Plant biomass and reproduction responses to elevated atmospheric CO_2 and N in a large-scale grassland field study

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Introduction & Objective

Carbon dioxide (CO_2) and soil nitrogen (N) are vital for plant growth, but anthropogenic emissions of CO_2 and the use of N fertilizer are altering the cycling of these elements. In 2013, atmospheric carbon dioxide levels exceeded 400 parts per million (ppm) (NASA 2016), which have steadily increased from pre-industrial revolution levels of about 280 ppm (IPCC 2007). Plants that are more responsive to elevated CO_2 levels will likely have greater abundance, possibly outcompete other species, and shift community structure and function (Ali et al. 2013).

C4 grasses have additional biochemical steps in carbon fixation than C3 grasses, and these steps are considered an adaptation to arid environments (Wand et al. 1999). C4 grasses commonly have a higher photosynthetic rate per unit N than C3 grasses (Sage & Pearcy 1987) and thus require less N during energy production. Therefore, C4 plants may have distinctive responses compared to C3 plants in the face of global change.

OBJECTIVE: Our objective was to investigate growth and reproductive responses of focal C3 and C4 prairie grasses to differing CO_2 concentrations and soil nitrogen levels to reveal possible mechanisms behind species dynamics in future climate scenarios.

Hypotheses

1. Elevated CO_2 will increase biomass and reproductive output of the C3 more than the C4 species and these increases due to elevated CO_2 will be greater at elevated N compared to ambient N.
2. Response to elevated N treatment will increase biomass of all species.
3. Elevated N treatment will increase relative abundance of C4 species more than C3 species.

Materials and Methods

- Experiment site: Cedar Creek Ecosystem Science Reserve's BioCON experiment in East Bethel, MN (http://www.biocon.umn.edu/), Summer 2015.
- The experimental design had a factorial combination of CO_2 (ambient, ambient +200ppm) and soil N (ambient, ambient +4 $gNm^{-2}y^{-1}$) treatments.
- We chose four focal species of common prairie plants; *Agropyron repens* (C3), *Bromus inermis* (C3), *Andropogon gerardii* (C4), and *Schizachyrium scoparium* (C4), grown in 2x2 m^2 plots of either monoculture or 16 species mixtures.
- We evaluated growth as total aboveground biomass and relative abundance as percent cover of species.
- Reproductive output was evaluated as mean dispersule mass.
- Analysis of Variance (ANOVA) statistical tests were conducted in JMP v7 (SAS Institute, Cary NC) and R 3.1.1 (R Foundation for Statistical Computing, Vienna Austria). P-values ≤ 0.05 were interpreted as indicating significant treatment effects.

Figure 1.

Relative Abundance
16 Species Plots (by species)

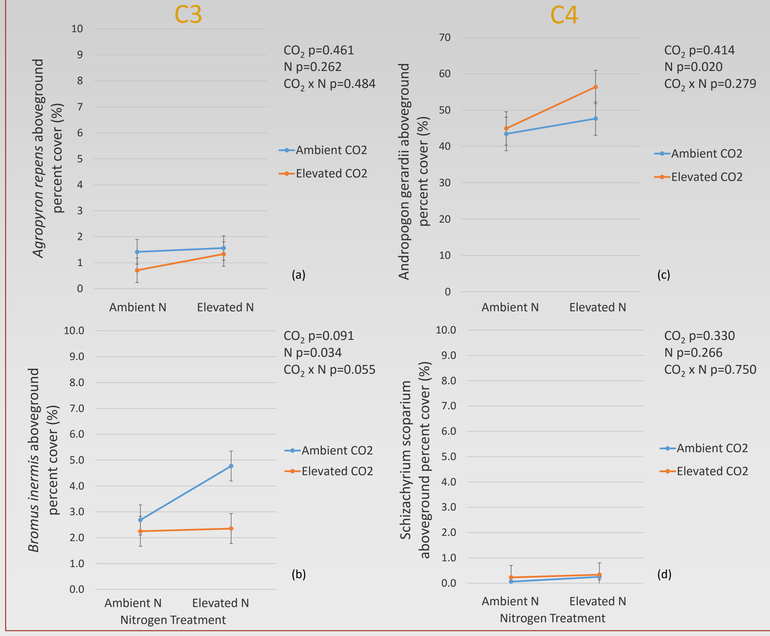
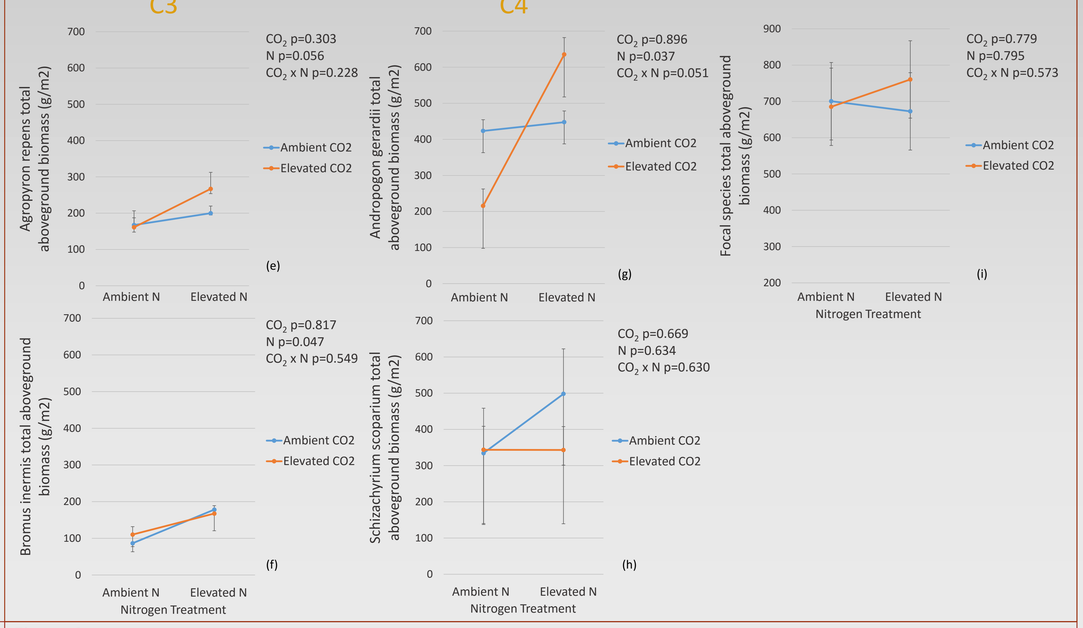


