GENETIC VARIATION IN *QUERCUS RUBRA* L., A NEBRASKA PROVENANCE TEST REPORT

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Abstract. Twenty-seven provenances of *Quercus rubra* L. were planted in eastern Nebraska in 1962-4. Height and diameter growth, leaf flush date, leaf retention, and number of growing days showed no meaningful association with latitude or longitude and are discontinuous in variation. Observation of fall phenology, including dates of leaf color, death, and drop were strongly correlated with latitude suggesting that these traits are clinal in variation.

Key words: northern red oak, height and diameter growth, phenology.

Northern red oak, *Quercus rubra* L., is a native species to North America. Its range is from the northern Atlantic coast to the midwest prairies and slightly above the St. Lawrence River to near the Gulf coast (Figure 1). It is a valuable source of lumber, an excellent landscape tree, and has potential use for windbreaks.

Little work has been done on the genetics and improvement of red oak because of the difficulty to propagate vegetatively and the length of time to reproductive maturity. Studies have shown that red oak is genetically variable. Kriebel (1965), Kriebel *et al*. (unpublished) observed that variation of provenances is discontinuous for juvenile and adult growth and clinal for fall phenology. McGee (1970 and 1974) reported that differences in date of bud break were related to altitude of seed source. Gall and Taft (1973) recorded provenances differing in rate of height growth with no relation to source location and in date of leaf flush according to latitude. Flint (1972) measured the cold hardiness of red oak twigs of different seed sources and found significant variation with north-south trends.

During the period 1962-1964, a provenance plantation of *Quercus rubra* was established at the Horning State Farm near Plattsmouth, Nebraska. The objective of this study was to determine the growth and phenology of the various sources.

MATERIALS AND METHODS

This provenance test is part of a cooperative red oak improvement program, which consists of plantations in eight states. Professor H. B. Kriebel

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of the Ohio Agricultural Research and Development Center designed the plantations and was responsible for collecting seed and distributing planting stock to cooperators.

Two-year old seedlings representing 26 native stands and one plantation (source 31) were received over a three year period (Figure 1, Table 1). Each provenance was represented by open-pollinated progenies from as many as ten mother trees. The plantation was designed for 32 provenances, 16 trees per square plot, spaced 2.75 x 2.75 meters (9 x 9 ft.) apart, in seven randomized complete blocks. Since only 27 provenances were received for the Nebraska planting, the empty plots were direct seeded with local seed sources of northern red oak and bur oak (Quercus macrocarpa Michx.) and were deleted from the analysis.

Data analyzed included height and diameter growth and spring and fall phenology. Height growth rates were calculated by subtracting 1969 from 1974 heights. This method was used to adjust for the different years of planting of the 1962 and 1963 trees. An annual height and diameter(at 1.4 meters above ground) growth was calculated by dividing the 1974 height and the 1975 diameter by tree age. Growth of trees planted in 1962 and 1963 was analyzed separately from those planted in 1964.

Trees were observed every two days in the spring of 1975 to determine date of leaf flush. The date recorded was the day when 50 percent of the buds had expanded to reveal small leave.

Observations of fall phenology were made in 1975. Leaf color was determined and recorded on the date when 25 percent or more of a tree's leaves changed color. When 75 percent or more of the leaves turned brown, they were recorded as dead. Leaf drop was scored as completed when a tree had lost 75 percent or more of its leaves. Observations were recorded once a week until no changes could be observed in the trees with leaves remaining. Leaf retention was evaluated in January, 1976. The number of growing days was the difference between dates of leaf flush and leaf color.

All variables were subjected to an analysis of variance for the randomized complete block. Simple correlation coefficients were calculated for annual growth measurements and spring and fall characteristics to show association of traits. Partial correlation coefficients were calculated to show association of traits with latitude, longitude, and altitude (Table 2). The trees from the plantation (source 31) were not included.

RESULTS

Differences among provenances were found to be statistically signifcant (Table 1). Trees of certain provenances grew fast during the early life of the plantation and then slowed while those of other provenances continued to grow at a constant or accelerated rate of height growth with increase in age (Figure 2).

