Short communication

The effect of plant material grown under elevated CO₂ on soil respiratory activity

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Abstract

The biodegradability of aerial material from a C₄ plant, sorghum grown under ambient (345 μmol mol⁻¹) and elevated (700 μmol mol⁻¹) atmospheric CO₂ concentrations were compared by measuring soil respiratory activity. Initial daily respiratory activity (measured over 10 h per day) increased four fold from 110 to 440 cm³ CO₂ 100g dry weight soil⁻¹ in soils amended with sorghum grown under either elevated or ambient CO₂. Although soil respiratory activity decreased over the following 30 days, respiration remained significantly higher (t-test; p > 0.05) in soils amended with sorghum grown under elevated CO₂ concentrations. Analysis of the plant material revealed no significant differences in C:N ratios between sorghum grown under elevated or ambient CO₂. The reason for the differences in soil respiratory activity have yet to be elucidated. However if this trend is repeated in natural ecosystems, this may have important implications for C and N cycling.

Introduction

Present atmospheric concentrations of carbon dioxide (ca. 350 μmol mol⁻¹) are higher than at any time in the last 160,000 years (Watson et al., 1990), and increasing at a rate of 0.5% per year. The response mediated by plants to elevated atmospheric CO₂ may be general or species specific; for example both C₃ and C₄ plants show an increased water use efficiency when grown under elevated CO₂ (Curtis et al., 1989a). Other responses such as increased shoot:root ratio (Curtis et al., 1989a), increased starch levels (Kimball, 1983; Sionit et al., 1980), modifications in the leaf-nitrogen and leaf-phosphate content (Curtis et al., 1989b: Tissue and Oechel, 1987), and changes in protein composition (Acoc and Allen, 1985) are less general and more species dependent. The reason for these changes in plant composition/efficiency have not yet been fully elucidated and it is likely that many other responses to elevated CO₂ are elicited.

The effects of climate change on the subsequent decomposition of plant material have largely been ignored, yet soil C represents an essential C reservoir (Bouwman, 1990). Any changes in the rate of decomposition of organic C in terrestrial systems may have significant effects on the global carbon cycle. Our recent comparison of the rates of microbial degradation of stem material derived from a C₃ plant, wheat (Triticum aestivum cv Avalon) grown at either ambient (350 μmol mol⁻¹) or elevated (700 μmol mol⁻¹) atmospheric CO₂ concentrations revealed significant differences in biodegradability, with a reduction in microbial biomass and biodegradation of approximately 20% when plant material derived from wheat grown under elevated CO₂ replaced ambient-derived plant material (Ball, 1991). Although the reasons for the observed differences were not elucidated it is widely assumed that the generally observed increase in the C:N ratio of C₃ plant material grown under elevated CO₂ largely accounts for these observed change in decomposition rates. In contrast it is assumed that C₄ plants will
exhibit only minor modifications in response to elevated CO₂, resulting in a largely unchanged rate of decomposition.

In this paper we examine the effects of elevated CO₂ on soil respiratory activity using a C₄ plant, sorghum, grown under either elevated (700 μmol mol⁻¹) or ambient (345 μmol mol⁻¹) atmospheric CO₂, and a laboratory based soil system.

**Materials and methods**

Plant material and soil samples were kindly donated by Dr. S. Azam-Ali (Nottingham University, UK). Sorghum was grown in either ambient (345 μmol mol⁻¹) or elevated (700 μmol mol⁻¹) atmospheric CO₂ levels at a temperature of 28 °C ± 5 °C; computer controlled in a predetermined sinusoidal wave under optimum nutrient/water conditions. After final harvest (140 d) the sorghum was separated into stems, leaves and seed. Fractions were then dried and stored in a dark coldroom. Leaf material was used throughout the study, after physical pre-treatment (chopped and blended), resulting in plant material of uniform size (approx 5mm).

