Effects of a thermal excursion on biomass yield and gas exchange traits in *Glycine max*

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Introduction

The multi-billion dollar agriculture sector may see a decline in crop yields in the next 50 years under predicted climate change scenarios. Prediction scenarios include the high likelihood that there will be an increase in the frequency and intensity of high temperature thermal excursions in temperate regions (IPCC 2013). Temperature plays a major role in many of the processes underlying photosynthesis. For example, in maize (*Zea mays*), damage to Photosystem II that is reversible under warm conditions becomes irreparable under cold conditions due to an inability to synthesize a protein necessary for repair, reducing photosynthetic efficiency and function (Spence et al 2014). Previous studies have shown small changes in the efficiency of photosynthetic biochemistry can result in large changes at the whole-plant level that impact the amount of biomass produced by the plant (Dohleman and Long 2009; Koester et al 2014).

Soybean (*Glycine max*) is an important crop in the United States, and a greater knowledge of the physiological basis of biomass production and crop yield is critical, especially under predicted climate change conditions. To better understand this interaction, we sought to determine the impact of a single thermal excursion event on key physiological traits and biomass yield in soybean.

Objectives

- Evaluate the impact of a short term thermal excursion on carbon accumulation in *Glycine max* (soybean) by
  - Quantifying the acute effect of key physiological traits and recovery of those traits through assessment of:
    - Photosynthesis
    - Nocturnal respiration
    - CO_2 response curves
    - Chlorophyll fluorescence
  - Quantifying the effect of a thermal excursion on biomass yield

Methods

- Two groups of soybeans (15 in treatment group, 16 in control) were grown from seeds (91.2% germination) in growth chambers under the same conditions
  - 14 hour day/10 hour night
  - 25°C day/15°C night
  - 400 ppm CO_2
  - Ambient light 600 μmol $m^{-2}s^{-1}$
- After 42 days plants in treatment group were exposed to a thermal excursion for 72 hours
  - 37°C day/30°C night
  - All other parameters are the same
- Before, during, and 1, 3, and 4 days after the thermal excursion the LiCor 6400XT Portable Photosynthesis System was used to measure:
  - Photosynthesis
  - Nighttime respiration
  - Dark adapted Fv/Fm (Fluorescence)
  - CO_2 response curves
- All plants were harvested, dried, and weighed after 46 days of growth to evaluate plant yield in both groups

Acknowledgements

I would like to thank Dr. Chris Bickford for his support and guidance over the course of this research. This project was funded by the Kenyon College Summer Science Scholars Program.

