Genetic and Phenotypic Variability for Constitutive Oleoresin Flow in Loblolly Pine

J. H. Roberds[1], B. L. Strom[2] and F. P. Hain[3]

In loblolly pine, *Pinus taeda* L., flow of oleoresin at penetration sites is considered to be a major component of defense against attack by the southern pine beetle (SPB) *Dendroctonus frontalis* Zimm. Trees with copious amounts of constitutive or preformed oleoresin appear to be most able to prevent or impede colonization by this destructive insect pest of southern pines.

Prior research has revealed that flow of constitutive oleoresin, referred to hereafter as resin flow, is influenced by both genetic and environmental factors (Lorio 1986, Lorio et al. 1990, Nebeker et al. 1988, Nebeker et al. 1990). Little is known, however, about levels of genetic variability for resin yielding capacity existing in populations of loblolly pine, and genetic associations between resin flow and growth traits have not been investigated. In view of questions regarding the feasibility of breeding for resistance to attack by SPB and interest in the evolutionary biology of traits associated with insect resistance in conifers, we studied components of genetic variation and covariation for resin flow and growth traits in a population of this host species.

Data were collected for resin yield, total height and DBH on 10- and 11- year old trees in progeny trials located near Pensacola, Florida. These tests were established in 1989 and 1990 as part of the loblolly pine breeding program being conducted by International Paper Company in cooperation with the N. C. State University — Industry Cooperative Tree Improvement Program. Trees included in our investigation were from a subset of the plots in these trials and constitute a progeny sample from 72 full-sib families. This sample of families resulted from intercrossing 48 parents in a disconnected diallel mating design composed of six-parent, balanced partial diallel units. In this design, each parent tree was mated to three others. Field plot layout for the experiment followed a replications-in-blocks experimental design. Data from 1131 trees were available for analysis. Two resin flow measurements were taken. The first at a time in late summer when latewood is normally produced (summer resin flow), and the second at a time in the following spring during earlywood formation (spring resin flow). Resin yields were determined from samples obtained from wounds made at breast height using a modification of the sampling procedure described in Strom et al. (2000). Weight of the resin collected during the 24 hours following wounding was used as a measure of resin flow.

---

[1] USDA Forest Service, Southern Research Station, Southern Institute of Forest Genetics, Saucier, MS 39574; [2] USDA Forest Service, Southern Research Station, Alexandria Forestry Center, Pineville, LA 71360; [3] Department of Entomology, North Carolina State University, Raleigh, NC 27695.

Mean values for the growth variables indicate that trees in the experiment had good growth. The 11-year old trees had a mean height of 12.6 m and mean DBH of 18.9 cm. Corresponding values for the 10-year old trees were 12.1 m and 17.7 cm. Spring (= 1.88 g) and summer (= 1.72 g) resin flow did not differ greatly in the 11-year old trees. A somewhat larger difference was found in the 10-year old cohort, which had a mean of 1.92 g for spring resin flow as opposed to 1.28 g for summer resin flow.

Genetic components of variance made up a significant portion of the phenotypic variance observed in both the resin flow and growth traits. Except for spring resin flow, dominance variance was small and inconsequential compared to additive variance. Dominance variance for spring flow was roughly half that of the additive component indicating that differences in nonadditive genetic effects contributed substantially to variation in this trait.

Estimates of individual tree heritabilities were moderately large for both the resin flow and growth traits. Values obtained for the resin flow traits were $h^2 = 0.44$ for spring flow and $h^2 = 0.59$ for summer flow. For the growth variables, estimates were h^2 0.48 for height, $h^2 = 0.49$ for DBH and $h^2 = 0.53$ for volume. While these values are consistent with estimates for comparable growth traits in several loblolly pine experiments (Gwaze et al. 1997, Hodge et al. 1999, Gwaze et al. 2001), they are higher than values reported for most tests of similar age in southern United States (Bridgwater et al. 1983, Foster 1986, Balocchi et al. 1993, Xiang 2000, Gwaze et al. 2001). In contrast to results for heritability, estimates for additive and dominance coefficients of variation for the resin flow traits were greater than those for the growth traits. These findings suggest that the resin flow traits exhibited higher genetic variance.

Additive genetic correlation estimates between the resin flow and growth traits were positive and of moderate size. Values for trait pairs involving summer resin flow were rA = 0.67 for height, $r_A = 0.58$ for DBH and $r_A = 0.59$ for volume. Similar but slightly lower estimates were obtained for spring flow. Phenotypic correlation estimates for these character combinations while positive, were somewhat smaller than those for the additive genetic correlations.

In conclusion, our results demonstrate that substantial genetic variation exists for resin flow in the loblolly population we studied. This suggests that directional selection to improve resin flow should be successful. Moreover, since genetic correlations between resin flow and tree growth traits appear to be positive and sizeable, it should be possible in this population to concurrently improve both through breeding.

LITERATURE CITED

Balocchi, C. E., Bridgwater, F. E., Zobel, B. J., and Jahromi, S. 1993. Age trends for tree heights in a nonselected population of loblolly pine. Forest Science 39: 231-251

Bridgwater, F. E., Talbert, J. T., and Jahromi, S. 1983. Index selection for increased dry weight in a young loblolly pine population. Silvae Genetica 32: 157-161.

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

Gwaze, D. P., Woolliams, J. A., and Kanowski, P. J 1997. Genetic parameters for height and stem straightness in *Pinus taeda* Linnaeus in Zimbabwe. Forest Genetics 4: 159-169.

Gwaze, D. P., Bridgwater, F. E., Byram, T. D., and Lowe, W. J. 2001. Genetic parameter estimates for growth and wood density in loblolly pine *(Pinus taeda L.)*. Forest Genetics 8: 47-55.

Hodge, G. R., Chaves, D., and Moreira, A. M. 1991. Growth rates and genetic parameters of loblolly pine in southern Brazil. *In* Proceedings of the 25thBiennial Southern Forest Tree Improvement Conference. New Orleans. pp. 85-86.

Lorio, P. L. Jr. 1986. Growth-differentiation balance: A basis for understanding southern pine beetle-tree interactions. Forest Ecology and Management 14: 259-273.

Lorio, P. L. Jr., Sommers, R. A., Blanche, C. A., Hodges J. D., and Nebeker, T. E. 1990. Modeling pine resistance to bark beetles based on growth and differentiation balance principles. *In* Process modeling of forest growth responses to environmental stress. *Edited by* R. K. Dixon, R. S. Meldahl, G. A. Ruark, and W.G. Warrne. Timber Press, Portland. pp. 402-409.

Nebeker, T. E., Hodges, J. D., Honea, C. R., and Blanche, C. A. 1988. Preformed defensive system in loblolly pine: Variability and impact on management practices. *In* Proceedings of the IUFRO working party and XVII international congress of entomology symposium, integrated control of scolytid bark beetles. *Edited by* T. L. Payne and H. Saarenmaa. VPI Press, Blacksburg. pp. 147-162.

Nebeker, T. E., Hodges, J. D., Blanche, C. A., Honea, C. R., and Tisdale R. A. 1992. Variation in the constitutive defensive system of loblolly pine in relation to bark beetle attack. Forest Science 38: 457-466.

Strom, R. A., Goyer, R. A., Ingram L. L. Jr., Boyd, G. D. L., and Lott, L. H. 2002. Oleoresin characteristics of progeny of loblolly pines that escaped attack by the southern pine beetle. Forest Ecology and Management 158: 169-178.

Xiang, B. 2000. Genetic analysis of diallel tests of loblolly pine *(Pinus taeda L.)*. Ph. D. Dissertation. North Carolina State University, Raleigh.