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Genetic Variation in Seed Size and Germination Patterns and their Effect on White Spruce Seedling Characteristics

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Abstract

We determined the degree to which families differ in seed and germination characteristics and examined the extent to which these characteristics influence the early growth of 75 open-pollinated white spruce families. Seed characteristics (1000-seed weight, length, width, area, volume) were measured for 400 seeds per family. Germination variables (germination capacity, peak value, germination value) were determined for each of the 75 families under controlled conditions and germination patterns were modelled using the Weibull function. Seedling characteristics (height, diameter, shoot and root dry weights) were measured at the end of the first and second growing seasons under standard nursery cultural practices. Statistically significant family variation ($p < 0.0001$) was found for all seed characteristics and germination variables measured. The between-family variance explained 23% to 98% of the total variance of morphological and physiological seed characteristics. Family differences at the seed stage explained up to 33% (root dry weight) and 12% (shoot dry weight) of the family differences observed at the one-year and two-year seedling stages, respectively. Since, in this study based

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on a comparison of family means, a maximum of only 12% of the family differences observed at the two-year seedling stage were explained by the effect of seed size, a selection for families with better juvenile characteristics could be envisaged without considering the maternal effect of seed size.

Key words: Weibull function, genetic variation, repeatability, heritabilities, maternal effect, *Picea glauca.*

Introduction

White spruce (*Picea glauca* [Moench] Voss) is one of the most widely distributed conifers in North America (NIENSTAEDT and TEICH, 1972) and is adapted to a wide range of edaphic and climatic conditions (NIENSTAEDT and ZASADA, 1990). It exhibits high genetic variability for characteristics such as wood density, ring width (CORRIVEAU *et al.*, 1991), height, branch number, growth duration, and growth rate (LI *et al.*, 1993). White spruce seedlings exhibit significant inter-family (KHALIL, 1985; LI *et al.*, 1993; RWEYONGEZA *et al.*, 2005) and clonal (LAMHAMEDI *et al.*, 2000) variability for many morpho-physiological characteristics. To date, this variability at the provenance and family levels has been used for the early selection of older tree traits, rather than as a tool for improving seedling quality. KHALIL (1985) estimated family heritability for root length and root dry weight 13 months after sowing. He found a heritability for root length of 0.80 (± 0.65), whereas family heritability for root dry-weight family was close to zero. RWEYONGEZA *et al.* (2005) found a moderate (0.453 ± 0.107) family heritability for root dry weight of 3-year-old white spruce seedlings. Root growth is critical to the establishment of planted seedlings because they have to absorb water from the soil to meet shoot evaporative demand and limit post-planting water stress (GROSSNICKLE, 2005). A root system that is well developed under nursery conditions increases a seedling's chance of survival after planting. To determine whether genetic gains for desired seedling root characteristics are achievable, it is first necessary to estimate the genetic parameters for these traits.

Growth of white spruce seedlings is known to be positively correlated with seed size (KHALIL, 1981; LAMHAMEDI *et al.*, 2006). PARKER *et al.* (2006) and WRIGHT *et al.* (1992) showed that root dry weight and root length increased with seed weight in pines. LAMHAMEDI *et al.* (2006) also reported that seedlings from large seeds (diameter ≥1.75 mm) had greater root dry weight than those grown from small seeds (1.5 mm ≤ diameter < 1.75 mm). Seed size is influenced by the morphological characteristics, such as diameter (CARON *et al.*, 1993) and height-to-diameter ratio (NOLAND *et al.*, 2006), and the genotype of the mother tree (CASTRO, 1999), and can lead to observable differences among families at the seedling stage (SORENSEN and CAMPBELL, 1993). Variation in seed size may cause an overestimation of genetic parameters and expected genetic gains of seedling characteristics (SORENSEN and CAMPBELL, 1993). ST. CLAIR and ADAMS (1991) found that family differences in seed weight explained 23% of the variation in total dry weight of Douglas-fir seedlings. Family-level studies often investigate the relationship between seed-size class and seedling characteristics. This may mask some of the variation that appears when absolute seed size values are used rather than seed size classes (CHAISURISRI *et al.*, 1992). Estimating variation among families for absolute seed size values, such as seed weight, length or width, and its effect on variation in seedling characteristics provides a measure of the degree to which the observed variation in seedlings is due to maternal effects.

Like seed size, germination can influence seedling characteristics. PARKER *et al.* (2006) suggested that early emergence accounted for 27% of variation in total dry mass of 8-week-old eastern white pine (*Pinus strobus* L.). DUNLAP and BARNETT (1983) showed that the speed of germination contributed substantially to size variation in loblolly pine (*Pinus taeda* L.) seedlings, with faster germinating seeds producing larger seedlings. Seed germination variables exhibit both genetic and environmental components (FARMER, 1997). CARON *et al.* (1993) and KRAKOWSKI and EL-KASSABY (2005) found that white spruce families had highly variable germination percentages and rates of germination. Single-value indices, such as germination and peak values (CZABATOR, 1962), germination capacity, or time to reach 50% of germination are important descriptive characteristics. In addition, the pattern of seed germination should also be modelled (BROWN and MAYER, 1988) so that the family variability in germination curves can be studied and the relationship between germination patterns and seedling characteristics for different families can be compared.

In the present study, we examined the extent to which seed size and germination pattern influenced early growth of white spruce families. Our objectives were to: (1) determine the degree to which families differ in seed and germination characteristics under controlled conditions, (2) mathematically model the pattern of seed germination and study its variation among families, and (3) determine the relationship between morphological and physiological seed characteristics and the morphology and growth characteristics of seedlings under nursery conditions.

Materials and Methods

Genetic material

Cones were collected on 75 plus-trees in the Québec first-generation breeding orchard located at the Cap Tourmente National Wildlife Reserve (47°04'N, 70°50'W). This breeding orchard is an assembly of 100 plus-trees from 17 provenances sampled in Quebec and Ontario. The original latitude and longitude ranges of these provenances were from 44°10'N to 46°55'N and 72°56'W to 79°20'W (BEAULIEU, 1996). Cones for the first 68 families were collected in the fourth week of August, 1996 and those of the remaining families were collected in the fourth week of August, 2001. They were then matured at ambient temperature for approximately two months, after which seeds from each open-pollinated family were extracted, cleaned and stored separately at −20 °C.