VARIATION IN SOUTHERN SEED SOURCES OF NORTHERN RED OAK

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Abstract: A half-sib progeny test of 176 northern red oak families from the species' range south of Ohio was evaluated for growth characteristics at ages 2, 5, 8, and 10. After 10 years, survival, height, and diameter averaged 75%, 4.7 m, and 5.5 cm, respectively. There were significant differences among families for all growth characters measured, but no apparent variation patterns related to latitude, longitude, or elevation of origin.

Additional key words: Height growth, diameter growth, survival, *Quercus rubra*, early selection, half-sib progeny test.

In 1962, cooperative testing of northern red oak in the North Central region was initiated by the NC-51 Regional Technical Committee, under the leadership of Dr. H. S. Kriebel, Ohio State University. This effort resulted in the establishment of seven test plantings across the north central portion or the region, and results through the early third decade of testing have been reported (Kriebel 1965; Deneke 1975; Kriegel *et al*. 1976; Schlarbaum and Bagley 1981; Schlarbaum *et al*. 198 2; Kriebel et al. (in press)).

In the late 1960's, the Tennessee Valley Authority also initiated a program of selection and progeny testing with this species. The objectives of the program were to (1) locate throughout the Tennessee Valley and surrounding areas superior or outstanding northern red oak trees, (2) establish evenaged plantations with seeds from these trees, (3) select superior phenotypes from within these plantations, and (4) propagate these selections vegetatively and/or convert the plantations to seedling seed orchards.

By 1971, initial parent tree selections had been completed. Trees included in the program were labeled as "superior" it the tree was straight, well pruned, appeared to be growing well (bark characteristics), was in the dominant or codominant portion of the forest canopy, and looked better than trees the viewer had seen before (except for other superior trees). Comparison trees were not used, nor were growth and age determinations made. Elevations of seed sources ranged from 500' to 4,600'.

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METHODS AND MATERIALS

In Autumn of 1971, seed collections were completed from 225 parent trees from northern Alabama to southwest Virginia. In some cases, based on available location data, individual tree collections can be grouped into recognizable stands, while others can be identified only as individual female parent trees located by county and state of origin.

Seed was sown in the TVA Nursery at Norris, TN, and 1-0 seedlings distributed to cooperators in Spring, 1973. Eleven plantings of various sizes were established in Alabama, Georgia, Illinois, Indiana, Kentucky, North Carolina, and Ohio, with four in Tennessee. The Ohio plantation is the northernmost replicate of the study, and is the one discussed in this report.

The Ohio planting, consisting of 176 half-sib families originating from numerous stands in the south-central portion of the species' range (rig. 1), was established at a spacing of 8' X 8', using 4-tree lineal plots in seven randomized complete blocks. The planting was sprayed within rows with atrazine plus simizine (2 lbs. active, of each per acre) each spring for the first five years to control competing vegetation, and was mowed between rows at least twice per growing season. Each tree 2m or taller was pruned to 50% live crown in 1981.

All trees were measured for height at 2, 5, 8, and 10 years of age (from planting), and diameter was measured at a height of one foot at 8 years and at breast height at 10 years (Table 1). Analyses of variance were completed for each measurement period for all families, and also at age 10 for a subset of 70 families that could be grouped into eight identifiable stands along a transect from northern Alabama to western Virginia, plus 12 families in a western Tennessee stand.

RESULTS AND DISCUSSION

One-way ANOVA's, based on individual tree data and on plot means, computed variance components for evaluation of (1) variation among and within families, and (2) variation among stands. These analyses demonstrated the existence of significant differences among both families and stands (Tables 2, 4). The varia tion pattern for all variables measured was essentially random, with no discernible trends in survival, height or diameter growth which could be related to longitude, latitude, or elevation of origin. In the discussion which follows, families (seed sources) are identified as to county and state of origin, although there are many instances where more than one stand per county is represented in the test.

