Productivity and nitrogen dynamics of pasture under warmer, high CO_2 conditions

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ABSTRACT

Pure and mixed swards of phalaris (*Phalaris aquatica*) and subterranean clover (*Trifolium subterraneum*) were exposed to 'field' (ambient) and warmed (field +3.4^{o}C) temperatures, at CO_2 concentrations of either 380 or 690 ppm in field tunnels for one year. In general, both herbage yield (above a 7 cm cutting height) and nitrogen (N) fixation by subterranean clover increased in response to elevated CO_2, but warming negated the stimulatory effect of CO_2 in pure swards. In contrast, herbage yield of the phalaris monoculture was not significantly affected by elevated CO_2 or by higher temperature. Nitrogen concentration of both phalaris and clover was decreased by elevated CO_2. The amounts of N fixed by clover ranged between 20 and 28 kg N per t clover dry matter, depending on treatment. The results suggest that the productivity of mixed swards will be higher under the predicted climatic changes in CO_2 and herbage N yield may be slightly higher.

KEY WORDS

Carbon dioxide, temperature, climate change, subterranean clover, phalaris, nitrogen fixation.

INTRODUCTION

Relatively little is known about the likely impacts of elevated CO_2 and temperature on pasture productivity and inter-specific competition or herbage nutritive value in mixed pasture swards, particularly for species of importance in Australia. The N dynamics of southern Australian farming systems are dominated by inputs of fixed N by pasture legumes (Peoples & Baldock, 2000), and it will be essential to be able to predict the response of legumes to environmental change before any long-term implications for livestock or crop production can be determined. This paper reports a study of the effects of elevated CO_2 and increased temperature on pasture growth and N dynamics, using the most important and widely distributed pasture legume in Australia, subterranean clover, either grown separately or in combination with phalaris. Such mixed perennial grass-legume swards represent over 40% of the areas of improved pastures sown in south-eastern Australia (Australian Bureau of Statistics, 1998). Experiments were conducted in the field, using six temperature gradient tunnels under realistic daily and annual temperature and radiation fluctuations. Two temperature and two CO_2 regimes, were imposed in a split-split plot design with CO_2 as main plots (whole tunnels), temperature as subplot (tunnel sections), and with three replications. Average CO_2 concentrations for the period were 380 and 690 ppm, while warming raised air temperature 3.4^{o}C and soil temperature 1.9^{o}C. Each temperature x CO_2 subplot was further split into three sward types. These were phalaris monoculture, clover monoculture, and a 50:50 mixture of these species on an area basis using a substitution design. Plots were sown on 15 December 1995 and herbage (biomass above a 7 cm cutting height) was sampled at 16 to 71 day intervals, depending on growth rate, until 26 November 1996. Data are presented for cumulative herbage over the period.

RESULTS

Pure clover and the mixture had similar herbage productivity, while pure phalaris was less productive (Fig. 1). Elevated CO_2 increased clover foliage growth (cumulative herbage cut above 7 cm) by 19% in the monoculture and by 31% in the mixture relative to the ambient CO_2 treatment. Warming reduced clover monoculture herbage at ambient CO_2 by 28% and reduced the growth enhancement by elevated CO_2 to 8%. In contrast, growth of the phalaris monoculture was not significantly affected by elevated CO_2 or by higher temperature. Clover dominated the mixture, except at warm temperature and ambient CO_2 where clover growth was weak but the phalaris component increased such that overall growth rate of the mixture

was maintained. Herbage yield of the mixture was increased by 34% in response to higher CO_2, but was unaffected by warming, while elevated CO_2 combined with warming increased herbage yield by 23%.

Nitrogen concentration (data not shown) and total N-yield (Fig. 2) of both phalaris and clover were decreased by elevated CO_2. Warming increased N concentration of phalaris at ambient CO_2, but not at elevated CO_2, and this resulted in a small increase in total N yield. There was no effect of warming on N concentration in clover. No treatment effect was observed on soil N uptake by clover (Fig. 2). However, elevated CO_2 increased the proportion of clover N derived from N_2 fixation from 60 to 70%, while warming at ambient CO_2 decreased it to 50%. Clover reliance upon N_2 fixation for growth in the mixture followed the same response to treatments as the monoculture, but was approximately 10% greater overall. The contribution of fixed N in cut herbage ranged between 20 and 28 kg N per t clover biomass, depending on treatment. Total N uptake directly from the soil was higher in the mixture than either monoculture; however, total N yield (including fixed N) was greater in the clover monoculture than the mixture.

