

OAK PROVENANCE RESEARCH: THE MICHAUX QUERCETUM AFTER 25 YEARS

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Abstract: Growth and survival data after 25 years are given for trees representing 92 seedlots from known geographic origins of 12 eastern American oak species. Both survival and growth depended more on the genetic characteristics of the parent tree than on its geographic origin. No single species was clearly superior to others in either growth or survival, and there was sufficient variation within all species to allow for meaningful selection for higher survival and more rapid growth. Growth at age 25 was significantly correlated with growth at age 13, so the selection process could begin at the earlier age.

One of the most neglected areas of research pertaining to the survival, performance, and selection of landscape trees has been the comparison of trees from known geographic seed sources (provenances). Even when such studies have been attempted, published reports have dealt largely with juvenile growth and behavior. This paper is a report on the survival and growth of 12 oak (*Quercus*) species at 25 years of age.

The Michaux Quercetum study is a joint project of the Morris Arboretum of the University of Pennsylvania and the Northeastern Forest Experiment Station of the USDA Forest Service, financed in part by the Michaux Fund of the American Philosophical Society. One of the objectives of this project, as outlined by Schramm and Schreiner (1954), is to provide information about the variation within major oak species.

Several papers have already been published on the Quercetum. Acknowledgments to seed collectors and outlines and progress of early work were reported by Schramm and Schreiner (1954) and Li (1955). Gabriel (1958) described juvenile variation in Shumard oak (*Q. shumardii* Buckl.) and Santamour (1960) reported on seedling performance of oak species from the southern and western United States. Santamour and Schreiner (1961) and Schreiner and Santamour (1961)

summarized the seedling studies on the important eastern white oak and red oak species. Garrett and Kettlewood (1975) presented data on the 1966 remeasurement of the major outplanting at Longwood Gardens, Kennett Square, Pennsylvania.

Materials and Methods

For each oak species, cooperators were asked to supply 100-125 acorns from each of two typical trees growing in natural woodlands in their locality. Each seed collection was accompanied by a herbarium specimen from the mother-tree, and any suspected natural hybrids were excluded from the study. All acorns were sown in special seedbeds in the fall of the year in which they were collected. These seedbeds were provided with a 14-mesh, galvanized window screen at a soil depth of nine inches. The wire screen prevented the development of the characteristic tap roots of the oaks and facilitated lifting the seedlings from the seedbeds.

The seedlings were transplanted to nursery rows in the spring of their second growing season. All but a few of the red oak progenies reported in this paper were derived from 1953 seed collections. The white oak (*Q. alba* L.) progenies were grown from acorns collected in 1954. Bur oak (*Q. macrocarpa* Michx.) progenies were from both collection years.

The major planting of the red oak (subgenus *Erythrobalanus*) seedlings and *Q. macrocarpa* was made in the spring of 1957 at Longwood Gardens, Kennett Square, Pennsylvania (lat. 40° 50' N.-growing season ca. 209 days). Spacing between trees and rows was 10 feet. Seedlots were represented by 2-tree plots in species replicates of various sizes, depending on the number of seedlings available. Seedlings of *Q.*

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alba were planted in 1958 at the same spacing. Equal numbers of each progeny were planted in two "row-replicates" following a prescribed planting sequence.

The 1957 planting of red oak species and *Q. macrocarpa* contained approximately 1737 trees and the total for *Q. alba* was 359. The number of trees planted from each seedlot was about 30 for northern red oak (*Q. rubra* L.), black oak (*Q. velutina* Lam.), and scarlet oak (*Q. coccinea* Muenchh.); about 20 for shumard oak, shingle oak (*Q. imbricaria* Michx.), water oak (*Q. nigra* L.), and willow oak (*Q. phellos* L.); and varied from 13 to 42 for bur oak, 6 to 20 for southern red oak (*Q. falcata* Michx.) 8 to 20 for blackjack oak (*Q. marilandica* Muenchh.), and 8 to 30 for pin oak (*Q. palustris* Muenchh.). Between 11 to 33 trees (ave. 20) were planted from each seedlot of *Q. alba*.

It was recognized at the outset that the acorn collections, even in the most well-represented species, did not provide an adequate sampling of the species' natural ranges. Furthermore, the planting designs precluded any but the simplest statistical analyses. However, it was also recognized that the Quercetum collection represented the most extensive and intensive sampling of eastern American oak species that had ever been assembled anywhere in the world. Thus it seemed reasonable to provide data on the growth and survival of the species in the major Quercetum planting at 25 years of age.

