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Effects of Elevated Carbon Dioxide Concentration on Kentucky Bluegrass Response to Heat and Drought stress

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Introduction

- Atmospheric CO_2 levels have been increasing and are predicted to continue rising, which was found to promote plant growth in many cool-season plant species under favorable environmental conditions (Kirkham, 2011).
- Cool-season turfgrass species often suffer from heat stress and drought stress, exhibiting growth inhibition and turf quality decline (Fry and Huang, 2004) .
- Limited information is available on the interactive effects of elevated CO_2 and abiotic stresses, such as heat and drought, particularly in perennial grass species, such as used as turfgrass. In addition, mechanisms of CO_2-regulation of cool-season grass tolerance to heat and drought stress are not well understood.

Objectives

- To examine whether elevated CO_2 levels may promote Kentucky bluegrass tolerance to heat and drought stress.
- To determine whether elevated CO_2-regulated heat and drought tolerance was associated with improvement in carbon balance and metabolism.

Materials and Methods

Plant Materials and Growing Conditions

Kentucky bluegrass (cv. 'Baron') plants

- Propagated in pots filled with fritted clay for 38 d establishment
- Trimmed weekly to maintain at 10 cm canopy height
- Irrigated every two days
- Fertilized every three days with half-strength Hoagland's nutrient solution

Treatments

- CO_2 levels: 400 ± 20 ppm (ambient) or 800 ± 20 ppm (elevated)
- Temperature levels: 20/15 °C (control, C) or 35/30 °C (heat stress, H)
- Irrigation levels: watering at 100% of evapotranspiration rate (100% ET control, C) or watering at 50% ET rate (50% ET, drought, D)
- Combined heat and drought: 35/30 °C (heat stress, H) and watering at 50% ET rate (50% ET, drought, D)

Experimental Design and Statistical Analysis

Split-plot design

- CO_2 treatments as main plots
- Heat and drought stress as sub-plots

Four replicate plants per treatment

Treatment effects analyzed by ANOVA using SAS 9.2. LSD means tested at P<0.05 level

Automated CO_2 controlling system

Measurements

- Turf quality (TQ)
- Root/shoot biomass ratio
- Root and shoot dry weight
- Single-leaf net photosynthetic rate using LI-6400 gas analyzer
- Single-leaf respiration rate -LI-6400 gas analyzer

References

Fry, J.D. and B. Huang. Applied turfgrass science and physiology. Wileys, New York.
Kirkham, M.B. 2011. Elevated carbon dioxide: impacts on soil and plant water relations. Boca Raton, FL: CRC Press.

Results and Discussion

Effects of elevated CO_2 on turf quality responses to drought, heat and combined drought and heat stress

