppm.	278	270	1156	1177
Molybdenum, ppm.	1.79	1.64	1.72	1.71
Cobalt, ppm.	5.32	3.13	1.20	1.12
Strontium, ppm.	32.2	36.0	10.1	13.7
Sodium, percent	1.0	1.1	1.0	1.0
Silicon, percent	40.1	40.4	17.7	21.0
Barium, ppm.	14.3	7.3	1.7	1.7

Table 6.—Concentrations of foliar macronutrients in hardwoods planted with and without alder

Macronutrients	Sycamore		Sweetgum		White Ash		Cottonwood		Yellow-Poplar	
	With alder	Without alder	With alder	Without alder	With alder	Without alder	With alder	Without alder	With alder	Without alder
Nitrogen	0.71	0.82	1.00**	0.65	1.50*	1.21	0.91	0.94	1.75*	1.56
Potassium	1.03	1.18	.77	.69	1.28	1.43	1.27	1.20	1.16	.94
Phosphorus	.18	.18	.20	.39**	.20	.43**	.16	.14	.18	.19
Calcium	.92	.85	.94	1.01	.42	.66*	.95	.98	.99	1.35**
Magnesium	.45	.37	.27	.29	.30	.27	.69*	.59	.82	.85

**Difference significant at 1% level
*Difference significant at 5% level

Table 7.—Concentrations of foliar macronutrients in pines planted with and without alder

Macronutrients	Pine species: Virginia With alder	Virginia Without alder	Shortleaf With alder	Shortleaf Without alder	Loblolly With alder	Loblolly Without alder	Pitch With alder	Pitch Without alder	White With alder	White Without alder
Nitrogen	0.60	0.52	1.46**	1.13	0.61	0.56	0.77	0.68	1.54**	1.25
Potassium	.73	.74	1.02	1.05	1.04	.95	.69	.74	.69*	.60
Phosphorus	.17	.17	.20	.20	.17	.13	.12	.12	.29	.26
Calcium	.21	.21	.19	.26**	.12	.19**	.22	.25	.61*	.47
Magnesium	.05	.05	.10	.11	.06	.06	.06	.07	.15	.19

**Differences significant at the 1% level
*Differences significant at the 5% level

Table 8.—Concentrations of foliar nutrients in Virginia pine planted with and without alder on surface mined land and growing on an old field

Foliar nutrient	Surface mine spoil: With alder	Surface mine spoil: Without alder	Old field
Nitrogen, percent	0.60	0.52	0.85
Potassium, percent	.73	.74	.68
Phosphorus, percent	.17	.17	.17
Calcium, percent	.21	.31	.21
Magnesium, percent	.05	.05	.05
Manganese, ppm.	740	825	379
Iron, ppm.	60	72	64
Boron, ppm.	22	24	22
Copper, ppm.	5	3	8
Zinc, ppm.	40	40	37
Aluminum, ppm.	1100	1086	1097
Molybdenum, ppm.	2.31	2.10	2.17
Cobalt, ppm.	1.15	0.82	1.43
Strontium, ppm.	0	0	1.6
Sodium, ppm.	1.5	1.4	2.0
Silicon, ppm.	33.5	34.2	13.2
Barium, ppm.	.1	.4	6.8

nitrogen, copper, cobalt, and barium (table 8). Trees on the spoil were higher in potassium, manganese, and silicon.

CONCLUSIONS

This study showed important site changes, improved growth, and differences in foliar nutrient concentrations when alder was used as a nurse crop. Specifically:

- Within 10 years, alders significantly reduce spoil pH and increase total soluble salt concentrations. Apparently no reduction in tree growth results from these soil changes.
- At the 7- x 7-foot spacing the alders overtopped and killed cottonwoods and loblolly pines. The survival of the other eight species was not affected by the alder nurse crop.
- Height and diameter growth of hardwoods and pines are accelerated when they are planted at an appropriate spacing with alder.
- Regression analyses demonstrated a straight line relationship between diameter and height for hardwood species growing with and without an alder nurse crop.
- The pine species showed wide variation in the shape of the diameter-to-height curves. A change from linear to curvilinear for shortleaf and Virginia pine suggests that alder suppressed growth for these species. The change from curvilinear to linear for white pine indicates that this species benefited from the alder nurse crop. The relationship between

diameter and height for pitch pine and loblolly pine indicates little or no response to the alder nurse crop.

- Nitrogen fixation by alders increased foliar nitrogen in the interplanted species. There was no other consistent effect on foliar nutrients.

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