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Success of Trees and Shrubs in an 18-Year-Old Planting on Mine Spoil

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Abstract

Plantings of 25 shrub and 25 tree species on a surface mine were evaluated after 18 years and results were compared to a 4-year evaluation. Pin oak, sweet birch, European white birch, Austrian pine, and bur oak show promise of value for wood products. Several other species are useful as soil builders and site stabilizers and for wildlife habitat. Results of the evaluation suggest that mortality of some species over the past 14 years is related primarily to intraspecific and interspecific competition rather than spoil characteristics.

Cover Photo: Trees in an experimental plot and volunteering Virginia pine on acid spoils of the Lily site, Lily, Kentucky.

Introduction

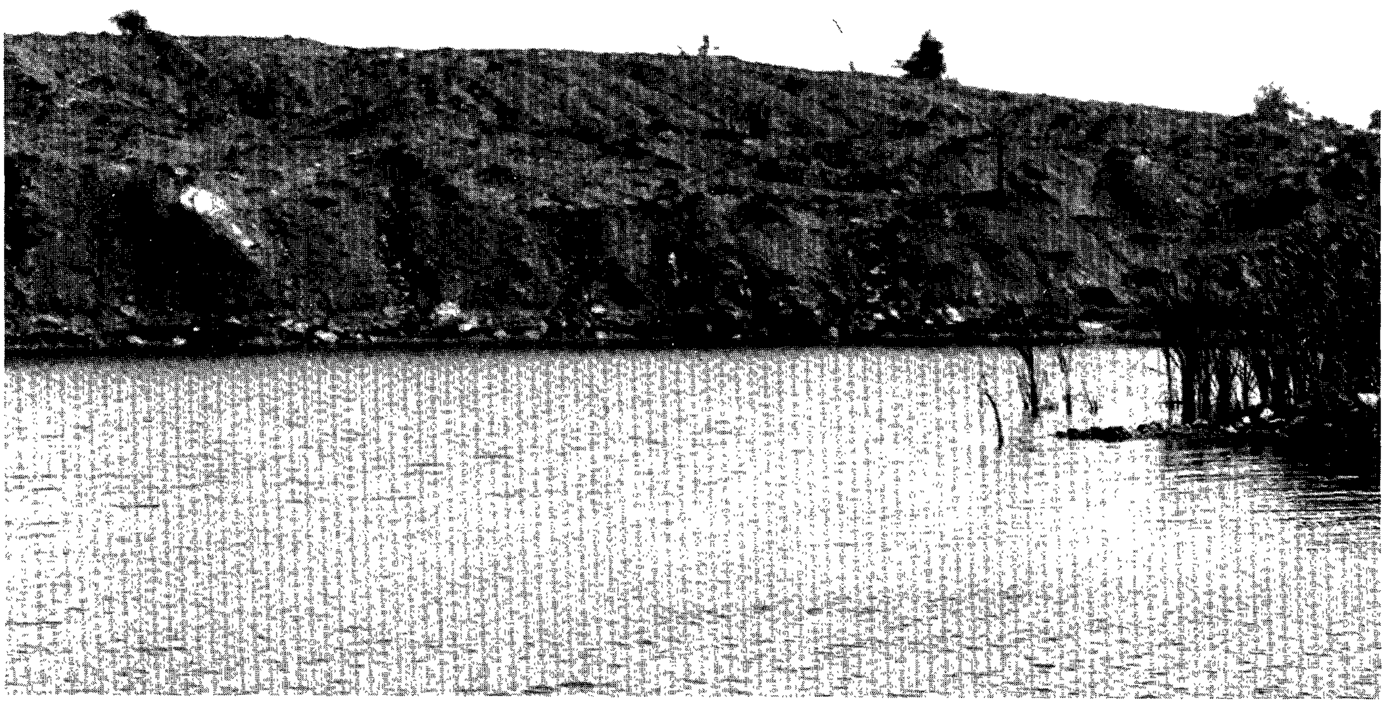
There have been numerous trials of tree and shrub species to determine their suitability for vegetating surface-mined lands for wildlife habitat and forestry. Some of the earlier trials were concerned with selecting tree species that would produce forest products of commercial value. More recently, trials included species of trees and shrubs that will provide diversity in food and cover for wildlife, enhance development of soil and site conditions favorable to natural forest succession, and contribute esthetic enrichment. One such species trial was evaluated 4 years after planting by Plass (1975). In this paper we report on a followup evaluation made 18 years after planting at one of the sites reported on by Plass.

