Comparison of Genetic Variances Estimated from Seedlings and Rooted Cuttings of the Same Families of Loblolly Pine

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INTRODUCTION

The levels of the additive and non-additive genetic variance in traits important for tree breeding programs have a great impact on the determination of the breeding strategies (Stonecypher and McCullough 1986). Also, it is very important for designing efficient deployment strategies. A few studies have reported considerable variation among clones within families for growth traits, fusiform rust resistance and root collar diameter in loblolly pine (Foster 1988, McRae et al. 1987, Paul et al. 1997). However, to our knowledge, comparison of genetic variances estimated from seedlings and clones of the same families has not been covered in the literature that could give further insight into the genetic basis of economically important traits. The objectives of this study were: (i) to partition genetic variance into additive, dominant and epistatic components and examine the time trends and differences among traits and (ii) to compare variance components and genetic variances from cuttings and seedlings of the same families.

MATERIALS AND METHODS

A factorial mating design consisting of three unrelated individuals as females and three others as males was implemented to produce nine full-sib families of loblolly pine. Rooted cuttings propagated from hedges and seedlings were used to establish one study in Monroe County, Alabama, in spring of 1990 and the second study site in Nassau Co., Florida, in spring of 1991 (Frampton et al. 2000). A split plot design with six replications (blocks) was installed at two locations. Each block was split into two main plots, one for seedlings and one for rooted cuttings. Each full-sib family was represented by three seedling subplots and 5 to 9 rooted cutting subplots per main plot. There were two trees in subplots. Additive and non-additive genetic variances were estimated for height, volume and fusiform rust incidence using the model suggested by Foster and Shaw (1988).

RESULTS AND DISCUSSIONS

Seedlings and rooted cuttings did not differ significantly for height and volume at both sites at all ages, except at age one for height (Frampton et al. 2000). However, seedlings of the same full-sib families had a significantly greater fusiform rust incidence than the rooted cuttings in both the Florida (22.3 versus 15.6%) and Alabama (51.0 versus 46.0%) sites at age six.

Variance components estimated from rooted cuttings were always greater than the estimates from seedlings for growth traits. The clone component made up 1.1% and 6.9% of the total variance for height and volume, respectively. A very high percentage (48.6%) of the total variance for rust incidence was due to variation among clones. Anderson et al. (1999) reported a significant clonal variance for rooting percentage. In another study on loblolly pine, the clonal effect was also significant for height, diameter and volume, and accounted for 14 to 23 % of the total variation (McRae et al. 1993). Clonal variance may be utilized in loblolly pine tree breeding strategies for the reduction of rust incidence. Within plot variance for rooted cuttings and seedlings were 8.8 and 12.1% for height, 40.2 and 50.2% for volume, respectively, implying that, clonally replicated progeny tests would substantially increase the efficiency of testing by reducing the micro-environmental variance.

Almost all the genetic variance for height was due to the additive genetic effects in early ages with a slight increase of non-additive variance at age six (Figure 1). Variances due to additive effects estimated from rooted cuttings were always greater than the estimates from seedlings for growth traits and the coefficients ranged from 4.0 to 26.1. The coefficient of additive variance (CV_A) of cuttings for volume at age six was two times that of the seedlings. The difference between two material types for additive genetic variance implies the efficiency of clonal testing in estimation of genetic parameters (Libby and Jund 1962). The CV_A for fusiform rust incidence was high and ranged from 53.6 to 66.6. Dominance genetic variance (CV_D) estimated from seedlings was greater than the estimate from rooted cuttings for all the traits. This could be due to confounding effect of epistatic variance within dominance variance, which was not separated for the seedling data. The coefficients of variation for epistatic variance (CV_I) were negative for all growth traits at all ages. In contrast, the CV_I for the rust incidence was much greater; the coefficients of variation were 58.9 at age four and 44.5 at age six. The results indicated that epistatic genetic interactions have a strong control on fusiform rust incidence for loblolly pine, together with additive gene effects.

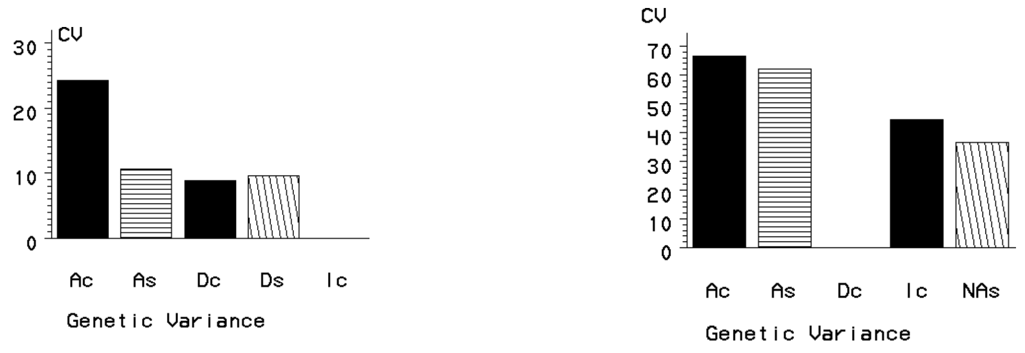

Figure 1. Coefficients of additive (A), dominance (D) and epistatic (I) genetic variances estimated from cuttings (c) and seedlings (s) for volume (left figure) and fusiform rust incidence (right figure) at age six.

