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Research article

Simulated warming does not impair seedling survival and growth of *Nothofagus pumilio* in the southern Andes

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ABSTRACT

It has been predicted that subalpine forests will be negatively affected by global warming; however, direct responses to experimental warming have been scarcely examined in these systems. In this study we evaluated the effects of higher temperatures with and without water addition on the survival and growth of recently emerged (small) and large seedlings of the widely distributed species *Nothofagus pumilio* in subalpine forests of the southern Chilean Andes. We also examined the variations in seedling traits related to carbon balance in order to infer the causal mechanisms of survival and growth responses. Treatments of open top chambers (OTCs) were combined with watering in two locations with differing climates: Antillanca (40°S, humid) and Cerro Castillo (46°S, drier). OTCs increased mean and maximum air temperatures by 0.6 °C and 2–3 °C, respectively, and decreased soil humidity by 56% in Antillanca and 30% in Cerro Castillo, fulfilling methodological expectations and climate model predictions. After two complete growing seasons, the survival, relative growth rate (RGR), biomass, and a suite of seedling traits were measured and analyzed using mixed-effects models. Warming and warming in combination with watering significantly increased large seedling survival in Cerro Castillo. In Antillanca, warmer conditions increased the height, biomass, and leaf area of small seedlings, and the RGR of large seedlings. In this location, warming also caused lower leaf carbon isotopic composition in both age classes and higher specific leaf area in small seedlings, suggesting whole-plant carbon gain improvements; warming did not produce any drought effects. Our results indicate that warming produces positive effects on the seedling establishment of *N. pumilio* in the southern Andes, highlighting the importance of site-specific effects in response to climate change in widespread species. Site-specific effects can most likely explain the discrepancies between the results of this study and the predictions outlined by previous studies for these forests.

Introduction

Low temperatures are one of the major constraints for seedling establishment in subalpine forests (Tranquillini, 1979; Ferrar et al., 1988; Woodward et al., 1995; Cuevas, 2000; Lajzerowicz et al., 2004). Consequently, global warming may mitigate the physiological limitations imposed by cold temperatures on the survival and growth of seedlings located at high elevations, thus promoting their establishment and causing timberline infilling (Innes, 1991). Such unidirectional expected changes, however, may not occur if warmer conditions simultaneously lead to higher water deficit in plants. An increased water deficit could offset the expected positive effects from temperature increases, limiting, for instance, seedling survival and growth (Daniels and Veblen, 2004; Oberhuber, 2004). Ultimately, this may even lead to a reduction in subalpine forest cover (Hayhoe et al., 2004).

In many regions of the world, it has been predicted that water stress will become more frequent and intense under a global warming scenario (Bates et al., 2008). Water stress driven by higher temperatures (via increased evapotranspiration) causes substantial impacts on plant communities including seedling mortality, growth cessation (Tercero-Bucardo et al., 2007), and reduction of species richness (Lloret et al., 2004). In widely distributed species, predictions on seedling responses to climate warming are difficult to make because a given species may show contrasting responses depending on the location; e.g., warming increased growth of

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