2009 Report from Arkansas for NCERA-101

Derrick M. Oosterhuis

Department of Crop, Soil, and Environmental Sciences, University of Arkansas

Impact Nugget:

The University of Arkansas has continued to develop techniques to measure the effects of high temperature and water-deficit stresses in cotton flower pistils in controlled environment conditions. These studies have improved our understanding of the effects of high temperature stress on cotton reproductive development in order to explain the yield variability experienced by Arkansas farmers and facilitate the development of methods of amelioration for yield stabilization and enhancement.

New Facilities and Equipment:

Plans have been made and the funds solicited to improve and continue replacing the existing controlled environment chambers. New equipment and techniques was used to augment the micro measurements of plant response to elevated temperature and water stress, included measurement of the energetics, carbohydrate and enzymes within the pistil, micro probes for temperature within the ovary, and a new fluorometer.

Unique Plant Responses:

High temperature stress caused a decline in the pistil of pollen tube growth, soluble carbohydrates, ATP content, and NADPH oxidase activity, whereas water soluble calcium and glutathione reductase activity increased, and superoxide dismutase activity remained unchanged. In leaves, heat stress decreased photosynthesis, quantum efficiency, and chlorophyll content, but increased stomatal conductance. 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.

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*. To test this hypothesis, thermosensitive (cv. ST4554B2RF from the US Cotton Belt) and thermotolerant (cv. VH260 from Pakistan) plants were exposed to control (30/20°C) or high day temperature (38/20°C) conditions during flowering and source leaf gas exchange, chlorophyll content, and maximum photochemical efficiency (F_v/F_m) were measured for each treatment. The relationship between source leaf thermostability and pre-stress antioxidant capacity was quantified by monitoring the actual quantum yield response of photosystem II (Φ_{PSII}) to a range of temperatures for both cultivars grown under the control temperature regime and measuring antioxidant enzyme activity for those same leaves. VH260 was more thermotolerant than ST4554 as evidenced by photosynthesis and F_v/F_m being significantly lower under high temperature for ST4554 but not VH260. Under identical growth conditions, VH260 had significantly higher optimal and threshold temperatures for Φ_{PSII} and glutathione reductase (GR; EC 1.8.1.7) activity than ST4554, and innate threshold temperature was dependent upon endogenous GR and superoxide dismutase (SOD; EC 1.15.1.1) activity.

Impact Statement:

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. Furthermore, 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 sensitivity of pollen tube growth to high temperature is a major cause of low yields for crops with valuable reproductive structures.

Published Written Works:

Refereed Journal Articles:

Bibi, A.C, Oosterhuis, D.M, and Gonias, ED. and Stewart, J.M 2009. Comparison of a responses of a ruderal *Gossypium hirsutum* L. with commercial cotton genotypes under high temperature stress. *Amer. J. Plant Sci. And Biotechnol. (in press)*

Loka, D. and Oosterhuis, D.M. 2009. Effects of high night temperature on cotton respiration, ATP levels and carbohydrate content. *J. Exp. Environ.Bot. (in press)*

Snider, J.L., Oosterhuis, D.M., Skulman, B.W., and Kawakami, E.M. 2009. Heat-stress induced limitations to reproductive success in *Gossypium hirsutum* L. *Physiol. Plant.* 137:125-138.

Symposium Proceeding:

Oosterhuis, D.M, Bourland, F.M., Bibi, A.C., Gonias, E.D., Loka, D. and Storch, D.K. 2009. Screening for temperature tolerance in cotton. Summaries of Cotton Research in 2008. Univ. Arkansas Agric. Exp. Sta., *Research Series* 573:37-41.

Snider, J.L., Oosterhuis, D.M., Skulman, B.W., Kawakami, E.M. and Storch, D.K. 2009. The effect of high temperature on *in vivo* pollen tube growth, calcium levels, antioxidant response, and superoxide production in the cotton pistil. Univ. Arkansas Agric. Exp. Sta., *Research Series* 573:46-51.

Snider, J.L., Oosterhuis, D.M., Skulman, B.W., Kawakami, E.M. and Storch, D.K. 2009. Effect of high temperature on pollen tube growth and energetics in the cotton pistil. Univ. Arkansas Agric. Exp. Sta., *Research Series* 573:52-57.

Scientific and Outreach Oral Presentations:

Loka, D., and Oosterhuis, D.M. 2009. High temperature effects on cotton respiration, ATP levels and carbohydrates. CD-ROM *Proc. Beltwide Cotton Conferences*. San Antonio, TX., Jan 5-8, 2009. National Cotton Council of America, Memphis, TN.

Kawakami, E. and Oosterhuis, D.M. 2009. Physiological effects of 1-methylcyclopropene on the cotton flowers and subsequent boll development under normal and high temperatures. CD-ROM *Proc. Beltwide Cotton Conferences*. San Antonio, TX., Jan 5-8, 2009. National Cotton Council of America, Memphis, TN.

Snider, J, Oosterhuis, D.M., Skulman, B., Kawakami, E. and Storch, D. 2009. Heat stressed-induced changes in pollen tube growth, calcium levels, antioxidant defense, and superoxide production in cotton pistils. CD-ROM *Proc. Beltwide Cotton Conferences*. San Antonio, TX., Jan 5-8, 2009. National Cotton Council of America, Memphis, TN.

Snider, J., Oosterhuis, D., Skulman, B., and Kawakami, E. 2009. Effect of high temperature on pollen tube growth and energetics in cotton. *Amer. Soc. Plant Biology Annual Meeting, Honolulu, Hawaii. Pp141. (abstract #P08032)*