GROWTH OF WHITE AND RED OAK SEEDLINGS AND SEED ON MINED UNGRADED CAST OVERBURDEN

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Abstract—Tree seedlings and/or seed of white oak (*Quercus alba* L.) and red oak (*Q. rubra* L.) were planted spring and fall from 1978 to 1982 on ungraded cast overburden (also termed spoil banks) in southern Illinois. Each planting season there were 50 seedlings, or seed spots, of each species per row in replicated plots. Some seasons no seedlings or seed were available for planting. The 20 plots had 1800 white oak and 1700 red oak planting spots total. The oak seedling and seed rows were randomly assigned with other species in a plot so that nearest neighbor tree rows differed from plot to plot. Soil bulk density averaged 1.3 grams per cubic centimeter, pH 7.5, and plant nutrients were low by agricultural standards. The ground cover was old-field weeds that were sprayed with herbicide in later planting years.

Trees in each row were counted 3 years after planting to determine establishment, that varied widely. In 1993-1994 all trees were measured for height and diameter breast height (DBH). Ages then ranged from 11 to 16 years. Survival after establishment was generally good, somewhat greater for red than white oak, for spring- than fall-planted trees of each species, and for trees planted as seedlings rather than seed. Heights of older spring-planted seedlings averaged more than 6 meters with DBHs, not here reported, more than 8 centimeters. Red oak tended to be taller than white oak. DBHs were more variable. Heights and DBHs of trees planted as seedlings tended to be greater than those planted as seed. Variations in survival and growth were not clearly attributable to quality of planting stock, use of herbicides, or differences in randomized nearest-row neighbors. Holding white oak seedlings in a cold room from spring over summer for fall planting gave reduced survival and equivalent growth.

INTRODUCTION

White and northern red oak are major components of forests in Illinois and other midwestern states (Burns and Honkala 1990). The natural importance of white oak is greater on mid to upper slopes, and of northern red, here called red, oak is greater in ravines and on lower slopes, related to aspect. These two high-quality species seem logical choices to use in reforestation of minesoils in the lower midwest. In turn, their growth on a rooting medium that does not occur naturally in the local climate can add to understanding of their ecological life requirements.

Within the past 50 years thousands of hectares in the midwest have been surface mined for coal and planted to millions of trees. In a pre-law period roughly from 1930 to 1960 in Illinois, 8.7 million hardwoods and 7.2 million conifers were voluntarily planted by coal companies and coal associations in cooperation with the Illinois Department of Conservation, the USDA Forest Service, and a few universities (Ashby and others 1978). Although scant records exist of the performance of these plantings other than the Forest Service and university research plots, overall tree performance was considered to be good to excellent, with failures of non-adapted species planted on isolated acidic areas.

A quarter million of the 8.7 million hardwoods in Illinois were white or bur (*Q. macrocarpa* Michx.) oak, and half a million were red or black (*Q. velutina* Lam.) oak. A 50-year-old white oak stand growing on ungraded cast overburden in southern Illinois had excellent survival, height of 26±3 meters, and a DBH of 23±1 centimeters (Ashby 1996). A near-by stand of red (intermixed with *Q. shumardii Buckley*) oak 55 years old also had excellent survival, average height of 33±3 meters, and DBH of 35±1 centimeters.

Many experienced reclamation, and an increasing number of regulatory, personnel have been concerned that trees planted in the 20 years since passage of a federal 1977 reclamation law have not survived and grown well compared to those planted pre-law (Ashby 1991). Another problem is that species with high 5-year survival rates selected for bond release commonly are not ecologically or economically desirable for long-term forestry plantings.

Viewing tree planting on post-law minesoils as a lost cause has unfortunately become a common misconception. State and federal regulatory authorities are now recognizing the need for re-evaluating out-dated regulations, with increased interest in successful reforestation. Even the well-documented effects of soil compaction from mandatory grading after mining (Josiah 1986) need not detract from the utility of studies of tree growth on minesoils. The adverse ecological and economic consequences of grading to parking-lot standards have been demonstrated. Mined lands can be reclaimed with minimal compaction using new grading methods and understanding. A great opportunity for restoring mined lands to productive forestry should not be neglected.

