TPN 44(4): 166-171.

Survival and Growth of Trees and Shrubs on Different Lignite Minesoils in Louisiana

James D. Haywood, Allan E. Tiarks, and James P. Barnett

Silviculturist, principal soil scientist, and project leader, USDA Forest Service Southern Forest Experiment Station, Pineville, Louisiana

In 1980, an experimental opencast lignite mine was developed to compare redistributed A horizon with three minesoil mixtures as growth media for woody plants. The three minesoil mixtures contained different amounts and types of overburden materials, and normal reclamation practices were followed. Loblolly pine (Pinus taeda *L.), sawtooth oak* (Quercus acutissima *Carruthers), yaupon* (Ilex vomitoria *Ait.), Amur honeysuckle* (Lonicera maackii *Maxim.), water oak* (Q. nigra *L.), white oak* (Q. alba *L.), longleaf pine* (P. palustris *Mill.), and Osage-orange* (Maclura pomifera *(Raf.) Schneid.) were planted in each reclaimed soil. Survival and growth of all eight species were good on all soils. Therefore, replacement of the A horizon is not always necessary to satisfactorily revegetate lignite minesoils.* Tree Planters' Notes **44(4): 166–171; 1993.**

Under the 1977 Surface Mining and Reclamation Act (P.L. 95-87), the reclamation of lands stripped for lignite involves replacing the overburden (the material overlying a useful mineral deposit) to return the land to approximately its original contour, restoring the land to its original productivity, and reestablishing its original plant cover (Torbert and Burger 1990). Rapid establishment of ground cover is important for protecting newly contoured slopes from erosion, and woody species used for reclamation must tolerate this ground cover and be adapted to growing in the reclaimed soil (Torbert and others 1985).

Capping the overburden with the A horizon (the topsoil) aids in rapid establishment of ground cover and benefits tree growth (McGinnies and Nicholas 1983). However, there are two drawbacks to using the A horizon. Separately stockpiling A horizon material is an added expense, and the A horizon may be too shallow and difficult to recover or have such poor physical properties that its recovery is not practical or desirable.

Therefore, the objective of our research was to determine if A horizon restoration was necessary on lignite mine lands in Louisiana, or if establishing selected tree and shrub species on several overburden mixtures would be sufficient. To study this objective, an experimental opencast lignite mine was operated, closed, and reclaimed in northwestern Louisiana in 1980.

Methods

Study site. The study site is in DeSoto Parish, Louisiana. Before mining, the soils were in the Woodtell (fine, montmorillonitic, thermic Vertic Hapludalfs) and Metcalf (fine-silty, siliceous, thermic Aquic Glossudalfs) series. These are moderately well to somewhat poorly drained, very slowly permeable soils formed in gently sloping to nearly level Coastal Plain uplands. These soils are best suited to growing forest crops but may be converted to pasture. The typical native vegetation is loblolly pine (*Pinus taeda* L.), shortleaf pine (*P. echinata* Mill.), southern red oak (*Q. falcata* Michx.), and post oak (*Q. stellata* Wangenh.). The site is nearly level.

Stockpiles. During mining in 1980, soil material was extracted from different depths, segregated, and stored in seven stockpiles (SP1 through SP7) (figure 1):

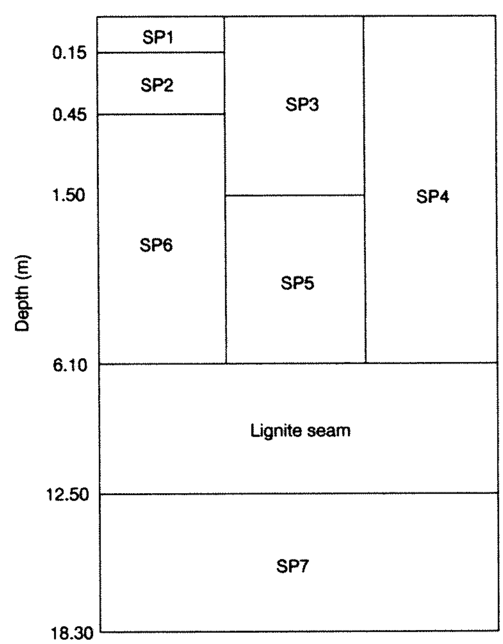

Figure 1—*Depths from which the different stockpiles (SP1 through SP7) were extracted. The depths given in the figure are not to scale, and the lignite seam may have varied in thickness.*

SP1 *A horizon*—the upper 0.15 m (0 to 0.5 feet) of the soil profile. Texture is sandy loam, available water-holding capacity is 0.07 kg/kg of soil (0.07 pounds per pound of soil), and total sulfur content is 0.3 g/kg of soil (0.005 ounces per pound of soil).