Methods

The Lily site in this study is referred to as Site 1 in the report by Plass (1975). It resulted from surface mining of the Lily coal seam in 1963 and 1964. The spoils, predominantly acid to very strongly acid grey to black shales, were graded to a nearly level topography. There was no topsoiling treatment, fertilization, or liming, and no grass or leguminous ground cover was established.

In 1965, 25 tree and 25 shrub species were planted on this site near Lily in Laurel County, Kentucky. Three tree and two shrub species were planted as replacements in 1966. Twelve blocks each of trees and shrubs, including both native and introduced species, were planted. Each species was randomly assigned to a 6- by 6-foot plot in each block. Four seedlings were planted 3 by 3 feet apart in each plot. All stock was planted bare root except rhododendron, which was planted with a small ball of nursery soil around the roots. Plass (1975) reported species survival and height of plants at the end of the fourth growing season.

In 1965, a soil sample was taken at the center of every plot in every tree and shrub block. The samples were analyzed for pH and specific conductivity by the 1:2 soil to water method, and for available phosphorus by Bray-1 extract (Black 1965). In 1983, four samples from the top 10 cm were taken from each tree block and analyzed by the same



The Lily experimental site at the time of tree plot establishment in 1965.

methods to get soils development data for the same three variables. The 1983 sampling was stratified by tree species: one sample was taken from a mimosa plot, one from an olive plot (nonspecific as to species), one from a birch plot (nonspecific as to species), and the fourth was taken next to a volunteer Virginia pine (*Pinus virginiana*) either in or adjacent to the tree blocks.

The 1983 soils data were analyzed by two-way analysis of variance (ANOVA) with tree species considered a fixed factor and tree block considered a random factor. Tukey's ω test (Steel and Torrie 1980) was performed on tree species means of the three variables where the ANOVA indicated significant differences. Percentage of plots with surviving plants (block frequency), total survival of trees, height of surviving trees and shrubs, and diameter at breast height (d.b.h.) of trees were determined. Tree and shrub heights were measured to the nearest 0.1 foot with a fiberglass measuring pole. The diameter at breast height of trees was determined to the nearest 0.1 inch with a steel d.b.h. tape. Where there were multiple tree stems, the d.b.h. of the largest stem was recorded.

Results

Tree Species

The frequency of survival (percent of plots with surviving trees of a given species) and total survival of trees are shown in Table 1. Half of the tree species maintained a survival frequency of 50 percent or better in the 12 blocks. Mimosa (silktree) had 69 percent actual survival and 100 percent block frequency, better than any other species. Crab apple had a block frequency of 83 percent at 18 years. Of the trees originally listed by Plass (1975) as commercially important based on potential value for wood products, pin oak, European white birch, sweet birch, little leaf linden, bur oak, and Austrian pine had the greatest 18th-year total survival and a frequency of 50 percent or more. Other successful species still present in 50 percent or more of the plots were thornless honeylocust, tree-of-heaven, Siberian elm, boxelder, and Russian mulberry. Several species have disappeared completely.

While tree growth probably is not as great or as significant as it might be because of the effect of close spacing and shading, it still provides useful information on the relative performance of the tree species (Table 2). The best species in terms of mean height growth were European white birch, tree-of-heaven, Austrian pine, sweet birch, pin oak, and Siberian elm. Mean diameter growth of survivors was greatest in Austrian pine, tree-of-heaven, mimosa, European white birch, and pin oak.

