From Forest Nursery Notes Winter 2013

72. © Cultivation of Norway spruce and Scots pine on organic nitrogen improves seedlings morphology and field performance. Gruffman, L., Ishida, T., Nordin, A., and Nasholm, T. Forest Ecology and Management 276:118-124. 2012.

Forest Ecology and Management 276 (2012) 118–124

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Cultivation of Norway spruce and Scots pine on organic nitrogen improves seedling morphology and field performance

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ARTICLE INFO

Article history:
Received 3 February 2012
Received in revised form 30 March 2012
Accepted 31 March 2012
Available online 26 April 2012

Keywords:
Organic nitrogen
Root: shoot ratio
Biomass allocation
Picea abies (L.) Karst.
Pinus sylvestris (L.)

ABSTRACT

Nitrogen availability exerts a significant control on biomass allocation of plants including Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* (L.)) in boreal forest ecosystems. Recent studies suggest, however, this control differs for inorganic and organic nitrogen sources. The importance of the chemical form of nitrogen (inorganic or organic) for the morphology and growth of conifer seedlings was studied during production of seedlings in a forest nursery and subsequently in a field trial in northern Sweden. Seedlings were supplied with two different nutrient solutions; an inorganic conventional fertilizer and an organic, amino acid-based fertilizer. Seedlings cultivated on the organic nitrogen source displayed larger root systems resulting in a higher root: shoot ratio than did seedlings cultivated on the inorganic nitrogen source. The proportion of fine roots to lateral roots and the root tip proportion colonized by mycorrhiza were positively affected by the organic nitrogen source. Norway spruce seedlings cultivated on organic nitrogen displayed significantly increased shoot growth compared to seedlings cultivated on inorganic nitrogen. Our results suggest that the chemical form of nitrogen influences the allocation of biomass in conifer seedlings. The shift in allocation of resources to root biomass further leads to a competitive advantage in field conditions, resulting in a significant increase in shoot growth one year following transplant.

1. Introduction

The long rotation times of northern coniferous forests and high costs for forest regeneration underscore the importance of successful seedling establishment. In Scandinavia, conifer seedlings are mainly transplanted from the nursery to the field during a short period in spring and early summer before soil conditions become too dry (Helenius et al., 2002, 2005) and irradiance is supra-optimal for seedling establishment. One of the most common stresses to recently transplanted seedlings is therefore water deficiency (Burdett, 1990; Haase and Rose, 1993; Helenius et al., 2002, 2005). The water stress may be caused by factors such as poor root-soil contact and low root permeability (Burdett, 1990). Water stress and insufficient supply of photosynthate from the shoot to the root of the newly transplanted seedling might lead to limited root establishment which in turn restricts photosynthesis. Thus, there is a mutual dependency between root growth and current photosynthesis (Burdett, 1990). Successful seedling establishment is hence dependent on the seedling ability to acquire enough water to support a transpiring shoot, and the size and distribution of the root system are important seedling traits in overcoming post-planting stress (Grossnickle, 2005).

It is well documented that plants preferentially allocate growth to shoots at high nitrogen availability and when nitrogen availability is limited allocation to below-ground structures is favored (Brouwer, 1962; Ingestad and Kähr, 1985; Ericsson, 1995; Rytter et al., 2003; Kaakinen et al., 2004; Hermans et al., 2006). Traditionally, seedling size and root-collar diameter have been important criteria in the evaluation of seedling quality. However, above-ground seedling traits might not be optimal in predicting seedling performance in the field (Davis and Jacobs, 2005). Moreover, seedling height is acquired at the expense of a well developed root system as cultivated seedlings receive high concentrations of fertilizer in the form of mineral nitrogen in forest nurseries (Juntunen and Rikala, 2001). The above described nitrogen responses of biomass allocation in plants entail a potential problem concerning forest regeneration. Newly transplanted seedlings with restricted root systems, and with a high proportion of transpiring shoot area, would probably be susceptible to desiccation, which might lead to lower survival rates of planted seedlings. The scope of producing seedlings with a large proportion of roots and a high root: shoot ratio could be achieved by a decrease in the nitrogen fertilizer in forest nurseries. However, such restriction of nitrogen leads to stressed plants, deprived of the most important plant nutrient

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http://dx.doi.org/10.1016/j.foreco.2012.03.030