Survival averaged 83% at age 2, decreased to 76% at age 5, and was stable at 75% (range = 36%-10u%) for ages d and 10. Compared to survival rates reported by Kriebel et a1. (1976) for

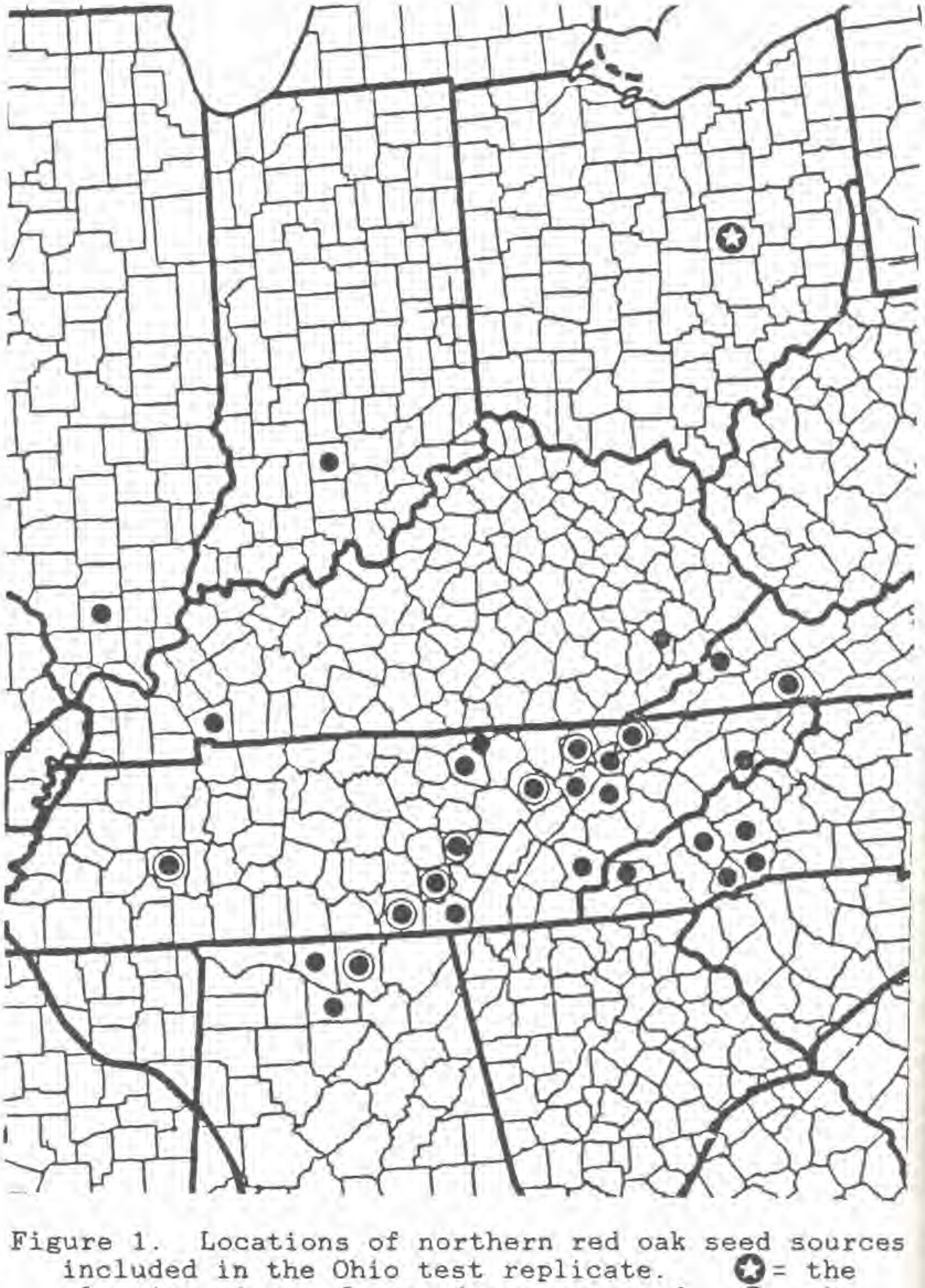

Figure 1. Locations of northern red oak seed sources included in the Ohio test replicate. ✪ = the planting site, ● = seed sources, and ◉ = the nine stands included in separate analysis.