During the winter of 1979-80, diameter (dbh) measurements, to the nearest inch, were made at breast height (4.5 ft. above the ground) with a steel diameter tape. Height measurements were made to the nearest foot with an optical measuring device. Garrett and Kettlewood (1975) found some statistically significant differences in growth between progenies within species but reported a lack of correlation of growth or survival with latitude of seed source. In our analyses we attempted to correlate 25-year growth with height data on three-year-old seedlings (Santamour and Schreiner 1961, Schreiner and Santamour 1961) and 13-year-old saplings (Garrett and Kettlewood 1975).

Results and Discussion

Survival and growth data for all seedlots are given in Table 1, in much the same sequence as presented by Garrett and Kettlewood (1975). There are some discrepancies between these survival data and those of Garrett and Kettlewood, especially in *Q. palustris*, where they did not measure all the trees of that species. Furthermore, Garrett and Kettlewood did not measure or evaluate any of the *Q. alba* progenies in 1966.

Table 1. Survival and growth of oak provenances at Longwood Gardens, Pa. at age 25

Number	Species	Source	Survival (%)	Mean dbh (in.)	Mean height (ft.)
017	<i>Q. rubra</i>	NH	23.3	7.8	49.1
018	"	NH	40.0	9.9	53.3
019	"	NH	40.0	8.7	50.2
020	"	NH	36.7	7.2	47.6
052	"	KS	43.3	5.9	40.5
058	"	KS	36.7	6.5	44.5
209	"	NC	20.0	8.7	53.0
210	"	NC	26.7	7.8	47.6
212	"	NC	26.7	8.1	48.1
376	"	PA	16.7	7.9	50.2
377	"	PA	30.0	8.8	46.7
416	"	IL	43.3	8.1	45.4
418	"	IL	46.7	7.6	50.8
426	"	IL	56.7	8.3	49.5
471	"	IL	40.0	7.8	49.6
107	<i>Q. velutina</i>	VA	23.3	7.8	52.4
233	"	TN	20.0	8.0	48.3
234	"	TN	33.3	9.3	53.6
290	"	AL	16.7	6.5	49.6
291	"	AL	35.7	7.8	53.0
366	"	MI	53.3	8.6	52.4
372	"	NC	60.0	8.6	51.2
379	"	IL	46.7	7.2	48.6
422	"	IL	26.7	7.1	52.5
425	"	IL	40.0	7.8	49.7
428	"	IL	50.0	8.0	51.2
108	<i>Q. coccinea</i>	VA	53.3	7.5	47.1
231	"	TN	26.7	6.2	46.0
232	"	TN	63.3	7.5	50.6
289	"	AL	53.3	6.9	47.9
293	"	AL	53.3	6.8	49.0
470	"	IL	36.7	8.3	51.4
550	"	IL	25.0	6.0	44.4
214	<i>Q. shumardii</i>	TN	55.0	7.8	47.7
215	"	TN	60.0	7.2	48.7
284	"	MS	70.0	9.3	56.2
287	"	MS	55.0	5.5	37.4
332	"	FL	45.0	6.8	43.1
420	"	IL	75.0	7.2	47.5