SP2 *B horizon*—the 0.15- to 0.45-m (0.5- to 1.5-foot) layer of the soil profile. Texture is clay, available water-holding capacity is 0.11 kg/kg of soil (0.11 pounds per pound of soil), and total sulfur content is 0.2 g/kg of soil (0.003 ounces per pound of soil).

SP3 *A, B, and C horizons*—the upper 1.5 m (0 to 5 feet) of the soil profile containing 10% A horizon by volume, and the remainder is B and C horizon material. Texture is clay, available water-holding capacity is 0.11 kg/kg of soil (0.11 pounds per pound of soil), and total sulfur content is 0.1 g/kg of soil (0.002 ounces per pound of soil).

SP4 *0 to 6.1 m overburden*—the upper 6.1 m (0 to 20 feet) of the soil profile containing 2.5% A horizon material by volume. Texture is clay loam, available water-holding capacity is 0. 07 kg/kg of soil (0.07 pounds per pound of soil), and total sulfur content is 0.2 g/kg of soil (0.003 ounces per pounds of soil).

SP5 *Clay loam subsoil overburden*—the 1.5- to 6.1-m (5- to 20-foot) layer of the soil profile. Texture is clay loam, available water-holding capacity is 0.06 kg/kg of soil (0. 06 pounds per pound of soil), and total sulfur content is 0.5 g/kg of soil (0.008 ounces per pound of soil).

SP6 *Sandy clay loam overburden*—the 0.45- to 6.1-m (1.5- to 20-foot) depth in the soil profile. Texture is sandy clay loam, available water-holding capacity is 0.07 kg/kg of soil (0.07 pounds per pound of soil), and total sulfur content is 0.2 g/kg of soil (0.003 ounces per pound of soil).

SP7 *Deep loamy sand*—the layer was at a depth of 12.5 to 18.3 m (41 to 60 feet), which was below the lignite. Texture is loamy sand, available water-holding capacity is 0.05 kg/kg of soil (0.05 pounds per pound of soil), and total sulfur content is 0.2 g/kg of soil (0.003 ounces per pound of soil).

Soil samples from each stockpile were analyzed at the Louisiana State University Soil Analysis Laboratory, Baton Rouge, LA. Based on these chemical analyses, ammonium nitrate and triple superphosphate were applied to all stockpiles at the minimum rates recommended by the laboratory. Rates were different for each stockpile, reflecting the different nutritional status of each overburden mixture. However, the rates per unit volume of overburden were not determined. Muriate of potash was also added to the SP7 stockpile. Each stockpile was seeded with Pensacola bahiagrass (*Paspalum notatum* Fluegge) and common Bermuda grass (*Cynodon dactylon* (L.) Pers.) and mulched with straw.

Plot installation, fertilization, and plantings. The mine was closed in winter 1980, and the pit was backfilled to within 3.05 m (10.0 feet) of the final, leveled surface. The pit area was divided longitudinally into four parallel east-west strips, each 13.7 m (45.0 feet) in width and 88.4 m (290 feet) in length (figure 2).