Table 1. <u>Plantation means for height, diameter and survival at ages 2, 5, 8 and 10 for 176 northern red oak half-sib families</u>.[a]

Age (yrs)	Height (cm)	Diameter (cm)	Survival (%)
2	39.7	---	83
5	91.9	---	76
8	309.2	5.6[b]	75
10	467.0	5.5[c]	74

[a]There were highly significant differences among families for all measured variables.
[b]Diameter measured at 1 ft.
[c]Diameter measured at breast height.

Table 2. <u>Variance components for among- vs within-family variation in height, diameter, and survival of 1 half-sib northern red oak families</u>.

	Source of variance			
Character	Among-family	%[a]	Within-family	%
Height, age 2	1978.8[b]	80	489.4	20
Survival, age 2	.27	68	.13	32
Height, age 5	13445.7	75	4476.6	25
Survival, age 5	.41	71	.17	29
Height, age 8	18511.2	64	10596.0	36
Diameter, age 8	162.6	66	84.8	34
Survival, age 8	.45	71	.18	29
Height, age 10	374.0	64	208.9	36
Diameter, age 10	7.4	65	4.0	35
Survival, age 10	.46	72	.18	28

[a]Percent of total variance
[b]Table values = mean squares from analyses of variance.

seven North Central region plantations of red oak (avg. = 59%), these results undoubtedly reflect the improved methods now available for control of competing vegetation in such plantings. There were significant differences among families (p = 0.01) but with no apparent elevational or geographic patterns, e.g., survival rates for 12 families from one of the southernmost sources, Madison, AL (elev. = 1500') averaged 75%, while one of the northernmost sources, Pickett, TN (elev, = 1500') averaged 63%.

Likewise, in several cases different families from the same county or stand within county were represented in the top and bottom 10% of the observed distribution for height growth, e.g., families from the three sources: Franklin, TN, Campbell, TN, and Buncombe, NC. The families from the Franklin, TN source (ranks = 2 and 170, of 176) were from the same stand. Two families from one of the Campbell, TN locations were in both the top and bottom 10%, while two other families in the top 10% were from a different stand in Campbell County. Similarly, one stand in Buncombe County, NC produced families represented in both the top and bottom 10% groups, while a second Buncombe County stand had all three families in the top 10%. While it is somewhat difficult to identify exact family/stand identities from available location data, it is clear that, where this is possible, there is substantial intra-stand as well as inter-stand variability.

The ratio of among- to within-family variance for height decreased from age 2 (4:1) to age 10 (1.8:1), and may have stabilized at this value at about age 8 (Table 2). For diameter, there was also about twice as much variation among as within families at both age 8 and age 10.

The mean 10-year height for the top 10% (i.e., 17) of the families was 37% greater than that of the bottom 10%. If the top and bottom 5% (i.e., 8) of the families are considered, this differential increases to 47%. Overall, there was a 75% differential between the tallest (#583, Claiborne, TN) and the shortest (*2422, Buncombe, NC) families in the test. Substantial differences were also found for height at age 8 (47%), age 5 (120%), age 2 (117%), and diameter at age 10 (53%) and age 3 (62%).

Age-age correlations for height (Table 3) indicate that selection for height growth before age 5 involves a considerable risk of eliminating many faster-growing families. The correlation of height at age 5 versus age 10 (r = 0.73) is somewhat higher than that obtained by Kriebel et al. (1976) (r = 0.61) for an age 8 vs age 14 comparison in a provenance test including a broader geographic range of sources. Even so, in this study, only 29% of the top 10% families at age 5 would have been represented in the top 10% at age 8, with an identical percentage for the comparison of age 5 vs age 10. By age 8, 65% of the families in the top 10% were still in the top 10% at age 10, suggesting that family ranks may be stabilizing. Plantation measurements to be taken at age 15 may determine if this has occurred. Data

Table 3. Simple age-age correlations among growth variables for 176 half-sib northern red oak families .a

Character:

	Surv2	Ht5	Surv5	Ht8	Diam8	Surv8	Ht10	Diam10	Surv10
Ht2	.74	.74	.71	.46	.45	.70	.43	.37	.69
Surv2		.57	.80	.23	.21	.77	.21	.17	.76
Ht5			.75	.77	.74	.75	.73	.64	.76
Surv5				.36	.34	.94	.33	.26	.93
Ht8					.90	.36	.94	.80	.38
Diam8						.34	.88	.85	.36
Surv8							.34	.27	.98
Ht10								.82	.34
Diam10									.26

[a]Correlation coefficients computed using plot means.

reported by Kriebel et al. (1987) for an older test of northern red oak suggests that seed source shifts relative to height may stabilize by age 14. The correlation of height at age 2 with later survival remained high through age 10 (r = .69), but this relationship did not hold for height and survival after age 5.

