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ORIGINAL ARTICLE

Density and substrate effects on morphological and physiological parameters of plant stock material of four forest species grown in mini-plugs

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Abstract
The aim of this study was to measure a number of morphological and physiological parameters of planting stock material of forest species grown in mini-plugs and to evaluate them as indicators of planting stock quality under different density and substrate treatments. The studied species were black locust (*Robinia pseudoacacia* L.), Italian cypress (*Cupressus sempervirens* L.), brutia (*Pinus brutia* Ten.) and black pine (*Pinus nigra* Arnold). Seeds were sown in two growing substrates (peat and stabilized medium), using two mini-plug densities (3500 and 975 mini-plugs m^{-2}). After a 4–5 week growth period under controlled conditions, both morphological (root length, shoot height, leaf area, root and shoot dry weight) and physiological (shoot electrolyte leakage, root growth potential) parameters were assessed. The use of stabilized growing medium and lower densities resulted in higher quality seedlings of black locust, black and brutia pine, in terms of growth and physiological status. In the case of Italian cypress, the use of low density improved seedling morphological characters, but negatively affected its root growth potential. Moreover, this species performed better when peat was used. Correlation analysis showed that for brutia and black pine, seedling morphological traits reliably reflect seedling quality during the precultivation phase in mini-plugs.

Keywords: *planting stock material, root growth potential, seedling quality, shoot electrolyte leakage.*

Introduction

A newly planted seedling has a root system which, although great in mass, provides access to only a limited volume of soil, making the tree prone to both desiccation and nutrient deficiency. Therefore, successful seedling establishment is largely dependent on the capacity of seedlings to initiate new roots rapidly (Grossnickle, 2005). Rapid root growth early in the growing season is important as plants can maximize water uptake and compete with neighbouring vegetation on the transplanting site (Riley & Steinfeld, 2005), especially in Mediterranean areas, which are characterized by xerothermic conditions from June to September.

Root development is a reliable criterion for predicting seedling survival after transplanting (Duryea, 1984). The primary cause of transplanting shock is water stress, which results from poor root proliferation and insufficient root–soil contact (Burdett, 1990). In the period immediately after planting, the seedling must rely on active root water uptake. As water demand increases during spring because of the increase in leaf area and evapotranspiration, the original root system may not supply sufficient water; the transplanted seedling relies then on root growth (McKay, 1998).

The physiological state of a seedling before transplanting can, at least partially, be reflected by root growth potential (RGP), which is defined as the capacity of a seedling to increase its root size at a certain time and under controlled conditions through the elongation of roots already present and/or the initiation of new roots and their elongation (Mattsson, 1986).

In planted seedlings, early root development depends on the morphological and physiological characteristics at the time of planting (Burdett et al.,

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