Fig. 1

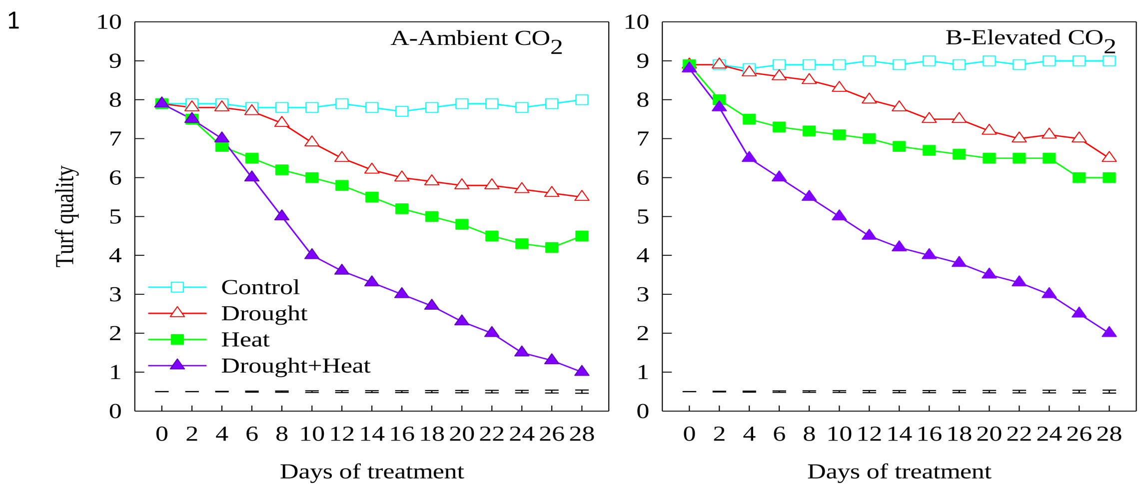


Fig. 2

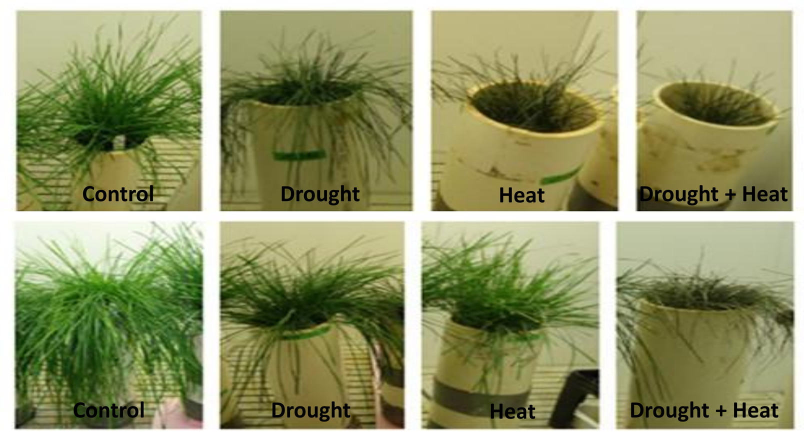
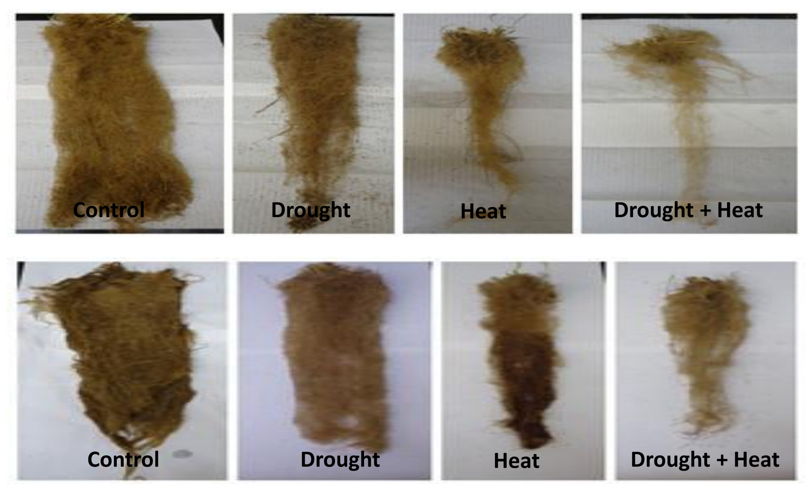