Table 1.—Survival of tree species, in present

Species	Frequency[a]	Total survival[b]	
		18 years	4 years[c]
Mimosa *Albizzia julibrissin* Durazz.	100	69	94
Pin oak *Quercus palustris* Muenchh.	91.7	40	42
Thornless honeylocust *Gleditisia triacanthos* L. f. *inermis* (Pursh) Schneid.	83.3	42	75
Japanese crab apple *Malus zumi*[d] Matsum.	83.3	38	56
Tree-of-heaven *Ailanthus altissima* Swingle	75.0	33	46
Siberian elm *Ulmus pumila* L.	75.0	33	67
European white birch *Betula pendula* Roth	66.7	27	35
Sweet birch *Betula lenta* L.	58.3	27	40
Littleleaf linden *Tilia cordata* Mill.	58.3	23	40
Boxelder *Acer negundo* L.	50.0	19	21
Bur oak *Quercus macrocarpa* Michx.	50.0	15	29
Russian mulberry *Morus alba* L. v. *tatarica* Loud.	50.0	15	17
Austrian pine *Pinus nigra* Arnold	50.0	15	29
Black mulberry *Morus nigra* L.	41.7	17	25
American smoketree *Cotinus obovatus* Raf.	41.7	15	21
Sourwood *Oxydendrum arboreum* (L.) DC.	41.7	15	15
Flowering dogwood *Cornus florida* L.	41.7	13	13
Blackgum *Nyssa sylvatica* Marsh.	25.0	6	6
Yellow birch *Betula allegheniensis* Britt.	8.3	2	35[e]
Tamarisk *Tamarix parviflora* DC.	0.0	0	71
Siberian peashrub *Caragana arborescens* Lam.	0.0	0	44
Japanese pagodatree *Sophora japonica* L.	0.0	0	29
Japanese black pine *Pinus thunbergi* Parl.	0.0	0	8
Fraser fir *Abies fraseri* (Pursh) Poir.	0.0	0	0
Cucumbertree *Magnolia acuminata* L.	0.0	0	0

[a] Percentage of plots with surviving plants at 18 years.
[b] Percent surviving plants of total number planted.
[c] Plass (1975).
[d] Reported as Hawthorn (*Crataegus* spp.) by Plass (1975).
[e] Some plots reported as yellow birch by Plass (1975) were identified as sweet birch in 1983.

Table 2.—Mean and maximum height and diameter at breast height of tree species

Species	*n*	Height Mean	Height Maximum	D.b.h. Mean	D.b.h. Maximum
		- - Feet - -		*- - Inches - -*	
Mimosa	37	19.8	30.6	4.2	7.2
Pin oak	19	23.9	38.5	3.4	6.5
Thornless honeylocust	20	17.1	32.2	2.7	4.6
Crab apple	9	13.2	14.9	—	—
Tree-of-heaven	14	29.9	36.0	4.2	8.0
Siberian elm	16	21.0	43.0	2.5	8.4
European white birch	13	37.2	37.8	3.7	5.5
Sweet birch	12	24.8	31.2	2.3	4.6
Littleleaf linden	11	8.4	17.9	0.9	3.1
Boxelder	9	11.6	27.0	0.5	4.6
Bur oak	7	17.8	23.1	2.2	3.6
Russian mulberry	6	11.4	26.5	1.6	5.1
Austrian pine	7	25.7	34.5	4.7	8.3
Black mulberry	8	12.5	19.2	1.8	2.5
Smoketree	7	11.3	16.6	1.0	2.5
Sourwood	7	16.9	23.2	2.9	4.3
Flowering dogwood	6	15.3	23.0	—	1.9
Blackgum	3	12.1	16.4	1.0	1.6
Yellow birch	1	18.8	18.8	1.9	1.9
Weighted Mean		19.2		2.9	
Mean			26.9		4.7

Shrub Species

The shrub plots have become dense thickets. The spreading habit of the shrubs along with invading species made actual survival determinations impossible, so only percent frequency of survival (presence or absence) in the blocks was determined. Twelve of the 25 species maintained themselves in at least half of the blocks (Table 3). Japanese fleeceflower maintained itself in all of the blocks, and silky dogwood in all but one. Chinese privet and thorny, autumn, and cherry olives persisted with 75 percent frequency or better and dominated the plots by overtopping many adjacent species. There were no surviving plants of six species originally planted.

Soils

Soil pH increased from a mean of 3.90 to 4.46 during the 18-year period. Soluble salts as determined by specific conductivity dropped from a mean of 0.31 mmhos/cm to 0.15 mmhos/cm, or 52 percent. Available phosphorus dropped from 6.83 ppm to 4.02 ppm (Table 4). Paired t-tests of block means showed that the changes over time in these three variables were statistically significant at the $\alpha = 0.001$ level. Spoil pH was significantly ($\alpha = 0.05$) related to the species occupying the plot in which the samples were taken (Table 5). There were no significant differences related to tree species for specific conductivity and phosphorus.