053	<i>Q. macrocarpa</i>	KS	69.2	9.1	41.0
402	"	KS	53.3	8.8	40.6
185	"	SD	36.7	5.4	33.6
186	"	SD	35.7	6.3	34.4
354	"	MN	16.7	2.9	21.3
355	"	MN	11.8	4.2	35.5
292	<i>Q. falcata</i>	AL	12.5	4.9	40.0
298	"	AR	50.0	8.7	47.2
409	"	VA	35.0	7.2	44.8
410	"	VA	30.0	11.3	52.8
412	"	VA	35.3	9.2	52.0
582	"	MD	33.3	8.6	48.0
350	<i>Q. imbricaria</i>	OH	68.4	7.5	48.2
351	"	OH	70.0	6.8	44.8
417	"	IL	75.0	6.8	43.6
462	"	IN	38.0	8.2	52.0
031	<i>Q. nigra</i>	MD	30.0	7.6	47.5
033	"	MD	21.4	7.3	47.3
286	"	MS	56.2	6.9	43.2
299A	"	MS	65.0	7.8	44.6
409	"	VA	80.0	6.2	43.7
414	"	VA	72.2	6.4	44.3
285	<i>Q. phellos</i>	MS	25.0	8.1	45.4
297	"	AR	60.0	8.2	44.7
411	"	VA	25.0	9.4	49.2
413	"	VA	40.0	9.7	53.9
576	"	MD	10.0	8.5	47.0
584	"	MD	45.0	8.1	48.0
016	<i>Q. marilandica</i>	TX	10.0	4.8	31.0
057	"	KN	31.2	7.2	29.4
227	"	NJ	37.5	4.3	23.7
299	"	AR	25.0	7.3	27.0
348	<i>Q. palustris</i>	OH	56.7	7.5	51.0
349	"	OH	75.0	8.2	51.5
424	"	IL	70.0	7.1	51.4
032	<i>Q. alba</i>	MD	31.6	7.9	41.8
034	"	MD	53.8	8.7	39.0
575	"	MD	61.1	8.2	46.0
577	"	MD	16.7	7.0	35.7
174	"	MA	22.6	6.4	36.8
175	"	MA	26.9	6.4	34.0
263	"	AR	41.7	7.0	31.0
360	"	MI	33.3	7.8	33.5
400	"	PA	15.2	7.2	40.6
442	"	PA	19.0	7.8	41.5
540	"	PA	66.7	6.7	36.4
463	"	IL	54.5	6.1	36.8
519	"	NJ	30.8	6.6	42.8
520	"	NJ	27.8	6.7	34.4
533	"	VA	61.9	7.5	39.1
535	"	VA	39.1	9.0	42.4
753	"	WI	33.3	8.5	42.0
754	"	WI	15.8	8.2	45.0

genies planted during the severe drought year of 1957. Cold hardiness did not appear to be a major factor in survival, perhaps because of the generally mild climate at the planting site. Progenies from the South frequently had better survival than more northern sources. It should be stressed that although cold hardiness was not a critical survival factor in this particular test planting, trials of similar seed sources in more severe climates would undoubtedly reveal some cold damage to southern provenances.

Mortality since the past survey in 1966 (Garrett and Kettlewood 1975) amounted to only a few trees per progeny, with some major exceptions. The four *Q. rubra* progenies from Illinois had an overall survival of 72.5% (87/120) in 1966, but only 46.7% (56/120) in 1979. It is interesting that the Illinois sources were the only collections in the Quercetum that originated within the central area of known distribution of oak wilt. Oak wilt, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, is not known to occur in eastern Pennsylvania but any further mortality in these progenies will be checked closely.

Which species showed the best survival? Table 2 gives the average survival for all species as well as for the best progeny in each species. As might be expected from arboricultural experience, pin oak had the highest survival. Several other species also had good overall survival. However, the data in both Table 1 and Table 2 show that there are meaningful differences in survival among progenies within a species, and often among progenies from the same geographic area. The data indicate that the differences in survival are more likely influenced by the genetic constitution of the parent tree(s). Progenies with high transplantability potential could probably be selected within all oak species, but only after a long and laborious testing program.

Growth — one of the most frequently asked questions about landscape trees is "How fast will it grow?". This question is usually asked with regard to species, as if all trees of a species possessed the same growth potential. The data in Table 1 are ample evidence that there are few generalities that can be drawn regarding species performance. It might appear that, with the limited sampling, trees from certain geographic areas

Survival — most of the mortality in all progenies occurred during the first year after planting, and may be considered as a measure of transplantability. This was especially true for those pro-

grow better than others. However, the lack of significant correlation between growth and latitude and the large growth differences between progenies from the same area (see especially *Q. coccinea* and *Q. shumardii*) argue against such an interpretation. Growth rate, as well as survivability, depend more on the genetic nature of the parent trees than on their geographic origin.

Growth data for the fastest growing progenies of each species are given in Table 2. It is possible that with more extensive sampling, any of the faster growing species could attain "first place" in both diameter and height. The white oak species (*Q. alba* and *Q. macrocarpa*) attained considerably less height growth than the red oaks of comparable dbh. Also listed in Table 3 are the height and diameters of the three trees in each progeny that showed the greatest diameter growth. These data demonstrate that there is opportunity not only for selection of rapid growing progenies within species but also of individuals within progenies.

Juvenile-Mature Correlations — all within-species correlations between the average height of 3-year-old seedling progenies and the dbh and height of the same progenies at age 25 were low and decidedly non-significant. On the other hand, all correlations between 13-year height of in-

dividual trees within progenies or progenies within species and the 25-year growth data were statistically significant at the 5% or 1% level. Basically, these correlations show that some meaningful selection for growth rate could be made at age 13. If it were desired to utilize the most rapid-growing trees in a seed orchard, the selection could be made as early as 10 years after planting and the candidate trees could be dug and moved to an isolated site at wider spacing for future seed production. Such a procedure would also provide a further test of transplantability of the selected trees.

