Oak Seedling Root and Shoot Growth on Restored Topsoil

W. Clark Ashby

Professor emeritus and visiting research professor
Department of Plant Biology, Southern Illinois University at Carbondale
Carbondale, Illinois

Five oak species were planted on land reclaimed after mining for coal in southern Illinois. The replaced soils were compacted and had been chisel-plowed. Tree numbers varied among the species and were chiefly affected by seedling establishment rather than later survival. Rooting depths of bur (Quercus macrocarpa *Michx.), pin* (Q. palustris *Muenchh.), chestnut* (Q. prinus *L.), and English* (Q. robur *L.) oaks greatly exceeded shoot height after 3 years. All species, and black oak* (Q. velutina *Lam.), had heights of 100 cm (40 in) or greater after 5 years. English oak was significantly tallest at nearly 200 cm (80 in). Animal damage varied among species.* Tree Planters' Notes *46(2):54-57; 1995.*

Reforestation projects are often carried out on soils unlike those on which the designated species occur naturally. Typical instances include urban settings, eroded abandoned fields, landfills, and reclaimed surface coal mines. The present study compared *5* oak species planted on fields with restored rooting medium after surface mining for coal. The uppermost soil layers of the pre-mining Hosmer silt loam had been selectively replaced. Compaction of these fine-textured soils from traffic ("tracpaction") by tractors, pan scrapers, and other heavy machinery was documented by a retired USDA Soil Conservation Service soil surveyor. These fields had been chisel-plowed or ripped.

Two series of plots were established. One had 4 oak species— English *(Quercus robur* L.), bur *(Q. macrocarpa* Michx.), pin (Q. *palustris* Muenchh.), and chestnut oak (Q. *prinus* L.) planted from seed in the autumn of *1988.* Both root and top growth were measured for 3 years, and top growth for *5* years. Other plots had pin oak from seed or black oak (Q. *velutina* Lam.) seedlings.

The objectives of this study were to determine the relative survival and shoot heights of 5 oak species and the rooting depths of 4 oak species on reclaimed land that had been graded, topsoiled, and chisel-plowed.

Materials and Methods

Rooting and growth study. Acorns of English, bur, pin, and chestnut oak were planted in November 1988 on a site in Saline County west of Harrisburg in southeastern Illinois that had been mined several years earlier. The field had been graded relatively level with replaced topsoil and ripped in 1987 to 60 cm *(*24 in) depth with a chisel plow and planted to oats followed by alfalfa.

We killed most of the alfalfa by spraying with glyphosate (Roundup®) herbicide at *2%* solution prior to tree planting, and followed up with wick application of glyphosate to alfalfa sprouts. Simazine (Princep 4G®) at 44 kg/ha (50 lb/acre) was spread on the plots in spring 1990 and at *62* kg/ha (70 lb/acre) in spring 1991. The aisles between plots, planted to red fescue *(Festuca rubra* L.) , and some weedy plot areas sparsely occupied by tree seedlings, were mowed in the first *2* years.

The experimental design was a 4 x 4 Latin square with 16 plots. A species was randomly located once in each column and once in each row of the Latin square. A plot had 12 rows with 12 seed spots per row on 1-m spacing. There were 576 seed spots per species, 144 per plot.

The English, bur, and chestnut oaks are in the white oak group that fall-germinate when ripe in the autumn. We planted 1 acorn if it had germinated, otherwise *2* acorns, of these species and pin oak in each seed spot in the fall. The English oak acorns were collected from trees planted about 1970 in Carbondale. Most of the chestnut oak acorns, which were obtained from southern Maryland, had germinated and their roots, which were between 5 and 15 cm *(*2 to 6 in) long, were trimmed to *5* cm (2 in) before planting. Acorns with roots > 15 cm (6 in) long were not planted. The bur and pin oak acorns were collected from sites in southern Illinois. We took care to keep the acorns from drying

out and becoming non-viable before planting (Bonner 1993).

Number of seed spots with a tree seedling were counted in spring 1989 (year 1) and each autumn for years 1 to 5. If a second seedling was present, it was clipped off. Percentage survival was calculated as the number of seed spots with a tree present each autumn divided by the original number of trees established in spring of year 1. Notes were taken periodically on mammal damage. Insect and disease problems were not evident. Root depths were determined for 1 or more trees judged to be typical of each species per plot (4 or more trees of each species per year) in the first 2 years by hand digging, and the third year by using a backhoe followed by hand digging.

Tree heights were taken each autumn for 5 years. Statistically significant differences in height among the species were determined using an ABSTAT® program for analysis of variance and between species were determined using the Scheffe test at a level of " = 0.05.