Discussion

Tree Species

There has been some mortality among most of the tree species since the last evaluation. For some species this probably is caused by overcrowding, shading, and competition for water and nutrients, more due to close spacing than to effects of the acid mine spoil. Interspecific and intraspecific competition probably was not important during the first 4 years but would have been intense sometime within the last 14 years. Standing, dead, overtopped trees were found next to larger live trees of the same species in several of the plots. Some species may not be adapted climatically to this area. Tamarisk and Siberian peashrub showed good survival after 4 years but were absent after 18 years.

Pin oak was one of the most successful tree species. Its general form was excellent, and height and diameter growth were among the best of the trees on the site. Pin oak seems to be a good choice in this region for surface-mine spoils that are high in clay content and subject to summer droughts. It normally is an important species on wet, intermittently flooded lowlands and on upland flats with heavy soils subject to winter and spring waterlogging and summer droughts. Interspecific competition limits the importance of pin oak on better sites (Fowells 1965). Forty-two percent survival after 4 years with loss of only one more tree in the following 14 years indicates that initial site conditions and not interspecific competition were the principal causes of mortality at the Lily site. Acceptable survival and good growth indicate the value of pin oak for long-term economic returns. Seed usually is not produced before about 25 years of age (Fowells 1965). However, some seed apparently were being produced at the Lily site because pin oak seedlings were found. These seedlings may have a limited future because pin oak is moderately shade intolerant.

Table 3.—Survival and height of shrubs

Species	Frequency[a]	Mean Height[b]
	Percent	*Feet*
Japanese fleeceflower *Polygonum cuspidatum* Sieb. & Zucc.	100	9
Silky dogwood *Cornus amomum* Mill.	91.7	8
Chinese privet *Ligustrum sinense* Lour.	83.3	13
Thorny olive *Elaeagnus pungens* Thunb.	83.3	16
Autumn olive *Elaeagnus umbellata* Thunb.	75.0	19
Cherry olive *Elaeagnus multiflora* Thunb.	75.0	17
Amur privet *Ligustrum amurense* Carr.	75.0	11
Multiflora rose *Rosa multiflora* Thunb.	75.0	9
Indigobush *Amorpha fruticosa* L.	66.7	6
Oakleaf hydrangea *Hydrangea quercifolia* Bartr.	58.3	6
Cotoneaster *Cotoneaster acutifolius* Turcz.	50.0	6
Tatarian honeysuckle *Lonicera tatarica* L.	50.0	10
Coralberry *Symphoricarpus orbiculatus* Moench	41.7	5
European barberry *Berberis thunbergii*[c] DC.	41.7	4
Blueberry *Vaccinium corymbosum* L. v. *glabrum* Gray	33.3	5
Rugosa rose *Rosa rugosa* Thunb.	25.0	—
Red honeysuckle *Lonicera korolkowi* Staph. v. *zabelii* Rehd.	8.3	5
Althea *Hibiscus syriacus* L.	8.3	7
Arrow-wood *Viburnum dentatum* L.	8.3	—
Scotch broom *Cytisus scoparius* L.	0.0	—
Rhododendron *Rhododendron catawabiense* Michx.	0.0	—
Russian olive *Elaeagnus angustifolia* L.	0.0	—
Chinese lilac *Syringa chinensis* Willd.	0.0	—
Dewberry *Rubus* spp. Hort. v.	0.0	—
Blackberry *Rubus* spp. Hort. v.	0.0	—

[a] Percentage of plots with surviving plants.
[b] Average of estimated height of tallest plant in plot.
[c] Reported as *Berberis vulgaris* by Plass (1975).

