LIRIODENDRON GROWTH ON NATIVE AND STRIPMINE SOILS

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ABSTRACT.—Liriodendron seedlings were planted each spring and fall for 5 years on unmined lands, ungraded spoils, graded to approximate original contour (AOC), and graded to contour with "topsoil" replaced. Survival was greatest on unmined lands and height greatest on ungraded ridge and valley spoil. No Liriodendron seedlings survived on AOC graded mine land. A few small trees survived on graded "topsoil" sites where surface materials had been segregated and replaced. Reclaimed sites with topsoil replaced were highly compacted and had a dense tall fescue grass ground cover. On unmined lands and ungraded spoils, Liriodendron seedlings outgrew black walnut and northern red oak seedlings.

Liriodendron (*Liriodendron tulipifera* L.), also known as tuliptree, yellow-poplar, tulip-poplar, white poplar, or whitewood, is a valuable, fast-growing eastern hardwood that produces large quantities of seed from which planting stock is readily available. From its natural distribution related to climate, parent material, relief and biota and from past planting studies, Liriodendron is known to be more site sensitive than many of its associates. This paper focuses on reinforced or new understanding of Liriodendron's site requirements to guide future plantings, and on its potential for evaluating planting sites in stripmine reclamation.

Surface-mined lands are of importance because of their large and expanding extent, non-vegetated post-mining condition, and potential for highly productive tree growth when site conditions and choices of species for planting are fitting. Different kinds of post-mining landscape and soils are found depending on applicable government regulations when mined. Greater understanding of plant/rooting medium relationships is needed for successful management of new lands after mining. A fuller description of the mining process and resultant site conditions in southern Illinois is given in Ashby (1999).

My objectives were to evaluate
1) how well does Liriodendron grow on mined land,
2) what planting practices are useful for reforesting mined lands with Liriodendron,
3) how does Liriodendron seeding survival and growth on three kinds of mined lands compare to seedlings on unmined reference areas, and
4) how does Liriodendron seedling growth compare to other tree species used in reclamation?

GROWTH ON MINED LANDS

Related to seed source, Liriodendron has readily invaded mined land in eastern Kentucky and Tennessee (Rafaill 1988). Liriodendron saplings dominated on one unreclaimed mountainside contour mine (833 stems/ha). On two mines reclaimed by planting black locust (*Robinia pseudoacacia* L.) plus herbaceous legumes and grass, the dominant invading species were red maple (*Acer rubrum* L.) and Liriodendron with 300 and 167 stems/ha, respectively.

Limstrom (1960) summarized numerous species trials on mined lands in the midwest from a series of USDA Forest Service research plots.

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Liriodendron was successful on deep well-drained spoil in the pH range 4.5 to 7.5, with best growth at near-neutral pHs (fig. 1). The N, P, K content of leaves from 4-year-old Liriodendron on both not graded and graded areas of three strip-mine areas in Ohio compared favorably with that of leaves from trees growing on unmined land (Finn 1952). Stony soils on stripmines have been productive for tree growth and crops (Ashby and others 1984).

Although Liriodendron is commonly dominant on better soils in ravines of the southern Illinois hill country, it is conspicuously absent from the fragipan and other soils of adjacent glaciated counties surface mined for coal. Planted Liriodendron is one of the fastest-growing species on ungraded minesoils in these counties and reached small sawtimber size in 50 years. Heights and diameters at breast height (DBH) were measured more than one time for three of eight sets of plots (table 1).

Liriodendron has failed or grown poorly on other USDA Forest Service plantings, especially those using other reclamation practices. These plantings failed because of poor drainage, tight clay soils, continuous rock surfaces, dense overhead or ground cover, and other causes atypical of good sites for Liriodendron in its natural range (Limstrom 1960).

