Northeastern States Research Cooperative

Theme 3: Forest Productivity and Forest Products

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Project Title: Understanding the molecular basis of age-related productivity decline in red spruce: Integrating physiological and genomics approaches

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Summary:

Tree stem wood productivity peaks at mid-age and declines thereafter, this trend is a principal factor in determining optimum ages of harvest and projecting carbon sequestration rates. The physiological basis for this trend has evaded researchers, who have principally focused on factors limiting productivity, i.e., supply-side factors such as decreased rates of photosynthesis, hydraulic restrictions or nutrient supply. This study continues our research into alternative explanations based on demand side limitations, defined as the evolved restrictions on growth rates that have an adaptive value to tree life strategies. These trends will be evident in age-related differences in growth sink strength reflected in both the pools of non-structural carbohydrates (NSC) and in the activity of genes coding for enzymes functioning in NSC metabolism. Using red spruce as a model species, we assessed age-related and seasonal changes in NSC concentrations, and, at the genomic level, we identified and quantified relative expression levels of putative spruce invertases, enzymes which irreversibly break down sucrose for construction of cellulose and other sugar polymers. The levels of invertase messenger ribulose nucleic acid (mRNA) correlates directly with the breakdown of storage NSC (starch) and transport NSC (sucrose)

Results from our NSC analysis revealed higher sugar concentrations in August foliage from mid-age trees compared to juvenile and old age-classes, but no difference between age classes and maximum pre-budburst concentrations in March and during June budburst. Twig concentrations peaked during spring, and likely represent transient sugars associated with budburst activity. August sugar levels showed that mid-age trees exhibited the most rapid recovery to pre-budburst concentrations.

Identification and expression analysis of three spruce invertase gene sequences (PiCIN3, PiNIN1, PiNIN2) revealed up-regulation of all primers in the mid-age age-class and of only primer PiCIN3 in old-growth trees. These results indicate increased expression of genes encoding the invertase sucrose cleaving enzyme in mid-age trees, corresponding with the life stage with the highest growth rates (Figure 1). The PiCIN3 gene sequence is associated with cell walls, and its increased expression in old trees correlates with known higher cell wall carbon costs in the foliage of older trees.

In addition to providing valuable insight into the mechanisms underlying age-related change in temperate conifers, this study has directly resulted in completion of a MS thesis by Ms. Katherine Spencer, a presentation at the Eastern Canada-USA Forest Science Conference in October 2010, and a manuscript in preparation.

Figure 1. Age-related expression of invertase L24 mRNA evaluated with respect to foliar non-structural carbohydrates (NSC) as starch and age of maximum tree stemwood productivity (insert).