Growth study. One plot was planted in April 1989 with additional pin oak acorns that had been stratified at 5 ºC over winter. Roots were starting to grow when planted, 2 per seed spot, and the seedlings emerged at about the same time as the fall-planted acorns of the rooting study. The soil of this plot area had been ripped with a 2-spike ripper to 80 cm (32 in) depth in 1988 and planted to oats.

Two plots were planted to black oak seedlings in April 1989. One was next to the pin oak plot on the ripped area, and the other near the oak rooting study on the chisel-plowed area. These 3 growth-study plots were treated with herbicide the same as the other plots with Princep 4G in spring 1990 and 1991 and mowed as feasible and needed. Trees in the growth study were counted and measured each year.

Results

Rooting and growth study. Although the 4 oak species differed in number of trees established the first spring, subsequent percentage survival was relatively similar (table 1). All species had a small increase in number of trees from 1989 to 1993.

Rooting depths of bur, pin, and chestnut oak in the first 3 years were more than double their heights (figure 1). The differences were less great for English oak. There were major differences in the nature of the root systems. The bur oak roots were relatively massive and more roots penetrated to lower depths. Chestnut oak root penetration was least deep and thorough. Only a slender root penetrated to the depths

Table 1-*Number of trees established in spring 1989 and 5-year percent survival and height of 5 oak species on replaced topsoil*

	No. of trees in spring 1989	Survival 1993 (%)	Height 1993 cm	Height 1993 in
Rooting and growth study'				
English oak	263	107	192†	75.6†
Bur oak	157	101	113	44.5
Pin oak	71	104	104	40.9
Chestnut oak	54	106	106	41.7
Growth study				
Pin oak‡	100	95	117	46.1
Black oak§	245	95	108	42.5

Each species had 576 total seed spots planted in fall 1988.

† Height was significantly greater than other species.

‡ One plot with 144 seed spots planted in spring 1989.

§ Two plots planted with a total of 288 seedlings in spring 1989.

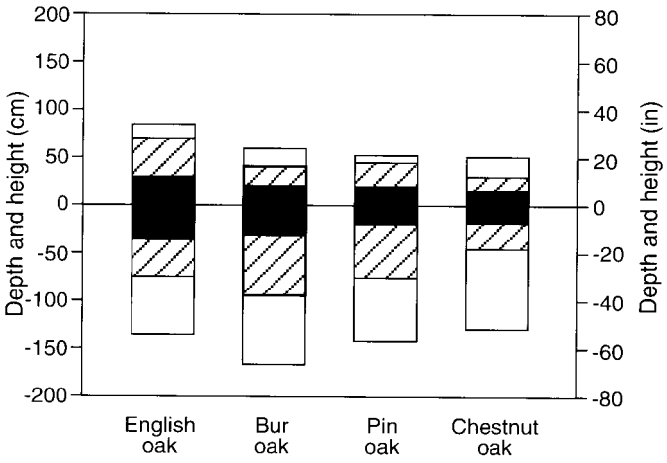

Figure 1— *Mean rooting depth and shoot height of 4 oak species at ages 1, 2, and 3 years on a chisel-plowed compacted rooting medium. English oak third–year height was statistically significantly greater.*

listed. The ratio of top-to-root length was highest for the English oak.

The 5-year shoot heights of bur, pin, and chestnut oak were roughly equivalent and significantly less than that of English oak (table 1). Tender new terminal shoots of the tallest trees, chiefly English oak and a few bur oak, were commonly broken off each spring by birds perching on them.

All species had some type of mammal damage (table 2). Bur oak trees were especially damaged from girdling by voles and nipping by rabbits. Pin oak trees were least damaged, discounting an initial substantial

Table 2-*Percent of trees in the rooting and growth study with animal damage in year 5*

	Percent seedlings with animal damage				
	Girdled (vole)	Nipped (rabbit)	Browsed (deer)	Rubbed (Buck deer)	All types
English oak	0.4	0.4	0.0	1.4	2.2
Bur oak	12.6	3.8	0.6	0.0	17.0
Pin oak	0.0	1.4	0.0	0.0	1.4*
Chestnut oak	7.0	0.0	3.5	0.0	10.5

* Many of the small pin oak acorns were pilfered over winter.

loss of acorns over winter. Damage overall was probably more severe than observed.

Growth study. The pin oak spring-planted acorns had higher establishment and somewhat lower percent survival after 5 years than did the fall-planted root-study trees (table 1). Height tended to be somewhat greater. The black oak spring-planted seedlings established well and had similar survival to the pin oak. Five-year height was similar to the other oaks except English oak. Survival and height of black oak on the chisel-plowed or ripped plots were similar and were combined in table 1.

