CAN CLIMATE DRIVEN CHANGES IN PHOTOSYNTHESIS BE USED TO PREDICT CHANGES IN THE RATE AND TEMPERATURE SENSITIVITY OF ECOSYSTEM RESPIRATION?

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INTRODUCTION

Terrestrial ecosystem respiration releases approximately 60 Pg carbon into the atmosphere anually (Schimel et al 1995). This is a relatively large amount in comparison to the 7.1 Pg carbon released per year from fossil fuel combustion, cement production and land use changes. Terrestrial ecosystem respiration thus plays a critical role in determining net CO_2 fluxes into the atmosphere. Understanding the factors that regulate ecosystem respiration (R_e) is therefore a prerequisite for understanding how future changes in climate will affect atmospheric CO_2 concentrations. The response of R_e to elevated CO_2 is unclear. However, there is growing evidence that climate dependent variations in photosynthesis, and thus substrate supply, influence the rate of ecosystem respiration (R_e). Furthermore, there is evidence that variations in substrate supply can affect the temperature-sensitivity of respiration (Azcón-Bieto & Osmond 1983, Atkin et al 2002, Covey-Crump et al 2002). Consequently, climate-dependent changes in photosynthesis might result in concomitant changes in both the rate, and temperature-sensitivity, of R_e. R_e is the sum of several respiratory processes, which, for the purposes of simplicity, can be divided into above- and below-ground respiration. If we are to better understand the impact of a changing climate on R_e, it will be necessary to understand the response of these above- and below-ground processes to changes in climate, and the extent to which they determine the respiratory response at the whole ecosystem level.

In this study we investigated the impact of elevated atmospheric CO_2 on leaf, soil and whole ecosystem respiration in order to determine (1) the extent to which photosynthetic CO_2 uptake dictates the rate and temperature-sensitivity of respiratory CO_2 release, and (2) the degree to which changes in leaf and soil respiration determine the ecosystem level response to changes in climate.

MATERIALS AND METHODS

The experiment was conducted in three enclosed cottonwood (*Populus deltoides*) stands at the Biosphere 2 Research Centre in Tucson, Arizona (Griffin et al 2002). Biosphere 2 provided a unique opportunity to integrate measurements of CO_2 flux at the leaf, soil and whole ecosystem level in a controlled environment, allowing us to assess the impact of short-term changes in climate (e.g. temperature, irradiance and atmospheric CO_2) on CO_2 exchange processes in a whole forest. As there was no litter input into the soil, root inputs were the only source of new soil carbon.

Prior to the start of the experiment, entire stands of trees were exposed to three CO_2 treatments (east bay 280 ppm, central bay 400 ppm, west bay 900 ppm) and day/night temperatures of 30/25 °C. Four days into the experiment the CO_2 concentrations in the east and west bays were switched (east bay to 900 ppm, west bay to 280 ppm). These conditions were maintained for two weeks, after which time the impact of an increase in temperature to 35/30 °C for 7 days, followed by a decrease to 25/20 °C for 7 days, was assessed. The experiment took place over a 5-week period (Sept.–Oct. 2003).

Net CO_2 flux at the ecosystem level was monitored throughout the experimental period. Soil respiration was measured using a Licor 6200 IRGA, and leaf photosynthesis and dark respiration were measured using a Licor 6400 IRGA (with CO_2 control). Leaf measurements were conducted on fully expanded leaves that were present in week one of the experiment. Leaf soluble sugar concentrations were measured using dried leaf material.

RESULTS

Night-Time Respiration was Dependent Upon Daytime Photosynthesis. Respiration was strongly coupled to photosynthesis at the leaf and whole ecosystem level (data not shown). Leaf respiration rates and soluble sugar concentrations were positively correlated (data not shown) suggesting that photosynthetic-mediated changes in substrate supply were responsible for the variations in R_e. Alterations in canopy photosynthesis also had a significant effect on the rate of soil respiration (data not shown). For example, two weeks after the atmospheric CO_2 concentration in the east bay had been increased from 280 to 900 ppm, a 17% increase in the soil respiration rate was recorded.

Above-Ground Respiration Responded more *Strongly* than Below-Ground Respiration. Figure 1A shows the percentage change in respiration rates (data shown is an average of all three bays) that occurred after one day of reduced irradiance (increased cloud cover event) in week 2; leaves from the lower canopy exhibited the greatest response. The change in leaf, ecosystem and soil respiration following the change in atmospheric CO_2 concentrations is shown in Fig. 1B (comparison of respiration prior to, and two weeks after, the change in CO_2 concentration), again highlighting the importance of leaf respiration in determining the ecosystem response. The differential response of above- and below-ground components in the short-term might be indicative of differences in the speed of response in leaves versus soils.