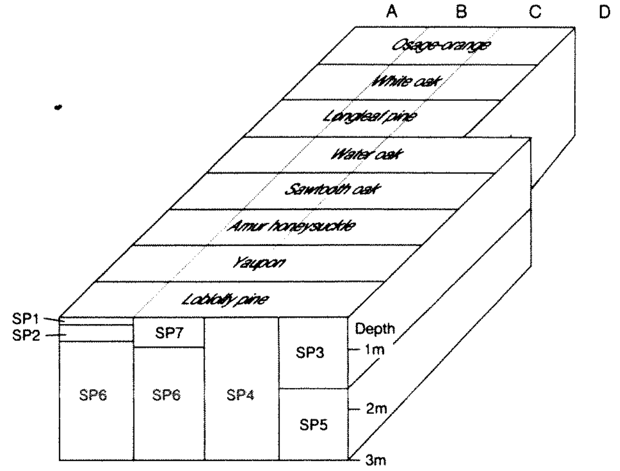

Figure 2—*Placement of stockpiled minesoils (SP1 through SP7) in strips (A through D) and species rankings.*

The northernmost strip (A) was backfilled with 2.6 m (8.5 feet) of SP6 overburden, overlaid with 0.3 m (1.0 foot) of the SP2 material, and surfaced with 0.15 m (0.5 foot) of SPl material (figure 2). Strip B consisted of 2.45 m (8.0 feet) of SP6 overburden covered by 0.6 m (2.0 feet) of the SP7 material. Strip C was entirely filled with SP4 overburden. Strip D consisted of 1.5 m (5.0 feet) of SP5 overburden covered by 1.5 m (5.0 feet) of SP3 material. Strip D was 13.0 m (43.0 feet) short on the east end because it contained the access ramp for backfilling.

Therefore, the stockpiles in strip A were returned to the pit in the same order in which they were extracted, resulting in the restoration of the A horizon (figures 1 and 2). In strip B, the loamy sand from beneath the lignite seam replaced the A and B horizons. Strip C was a mixture of all soil horizons from a depth of 0 to 6.1 m, and this mixture contained 2.5% A-horizon material. Strip D was a coarse attempt to restore the original soil structure by returning to the pit a mixture of the upper 1.5 m of soil material (an aggregate of the A, B, and C horizons) overlying a mixture of the soil material found at a 1.5 to 6.1 m depth.

In 1981, lime and fertilizer were applied uniformly along each strip, but at a different rate for each strip (Burton and Tiarks 1986). A native grass, carpetgrass (*Axonopis affinis* Chase), was seeded over the entire test pit, but common Bermuda grass and Pensacola bahiagrass quickly reestablished and formed a vigorous stand, overtaking the carpetgrass.

Woody species were hand-planted in pure stands at a 0.9- by 0.9-m (3- by 3-foot) spacing (11,960 stems/ha or 4,840 stems/acre). The planting rows ran perpendicular to the backfilled strips (A through D), and each species–strip combination formed a plot (figure 2). Therefore, species were not randomized or replicated. The planting scheme resulted in 24 rows of 15 plants (360 plants/plot) of loblolly pine or sawtooth oak (*Quercus acutissima* Carruthers), and 8 rows of 15 plants (120 plants/plot) of yaupon (*Ilex vomitoria* Ait.), Amur honeysuckle (*Lonicera maackii* Maxim.), water oak (*Q. nigra* L.), longleaf pine (*P. palustris* Mill.), white oak (*Q. alba* L.), or Osage-orange (*Maclura pomifera* (Raf.) Schneid.) per species–strip combination. The backfilling ramp precluded the plots at the end of strip D.

Not all species were planted in the same year because of poor seedling quality, delays in obtaining planting stock, poor success at stand establishment, and species replacement (Burton and Tiarks 1986). However, between 1981 and 1986, the following species were successfully established in terms of survival and early growth: loblolly pine and sawtooth oak in February 1981; water oak, Amur honeysuckle, and yaupon in January 1982; white oak in January 1983; longleaf pine in May 1985; and Osage-orange in October 1986 (figure 2). Plantings were made with 1 + 0 bareroot seedlings, except for yaupon, longleaf pine, and Osage-orange. The yaupon seedlings were grown in peat pots by a commercial nursery. The longleaf pine and Osage-orange seedlings were grown in containers by USDA Forest Service personnel.

All plots were irrigated frequently in 1981 and 1982. All the planted trees and shrubs were quickly overtopped by herbaceous plants, and frequent mowing was necessary.