Table 1.—*Height/DBH of Liriodendron at several ages related to topography and pH at planting on stripmines. Boyce and Neebe 1959, Ashby 1996, Unpublished data.*[1]

	AGE				
PLOT	**10**	**22**	**30**	**40**	**47**
			m/cm		
Unleveled					
pH 3.4	3/-	-/-	-/17	-/-	28/33
pH 5.7	-/-	18/21	-/-	30/30	-/-
Leveled					
pH 6.1	3/-	-/-	-/28	-/-	27/36

[1]The pH 5.7 planting was under decadent black locust.

PLANTING PRACTICES

Varied planting practices to improve reclamation success have been used in conventional forestry and in reclamation. We evaluated their usefulness to cope with new and difficult problems after passage of a 1977 federal reclamation law (P.L. 95-87, 1977). Our research plan included successive spring and fall plantings from 1978 to 1982 on three types of reclaimed lands and on unmined lands. These studies were carried out on the Sahara Coal Co., Inc. Mine No. 6 in southeastern Illinois near Harrisburg.

Figure 1.—*Cross-section of stripmine spoil banks at pH 5.1 in southern Illinois with 36-year-old shortleaf pine (*Pinus echinata *Mill.) on the sides and white oak (*Quercus alba *L.) on the left, and 23-year-old Liriodendron in the center. The tree by the person is 22 m tall, 30 cm DBH. Mean Liriodendron stand height was 18 m and DBH was 21 cm.*

Planting methods were similar to those of earlier USDA Forest Service plantings. Replicated plots were planted to 50 trees for each of 20 species at 2.5 m spacing of trees within and between rows. Liriodendron was included as a known site-sensitive tree to characterize limiting conditions and hopefully to find a way to use it in reclamation plantings. Black walnut (*Juglans nigra* L.) and northern red oak (*Quercus rubra* L.) were included for comparison with Liriodendron. Species were randomly assigned to tree rows in a plot so that the nearest neighbors to Liriodendron varied.

Liriodendron seedlings (1-0) from the Union County State Tree Nursery were kept in cold storage until planted. All seedlings were measured for seedling diameter, stem and root length, and graded for quality and dormancy to select for seedling uniformity. Only one-half to two-thirds of each lot of seedlings were used for these plantings. Roots were trimmed to 20 cm long and laterally pruned if needed for planting with a planting bar.

Seedling lots differed in seedling size and dormancy from planting season to planting season. Differences in average stem caliper varied from 11 mm in fall 1981 to 6 mm in spring 1981. Average stem caliper was not consistently related to survival. Root lengths were atypically short in fall 1978, spring 1979, and spring 1980 and were only 15 cm long in spring 1982.

Spring-planted seedlings had been held in cold storage for approximately 6 months. Fall-planted seedlings had been held in cold storage for a few weeks to months. Survival and growth of fall-planted dormant stock were similar to that for seedlings planted the following April. Newly-lifted Liriodendron seedlings planted in September 1978 and September 1979 had no or low survival in contrast to good survival for stored seedlings planted in November 1980 and early December 1981. Frost heaving was not reported.

Seedling counts were taken in years 1 and 3 after planting. Surviving trees were measured for height in 1988 and for height and DBH in 1993. Ages in 1993 thus varied from 16 to 11 years for the successively-planted plots. From 1979 to 1982 the seedlings planted the previous fall and the spring-planted seedlings had simultaneous growing seasons. Survival was equal to or greater for spring- than fall-planted seedlings except for the excessively wet spring in 1981 when the planting was also in late May rather than April (fig. 2).

Starting with the 1981 growing season, all vegetation in a 1.5 m circle around tree seedlings planted the previous fall and that spring was sprayed with a contact and pre-emergence herbicide mixture of glyphosate (Roundup®) and simazine (Princep®). Tree seedlings were shielded during spraying. Herbaceous weed control lasted 2 to 4 years. Other than exceptionally vigorous seedlings planted in spring 1979, survival of Liriodendron seedlings planted in 1981 and 1982 on unmined land and on ungraded spoil with chemical weed control had overall greater survival than seedlings planted in 1978, 1979, and 1980 without chemical weed control (fig. 2). Sapling heights on the plots with chemical weed control, especially on the ungraded plots, were greater than expected for the youngest trees (fig. 3).

