Physiological Changes to Cotton Under Heat Stress During Reproductive Development

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Objectives

- Identify metabolic and physiological responses to cotton during and after heat stress.
- Determine if residual response effects may linger following heat stress, indicating a possible acclimation effect.

Introduction

- The optimum growth temperature for cotton based upon the enzyme kinetics is 23.5 ºC to 32 ºC (Burke et al. 1988).
- Heat stress also reduces the efficiency of photosystem II from several different sources such as diminished RUBISCO and increased reactive oxygen species (Sharkey 2005).
- Plasma membranes experience increased leakage with increased temperatures past optimum (ur Rahman et al. 2004).
- Cotton varieties that are bred for their heat tolerance exhibit higher amounts of antioxidants than those varieties that are not tolerant. (Snider et al. 2010).

Hypothesis

Cotton will exhibit both a decrease in metabolic efficiency and an increase in protective responses to increased temperature stress, and display an acclimation effect post-stress.

Materials & Methods

- **Field**
  - Conducted at the Arkansas Agricultural Research Station in Fayetteville, AR
  - Planted late May 2011
  - Furrow irrigated
- **Treatments**
  - **Three planting dates**
    - Each two weeks apart
      - Ensured temperature stress was on at least one treatment during anthesis
      - Randomized complete block design with three replications
  - **Collections**
    - During peak flower
      - White flower and subtending leaf
  - **Temperatures at time of collection**
    - 8/04/2011 = *33°C*
    - 8/07/2011 = *41°C*
    - 8/12/2011 = *29°C*

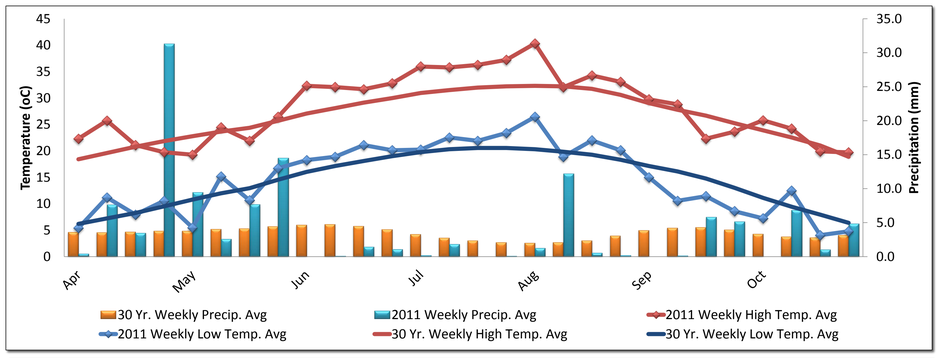

Plate 1: Temperature and precipitation averages for 2011 and over a 30 year period in NW Arkansas.

Results

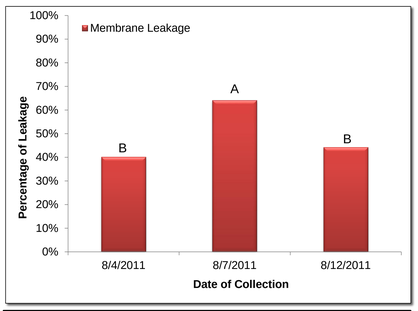

Figure 1: Subtending leaf membrane leakage. Different letters indicate significant differences (p = 0.05).

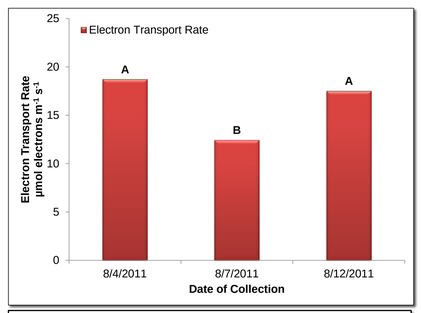

Figure 2: Subtending leaf electron transport rate (ETR) efficiencies. Different letters indicate significant differences (p = 0.05).