The soil used in this study, a sandy loam soil (pH 6.5 ± 0.2), containing 1.26% C and 0.08% N (Table 1) and 10% moisture (w/w) corresponding to an approximate moisture potential for this soil type of −0.8 MPa (Saxton et al., 1986), was taken from undisturbed soil site (15-40 cm below the surface) from the ambient carbon dioxide treatment.

Measurements of soil respiratory activity were recorded using an infra red gas analyser (IRGA, ADC 225) attached to a six point multi channel selector (ADC WA161). The degradation studies were performed using water jacketed respiration chambers through which sterile humidified air was passed, and the amount of CO₂ in the replaced air was assessed by IRGA. Both reference and sample air were maintained at a flow rate of 400 mL min⁻¹. Carbon dioxide flux was recorded for a dwell time of five minutes. The chambers were kept in the dark at 20 °C, and the moisture content maintained at 10% (w/w) by the daily addition of sterile water. Each chamber contained 80g soil. Following stabilisation of respiratory activities in unamended soils, triplicate chambers were inoculated with 0.8 g (representing 33% of the initial soil C) of leaf material prepared from sorghum grown under either ambient or elevated atmospheric CO₂, and incubated for 30 days at 20 °C. Soil respiratory measurements were recorded daily over a ten hour period using a chart recorder (Kipp and Zonen BD 111).

The carbon:nitrogen ratio of soil and leaf material used in the study was taken using an automated Perkin Elmer CHNS/O analyser (Series ii, 2400). Soil samples (20 mg) and plant samples (5 mg) were ground to small particles and placed in foil capsules for analysis by combustion and spectral characterisation.

**Results**

Soil respiration measurements were taken daily over a ten hour period for thirty days. Figure 1 shows the mean daily total soil respiratory rates, measured over a period of 10 h per day, for soils amended with plant material derived from ambient and elevated CO₂ grown material. Addition of plant material (derived from either ambient or elevated grown sorghum) to soil resulted in an approximate four fold increase in respiratory activity (Fig. 1) from approximately 110 to 440 cm³ CO₂ per 100 g of soil (dry weight). During the first six days of incubation, no significant differences were observed in respiratory rates between soil inoculated with plant material derived from either ambient or elevated CO₂ grown sorghum (unpaired t-test; p > 0.05). A reduction in maximum daily respiratory rate was observed from day 5 and continued until day 22, when respiratory rates returned to day 0 levels (approximately

**Table 1.** Elemental analysis of soil and sorghum leaves. Carbon, hydrogen and nitrogen content (%) of unamended soils and sorghum grown under ambient and elevated CO₂ concentrations. The results are the means of three replicates, with standard deviations given in brackets

<table>
<thead>
<tr>
<th>Element</th>
<th>Soil ▪ ▪ ▪</th>
<th>Sorghum ▪ ▪ ▪</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ambient</td>
<td>Elevated</td>
</tr>
<tr>
<td>Carbon</td>
<td>1.26 ▪ (± 0.06)</td>
<td>42.2 ▪ (± 0.2)</td>
</tr>
<tr>
<td></td>
<td>44.2 ▪ (± 1.8)</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.34 ▪ (± 0.05)</td>
<td>6.1 ▪ (± 0.1)</td>
</tr>
<tr>
<td></td>
<td>6.3 ▪ (± 0.1)</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.08 ▪ (± 0.01)</td>
<td>3.0 ▪ (± 0.3)</td>
</tr>
<tr>
<td></td>
<td>3.1 ▪ (± 0.3)</td>
<td></td>
</tr>
<tr>
<td>C:H:N Ratio</td>
<td>16:4:1 ▪ 14:2:1</td>
<td>14:2:1 ▪ 14:2:1</td>
</tr>
</tbody>
</table>

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Elemental analysis for soils amended with plant material were similar to those values for unamended soils.

No significant differences in values between ambient and elevated plant material (p > 0.05)