My research group in 1978 set up studies to document carefully the survival and growth of 25 tree species planted on ungraded cast overburden, including many of the hardwood species grown earlier. This paper reports

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performance of white and red oak, planted as seedlings, and as seed, if available. Plots replicated once were established each spring and fall from 1978 to 1982. Several survival counts and growth measurements were taken in later years. The goals of this paper include:

1. To evaluate and compare relative performance of white and red oak planted as seedlings or seed during fall and spring for 5 years on ungraded cast overburden.
2. To compare tree performance when planted fall or spring.
3. To compare tree performance when planted as seedlings or seed.
4. To evaluate white oak performance using other kinds of growing stock.

METHODS AND MATERIALS

My study area is on the Sahara Coal Company, Inc. surface mine No. 6 just west of Harrisburg in southeastern Illinois. Annual temperature averages 13 degrees Centigrade, with July 25 degrees and January 0 degrees Centigrade, and annual precipitation 1100 millimeters. Figure 1 has the growing season precipitation from April through September 1978 to 1984, years of tree establishment and early growth. Monthly temperatures for this period were tabulated and are not here listed.

Rooting Medium

The predominant regional pre-mining soil was Hosmer silt loam, Typic Fragiudalfs Alfisols (Miles and Weiss 1978). A geological column taken on the permit area in 1981 prior to mining was described in an unpublished report by W.C. Hood. He reported 4 meters of unconsolidated material overlying numerous intermixed layers of sandy shale (9 meters total), limestone (3 meters), and sandstone (1 meter) above a 1.5 meter-thick seam of No. 6 coal. The rooting medium of the spoil banks cast by a Marion 5761 power shovel was thus a mixture of soil fines and coarse fragments from shattered rock layers above the coal. The slopes of the bank ridges trending southeast-northwest ranged from 21 to 34 degrees and averaged 29 degrees. The ridges were spaced from 8 to 30 meters apart with an average distance of 20 meters. Bank heights ranged from 3 to 10 meters with an average height of 6 meters. Flooded areas between the banks were not found.

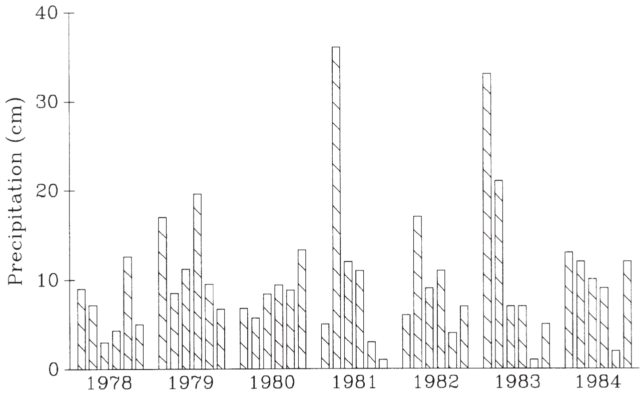

Figure 1—Growing-season (April-September) monthly precipitation from 1978 to 1984 recorded at Harrisburg, IL.

The bulk density of the cast overburden corrected for rock fragments ranged from 1.22-1.35 grams per cubic centimeter and the percent coarse fragments larger than 2 millimeters from 38-52 percent. Stones of varying sizes exposed on the surface functioned as an erosion pavement and provided numerous niches or micro-habitats for plant establishment and growth. Numerous excavations of cast overburden in later years showed deep rooting to 4 meters by various species with extensive branching of root systems. Roots also penetrated shale and sandstone fragments as they broke apart when exposed to near-surface weathering agents. The minesoil likely had a more favorable moisture regime for growth of deep-rooted plants than the fine-textured, fragipan native soils.