Results

Gas Exchange Response

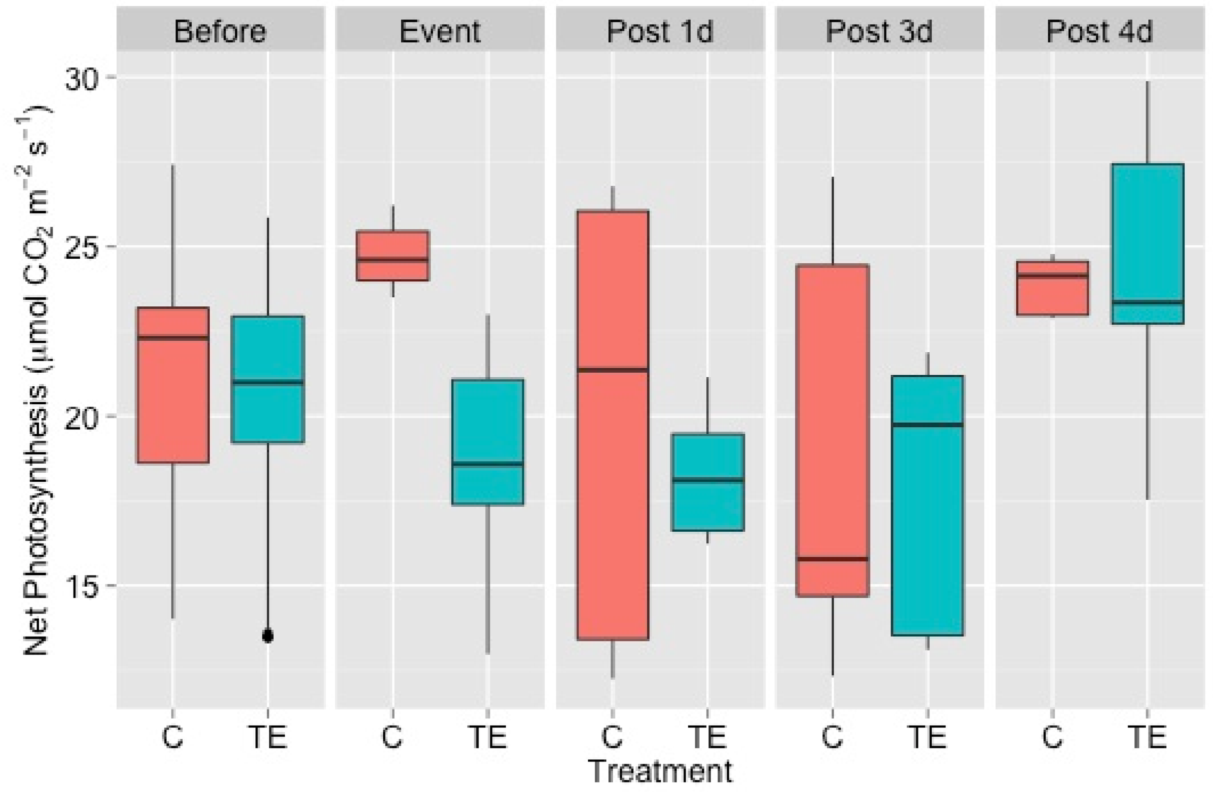

Figure 1. Photosynthesis rates before, during, and after a thermal excursion. Control group rates were significantly higher during the event (P<0.001) and one day (P=0.003) after the thermal excursion. Plants appear to have recovered to control group rates three days following the excursion.

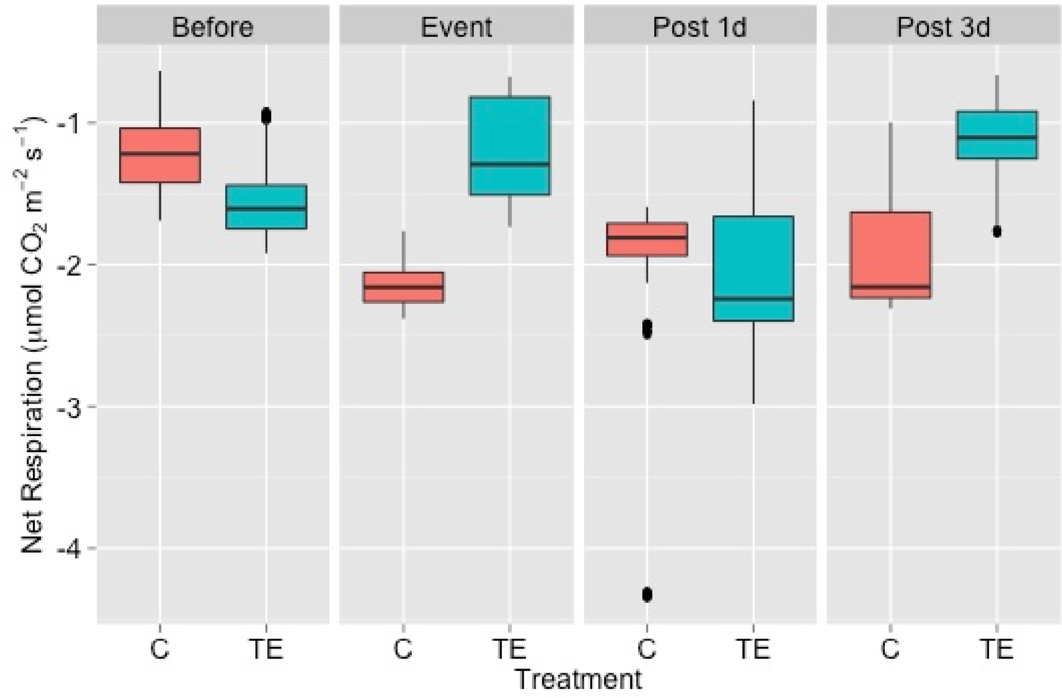

Figure 2. Nocturnal respiration rates before, during, and after a thermal excursion. Rates were significantly higher in the control group during the event (P<0.001) and showed signs of recovery one day after the event.

