Genetic Variation in Young Fraser Fir Progeny Tests

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Fraser fir (*Abies fraseri* [Pursh] Poir.) is found naturally in only a few stands at high elevations in North Carolina, Virginia, and Tennessee. These forests are associated with important scenic and recreational areas such as the Great Smoky Mountains National Park, Mount Mitchell State Park, the Balsam Mountains, and the Mount Rogers National Recreation Area (Dull et al. 1988). In addition to its recreational and ecological importance, Fraser fir also holds great economic importance as a Christmas tree species. It is grown in plantations as Christmas trees throughout the southern Appalachians as well as other areas of the United States.

Although Fraser fir Christmas tree production is an important industry in the state of North Carolina, there has not been a great deal of previous research on breeding and selection to increase the quality of production. Only one previous progeny test series has been completed with Fraser fir, and it had a limited sampling of seed sources tested at only three sites. A more thorough testing of families from throughout the natural range of Fraser fir was needed. In 1994, a more extensive seed collection was performed, where seeds from over 500 parent trees were collected from the six main populations of Fraser fir (McKeand et al. 1995). Seedlings were grown from the seed collected in 1994 to establish this progeny test series at eight sites in 2000. The objectives of this study were to determine genetic variation among six seed sources of Fraser fir and to estimate genetic parameters for traits important in Christmas tree production. In addition, genetic variation of spring frost damage to the terminal leader and lateral branches in May of 2002, the third year in the field, and how it related to bud flush dates in the nursery as well as parent elevation were studied.

MATERIALS AND METHODS

Seedlings were grown from open-pollinated seed collected during the 1994 range-wide cone collection. Progeny from 188 of these trees were included in this study, and they were from the following six seed sources: Balsam Mountains, Grandfather Mountain, the Great Smoky Mountains, the Black Mountains, Mount Rogers, and Roan Mountain.

In the spring of 2000, seedlings were transplanted from the nursery beds to field trials that were established at eight sites in the mountains of western North Carolina. The families from each seed source were divided equally into two groups, with each group of families being tested at four of the eight sites. A randomized complete block design was used at each site, with 35 replications of single-tree-plots per family. The progeny test sites were located on working Christmas tree plantations and were each managed individually by the landowners according to their standard practices.

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The following traits were measured each year for the first four seasons in the field: height, number of leaders, overall tree quality, number of lateral buds, number of whorl buds, number of lateral branches, and number of whorl branches. The quality measurement was an overall subjective rating of the quality of the individual as a Christmas tree, integrating tree density, shape, and overall symmetry. This rating was given on a scale of 1 to 5, with 1 being poor, 3 being average, and 5 being excellent Christmas tree quality. The bud and branch measurements were taken only on a sub-sample, one-third of the families at 4 of the sites. In 2002, the third year in the field, individual trees were rated in the field on the severity of the damage both to the terminal leader and to the lateral branch from a late spring frost. The terminal leader was scored from 0 to 2, with 0 being no damage, and 1 being some damage, where the terminal was elongating when the frost hit but only a portion was killed. A score of 2 was where the entire terminal was killed and a lateral branch became a new leader. The lateral branches were scored from 0 to 3, with 0 being no damage. A score of 1 was for light damage, with approximately 15% or fewer of the lateral branches being damaged. Two was a medium level of lateral branch damage, with approximately 15% to 85% damage, and three was for heavy damage, with over 85% of the lateral branches affected.

Individual-tree within population heritabilities were calculated for all traits in year 4, for height each year in the field, and for frost damage measurements and bud flush dates. Shukla's (1972) stability variance (σ^2_i) was calculated for each source to identify those sources showing instability across the eight sites for height growth after four years. Family mean correlations were calculated for all traits in year 4. Family mean correlations were also calculated for the terminal and lateral frost damage, parent elevation, bud flush dates in the nursery for the terminal and lateral buds, and height in the nursery and each year in the field for all sites.

RESULTS AND DISCUSSION

Highly significant differences were found among seed sources and families within sources ($p \leq 0.0001$) for height, number of lateral buds, and quality. The seed source mean heights for year four ranged from a high of 114 cm for the Balsam Mountains to a low of 99 cm for Roan Mountain. Large ranges in family means within sources also existed; the family means for year four height within the Balsam Mountains source ranged from 79 cm to 135 cm. The sources showing instability for height across the test sites were the Balsam Mountains and Roan Mountain. Due to the fact that the Balsam Mountains still ranked first for height at seven out of the eight sites, and that Roan Mountain ranked lowest for mean height at five out of the eight sites and was not significantly greater than the lowest source at the other three sites, this instability is probably not of much practical importance. The individual tree within population heritability value for height in year four was the highest of all the traits measured, at 0.44. The heritability values for height varied greatly among the six sources, from 0.15 for the Black Mountains to 0.67 for the Great Smoky Mountains. The high heritability values for height show promise for improving Fraser fir for Christmas tree production via breeding because of the importance of height in determining Christmas tree value. The highly significant family mean correlations seen for height, number of lateral buds, and quality in year four indicate that if selections are made based on height, it will also indirectly select for these other traits.

Significant differences among sources and families within sources were seen for lateral branch frost damage. The heritability for terminal frost damage was only 0.045, but the heritability for lateral frost damage was higher at 0.14. Greater terminal and lateral frost damage were significantly associated with greater height for all years. Parent elevation was negatively associated with progeny height, and higher parent elevation was associated with later lateral bud flush dates in the nursery. Less lateral branch frost damage during the third year in the field was also associated with later terminal and lateral bud flush dates of the same progeny in the nursery. Although taller individual trees appear to be less tolerant of a late spring frost, many of the same families were ranked in the top 25 for height after four years in the field when only those individual trees with no frost damage were included compared to all individuals. Family mean height in years prior to the frost is also highly correlated with family mean height in years after the frost damage occurred. Therefore, it appears that the fast growing families can quickly make up for any loss of height from a late spring frost.

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