Ann Sci For (1993) 50, Suppl 1, 410s-415s

Original article

A means of accelerating red oak genetic tests

DK Struve [1], SE McKeand [2]

[1] *Department of Horticulture, The Ohio State University, Colombus, OH 43210-1097, USA;*
[2] *Department of Forestry, North Carolina State University, Raleigh, NC 27695-8002, USA*

Summary — Half-sib seedlings from 19 mother trees were grown in containers under intensive cultural practices for 1 year and then field planted. Field growth was measured for 2 growing seasons. Height averaged 122 cm in containers and 189 and 190 cm the 1 and the 2nd years in the field. There were significant family differences for all growth characteristics. Narrow-sense individual tree heritability (17 families) for field height was extremely high, 0.89 in 1990 and 0.60 in 1991. First year growth characteristics, number of flushes, duration of shoot elongation (in days), and growth during the continuous flushing phase were measured and correlations developed with subsequent field height. Growth characteristics during the continuous elongation phase, number days of stem elongation, shoot length and growth rate, were significantly correlated with field height growth. Container production has the potential to speed genetic testing of northern red oak by rapidly producing large, high quality planting stock for field testing and by reducting confounding variation associated with seedling establishment.

Quercus rubra **/ Ohio production system / transplanting / seedling establishment**

Résumé — Une méthode rapide de mise en place de tests comparatifs de chêne rouge. *Des semis de demi-frères issus de 19 arbres mères ont été élevés durant une saison dans des conteneurs dans des conditions de culture intensive, puis transférés en forêt. Des mesures de croissance ont été effectuées durant 2 saisons de végétation. La croissance moyenne était de 122 cm durant la première saison dans les conteneurs, puis de 189 et 190 cm au cours des 2 saisons passées en forêt. Des différences significatives ont été observées pour tous les caractères de croissance. Les héritabilités au sens strict de la hauteur totale (17 familles) étaient très élevées, 0,89 en 1990 et 0,60 en 1991. Les mesures durant la première saison (en conteneur) ont porté sur le nombre de pousses, la durée de l'élongation (en jours), et la croissance durant la phase d'élongation de la tige; elles ont été corrélées avec les caractères mesurés en forêt au cours des 2 saisons suivantes. Les caractères de croissance durant la phase continue d'élongation, la durée d'élongation, la longueur de la pousse et le taux de croissance étaient corrélés significativement avec la croissance en forêt. L'élevage en conteneur a l'avantage d'accélérer la mise en place des plantations comparatives de chêne rouge grâce à la production rapide de plants de taille importante et de bonne qualité. Elle tend également à diminuer la variation due à la crise de transplantation.*

Quercus rubra ***/ système de production Ohio / transplantation / mise en place de plants***

INTRODUCTION

The earlier accurate genetic estimates of important traits can be made, the more rapidly genetic gains can be realized. In tree improvement programs, juvenile genetic tests are conducted under intensive cultural regimes (Bongarten and Hanover, 1985; Lowe and van Buijtenen, 1989; Pharis *et al*, 1991). The combination of intense cultural practices, which reduce experimental error, and development of juvenile–mature correlations allow genetic selection to be made at juvenile ages rather than at rotation age. Any method that reduces experimental error and/or accelerates initial growth could allow for earlier genetic assessment.

A container production system, the Ohio Production System (OPS), has been developed for northern red oak (*Quercus rubra* L) (Struve *et al*, 1987). Red oak grows rapidly in the system and establishes quickly when field planted (Arnold and Struve, 1989). The OPS may be useful for testing family differences, since early growth is uniform and rapid. The purpose of this study was to determine if OPS could speed northern red oak genetic testing.

