2010 Report from Arkansas for NCERA-101

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Impact Nugget:

Research at the University of Arkansas has continued to study the effects of high temperature stress on pollen tube growth and fertilization in cotton flower pistils in field and controlled environment conditions. These studies have shown the extreme sensitivity of pollen tube growth to high temperature and helped explained the yield losses and yield variability experienced by Arkansas farmers.

New Facilities and Equipment:

A new CONVIRON PGW40, , controlled environment chamber was installed, with a CMP6050 control system and increased light intensity capabilities (1400 µmol/m^2/s), to supplement the existing set of chambers. Plans have been made and the funds solicited to improve and continue replacing the existing controlled environment chambers. To augment the micro measurements of plant response to elevated temperature and water stress, we have assembled an enhanced thermoelectric cooler/heater with an actinic LED light source, and built-in PAR sensor, to allow for stable and continuous illumination of the leaf surface during temperature changes, for measurement of fluorescence.

Unique Plant Responses:

In cotton, the growth of pollen tubes through the style has been shown to be especially sensitive to elevated temperatures. High temperatures cause a decline in pollen tube growth, soluble carbohydrates, ATP content, and NADPH oxidase activity, whereas water soluble calcium and glutathione reductase activity increase, and superoxide dismutase activity remains unchanged. The energy demands of growing pollen tubes cannot be met under heat stress due to decreased source leaf activity, because a calcium-augmented antioxidant response in heat stressed pistils interferes with enzymatic superoxide production needed for normal pollen tube growth. Also, 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.

Accomplishment Summaries:

In our earlier studies, we investigated the hypothesis that *in vivo* pollen tube growth would be affected by heat stress-induced changes in energy reserves and calcium-mediated oxidative status in the pistil. The conclusion was that the energy demands of growing pollen tubes cannot 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.

In 2009, we investigated the hypothesis that genotypic differences in source leaf photosynthetic thermostability would be dependent upon pre-stress capacity for antioxidant protection of photosystem II in *Gossypium hirsutum*. We compared the physiological and biochemical responses of a thermosensitive cv. ST4554B2RF from the US Cotton Belt and thermotolerant cv. VH260 from Pakistan, exposed to normal control (30/20°C) or high (38/20°C) temperature conditions during flowering. We concluded 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.

In 2010, we studied diurnal pollen tube growth in the cotton pistil. Because reproductive success is influenced by photosynthetic activity of major source leaves, we hypothesized that high temperatures under field conditions would limit fertilization by inhibiting diurnal pollen tube growth through the style and decreasing subtending leaf photosynthesis. To address this hypothesis, *G. hirsutum* seeds were sown on different dates to obtain flowers exposed to contrasting ambient temperature conditions but at the same developmental stage (node 8 above the cotyledons). Collection and measurement were conducted at 0600, 0900, 1200, 1500, and 1800 h on August 4 (34.6°C maximum air temperature) and 14, 2009 (29.9°C maximum air temperature). 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. 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), but there were no differences in fertilization efficiency, number of fertilized ovules, or ovule number. There was no effect of sample date on diurnal photosynthetic patterns, where the maximum photosynthetic rate was observed at 1200 h. Because in vivo pollen tube growth was negatively impacted under high temperature without a concomitant decline in pollen germination, ovule fertilization, or subtending leaf photosynthesis, we conclude that diurnal pollen tube growth is exceptionally sensitive to high temperature.

Impact Statement:

In cotton (*Gossypium hirsutum* L.), the growth of pollen tubes through the style has been shown to be especially sensitive to elevated temperatures. The energy demands of growing pollen tubes cannot 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. Also, 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. The findings will facilitate the development of methods of ameliorating heat stress for yield stabilization.

Published Written Works:

Refereed Journal Articles:

Bibi, A.C, Oosterhuis, D.M,and Gonias, ED. and Stewart, J.M 2010. Comparison of a responses of a ruderal *Gossypium hirsutum* L. with commercial cotton genotypes under high temperature stress. *Amer. J. Plant Sci. And Biotechnol*.4 (special issue 2): 87-92.

