CO_2 ENRICHMENT AND TEMPERATURE EFFECTS ON PRODUCTIVITY OF FIELD-GROWN PHALARIS AND SUBTERRANEAN CLOVER

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ABSTRACT

Pure and mixed swards of *Phalaris aquatica* and *Trifolium subterraneum* were exposed to cool (ambient) and warm (cool +3°C) temperatures, at both 380 and 690 ppm CO_2 concentrations in field temperature gradient tunnels for 5 months. In general, clover and the mixture had similar forage productivity in each treatment, while phalaris was less productive. Elevated CO_2 increased clover production 40% in the monoculture and the mixture. Higher temperatures reduced clover regrowth at ambient CO_2 and reduced the response to elevated CO_2 in the monoculture but not in the mixture. In contrast, phalaris regrowth in the monoculture was not increased by elevated CO_2 or higher temperature, while the combination of these increased production 31%. In the mixture, phalaris growth increased by 65 and 93%, respectively, in response to elevated CO_2 and higher temperature, but less (31%) with both together. Clover dominated the mixture. However, at warm temperature and ambient CO_2, clover growth was poor and phalaris growth increased so that total productivity of the mixture was unaffected.

KEYWORDS

carbon dioxide, temperature, climate change, subterranean clover, phalaris, pasture

INTRODUCTION

Increased atmospheric CO_2 concentration and associated global warming are expected to alter growth rates and competitive relationships in pasture communities. Many studies have been conducted in pots in fully-controlled environments under constant temperatures and artificial lighting. There is a need to complement these experiments with field studies, where realistic diurnal and seasonal temperature and radiation fluctuations occur. The aims of this study are to examine pasture responses in terms of productivity and quality to elevated CO_2 and increased temperature . This paper reports preliminary findings on growth of pure phalaris (*Phalaris aquatica* cv. Australian), subterranean clover (*Trifolium subterraneum* cv. Mt Barker), and mixed phalaris-clover swards grown in the field in Canberra, Australia, in temperature gradient tunnels under two temperature and two CO_2 regimes.

MATERIALS AND METHODS

Pure and mixed swards of phalaris and subterranean clover were established in six clear plastic-coated temperature gradient tunnels (modified from Rawson et al., 1995), which were configured to establish two distinct temperature zones. The experiment used a split-split plot design, with two CO_2 levels as the main effect, two temperature regimes as sub-plots and three species treatments as sub-sub-plots. There were three replications. CO_2 concentration averaged 380 ppm in the three 'ambient CO_2' tunnels and 690 ppm in the three 'elevated CO_2' tunnels. The two temperature regimes followed diurnal and seasonal temperature fluctuations. The 'cool' treatment, at the air intake end of the tunnel, was close to the ambient temperature. The 'warm' treatment at the outlet end was controlled to a target of 'cool' + 3 °C. The three species treatments were phalaris monoculture, clover monoculture, and a 50:50 mixture of these species on an area basis using a substitution design.

Seeds were sown on 14 December 1995 in rows 8.5 cm apart with a basal fertiliser application of superphosphate and molybdenum (27.5: 22.5: 0.075,S:P:Mo kg ha^{-1}). Swards were well watered and hand weeded for the duration of the experiment. Each temperature x CO_2 treatment area was 1.2 x 2.45 m and sampling area for each species plot was 0.85 x 0.4 m. Swards were harvested when the pasture reached a height of 15 cm on Jan 12, Jan 30, Feb 15, Mar 6, Apr 2 and May 15 (29, 47, 63, 83, 110, and 153 days after sowing). At each harvest, swards were cut 7 cm above ground level, separated by plant species, and dry weight determined.

RESULTS AND DISCUSSION

Average daily air temperatures (50 cm above the soil surface) in the 'cool' treatments for the six harvest periods were; 17.3, 20.5, 17.6, 17.9, 16.0 and 12.6°C. Daily temperatures in the 'warm' treatments averaged 3.0±0.3°C higher.