The post-mining rooting medium based on soil fines was classified as a silty clay loam to clay loam, probably related to the well-developed B horizon of the pre-mining fragiudalfs and to rapid weathering of the predominant shales of the overburden in the years between mining and tree planting. The rooting medium was mildly alkaline (pH 7.5) with average Bray-1 phosphorus 5 parts per million, Bray-2 phosphorus 24 parts per million, potassium 154 parts per million, magnesium 175 parts per million, and calcium 2313 parts per million (Josiah 1986). Variations among the individual measurements of these properties on the total 14-hectare plot area likely came from differential mixing of overburden materials in the mining process. The ground cover at planting ranged from sparse goldenrod (*Solidago L.* spp.) or broomsedge (*Andropogon virginicus* L.) and other old-field invaders to relatively dense patches of trumpet creeper (*Campsis radicans* (L.) Seemann.) or Japanese honeysuckle (*Lonicera japonica* Thunb.).

Planting Stock and Plot Layout

All seedlings were graded in the laboratory by basal caliper and the smallest ones rejected. Depending on stock quality and numbers available, the largest seedlings and those with carrot-type roots were also rejected. Numbers of lateral roots were not counted. Roots were trimmed to fit in a planting hole without distortion. Representative-sized seedlings for each row were bundled, 52 each, with roots packed in moist sphagnum moss in a plastic bag tied off around the lower stems. Acorns when collected were floated in water for approximately an hour and those undamaged that sank were similarly placed in moist sphagnum moss as recommended by Bonner (1993). Seedlings and seed were stored in a 5 degrees Centigrade cold room until planted.

Seedlings were planted with planting bars (dibbles). Seed was planted with a mattock, three acorns in a hole three times their diameter in depth. Each planting spot was marked with a color-coded pot label that aided in following a row for early survival counts on rough terrain and occasional thick vegetation.

Each replicated tree plot of this study had 20 randomly-assigned, single-species rows that included rows of white and red oak. Thus a red oak seedling row in one randomized plot was planted between a row of walnut (*Juglans nigra* L.) and of pin oak (*Q. palustris* Muenchh.), and in the paired plot was planted between a row of baldcypress (*Taxodium distichum* (L). Rich.) and of red oak from seed. An oak row was planted all to seedlings or all to acorns. Each row had 50 planting spots with 2.5 meters spacing between trees and rows. The replicated plots had 100 of each available oak species/planting stock planted each season. The rows ran primarily up and down across the banks rather than along the length of a bank.

White oak—The sum of the areas of the rows of white oak seedlings or seed spots planted both spring and fall from 1978 to 1982 was 1.12 hectares with 1800 trees. Quality of white oak nursery stock as received each year was rated as good to excellent except for root and stem damage noted for the 1980 seedlings planted fall 1980 and spring 1981. Limitations to growth of these seedlings were not evident in the 1993 measurements. Seedlings were donated from the Illinois Union County state tree nursery 100 kilometers southwest of the study site, except for fall 1981. The only seedlings planted fall 1981 were donated from the Licking, MO state nursery 200 kilometers further west. The Missouri seedlings were planted again for comparison with Illinois seedlings spring 1982. In other comparisons white oak seedlings were held in cold storage over a summer each for planting in fall 1979, and in fall 1980. Roots of the seedlings held over were dipped in a 1 percent Captan solution before placing in cold storage.

White oak seed was planted only in the fall each year. We were not successful in holding over a sufficient number of white oak acorns for spring planting without germination and growth of radicles that were broken in handling. The amount of local seed we collected each fall varied greatly; some years only one tree we found had a good crop and other years many trees had acorns. All the white oak seed planted was rated excellent. It was not unusual to have acorns already germinating at fall planting.

Red oak—The sum of the areas of the rows of red oak seedlings or seed spots was 1.06 hectares planted to 1700 trees. Seedlings were donated by the Illinois state nursery. Quality of red oak nursery stock was rated fair for fall 1979, the season with the lowest later field survival, and otherwise good to excellent. We dug at the nursery the fall-lifted red oak seedlings for the test plantings. In fall 1978, 1979, 1980, and 1982 many seedlings when dug were still in leaf or even actively growing.