MATERIALS AND METHODS

In mid-september 1989, acorns were picked from 28 randomly selected red oak trees on the Ohio State University campus, placed in plastic bags and stored at 2 °C. In March, acorns were germinated and transplanted into 3.8 1 plastic containers and grown under OPS conditions. Briefly, the conditions were: 10 weeks in a greenhouse (25/18 °C day/night temperature, natural photoperiod), 2 weeks under 70% shade to acclimate to outdoor conditions and transplantion into a 14.4 l container about June 1. Plants were grown in copper-treated containers (100 gm of $Cu(OH)_2$/1 latex paint applied to interior surfaces) which inhibited root elongation and thus spiralling root development.

The plants were grown in a completely random design in the greenhouse and outdoors. Between 20 and 70 half-sibs per mother tree were grown. The plants were over-wintered in plastic houses and field planted in the spring of 1990. Between 16 and 20 randomly selected trees per family were planted at a single site at 3 x 3 m spacing in a completely random design. The field was clean cultivated the 1st year and grass strips established between the rows the 2nd year.

During the 1st year (in the containers), plant height was measured once in the greenhouse and 11 times between June 20 and September 22. Plant height was measured in the field at spring planting, in October 1990 and July 1991 (in the field a single flush typically completes elongation by mid-June).

During the container production phase, number of flushes and number of days that shoot elongation occurred were calculated from the height measurements. About mid-July, most plants switched from recurrent flushing habit to continuous shoot elongation. For this growth period, the shoot growth, number of days that shoot elongation occurred and the daily shoot elongation rate were calculated to determine if any of these characters would predict field performance.

Of the original 28 open-pollinated families, 19 had sufficient germination and survival for inclusion in the container trial, and 17 families were included in the field trial. Families were assumed to be half-siblings so that the observed variation among families equated to 1/4 of the additive genetic variance (Falconer, 1989). The GLM and VARCOMP procedures of SAS (SAS Institute, 1982) were used to determine significance levels and for estimating variance components. Narrow-sense individual tree heritabilities and their standard errors were calculated using the methods of Becker (1984).

For the sub-sample of trees transplanted in to the field, genetic correlations (Becker, 1984) were calculated between traits assessed in the containers and height in the field. Only those trees that were transplanted into the field were used to calculate family means.

RESULTS

Height growth in the containers was rapid, averaging 122 cm (fig 1; family growth

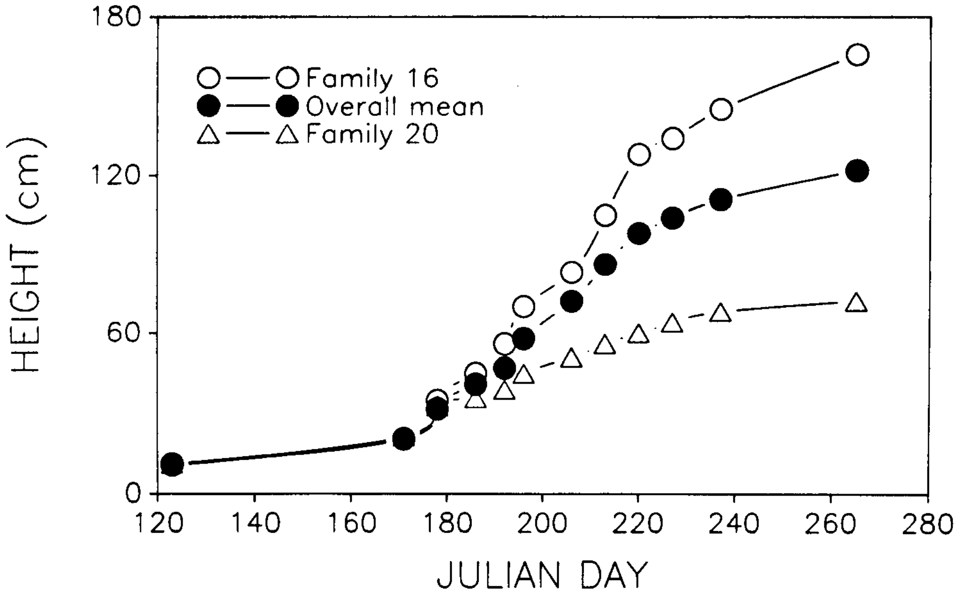

Fig 1. Average and family extremes for red oak height growth during the first year under Ohio Production System conditions.

curve extremes are also reported). Most of the height growth occurred after the greenhouse phase. Some individuals exceeded 280 cm. There were highly significant differences among families (P = 0.001) at all measurement periods.