Table 4.—Mean soil chemical characteristics of tree blocks at the Lily site in 1965 and 1983[a]

Tree	Mean pH value[b]		Specific conductivity		Available phosphorus[c]	
	1965	1983	1965	1983	1965	1983
			mmhos/cm		*ppm*	
1	4.24	4.60	0.20	0.13	7.6	3.1
2	4.37	5.00	.21	.19	7.1	5.3
3	3.76	4.20	.27	.14	5.1	2.8
4	3.89	4.58	.25	.15	6.0	4.0
5	4.02	4.70	.27	.16	7.2	4.0
6	3.96	4.30	.18	.14	6.2	3.6
7	3.52	4.50	.31	.18	6.1	4.4
8	3.83	4.55	.36	.18	8.1	4.7
9	4.33	4.48	.33	.13	9.6	4.2
10	3.66	4.18	.53	.13	6.5	3.4
11	3.86	4.28	.33	.11	7.9	5.9
12	3.41	4.20	.44	.10	4.6	2.8
Mean	3.90	4.46	.31	.15	6.8	4.0
Sd	.303	.244	.102	.028	1.38	.96

[a] Mean difference over time for each variable was statistically significant, α = .001, paired t-test.
[b] 1965 mean for every plot; 1983 mean for four samples per block.
[c] Bray-1 extractant.

Table 5.—Comparison of mean soil pH value, specific conductivity, and available phosphorus under four tree genera in the tree blocks, 1983

Species	pH	Specific conductivity	Phosphorus
		mmhos/cm	*ppm*
Mimosa	4.71 a	.16 a	4.0 a
Birch	4.48 ab	.13 a	4.5 a
Olive	4.44 ab	.15 a	3.6 a
Pine	4.22 b	.13 a	3.9 a

Means for the same variable followed by the same letter are not significantly different, $\alpha = 0.05$, Tukey's ω.

An experimental tree plot on the Lily site showing forest development in 1985, 20 years after tree planting on acid spoils.

European white, sweet, and yellow birches survived in similar numbers through the first 4 years. However, survival of European white birch and sweet birch declined by about one-third, and yellow birch nearly disappeared by the 18th year. Survival of European white and sweet birch was equal at 18 years, but unequal distribution of survivors gave European white birch a higher survival frequency.

European white birch was the best of the birches in height and diameter growth. Height growth of both European white birch and sweet birch was better than the overall average of tree species included in this test. On "average" sites in New York and Pennsylvania, sweet birch can grow to 4 inches d.b.h. at age 20 (Fowells 1965). The largest sweet birch trees on the Lily site achieved this size. Yellow birch at this location is well south of its normal lowland growth range; the warmer climate plus the xeric nature of the surface-mine environment probably is responsible for its poor performance.

In a study of seven birch species planted on a variety of coal-mine spoils in Pennsylvania, Davidson (1976, 1979) found that European white birch had significantly better survival than sweet and yellow birches; yellow birch had the least height growth. Davidson noted the best birch growth was on spoil with a pH of 4.0, though performance was satisfactory down to pH 3.3. Deer browsing damaged the birches in Pennsylvania; yellow and sweet birches were browsed more heavily than other species. Davidson recommends not planting these two species in areas with high deer populations. Improvement of the soil surrounding the birches probably is their greatest contribution to the forest ecosystem. At the Lily site, a developing A horizon in the spoil around them was noted.

Total survival and block frequency of Austrian pine was 15 and 50 percent. Average height of this tree was 25.7 feet, third best of the species tested. The mean d.b.h. of 4.7 inches and its maximum of 8.3 were largest and second largest, respectively. Many of the surviving trees were on plots characterized as "extremely acid" and "very strongly acid" (Soil Survey Staff 1957). The tallest individual was on an extremely acid plot. Only one plot had more than one surviving tree. In several plots a smaller dead pine stood next to the survivor. This indicates that intraspecific competition may have been intense for this species. Keys et al. (1980) cited competition and spoil acidity as factors contributing to mortality of Austrian pine planted on mine spoils. They also determined that seed source and elevation were important in determining the success of this species. Austrian pine has value as a timber species in Europe, but is used primarily as an ornamental in the United States (Little 1979). Our results indicate that more research on management of Austrian pine on surface-mine environments is justified.

