# EARLY GROWTH OF PLANTED NORTHERN RED OAK AS INFLUENCED BY GENOTYPE AND NITROGEN FERTILIZATION

by

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Abstract--Twenty open-pollinated families of 1-0 seedlings were grown for five years on a well-drained, alluvial site after applying 360 kg/hectare of nitrogen during the first and second years after planting. Mean five-year height of individual families ranged from 2 to 3 meters, and was on the average 47 percent greater than unfertilized controls. After deletion of treatment variance, 16-percent of remaining variance in height was associated with family differences, while the family x fertilization interaction was not significant until the fifth year when it accounted for 8 percent of variance. The genetic correlation between five-year heights in controls and the fertilization treatment, another measure of genotype x environment interaction, had a coefficient of 0.67. Larger trees had both greater numbers of shoot elongation flushes per season and larger individual flushes than poor performers.

Additional keywords: Genotype x fertilization interaction, shoot growth components.

Growth of planted northern red oak (Quercus rubra L.) has been stimulated by nitrogen fertilization (Foster and Farmer 1970, Gall and Taft 1973) which shows promise of being a beneficial establishment practice. Looking beyond this general response, however, it will be important to use planting stock which has especially good response to nitrogen since fertilization interaction research is stock with excellent potential for both early growth and reponse to nitrogen.

## METHODS

One-year-old bare-rooted northern red oak seedlings from 20 open-pollinated southern Appalachian parent trees were lifted in March 1973. Twelve replicates of 4-tree family subplots were planted at 1.2 x 1.2 m spacing in an abandoned nursery area, which had been treated with Dalapon to kill grasses, then plowed and disced. The planting was divided into three blocks of four treatment plots, each of which received one of the following treatments:

(1) Control
(2) Irrigation
(3) Fertilization
(4) Fertilization and irrigation

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The design was thus a split-plot with treatments as main plots and families as subplots.

The irrigation treatment consisted of supplementing natural rainfall in July and August of 1973 and 1974, when soil moisture deficits might have limited growth. An irrigation hose was attached to the nursery irrigation system and plots were thoroughly soaked at biweekly intervals. Ammonium nitrate (1000 kg/hectare) was broadcast on fertilization plots on May 4, 1973, and again in mid-April 1974. During the 1973 and 1974 growing season, the test area was cultivated as necessary to keep it free of weeds. In 1975, the area was cultivated once; it was not cultivated in 1976 or 1977

Total height of each tree was recorded at planting and after each growing season from 1973 through 1977. Each year's height growth was also recorded as number and length of individual flushes of main shoot elongation.

In August 1974, leaf samples (without petioles) were taken from three trees in each plot and ovendried for 24 hours. After grinding to 60 mesh in a Wiley mill, samples were analyzed for nitrogen, phosphorus, potassium, calcium, and magnesium. The semimicro-Kjeldahl procedure was used for N, the molybdovanadate test for P, and atomic absorption spectroscopy for Ca, K, and Mg.

## RESULTS

Analyses of variance in total height revealed significant family differences throughout the test period and significant treatment differences starting with the second growing season. Irrigation had no effect on growth in either the first or second years and was discontinued after the second year. The degree of height response to fertilization (Figure 1) ranged from 28 percent over controls after the second growing season to 47 percent over controls at the end of the test. The range of family means around treatment means was broad throughout the test; at five years it was slightly over 1 m for the fertilized trees, which has a mean of 2.5 m. There was, however, no significant fertilizer x family interaction until the fifth year. Since some family differences in height were present at planting, a correlation analysis of family means at planting with those at five years was computed. The resulting correlation coefficient of 0.41 indicated that major changes in family rankings took place during the course of the test.

Variance components for families and the family x treatment interaction were computed using the model below with data from the fifth year measurement. Within-plot variance was computed using data from every tenth plot.

| Source of Variation | Expected Mean Square | Variance Component | Percent of Variance |
|---|---|---|---|
| Families | $\frac{\nabla^2 w}{K} + \nabla_R^2 + RT\nabla_F^2$ | 527 | 16 |
| Treatment x Families | $\frac{\nabla^2 w}{K} + \nabla_R^2 + R\nabla_{TF}^2$ | 256 | 8 |
| Error II | $\frac{\nabla^2 w}{K} + \nabla_R^2$ | ±0 | 0 |
| Within Plot | $\frac{\nabla^2 w}{K}$ | 2,466 | 76 |

Separate analyses of variance were also computed for control and fertilized plots with the following results:

| Source of Variation | Expected Mean Square | Control | | Fertilization | |
|---|---|---|---|---|---|
| | | Variance Component | Percent Variance | Variance Component | Percent Variance |
| Families | $\frac{\nabla^2 w}{K} + \nabla^2_R + R\nabla^2_F$ | 376 | 14 | 534 | 17 |
| Replication x Families | $\frac{\nabla^2 w}{K} + \nabla^2_R$ | ±0 | 0 | ±0 | 0 |
| Within Plot | $\frac{\nabla^2 w}{K}$ | 2,250 | 86 | 2,599 | 83 |

Together these analyses indicate that around 16 percent of the total variance unrelated to fertilizer effects was associated with family differences, and that the degree of genetic variation was roughly the same under both control and fertilizer treatment.

