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Importance of Red Oak Mother Tree to Nursery Productivity[1]

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Abstract

Acorns from 19 red oak (*Quercus rubra* L.) trees were collected in fall 1988. Whips were produced in 1989 and field planted in 1990. Mother tree identity was maintained throughout the study. Growth during the whip production phase was rapid; the average height growth for the 19 families was 122 cm (approximately 4 ft). The best family averaged 167 cm (5.5 ft), the worst 73 cm (2.5 ft) with average individual whip values of $11.20 and $2.80, respectively. When transplanted to nursery fields, the whips had high survival and rapid growth rates. Average individual tree value at the end of three growing seasons ranged from $38.60 to $11.20 for families 6 and 12, respectively. All the traits measured in this study: height, caliper, % acceptable and individual tree value, have relatively high heritability estimates, indicating that traits are under genetic control and thus subject to manipulation by nursery mangers and breeders. The family that produced the highest value whips, did not produce the highest value finish stock. Average finish stock value for a family was determined more by the percentage of the acceptable trees (a measure of quality), than by plant height or caliper (measures of growth).

Index words: heritability, tree improvement, nursery productivity, plant quality, *Quercus rubra.*

Significance to the Nursery Industry

High quality red oak whips can be produced rapidly under Ohio Production System conditions. OPS-produced whips transplanted to nursery fields have high survival and rapid growth rates. During production, growth and quality are strongly influenced by red oak mother tree. All the traits measured in this study, height, caliper, percent acceptable and family individual tree value, have relatively high heritability estimates, indicating that traits are under genetic control and thus subject to manipulation by nursery managers. Nursery productivity (defined in this study as gross dollars/year) can be significantly increased by raising whips and finish stock from selected mother trees. It is also expected that net nursery productivity would also be increased by raising nursery stock from genetically superior mother trees. The best family for whip production was not the best family for finish stock production. Finish stock value was determined more by percentage of acceptable trees (a quality indicator), than by growth (plant height or caliper). The greatest gains are made by combining the best cultural practices, which may included novel production systems, with genetically superior seed sources. However, raising nursery stock from genetically superior seed sources will increase nursery productivity in any production system.

Introduction

Most tree species are propagated by seed. With woody landscape plants, seed source, or provenance, has a dramatic effect on plant growth (10, 11) and thus on nursery productivity. Selecting and growing the best seed sources can boost nursery productivity because it costs no more to produce seedlings from genetically superior seed sources than it does genetically inferior sources.

There is great variability in economically important traits among red oak provenances (4, 5, 6). If the variability is under genetic control then the variability can be manipulated by the nursery manager. Narrow sense heritability estimates are used to estimate the degree of genetic control for a given trait when using seed (sexual) propagation. Heritability estimates range from 0, no genetic control, to 1, complete genetic control. One study found narrow sense heritability estimates for juvenile red oak height growth to be high, 0.64 (9).

The effects of mother tree on whip production have been described (8). The purpose of this study was to document

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the effects of red oak mother trees on nursery productivity during whip and field production and to estimate genetic control over economically important traits.

Materials and Methods

In mid-September 1988, acorns were picked from 28 randomly selected red oak trees on The Ohio State University campus. The acorns were placed in plastic bags and kept in a walk-in cooler at 2°C (40°F) until March. In March, the acorns were sown into 3:1:1 (pine bark:peatmoss:sand, by vol.) medium and placed in a greenhouse under a poly (white poly with 70% light transmission) tent to germinate. Before the emerging seedling shoots were 6 cm (2 in) long, the acorns were gently removed from the flats, root pruned to 6 cm (2 in) length and transplanted to 3.8 l (1 gal, 6 in × 6 in) black plastic containers that had the interior surfaces treated with 100 g (3.5 oz) $Cu(OH)_2$/l (qt) white latex paint. The same pine bark:peatmoss:sand medium was used for the 3.8 l containers as for the germination medium. Whips were produced via Ohio Production System conditions which are described in references 7 and 8.

Greenhouse conditions were: 25/18°C (77/65°F) day/night temperature with natural photoperiod. Each container received 15 g (1 Tbsp) 18N-2.6P-10K (18-6-12) slow release fertilizer (Osmocote, Grace/Sierra) at planting and weekly application of 20N-8P-16.6K (20-10-20) water soluble fertilizer (Peters, Grace/Sierra).