Heritability estimates for height growth in containers were high in May (greenhouse conditions). After the trees were moved outdoors, estimates decreased until July 25 and then increased through the season's end (fig 2).

Field survival was 100% and growth was excellent; plant height averaged 189 and 190 cm in 1990 and 1991, respectively (table I). During winter 1990–1991, the plants were pruned to correct bent terminals. Height, after pruning, averaged 150 cm. There were highly significant (P = 0.0001) among family height differences. Narrow-sense heritability estimates for height were extremely high, 0.89 in 1990 and 0.60 in 1991.

During the 1st year in containers, there were highly significant differences among the families for all shoot growth characteristics during the continuous flushing phase (table I). During this period, plant height increased rapidly; see family 16, Julian day 200 (fig 1). The highest heritability estimate was for duration of shoot elongation (d); the lowest was for daily growth rate (table I).

Genetic correlations between season-long duration of shoot elongation in 1989 and field height in 1990 and 1991 were 0.74 and 0.70, respectively (table II). Genetic correlations with field height and

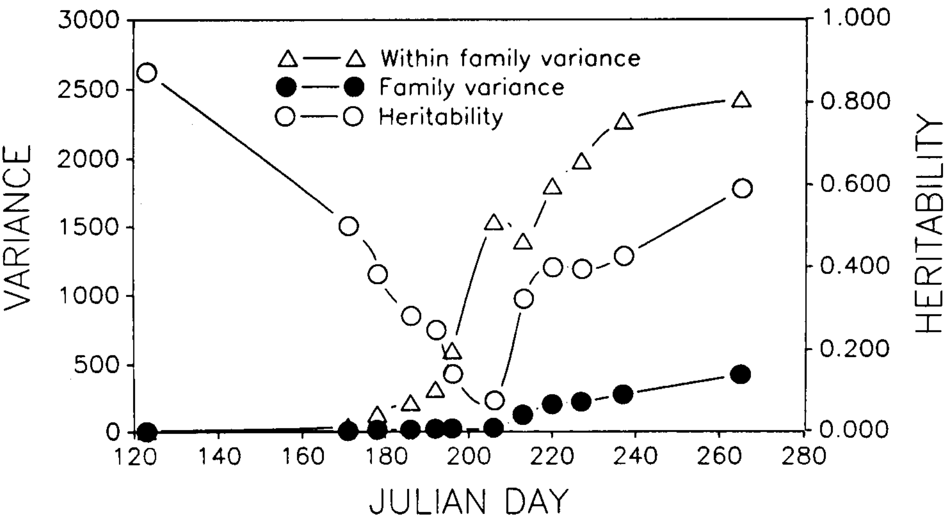

Fig 2. Narrow sense heritability estimates for height growth of red oak seedlings during the first year under Ohio Production System conditions.

Table I. Overall means, ranges of family means and individual tree heritabilities (with standard errors) for traits measured for trees during container production and after field planting.

Trait	*Overall mean*	*Range of family means* [a]		
		Minimum	*Maximum*	h^2 *(SE)*
Containers – 19 families				
Season long				
No of flushes	2.1	1.4	2.8	0.29 (0.12)
Duration of shoot elongation (d)	41.3	23.4	56.6	0.64 (0.20)
During period of greatest growth				
Duration of shoot elongation (d)	26.5	17.0	36.6	0.42 (0.15)
Shoot length (cm)	68.9	45.8	101.5	0.30 (0.12)
Growth rate (cm/d)	2.5	2.0	3.0	0.08 (0.05)
Field – 17 families				
Spring 1990 – time of planting (cm)	136.0	100.3	158.5	0.66 (0.26)
October 1990	188.9	151.8	232.2	0.89 (0.30)
June 1991	190.0	164.4	222.9	0.60 (0.19)

[a] All family differences were highly significant ($P \leq 0.01$).