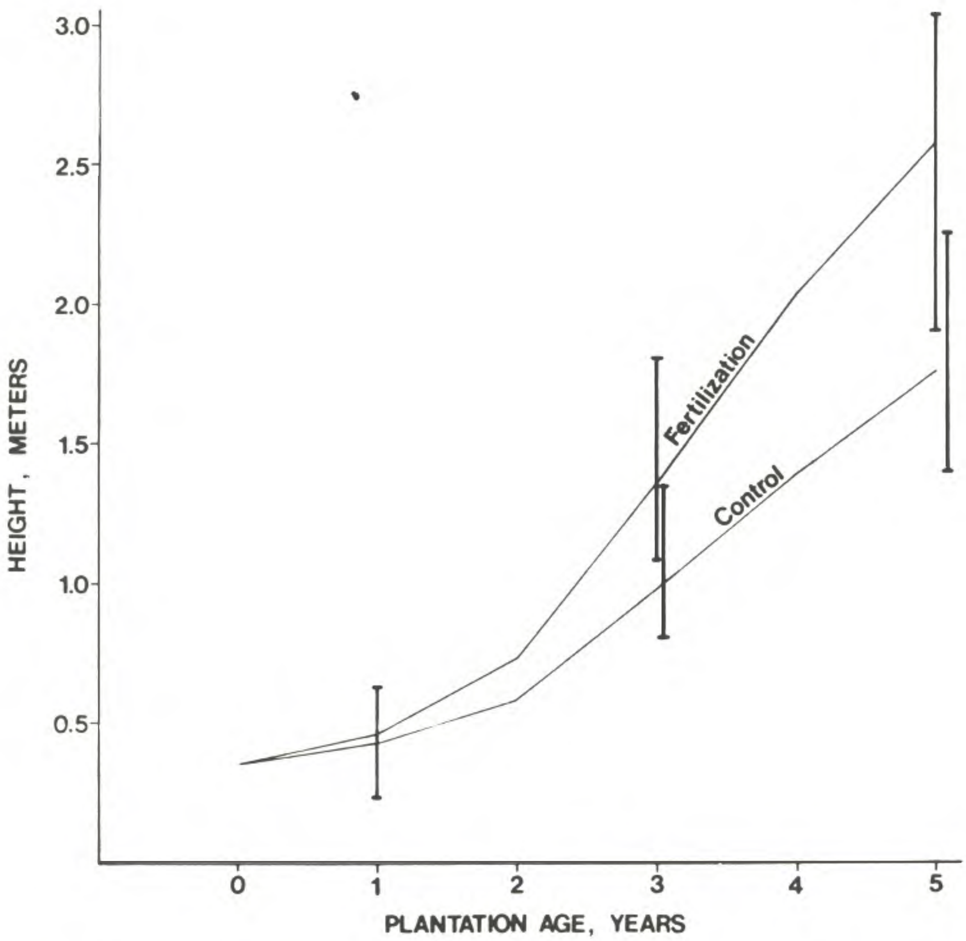


Figure 1. Effect of nitrogen fertilization on height of planted northern red oak. Vertical bars indicate range of family means in control and fertilization treatments.

The family (genotype) x fertilizer interaction accounted for approximately 8 percent of the variance. Family means for fifth year height in' the fertilization treatment ranged from 18 to 89 percent over equivalent means in controls. Effect of fertilization upon the relative performance of families was also examined by correlation analysis, as suggested by Burton (1977). The correlation of family means for fifth year height in the control and in fertilization treatment had a coefficient of 0.67; the rank correlation coefficient was 0.33. The genetic correlation between these two sets of heights also had a coefficient of 0.67. Thus, **less** than 50 percent of the family variation in height in the fertilization treatment was associated with family differences in controls. Correlation analysis of family means in controls vs percentage response produced a correlation coefficient of -0.56, indicating that the slower growing families in controls tended to respond slightly better to fertilization than the control families with the higher rate.

Differences in height growth due to fertilization and family effects were examined in terms of shoot growth components. Shoot length of individual plants in a species with episodic elongation patterns, such as *Quercus,* is related to at least two components: (1) number of elongation flushes and (2) the spatial length of flushes. Data for the second, third, and fourth seasons are presented in Table 1. Fertilization resulted in a greater number of flushes in all three seasons, and the number of flushes per season decreased with plant age. In all years a higher precentage of fertilized plants made second, third, and fourth flushes than did control plants. Plants which made the greatest number of flushes also had greater flush length throughout the season. These same components were examined for several fertilized families with small and large heights at five years, and the same pattern (Table 1) was apparent. Height differences are positively related to both number and length of flushes. Number of flushes decreased and the length of individual flushes increased with age.