Above-Ground Respiration Responded more *Quickly* than Below Ground Respiration. Comparison of Fig. 1A and 1B reveals that soil respiration exhibited a greater response two weeks after CO_2 reversal (Fig. 1B), than after one day of decreased illumination (Fig. 1A), suggesting that soil respiration is slower to respond to changes in canopy photosynthesis than leaf respiration. This hypothesis is supported by the results shown in Fig. 2; R_e had almost

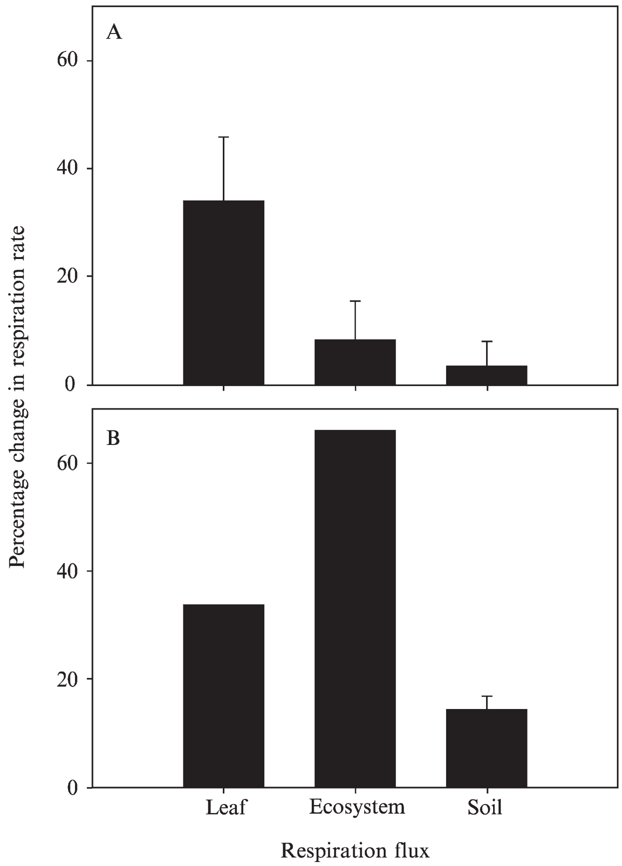

Figure 1: Percentage change in rates of leaf, ecosystem and soil respiration caused by (A) low light conditions and (B) CO_2 changes. Error bars represent SE.

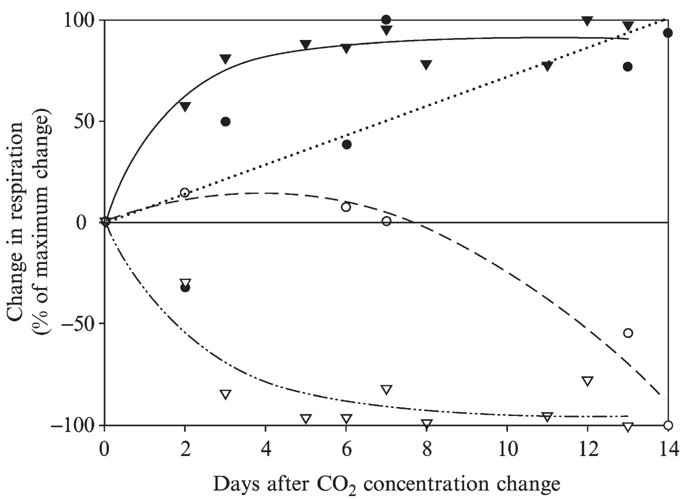

Figure 2: Effect of changing the atmospheric CO_2 conditions on ecosystem [(East bay }), (West bay Π)] and soil [(East Bay ¬), (West Bay ○)] respiration. Responses are expressed as a percentage of the maximum change occurring during the 2 week period.

fully adjusted to changes in atmospheric CO_2 concentration within 4–5 days (with 50% of maximal change being achieved within 2 days), whereas soil respiration alone took nearly 14 days to fully adjust to changes in aboveground CO_2 concentrations.

Temperature-Sensitivity of Soil Respiration was Dependent Upon Photosynthesis. To assess whether changes in canopy level photosynthesis affected the short-term temperature-sensitivity of soil respiration, we calculated Q_{10} values of soil respiration by comparing rates of respiration in week 4, with those in week 5 (i.e. 30 versus 20 °C). Q_{10} values were higher in fast-respiring soils. Given that soil respiration and canopy photosynthesis were positively correlated (data not shown), this suggests that climate mediated changes in canopy photosynthesis were able to alter the Q_{10} of soil respiration.

DISCUSSION

We have shown that rates of leaf, soil and whole ecosystem respiration are tightly coupled to the preceding days photosynthetic rates. However, the degree of coupling differed, with leaf respiration responding to changes in photosynthesis to a greater extent than soil respiration. The differential response of above- and below-ground processes was most likely due to differences in the speed of response. To conclude, our results demonstrate the pivotal role which photosynthesis plays in determining respiratory flux in whole ecosystems, and enhance our understanding of the differential contributions of above- and below-ground processes to R_e.

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EFFECT OF WATER DEFICIT ON THYLAKOID MEMBRANE OF TWO WHEAT CULTIVARS

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INTRODUCTION

The responses of crop plants to drought stress are a serious problem and the important selective factor in evolution of plants, which influence their growth and development. To cope with these external stresses, plants fulfill numerous morphological, physiological and metabolic answers. Of crucial importance in desiccation-tolerant plants are the physical properties of the photosynthetic apparatus,