Figure 2.

Total Aboveground Biomass (Growth)
Monoculture Plots
16 Species Plots



Results & Discussion

- Figure 1. Relative abundance of all species were not affected by elevated CO_2, however, relative abundance of *A. gerardii* (c) and *B. inermis* (b) both increased under elevated compared to ambient N ($p < 0.05$) and for *B. inermis*, this effect was greatest under ambient CO_2.
- Figure 2. All species in general accumulated more aboveground biomass (growth) at elevated compared to ambient N when grown in monoculture and for *A. gerardii* this increase was significantly greater under elevated CO_2. Total aboveground growth of 16 species plots were not affected by N or CO_2 treatments.
- Figure 3. CO_2 and N treatments did not affect reproductive output of any of the focal species in monoculture or 16 species mixtures (j – i).

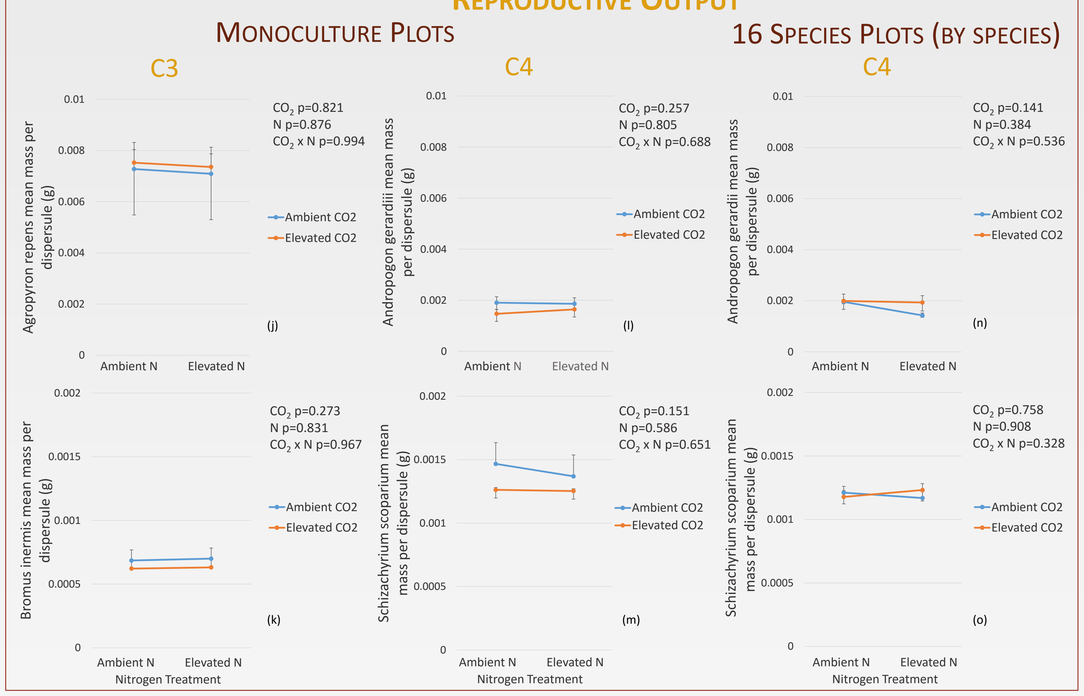
Elevated N promoted increased growth in three of the four species which translated to increased relative abundance in two species, a C3 and a C4. This result does not support hypothesis 1. Instead, it suggests functional traits other than the C3/C4 photosynthetic pathway appear to be more important in determining responsiveness to increased N availability.

A. gerardii clearly dominated the 16 species mixtures with a tenfold larger relative abundance amount of 50% compared to *B. inermis* and other focal species being infrequently present at 1 – 3%. As a C4 species, *A. gerardii* supports hypotheses 2 & 3. The stronger response of *A. gerardii* to elevated N seen at elevated CO_2 suggests that *A. gerardii* will continue to dominate communities under future global conditions.

Surprisingly, overall elevated CO_2 had minimal impact on measured responses. While reproductive output was similar across treatments, potential responses of germination and seedling traits are still being determined.

Figure 3.

Reproductive Output
Monoculture Plots
16 Species Plots (by species)



Conclusion

Our results suggest increasing global N availability may be the most significant factor altering species dynamics, presumably changing landscapes and ecosystem functioning.

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Seedheads of *Agropyron repens* (top left), *Andropogon gerardii* (top right), *Bromus inermis* (bottom left), and *Schizachyrium scoparium* (bottom right). The picture of *Agropyron repens* is courtesy of www.cedarcreek.umn.edu

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