In general, clover growth was greater than phalaris growth and total productivity of the mixture was similar to that of pure clover swards (Figure 1). Clover growth responded significantly to elevated CO_2 in both the monoculture and the mixture, with an increase in cumulative biomass production of 40% by harvest 6 in the 'cool' treatment. However, the 'warm' relative to 'cool' temperature decreased the productivity of the pure clover sward at both CO_2 levels. At ambient CO_2 this increased temperature decreased clover production by 25% in the monoculture (Figure 1) and 47 % in the mixture (Figure 2). Clover growth rates in each treatment remained relatively constant until about the fifth period when both growth rate and temperature began to decline. The negative response to the 'warm' treatment is supported by Fukai and Silsbury (1976), who showed that growth rate of subterranean clover swards decreased as temperature increased from 15 to 30 °C. In this experiment, the negative effect on growth rate of higher temperature disappeared during period 5, when average temperature fell to 16°C.

Growth of pure phalaris swards did not respond to either increased CO_2 concentration or temperature alone, although the combination did result in a growth increase of 25% (Figure 1). Growth rates of phalaris in the monoculture and the mixture were greatest during the second growth period and declined after this due to nitrogen limitation (data not shown). Rawson (1992) and Cure et al. (1988) showed that CO_2 stimulation increased as nitrogen availability increased in cowpea and soybean, respectively. Therefore it appears that the lack of CO_2 response in the pure phalaris sward may be due to nutritional limitation. In the mixture, however, phalaris growth did improve where clover was less competitive in its demand for resources. In the cool, phalaris growth within the mixture increased by 65% due to elevated CO_2 (Figure 2). In the warm, ambient CO_2 treatment, poor growth of clover in the mixture enabled phalaris to capture more resources, doubling its growth so that it became 62% of total biomass compared to 30-34% in the other treatments.

Increased temperature and CO_2 concentration combined stimulated both clover and phalaris monocultures by 25% and the mixture by 37%. For clover and the mixture, this was a result of the positive effect of CO_2 and a negative effect of temperature on growth. For phalaris, a positive interaction occurred, with the combination of elevated CO_2 and increased temperature producing a much greater response than either CO_2 or temperature increase on their own.

Elevated CO_2 increased productivity of all swards in the 'warm' temperature treatments.

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Figure 1
Cumulative biomass removed from plots of pure clover, pure phalaris and mixed clover-phalaris swards over five months from sowing. Relative response to environmental conditions is shown where significantly different from the cool, ambient CO_2 treatment.

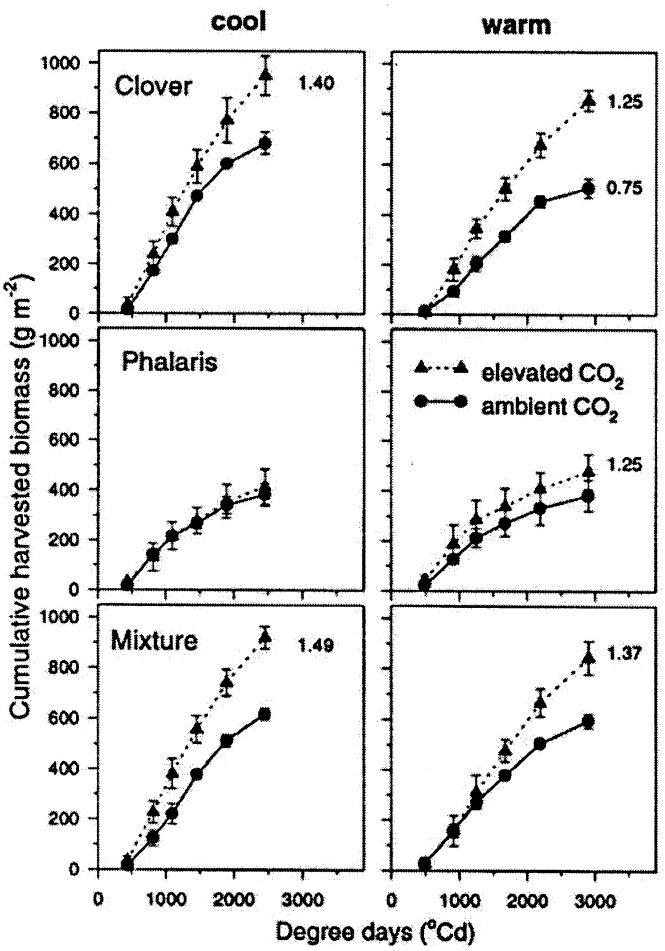

Figure 2
Species components and total cumulative biomass removed from plots of mixed clover-phalaris swards over five months from sowing. Response to environmental conditions is shown as a ratio to growth in the cool, ambient CO_2 treatment.