Carbon Balance in Stand of an Annual Herb at an Elevated CO_2 Concentration

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Key words: carbon balance, stand, photosynthesis, respiration, elevated CO_2 concentration, *Chenopodium album*

Introduction Global atmospheric CO_2 concentration is predicted to double by the end of the present century (IPCC, 2001). The influence of increased CO_2 on plant and ecosystem functions has been a major concern in ecology and global change sciences (Long et al., 2004). In most studies, elevated CO_2 enhanced canopy photosynthesis. However, the magnitude of the enhancement varies among studies (Nowak et al. 2004). More recently, Sakai et al. (2006) showed that enhancement of canopy carbon gain by elevated CO_2 is sensitive to the growth stage and leaf nitrogen concentration in the rice stand. However, since most of these studies determined photosynthesis in the stand without destructive harvests, they were not able to fully analyze mechanisms involved in variation in stand carbon balance. Canopy photosynthesis is a function of canopy structure (leaf area index, K, leaf nitrogen distribution etc.), leaf physiology (photosynthesis, respiration etc.) and environmental factors (irradiance, N availability, temperature etc.). In the present study, we studied the effect of elevated CO_2 on carbon balance for stands of an annual *Chenopodium album*.

Materials and methods Stands of C. album were established in open top chambers at ambient and elevated CO_2 concentrations (370 and 700 μmol mol^{-1}) in the experimental garden of Tohoku University, Sendai, Japan (38°15′N, 140°52′E). Plant dry mass growth, photosynthesis and respiration were determined through the growing season. CO_2 exchange of the stand was estimated with a canopy photosynthesis model (Hirose, 2005). Rates of light-saturated photosynthesis (Pmax) and dark respiration (Rm) of leaves as related with nitrogen content per unit leaf area (Narea) and time-dependent reduction in specific respiration rates (SRR) of stems and roots were incorporated into the model.

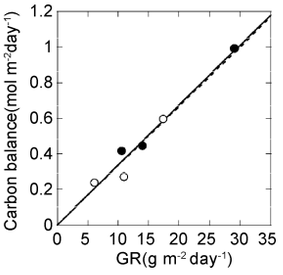

Figure 1 *Comparison of stand carbon balance (canopy photosynthesis minus stems and roots respiration) with mean daily plant growth rates (GR) in C. album stands. Carbon balance is a mean of calculated values for a period between harvests (29 and 41, 42 and 62, 63 and 81 DAT). Open circles, ambient CO_2 (370 μmol mol^{-1}); closed circles, elevated CO_2 (700 μmol mol^{-1}). Solid line represents regression line: $y = 0.034x$, $r = 0.99$. Dotted line indicates equivalence of 1 mol CO_2 with 30 g dry mass.*

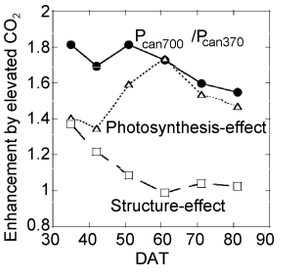

Figure 2 *Enhancement of canopy photosynthesis by elevated CO_2 as a function of DAT (Days after transplanting). Each data point expresses a mean of canopy photosynthesis. Results of sensitivity analyses (Photosynthesis-effect, triangles, and Structure effect, squares) are also shown.*

Results and conclusions Daily canopy carbon balance, calculated as an integration of leaf photosynthesis minus stem and root respiration, showed a fairly good agreement with dry mass growth determined by harvests (Figure 1). The enhancement of canopy photosynthesis with elevated CO_2 was 80% at an early stage and decreased to 55% at flowering. Sensitivity analyses suggested that an alteration in leaf photosynthetic traits enhanced canopy photosynthesis by 40-60% throughout the experiment period, whereas altered canopy structure (leaf area index, leaf nitrogen distribution and light gradient in the canopy) contributed to the enhancement at the early stage only (Figure 2). In early stages when plant size was small, nutrient supply might not be a limiting factor of plant growth, leading to an enhancement of LAI at elevated CO_2, while in later stages of plant growth, nutrient supply became more limiting and the structural difference might diminish between the two growth CO_2 concentrations. Thus various factors interact to determine the stand carbon balance that is influenced by elevated CO_2.

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