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Low soil temperature reduces the positive effects of high nutrient supply on the growth and biomass of white birch seedlings in ambient and elevated carbon dioxide concentrations

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Abstract: To investigate the interactive effects of soil temperature (T_{soil}) and nutrient supply on the responses of growth and biomass of white birch (*Betula papyrifera* Marsh.) to atmospheric carbon dioxide concentration ([CO_2]), seedlings were grown under two [CO_2] (360 and 720 μmol·mol^{-1}), three T_{soil} (5, 15, and 25 °C initially, increased to 7, 17, and 27 °C one month later), and three nutrient regimes (Low: N–P–K = 4:1.8:3.3 mg·L^{-1}; Intermediate: N–P–K = 80:35:66 mg·L^{-1}; and High: N–P–K = 160:70:132 mg·L^{-1}) for 4 months. Low T_{soil} reduced leaf and total biomass at high nutrient supply and root biomass at intermediate and high nutrient supply. There were significant three-factor interactive effects on root collar diameter (RCD), stem biomass, and leaf mass ratio. Low T_{soil} reduced RCD at high nutrient supply and stem biomass at intermediate and high nutrient supply in elevated [CO_2] while intermediate and high T_{soil} enhanced them. Values of leaf mass ratio were lowest at low T_{soil} and low nutrient supply in elevated [CO_2]. The effect of T_{soil} was generally insignificant at low nutrient supply, but the responses of growth and biomass remained significantly higher under high than low nutrient supply at all T_{soil}.

Key words: boreal forest, global change, T_{soil} × nutrition, CO_2 × T_{soil} × nutrition.

Résumé : Afin d'examiner les effets interactifs entre la température du sol (T_{sol}) et l'apport en nutriments sur les réactions de croissance et en biomasse du bouleau blanc (*Betula papyrifera* Marsh) aux concentrations de bioxyde de carbone ([CO2]), les auteurs ont cultivé des plantules sous deux teneurs [CO2] (360 et 720 μmol·mol^{-1}) et trois T_{sol} (5, 15 et 25 °C au départ, avec des augmentations à 7, 17 et 27 °C, un mois plus tard), et trois régimes nutritifs (Faible: N–P–K = 4:1.8:3.3 mg·L^{-1}, Intermédiaire; N–P–K = 80:35:66 mg·L^{-1}, et Élevé; N–P–K = 160:70:132 mg·L^{-1}), pendant quatre mois. La basse température du sol réduit la biomasse foliaire et totale avec nutriments élevés et la biomasse racinaire avec des apports intermédiaires et élevés. On observe des effets trifactoriels significatifs sur le diamètre racinaire au collet (RCD), et le rapport de la biomasse de la tige sur la biomasse foliaire. La faible T_{sol} réduit le RCD avec des nutriments élevés et la biomasse de la tige avec des nutriments intermédiaires et élevés, avec un [CO_2] élevé, alors que les T_{sol} intermédiaires et élevés les augmentent. Les valeurs de ratio de la masse foliaire sont plus faibles à T_{sol} faible et faible apport en nutriments en présence de [CO_2] élevé. L'effet de T_{sol} demeure généralement non significatif à faibles apports de nutriments, mais les réactions de croissance et de biomasse demeurent significativement plus élevées avec des teneurs en nutriments élevées que faibles, à toutes les températures du sol.

Mots-clés : forêt boréale, changement global, T_{sol} × nutrition, CO_2 × T_{sol} × nutrition.

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Introduction

Global atmospheric carbon dioxide concentration ([CO_2]) has gradually risen from 280 μmol·mol^{-1} in 1850 to 379 μmol·mol^{-1} in 2005, and is currently increasing at a rate of 1.9 μmol·mol^{-1} per year as a result of both natural and human-induced emissions (IPCC 2007). The majority of experimental evidence indicates that elevated [CO_2] stimulates the growth (Bowes 1993; Cipollini et al. 1993; Johnsen and Major 1998; Zhang et al. 2006; Zhang and Dang 2007) and CO_2 assimilation rate (Bazzaz 1990; Drake et al. 1997; Zhang and Dang 2005; Zhang and Dang 2006) of C_3 plants. Common growth responses to high [CO_2] include increases in plant biomass, root:shoot ratio (R:S ratio), leaf area, numbers of leaves and branches, plant height, and root length (Norby et al. 1986; Bazzaz et al. 1990; Cipollini et al. 1993; Stulen and den Hertog 1993; Centritto et al. 1999; Pritchard et al. 1999; Liu et al. 2006; Zhang et al. 2006; Zhang and Dang 2007). However, the magnitude of response varies considerably among species. In any case, the allocation of assimilated carbon in elevated [CO_2] appears to depend greatly upon the prevailing environmental conditions (Saxe et al. 1998; Zhang et al. 2006; Zhang and Dang 2007).

Soil temperature (T_{soil}) is a key environmental factor limiting tree growth in the boreal forest (Bonan 1992). Low T_{soil} reduces shoot growth (Landhäusser et al. 2001; Zhang and Dang 2007), and tends to increase the relative allocation

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