ROOTING MEDIA EFFECTS

The plots for the present study were on unmined lands, ungraded pre-law ridge and valley spoil, spoil graded to approximate original contour (AOC), and "topsoil" or AOC graded spoil with replaced surface materials as required under P.L. 95-87. The replaced surface materials of pre-mining eroded old fields were chiefly unproductive subsoils. These sites were only cosmetically similar to the adjacent unmined lands in the present study. Regulatory authorities coined the terms "Topsoil" and "Prime Farmland Fragipan Soil" for the landscapes graded with replaced surface materials. Agronomic practices of fertilization and planted legume and grass ground cover had been carried out as required on both the graded and "topsoil" sites. Dense stands of tall fescue (*Festuca arundinacea* Schreb.) had become dominant on most planting sites.

Survival

Liriodendron survival varied greatly depending on the year of planting and on the rooting media (fig. 2). With few exceptions most mortality took place in the first 3 years after planting. No plantings of 1,000 seedlings each on graded AOC plots survived for any planting season from spring 1978 to fall 1982. Overall survival on the ungraded plots averaged 28 percent (280 of 1,000 trees planted) and 52 percent (520 of 1,000 trees planted) on the unmined plots. Only seven small trees of the 500 planted on the "topsoil" plots from fall 1980 to fall 1982 survived to 1993 out of the 34 that had survived to age 3.

Features of the two graded spoils that likely resulted in little or no survival are the combined effects of compaction and dense ground cover, both of which are otherwise recognized as limiting factors for Liriodendron (Burns and Honkala 1990). Bulk densities at several plot locations ranged from 1.70 to 1.94 with an average 1.80 g/cm^3 compared to 1.27 g/cm^3 for the ungraded spoil. A compaction level of 1.60 g/cm^3 is commonly considered limiting for root growth (Josiah 1986). Biological factors affecting Liriodendron likely included competition especially for water and known allelopathic toxicity from the dense tall fescue cover (Peters and Zam 1981, Rink and Van Sambeek 1985).

Survival on the unmined plots in the present study has been greater than on any of the mine soils related to undisturbed surface soil properties and organisms and partial tree cover at time of planting. The unusually wet 1981 spring season (planting number 7 in figure 2) was an exception with poor survival. Those plots were on a bottomland soil and excessive moisture was likely the cause.

Limited survival during some planting seasons on the ungraded ridge and valley banks may have been caused by drought. The two driest years, 1978 and 1980, had the greatest mortality. Root growth of seedlings planted those years (plantings numbers 1, 4, and 5 of figure 2) on the relatively coarse-textured minesoil may have been too slow to reach deeper moisture reserves. The few surviving small Liriodendron trees on the compacted "topsoil" plots were on a lower-lying area of the mine.

No pre-mining soil features except textures were evident on the "topsoil". The rooting medium was commonly unproductive B-horizon fragipan with occasional gray layer materials. Both the replaced surface materials and the underlying graded minesoil sites were highly compacted. The tall fescue cover with interspersed old-field broomsedge (*Andropogon virginicus* L.) and goldenrod (*Solidago* L. spp.) was less dense on the "topsoil" plots than on the graded AOC plots.