Red oak annual acorn crops varied substantially. If available they were planted both fall and spring. Missing seasons were fall 1978 and 1979, and spring 1980. Acorns were treated the same as white oak acorns, and for spring planting were stratified over winter in cold storage. The red oak seed planted was rated good to excellent. Germination after stratification was typically good, and ranged from 50 percent to over 90 percent in several seasons.

Herbicide Applications and Tree Counts and Measurements

Starting in spring 1981 all seedling and seed planting spots that had been planted either the previous fall or in the spring were sprayed in a 1.5 meter circle before tree growth began using a backpack sprayer with a mixture of glyphosate (Roundup®) and simazine (Princep®). Herbicide control was effective in the first year, and often not observable by the fourth year after planting. No further cultural practices were carried out.

All trees were counted for establishment the first summer after planting. If there was more than one seedling per seed spot, those of lesser vigor were clipped off at ground level. All trees were also counted and measured for height and basal caliper in year 3. As an example those planted in fall 1978 and spring 1979 were both measured in summer 1981. The number of trees established after 3 years was used to calculate the subsequent percent survival in 1993 shown in table 1. All trees were measured for height in 1988, and for height and diameter breast height (DBH), if that tall, in 1993 (Ashby and others 1995). Statistical methods were analysis of variance for heights and DBHs of several groupings of trees. Acorn production, animal damage if any, and other observations were recorded at each measurement and occasionally at other times.

RESULTS AND DISCUSSION

Relative Performance of White and Red Oak

Number of trees in 1993 of the 11- to 16-year-old Illinois white oak was 411 of 1800 planted (23 percent) and of red oak was 728 of 1700 planted (43 percent). Most of the losses of trees by 1993 took place in the first years after planting. Mortality from year 3 to 1993 was much lower, especially for red oak (table 1). Mortality was commonly several trees in a gap and canopy closure was found where trees were contiguous. If these white or red oaks had been planted solidly in a stand, a full forest canopy as found in pre-law plantings could be expected, even though higher planting rates would be needed for bond release.

Table 1—Percent of fall- and spring-planted white and red oak established at age 3 that survived to age 11-16 years when planted as seedlings or as seed

Season planted	White oak	Red oak
	------------- %	----------------
Seedlings		
Fall	85	98
Spring	79	95
Seed		
Fall	62	89
Spring	-	88

Tree form was good where trees were contiguous. Red oak would be the better choice for planting based on survival after establishment.

Irregularities in survival from year to year were found for both species (fig. 2). Some of the variability likely was related to undetected variation in planting-stock quality. Planting was carefully supervised with the planting crew supervisors and many of the planters the same from year to year. An important time-related factor that likely affected survival was weather conditions among the several planting seasons. April, May, and total precipitation were low in 1980, with only September at the end of the growing season relatively wet (figure 1). July, August, and September were so hot and dry that many corn fields were not harvested. The white oak seedlings that established in spring 1980 had relatively low survival at age 14. White oak growth was, however, not evidently suppressed (fig. 3), and the 14-year-old red oak trees were essentially equal in height to the 15- and 16-year-old trees (fig. 4).

