**Report for 2013 from Arkansas for NCERA-101**

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## Impact Nugget:

Controlled environment studies at the University of Arkansas have shown that high night temperatures may be more important than high day temperatures for effects on the growth and yield development of cotton. Both high day and high night heat stresses decrease carbohydrates and energy levels in the flower, causing decreased pollen tube growth and fewer ovules being fertilized, resulting in fewer seeds per ovary and decrease cotton fiber quality.

## New Facilities and Equipment:

We have replaced an older controlled environment chamber with a new CONVIRON PGR15. We are currently investigating replacing our current fluorescence and incandescent lighting systems in our twelve chambers with appropriate LED lighting to provide the full PAR spectrum.

## Unique Plant Responses:

High *day* temperature stress resulted in a decrease in soluble carbohydrates and ATP in the flower pistil, which resulted in decreased pollen tube growth and fewer ovules being fertilized. Maintaining a sufficient antioxidant enzyme pool prior to heat stress was shown to be an innate mechanism for coping with rapid leaf temperature increases that commonly occur under field conditions. Excessively warm *night* temperatures significantly increased respiration, which resulted in a reduction in leaf carbohydrate content, and an accumulation of glucose, sucrose and starch in the pistil. The overall result of high temperature is that available carbohydrate is reduced and may not be sufficient to satisfy all the plant's needs, resulting in increased boll shedding, fewer seeds per boll, less fiber per seed, and lower yields.

## Accomplishment Summaries:

In our earlier studies, we investigated the effect of heat stress on *in vivo* pollen tube growth, changes in energy reserves and calcium-mediated oxidative status in the pistil. The conclusion was that the energy demands of growing pollen tubes could not be met under heat stress due to decreased source leaf activity, and a calcium-augmented antioxidant response in heat-stressed pistils that interferes with enzymatic superoxide production needed for normal pollen tube growth. A comparison of the physiological and biochemical responses of a thermosensitive cultivar (ST4554B2RF) from the US Cotton Belt and thermotolerant cultivar (VH260) from Pakistan, showed that maintaining a sufficient antioxidant enzyme pool prior to heat stress is an innate mechanism for coping with rapid leaf temperature increases that commonly occur under field conditions.

A diurnal study of pollen tube growth in the cotton pistil was conducted. Microclimate measurements included photosynthetically active radiation, relative humidity, and air temperature. Pistil measurements included surface temperature, pollen germination, and pollen tube growth through the style, fertilization efficiency, fertilized ovule number, and total number of ovules per ovary. Subtending leaf measurements included leaf temperature, photosynthesis, and stomatal conductance. Results showed that under high temperatures the first measureable pollen tube growth through the style was observed earlier in the day (1200 h) than under cooler conditions (1500 h). Also, high temperature resulted in slower pollen tube growth through the style (2.05 mm $h^{-1}$) relative to cooler conditions (3.35 mm $h^{-1}$). We concluded that diurnal pollen tube growth is exceptionally sensitive to high temperature.

Growth chamber studies showed that there was considerable stress-related adjustments during anthesis. Ovaries from the day before flowering, during flowering, and the day after flowering were analyzed along with its subtending leaf for cell membrane damage, antioxidant, and carbohydrate changes. Membrane leakage indicated significant damage caused by the heat, but this effect decreased to that of the control by the fourth day, indicating an acclimation. Protein concentrations decreased with high temperature in the leaves, but not in the ovaries. The activity of antioxidant enzymes, peroxidase and glutathione reductase, decreased in the stressed leaves compared to the ovaries during all stages of anthesis. Carbohydrate analysis indicated no differences amongst the leaves, but the ovaries had significant differences in fructose, sucrose, and starch concentrations during different stages of anthesis.

High night temperature (30C compared to 24C) significantly increased leaf respiration, reduced, and decreased carbohydrates. In the flower pistil there was an increase in respiration and an accumulation of glucose, sucrose and starch indicating a perturbation in carbohydrate metabolism that contributes to poor fertilization and seed development. The result was increased boll abscission and decreased the weight of lint per seed which would have decreased final lint yield. The overall result of high temperature is that available carbohydrate and energy levels will be reduced and may not be sufficient to satisfy all the plant's needs, resulting in poor pollen tube growth and fertilization, with increased boll shedding, fewer seeds per boll, less fiber per seed, and lower yields.