Foliage samples were collected from the loblolly pine, sawtooth oak, and water oak plots in August 1983. Nitrogen (N), phosphorus (P), and potassium (K) concentrations were determined on a Kjeldahl digest by ammonium probe, by colorimetry, and by atomic absorption, respectively (Burton and Tiarks 1986). Nitrogen was applied as ammonium nitrate to all plots at 56 kg/ha (50 pounds per acre) in May 1984 and 28 kg/ha (25 pounds per acre) in May 1985. Foliage samples were collected from loblolly pine, sawtooth oak, and water oak again in August 1992 to determine N, P, and K concentrations.

In April 1984, loblolly pine and sawtooth oak numbers were reduced (by thinning) from 360 plants/plot to 40 loblolly pines/plot or 180 sawtooth oaks/plot (from 11,960 plants/ha to 1,329 pine and 5,980 oak/ha or from 4,840 plants/acre to 539 pine and 2,420 oak/acre). Individual plants among the other established species were too small to warrant thinning in 1984.

Tree and shrub measurements. Each plot (or species–strip combination) was inventoried periodically through March 1990. Plot results were based on the center 32 loblolly pines, 99 sawtooth oaks, and 66 plants for each of the other six species. The other plants were in the unmeasured border area of each plot. Because of the differences in planting dates, the most recent measurements were taken after nine growing seasons for loblolly pine and sawtooth oak; eight growing seasons for yaupon, Amur honeysuckle, and water oak; seven growing seasons for white oak; five growing seasons for longleaf pine; and three growing seasons for Osage-orange. Survival was determined, total height was measured, and percentage of crown cover was estimated for each species–strip combination. Diameter at breast height (dbh) was measured on the loblolly pines, and groundline diameter was measured on all other species. Statistical analysis was not performed because there was no replication; all comparisons and interpretations are subjective.

Results and Discussion

Tree and shrub survival and growth. In terms of height and diameter growth, loblolly pines were the largest trees on all four strips (A through D). First-year survival of loblolly pine ranged from 63 to 90% across the four strips, probably because of the initial irrigation. No mortality occurred in the second and third growing seasons. Few of the remaining loblolly pines died after thinning to a stocking of 1,329 trees/ha (538 trees/acre) at age 3, and among the remaining trees, survival averaged 98% across the four strips at age 9 (table 1). Loblolly pine trees were no larger on strip A than on strip D. Nine-year-old loblolly pine height and quadratic mean dbh averaged 9.0 m (29.6 feet) and 15.4 cm (6.0 inches), respectively, across the four strips. Plot canopies were not closed at age 9 because of the earlier thinning treatment.

Longleaf pine was planted 4 years after loblolly pine. Because longleaf pine has an extended "grass" stage and its plots were not irrigated, the longleaf

Table 1—*Percent survival, heights, diameters, and crown cover by species, date, and overburden mixture**

Species and variables	Growing season	Lignite minesoil strips			
		A	B	C	D
Loblolly pine	9th				
Survival (%)		96	100	100	97
Height (m)		8.7	9.1	9.0	9.3
Diameter (cm)		16.3	14.5	14.3	16.3
Crown cover (%)		45	45	45	45
Sawtooth oak	9th				
Survival (%)		95	93	94	93
Height (m)		5.1	1.7	2.2	4.5
Diameter (cm)		6.8	3.4	3.8	6.2
Crown cover (%)		100	90	100	100
Water Oak	8th				
Survival (%)		67	88	85	85
Height (m)		3.2	3.1	3.0	4.2
Diameter (cm)		4.4	3.9	3.8	5.9
Crown cover (%)		80	90	80	100
Amur honeysuckle	8th				
Survival (%)		92	27	89	94
Height (m)		2.1	0.4	1.0	1.4
Diameter (cm)		ND	ND	ND	ND
Crown cover (%)		100	5	60	80
Yaupon	8th				
Survival (%)		79	79	77	80
Height (m)		1.9	0.8	1.0	1.1
Diameter (cm)		3.0	1.6	1.6	2.1
Crown cover (%)		90	30	40	60
White oak	7th				
Survival (%)		70	91	56	NP
Height (m)		2.1	1.6	2.1	NP
Diameter (cm)		3.9	2.9	3.8	NP
Crown cover (%)		80	70	90	NP
Longleaf pine	5th				
Survival (%)		47	64	94	NP
Height (m)		0.9	1.6	1.3	NP
Diameter (cm)		ND	ND	ND	NP
Crown cover (%)		ND	ND	ND	NP
Osage-orange	3rd				
Survival (%)		92	89	100	NP
Height (m)		0.6	0.4	1.0	NP
Diameter (cm)		ND	ND	ND	NP
Crown cover (%)		ND	ND	ND	NP

