CHAPTER FOUR

The Effects of Elevated CO_2 on Tropical Trees Are Related to Successional Status and Soil Nutritional Conditions

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Abstract Nutrient requirements for plant growth are expected to impact changes in atmospheric carbon dioxide concentration [CO_2] and temperature. We examined the effects of elevated [CO_2] and soil nutrient availability on photosynthesis and biomass enhancement of pioneer and late successional tropical tree species. Plants were grown in open-top chambers at 380, 555 or 740 µmol mol^{-1} of [CO_2]. The pioneer tree *Croton urucurana,* grown under low nutrient showed only half the photosynthetic stimulatory effect of elevated [CO_2] when compared to plants grown under high nutrient content. Photosynthesis was higher in the late-type successional plant *Essenbeckia leiocarpa* at high [CO_2] (555 µmol mol^{-1}), under both high and low nutrient levels. Elevated [CO_2] significantly increased the total biomass of stem, root, and leaf only under the high nutrient, but the magnitude of this response depended on the functional group. In late successional species, the diurnal minimum *F*v/*F*m was significantly higher under 740 µmol mol^{-1} of [CO_2], thus decreasing the susceptibility of plants to suffer photoinhibition. These findings support the hypothesis that soil nutrition has the potential to influence the response of plant species to changes in [CO_2], and that elevated CO_2 would partially protect PSII from photoinhibition when grown under high nutrient levels by providing adequate sinks for extra photosynthate.

Keywords Atmospheric change, chlorophyll fluorescence, elevated carbon dioxide, photosynthesis, tropical trees

Introduction

The evidence of significant increases in atmospheric global greenhouse gas concentrations (IPCC 2007), and of rapid changes in climate due to human activities and their impacts on plants and animals, grows daily (Morison and Morecroft 2006). Photosynthesis is the primary process by which carbon enters into the biosphere and by which plants sense permanently

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rising atmospheric carbon dioxide concentrations [CO_2]. Forest trees constitute a critical component of the global carbon budget accounting for over half of the total net carbon uptake into terrestrial vegetation (Saxe et al. 1998). It has been suggested that trees will only respond to increasing [CO_2] when other resources are not limiting (Eamus and Jarvis 1989). Forests are frequently found on nutrient-poor soils and their productivity is strongly related to soil fertility (Norby et al. 1992). Therefore, it is important to understand how photosynthesis of main tree species will respond to changes of [CO_2].

The objective of this work was to determine the effects of CO_2 concentration, and soil nutrient availability, on the photosynthesis and biomass enhancement of pioneer and late successional tropical tree species. We aimed to test whether elevated [CO_2] influences the growth of trees differing in their successional characteristics in a predictable way.

Materials and methods

Plant material and growth conditions. Two pioneer (*Croton urucurana* and *Cecropia pachystachya*) and two late successional (*Essenbeckia leiocarpa* and *Cariniana legalis*) tropical tree species were studied. We conducted two experiments in open top chambers (OTCs). On the first experiment, the species *C. urucurana* and *C. legalis* grown under high nutrition level were exposed to three levels of [CO_2]: 380 µmol mol^{-1} (approximated as ambient); 555 µmol mol^{-1}; and 740 µmol mol^{-1}. In the second experiment, the species *C. pachystachya* and *E. leiocarpa* grown under high (fertilized) and low (no fertilized) nutritional levels, were exposed to three levels of [CO_2]. In both experiments, plants were grown in 15 L pots containing soil from a forestry area. Plants were well-watered throughout the experiment.

Measurements. Leaf net photosynthesis was measured at constant temperature (25°C) with an open-flow infrared gas analysis system (LCpro$^+$, ADC, Hoddesdon, UK). Measurements of chlorophyll fluorescence parameters, following dark-adaptation for 15 min, were made with an OS-30P fluorimeter (Opti-Science, USA). After 2 months under CO_2 treatments, the plants were harvested to determine the dry biomass.

Statistical analysis. To avoid pseudo replication, average values were calculated for each OTC treatment (n = 3). The average for an OTC was then treated as the individual in deriving mean and variance for the population of the chambers.

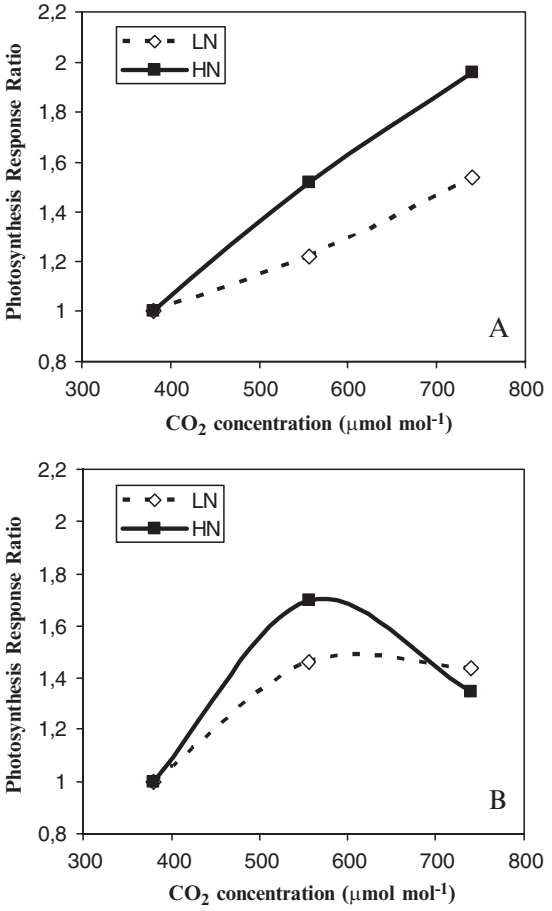

Fig. 1 Scaling of photosynthesis response ratio of *Cecropia pachystachya* (A), a pioneer tropical tree species and *Essenbeckia leiocarpa* (B), a late successional tree species to elevated atmospheric CO_2 concentrations (555 and 740 µmol mol^{-1}), relative to 380 µmol mol^{-1}. Plants were grown under low (LN) and high (HN) nutritional levels