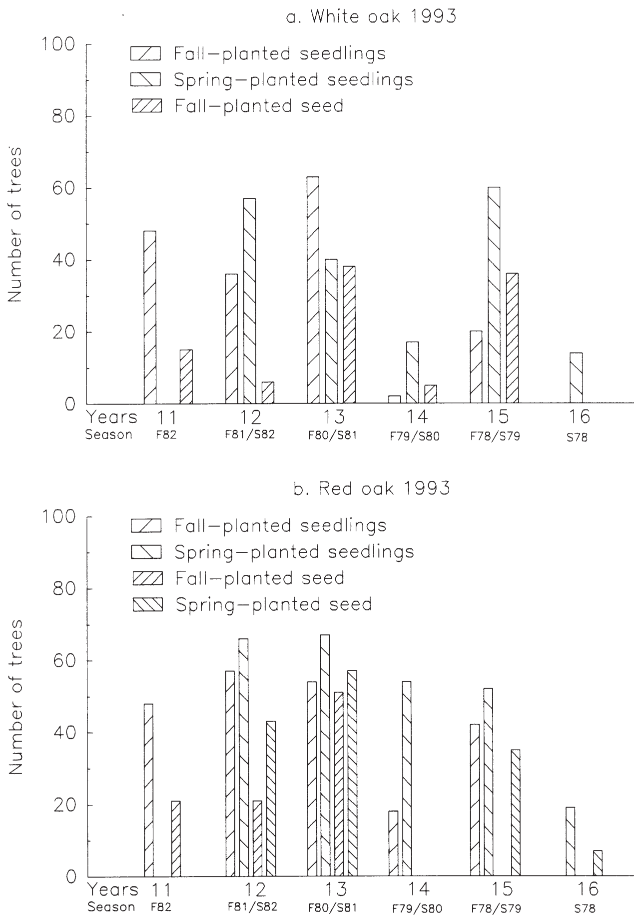

Figure 2—a. Average number of survivors in 1993 of 11- to 16-year-old white oak planted in fall or spring as seedlings or as seed. Each column is based on 100 seedlings or seed spots in 2 rows of 50 each planted per season.
b. Average number of survivors in 1993 of 11- to 16-year-old red oak planted in fall and spring as seedlings and/or as seed.

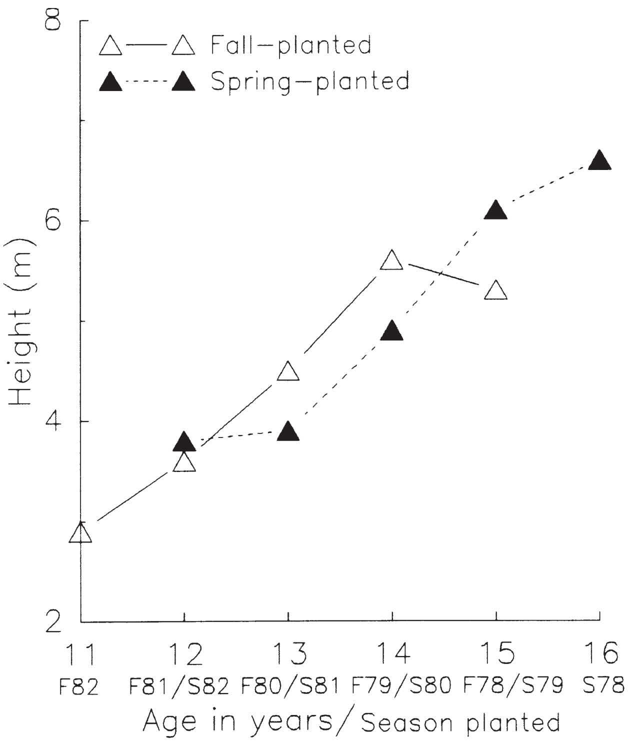

Figure 3—Average height in 1993 of 11- to 16-year-old white oak planted in fall or spring as seedlings or as seed.