Discussion

Establishment was a critical stage for all 5 oak species. The number of trees surviving at one year adequately represented species numbers at 5 years. Mining companies, highway planting contractors, and others could well replant as early as possible in the first year to minimize the period for bond release or to avoid penalty payments if initial establishment of oaks were deficient. The slight increase in the number of trees from year 1 to 5 could have resulted from delayed top growth, recovery after early animal destruction of their tops, and increased visibility to the researcher as the trees became larger.

There was no evidence that this mined area was visited by squirrels that would take the relatively large acorns of English, bur, or chestnut oak. Both black and pin oak have relatively small acorns that may be dug up by field mice. A plastic pot label had been placed at each seed spot, and for pin oak many of the labels later marked holes where acorns had been pilfered. In a recent unpublished study, we found that squirting Surf® laundry detergent on the soil surface at each planting spot resulted in very few acorns being dug up over winter. Spring planting of pin oak acorns and use of black oak seedlings avoided winter losses in our growth study. Least-good establishment of chestnut oak apparently resulted from too long a delay in planting the acorns.

Although deer were seen occasionally, damage to the developing trees compared to other plantings may have been lessened because the plots were within sight of a house and dogs roamed at the edge of town. Only the bushy English white oak was big enough to be used for typical buck rub, and its many branches likely somewhat protected the trunks. In the past 25 years, no evidence of spreading by this introduced oak has been noted in the Carbondale area.

Acorns were planted to avoid possible effects of poorly planted seedlings on root systems. The main characteristic of the soil that could affect root development seemed to be soil strength, which varied enormously with moisture content. The soils when dry were so hard that digging with a shovel was not possible and using a pick would damage the roots. Excavations were postponed until the soil was moister and less hard. Roots in the lower soil depths were commonly strongly flattened along a crack in the soil. By year 2 root depths of bur, pin and English oak were below the 60-cm (24-in) depth of chisel plowing.

Root excavations were not attempted after the third year. The labor of digging out deeper roots, even using a backhoe, became excessive. Also, by that time all species had reached the mandated depth of the rooting medium under current mining regulations and could exploit the lower, mineral-rich mixed overburden materials. Roots that penetrate a topsoil cap often develop well in coarser-textured underlying materials (Ashby and others 1984).

Fine-textured replaced minesoils that have been graded and compacted are anaerobic from the perched water tables that lie above compacted layers during winter/early spring and rainy periods in the growing season. Mid-summer drought periods are characteristic of the southern Illinois climate. That English oak has grown well in urban forestry in southern Illinois on a fragipan soil, Hosmer silt loam, suggests a similar adaptation to that of pin oak to alternately saturated and droughty soils.

The native oaks differ in their ecological habitat distributions in nature (Burns and Honkala 1990). In southern Illinois, bur and pin oak are most commonly found on poorly drained bottomlands, and black and chestnut oak on well-drained ridges. Only black oak was a component of the tree cover on a nearby pioneer cemetery.

Pin oak, the only 1 of our 5 species reported in another study, was the least deeply rooted of 6 species after 8 years growth on a graded and compacted minesoil with replaced topsoil (Ashby and McCarthy

1990). The deepest rooting species was baldcypress *(Taxodium distichum* (L.) Rich). A lack of close correspondence between shoot height and rooting depth in that study, and in the present one, suggests that factors such as drought resistance are also important in tree performance on compacted soils.

There were statistically significant differences in tree height between rows, and columns, of the Latin square using the Scheffe test. This amount of variation in height growth in a relatively small area (54 x 54 m or 177 x 177 ft) needs to be considered in interpreting results of studies with reclamation tree plots. The plot area seemed uniform when the acorns were planted.

Conclusions

Tree numbers of each species after 5 years were chiefly determined by rate of first-year establishment and very little by the subsequent mortality. Various kinds of animal damage affected growth of the several oak species each year.

Roots of the 4 selected oak species penetrated to the depth of replaced fine-textured soil materials within 3 years after planting. Bur oak had the deepest and most massive roots. English oak was tallest and had the highest top-toroot ratio.

Chestnut oak does not seem to be as well-suited for planting on fine-textured, compacted and chiselplowed soils in southern Illinois as bur, pin, and black oak. Fallplanted pin oak acorns need to be protected from pilfering by animals. English oak seemed most suited for settings where non-native species are valued.

Address correspondence to Clark Ashby, Department of Plant Biology, Mailcode 6509, Southern Illinois University at Carbondale, Carbondale, IL 62901.

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