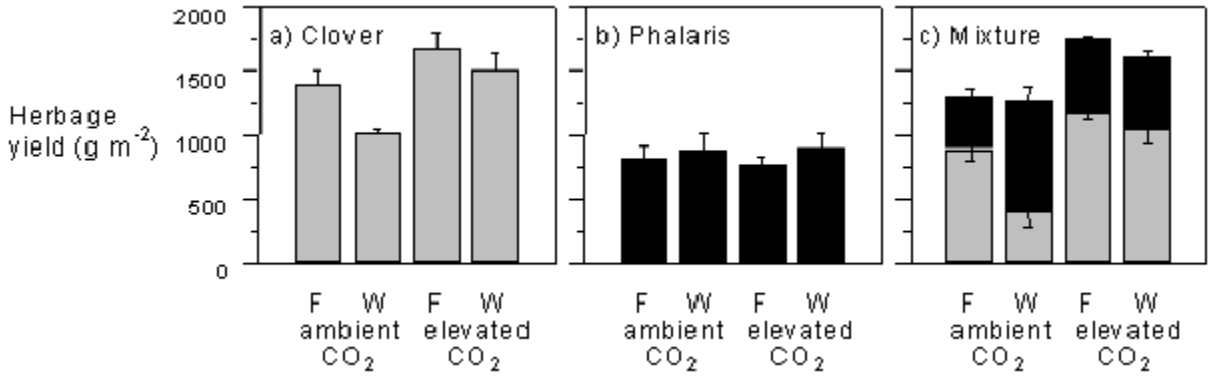

Figure 1. Total herbage (biomass above the 7 cm cutting height) (g m^{-2}) removed between 15 December and 26 November for a) clover monoculture, b) phalaris monoculture, and c) mixed sward of phalaris and clover, separated into clover (grey) and phalaris (black) components. Temperature treatments are denoted F - field temperature and W - warmed treatment.

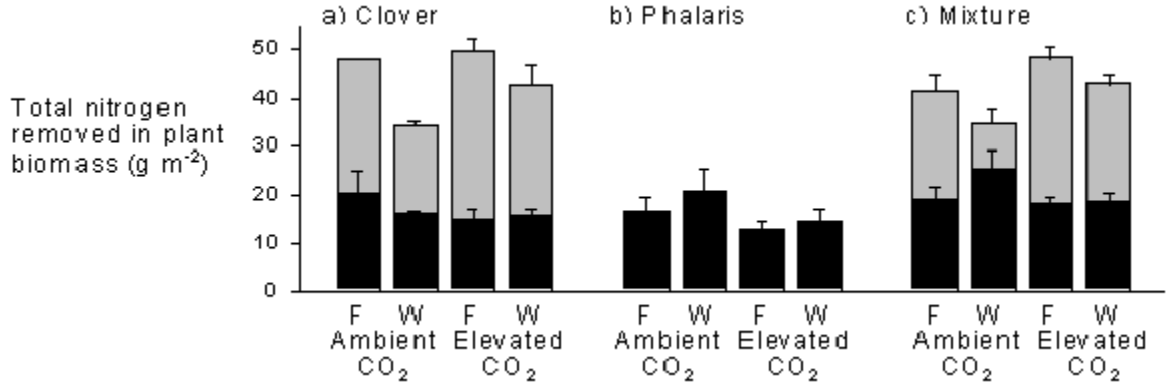

Figure 2. Total nitrogen (g m^{-2}) in harvested biomass of a) clover monoculture, b) phalaris monoculture and c) mixed pasture swards grown during the period from 15 December to 26 November. Black bars indicate N acquired from the soil and grey bars indicate atmospherically fixed N.

CONCLUSIONS

On the basis of the current study, the predicted effects of warmer, higher CO_2 conditions are an increase in herbage yield for mixed swards of temperate species. Total N yield of herbage may be slightly higher

for subterranean clover-phalaris mixtures, but there might be little change if increased CO_2 concentration is accompanied by a warming of 3-4 ^{o}C. Longer-term studies are required to assess the effects of climate change on persistence of pasture species and the competitive interactions between the species in subsequent years.

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