A 30-Year Record of Tree Growth in Strip Mine Plantings

Knowledge of differential species survival and growth can be used in predicting forest successional trends and guide implementation of management practices.

W. Clark Ashby, and Clay A. Kolar, Professor and Researcher, Botany Department
Southern Illinois University-Carbondale

A plantation of black locust *(Robinia pseudoacacia*) on a 4- by 4- foot spacing was established in 1938 on the Fidelity Mine of the United Electric Coal Companies in Perry Co., III., 4 miles west of DuQuoin (*9*). A second plantation of shortleaf pine *(Pinus echinata)* on a 6- by 6- foot spacing was planted in 1939. By 1946 the number of black locust had dropped from an original 2,700 trees planted per acre to 1,170 stems per acre. The shortleaf pine originally planted at about 1,200 trees to the acre dropped to an average of 690 trees per acre.

In the spring of 1947 an experiment was set up to determine which, if any, of available hardwood species (and red cedar) were adapted to underplanting (or interplanting) in the black locust and shortleaf pine plantations for the purpose of stand conversion. Four plots were established in this experiment, two in each plantation. Each plot consisted of nine rows of trees 7 feet apart and each row consisted of 50 trees planted in a different species. The row was chosen at random for each plot. The rows were oriented at right angles to the original, ungraded spoil bank ridges. The following trees were used:

Ash *(Fraxinus sp.)*
Black locust (Pine plantation only)
Black walnut (*Juglans nigra)*
Black walnut seed
Cottonwood (*Populus deltoides)*
Osage orange *(Maclura pomifera*)
Redcedar (*Juniperus virginiana)*
(Black locust plantation only)
Sweetgum *(Liquidambar styraciflua*)
Silver maple (*Acer saccharinum)*
Yellow-poplar *(Liriodendron tulipifera)*

Changes in number and growth of the original plantation trees, of the underplanted hardwoods, and of volunteer species were reported in several studies (*1, 3, 5, 8, 9).*

Diameters of all underplanted trees and heights of six sample trees for each-of the more vigorous underplanted species in the 30th year of growth were measured in August 1976. In addition, the original overstory trees and the volunteer tree species were measured on one of the paired plots in each plantation. In April 1976, a soil pit was dug to a depth of 1 foot for examination of the soil profile, and 10 soil samples to a 6-inch depth were also taken at varied locations in one plot within each plantation. These soil samples were air dried, and the soil material that passed through a 2mm sieve was used in soil analyses. A phosphorus analysis used acidified ammonium fluoride (Bray No. 1) as an extractant and the ascorbic acid spectrophotometer method for analysis of the extracted solutions (*10*). These extracts were also analyzed for potassium using an atomic absorption spectrophotometer. A 2:1 distilled water to soil mixture was used with a Beckman Zeromatic SS-3 pH meter for pH values. Because of pH values near 7.0 or higher, the phosphorus determinations were repeated using the sodium bicarbonate (Olsen) extractant and the ascorbic acid method (*10*).

Species Performance

There were substantial differences in growth and survival of the two original plantation species, of the underplanted hardwoods, and of volunteer species (table 1). The major species in size or number will be reviewed individually. Very few seedlings or sprouts were found for any planted species except black locust.

BLACK LOCUST—Seedlings from the original locust plantation and volunteers could not be separated in the data-taking and are reported as one population: Locust was one of the species planted in a row under the shortleaf pine plots. Volunteer locust seedlings in the pine area were recognized because they were outside the row.

Black locust made good growth relative to other species under all circumstances. Mortality was comparable to or greater than other species of equal age. Many trees showed borer damage. Trees with good form were present on each plot.

A dense, waist high herbaceous cover of white snakeroot (Eupa-

Table 1.—*Mean DBH, basal area per acre, and number per acre of major species in the black locust and shortleaf pine areas.*

	DBH in	Basal Area ft .2	Numbers	Survival percent
Black Locust (38 years) Plantation and Volunteer				
Black Locust	7.3	23.8	78	6
Hardwoods Underplanted in Black Locust Area (30 years)[2]				
Yellow-poplar (66 ft)[1]	8.4	10.0	23	23
Silver maple	8.0	8.9	24	24
Black walnut				
Seedlings (84 ft)	7.3	14.3	41	42
Seed (67 ft)	5.6	4.4	22	22[3]
Sweetgum	3.2	0.3	5	5
Osage orange	3.2	2.7	38	39
Subtotal		40.6	155	
Volunteers in Black Locust Area				
Hackberry	3.9	7.8	70	—
Elm	2.9	8.8	126	—
Boxelder	1.8	5.0	126	—
Other species	—	10.8	54	—
Subtotal		32.4	376	
GRAND TOTAL		96.8	609	
Shortleaf Pine (37 years) Plantation				
Shortleaf pine	6.4	8.4	36	6
Hardwoods Underplanted in Shortleaf Pine Area (30 years)[4]				
Black locust	7.1	9.7	33	34
Black walnut				
Seedlings (42 ft)	4.7	6.6	49	52
Seed (46 ft)	3.7	3.8	44	44[3]
Yellow-poplar (56 ft)	4.2	7.6	60	64
Sweetgum (39 ft)	4.1	6.0	60	63
Silver maple	2.5	0.1	3	3
Osage orange	2.1	2.2	72	75
Subtotal		36.0	323	
Volunteers in Shortleaf Pine Area				
Black locust	4.2	4.0	36	—
Elm	2.9	8.5	124	—
Boxelder	1.4	1.9	118	—
Other species	—	13.4	62	—
Subtotal		27.8	340	
GRAND TOTAL		72.2	699	

[1]Mean heights (ft) are listed for yellow-poplar and black walnut in both areas, and for sweetgum in the pine area. Percent survival is listed for planted species.

