Warming promotes cheatgrass invasion in mixed-grass prairie

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INTRODUCTION

Cheatgrass and global change

Cheatgrass (*Bromus tectorum*) is one of the most problematic invasive species in the western U.S., and may become even more problematic with global change (Bradley *et al.* 2009):

Elevated CO_2

- Greatly increases cheatgrass biomass and seed set in controlled environments (Smith *et al.* 1987, Ziska *et al.* 2005).
- Increases growth of the closely related grass *Bromus rubens* relative to native species in Nevada desert (Smith *et al.* 2000).

Warming

- Favors cheatgrass in wet years and inhibits cheatgrass in dry years in Utah desert (Zelikova *et al.* 2013).
- Could expand cheatgrass range in parts of Wyoming (Bradley *et al.* 2009).

The Mixed-grass Prairie is the largest remaining native grassland in the Great Plains, representing 38% of the grassland area in North America (Lauenroth 1979). Cheatgrass is abundant, but currently less invasive than in ecosystems with more winter precipitation. Increases in its abundance would greatly decrease economic productivity and biological diversity of mixed-grass rangelands.

OBJECTIVE: Learn how CO_2 and warming influence cheatgrass

In semi-arid ecosystems warming and elevated CO_2 can influence invasion both directly and indirectly, by changing water availability (Morgan *et al.* 2011, Blumenthal *et al.*, in press).

METHODS

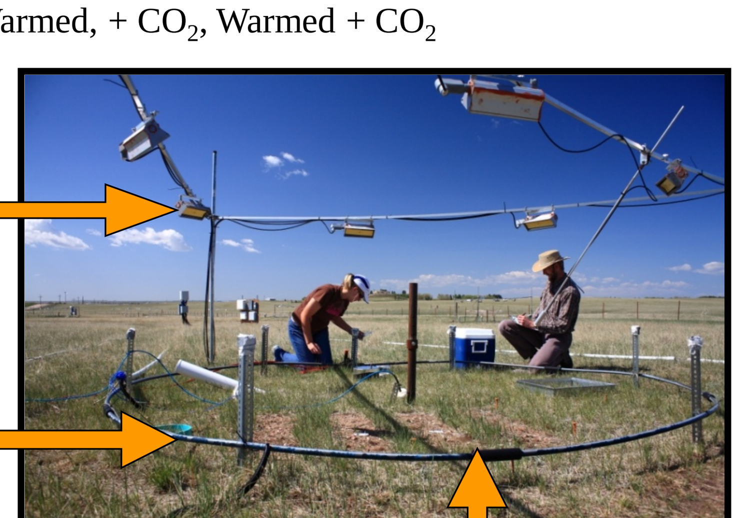
Manipulating CO_2 and temperature

The Prairie Heating and CO_2 Enrichment experiment located in southeastern WY. Annual precipitation: 458 mm. **(http://www.phace.us/).**