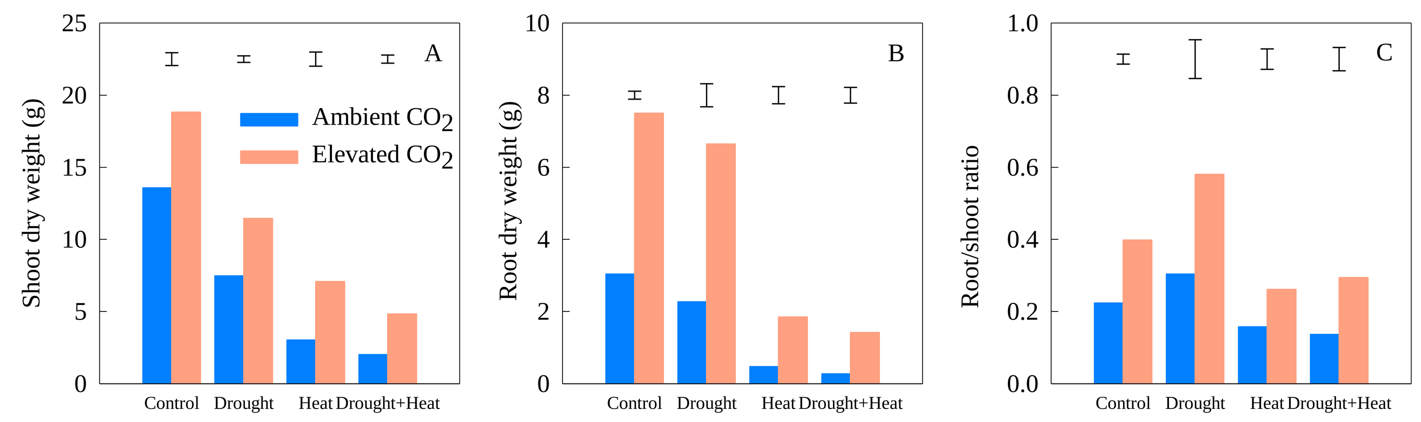
Fig. 3



- Turf quality (TQ) declined significantly with drought (D), heat (H) and D+H under both ambient and elevated CO_2. D+H was detrimental than either stress alone.
- Elevated CO_2 suppressed the decline or enhanced TQ under all three stresses, particularly effective for plants exposed to D+H (Fig. 1 and 2).

Effects of elevated CO_2 on shoot biomass, root biomass, and root/shoot ratio under drought, heat and combined drought and heat stress

Fig. 4



- Total shoot and root dry weight decreased under D, H, and D+H, to a greater extent at D+H.
- Root/shoot ratio increased under D, but decreased under H and D+H.
- Elevated CO_2 increased both shoot and root dry weight under all treatments, and resulted in significantly lower root/shoot ratio, particularly under D+H (Fig. 3 and 4)

Effects of elevated CO_2 on single-leaf photosynthetic rate (Pn), single-leaf respiration rate (R), and carbon balance as the ratio of Pn/R under drought, heat and combined drought and heat stress

