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ORIGINAL PAPER

Amelioration of planting stress by soil amendment with a hydrogel–mycorrhiza mixture for early establishment of beech (*Fagus sylvatica* L.) seedlings

Rajender S. Beniwal · Mahinder S. Hooda · Andrea Polle

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Abstract
• ***Introduction*** The mortality of nursery-grown beech (*Fagus sylvatica* L.) seedlings after out planting into the field is usually high.
• ***Objectives*** The goal of this study was to characterize the response of beech seedlings to planting stress and to test if soil amendment with a mixture of hydrogel and the ectomycorrhizal fungus *Paxillus involutus* could rescue the establishment of stressed plants. For this purpose, bare-rooted, dormant seedlings were exposed for 0, 2 and 6 h to air before planting.
• ***Results*** Water loss in response to air exposure caused increasing concentrations of soluble carbohydrates in buds and fine roots suggesting only passive of osmoprotection. Short-term exposure for 2 h delayed bud burst in spring, whereas long-term stress for 6 h also increased mortality. Growth of the seedlings in amended soil improved plant performance compared with plant grown in untreated soil. In particular, mycorrhizal colonization, plant water status and biomass increased, whereas carbohydrate storage pools were decreased. Total plant nitrogen allocated to leaves but not the nitrogen or carbohydrate concentrations were correlated with the degree of ectomycorrhizal colonization.
• ***Conclusion*** This suggests that soil amendment enhanced nitrogen uptake via ectomycorrhizals, which in turn stimulated growth, thereby, increasing carbon consumption and preventing starch accumulation. In conclusion, soil amendment with hydrogel and an ectomycorrhizal fungus significantly improved the performance of both stressed and unstressed young beech trees.

Keywords *Fagus sylvatica* · *Paxillus involutus* · Hydrogel · Planting stress · Vitality

1 Introduction

European beech (*Fagus sylvatica* L.) is the potentially dominating tree species of the natural vegetation in Central Europe (Ellenberg 1992). In the past, reforestation in many European areas was mainly performed with conifers. One of the most important aims of the current forest silvicultural programs in Germany is to transform monocultures of conifers into mixed forests with beech (Tarp et al. 2000). When nursery-grown seedlings are out planted, the mortality can be as high as 60% in the first year (McKay 1997). Growth of the surviving seedlings is often poor. Possible reasons for these high losses and poor quality are frequently related to inadequate treatment of the planting stock during transfer from the nursery to the field site exposing the roots to air, thereby imposing drought stress (McKay 1997). For successful field establishment, seedlings have to overcome the transplanting shock, which is primarily caused by desiccation (Girard et al. 1997a, b; McKay et al. 1999; Apostol et al. 2009). Beech seedlings were particularly sensitive to air exposure of the roots after lifting the plants

Dedicated to the memory of Aloys Hüttermann, a pioneer in hydrogel research.

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R. S. Beniwal · A. Polle (✉)
Büsgen-Institut, Forstbotanik und Baumphysiologie,
Georg-August-Universität Göttingen,
Büsgenweg 2,
37077 Göttingen, Germany
e-mail: apolle@gwdg.de

Present Address:
R. S. Beniwal · M. S. Hooda
Department of Forestry, CCS Haryana Agricultural University,
Hisar 125 004 Haryana, India