Stress Response

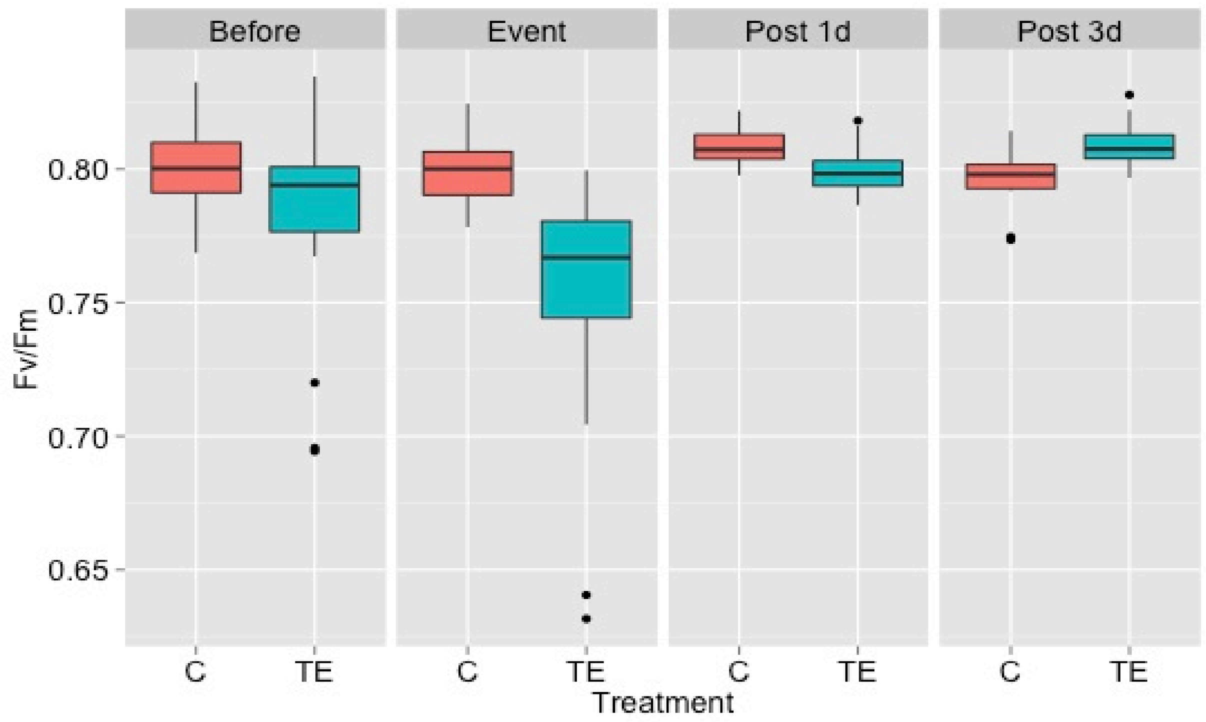

Figure 3. Chlorophyll fluorescence (Fv/Fm) in both groups before, during, and after a thermal excursion. Fluorescence was significantly inhibited during the event (P=0.008).