Bur oak had a modest tolerance of initial site conditions; 29 percent of the planted trees survived to 4 years of age (Plass 1975). Competition apparently decreased this number by half but bur oak still had a block frequency of 50 percent. Height and diameter growth were less than the weighted mean for all species. Bur oak's growth rate at Lily is not unusually low for this species, however. Plantation growth rates reported by Fowells (1965) bracket the height and diameter growths found on the Lily plots. Bur oak rapidly develops a deep, spreading taproot system. Mature trees may have a root biomass and volume about equal to the aboveground portion of the tree. Such a characteristic gives this tree extreme drought tolerance and gives the species high value as a slope stabilizer. Bur oak tolerates a variety of soil conditions but favors limestone soils in Kentucky (Fowells 1965). This species should have good long-term economic potential on sites with less competition and better spoils. Bur oak was rated as one of the better performing hardwoods on surface-mined lands in Ohio (Larson and Vimmerstedt 1983) and in Missouri and Kansas (Vogel 1977).

Survival of littleleaf linden was 40 percent at 4 years but over the next 14 years it dropped to about half that. The species was included in this test because of potential commercial value. However, survival, and especially growth, do not warrant its further consideration for wood product purposes on this or similar sites.

Blackgum was the least successful in growth of the surviving commercial tree species planted on the site. However, blackgum was an important volunteer tree in the natural plant communities on the site (Thompson et al. 1984). Plass (unpublished progress report 1967) noted the small size of the blackgum planting stock, which may have been primarily responsible for poor survival. The remaining tree species in the experimental plots had little or no timber product value; they were included for other reasons.

Mimosa, a nitrogen-fixing legume, was present in all blocks and had the highest survival at 4 and 18 years. However, most of the mimosa trees were multistemmed and degenerating, with many dead stems per tree, poor form, and dieback of the tops. Many of the surviving mimosa were on spoils initially characterized as very acid, so soil acidity per se may not be the main factor determining the survival of mimosa on these spoils. Mimosa may continue to persist at Lily because of sprouting and suckering near the plantings. This semitropical tree, introduced from Asia, is naturalized in the southeastern United States (Little 1979). Although it is mainly planted as an ornamental, it appears to have value on surface mines as a nitrogen fixer and soil modifier, and as a nurse crop for commercial tree species. Its stem form and attractive flowers are esthetically pleasing.

Thornless honeylocust, a less-armed form of the common honeylocust, showed very good 4-year and reasonably good 18-year survival. Nearly half of these trees were less than 1 inch in d.b.h., and their mean height was less than the mean height (weighted average) of all the trees measured. Only one individual's growth exceeded the minimal 4-inch d.b.h. that is desirable for posts, so this tree's economic potential at the Lily site was poor. Thornless honeylocust is drought resistant but ample water is required for good growth (Fowells 1965). Primary values of this tree are for nitrogen fixation and wildlife food. Where penetration is not inhibited by compaction, the taproots of thornless honeylocust may descend 12 to 20 feet (Fowells 1965) to function as slope stabilizers and as biological pumps for raising nutrients to the surface from deep spoil layers. Thornless honeylocust may have greater value on spoils less acid than the ones at the Lily site. Its growth might be improved through proper management.

Crab apple (*Malus zumi*), reported as hawthorn (*Crataegus* spp.) by Plass (1975), had 56 percent survival at 4 years. At 18 years it still had a block frequency of 83 percent and an actual percentage survival of 38 percent. This Asian species was present only as a small tree. Good survival and production of fruit make it a species worthy of consideration in wildlife plantings.

Tree-of-heaven, introduced from China as an ornamental (Little 1979), has become naturalized over much of the United States and has a wide environmental tolerance. It had a 33 percent overall survival rate at the Lily site. This was one of the largest trees on the site and reproduction by suckering was evident. It has value primarily as an ornamental.

Siberian elm maintained 75 percent block frequency and had reasonably good survival after 18 years. This introduction from northern China and Siberia (Little 1979) produced the largest tree (43 feet tall and 8.4 inches in d.b.h.) in the planted blocks, but the mean growth for this species was not exceptional.

Survival of flowering dogwood is low (13 percent) but there has been no mortality over the last 14 years. Height growth was reasonable for an understory tree. This species also was an important invading tree on the Lily site (Thompson et al. 1984). Dogwood litter is high in nutrients, especially calcium. Thomas (1969) found that flowering dogwood is important in maintaining the calcium cycle in pine plantations on poor soils in Tennessee. This species could contribute to soil building and fertility maintenance in the mine spoils. Dogwood is a favored deer browse and its fruit is eaten by birds (Fuller 1980).

