Separating species and functional group diversity effects on plant tissue chemistry and biomass production under elevated CO_2 in a grassland ecosystem

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Background/ Introduction:

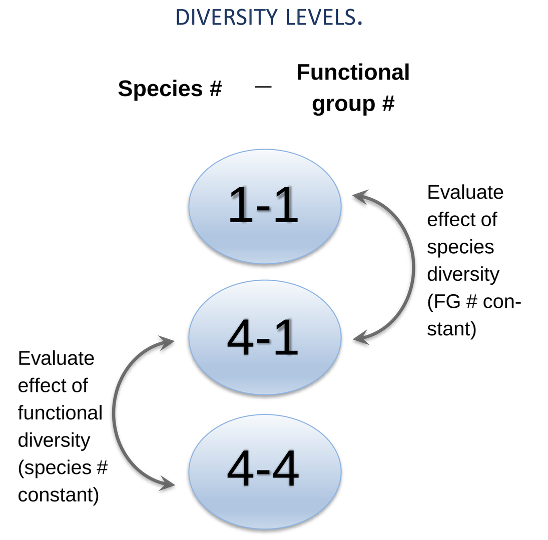
Our planet is undergoing environmental change at an accelerated rate. Increases in atmospheric CO_2 concentrations are increasing global temperatures and biodiversity is being threatened by habitat loss and exploitation. A decrease in tissue nitrogen (N) concentration is a common response of plants when grown under elevated CO_2 (eCO_2)[1], which can limit other aspects of ecosystem function such as herbivore success[2] and N cycling[3]. Ecosystem responses to eCO_2 have been found to differ depending on the number of species present (*species diversity*) and/or the functional attributes (such as differing photosynthetic pathways or N-fixing ability) of the species present (*functional diversity*). For example, higher species diversity and functional diversity each independently resulted in increased biomass under eCO_2 conditions compared to lower diversity assemblages in a grassland ecosystem[4].

Objective:

Species and Functional Group Diversity in a Changing Climate

To tease apart the relative effects of species and functional diversity on species-level responses to eCO_2, I evaluated leaf N concentrations of species representing three functional groups (C3 grasses, C4 grasses, and N-fixers) at ambient and eCO_2 and when grown in monoculture or 4-species plots of a single functional group (independent effect of *species diversity*) or when grown in 4-species plots with 1 or 4 functional groups (independent effect of *functional diversity*) to test the hypothesis that individual species show less eCO_2-induced decline in tissue N when grown in more diverse plots, especially those that are more functionally diverse. (Fig. 1)

Fig. 1 Experimental design concept. Arrows address the objectives of study between diversity levels.



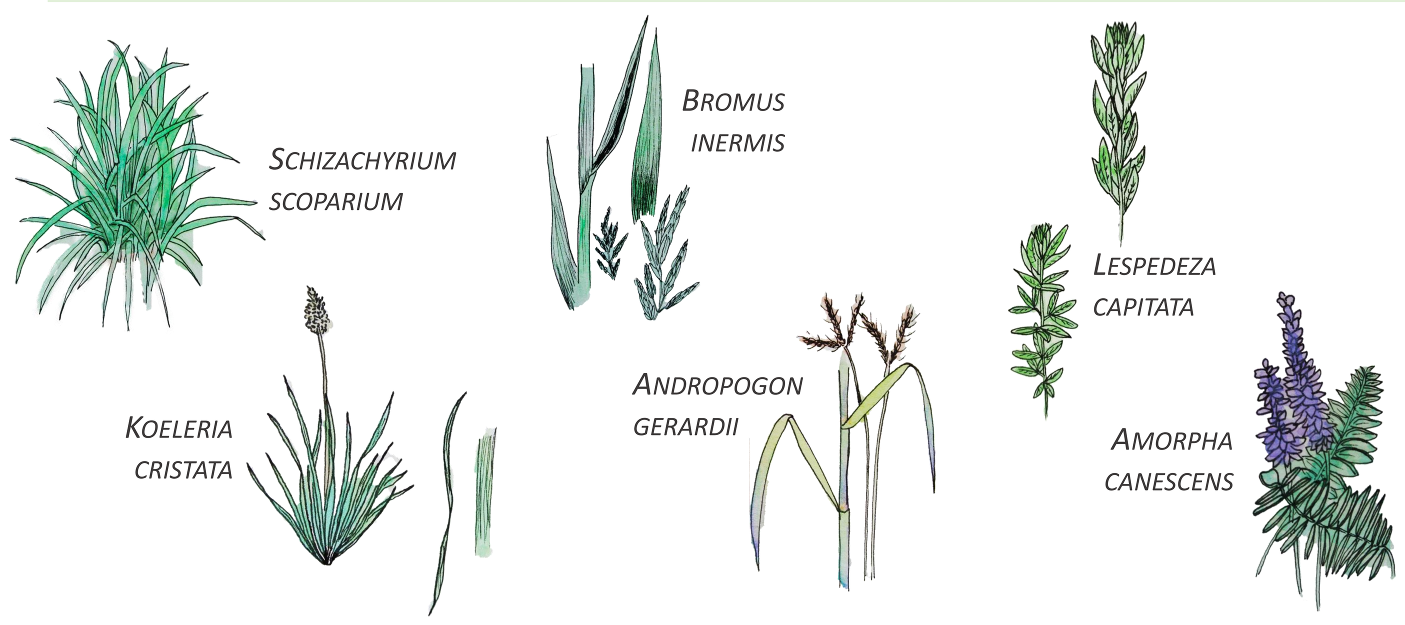
Aerial view of a section of BioCON long-term grassland experiment. Plots surrounded by CO_2 emission risers.