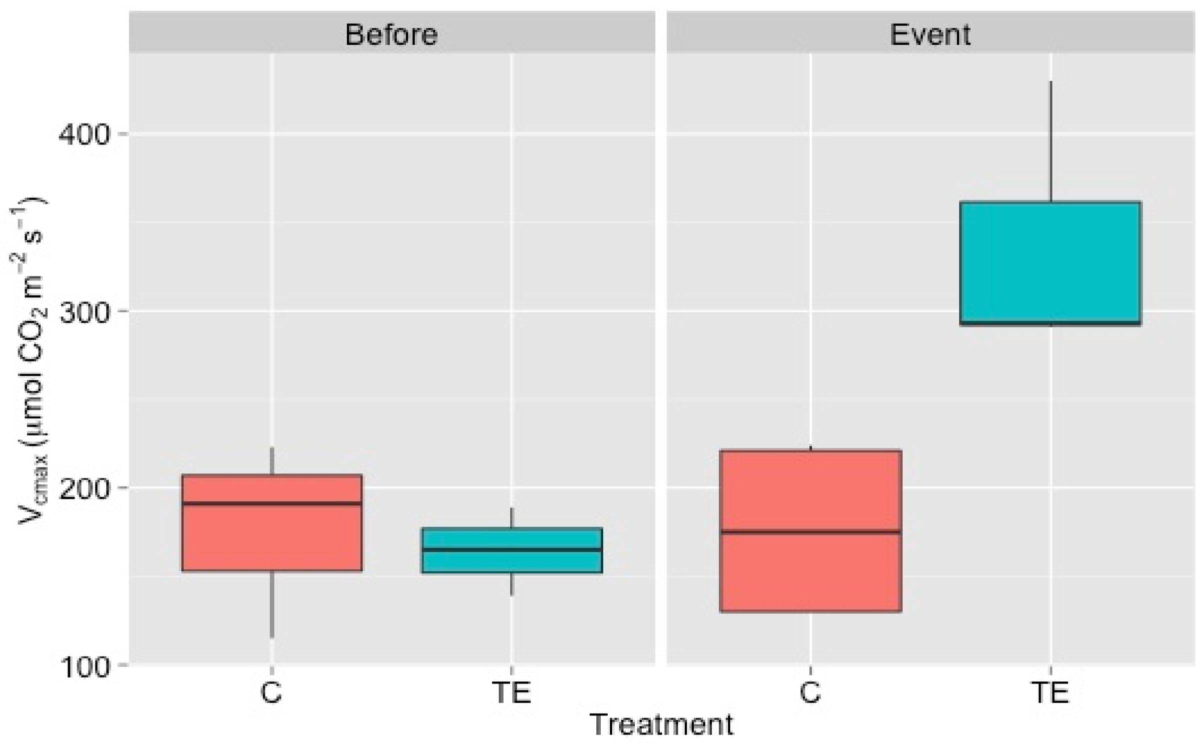

Figure 4. Comparison of V_{cmax} before and during thermal excursion. The treatment group had significantly higher V_{cmax} during the event (P=0.048).

Yield Response

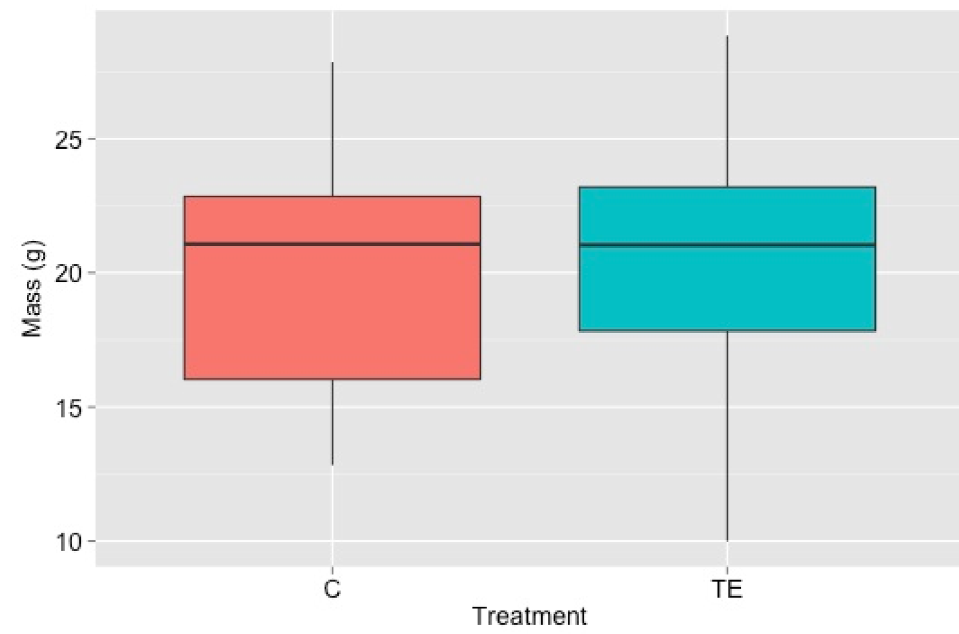

Figure 5. Response of plant biomass produced over the course of 46 days of growth. There was no significant difference between groups (P=0.6).

Conclusions

- Photosynthesis and respiration rates as well as fluorescence were all negatively impacted by the thermal excursion but recovered within three days.
- During the excursion:
  - The pathways that produce sugars necessary for growth and survival of the plants (photosynthesis) were not functioning normally during the thermal excursion
  - The sugars produced were not being converted into energy for the plant at normal rate (respiration)
- Immediately following the excursion the plants recovered very quickly (within 1-3 days)
- Lack of difference between the yields of the treatment and control groups indicates that the damage done to the biochemical systems was not significant enough to do serious damage to the overall biomass produced by the plant during the study period.

Implications

- In July 2014, global atmospheric CO_2 levels were measured at 398 ppm, up from 316 ppm in 1960 (Tans and Keeling, 2014)
- Increased atmospheric CO_2 is a main driver of climate change, which is predicted to cause increased frequency and intensity of heat waves (IPCC 2013)
- If these predictions prove to be accurate, there is huge potential for negative impact on crop yields and agriculture
  - Over 4 million acres of soybean were harvested in Ohio in 2013, with a production value of over $2 billion (2013 State Agriculture Overview-Ohio 2013)
- It is important to understand how agricultural crops such as soybeans may respond to the stressful conditions associated with climate change
- This study indicates that short term, single thermal excursions may not cause significant alteration to the accumulation of carbon in plant tissues.

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