**Impact Statement:**

In cotton (*Gossypium hirsutum* L.), the growth of pollen tubes through the style has been shown to be especially sensitive to elevated day temperatures. Under high temperatures the energy demands of growing pollen tubes cannot be met under heat stress due to decreased source leaf photosynthetic activity. High night temperatures increase respiration and decrease carbohydrates affecting fiber growth and development. There is an increase in antioxidants in the pistil under stress, which helps ameliorate the deleterious effects of the stress. These studies have indicated that the effects on growth and yield development from elevated temperatures during the night may be of more importance than during the day. The findings will facilitate the development of methods of ameliorating heat stress for yield stabilization.

**Published Written Works:**

<ins>Refereed Journal Articles and Chapters</ins>:

Kawakami, E.M., Oosterhuis, D.M., Snider, J.L. and FitzSimons. T.R. 2013. High temperature and ethylene antagonist 1-methylcycloprpene alter ethylene evolution patterns, antioxidant responses, and boll growth in *Gossypium hirsutum*. Amer. J. Plant Sci. 4:1400-1408.

Roselem, C.A., Oosterhuis, D.M. and De Souza, F.S. 2013. Cotton response to mepiquat chloride and temperature. Scientia Agricola 70:82-87.

Snider, J.L., Oosterhuis, D.M., Collins, G.D., Pilon, C. and FitzSimons, T.R. 2013. Field-acclimated Gossypium hirsutum cultivars exhibit genotypic and seasonal differences in photosystem ll thermostability. Plant Physiology. 170:489-496.

Symposium Proceedings:

Oosterhuis, D.M., Raper, T.B., Pilon, C., and Burke, J.M. 2013. Development of 1-Methylcyclopropene application triggers o high temperature in cotton production. pp. 63-65. In: D.M. Oosterhuis (Ed.) Summaries of Arkansas Cotton Research 2012. Univ. Arkansas Agric. Exp. Sta., Research Series 610.

Echer, F.R., Oosterhuis, D.M., Loka, D.A., and Rosolem, C.A. 2013. Molybdenum and abscisic acid effects on cotton under high night temperature stress. pp. 56-62. In: D.M. Oosterhuis (Ed.) Summaries of Arkansas Cotton Research 2012. Univ. Arkansas Agric. Exp. Sta., Research Series 610.

FitzSimons, T.R. and Oosterhuis, D.M. 2013. Acclimatization of cotton exposed to high-temperature stress. pp. 51-55. In: D.M. Oosterhuis (Ed.) Summaries of Arkansas Cotton Research 2012. Univ. Arkansas Agric. Exp. Sta., Research Series 610.

Pretorius, M.M., Oosterhuis, D.M., Loka, D.A., and FitzSimons, T.R. 2013. Screening for temperature tolerance in cotton. pp. 45-50. In: D.M. Oosterhuis (Ed.) Summaries of Arkansas Cotton Research 2012. Univ. Arkansas Agric. Exp. Sta., Research Series 610.

Raper, T.B. and Oosterhuis, D.M.., Espinoza, L., Pilon, C. and Burke, J. 2013. Spectral characteristics of K deficiencies in multiple cotton cultivars at the canopy scale. CD-ROM. Proc. Beltwide Cotton Conferences. San Antonio, TX. Jan 7-10, 2013. National Cotton Council of America, Memphis, TN.

Scientific and Outreach Oral Presentations:

Oosterhuis, D.M. Heat stress and cotton production. Nanjing Agricultural University, Nanjing. October 2013.

Oosterhuis, D.M. Dealing with heat. 16th Annual National Cotton and Soybean Conservation Symposium, Jan 30-Feb1, 2013. Baton Rouge, LA.

FitzSimons, T.R and Oosterhuis, D.M. The biochemical effects of heat stress on cotton flowering. Beltwide Cotton Conferences. San Antonio, TX. Jan 7-10, 2013. National Cotton Council of America, Memphis, TN

Raper, T. and Oosterhuis, D.M., Barnes, E.M., Andrade-Snachez, P., Bauer, P.J., Ritchie, G.L., Rowland, D.L. and Snider, J.L. 2013. Regional evaluation of wireless soil moisture sensor system s and advanced irrigation scheduling technologies to optimize water use efficiency. CD-ROM *Proc. Beltwide Cotton Conferences*. San Antonio, TX. Jan 7-10, 2013. National Cotton Council of America, Memphis, TN.

Pilon, C., Oosterhuis, D.M. and Ritchie, G. Photosystem II thermostability in Gossypium hirsutum cultivars under water stress. American Society of Agronomy meetings. Orlando, FL. Nov. 2013.