[2]Ash had two trees (2.1"DBH). Cottonwood and redcedar had none.

[3]Based on 100 seed spots with two seeds planted in each.

[4]Ash (0.2"DBH) and cottonwood (17.1"DBH) had one tree each apparently in the row. Either could have been a volunteer.

torium rugosum), spring avens (*Geum vernum*), pokeweed (*Phytolacca americana*), and other species characteristic of moist woodlands was present throughout the locust plantation. Elm (*Ulmus* spp.) seedlings formed dense patches 3 to 4 feet high. Japanese honeysuckle (*Lonicera japonica*) was infrequent in the stand and did not form clumps.

SHORTLEAF PINE—Shortleaf pine in the plot areas was represented by scattered survivors (6 percent) from the original plantation established 37 years earlier. Tree size was larger than any of the underplanted hardwoods, except black locust. The plantation surrounding the the plot areas still had a continuous canopy of shortleaf pine.

The most conspicuous ground-layer or shrub species in the shortleaf pine plantation where underplanted by hardwoods were Japanese honeysuckle, which covered (smothered) the banks at the east end of the pine plots, and poison ivy (*Rhus radicans*) present locally as head-high patches in other areas of the plots. Herbaceous species included white snakeroot, pokeweed, and grape fern (*Botrychium virginianum*). Effects of established hardwoods, including black locust, likely have influenced growth of both planted and volunteer species on the shortleaf pine plots for 10 or more years.

YELLOW-POPLAR—Yellow-poplar had significantly greater diameter

growth, non-significantly greater height, and poorer survival in the black locust plots compared to the shortleaf pine plots. Tree form was generally good. Several trees had bark damage on the lower, usually south-facing, trunk. Similar damage was observed on yellow-poplar trees that died in earlier years in the locust area.

SILVER MAPLE—Silver maple performed conspicuously better in the black locust plots than in the pine plots. More dead than live trees were found in the pine area. Multiple stems, commonly observed in strip mine plantings, were infrequent.

BLACK WALNUT—Diameter and height growth of both seedling and seeded walnut were significantly better, and survival poorer, in the locust plots than in the pine plots. Form was generally good (figure 1). Although numerous green-hull nuts were locally present under trees, no seedlings were observed.

Walnut trees planted as seedlings in both the locust and the pine plots had significantly greater DBH than those from seed spots. Heights were not significantly different.

SWEETGUM—Sweetgum growth and survival were markedly better in the pine than in the locust plots. Sixteen trees at one end of the row in a pine plot showed pronounced leaf chlorosis. The nature of the symptoms was suggestive of iron deficiency, perhaps related to high pH.

Figure 1.—*Canopy 30-year seedling black walnut row underplanted on the ungraded spoil banks of the black locust plantation. Note poor survival of black locust and general appearance of a mesic woods in early winter. The largest black walnut measured was 15.0 inches DBH.*

OSAGE ORANGE—This species, with significantly better growth and poorer survival in the locust plots than in the pine plots, was not a canopy tree. Based on its good survival and wildlife values it can be recommended for strip mine plantings. Growth form was poor. Osage orange was the only planted species observed standing in water from recent heavy rains. Some flooded trees were dead.

ELM (*Ulmus americana*; *U. rubra* or *U. alata* may also have occurred)—Although second in mean DBH among volunteer trees on both plots, elm had the greatest basal area and numbers. Numerous small elm seedlings were present.

BOULDER (*Acer negundo*)—Second to elm in number, and third in basal area of the volunteer species reported on both plots, boxelder indicated a mesic-to-hydric site on these strip mine spoil banks.

HACKBERRY (*Celtis occidentalis*; *C. laevigata* was not observed)—The strong representation of hackberry on the locust plots supports the recognition of these sites as mesic-to-hydric in southern Illinois. Mean DBH of hackberry was substantially greater, and density lesser, than elm or boxelder. No hackberry was recorded on the pine plots.

OTHER SPECIES—On the locust plots a few large sycamore (*Platanus occidentalis*) averaging 14 inches DBH, a 16 inch mulberry (*Morus rubra*), and wild black cherry (*Prunus serotina)* averaging 10 inch DBH contributed most of the basal area of the volunteer species. In the pine plots scattered, very large cottonwood averaging 21 inches DBH and sycamore averaging 12 inches DBH made the greatest contributions to basal area.