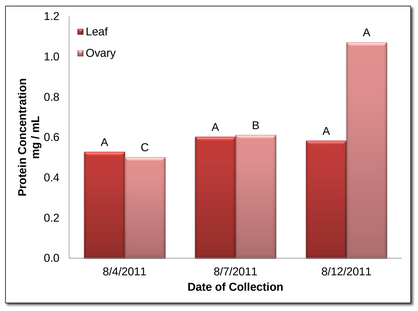

Figure 3: Subtending leaf and ovary protein concentrations. Different letters indicate significant differences (p = 0.05).

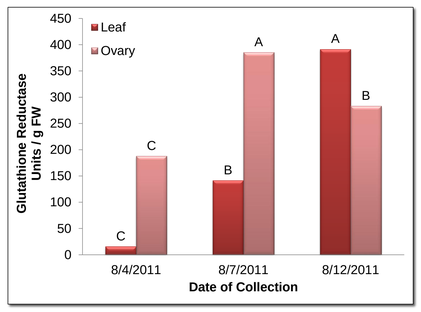

Figure 4: Subtending leaf and ovary glutathione reductase (GR) units per gram of fresh weight. Different letters indicate significant differences (p = 0.05).

Plate 2: Microplate Reader

Plate 3: Spectrophotometer

Plate 4: Fluorometer

Plate 5: Conductivity Meter

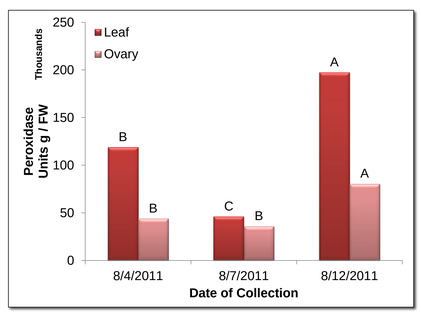

Figure 5: Subtending leaf and ovary peroxidase units per gram of fresh weight. Different letters indicate significant differences (p = 0.05).

Discussion

Figure 1:

- Temperatures of 41°C on 8/7/2011 led to an increase in leaf membrane leakage that was significantly different from other days.
- The five day recovery ending 8/12/2012 had leakage amounts similar to collections prior to the heat stress.

Figure 2:

- Electron transport rates were depressed near 30% during heat stress .
- Electron transport rates on 8/12/2011 at 29°C recovered to near the same rates as 8/4/2011 at 33°C.

Figure 3:

- Protein concentrations for leaves remained constant
- Ovary protein concentration displayed a 40% increase in protein in the recovery days following heat stress

Figure 4:

- GR in leaf tissue increased significantly during heat stress and most significantly following the heat stress
- Ovarian GR levels displayed a maximum during heat stress, and a decrease following the stress

Figure 5:

- Peroxidase in the leaves fell during heat stress, but were near 40% higher than levels prior to heat stress
- Ovarian peroxidase levels were not as high as in the leaf during heat stress but were substantially higher than the first date of collection

Conclusions

- **Cotton demonstrated a strong response to high temperature stress:**
  - Diminished ETR response
  - Increased membrane leakages
  - Protein level increase within the ovary
  - Substantial GR increases in both leaves and ovaries
  - Peroxidase levels fell during heat stress, but rebounded
- **Residual effects following heat stress:**
  - Higher levels of proteins
  - Increased antioxidant levels for both leaves and ovaries

Literature Cited

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- Sharkey, T. D. (2005). Effects of moderate heat stress on photosynthesis: importance of thylakoid reactions, rubisco deactivation, reactive oxygen species, and thermotolerance provided by isoprene. Plant, Cell & Environment, 28(3), 269–277.
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- ur Rahman, H., Malik, S. A., & Saleem, M. (2004). Heat tolerance of upland cotton during the fruiting stage evaluated using cellular membrane thermostability. Field Crops Research, 85(2-3), 149–158.