American smoketree is one of the rarer native trees in America and it is normally found on calcareous soils (Fernald 1950). The survival and growth of this tree indicate it is not suited to the Lily site or sites with similar site conditions.

Sourwood had 15 percent survival with no mortality after the fourth year. This suggests that site quality was a greater obstacle to this species than competition. Another possible reason for poor early survival is the small size of planting stock noted by Plass (unpublished progress report 1967). Its growth is about average for established trees on the Lily site. It is a frequent pioneer on disturbed sites and we have noted it invading other surface-mined areas. Thompson et al. (1984) documented sourwood as one of the most important invading native species on the Lily site. The fruit is eaten by wildlife, and the twigs are browsed by deer. Honey produced from sourwood nectar is a much desired product. Its potential value for reclamation on sites such as this needs more investigation.

Black mulberry and Russian mulberry, both naturalized from Asia (Little 1979), had relatively poor initial survival (Plass 1975). However, mortality was quite low over the next 14 years. This indicates that stands would have a good chance if they could be maintained through the early years. The same is true for dogwood and sourwood. Neither the black nor Russian mulberry formed sizable trees except for one Russian mulberry individual which was 5.1 inches in d.b.h. and 26.5 feet tall. These species have value as wildlife food but growth and survival do not warrant their inclusion in a tree mix where survival is of great importance.

The 21 percent survival of boxelder at 4 years and 19 percent survival at 18 years indicates that initial site conditions, not competition, are responsible for its poor performance. Although this normally is a small tree of mesic and fertile soils, it is an important volunteer in tree plantations on spoils in the Midwest (Ashby et al. 1980). The fruits are eaten by squirrels and birds.

Because of its good early survival, Plass (1975) recommended planting tamarisk on spoils as an ornamental. However, there were no surviving tamarisk at 18 years. This suggests that although the species could withstand initial site conditions, it is unable to tolerate competition on poor sites. It also may be unadapted climatically. Tamarisk is considered a pest in the Southwest, where it readily colonizes along irrigation ditches and around reservoirs. It apparently requires excessive ground water or free water to thrive. Results with tamarisk at Lily demonstrates the importance of long-term studies for making recommendations on species suitable for surface-mine plantings.

Japanese pagodatree, Japanese black pine, and Siberian peashrub all had surviving individuals at the end of the fourth year but none at the 18th year. Fraser fir, and cucumbertree did not survive to the fourth year. None of these species are recommended for mine reclamation.

Shrub Species

The complete overgrowth of many of the shrub blocks by the species planted therein made it impossible to determine whether a shrub's presence represented survival of one or several planted individuals. Frequency of survival can serve as a guide to overall survival.

Japanese fleeceflower was present in all plots. This species, naturalized from Asia, is a shrub-like herb. It had developed into dense clumps spreading away from the point of planting. The species formed a dense stand of stems in several small gullies and showed great value as an erosion arrester and wildlife food. It has been reported as tolerant of extremely acid spoils (Ruffner 1978). Patterson (1976) indicates that Japanese fleeceflower may become an important weed due to its spreading nature.

Silky dogwood persisted in 92 percent of the blocks. It makes an excellent deer browse and the fruit is consumed by birds. Persistence of this species, besides its tolerance to acid conditions, also may be due to its shade tolerance. Because of its persistence and value for wildlife, we recommend planting it for wildlife habitat.

The two *Ligustrum* species, Chinese privet and Amur privet, both survived with a frequency of 75 percent or better. These two species were naturalized from China (Staff, L. H. Bailey Hortorium 1976). Their tolerance of surface-mine spoil conditions and production of wildlife food and cover make them species worthy of consideration in reclamation.

Thorny, autumn, and cherry olives were successful in their frequency of survival and in their role as soil builders. These nitrogen-fixing shrubs formed thick canopies overhead and developed a rich leaf-litter mulch on the soil surface. The relatively high nitrogen content of their leaves probably was responsible for the rapid litter breakdown and formation of a rich organic horizon in the top 1 to 2 inches of the soil profile. These species, naturalized from Asia (Staff, L. H. Bailey Hortorium 1976), provide good deer browse and the fruit is used by birds and mammals. In some areas, autumn olive is regarded as a pest because of its spreading nature; it also has been used widely as a nurse species with trees on surface-mine spoils (Vogel 1981).

