From Forest Nursery Notes, Winter 2011

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Ann. For. Sci. 67 (2010) 602
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DOI: 10.1051/forest/2010015

Available online at:
www.afs-journal.org

Original article

Morphology and foliar chemistry of containerized *Abies fraseri* (Pursh) Poir. seedlings as affected by water availability and nutrition

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(Received 14 July 2009; accepted 8 December 2009)

Keywords:
Abies fraseri /
biomass /
water stress /
foliar nitrogen /
nutrient uptake

Abstract

• We present the results of a two-year (2007–2008) greenhouse study investigating the effect of water availability and nitrogen fertilization on the growth, biomass partitioning, and foliar nutrient content of *Abies fraseri* (Pursh) Poir.

• Fertilizer and moisture content (irrigation) were varied in a factorial experiment combining four levels of irrigation and three levels of fertilization to evaluate growth and foliar nutrient content. In addition, a numerical optimization was used to estimate appropriate levels of each factor necessary to achieve simulated goals for response variables.

• Irrigation increased the height growth by 12 to 35% depending on the fertilization treatment ($p = 0.0001$). Fertilization increased height growth by 10 to 26% ($p = 0.02$). A similar response was observed for stem diameter growth (SDG). Total biomass accumulation increased as result of positive response of stem and root biomass development, and foliar nitrogen content was positively affected by nitrogen fertilization and negatively affected by irrigation. The numerical optimization for simulated target growth and nitrogen content responses produced levels of input combinations with high desirability factors to achieve the target responses.

• These results suggest that nutrient addition is a strong determining factor for early development of this species. The improved growth efficiency in this study is likely attributed to a combination of factors including, improved photosynthetic capacity, decreased stomatal limitations, or increased resource allocation to stems.

1. INTRODUCTION

The production of nursery trees has increased steadily in the United States in recent years rising from 3.3 to 4.6 billion dollars in value between 2000 and 2006 (USDA, 2007). From that value, coniferous evergreens represented 0.5 billion dollar for a total production of 48 thousand plants in 2006, of which 59% were produced in containers (USDA, 2007). In this production system, regular fertilization is necessary to supply the plant's nutrient requirements (Bilderback, 1999), and irrigation is provided to supply the water needed for growth and to fulfill physiological functions (Groves et al., 1998; McDonald, 1984). In addition to the genetic potential, growth and productivity of crops grown in containers are mostly affected by nitrogen fertilizer application (Miller and Timmer, 1994). However, growth and productivity can also be affected by many other factors including: container type and size, tray cell density pattern, substrate quality, fertilization application, and irrigation regime (Derby and Hinesley, 2005; Tilt et al., 1987; Worrall et al., 1987). These factors all affect growth individually, but constant interactions among them add to the effect of individual factors. Among these potential interactions, the combination of fertilizer and irrigation plays a critical role (McDonald, 1984; Oliet et al., 2004; 2005; van den Driessche et al., 2003).

Moisture availability and nutrient uptake are closely linked because nutrient movement in the soil and plant tissues depends on appropriate moisture content. Plant moisture stress may reduce transpiration rates and permeability of roots, thereby reducing mass flow and uptake of elements (Brown and van den Driessche, 2002). For instance, in some deciduous broadleaf tree species, water stress reduces uptake of calcium and magnesium less than that of nitrogen, phosphorus, and potassium (Sands and Mulligan, 1990). Also, the uptake of boron is sharply reduced under moisture stress (Marschner, 1986). Sheriff et al. (1986) observed that higher concentrations of phosphorus and nitrogen were both accompanied with higher water use efficiency by the foliage in *Pinus radiata* (D. Don), improving the photosynthetic ability of the plant. Furthermore, proper irrigation can increase fertilizer uptake efficiency and nutrient accumulation due to both the increased

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