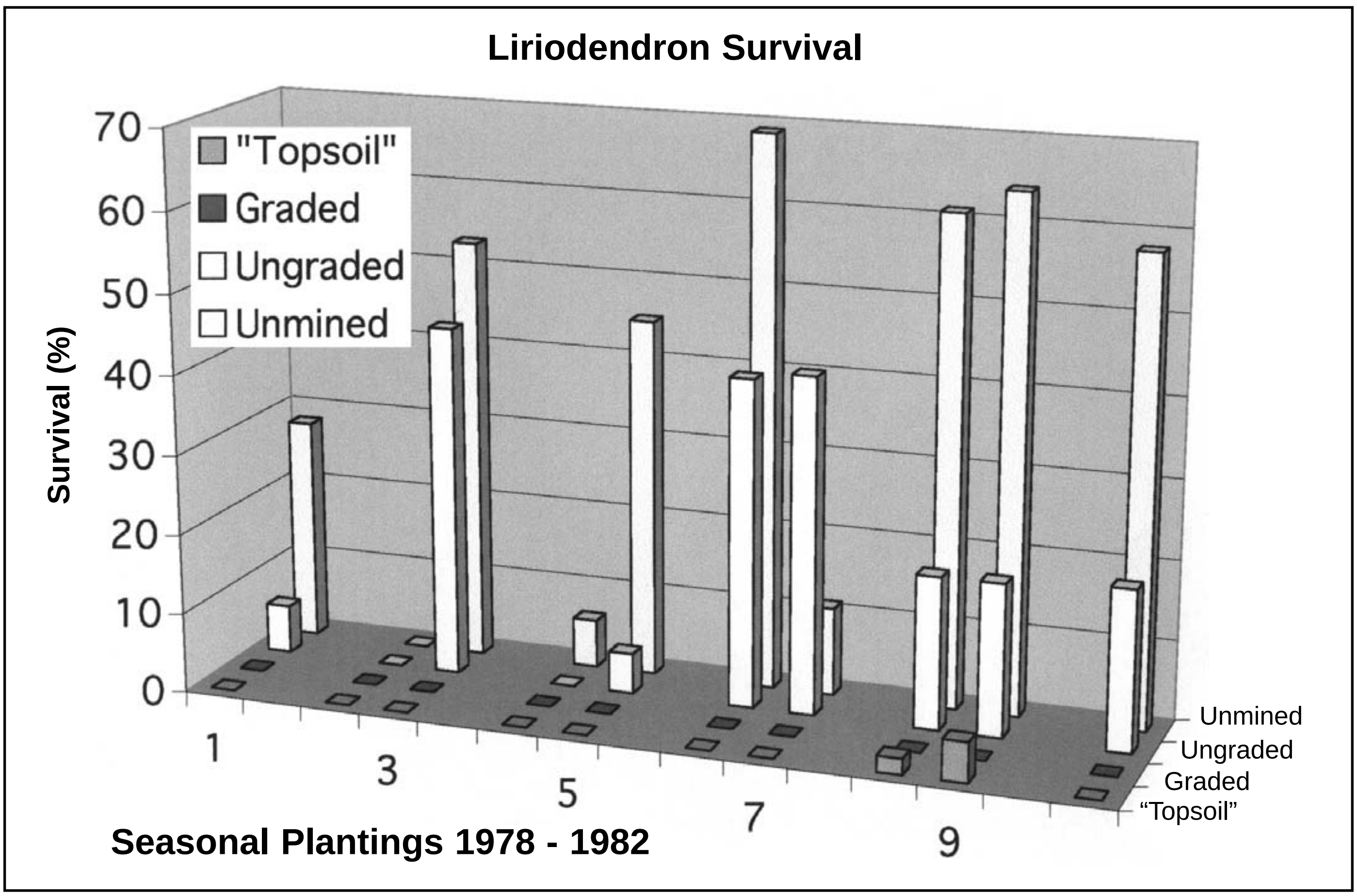

Figure 2.—*Liriodendron survival in 1993 related to rooting media and initial growing season on graded spoils with "topsoil" replaced, spoils graded to original contour, ungraded ridge and valley spoils, and adjacent unmined land. For each paired column the odd-numbered (right) one was planted that spring and the even-numbered (left) one was planted the previous fall. Column one was spring-planted in 1978 and column 10 fall-planted in 1982.*

Height

Liriodendron height related to planting season showed less variation than did survival (fig. 3). Average tree heights were typically greatest on the ungraded ridge and valley spoils, variable on the unmined lands, and very low on the "topsoil" sites. The mandated poor quality and compacted rooting medium together with the tall fescue and other cover on the "topsoil", even with chemical weed control, resulted in an average height growth of only 1.7 m after 12 years (plantings numbers 8 and 9 of figure 3). Required fertilization, commonly not recommended for forest tree plantings, likely accentuated the deleterious effects of the ground cover.

