Family Differences in Growth and Flowering in Young Southern Magnolia

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Abstract. Height and caliper (age 3 years), and flower count (age 3.5 years) were evaluated for 36 open-pollinated families of *Magnolia grandiflora* L. outplanted in two genetic tests in Bexar County, Texas. Significant family differences existed for height, caliper, number of flowers per tree, and percent of trees flowering in both tests. Family heritability estimates for all traits ranged from 0.72 to 0.92. Coefficients of genetic prediction (CGP) between growth and flowering characteristics were small but positive; CGP between height and percent of trees flowering was 0.28 and 0.24 in the two tests. Early growth rate and flowering appeared to be under strong genetic control; thus, improvement through selection would be efficient. However, both traits should be evaluated since the genetic relationship between them was weak.

Southern magnolia is a native tree of the southern United States that has been cultivated as an ornamental since 1734 (Vines, 1960). It is prized by horticulturists for its glossy evergreen foliage and its showy white flowers, which appear in late spring and early summer. The natural range of southern magnolia extends from southeastern Texas to eastern North Carolina, never reaching more than 320 km from the coast (Fowells, 1965). However, the species is cultivated as far north

as Washington, D.C. (Vines, 1960) and Illinois (Dirr et al., 1978).

Magnolia research has involved identification of cold-hardy cultivars and hybrids and propagation of various species by sexual or asexual means. Although several clones of southern magnolia have been released on the basis of phenotypic characteristics (Dirr and Brinson, 1985), no work has been done regarding progeny testing in the species. Also, no attempts have been made to select geno-

types with desirable growth or flowering characteristics on the basis of genetic test data.

Rapid early growth and flowering are important traits for commercial nursery growers. Rapid height and diameter growth in the nursery allows the producer to grow a larger, more valuable tree in a shorter period of time. For example, top-ranking families in Texas Forest Service Urban Tree Improvement Program magnolia progeny tests have grown 15% taller than the test average at 5 years (Texas Forest Service unpublished data). Improvement on this scale could potentially reduce the time required to produce, for example, a 2-m-tall tree by 1 year, permitting the grower to carry establishment costs over a shorter rotation. In addition, a young tree with flowers is more aesthetically pleasing and is thus apt to be more marketable. If it were possible to identify trees whose progeny combined the two traits, these families could be used for commercial production or as a base population for a breeding program or for clonal selections to be asexually propagated. Clonal selections could be based on a variety of important horticultural traits, such as growth form, leaf size and shape, internode length, etc. However, I found no studies on the genetic relationship between growth rate and flowering age, and it was not known whether it would be possible to identify fast-growing, early-flowering genotypes of southern magnolia.

The present study was designed to: 1) determine if a genetic relationship between early growth rate and early flower initiation exists

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Table 1. Characteristics of southern magnolia trees planted in southern Texas in two progeny tests.²

Test	Families (no.)	Ht (m)	Diam (cm)	Survival (%)	Flowers per tree	Flowering trees (%)
I	20	1.9 (1.4-2.2)	3.9 (3.1-4.4)	95	0.64 (0.03-2.0)	27 (2.5-68)
II	16	1.3 (0.9-1.7)	2.6 (1.8-3.6)	89	0.31 (0-0.9)	15 (0-43)

²Ranges of family means for which a significant family effect was identified are below plantation means.

Table 2. Analysis of variance of growth and flowering data from two genetic tests of southern magnolia in southern Texas.

Source of variation	df	Ht		Diam		Flowers per tree		Flowering trees (%)	
		Sum of squares	F value	Sum of squares	F value	Sum of squares	F value	Sum of squares	F value
Test I									
Rep.	9	1.416	3.00**	8.814	3.97**	2.077	2.76**	1.182	2.49*
Family	19	10.095	10.14**	21.393	4.57**	8.244	5.19**	6.639	6.63**
Error	171	8.958		42.166		14.305		9.014	
Test II									
Rep.	9	0.562	0.98	2.261	0.87	0.604	1.28	0.338	0.99
Family	15	11.326	11.86**	45.923	10.64**	2.814	3.58**	2.939	5.16**
Error	134	8.534		38.560		7.027		5.093	

***Significant at $P = 0.05$ or 0.01 , respectively.

Table 3. Heritabilities^a (diagonal) and coefficients of genetic prediction for two genetic tests of southern magnolia in southern Texas.