Multiflora rose, a naturalized shrub from China (Staff, L. H. Bailey Hortorium 1976), persisted in 75 percent of the plots. The flowers have esthetic value and wildlife may use the plants for cover and the fruits for food. This shrub spreads, forms impenetrable tangles of thorny clones, and can cause serious problems in most land uses (Patterson 1976). Despite its virtues for wildlife habitat, we do not recommend multiflora rose for reclamation of surface-mined land.

Indigobush persisted on two-thirds of the plots. Like the olives, it contributes to soil development through nitrogen fixation. This native shrub also has value as wildlife food and cover.

Oakleaf hydrangea persisted on 58 percent of the plots. It has a striking appearance with its large leaves and white flowers. It is one of the lowest growing of the successful shrubs and is shade tolerant. Its primary value may be for esthetic purposes.

The remaining shrub species had a plot frequency of 50 percent or less, which hints at low survival. Five species—Scotch broom, catawba rhododendron, Chinese lilac, dewberry, and blackberry—were absent after 18 years, though there were survivors at the fourth year. Failure of Russian olive by the fourth year was attributed to poor planting stock (Plass, unpublished progress report 1967). Even though the planted horticultural varieties of blackberry failed, the native blackberry species are invading the Lily site.

Spoil Characteristics

The analysis of the spoils shows evidence of good soils development. A mean pH increase of about 1/2 unit and a halving of the soluble salts as determined by specific conductivity show the ameliorating effect of time and perhaps vegetation (Table 4). The decline in Bray-1 extractable phosphorus from 6.8 to 4.0 ppm is equivalent to a loss of 5.5 pounds per acre, but more than this certainly is tied up in vegetation biomass. Both vegetation and time, appear to have had a significant influence on soil development. The nature and thickness of the O horizon varied with the kind of vegetation above it. A high organic-matter A_1 horizon was notable under the canopies of nitrogen-fixing trees and shrubs. The 1983 soil samples had a significantly higher pH where taken under mimosa than where taken under Virginia pine (Table 5). Samples from under the olives and birches had intermediate pH's not significantly different from either mimosa or Virginia pine.

Summary and Conclusions

At 18 years after planting, pin oak, sweet birch, European white birch, Austrian pine, and bur oak show promise of value for wood products on sites such as this. Tree species of little or no commercial timber value such as mimosa, thornless honeylocust, tree-of-heaven, and Siberian elm showed some usefulness as soil builders and site stabilizers. Shrubs with promise for ground cover, erosion control, soil building, and sources of wildlife food and habitat include silky dogwood, Chinese and amur privets, thorny, autumn, and cherry olives, indigobush, oakleaf hydrangea, and Japanese fleeceflower.

Several tree species showed significant decreases in survival between the fourth and 18th years, which may indicate that death is due more to intraspecific and interspecies competition than to site conditions.

Chemical conditions in the spoils have been modified during the 18-year period. The pH has increased, while specific conductivity and soil phosphorus have dropped significantly. Tree species had a significant influence on spoil pH. Spoil pH under the leguminous mimosa tree was significantly higher than under Virginia pine.

Results of this study and observations made at this site suggest that with proper choice of species even acidic surface-mined lands such as the Lily site have a long-term potential for forest production. Some economically important species can survive and have respectable growth. There is a need for studies to determine optimum management of these species in similar environments. Noncommercial and ornamental species also have a role on these sites as environmental modifiers, soil builders, and food and cover for wildlife.

This study was started during a period when extensive regrading, amendment, and herbaceous cover-cropping of surface-mined lands were not required and generally were not carried out. Results of current reclamation practices may well differ from those achieved here. The information gained still is applicable to abandoned mined lands on which site conditions are similar to those present on the Lily site at the inception of this study.

The importance of long-term evaluation of studies is made clear by the drastic changes in survival of several species such as yellow birch, tamarisk, Siberian peashrub, and Scotch broom. For example, on the basis of 4 years of data, Plass (1975) reasonably concluded that tamarisk and yellow birch were adapted to sites such as this. But results at 18 years did not bear this out.

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Reports the status of 18-year-old plantings of 25 tree and 25 shrub species on surface-mine spoil. The value of the species for wood products, wildlife habitat, site stabilizers, and soil builders is discussed.

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