Trees tended to be taller on the ungraded spoil than on the unmined land that was chiefly Hosmer silt loam, Typic Fragiudalfs Alfisols (Miles and Weiss 1978). Plantings numbers 5 and 6 were on Hoyleton silt loam, Aquollic Hapludalfs Alfisols, and the number 7 was on Banlic silt loam, Aeric Haplaquepts Inceptisols. Except for the planting on the Banlic silt loam, which has the highest estimated annual growth of timber for these soils (Fehrenbacher and others 1978), the ungraded minesoils had Liriodendron heights equal to or greater than the unmined reference areas. After 11 years on our ungraded mine spoil (number 10 in figure 3), tree heights averaged 5.1 m compared to only 3.1 m after 10 years in other studies on productive sites (table 1). Although tree age ranged from 11 to 16 years, height growth for fall-planted seedlings was similar possibly because only the young plantings received chemical weed control.

Liriodendron outgrew black walnut in eight comparisons of means on the ungraded plots, and in four comparisons on the unmined plots where black walnut survived (table 2). Liriodendron heights were relatively similar to those of northern red oak on the ungraded spoil and were greater on the unmined lands. Red oak on "topsoil" was about twice the height of the Liriodendron and black walnut trees that survived. Bottomland oaks are now recommended from several studies for planting on "topsoil" sites. The present study is an opportunity to

