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Nitrogen budgeting and quality of exponentially fertilized *Quercus robur* seedlings in Ireland

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Abstract Current policy in Ireland calls for increased quality and quantity of broadleaved seedling plantings. Simultaneously, concerns regarding environmental contamination necessitate development of nursery production methods that minimize impacts. Exponential (E) fertilization has potential for producing high-quality seedlings through nutrient loading, while simultaneously minimizing nitrogen (N) losses during culture. We investigated the effects of a wide range (0.10–1.0 g N seedling⁻¹ year⁻¹) of E fertilization rates on seedling morphology and nutrition of *Quercus robur* L., as well as soil N status and N budget during one growing season in a bareroot nursery in County Carlow, Ireland. The N budget showed significant N losses, especially in the highest fertilizer treatments, due to high precipitation. Seedlings receiving the 0.5 E rate were morphologically and nutritionally superior to all other treatments. Results indicate that it may be possible to produce 1-0 bareroot seedlings meeting target specifications in Ireland and other countries of similar climate and soils if further manipulations to seedling culture are implemented; however, potential environmental degradation via N leaching must be considered when N loading in wet years.

Keywords Exponential fertilization · Nitrogen budgeting · *Quercus robur* · Seedling quality

Introduction

Ireland is currently the least forested country in the European Union with only 10% of its total land area forested (Knaggs and O'Driscoll 2008; McCarthy et al. 2003). Thus, Ireland's Forest Service has prioritized efficient development of forestry including a specific goal to "increase quality of planting". Targets set by the Government's 1996 afforestation plan are to plant 20,000 ha/annum from 2001 to 2030 (McCarthy et al. 2003). To facilitate this objective, nursery production of seedlings and amount of land area planted in Ireland has increased dramatically. Planting of broadleaves is currently 30% of all plantings in Ireland (Forest Service 2008). Pedunculate oak (*Quercus robur* L.) is the most commonly planted broadleaved tree for reforestation in Ireland mainly due to its timber quality, good height attainment of ~30 m, excellent wind stability, and relative indifference to site conditions (Joyce et al. 1998; Renou-Wilson et al. 2008).

Irish nurseries have difficulty competing against 1-year imports of planting stock, since the cool climate has traditionally dictated 2-0 production of oak seedlings (Long 2006; O'Reilly et al. 2005). Several studies conducted at Irish bareroot nurseries indicate that it may be possible to grow broadleaved seedlings, including pedunculate oak, to target size (i.e., >45 cm shoot height and >6 mm root collar diameter) within one season by using a combination of seed storage/pre-treatments and specialized seedling cultural practices (i.e., use of cloches, higher fertilization rates, fall sowing, etc.; O'Reilly et al. 2005, 2009). Because

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