Table 1

Species	Functional Group	Attributes
Bromus inermis *Andropogon gerardii*	C3 Grasses	use C3 photosynthetic pathway, aka. cool season grasses
Koeleria cristata *Schizachyrium scoparium*	C4 Grasses	use additional C4 photosynthetic pathway, aka. warm season grasses
Amorpha canescens *Lespedeza capitata*	N - fixers	fix atmospheric N_2 symbiotically with bacteria in roots

Methods:

- This study took advantage of a long-term grassland global change study in its twentieth year (BioCON, http://www.biocon.umn.edu/).
- Two species from three functional groups (Table 1) were sampled at both ambient (~405 ppm) and elevated (585 ppm) CO_2 levels.
- Upper fully expanded leaf tissue was sampled from three randomly chosen plants of each species growing in 2 x 2 m plots of varying species and functional diversity (Fig.1)
- Leaves were dried and homogenized before tissue N was determined using an elemental analyzer.
- Plot-level total biomass and soil N availability were also evaluated to assess species responses in the larger context in which they were grown.



Drawings done by 2018 Cedar Creek Ecosystem Science Reserve intern, Brynn Rhode

Results:

Diversity effects on Tissue N at a species level

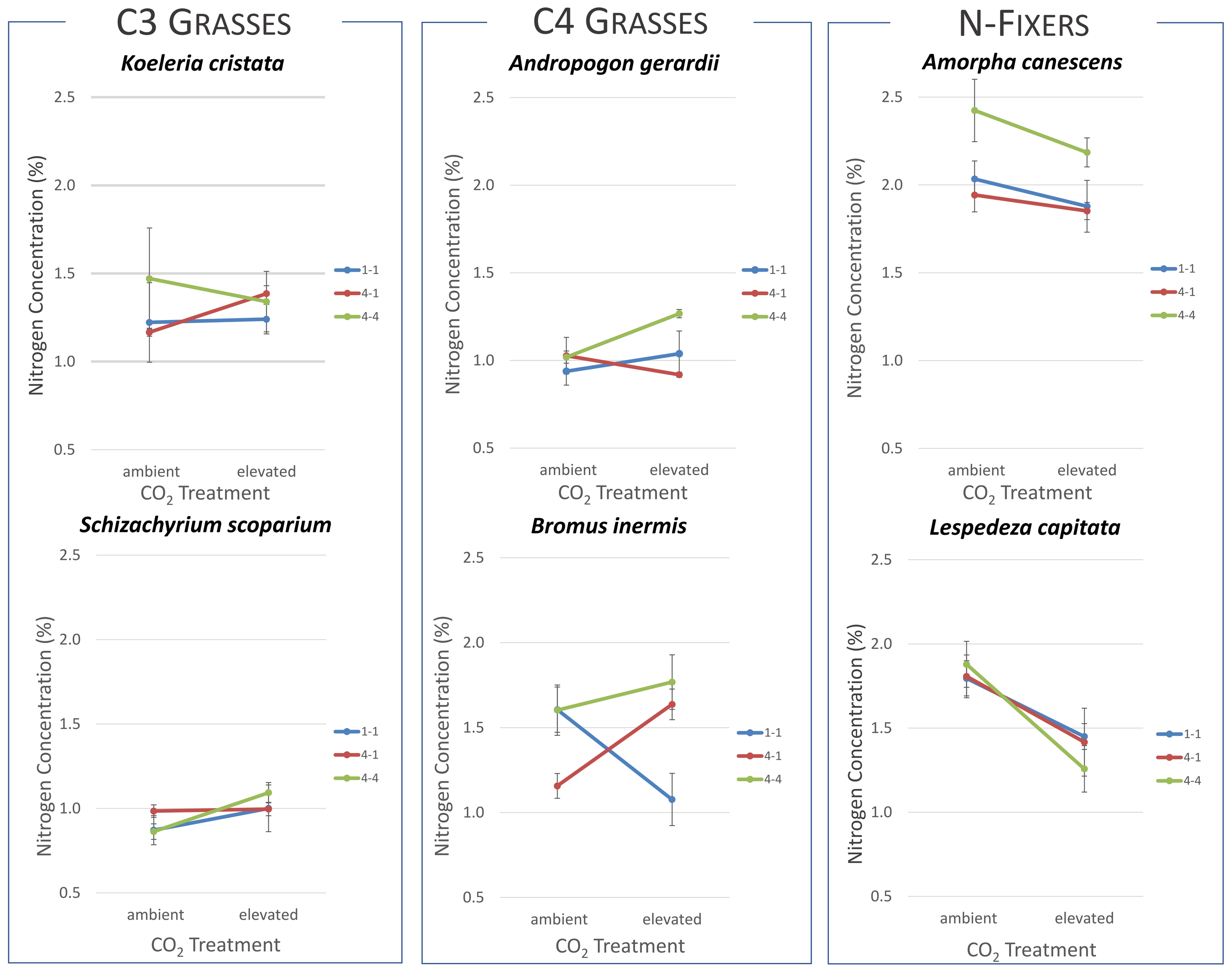
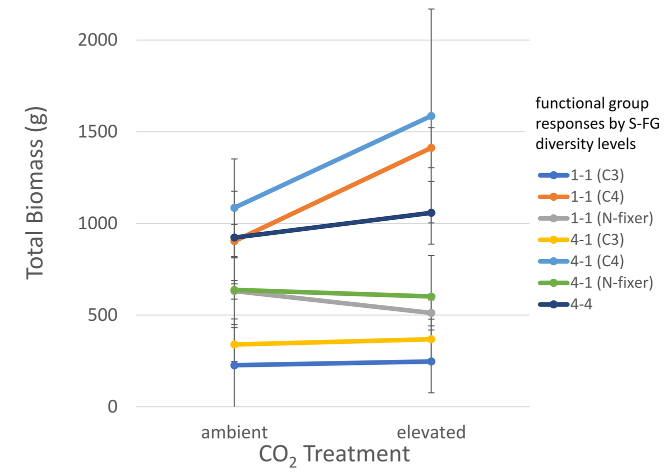


Fig. 2 Mean leaf tissue nitrogen concentration (%, ±SE) of plants growing in ambient and elevated CO_2. Two species representing each functional group (n=3). Legend shows diversity treatments (Species #- Functional Group #).

Leaf tissue N concentration was overall lower under eCO_2 grown plants, but this response was inconsistent across functional group (FG*CO_2 $p=0.0032$, ANOVA) and diversity treatment. N-fixers showed the most consistent response of eCO_2-induced lower N concentration. Across species, leaf N was highest in the most functionally diverse plots (diversity $p=0.0142$).

