Smaller than expected increases in integrated photosynthesis and biomass for plants grown at elevated CO_2 and temperature under fully open air CO_2 fumigation

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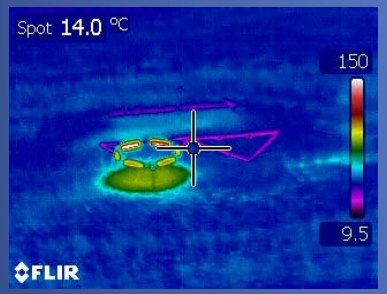
INTRODUCTION

-By 2050, land-surface mean temperature could rise 3.5°C and the CO_2 concentration could increase to 550 µmol mol^{-1} (IPCC - Intergovernmental Panel on Climate Change) leading to environmental changes that could significantly impact agro-ecosystems, particularly the maize-soybean ecosystem, which represents the largest continuous ecosystem type in temperate North America.

-For soybean, it has been demonstrated that elevated CO_2 concentrations improve water use efficiency, raise leaf photosynthesis levels and increase yield. Also, some theoretical and modeling studies have indicated that elevated temperature and CO_2 concentration could increase net leaf photosynthesis, despite the increased respiration.

-However, it is not clear how the interactions of CO_2 and temperature will affect plant productivity and fitness in open air field conditions. In order to study their interactive effects, the **T-FACE (Temperature by Free Air CO_2 Enrichment)** experiment was designed to expose soybean and corn to growth at elevated temperature and [CO_2].



OBJECTIVES

To understand the physiological responses and subsequent impact on carbon cycling for soybean grown in elevated [CO_2] and temperature in order to estimate the agronomic and ecological consequences.

EXPERIMENTAL DESIGN

-T-FACE is located at the SoyFACE facility, Champaign, IL. It uses IR heaters array mounted 1.2 m above the canopy to increase temperature 3.5 °C above ambient conditions. The plots have a functional area of $7m^2$.

-2009 was the first year of T-FACE when soybean grew under field conditions at ambient and elevated [CO_2] (385ppm or 585ppm) and at ambient or elevated temperature (+3. 5 °C) in a factorial experiment.

-The measurements included: net carbon assimilation (A) , respiration (Rd), stomatal limitation, leaf photosynthetic biochemistry ($V_{c,max}$ and J_{max}), seed number and total biomass.

PREDICTIONS

1.- The elevated temperature will lower photosynthetic rate in ambient [CO_2] plots, but the combination of elevated temperature and elevated [CO_2] will yield the highest photosynthetic rates.

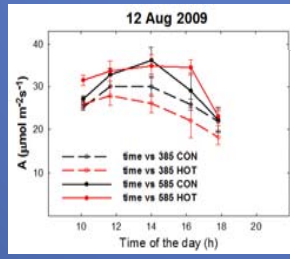
2.- The activity of the carboxylation enzyme Rubisco and the whole chain electron transport will decrease (lower $V_{c,max}$ and J_{max}) at elevated temperature. The combination of higher temperature and elevated [CO_2] will further reduce $V_{c,max}$ and J_{max} relative to the main effects.

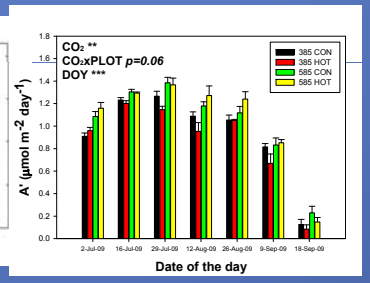
3.- Rd in elevated [CO_2] plots will be higher than in ambient [CO_2] plots, and the combined effect of elevated temperature and [CO_2] will have the highest Rd. The opposite effect is predicted for the stomatal limitation.

4.- Because of the predicted higher photosynthetic rates in the elevated [CO_2] and temperature treatment, increasing temperature will lower yield more in ambient [CO_2] plots than in the elevated [CO_2].

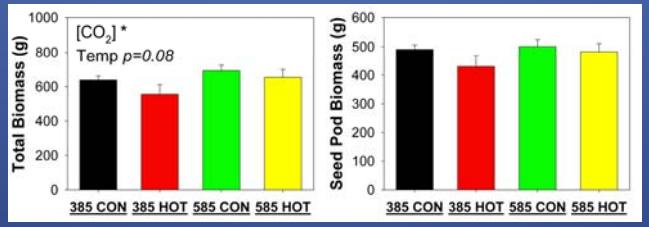
RESULTS

- The instantaneous carbon uptake (A) in elevated temperature and CO_2 had the highest photosynthesis rate during almost all the hours of the day, on 4 of the 7 diurnals taken. Opposite to that, ambient CO_2 and elevated temperature had the lowest A on 5 of the 7 diurnals.





-For all the growing season, in ambient CO_2 (385 ppm) and higher temperature (+3.5ºC), the daily integrated photosynthesis (A´) significantly decreased by 6.4%, the total biomass decreased by 13%, and the fruit/pod number decreased by 6%.



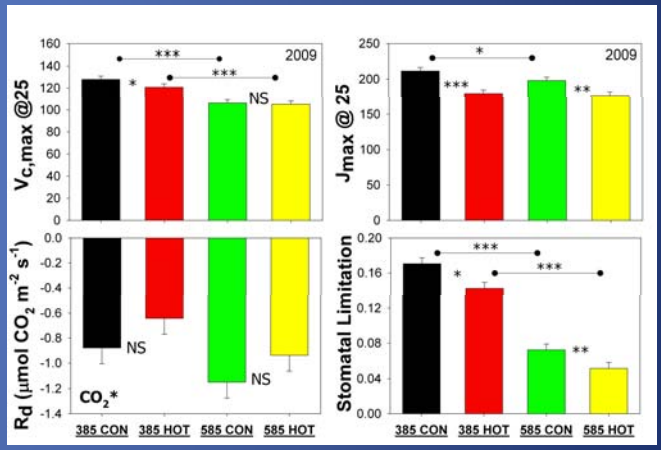
-In contrast, in elevated CO_2 (585 ppm) and higher temperature, A´ increased by 3.9% and final biomass by 5%.

-Elevating temperature decreased $V_{c,max}$ significantly in ambient CO_2.

-Elevating temperature significantly decreased maximum light driven photosynthetic electron transport, J_{max}, in both ambient and elevated CO_2 .

-In elevated CO_2, Rd increased significantly but tended to decrease at higher growth temperature when measured at 25°C.

-Elevated temperature and [CO_2] caused significant decreases in stomatal limitation, with increased [CO_2] having the largest effect. Further, the minimum limitation occurred when both treatments are applied.



DISCUSSION

Higher temperatures have a negative effect on growth and physiology of soybean. The effect of temperature, however, was offset when CO_2 was increased simultaneously with temperature. The benefit of combined increases in CO_2 and temperature were less than predicted.

A combination of low stomatal limitation, potentially higher respiration, and similar photosynthetic acclimation are likely responsible for the muted synergistic responses to combined increases in CO_2 and temperature.

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