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ORIGINAL PAPER

Growth and physiological activity in *Larix kaempferi* seedlings inoculated with ectomycorrhizae as affected by soil acidification

D. S. Choi · H. O. Jin · D. J. Chung · K. Sasa · T. Koike

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Abstract To evaluate the effect of ectomycorrhizal colonization on growth and physiological activity of *Larix kaempferi* seedlings grown under soil acidification, we grew *L. kaempferi* seedlings with three types of ectomycorrhizae for 180 days in acidified brown forest soil derived from granite. The soil had been treated with an acid solution (0 (control), 10, 30, 60, and 90 mmol H^+ kg^{-1}). The water-soluble concentrations of Ca, Mg, K, Al, and Mn increased with increasing amounts of H^+ added to the soil. Ectomycorrhizal development significantly increased in soil treated with 10 and 30 mmol H^+ kg^{-1} but was significantly reduced in soil treated with 60 and 90 mmol H^+ kg^{-1}. The concentrations of Al and Mn in needles or roots increased with increasing H^+ added to the soil. The total N in seedlings significantly increased with increasing H^+ in soil and colonization with ectomycorrhiza. The maximum net photosynthetic rate at light and CO_2 saturation (P_{max}) was greater in soil treated with 10 mmol H^+ kg^{-1} than in controls, and was less is soils treated with greater than with 30 mmol H^+ kg^{-1}, especially with 60 and 90 mmol H^+ kg^{-1}. However, colonization with ectomycorrhiza significantly reduced the concentration of Al and Mn in needles or roots and increased the values of P_{max} and total dry mass (TDM). The relative TDM of *L. kaempferi* seedlings was approximately 40% at a (BC, base cation)/Al ratio of 1.0. However, ectomycorrhizal seedlings had a 100–120% greater TDM at a BC/Al ratio of 1.0 than non-ectomycorrhizal seedlings, even though the acid treatment reduced their overall growth.

Keywords Soil acidification · Ectomycorrhiza · Photosynthesis · BC/Al ratio · Dry mass growth · Al · Mn · *Larix kaempferi*

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D. S. Choi
Institute of Symbiotic Science and Technology,
Tokyo University of Agriculture and Technology,
Fuchu, Tokyo 183-8509, Japan

H. O. Jin · D. J. Chung
College of Life Science, Kyunghee University,
Yongin 449-701, Korea

K. Sasa · T. Koike
Hokkaido University Forests, FSC, Sapporo 060-0809, Japan

T. Koike (✉)
Research Faculty of Agriculture, Hokkaido University,
Sapporo 060-8589, Japan
e-mail: tkoike@for.agr.hokudai.ac.jp

Introduction

Larch species are broadly distributed in the northern hemisphere, making up more than a third of the total Eurasian boreal forests and are most common in East Asia (Hytteborn et al. 2005; Koike et al. 2000; Nakamura and Krestov 2005; Qu et al. 2005). In recent years, however, the growth of pine and larch species in East Asia has decreased with the inhibition of ectomycorrhiza development near industrial areas and large cities, especially in Korea (Choi et al. 2003, 2006).

These symptoms of decline are partly related to the edaphic condition of the forests, where soils originate from granite. Many studies have shown that excess acid precipitation will lead to direct phytotoxic effects, eutrophication, and accelerated soil acidification, inducing a decline in forest ecosystems (Krupa 2003; Larcher 2004). Soil acidification is generally accompanied by increased leaching of base cations such as Ca^{2+}, Mg^{2+} and K^+ ions