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Interactive effects of carbon dioxide concentration and light on the morphological and biomass characteristics of black spruce and white spruce seedlings

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Abstract: CO_2–light interactions can influence the competition among boreal plants, but are poorly understood. We investigated the effect of such interactions on the growth and biomass of 1-year-old black spruce (Sb) (*Picea mariana* (Mill.) BSP) and white spruce (Sw) (*Picea glauca* (Moench) Voss) grown with CO_2 concentrations ($[CO_2]$) of 360 and 720 $\mu mol \cdot mol^{-1}$ under 30%, 50%, and 100% light, in greenhouses. There were significant two-way and three-way interactions. Root collar diameter (RCD) of Sw decreased with decreasing light, while in Sb, there was no significant difference in RCD for plants grown under 50% or 30% light. Height was greater for plants grown under 100% light than if the plants were shaded. Elevated $[CO_2]$ increased RCD by 33% and enhanced stem volume by 67%, 98%, and 84% under 100%, 50%, and 30% light, respectively. The CO_2 enhancement of total biomass was relatively higher under lower light, and greater for Sb than Sw. Elevated $[CO_2]$ decreased specific leaf area under 50% light only. Root mass was generally higher under 100% light than when shaded. Elevated $[CO_2]$ increased the root mass of Sb under 100% light, but decreased it under 30% light. Elevated $[CO_2]$ decreased the shoot/root ratio under 100% light, but increased it under 30% light. Our data suggest that raising $[CO_2]$ will likely increase species competitiveness under low light conditions, and that the increase will be greater in species that are relatively shade tolerant.

Key words: boreal forests, elevated $[CO_2]$, $[CO_2]$–light species interactions, black spruce, white spruce seedlings, climate change.

Résumé : L'interaction lumière–CO_2 peut influencer la compétition entre plantes boréales, mais on les comprend mal. Les auteurs ont examiné de telles interactions sur la croissance et la biomasse de plants d'un an d'épinettes noires (Sb) (*Picea mariana* (Mill.) B.S.P.) et d'épinettes blanches (Sw) (*Picea glauca* (Moench.) Voss), en présence de 360 et 720 μmol^{-1} $[CO_2]$ et 30, 50 et 100 % de lumière, en serres. On retrouve des interactions dans deux directions et dans trois directions. Le diamètre au collet (RDC) de Sw diminue avec une diminution de la lumière alors qu'il n'y a pas de différence significative chez Sb entre 50 et 30 % de lumière. La hauteur est plus grande avec 100 % de lumière, comparativement à l'ombre. Le $[CO_2]$ élevé augmente le RDC de 33 %. Il augmente la biomasse totale de 67, 98 et 84 %, respectivement à 100, 50 et 30 % de luminosité. L'augmentation de la biomasse totale sous l'effet du $[CO_2]$ est relativement plus élevée à faible intensité lumineuse et plus élevée chez Sb que chez Sw. L'augmentation du $[CO_2]$ diminue la surface foliaire spécifique seulement sous 50 % de luminosité. On observe une biomasse généralement plus importante à 100 % de luminosité qu'à l'ombre. L'augmentation de $[CO_2]$ augmenta la biomasse racinaire chez Sb à 100 % de lumière, mais la diminue à 30 %. L'augmentation de $[CO_2]$ diminue le rapport tige/racine à 100 % de lumière, mais la diminue à 30 %. Les données suggèrent que les augmentations de $[CO_2]$ favorisent vraisemblablement la compétitivité des espèces sous des conditions de faible luminosité et l'augmentation sera plus forte chez les espèces qui tolèrent relativement mieux l'ombre.

Mots-clés : forêts boréales, $[CO_2]$ élevé, interactions espèces lumière–$[CO_2]$, épinette noire, épinette blanches, plantule, changement climatique.

Introduction

The global atmospheric carbon dioxide concentration ($[CO_2]$) has increased from the pre-industrial value of 280 $\mu mol \cdot mol^{-1}$, to approximately 379 $\mu mol \cdot mol^{-1}$ in recent years, and the present annual $[CO_2]$ increase rate of 1.9 $\mu mol \cdot mol^{-1}$ is the highest on record (IPCC 2007). Research has shown that increasing $[CO_2]$ has great impact on plant growth and biomass production (Curtis and Wang 1998; Ward and Strain 1999). Numerous studies (Curtis 1996; Tissue et al. 1997; Wuebbles et al. 1999; Linder 2000) showed that elevated atmospheric $[CO_2]$ enhances photosynthesis and plant biomass production. Ceulemans and Mousseau (1994) found that a doubling of atmospheric $[CO_2]$ increases leaf-level photosynthesis by approximately 40% in conifers and 60% in deciduous trees. Zhang and Dang (2007) reported an enhancement of biomass produc-

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