A subset of the data, nine collections of 7 to 12 trees whose exact origins could be identified as being single stands, was also analyzed. One-way ANOVA's (Table 4) indicated significant differences among stands for seed weight (p = 0.10), heights at age 2 (p = 0.10), age 5 (p = 0.01), age 8 (p = 0.10), age 10 (p = 0.01), and diameters at age 8 (p = 0.01) and age 10 (p = 0.01). Simple correlations of seed weight and height were low, decreasing from 0.30 at age 2 to 0.006 at age 10.

Stand rankings for seed weight did not correspond closely to rankings based on heights (Table 5), as might be expected given the low correlations between these measures. Rankings of stands by height shifted substantially through age 8, but seemed to be more stable from age 8 to age 10. Certain stands, e.g., No. 1, exhibited rapid growth through age 2 (= rank 1), but had fallen to the 6th rank by age 10, while others, e.g., No. 6, exhibited slow growth during the first two years after establishment, but steadily improved to rank 1 by age 8 and 10. A third group of

Table 4. Analyses of variation for seed weight and growth characters in nine northern red oak stands.[a]

Character	Source	df	MS	F	Prob
1. Seed wgt	Stand	8	26191	1.92	0.10
	Error	73	13661		
2. Hgt, age 2	Stand	8	109	1.91	0.10
	Error	73	57		
3. Hgt, age 5	Stand	8	1176	3.50	0.01
	Error	73	336		
4. Hgt, age 8	Stand	8	1577	1.98	0.10
	Error	73	797		
5. Hgt, age 10	Stand	8	3859	2.64	0.01
	Error	73	1461		
6. Diam, age 8	Stand	8	1.161	2.93	0.01
	Error	73	0.397		
7. Diam, age 10	Stand	8	0.917	3.13	0.01
	Error	73	0.293		

[a]Analyses based on family means.

stands, e.g., Nos. 3, and 4, remained in about the same relative positions throughout the measurement period. Schlarbaum and Bagley (1981) reported similar results for certain provenances of the earlier NC-51 red oak test. Rankings based on diameters also did not change much from age 8 to age 10. No obvious patterns were evident relative to stand elevation, longitude, or latitude.

Some stands were much more variable than others, as judged by their coefficients of variation (CV) and stand variances based on family means. As an example, CV's for height at age 10 ranged from 4.8 to 10.6, while individual stand variances demonstrated a 5-fold range. The existence of significant among-family and among-stand variation, coupled with the lack of correlation between growth characters and geographic origin, indicates that genetic control of growth rate is more closely related to stand and family within this part of the species' distribution. This portion of the species' range was affected differently by glacial episodes than more northerly areas (Schlarbaum et al. 1982), and thus the regional patterns of differentiation which are becoming evident in provenance tests of northern sources (Kriebel et al., In press) may not be expressed in these southern populations.

Table 5. Ranks, by stand, for seed weight, height, and diameter growth of nine northern red oak stands.

	Numerical Rank[a]								
	1	2	3	4	5	6	7	8	9
Character	Stand Number								
Seed weight	8	9	6	1	7	4	5	2	3
Height, age 2	1	8	7	2	6	9	3	5	4
Height, age 5	8	6	7	2	1	9	5	3	4
Height, age 8	6	7	2	8	5	1	3	9	4
Height, age 10	6	8	7	5	2	1	3	9	4
Diameter, age 8	6	7	2	5	9	1	8	3	4
Diameter, age 10	7	6	5	2	8	1	9	3	4

[a]1 = largest value, 9 = lowest value.

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