Foliar analyses indicated that K, P, Ca, and Mg were at normal levels and were not affected by treatment. Fertilization increased nitrogen levels from 2.33 to 2.54 percent. The base levels of nitrogen were higher than those noted in studies by Phares (1971a, b) and Mitchell and Chandler (1939), whose work suggests that both levels in this test were adequate for good growth.

## DISCUSSION

In this test, nitrogen fertilization increased growth of planted seedlings on a site where foliar analysis of control trees suggested no major nitrogen deficiency. The percentage growth response (with control as basis) was substantially less on the average than the 70 percent increase observed by Foster and Farmer (1970) in a test where two applications of ammonium nitrate were supplemented by commercial fertilizer (15-15-15). However, some families exhibited a response equal to that in the previous test. Total growth and general response to fertilization were both greater than that noted by Buckner and Maki (1977) for northern red oak on an old field in eastern Tennessee.

The conclusion stemming from these tests is that nitrogen amendment, as well as weed control, will be essential to rapid dominance by oak on

Table 1. Flushing characteristics of northern red oak trees having variable height growth due to fertilization treatment or genotype.

| Item | Season | Mean Number of Flushes | Percent of Trees Making Flush Number | | | | Mean Length of Flush Number | | | | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | N |
| Control, all families | 2 | 2.1 ± 1.0[1/] | 100 | 68 | 30 | 10 | 7 | 11 | 17 | 21 | 60 |
| | 3 | 1.8 ± .9 | 100 | 60 | 12 | 0 | 26 | 22 | 21 | | 60 |
| | 4 | 1.3 ± .5 | 100 | 27 | 3 | 0 | 35 | 21 | 14[2/] | | 60 |
| Fertilization, all families | 2 | 2.4 ± .8 | 100 | 83 | 48 | 5 | 9 | 14 | 22 | 26 | 65 |
| | 3 | 2.4 ± .6 | 100 | 100 | 52 | 2 | 34 | 28 | 37 | 52[2/] | 66 |
| | 4 | 1.8 ± .6 | 100 | 67 | 13 | 0 | 45 | 36 | 23 | | 63 |
| Family #715, fertilization $\overline{M}$ height, 206 cm | 2 | 1.9 ± .8 | 100 | 58 | 26 | 0 | 6 | 8 | 20 | | 19 |
| | 3 | 2.0 ± .6 | 100 | 84 | 16 | 0 | 27 | 21 | 31 | | 19 |
| | 4 | 1.4 ± .5 | 100 | 37 | 0 | 0 | 39 | 29 | | | 19 |
| Family #876, fertilization $\overline{M}$ height, 320 cm | 2 | 2.9 ± .9 | 100 | 91 | 73 | 41 | 9 | 10 | 23 | 23 | 22 |
| | 3 | 2.2 ± .6 | 100 | 91 | 27 | 0 | 34 | 39 | 32 | | 22 |
| | 4 | 1.6 ± .6 | 100 | 50 | 5 | 0 | 51 | 37 | 20[2/] | | 22 |

1/ Standard deviation

2/ Based on 1 or 2 plants only

suitable old field sites where there is competition mainly from herbaceous vegetation. Moreover, it is likely that this amendment will be more beneficial, in terms of total growth on the best sites and that irrigation is unlikely to be valuable during establishment, at least under southern Appalachian conditions. Other research (Buckley and Farmer 1974) suggests that differences established during the first several years will persist.

There was wide variation among open-pollinated families under both control and fertilization. During the first few years, this variation was not significantly influenced by nitrogen amendment, but by five years when the establishment phase was completed, a genotype x fertilizer interaction accounted for substantial variance. Due to this interaction and the associated low correlation between family means in the two treatments, selection in one regime will not necessarily provide the best materials for the other. For example, at five years the top two families in controls were also the top two under fertilization, but a family ranking 16th in a field of 20 in controls ranked 3rd in the nitrogen treatment.

Data on the basis of differences in shoot growth (due to either genotype or fertilization) are of both fundamental and practical significance in that they (1) provide information on the way in which oak grows and (2) may offer keys to effective early selection of superior genotypes or evaluation of growth-stimulating treatments. This test indicates that good early performers can be expected to have both a greater number of flushes and larger individual flushes. Three to four flushes are common on good performers during the first year or two, but number of flushes rapidly declines during ontogeny until about the fifth year, when one long flush is probably typical of most plants. Gall and Taft (1973) noted that nitrogen amendment applied during the fourth growing season changed the number of flushes from one to two during that season. The reduction in number of flushes per season with ontogeny has been considered by Borchert (1976) as a function of the tree's increasing complexity and more specifically as the effect of rapid leaf area development on secondary shoots. If such a relationship does in fact control primary shoot elongation, pruning of lower branches (in stands such as those of this test) should promote height growth during the period of crown closure immediately after establishment (5-6 years).

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