Correlation coefficients for all of the measurements of growth and phenology were statistically significant except date of leaf flush was not correlated with date of leaf color. Height and diameter measurements were

Figure 1. Natural range of _Quercus rubra_ with source locations. Circle with crossbars is provenance test site.

Table 1. Summary of *Quercus rubra* growth and phenological data.

Source	Planting Date	Height (1974)	Diam (1975)	Height Growth (1969-74)	Mean Annual Growth		Leaf Flush a/	Leaf Characteristics b/			Leaf Retention c/	Growing Days d/
					Height	Diam		Color	Death	Drop		
		m	cm	m	m	cm	days	days	days	days	percent	no
2	1962	6.4	10.5	2.8	.46	.70	2	17	29	43	55	166
1	1962	6.1	9.4	2.5	.43	.63	7	30	47	52	0	174
11	1962	5.9	9.0	2.3	.42	.60	5	20	39	46	2	166
31	1962	5.8	10.0	2.1	.41	.67	8	22	39	45	2	166
22	1963	5.8	8.6	2.6	.44	.62	4	18	29	36	10	164
7	1962	5.7	9.5	1.8	.40	.64	8	29	43	50	0	172
19	1962	5.7	9.4	2.1	.41	.63	7	21	37	46	10	165
21	1962	5.6	9.2	2.5	.40	.61	6	23	38	45	2	167
29	1962	5.6	9.1	2.5	.40	.61	7	21	35	41	5	164
12	1963	5.6	8.1	2.7	.43	.58	5	22	35	45	51	168
20	1962	5.5	8.7	2.4	.40	.58	3	10	18	25	5	158
26	1962	5.5	8.4	2.3	.39	.56	5	14	24	29	0	159
9	1963	5.4	8.3	2.4	.41	.59	6	18	33	42	29	163
17	1962	5.4	8.0	2.1	.39	.54	10	22	38	43	4	163
3	1962	5.3	8.8	1.9	.38	.59	6	17	31	40	11	163
10	1963	5.3	7.6	2.2	.41	.55	7	22	42	47	2	167
23	1963	5.1	7.8	2.5	.39	.56	5	18	31	42	53	164
6	1962	5.0	8.2	1.8	.36	.55	7	19	34	41	5	164
24	1962	4.6	7.4	1.9	.33	.49	5	15	27	35	2	161
13	1962	4.5	7.2	1.9	.32	.48	5	13	23	29	0	159
32	1964	3.7	5.4	1.7	.31	.42	6	15	31	42	47	161
8	1964	3.6	5.2	1.7	.30	.40	14	20	37	43	5	157
18	1964	3.5	5.2	1.8	.29	.40	11	21	41	47	12	161
14	1964	3.5	4.8	1.4	.29	.37	15	18	37	43	2	154
15	1964	3.3	4.5	1.5	.27	.35	14	18	39	43	0	155
27	1964	3.0	4.3	1.2	.25	.33	12	18	37	44	2	156
30	1964	2.8	3.6	1.3	.23	.28	12	17	37	42	3	156

a/ Number of days after April 25, 1975

b/ Number of days after September 23, 1975

c/ Percent of trees retaining 25% or more leaves through winter

d/ Number of days between leaf flush and leaf color dates

Table 2. Partial correlation coefficients of <u>Quercus</u> <u>rubra</u> characters with latitude and longitude.

Characteristic	Latitude	Longitude
1969-1974 height growth of 1962-1963 sources	+.0714	+.3310
1969-1974 height growth of 1964 sources	+.2118	+.2124
Annual height growth of 1962-1963 sources	-.3876	+.2133
Annual height growth of 1964 sources	+.6745	+.7459
Annual DBH growth of 1962-1963 sources	-.2358	+.2038
Annual DBH growth of 1964 sources	+.5680	+.6425
Date of leaf flush	-.3043	-.4950*
Date of leaf color	-.6357*	-.1493
Date of leaf death	-.8094*	-.4047*
Date of leaf drop	-.7794*	-.1732
Leaf retention	+.0945	+.4830*
Number of growing days	-.3724	+.2432

* significant at the α = .05 level

Note: All but nine sources had unaveraged altitudes making the coefficients involving altitudes a misrepresentation; therefore, they will not be presented.