Additive genetic variance (CV_A) decreased with age for height (Figure 2). However, dominance genetic variance increased for both seedlings and rooted cuttings. Volume had similar pattern as height, i.e. zero dominance variance at age four and an increase at age six. Our results were not parallel with Franklin (1979), Foster (1986) and Paul et al. (1997) who reported an increase in additive genetic variance by age in loblolly pine. The discrepancy between studies could originate from measurement units, scale effect and sampling. In contrast to additive genetic variance, dominance genetic variances increased both for seedlings and rooted cuttings. Epistatic variance was not detected for any growth traits.

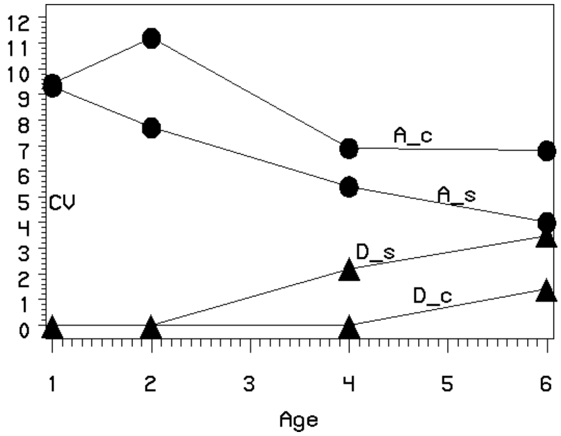

Figure 2. Time trends for additive (A_) and dominance (D_) genetic variances estimated from cuttings (c) and seedlings (s) for height at age six in loblolly pine.

Foster (1990) and Anderson et al. (1999) reported a dominance/additive variance ratio of less than 1.0 for shoot production and rooting ability and epistatic variances were zero in loblolly pine. McKeand et al. (1986) reported that nonadditive genetic variance ratio ranged from 0.0 to 0.25 for height at age one through five in loblolly pine. In the same study, the ratio was 0.0 for diameter at breast height at age five. Byram and Lowe (1986) concluded that additive genetic variance was the major source of genetic variance in loblolly pine for growth traits from ages 5 to 20. In a more recent study by Paul et al. (1997), inconsistent ratios of additive to nonadditive genetic variances were reported for height from two factorials in loblolly pine. In the same study, dominance genetic variance for diameter and volume was about equal or even exceeded the additive genetic variance at age five.

A tree improvement strategy based on clonally replicated trials might substantially increase genetic gain both in growth and especially in fusiform rust incidence. Clonally replicated tests should be considered more efficient than seedling based family tests to select for the fusiform rust resistance. Potential effects of the small parental sample size and violations of the assumptions of the genetic model should be considered when these results are interpreted.

LITERATURE CITED

Anderson, H.V., L.J. Jr. Frampton, and R.J. Weir. 1999. Shoot production and rooting ability of cuttings from juvenile greenhouse loblolly pine hedges. Trans. IL State Acad. Sci. 92: 1-14.

Byram, T. and B. Low. 1986. General and specific combining ability estimates for growth in loblolly pine. P. 352-360 *in* Proc. Joint meeting of working parties on breeding theory, progeny testing and seed orchards. North Carolina State University–Industry Tree Improvement Program, College of Natural Resourcs, Raleigh, NC.

Foster, G.S. 1986. Trends in genetic parameters with development and their influence on early selection for volume growth in loblolly pine. For. Sci. 32:944-959.

Foster, G.S. 1988. Growth and morphology of rooted cuttings and seedlings of loblolly pine and their genetic analysis. P. 67-78 *in* 10th North Am. For. Biol. Workshop, Univ. of B.C., Vancouver.

Foster, G.S., and D.V. Shaw. 1988. Using clonal replicates to explore genetic variation in a perennial plant species. Theo. Appl. Genet. 76:788-794.

Foster, G.S. 1990. Genetic control of rooting ability of stem cuttings from loblolly pine. Can. J. For. Res. 20:1361-1368.

Frampton, L.J.Jr., B. Li, and B. Goldfarb. 2000. Early field growth of loblolly pine rooted cuttings and seedlings. Southern J. of Appl. For. 24:98-105.

Franklin, E.C. 1979. Model relating levels of genetic variance to stand development of four North American conifers. Silvae Genetica 28:207-212.

Libby W.J., and E. Jund. 1962. Variance associated with cloning. Heredity 17:533-540.

McKeand, S.E., G.S. Foster, and F.E. Bridgwater. 1986. Breeding controlled production populations of loblolly pines. P. 53-61 *in* Advanced generation breeding of forest trees. Louisiana Agric. Exp. Sta. South. Coop. Series Bull. 309.

McRae, J. B., H.E. Steltzer, G.S. Foster, and T. Caldwell. 1993. Genetic test results from a tree improvement program to develop clones of loblolly pine for reforestation. P. 424-433 *in* 22nd Southern Forest Tree Improvement Conference, Atlanta, GA.

Paul, A.D., G.S. Foster, T. Caldwell, and J. McRae. 1997. Trends in genetic and environmental parameters for height, diameter, and volume in a multilocation clonal study with loblolly pine. For. Sci. 43:87-98.

Stonecypher, R.W., and R.B. McCullough. 1986. Estimates of additive and non-additive genetic variances from a clonal diallel of Douglas-fir Pseudotsuga *mensiesi*i (Mirb.) Franco. P. 211-227 *in* IUFRO Conference, A joint meeting of working parties on breeding theory, progeny testing, seed orchards. Conference proceedings. October 13-17, Williamsburg, VA.