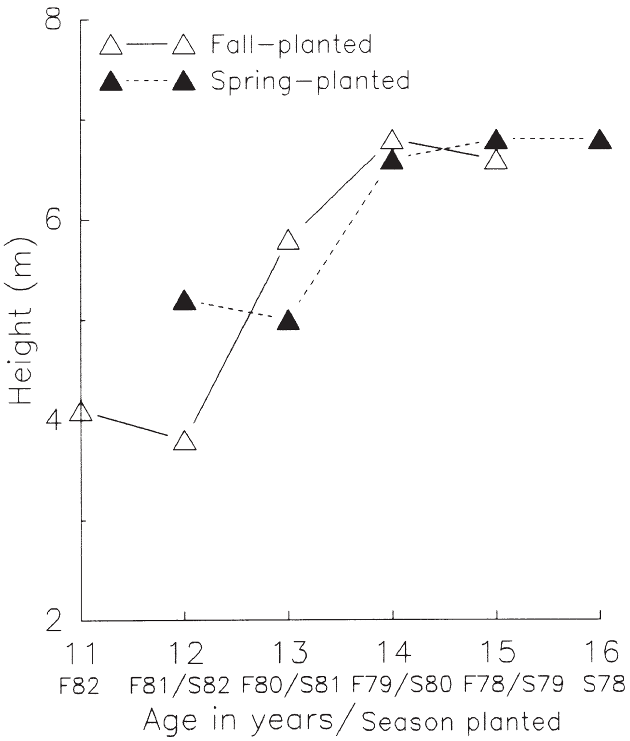

Figure 4—Average height in 1993 of 11- to 16-year-old red oak planted in fall or spring as seedlings or as seed.

A management change to application of herbicides happened only once. If no herbicide applications for trees ages 14, 15, or 16 years versus herbicide applications for trees ages 11, 12, and 13 years increased survival, it corresponded with greater expected survival of younger trees and did not seem to have done away with year-to-year variability.

Possible changes on a seasonal or yearly basis of spatial variation in properties of the successive plot areas planted on cast overburden for 5 years, or in competition from randomly assigned neighbors in the several plots, cannot be ruled out. Overall variation in topography or in observed spoil characteristics at the scale of an 0.7 hectare plot was not evidently synchronous with seasonal differences in survival and growth. The volunteer vegetation present seemed similarly heterogenous throughout the study area.

All the nearest neighbor species to each white and each red oak row were plotted. Neighbors were compared for oaks that had unusually low survival or growth performance in a given season. Any neighbor species consistently in common were, however, not found. For the seven lowest survival plantings, having one-fifth or fewer surviving trees in 1993 (fig. 2), most-common neighbors were four times black walnut planted as seedling or seed, three times each sycamore (*Platanus occidentalis* L.) or baldcypress, and two times or once nine other species. No neighbor species were in common for oak rows having unusually low height or DBH values. If there was a neighbor effect, how many years it would take to suppress growth of adjacent white or red oak is not known.

Relative height growth of the oaks was similar to survival. When all trees combined of each species are compared, white oak was significantly shorter (4.4 versus 5.4 meters) and differences in DBH (6.1 versus 6.0 centimeters) were not statistically significant. White oak planted as seedlings was, however, actively growing in years 15 and 16, while red oak had stagnated (figures 3 and 4). Reasons for the apparently lower heights of the 15- versus 14-year-old trees of both species from seed were not apparent. If growth criteria were of importance, choice of red oak with greater height may be offset by its apparent stagnation after age 14. Older trees of red oak produced acorns and could have enhanced forest succession if the mast had not been eaten or trampled by deer. Not much other animal damage was noted. Red oak typically has been much more damaged by deer than has white oak in stripmine plantings.

Tree Performance When Fall- versus Spring-Planted

Tree survival was highly variable with little consistency related to season. For example, white oak seedlings planted fall 1980 had the greatest number of trees and those planted fall 1979 the lowest (fig. 2). Red oak had the greatest number of trees when planted spring 1981 and the lowest when planted fall 1979 (fig. 2). Mortality after establishment was relatively similar for fall versus spring planting (table 1).

Average heights were lesser for fall- than spring-planted white and red oak seedlings and red oak planted as seed (table 2). DBH was greatest for spring-planted seedlings of both species, though not for spring-planted red oak seed. These averages mask year-to-year variability in relative heights, and DBHs not shown, of fall- versus spring-planted white or red oak (figs. 3 and 4).