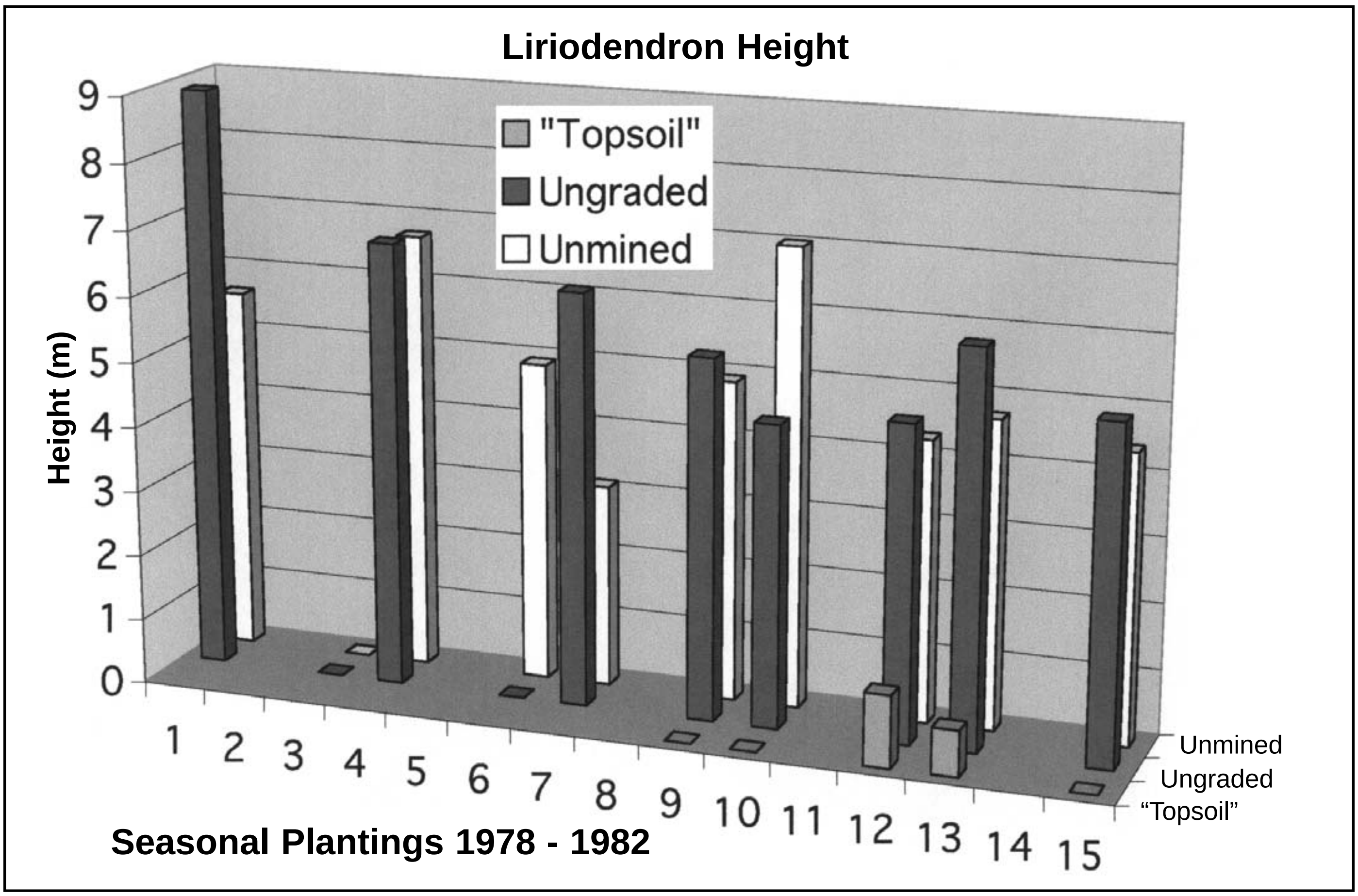

Figure 3.—*Liriodendron height related to rooting media and initial growing season. The mine spoil and planting designations are the same as in figure 2. No Liriodendron survived on the spoil graded to original contour plots.*

test the recently published equations to predict forest productivity for Liriodendron, black walnut, and northern red oak in southern Illinois (Woolery and others 2002).

CONCLUSIONS

1) Survival was lower and average height greater for planted Liriodendron on ungraded stripmine spoil than on adjacent unmined lands where it did not occur naturally.
2) Poor seedling survival on graded AOC or "topsoil" sites was associated with excessive compaction and dense tall fescue cover.
3) Seedlings planted in September failed, probably because they were not dormant.
4) Survival and growth of seedlings were similar when planted in early December or in April.
5) Percent survival was a poor predictor of height growth.
6) Better quality control in nursery production of Liriodendron is recommended, although effects of seedling size were not marked.
7) Benefits for chemical weed control on Liriodendron survival or height growth were confounded by age differences.
8) Only the ungraded spoil matched the productivity levels of Liriodendron on the unmined reference fields.
9) Liriodendron was a relatively better choice for ungraded and unmined lands, black walnut for AOC graded, and northern red oak for "topsoil" sites.

Table 2.—*Height differences in 1993 between Liriodendron and black walnut or northern red oak planted each season from spring 1978 to fall 1982 on ungraded minesoil or unmined rooting medium*

Planting season	Ungraded		Unmined	
	Lir/BW	Lir/RO	Lir/BW	Lir/RO
	m			
Spr. '78	3.6	0.1	2.1	–
Fall '78	–	–	–	–
Spr. '79	2.6	–	–	2.2
Fall '79	–	–	–	4.0
Spr. '80	2.4	–	-0.3	0.1
Fall '80	1.0	–	-0.3	–
Spr. '81	0.9	6.1	-0.4	5.2
Fall '81	1.1	3.4	1.0	2.1
Spr. '82	1.9	2.2	0.8	2.5
Fall '82	1.5	2.4	1.0	3.1

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