After a ten-week greenhouse production phase (March 1 to May 15), the plants were moved outdoors under 70% shade for a two-week acclimation period. On June 1, the seedlings were transplanted to 14.4 l (3 gal, 11 in × 9 in) copper-treated fiber containers (Keiding, Inc., Milwaukee, WI 53218) and placed in full sun in a completely random experimental design. Thirty grams (2 Tbsp) of slow release fertilizer (18N-2.6P-10K) (18-6-12) were applied to each container and weekly fertilization with 200 ppm N 20N-8.8P-16.6K (20-10-20) was continued until September 15. The plants were staked to train a central leader. Any lateral branches were pruned to 30 cm (12 in) length.

The plants were placed in a polyhouse in late November for over wintering. In April 1990, between 16 and 20 randomly selected individuals per family (326 total trees) were field planted at 3 m within row × 4 m between row (approximately 10 ft × 12 ft) spacing in a completely random design. The field was clean cultivated the first growing season with sod strips established in fall 1990. The plants were pruned according to Flemer (3), including pruning back to an upright bud on curved central leaders to encourage vertical growth.

Data collection and numbers of plants. During the first growing season (container production phases) final plant height was measured on September 22. In the field, initial plant height was measured after planting and annually each fall. Caliper was measured in fall 1992.

Value (dollars per tree) at the end of the container production phase was based on plant height according to Table 1. In fall 1992, plants were rated as acceptable, or not, for harvest. Individual trees were considered acceptable if they exceeded 2 m (6 ft) in height, 2.54 cm (1 in) in caliper, had a central leader and were firmly rooted (mechanically stable with no evidence of lean) into the native soil. Individual tree value was calculated for acceptable trees only accord-

Table 1. Whip prices (dollars per whip) used to determine one-year-old container-grown whip values.

Size, in cm (in)	Value ($)[z]
<15 (<6)	0.00
16-30 (6-12)	0.35
31-45 (12-18)	0.45
46-60 (18-24)	0.60
61-90 (24-36)	1.10
91-120 (36-48)	5.80
121-150 (48-60)	7.65
151-180 (60-72)	8.60
181-210 (72-84)	9.45
211-240 (84-96)	10.30
>241 (>96)	11.30

[z]Values were determined by averaging prices from 1992 nursery catalogues.

Table 2. Prices (dollars per tree) used to determine value of acceptable trees. Individual trees were considered acceptable if they exceeded 2 m (6 ft) in height, 2.5 cm (1 in) caliper, had a well defined central leader and were firmly rooted (mechanically stable with no evidence of lean) into the native soil. Value was based on caliper size for trees greater than 2.5 cm caliper, and on height for trees less than 2.5 cm caliper. Unacceptable trees were given a value of $0.00.

Size, in cm (in)	Value ($)
Less than 2.5 cm (1 in) caliper	
150 (60)	11.25
180 (72)	14.00
2.5 cm (1 in) or greater caliper	
2.5 to 3.1 (1 to 1.25)	16.85
3.2 to 3.7 (1.25 to 1.5)	19.50
3.8 to 4.3 (1.5 to 1.75)	35.00
4.4 to 4.9 (1.75 to 2)	52.00
5.0 to 6.2 (2 to 2.5)	56.00

[z]Values were determined by averaging prices from 1992 catalogues.

Table 3. Average tree height and value (average value per whip in dollars) of one-year-old red oak whips grown from 19 half-sib red oak families.

Family	Height (cm)	Value ($/tree)
16	167 a[z]	8.65 a
18	148 b	7.39 b
2	150 ab	7.37 b
22	144 bc	7.52 ab
6	135 bcd	6.80 bc
30	127 cde	6.46 bc
14	126 cdef	5.94 cd
10	124 defg	6.07 dc
5	121 defg	5.86 dc
9	119 defgh	6.08 dc
21	118 defgh	5.72 cd
8	113 efgh	5.64 cd
12	113 efgh	5.64 d
15	108 fgh	5.05 d
4	106 hg	2.80 d
19	101 h	5.05 d
20	73 i	2.80 e

[z]Means within a column followed by the same letters are not statistically different from each other (P = 0.05) using the Waller-Duncan K-ration T-test.