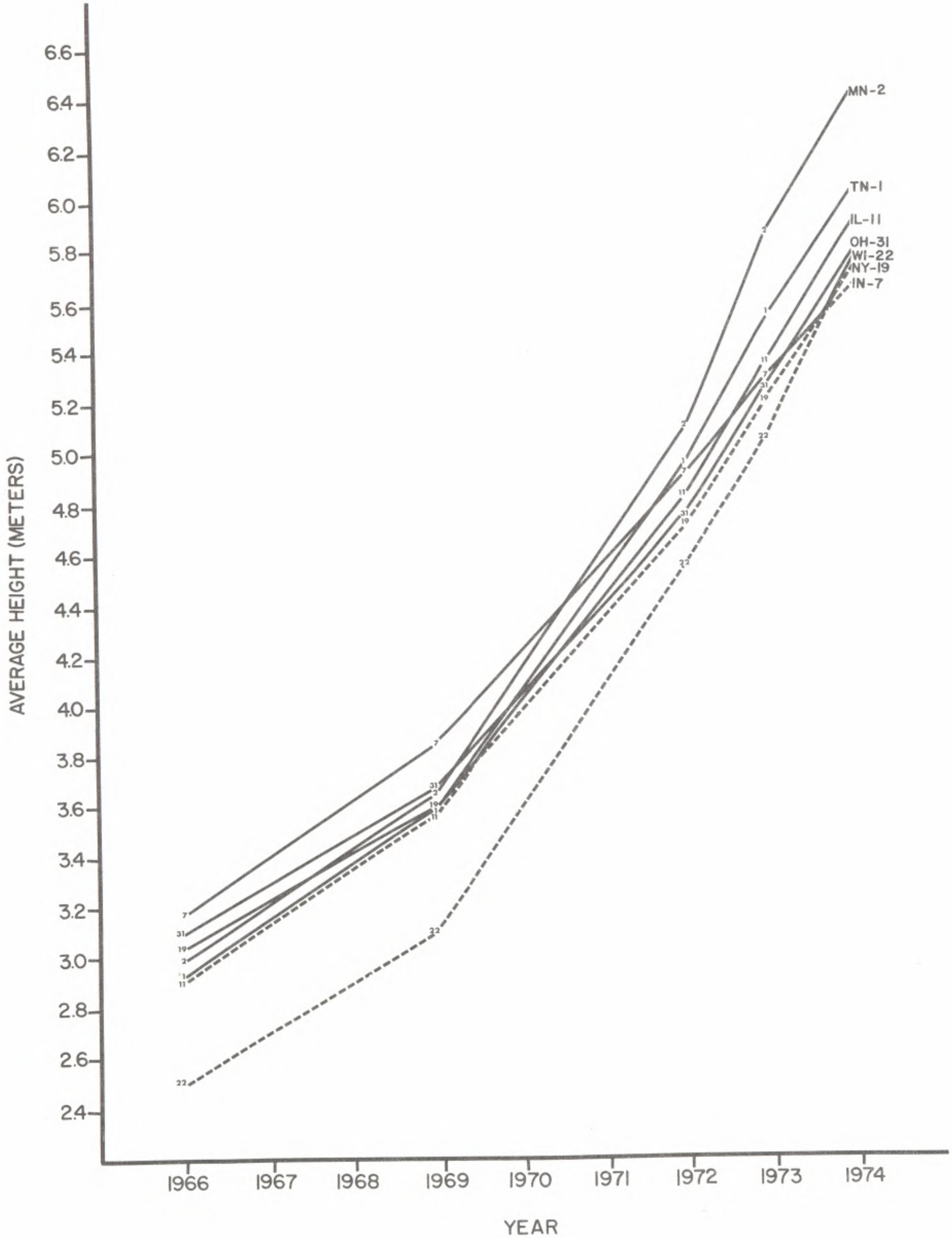

Figure 2. Height growth of seven provenances of northern red *oak* at Plattsmouth, Nebraska. The five fastest growing sources are depicted by solid lines. The line designating a source changes from solid to dash or vice versa as the ranking changes.