*Planting density was 11,960 stems/ha. Loblolly pine and sawtooth oak plots were thinned in April 1984 to 1,329 pine and 5,980 oak stems/ha. Survival percentages are based on these values. Loblolly pine diameters were taken at breast height. The other species' diameters were taken at groundline.
ND = no data, NP = no plot because of ramp location.

seedlings averaged only 1.3 m (4.3 feet) tall after 5 growing seasons, and trees on strip A were the shortest (table 1). However, height growth was comparable to or better than that of the three oak species at the same age (data not shown). Longleaf pine survival averaged 68% across the three strips (A through C), which is better than the average survival of 60% for 1-year-old planted longleaf pine seedlings in Louisiana (State of Louisiana 1993).

Sawtooth oak was the largest hardwood species through three growing seasons. Few of the remaining sawtooth oaks died after thinning to a stocking of 5,980 trees/ha (2,420 trees/acre) at age 3, and among the remaining trees, survival averaged 94% across the four strips at age 9 (table 1). After nine growing seasons, the trees on strips A and D were taller and had greater quadratic mean groundline diameters than those on strips B and C. Tree height and diameter averaged 3.4 m (11.1 feet) and 5.1 cm (2.0 inches), respectively. The tree crowns covered covered 98% of the four strip surfaces after 9 years.

Water oak was not initially as large as sawtooth oak. However, after eight growing seasons, water oaks were as large as the older sawtooth oaks, with water oaks having an average total height of 3.4 m (11.2 feet) across the four strips (table 1). The water oak plots were not thinned, which influenced groundline diameter growth comparisons with sawtooth oak. Survival averaged 81%, and crown cover averaged 88% across the four strips. Water oak was largest on strip D after eight growing seasons.

Height and diameter growth of white oak after seven growing seasons was as good as those of either sawtooth oak or water oak at the same age, although the white oak plots were not irrigated. After seven growing seasons, survival, total height, quadratic mean groundline diameter, and crown cover averaged 72%, 1.9 m (6.2 feet), 3.5 cm (1.4 inches), and 80%, respectively, across the three strips (table 1). The trees on strip A were similar in size to those on strip C.

Amur honeysuckle and yaupon survival averaged 76 and 79%, respectively, after eight growing seasons (table 1). Average height and crown cover of both shrub species were greater on strips A and D than on strips B and C.

Osage-orange was planted last and had completed only three growing seasons by 1990. Survival averaged 94%, and the seedlings were 0.7 m (2.3 feet) tall across the three strips at age 3 (table 1, figure 2).

Nutrient contents of foliage and soil properties. Foliage sampled in August 1983 from the three fastest growing species showed that trees on strip A had the highest concentration of N (table 2). However, N was applied to all strips in both 1984 and 1985. By August 1992, foliar N concentrations in strip A for loblolly pine, sawtooth oak, and water oak were 10.0, 14.1, and 14.0 g/kg, respectively. For the other three strips, foliar N concentrations of loblolly pine, sawtooth oak, and water oak averaged 10.1, 15.5, and 13.4 g/kg, respectively. The nitrogen levels in loblolly pine foliage indicated deficiency (Wells and Allen 1985), which is not surprising because the N-supplying capacity of new minesoil frequently is less than that of older, long-vegetated minesoil or of undisturbed soil with similar N concentrations (Hons and Hossner 1980, Reeder and Berg 1977).

The foliar concentrations of P and K were not consistently affected by the kind of lignite minesoil (table 2). However, the P concentration in loblolly pine foliage from both the 1983 and 1992 samples were above growth-limiting levels (Wells and Allen 1985). Thus, the differences in P are not affecting growth. Potassium concentrations in loblolly pine foliage were less in 1992 than in 1983, but concentrations in sawtooth oak foliage were greater in 1992 than in 1983.