Table 4. **Average growth, quality (percent acceptable trees) and value (average value per tree) on trees from 17 half-sib red oak families three years after field planting as one-year-old whips.**

No.	Family value 1989	Height (cm) 1990	1991	1992	Caliper 1992 (cm)	% Acceptable trees[z]	Average per tree ($)
6	134	192	191	284 ab[y]	4.1 ab	94 a	38.60 a
14	153	209	207	287 ab	4.0 abc	82 ab	33.06 ab
15	140	186	193	288 ab	3.8 abcde	82 ab	30.69 abc
16	138	191	201	295 a	4.0 abc	76 abc	32.40 ab
8	145	198	194	284 ab	3.8 abcd	74 abc	26.56 abcde
4	151	213	196	292 ab	3.8 abcde	72 abc	24.74 abcde
19	140	191	184	267 abcd	3.6 cdef	72 abc	25.37 abcde
22	134	192	191	266 abcd	4.0 abc	65 abc	26.84 abcd
10	126	187	189	268 abcd	3.7 bcdef	61 abcd	20.54 bcde
2	154	196	201	280 abc	3.6 cdef	61 abcd	18.52 bcde
21	151	213	196	264 bcd	3.3 f	56 bcd	18.37 bcde
30	109	168	179	266 abcd	3.7 bcdef	56 bcd	19.54 bcde
18	142	193	205	284 ab	3.9 abcd	50 bcd	16.37 cde
5	138	191	201	292 ab	4.2 a	50 bcd	24.87 abcde
20	106	157	172	244 d	3.4 def	47 bcd	16.63 cde
9	154	196	200	279 cd	3.6 cdef	41 dc	14.34 de
12	129	182	195	243 d	3.3 ef	28 d	11.61 e
Avg.	136	189	192	274	3.8	63	23.51

[z]Individual trees were rated as acceptable if they were firmly rooted with no evidence of leaning or instability and had developed a central leader. Unacceptable individuals were given a zero dollar value. Sample size ranged from 16 to 20 individuals per half-sib family.

[y]Means within a column followed by the same letters are not statistically different from each other ($P < 0.05$) using the Waller-Duncan K-ration T-test.

ing to Table 2. Value was based on caliper size for trees greater than 2.5 cm (1 in) caliper and on height for trees less than 2.5 cm (1 in) caliper. Unacceptable trees were given a value of $0.00.

Of the original 28 open-pollinated families, 19 had sufficient germination to be included in the container production phase. In the field study, 17 of the 19 families had at least 16 surviving individuals in fall 1992 and were included in the statistical analysis. Red oak families were assumed to be half-siblings so that the observed variation among families equated to ¼ of the additive genetic variance (2). The GLM and VARCOMP procedures of SAS were used to determine significance levels and for estimating variance components. Narrow-sense individual tree heritabilities and their standard error were calculated using methods of Becker (1).

Results and Discussion

Whip growth (height 1989) was rapid, averaging 122 cm (4 ft) for all 19 families (Table 3). Some individual heights exceeded 280 cm (9 ft). There were significant ($P = 0.0001$) family difference in height growth.

Field mortality was low, less than 8%. Of the 30 trees lost, 26 were lost to breakage caused by flat headed borer (*Chryosobothris femorata*) attack; the trees snapped off at the borer exit hole.

First year (1990) field growth was vigorous; the average increase was 53 cm (21 in) (Table 4). The height increase in 1991 was similar to 1990, although the net increase was only 3 cm (about 2 in). The reduced net height increase was attributed to heavy pruning of bent terminal shoots during winter 1990-91. Net height increase in 1992 averaged 81 cm (32 in). By 1992, caliper averaged 3.8 cm (1.5 in) and family means ranged from 1.2 cm (0.5 in) to 5.7 cm (2.25 in) (Table 4). There were highly significant ($P = 0.001$) family difference for height and caliper at all measurement periods (Table 4).

The 17 family average percent acceptable trees was 63% (Table 4) with family averages ranging from a low of 28% to a high of 94%, families 12 and 6, respectively. There were significant family differences in percentage of acceptable trees.