Trait	Ht	Diam	Flowers per tree (square root)	Flowering trees (%) (arcsin)
<i>Test I</i>				
Ht	0.90 (0.31)			
Diam	0.79	0.78 (0.31)		
Flowers per tree	0.27	0.14	0.81 (0.31)	
Flowering trees (%)	0.28	0.21	0.83	0.85 (0.31)
<i>Test II</i>				
Ht	0.92 (0.34)			
Diam	0.86	0.91 (0.34)		
Flowers per tree	0.32	0.21	0.72 (0.34)	
Flowering trees (%)	0.24	0.13	0.78	0.81 (0.34)

^aNumbers in parentheses following heritability values are standard errors.

in southern magnolia and 2) if possible, identify individuals whose open-pollinated progeny exhibit rapid early growth and produce flowers at an early age.

Open-pollinated seeds were collected from 36 southern magnolia ortets in Tarrant County in northern Texas (32.6°N), Brazes, Burleson, and Washington Counties of central Texas (30.0–30.5°N), and Frio County in southern Texas (29.0°N). All of the ortets were planted outside the natural range of the species.

With the exception of 12 trees in a commercial seed production area in Frio County, most of the ortets in this study were yard trees. It is recognized that partial isolation of the ortet increases the proportion of full sibs among the family members and violates the assumption of random mating. However, due to the nature of this study, it was impossible to avoid all isolated ortets. The proportion of self-pollinated seed also maybe increased by ortet isolation, since southern magnolia is self-compatible (Thien, 1974). Dirr and Brinson (1985) recommended collecting seed from isolated ortets to increase uniformity among the seedlings. No information about the provenance of any of the ortets is available; therefore, no inferences can be made about possible geographic provenance effects on growth or flowering.

Seeds were stratified for 90 days at 1 to 3°C, then sown in 6 × 25-cm (600 cm³) conical plastic pots in a greenhouse during early Spring 1984 and 1985. After one growing season, seedlings were outplanted into two progeny tests at a commercial nursery in Bexar County, Texas. Test I was outplanted 13 Nov. 1984 and contained 20 families, while test

II was outplanted 13 Nov. 1985 and contained 16 families. No families were common to both tests. Spacing in both tests, which were on adjacent areas in the nursery, was 1.8 × 1.8 m. both tests were planted in 10 randomized complete blocks. Each family was represented by a four-tree row plot in each block, for a total of 40 trees per family.

Soil on the area was a Crockett fine sandy loam with a 1% to 3% slope (Taylor et al., 1966). A composite soil sample collected from the surface horizon in the tests after their fifth growing season had a pH of 8.1 and very low levels of available N and P (1 and 5 ppm, respectively). The soil contained moderate levels of K (154 ppm), and high levels of Ca, Mg, and S (2933, 329, and 76 ppm, respectively). Mean annual temperature at the nursery is 21°C; average length of frost-free period is 275 days (Godfrey et al., 1973). The plantings were cultivated as needed during the growing season to control weeds, and the field was irrigated during the summers as soil conditions dictated. In keeping with standard practice at the nursery, no fertilizer was used on either planting. Growth was adequate throughout the life of the study, and no serious nutrient deficiency problems were noted.

At the end of the third growing season after outplanting, total height and trunk diameter at 15 cm above the ground line were measured. During late May of the fourth growing season, the number of flowers and flower buds on each tree was determined. Immature fruits originating from the current year's flowers were included in the count, while old fruits from previous years were not. The flower count was conducted at 3.5

years because many of the trees in the tests flowered for the first time during this fourth growing season after outplanting. Since one objective was to determine which families initiated flowering early, the survey was conducted after some families had initiated flowering, but before all families had done so.

The mean number of flowers per tree in each plot approximated a χ^2 distribution with the mean nearly equal to the variance. Therefore, the square root transformation (Steel and Torrie, 1980) was used for analysis. The proportion (percent) of trees with flowers in each four-tree row plot was calculated, and the inverse sine transformation was applied to the percent flowering data. Since zeros were common, the quantity $25/n$ was substituted for 0%, while the quantity $100 - 25/n$ was substituted for 100%, where n equals the number of live trees in the row plot (Steel and Torrie, 1980). Dead trees were excluded from all calculations. These flower data were combined with plot means of height and diameter and subjected to analysis of variance. Family heritability (h^2) estimates and coefficients of genetic prediction (CGP) were calculated for height and diameter and for transformed percent flowering and number of flowers per tree. CGP is calculated by dividing the covariance due to additive genetic effects of the two traits in question by the product of their phenotypic standard deviations and can be thought of as the fraction of the additive variation in one trait that is inherited when selection is performed on the other trait (Baradat, 1976). CGP differs from genetic correlation in that it is based on phenotypic standard deviation, which is the observed variation from which selections are made.