Bibi, A.C., Oosterhuis, D.M.,and Gonias, E.D. 2010. Exogenous application of putrescine ameliorates the effect of high temperature in *Gossypium hirsutum* L. flowers and fruit development. *J. Agron. and Crop Sci*.196:205-211.

Brown, S. and Oosterhuis, DM. 2010. High daytime temperature stress effects on the physiology of modern versus obsolete cultivars. *Amer. J. Plant Sci. And Biotechnol*..4 (special issue 2): 93-96.

Gonias, D.M., Oosterhuis, D.M. and Bibi.A. C. 2010. Ambient or internal boll temperatures to calculate heat units for timing defoliation *Amer. J. Plant Sci. And Biotechnol*. 4 (special issue 2): 97-100.

Loka, D. and Oosterhuis, D.M. 2010. Effects of high night temperature on cotton respiration, ATP levels and carbohydrate content. *J. Exp. Environ. Bot.* 68:258-263.

Snider, J.L., Oosterhuis, D.M., and Kawakami, E.M. 2010. Genotypic differences in thermotolerance are dependent upon prestress capacity for antioxidant protection of the photosynthetic apparatus in Gossypium hirsutum. *Physiol. Plant.* 138:268-277.

<u>Symposium Proceedings:</u>

Kawakami, E.M., Oosterhuis, D.M.and Snider, J.L. 2010. Effects of temperature and application of urea with N-butyl thiophosphoric triamide and Dicyandiaminde on cotton. Summaries of Cotton Research. Univ. Arkansas Agric. Exp. Sta., *Research Series* 582:44-50.

Loka, D.A. and Oosterhuis, D.M. 2010. Effects of water-deficit stress on reproductive development in the cotton pistil. Summaries of Cotton Research. Univ.Arkansas Agric. Exp. Sta., *Research Series* 582:37-43.

Oosterhuis, D.M., Kawakami, E.M. and Storch, D.K. 2010. Effects of 1-Methylcycloprpene on growth and biochemistry of heat-stressed cotton grown in a controlled environment. Summaries of Cotton Research. Univ. Arkansas Agric. Exp. Sta., *Research Series* 582:51-55.

Oosterhuis, D.M., Snider, J.L., Loka, D.A., and Bourland, F.M. 2010. Screening for temperature tolerance in cotton. Summaries of Cotton Research. Univ. Arkansas Agric. Exp. Sta., *Research Series* 582:20-24.

Snider, J.L., Oosterhuis, D.M., and Kawakami, E.M. 2010. Genotypic differences in thermotolerance are dependent upon pre-stress capacity for antioxidant protection of the photosynthetic apparatus in cotton. Summaries of Cotton Research. Univ. Arkansas Agric. Exp. Sta., *Research Series* 582:30-36.

<u>Scientific and Outreach Oral Presentations</u>:

Oosterhuis, D.M. AND Snider, J.L. 2010. The effect of high temperature stress on floral development and yield of cotton. CD-ROM. Proc. Beltwide Cotton Conferences. New Orleans, LA., Jan 4-7, 2010. National Cotton Council of America, Memphis, TN.

Oosterhuis, D.M. and Kawakami, E. 2010. Effect of 1-Methylcyclopropene on the growth and yield of cotton and response to water and high temperature. *Proceedings of Agro2010 the X1th European Society of Agronomy Congress*, Aug 29-Sep 3, 2010. Montpellier, France. Pp. 457-458.

Snider, J.L., Oosterhuis, D.M., Skulman, B., AND Kawakami, E. 2010. Heat stressed-induced changes in pollen tube growth, calcium levels, antioxidant defense, and superoxide production in cotton pistils. CD-ROM. *Proc. Beltwide Cotton Conferences*. New Orleans, LA., Jan 4-7, 2010. National Cotton Council of America, Memphis, TN.