Tree Performance When Planted as Seedlings versus Seed

Seedling versus seed differences were variable. Average percent survival tended to be lower for white versus red oak and greater for seedlings versus seed of both species (table 1). There was substantial variability. Number of surviving fall-planted white oak seedlings was greater than from seed at ages 11, 12 and 13 years, and vice versa at ages 14 and 15 years. Reasons for these differences were not evident. The few remaining white oak at age 14 had established in the dry, hot 1980 growing season. For the seasons when both were planted, red oak tended to have greater survival as seedlings than as seed.

The growth of either species from seedlings or seed was also irregular from year to year. White oak trees planted as seedlings were not significantly taller, or greater in DBH, than the averages of those planted as seed (table 3). Red oak seedlings tended to outgrow trees planted as seed when either fall- or spring-planted, and averaged significantly greater DBH when spring-planted.

In a recent survey of seven large coal companies, no local mine planted seedlings in the fall. Although seeding large-seeded tree species has been successful in the midwest, use of seed is unusual on local mines at present.

Table 2—Average height and dbh at age 11-16 years of white and red oak when fall- or spring-planted

Season planted	White oak Height	White oak D.b.h.	Red oak Height	Red oak D.b.h.
	m	*Cm*	*m*	*Cm*
Seedlings				
Fall	4.1[a]	5.5[a]	5.1[a]	5.5[a]
Spring	4.9	7.1	5.9	6.8
Seed				
Fall	3.8	5.0	4.8[a]	5.0[b]
Spring	No seed planted		5.5	5.7
Seedlings and seed				
Fall	4.0	5.3	5.0[a]	5.4[a]
Spring	No seed planted		5.8	6.4

[a] Differences in paired means in a column were statistically significant at $p \leq 0.01$.
[b] Differences in paired means in a column were not statistically significant at $p > 0.05$.

Table 3—Average height and dbh at age 11-16 years of white and red oak when planted as seedlings or seed

Season planted	White oak		Red oak	
	Height	D.b.h.	Height	D.b.h.
	m	*Cm*	*m*	*Cm*
Fall-planted only				
Seedlings	4.1[a]	5.5[a]	5.1[a]	5.5[a]
Seed	4.9	7.1	5.9	6.8
Spring-planted only				
Seedlings	3.8	5.0	4.8[a]	5.0[b]
Seed	No seed planted		5.5	5.7
Fall- and spring-planted				
Seedlings	4.0	5.3	5.0[c]	5.4[b]
Seed	No seed planted		5.8	6.4

[a] Differences in paired means in a column were not statistically significant at $p>0.05$.
[b] Differences in paired means in a column were statistically significant at $p\leq 0.01$.
[c] Differences in paired means in a column were statistically significant at $p\leq 0.05$.

White Oak Performance with Alternative Growing Stock

Spring-lifted white oak seedlings held in cold storage over summer 1979, or summer 1980, and fall-planted had heights and DBHs similar to those regularly planted in the fall. Growth of Illinois and Missouri seedlings both planted in spring 1982 did not differ. These planting options offer important gains for successful tree planting and bond release on mined lands by extending the planting season. Stuart Miller, Missouri Department of Natural Resources, recently outlined his method for extending to spring the seed planting season with white oak, based on successful over-winter storage of acorns collected in the autumn before or as falling from the trees.

CONCLUSIONS

1. White oak seemed to be inherently less vigorous than red oak in survival and height, and not so in DBH.
2. Trees of both species fall-planted as seedlings or seed had lesser survival, height, and DBH than if spring-planted.
3. Trees of both species tended to have greater survival, height, and DBH when planted as seedlings than as seed.
4. Fall planting of seedlings and fall and spring planting of seed usefully extended our white and red oak reforestation program compared to usual reclamation practice.
5. White oak seedlings held from spring over summer in cold storage for fall planting can have growth equivalent to those regularly fall-planted.
6. Availability of either white or red oak seedlings and seed varied greatly from season to season.
7. Red oak on mined cast overburden produced acorns by year 15.

ACKNOWLEDGMENTS

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