Table 2. Survival of oak species after 25 years

Species (No. of seedlots)	All seedlots	Best seedlot
	(%)	(%)
1. <i>Q. palustris</i> (3)	64.7	75.0
2. <i>Q. imbricaria</i> (4)	63.6	75.0
3. <i>Q. shumardii</i> (6)	60.0	75.0
4. <i>Q. nigra</i> (6)	54.4	80.0
5. <i>Q. coccinea</i> (7)	45.5	63.3
6. <i>Q. macrocarpa</i> (6)	37.3	69.2
7. <i>Q. velutina</i> (11)	36.9	60.0
8. <i>Q. phellos</i> (6)	36.3	60.0
9. <i>Q. rubra</i> (15)	35.1	56.7
10. <i>Q. alba</i> (18)	33.7	66.7
11. <i>Q. falcata</i> (6)	32.5	50.0
12. <i>Q. marilandica</i> (4)	23.4	37.5

Table 3. Growth of best seedlot of each oak species after 25 years.

Species	Seedlot No. & origin		All trees		Three best trees ^a	
			dbh	height	dbh	height
			(in.)	(ft.)	(in.)	(ft.)
1. <i>Q. falcata</i> ^b	410	VA	11.3	52.8	12.6	54.7
2. <i>Q. rubra</i>	018	NH	9.9	53.3	11.5	56.0
3. <i>Q. phellos</i>	413	VA	9.7	53.9	12.2	56.3
4. <i>Q. shumardii</i>	284	MS	9.3	56.2	11.8	57.3
5. <i>Q. velutina</i>	234	TN	9.3	53.6	10.2	51.0
6. <i>Q. macrocarpa</i>	053	KS	9.1	41.0	11.0	42.0
7. <i>Q. alba</i>	535	VA	9.0	42.4	10.2	41.0
8. <i>Q. coccinea</i>	470	IL	8.3	51.4	12.1	57.7
9. <i>Q. palustris</i>	348	OH	8.2	51.5	9.1	55.3
10. <i>Q. imbricaria</i>	462	IN	8.2	52.0	10.0	54.7
11. <i>Q. nigra</i>	299A	MS	7.8	44.6	10.8	51.3
12. <i>Q. marilandica</i>	299	AR	7.3	27.0	7.9	28.0

^aBest three trees chosen by dbh.

^bSeedlots listed in order of decreasing average dbh.

Conclusions

The observations and analyses made in the preparation of this report have pointed to some possibilities and some problems regarding the genetic improvement of oaks. One possibility is to utilize portions of the Longwood Gardens planting as seed sources for somewhat improved trees, and this is contemplated. However, the maximum genetic improvement of oak seedling planting stock for landscape purposes in urban areas will not be accomplished without some difficulty.

First, it would seem that intensive selection of superior trees in the wild may not be of paramount importance, since performance in Nature is not necessarily similar to that under cultivation. Seed collections should, of course, be made from climatic zones that would assure cold hardiness in the areas where the trees are expected to be used. Also, seedling identities should be maintained throughout the experiment. The initial seedling outplanting would constitute the first test of survivability, and could be made at a reasonably close spacing and without much, if any, cultural care.

The young plants could then be moved, with a

tree spade, after three years. This would be a test of transplantability. After three more years of growth, the most vigorous trees could be selected and moved, again, to a wider spacing in an initial "seed orchard" arrangement. Natural mortality and removal of less desirable trees would produce the final seed orchard from which seedlings with superior urban adaptability could be derived.

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ABSTRACT

HAMILTON, D.F. 1979. **Planting in unfavorable soils.** Am. Nurseryman 149(10): 10-11, 42, 44-45.

Heavy soils, poorly drained soils, compacted soils, excessively drained soils, and foreign objects left over from construction are among the unfavorable conditions existing at many planting sites. Landscape contractors and arborists must modify such planting soils so plants installed will not only survive but establish and grow. The concentration of oxygen in a well aerated soil is 10 to 15 percent but declines sharply to approximately one percent in a saturated soil. Plant roots can be injured whenever oxygen levels fall below 10 percent, and root growth stops completely at concentrations under five percent. The best way to avoid problems with excess moisture is to determine soil moisture and drainage patterns of an area. The planting site may require additional drainage. Generally, the expenses involved with area drainage cannot be justified on residential and smaller commercial projects. It then becomes necessary to provide drainage for individual plants.