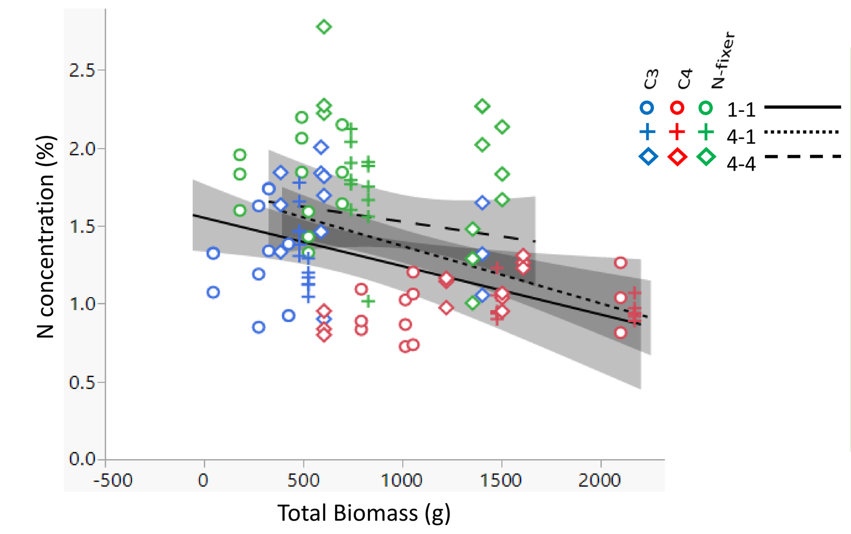
Diversity & Functional Group Level Biomass Effects



Plots with only C4 species had highest biomass overall and greatest positive responses to eCO_2. Of the remaining, biomass was highest in functionally diverse plots and interestingly, plots with only N-fixers grew less under eCO_2.

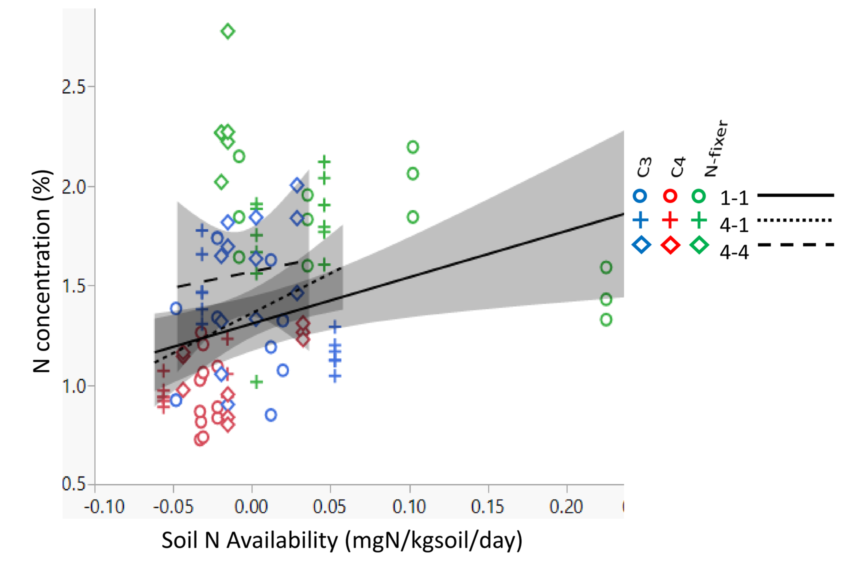
Fig. 3 Mean Total biomass (±SE) of plants growing in ambient and elevated CO_2. Legend shows diversity treatments (Species #- FG#) by functional group (C3, C4 grasses and N-fixers). Two species represent each functional group (n=3).

Plot by Species Level Relationships



As plot biomass increased, individual plant %N decreased, suggesting intensified competition. However at any given biomass, plants in the most functionally diverse plots had the highest %N.

Fig. 4 Mean leaf tissue nitrogen concentration (%) by total biomass (g) of corresponding plot. Shaded areas represent 95% confidence intervals. Two species represent each functional group (n=12).



As plot soil N availability increases, individual plant %N increases. At any given soil N availability, plants in the most functionally diverse plots have the highest %N. Most figure outliers are N-fixers, which overall have highest %N of the functional groups.

Fig. 5 Mean leaf tissue nitrogen concentration (%) and soil nitrogen availability (mgN/kgsoil/day) of corresponding plot. Shaded areas represent 95% confidence intervals. Two species representing each functional group (n=12).

Discussion:

Only the N-fixing species showed the expected elevated CO_2-induced reduction in leaf N concentrations and this was comparable across species-functional group diversity levels. There was little evidence that the response of these species to eCO_2 depended on level of diversity (which did not support my hypothesis). However across species, those growing in the functionally diverse plots maintained the highest leaf N and those in single species plots the lowest leaf N across CO_2 treatments. This would suggest that community and ecosystem functions that are related to the tissue chemistry of the vegetation (such as herbivore success[2] and N cycling[5]) depend on diversity and improve when higher diversity includes greater functional group richness.

Literature cited:

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