highly correlated with coefficients of 0.84 or greater. Correlation of measurements with phenology characteristics were statistically significant, but coefficients did not exceed 0.50. Date of leaf flush was not strongly correlated with other phenological characteristics and was negatively correlated with growth measurements. The fall phenology characteristics were strongly correlated with each other. Number of growing days and date of leaf color exhibited strong association with a coefficient of 0.89. The number of growing days and dates of leaf death and leaf drop were weakly associated (r = 0.58 and 0.53 respectively).

Height growth for the period 1969-1974 did not show any significant relationship with respect to latitude and longitude. Dates of leaf flush and death and leaf retention were associated with longitude. The highest percentage of trees with leaves retained occurred in four out of six sources originating west of the Mississippi River. Dates of leaf color, death, and drop were strongly correlated with latitude.

DISCUSSION AND CONCLUSIONS

A few years after plantation establishment it was noted that trees of sources planted in 1964 were growing at a slower rate that those planted in 1962 and 1963. We suspect that this slower growth rate might be due to genetic factors because all but two of these sources were collected from a small area within the total range (Table 1, Figure 1). However, another factor which may have caused slow growth was the increasing competition of invading perennial grasses after initial plantation preparation. Because of this latter possibility, we analysed growth of the 1964 sources separately from those sources planted in 1962-3.

Differences in initiation of rapid growth could be genetic or environmentally related. Growth could be accelerated or suppressed at certain physiological ages because of genetic differences among sources. Also, seedlings of a provenance might be able to recover from transplanting shock more quickly then those of another provenance because of size, vigor, and/or better root development, but might not be well enough adapted to a specific site to maintain rapid growth. Seedling trees of a source which establish themselves more slowly after planting may be better adapted to the site conditions and increase rate of growth during a later period of years. Another explanation is that climatic conditions could be favorable to growth of trees of a source until changes in rainfall, temperature, and/or other factors, slow their growth while favoring growth of trees from another source.

We found little correlation of growth with phenology. However, we observed phenology only one year. More phenology data is needed before reaching more definite conclusions.

We have not detected any die-back due to cold injury. Frost injury to emerging leaves in the spring has been noted which might reduce the growth of trees that flush early. However, the trees of source 2, which were the earliest to flush in 1975, were the tallest trees in the plantation in 1974.

Tree height and diameter does not necessarily depend upon latitude, longitude, or altitude of source, but rather upon individual stand genotypes.

A summary of results from plantations in other states reinforces this observation (Kriebel _et al_, unpublished). Apparently, localized site conditions are more important than widespread phenomena, such as photoperiod, in the evolution of growth response of northern red oak.

The weak association of leaf flush with longitude and the lack of a relationship to latitude and altitude is contrary to previous reports (McGee, 1968 and 1970; Gall and Taft, 1973). Nine provenances from different altitudes, but with all mother trees from the same altitude, were used to calculate a partial correlation coefficient which was found non-significant ($r = -0.06$) . We concluded that variation of date of leaf flush is discontinuous over the species range.

Although leaf retention and date of leaf death were weakly correlated with longitude, any prediction of source response is unrealistic due to low correlation coefficients. However, a prediction that western sources will have a high percentage of trees which retain their leaves throughout the winter would be reasonably accurate. Leaf death is so highly correlated with latitude that variation with longitude is, at best, secondary and discontinuous.

A strong association of latitude with dates of leaf color, death, and drop was found in the plantations of the other states (Kriebel _et al_, unpublished). Flint (1972) stated that northern red oak trees from the northern part of the natural range winter harden faster than trees of southern provenances. Provenances which harden the fastest are the earliest to exhibit visible signs of dormancy such as change in leaf color. This supports the correlation of fall phenology to latitude observed in this provenance test. Photoperiod, which is associated with latitude, is a key agent in the cessation of growth (Perry, 1971). Thus, we have concluded that initiation of northern red oak dormancy evolved under conditions associated with day length and is probably clinal in variation.

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