Fig. 5

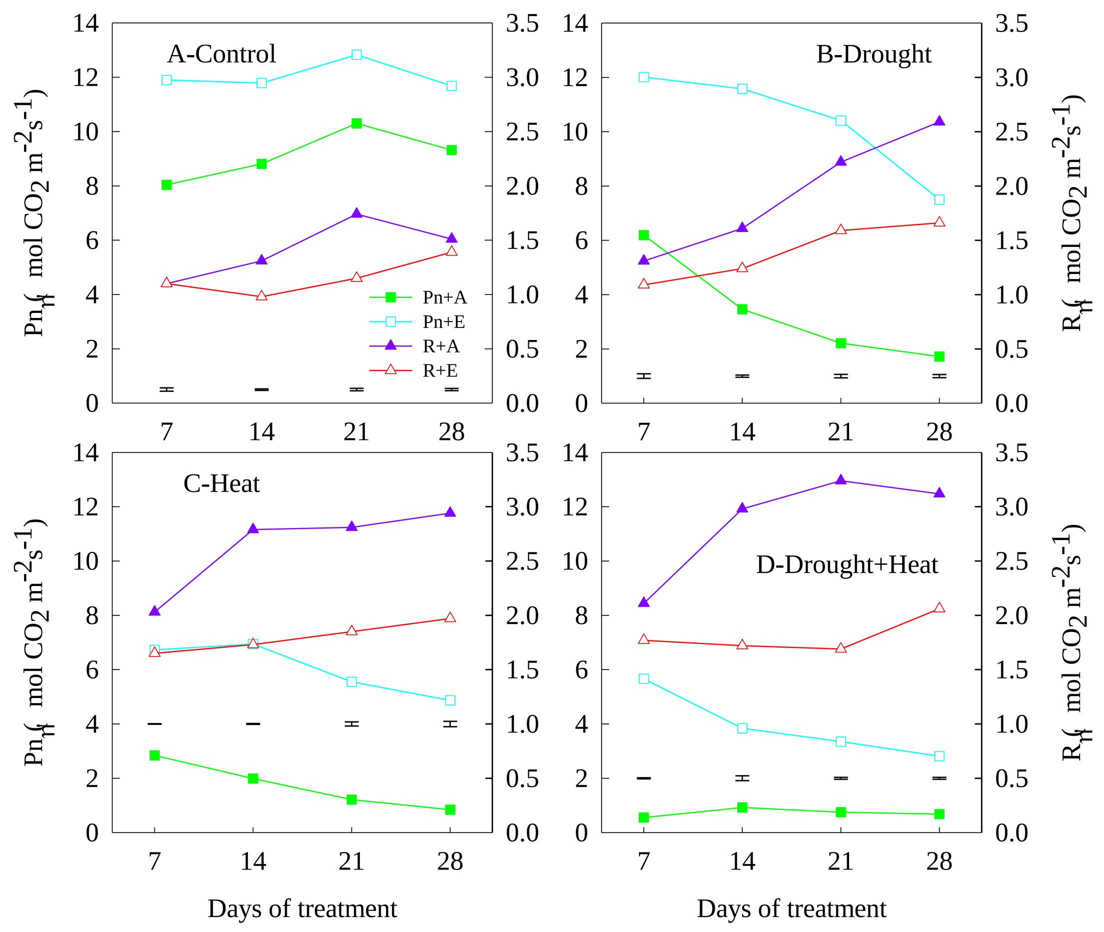
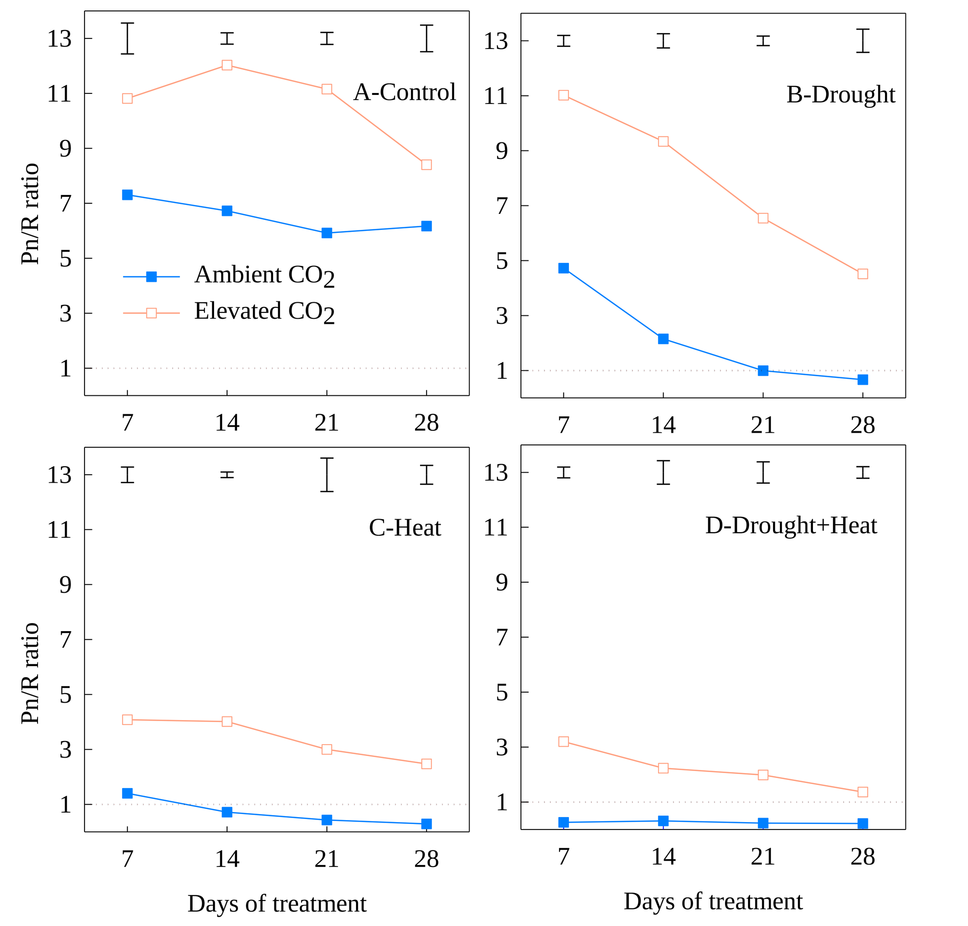


Fig. 6



- Drought, heat, and D+H inhibited Pn but enhanced respiration rate (Fig. 5), causing carbon deficit, as shown by Pn/R ratio less than 1.0 after 21 d of D, 14 d of H, and 7 d of D+H under ambient CO_2 conditions (Fig. 6).
- Elevated CO_2 enhanced Pn but suppressed R (Fig. 5), leading to a positive carbon gain or greater than 1.0 Pn/R under all treatments (Fig. 6).

Conclusions

- Single or combined drought and heat stress caused imbalanced photosynthesis and respiration, which may contribute to the decline in turf quality and shoot and root biomass, but the combined stress was more detrimental than either stress alone.
- Elevated CO_2 promoted Kentucky bluegrass tolerance to drought, heat, and combined stress, and was particularly effective for promoting tolerance to the combined stress.
- Elevated CO_2-enhancement in stress tolerance could be associated with the maintenance of a positive carbon balanced due to increases in photosynthesis and suppression of respiratory carbon consumption.