Table II. Genetic correlations between traits assessed in the containers and height in the field in 1990 and 1991 for 17 open-pollinated families.

Trait	Stem height	
	1990	*1991*
Season long		
No of flushes	0.19	0.10
Duration of shoot elongation	0.74	0.70
During period of greatest growth		
Duration of shoot elongation	0.71	0.69
Shoot length	0.91	0.89
Growth rate	0.55	0.60

growth characteristics for the period of fastest growth were all relatively high (table II). These traits also had moderate to high heritabilities (table I), indicating that selection in the containers would be effective for increasing early field height.

DISCUSSION

Red oak grew rapidly under OPS conditions and after field planting. Red oaks produced under this system transplanted with minimum loss and established quickly. For comparison, 8 year average height was 0.78 m in a range-wide red oak provenance test (Kriebel *et al*, 1988) and early mortality ranged between 90 and 11% (Kriebel *et al*, 1977). In our study, high transplant success (100%) and rapid establishment (1.9 m after 2 seasons in the field) are attributed to high root regeneration capacity (Arnold and Struve, 1989), intensive site preparation and after care.

Early selection, by age 12 or 14 years (Schlarbaum and Bagley, 1981; Kriebel *et al*, 1988, respectively), of red oak provenances is possible. Earlier selection was ineffective as early height growth was confounded by plantation establishment effects, such as planting stock size, vigor and root development.

The OPS reduced transplant shock thus reducing experimental error and may be effective for accelerating genetic testing for additional reasons. The relatively strong genetic correlations between field growth and number of days of stem elongation and shoot length in the containers suggests that some early selection may be possible. Field growth will be followed in subsequent years to determine the value of OPS in accelerating red oak genetic tests.

REFERENCES

Arnold MA, Struve DK (1989) Growing green ash and red oak in $CuCO_3$-treated containers increases root regeneration and shoot growth following transplant. *J Am Soc Hortic Sci* 114, 402-406

Becker WA (1984) *Manual of Quantitative Genetics.* Academic Enterprises, Pullman, WA, pp 190

Bongarten BC, Hanover JW (1985) Accelerating seedling growth through photoperiod extension for genetic testing: a case study with blue spruce *(Picea pungens). For Sci* 31, 631-643

Falconer DS (1989) *Introduction to Quantitative Genetics.* 3rd edn, Longman Scientific and Technical, Essex, UK, pp 438

Kriebel HB, Bagley WT, Deneke FJ, Funsch RW, Roth P, Jokel JJ, Merritt C, Wright JW, Williams RD (1977) Geographic variation in *Quercus rubra* in north central United States plantations. *Silvae Genetic* 25, 118-122

Kriebel HB, Merritt C, Stadt T (1988) Genetics of growth rate in *Quercus rubra*: provenance and family effects by the early third decade in the north central USA. *Silvae Genet* 37, 193-198

Lowe WJ, van Buijtenen JP (1989) The incorporation of early testing procedures into an operational tree improvement program. *Silvae Genet* 38, 243-250

Pharis RP, Yeh FC, Dancik BP (1991) Superior growth potential in trees: what is its basis, and can it be tested at an early age? *Can J For Res* 21, 368-374

SAS Institute, Inc (1982) *SAS User's Guide, Statistics.* SAS Institute, Cary, NC

Schlarbaum SE, Bagley WT (1981) Intraspecific genetic variation of *Quercus rubra* L, northern red oak. *Silvae Genet* 30, 50-56

Struve DK, Arnold MA, Chinery DH (1987) Red oak whip production in containers. *Int Plant Propag* Soc 37, 415-420