5 replications: Control, Warmed, + CO_2, Warmed + CO_2

Ceramic heaters (started May 2007)
+ 1.5°C day
+ 3°C night

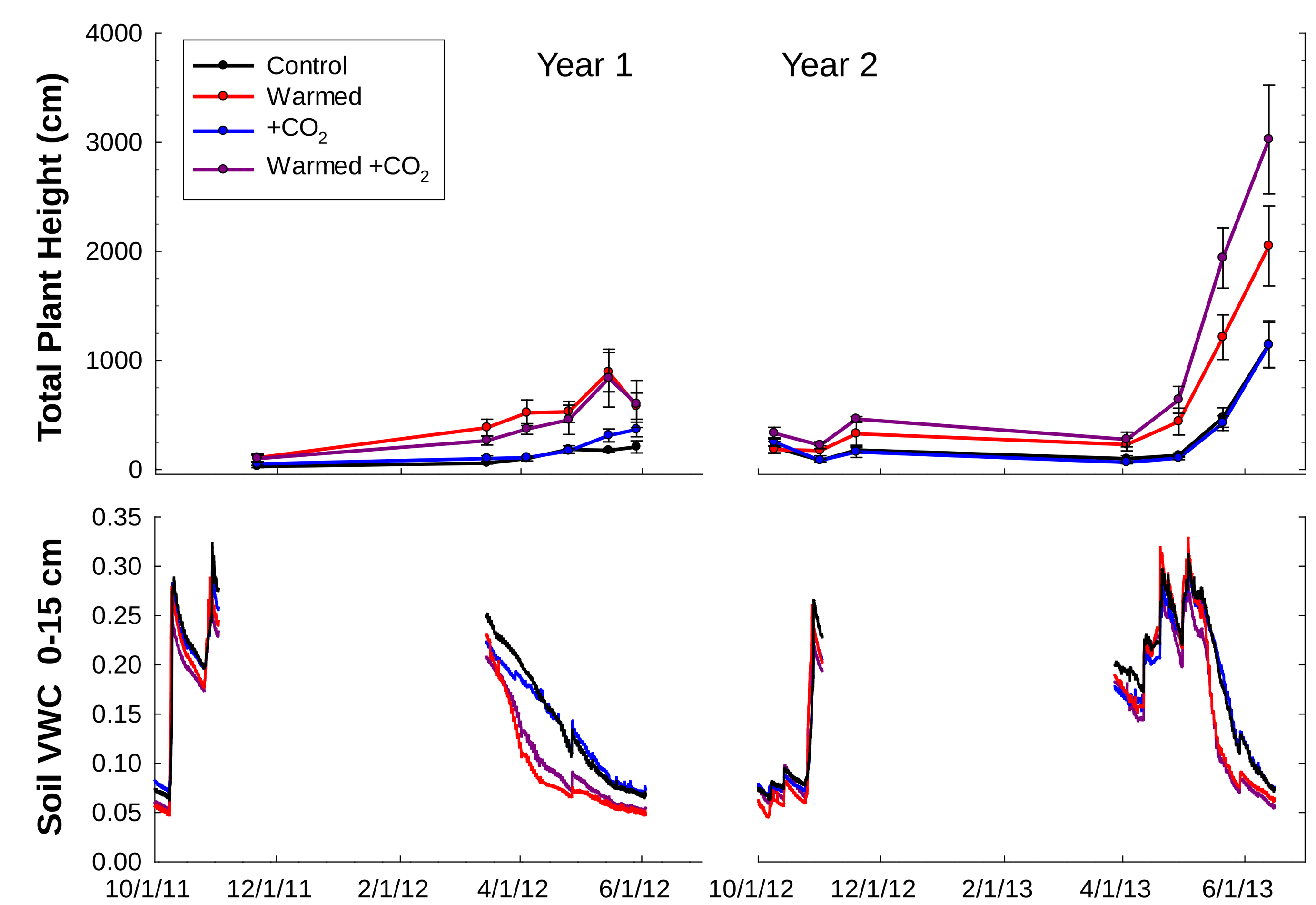
Free air CO_2 enrichment
(Started May 2006)
Ambient: 380 ppm
Elevated: 600 ppm



Cheatgrass experiment:
70x50 cm plot with center 30x50 cm strip treated with glyphosate.
Seed added (23 g/m²) to the entire plot in August of 2011 and 2012.