Conclusions

Plant survival and growth were generally satisfactory on all four kinds of minesoil, and therefore, replacement of the A horizon is not always necessary when correct reclamation practices are followed. The two pine and three oak species studied here are important forest trees, and all five species became readily established and grew well on these lignite minesoils, although established common Bermuda grass and Pensacola bahiagrass are effective competitors of planted tree seedlings (Barnett and Tiarks 1987, Fisher and Adrian 1981). In fact, loblolly pine and water oak grew best when a mixture of the A, B, and C horizons was used as the surface soil (strip D). Reclamation should continue to be successful as long

Table 2—*Nutrient concentrations of foliage samples collected from selected species in August 1983 (before nitrogen amendment in May 1984 and 1985) and in August 1992*

	Nutrients (g/kg)					
	August 1983			August 1992		
Species and lignite minesoil strip	N	P	K	N	P	K
Loblolly pine						
A	13.1	1.5	8.4	10.0	1.2	5.0
B	9.5	1.3	8.4	9.9	1.7	7.0
C	10.5	1.4	9.0	10.0	1.5	5.4
D	11.4	1.3	7.6	10.4	2.1	5.3
Sawtooth oak						
A	14.1	1.4	5.3	14.1	1.3	6.3
B	9.7	1.7	6.2	15.2	1.5	8.4
C	10.0	1.1	3.7	16.5	1.7	8.0
D	10.8	1.2	4.5	14.9	1.8	7.4
Water oak						
A	12.4	1.0	6.1	14.0	1.0	6.4
B	10.8	0.9	6.7	13.4	1.2	5.1
C	11.1	0.9	4.6	14.4	1.2	6.7
D	11.7	0.9	5.4	12.4	0.9	5.7

as these lignite minesoils provide acceptable chemical and physical soil properties and an adequate amount of nutrition is supplied through fertilization.

Literature Cited

Barnett JP, Tiarks AE. 1987. Reforesting disturbed sites in the South with pine species. In: Fourth biennial symposium on surface mining and reclamation on the Great Plains and fourth annual meeting of the American Society for Surface Mining and Reclamation, 1987 March 17–19, Billings, MT. Bozeman, MT: American Society for Surface Mining and Reclamation: H-5-1 to H-5-7.

Burton JD, Tiarks AE. 1986. Available nutrients and early growth of woody plants vary with overburden material in lignite minesoils of Louisiana. In: Proceedings, National Meeting of the American Society for Surface Mining and Reclamation, 1986 March 17–20, Jackson, MS. Princeton, WV: American Society for Surface Mining and Reclamation: 79–85.

Fisher RF, Adrian F. 1981. Bahiagrass impairs slash pine seedling growth. Tree Planters' Notes 32(2):19–21.

Hons FM, Hossner LR. 1980. Soil nitrogen relationships in spoil material generated by the surface mining of lignite coal. Soil Science 129(4):222–228.

McGinnies WJ, Nicholas PJ. 1983. Effects of topsoil depths and species selection on reclamation of coal-mine spoils. In: Smith JA, Hays VW, eds. Proceedings of the 14th International Grasslands Congress. 1981; Lexington, KY. Lexington, KY: Westview Press, 353–356.

Reeder, JD, Berg WA. 1977. Nitrogen mineralization and nitrification in a Cretaceous shale and coal mine spoils. Soil Science Society of America Journal 41(5):922–927.

State of Louisiana, Department of Agriculture and Forestry, Office of Forestry. 1993. Pine plantation survival report—1992. Baton Rouge, LA. 1. p.

Torbert JL, Burger JA. 1990. Tree survival and growth on graded and ungraded minesoil. Tree Planters' Notes 41(2):3–5.

Torbert JL, Jr, Burger JA, Lien JN, Schoenholtz SH. 1985. Results of a tree species trial on a recontoured surface mine in southwestern Virginia. Southern Journal of Applied Forestry 9(3):150–153.

Wells C, Allen L. 1985. A loblolly pine management guide—when and where to apply fertilizer. Gen. Tech. Rep. SE-36. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 23 p.