Soil Features

In mid-April the soil pits had litter layers 1- to 2- inches thick, scant fermentation layers, and humus staining the first inch or more of crumbly, upper mineral soil. Humus staining appeared to be deeper in the two black locust pits. Groundhog holes and large ant hills were present on top of the banks in the locust areas. Flooding of low-lying areas from heavy rains was more evident in the pine areas.

Soil texture observed in the field had appreciable clay and silt with very little to little sand. Mottling (brown or gray to orange) was observed from below about 4 inches to the bottom of the pits at 12 inches. Coal fragments and shale, were found in all pits.

The 10 soil samples collected in each area were reasonably uniform with average pH values of 6.8 for the locust and 7.6 for the pine. Phosphorus levels averaged 7 pounds per acre in the locust area and 4 pounds per acre in the pine area, with little difference for the Bray or Olsen extraction methods. Potassium averaged 178 and 168 pounds per acre, respectively.

Carmean et al (*4*) reported soil-forest relationships for hardwoods planted on old-field sites cleared from previous black locust and shortleaf pine plantations. After 16 years, superior growth of black walnut, yellow-poplar, and sweetgum was found on the black locust plots with the highest nitrogen levels.

Earlier reports (*2, 6*) for our ungraded, surface-mined study site showed higher soil nitrogen levels in the black locust area. We found the pH was less high and the phosphorus and potassium levels higher in the locust compared to the pine plots. These factors may account for the better growth in the locust plots of essentially all tree species except sweetgum and cottonwood.

Continuing soil development on these immature soils may lead to a gradual increase in clay content. A resulting decrease in soil drainage and aeration could make the sites less suitable for planted species such as black walnut and yellow-poplar (*7*).

Stand Development

We do not know why one species grew better than another. Sweetgum grew best on the pine plots where iron deficiency was suspected. Yellow-poplar grew best in the locust area where most bark damage had been noted. The absence of hackberry from the pine plots because of differential moisture conditions seems unlikely in view of the strong representation of boxelder and elm.

Greater competition, indicated by greater basal area and heights in the locust area, may account for only half as many surviving underplanted hardwoods in the locust as in the pine plots. The decrease in number of trees after planting observed in all plots is typical of developing forest stands (*7*). Also, basal area values of 97 square feet per acre for the black locust plots and of 72 square feet per acre for the shortleaf pine plots on the ungraded strip mine banks are comparable to forest development on good but not the very best natural sites in southern Illinois.

The large numbers of lowland invader species—elm and boxelder and, in the locust area only, hackberry—may suggest an important role of these species in future years. Oak invasion described in 1964 has not persisted (*1*). The nature of a climax successional forest on these well-forested plots is not yet clear.

This research was supported by funds provided by the Forest Service, U.S. Department of Agriculture, Northeastern Forest Experiment Station, Research Work Unit NE-1605. We wish to thank Paul N. Seastrom of Freeman United Coal Mining Co. for his cooperation, John R. Beuchner and C. Robert Wikel of the Botany Dept. for carrying out the soil analyses, and Dr. William C. Hood for assistance in the potassium analyses.

Literature Cited

1. Ashby, W. C. 1964. Vegetation development on a strip-mined area in southern Illinois. III. State Acad. Sci., Trans. 57:78-83.
2. Ashby, W. C. and M. B. Baker, Jr. 1968. Soil nutrients and tree growth

(Continued on p. 31)

(Continued from p. 21)

under black locust and shortleaf pine overstories in strip-mine plantings. J. For. 66:67-70.

3. Ashby, W. C., M. B. Baker, Jr., and J. B. Casteel.
1966. Forest cover changes in strip mine plantations. Tree Planters' Notes 76:17-20.
4. Carmean, W. H., F. B. Clark, R. D. Williams, and P. B. Hanna.
1976. Hardwoods planted in old fields favored by prior tree cover. U.S. Dep. Agric. For. Serv. Res. Pap. NC-134.16 p.
5. Deitschmann, G. H.
1956. Growth of underplanted hard woods in black locust and shortleaf pine plantations. Central States For. Exp. Stn. Note 94. 2 p.
6. Finn, R. F.
1953. Foliar nitrogen and growth of certain mixed and pure forest plantings. J. For. 51:31-33.
7. Fowells, H. A. (Editor).
1965. Silvics of forest trees of the United States. U.S. Dep. Agric., Agric. Handb. 271. 762 p.
8. Limstrom, G. A.
1960. Forestation of strip-mined land in the Central States. U.S. Dep. Agric. Handb. 166. 74 p.
9. Mather, D. W., J. W. McIntosh, and P. E. Lamendola.
1947. Tests in conversion of decadent black locust and shortleaf pine plan tations on strip-mined lands in Illi nois. Spoil Bank Exp. No. 2. Carbon dale Branch, Cent. States For. Exp. Stn., 21 p., mimeo.
10. NC Regional Publication.
1975. Recommended chemical soil test procedures. N.C. Reg. PubL 221. North Dakota Agric. Exp. Stn. Bull. 499. 23 p.