Mean height and diameter, survival percent, flower number per tree, and percentage of trees that flowered in the two tests are presented in Table 1. Significant family differences existed for height, trunk diameter, flowers per tree, and percent flowering in both tests (Table 2).

Family heritability values for height, trunk diameter, flowers per tree, and percentage of flowering trees were quite high and were similar in the two tests (Table 3). Combined analysis of tests in more than one location might have reduced h^2 estimates somewhat if the genotype × environment interaction were significant. Also, for reasons discussed

earlier, heritabilities calculated from open-pollinated test data are typically larger than those calculated from tests of control-pollinated crosses. However, the similarity of the h^2 values between the tests suggests that the values reflect a large genetic variance component for these traits in southern magnolia, since the tests were planted in different years and did not contain any common families. These high heritability values indicate that early growth and early flowering are under strong genetic control and would be susceptible to improvement in a genetic testing program.

Coefficients of genetic prediction between growth and flowering data were small but positive in both tests (Table 3). These numbers suggest that early growth and early flowering are genetically independent in magnolia, meaning that families that grow rapidly may or may not have a tendency to flower early, and vice versa. Indeed, while there were three families whose rates of growth and flowering percentages both ranked in the top 20% of the families in the test in which they were planted, it was also possible to identify families with high growth rates and few or no flowers, as well as families with high flowering percentages but below-average growth. In both tests, for example, the top-ranked family for percentage of flowering was average or below in height at 3 years. Small CGP values between growth and flowering are somewhat surprising; it might have been expected that early initiation of flowering would be positively related to tree size and general vigor. Conversely, if flowering competes with height growth within the plant for water and photosynthates, families that flower early might be expected to be shorter than their nonflowering counterparts. However, our data indicate that in a nursery environment, early flowering has little to do genetically with early growth rate.

This relative independence between height growth and flowering means that attention must be paid to both traits when selections are made if improvement in both is desired. Although a selection program based solely on height growth should produce a small degree of improvement in percent flowering, the height growth criterion alone is an inefficient and unreliable predictor of early flowering potential. Of course, it would be equally possible, based on the information presented herein, to select families with any combination of growth and flowering characteristics. For example, new cultivars for specialty landscape applications might be selected from slow-growing, early flowering families.

The following conclusions may be drawn from this study: 1) early growth rate and early flowering are both under strong genetic control in southern magnolia, making selection efficient for these traits; 2) early growth rate and early flowering are genetically relatively independent; evaluation of growth and flowering in progeny tests is necessary to identify families that exhibit desirable levels of these two traits.

Literature Cited

- Baradat, P. 1976. Use of juvenile-mature relationships and information from relatives in combined multitrait selection. IUFRO, Joint Meeting on Advanced Generation Breeding. Bordeaux, France, p. 121-137.
- Dirr, M.A. and B. Brinson. 1985. *Magnolia grandiflora*. a propagation guide. Amer. Nurseryman 162(9):38-51.
- Dirr, M. A., E. Friedhoff, and T. Smith. 1978. Plant hardiness evaluations. Amer. Nurseryman 148(5):12-72.
- Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S. Dept. Agr. For. Serv. Agr. Hdbk. 27.
- Godfrey, C. L., G.S. McKee and H. Oakes. 1973. General soil map of Texas. Texas Agr. Expt. Sta., Texas A&M Univ., College Station.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw-Hill, New York.
- Taylor, F. B., R.B. Hailey, and D.L. Richmond. 1966. Soil survey of Bexar County, Texas. U.S. Dept. Agr. Soil Conservation Serv.
- Thien, L.B. 1974. Floral biology of *Magnolia*. Amer. J. Bot. 61:1037-1045.
- Vines, R.A. 1960. Trees, shrubs, and woody vines of the Southwest. Univ. of Texas Press, Austin.