RESULTS

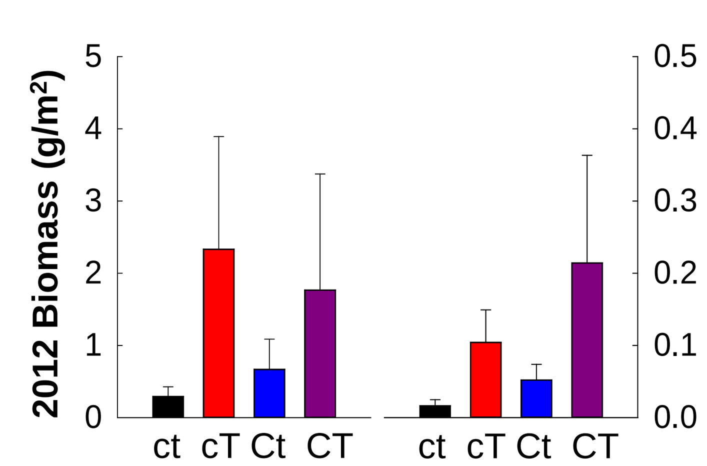
Cheatgrass likes warming



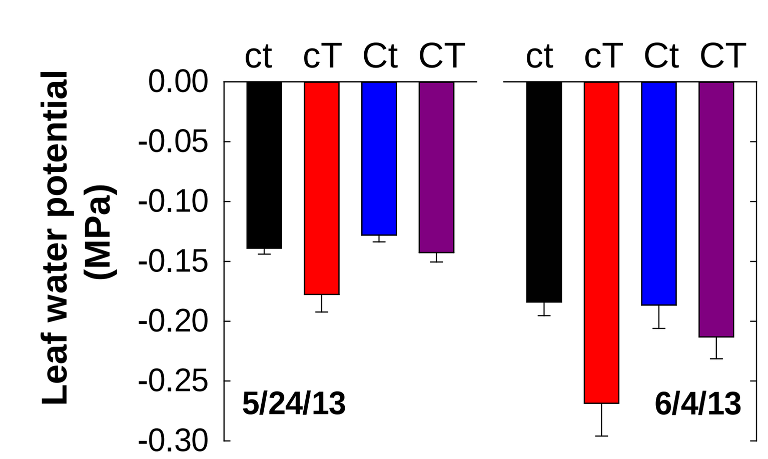
Warming favored cheatgrass growth in both years (p=0.003, p=0.001). In year 2, apparent effects of CO_2 in warmed plots were not significant (p>0.18).

11/2/12 5/6/13 6/7/13

Year 2: a. Photographs of treatment effects. **b.** Caterpillars (likely saltmarsh caterpillars, *Estigmene acrea*) provided an unplanned herbivory treatment, reducing biomass outside of gas exchange PVC collars.



Year 1: Although biomass was 10-fold greater in disturbed than in undisturbed areas (note different scales), disturbance did not alter the warming effect (p=0.006). Treatment codes: Control (ct), Warmed (cT), + CO_2 (Ct), Warmed + CO_2 (CT).



Year 2: Temperature increased cheatgrass water stress (p<0.02, both dates), and CO_2 alleviated water stress at the earlier date (p=0.02). Treatment codes: Control (ct), Warmed (cT), + CO_2 (Ct), Warmed + CO_2 (CT).

DISCUSSION

Decreased temperature limitation in fall/spring

- **Warming** strongly increased cheatgrass growth, both in a year with an unusually dry spring and in a year with a wetter spring. These results are largely in accord with previous studies showing that warming may favor cheatgrass under wet conditions in the (generally drier) Utah desert, and could allow cheatgrass to expand its range in parts of western Wyoming (Bradley *et al.* 2009, Zelikova *et al.* 2013).
- **The mechanism** underlying warming effects appears to be more rapid germination and growth during the late fall and early spring. Such fall-winter growth may allow cheatgrass to grow larger before senescing or encountering competition from perennial grasses (although warming effects were similar with and without removal of perennial species). Increased growth despite decreased soil water and increased water stress suggests that temperature can limit cheatgrass more than water in northern mixed-grass prairie.
- **Elevated CO_2** had little effect on cheatgrass, despite alleviating water stress. This is surprising in light of previous work in controlled environments and with similar species (Smith *et al.* 1987, Smith *et al.* 2000, Ziska *et al.* 2005). Positive effects of CO_2 on cheatgrass may be limited by lower N availability (Dijkstra *et al.* 2010), and the timing of soil water increases, which are strongest in mid summer when cheatgrass is not active.

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