Individual whip value (1989 height) averaged $5.97, ranging from $0.35 to $11.30 for families 20 and 16, respec-

Table 5. **Pearson correlation coefficients among growth traits and value for 17 half-sib red oak families after container production (1989) and three years after field planting as one-year-old whips. Sample size ranged from 16 to 20 individuals per family.**

Factor	Container value	Height 1991	Height 1992	Caliper 1992	Percent acceptable in 1992	Value 1992
Container value	1.00	0.99**	0.47	0.49*	0.24	0.29
Height 1991	—	1.00	0.49*	0.47	0.38	0.29
Height 1992	—	—	1.00	0.73**	0.69**	0.68**
Caliper 1992	—	—	—	1.00	0.54*	0.72**
Percent Acceptable	—	—	—	—	1.00	0.93**
Value	—	—	—	—	—	1.00

(*) and (**) indicate 0.05 and 0.01, respectively, levels of significance.

Table 6. Individual tree heritability estimates for selected traits from 17 half-sib red oak families.

Trait	Estimated individual tree heritability
Height 1989	0.689 (0.26)
Height 1990	0.950 (0.31)
Height 1991	0.744 (0.28)
Height 1992	0.398 (0.19)
Caliper 1992	0.381 (0.19)
Percent acceptable	0.279 (0.17)
Value in 1989	0.555 (0.20)
Value in 1992	0.317 (0.18)

[z]Standard error for each estimate, in parenthesis, follows each estimate.

tively (Table 3). In 1992, individual tree value averaged $20.29 (Table 4). Family individual tree value averages ranged from $11.61 to $39.60 (families 20 and 17, respectively). Family means for individual tree value were significantly correlated with caliper (0.68) and height (0.72), but were most highly correlated with percent acceptable trees (0.93) (Table 5).

Survival and growth during whip production and early field performance were excellent. Whip transplant survival was high; most losses could have been prevented with standard cultural practices (spraying for flat-headed borers). For comparison, the 10 year average survival for bare root whips in Ohio is 70% (Struve, unpublished data).

Under field conditions, overall caliper averaged 3.8 cm (1.5 in) after three growing seasons, with some families averaging 4.4 cm (1.75 in) caliper. Under present production practices, it can take three to five years to produce a red oak whip and an additional three years after one-year-old bare root whips are lined out to produce 1.5 to 2 in caliper stock. In this study, 1.5 in caliper stock was produced from seed in four growing seasons.

During whip production average individual tree value was determined by height. However, under field conditions, average individual tree value was determined more by quality measures (percent acceptable within a family) than by height or caliper (Table 5). Individual whips from family 16 averaged the tallest and after three growing seasons in the field, were ranked among the tallest and greatest in caliper but only 76% of the trees were deemed acceptable. In contrast, whips of family 6 were shorter than whips of family 16 and after three growing seasons in the field, family 6 was not among the tallest families nor the greatest in caliper, but it had the highest per tree family value. After three years in the field, average individual tree value difference between families 6 and 16 was $6.20 ($38.60 vs $32.40). The families that performed best during whip production may not perform best during finish stock production, as indicated by the low correlation between whip value and finish value in 1992 (Table 5).

Heritability is the ratio between genetic and phenotypic variances. Phenotype is the outward expression of the genotype as modified by the environment. Heritability's importance to the nursery manager is that it is a relative indicator of the genetic control of a trait. If a trait is under high genetic control, then the variability associated with that trait can be "captured" and used by a nursery manager. In this study, all traits studied were under moderate to very strong genetic control. The two most important heritability estimates for nursery managers are value in 1989 and family percent acceptable in 1992, 0.689 and 0.297, respectively (Table 6). Whip, and to a lesser degree, finish nursery productivity can be increased simply by collecting seed from the appropriate mother trees. Variable costs are the same whether a whip producer grows seed from mother tree 16 or 20. For instance, a whip producer can increase nursery productivity from $2.80 per whip to $11.40 by propagating seed from mother tree 16 instead of mother tree 20. Similarly, finish stock producers could gain an additional $26.94 per tree (family 6 at $38.60 per tree vs family 12 at $11.61 per tree) by selecting the proper mother tree.

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