COLD HARDINESS OF ATLANTIC COASTAL AND PIEDMONT SOURCES OF LOBLOLLY PINE AND THEIR HYBRIDS

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Planting loblolly pine (*Pinus taeda* L.) outside the natural range or at higher elevations than it normally occurs negatively impacts its survival, growth rate, and wood quality. Cold acclimation in loblolly pine appears to be more influenced by temperature compared to photoperiod. Also, there is interest in examining if inter-provenance hybridization can combine both fast growth and cold hardiness in commercial populations (Alizoti et al. 2006). Seedling growth differences of first-year of Atlantic Coastal and Piedmont provenances of loblolly pine and their hybrids in an outdoor environment in North Carolina were reported by Kegley et al. (2004). These results were verified at four years, when height and volume were assessed in five Piedmont regions (Alizoti et al. 2006). However, it was not confirmed that the hybrid populations would exhibit acceptable cold hardiness. The objective of this study was to evaluate differences in cold hardiness between one year-old seedlings of Atlantic Coastal sources, Piedmont sources, and their hybrids, after artificial freezing.

Materials and Methods

Seedlings of 59 polycross families representing two within provenance hybrids (Coastal x Coastal or CxC, Piedmont x Piedmont or PxP), and two inter-provenance hybrids (Coastal x Piedmont or CxP, Piedmont x Coastal or PxC) were used in this study. The preconditioning treatments consisted of three acclimation regimes designed to reflect climatic conditions in three deployment regions for loblolly pine. After acclimation, the seedlings were subjected to a standard freezing treatment. The plants were moved to a Delfield-Alco® 6000 series freezer to expose them to a controlled drop in temperature. Temperature was reduced at a rate of 3-5ºC per hour until the target -15ºC was reached. After thawing, the plants were removed to an outdoor facility for symptoms to develop. Initial height (cm) was measured before the freezing treatment as an indicator of plant vigor. Rating of injury occurred 10-14 days after freezing exposure, with one person evaluating all trees. Freezing injury I (%) of the entire seedling was measured as percent foliage dead. Final survival and vigor (%) of the trees was assessed in the spring when the plants began flushing. Elongation of the actively growing portion of the stem was measured as flush length (cm). Mortality percent of the trees and a secondary injury II (%) evaluation were assessed. Variance components for each trait were obtained by REML procedure using ASReml (Gilmour et al. 2009). Individual narrow-sense heritabilities pooled across populations and genetic correlations between pairs of traits were estimated as the ratio of the additive genetic variance and total phenotypic variance for each trait. We also examined relationships among response variables using family mean correlations obtained from Pearson product-moment correlations.

Results and Discussion

For injury and growth traits, acclimation treatment effects were not significant, and there were no significant interaction with population. The implication is that a single preconditioning treatment could be applied to different families regardless of origin. The relatively short time of the acclimation and no difference in photoperiod may have also contributed to the lack of treatment effect. In this experiment, differences in cold hardiness were important among and within populations. The PxP seedlings had increased hardiness and survival relative to the other populations. Most families with high injury had a Coastal maternal parent, whereas most families with the least injury had a Piedmont maternal parent. For the hybrids, it appeared that maternal influence was greater than the paternal influence for cold-hardiness, and the PxC population was as cold hardy as PxP. Differences in injury between the populations probably resulted from differences in timing of initiation of the acclimation process; PxC and PxP may have begun acclimating sooner than the CxC as part of their adaptive strategy. Kegley et al. (2004) and Alizoti et al. (2006) used the same families to determine populations effects on growth traits, and differences between pure CxC and PxP material were found: family differences in one year-old seedlings were observed, and some fast-growing PxP families could be used in controlled crosses for hybrid selection. The CxC and CxP populations exceeded growth of both PxC and PxP families at four years growing in different regions, although their advantage decreased as the regions became more inland or with harsher environmental conditions. The PxP material survived significantly better than coastal source provenances when planted in cold area regions, probably because of natural cold adaptation.

Narrow-sense heritability pooled across all populations was higher for injury II than injury I. Estimates were variable for each population, ranging from 0.02 to 0.43 for injury I and II. In general the CxC families exhibited higher heritability for the traits measured, followed by the PxC for injury I and the PxP hybrid for injury II. Previous experimental results suggest that cold damage traits are under moderate genetic control. We found higher family mean heritability for initial height in the PxC and PxP material, whose estimates had small standard errors. These results suggested that families from Piedmont parents could be selected in a breeding program for both growth and cold tolerance more efficiently than families from the CxC source. Kegley et al. (2004) found similar trends at first year height in outdoor conditions, although their plants were not exposed to cold.

The strong negative genetic correlation between flush length and injury II (-0.89) can be considered favorable: trees with less freeze damage had longer flushes. The Figure 1 showed that this trend was consistent for family means within populations with an overall phenotypic correlation of -0.74; while CxC and CxP families seemed to be scattered ranging from 40% to 100% injury, PxC and PxP families clustered within 30% to 60% of damage with few exceptions. Also, the growth recovery of elongated stem tissue was faster with reduced damage, which was also reflected in the high flush length mean for PxC and PxP populations. Howe et al. (2003) summarized several literature results where correlation between cold damage and flush increment is more consistent across populations, but weaker and more variable within populations. Our results within populations were more consistent than observed in previous studies, which might be important to detect stable families for advanced selection strategies.

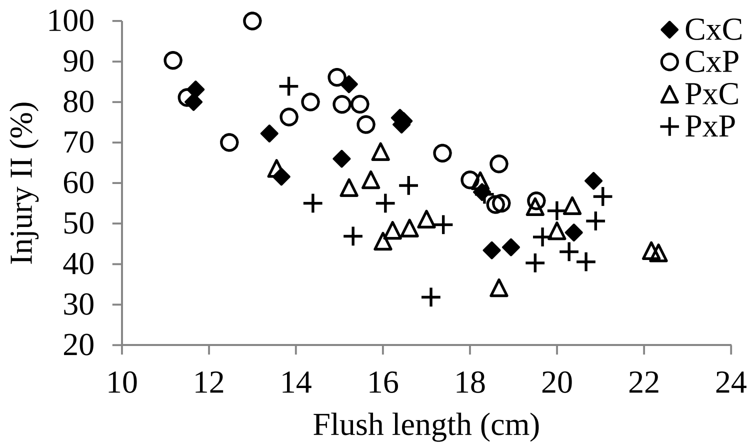

Figure 1. Scatterplot of family means between injury II and flush length for the Atlantic Coastal (CxC), Coastal x Piedmont (CxP), Piedmont x Coastal (PxC) and Piedmont (PxP) populations. The family mean correlation across all the populations was -0.74.

In summary, this freezing experiment showed that inter-provenance hybrids of loblolly pine have potential as planting stock for Piedmont sites. The CxP hybrids were cold injured, but they could grow as well as pure CxC families. On the other hand, PxC hybrids were as cold hardy as the pure PxP families. Also, there were large differences among families within populations for cold hardiness traits. The large variation suggested that cold hardiness could be improved by family and within population selection in a breeding program to combine better growth of Coastal sources with the superior cold tolerance of Piedmont sources into hybrids populations. However, selection impact seems difficult to predict due to variability within populations and probably because of genetic control of multiple genes with small effects. Additional studies are required to identify cold tolerant hybrid families that would allow for both cold hardiness and superior growth to be improved through breeding and selection.

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