2012 Report from Arkansas for NCERA-101

Derrick M. Oosterhuis

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

Impact Nugget:

Research has continued at the University of Arkansas to study the effects of high day and high night temperature on reproductive development of cotton in controlled environment conditions. These studies have shown that high day temperatures decrease soluble carbohydrates and ATP in the flower pistil resulting in decreased pollen tube growth and fewer ovules being fertilized. Whereas high night temperature significantly increased respiration resulting in a reduced leaf ATP levels and leaf carbohydrates content effecting fiber development. These results have helped explain the yield losses and yield variability experienced by Arkansas farmers.

New Facilities and Equipment:

We have continued to develop and test an enhanced thermoelectric cooler/heater to augment our micro measurements of plant fluorescence response to elevated temperatures. The equipment has an actinic LED light source and built-in PAR sensor, to allow for stable and continuous illumination of the leaf surface during temperature changes from 0 to 40^0C for measurement of fluorescence. We have ordered a new medium sized CONVIRON controlled environment chamber to supplement the existing set of twelve chambers.

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. A calcium-augmented antioxidant response in heat-stressed pistils interferes with enzymatic superoxide production needed for normal pollen tube growth. 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 ATP and leaf carbohydrate content. The overall result of high temperature is that available carbohydrate will be reduced and may not be sufficient to satisfy all the plant's needs, resulting in increased boll shedding, malformed bolls, smaller boll size, less fiber per seed, and lower yields.

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. Comparing the physiological and biochemical responses of a thermosensitive cultivar (ST4554B2RF) from the US

Cotton Belt and thermotolerant cultivar (VH260) from Pakistan, 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. 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.

In our earlier field studies, high night temperature increased leaf respiration, increased boll abscission, and decreased the weight of lint per seed which would have decreased final lint yield. In subsequent controlled environment studies, elevated night temperatures (30C compared to 24C) significantly increased respiration, which resulted in a reduction in leaf ATP and leaf carbohydrate content. The overall result of high temperature is that available carbohydrate will be reduced and may not be sufficient to satisfy all the plant's needs, resulting in increased boll shedding, malformed bolls, smaller boll size, 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, but not apparently to water stress. Under elevated temperatures the energy demands of growing pollen tubes cannot be met under heat stress due to decreased source leaf photosynthetic activity. High night temperatures, respiration is increased and carbohydrates decreased affecting fiber growth and development. Under water deficit, the cotton pistil seems to be well buffered compared to leaves adjacent in the canopy. There is an increase in antioxidants in the pistil under stress, which helps the ameliorate deleterious effects of the stress. The findings will facilitate the development of methods of ameliorating heat stress for yield stabilization.

Published Written Works:

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

OosterhuiS, D.M. and Cothren, J.T. (Eds.) 2012. Flowering and Fruiting in Cotton. Publ. Cotton Foundation, Memphis, TN. ISBN 978-0-939809-08-0

Oosterhuis, D.M. and Loka, D.A. 2012. Polyamines and cotton flowering. pp. 109-132. In: D.M. Oosterhuis and J.T. Cothren (Eds.) Flowering and Fruiting in Cotton. Publ. Cotton Foundation, Memphis, TN. ISBN 978-0-939809-08-0

Loka, D.A. and Oosterhuis, D.M. 2012. Water stress and reproductive development in cotton. pp. 51-57. In: D.M. Oosterhuis and J.T. Cothren (Eds.) Flowering and Fruiting in Cotton. Publ. Cotton Foundation, Memphis, TN. ISBN 978-0-939809-08-0

Snider, J.L. and Oosterhuis, D.M. 2012. Heat stress and pollen-pistil interactions. pp. 59-78. In: D.M. Oosterhuis and J.T. Cothren (Eds.) Flowering and Fruiting in Cotton. Publ. Cotton Foundation, Memphis, TN. ISBN 978-0-939809-08-0

Bibi, A., Oosterhuis, D., Gonias, E. and Mattice, J. 2012. Nodal distribution of free polyamines in cotton ovaries determined by HPLC. Journal of Agricultural Science, 150:365-372.

Loka, D., and Oosterhuis, D.M 2012. Effect of 1-Methylcyclopropene on the cotton flower under water-deficit stress. American Journal of Plant Science, 4:142-152.

Mills, N., Oosterhuis, D.M., and McMicahel, B.L. 2012. Seedling root growth response to cool environmental conditions of diverse cotton genotypes. Amererican Journal of Experimental Agricultural, 2:269-287.

Zhao, W., Meng, Y., Li, W., Chen, B., Xu, N., Wang, Y., Zhou, Z., and Oosterhuis, D.M. 2012. A model for cotton (*Gossypium hirsutum* L.) Fiber length and strength formation considering temperature-radiation and N effects. Ecological Modeling, 243:112-122.

Symposium Proceedings:

Loka, D.A., Oosterhuis, D.M., Echer, F.R. and Pretorius, M.M.. 2012. Effects of high night temperatures at flowering. CD-ROM Proc. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.

Loka, D.A., Oosterhuis, D.M., McMichael,B.L. and Fernandez, C.J. 2012. Water-deficit stress and reproductive development in cotton. CD-ROM (Abstract) Proc. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.

Oosterhuis, D.M., Pretorius, M.M., Loka, D.A. and Fitzsimons, T.R. 2012. High temperature tolerance in cotton. pp. 53-56. In: D.M. Oosterhuis (Ed.) Summaries of Arkansas Cotton Research 2012. Univ. Arkansas Agric. Exp. Sta., Research Series 602.

Scientific and Outreach Oral Presentations:

Echer, F. and Oosterhuis, D.M. 2012. Effects of high night temperatures on cotton during squaring and flowering. Agronomy Meetings, Cincinnati. Oct. 22-25, 2012.

Fitzsimons, T. and Oosterhuis, D.M. 2012. Temperature relationships of cotton yield. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.

Fitzsimons, T. and Oosterhuis, D.M. 2012. physiological changes to cotton under heat stress during reproductive development. Agronomy Meetings, Cincinnati. Oct. 22-25, 2012.

Loka, D.A. and Oosterhuis, D.M. 2012. Effects of high night temperatures at flowering. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis,TN

Loka, D.A. and Oosterhuis, D.M. 2012. Water-deficit stress and reproductive development in cotton. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.

Loka, D.A. and Oosterhuis, D.M. 2012. Effect of 1-MCP on the cotton flower under water deficit stress. Graduate Education week. Poster. University of Arkansas. Feb 10, 2012

Loka, D.A. and Oosterhuis, D.M. 2012. High night temperature effects during flowering in cotton. Agronomy Meetings, Cincinnati. Oct. 22-25, 2012

Oosterhuis, D.M. and Hake, K. 2012. Dealing with heat and drought in cotton production. Proc. 16th Annual Conservation Systems Cotton and Rice Conference. Tunica, MS. Jan31-Feb 1, 2012. pp. 8-111.

Oosterhuis, D.M., and Kawakami, E.M. 2012. Physiological and yield responses of field grown cotton to foliar application of urea with NBPT and DCD. Fluid Fertilizer Foundation annual meeting, Scottsdale, AZ. Feb. 20, 2012.

Oosterhuis, D.M. 2012. Effects of elevated temperature on reproductive development in cotton. NCERA 101, USDA, meeting. Cambridge, UK.

Oosterhuis, D.M. and Snider, J.L. 2012. Heat and drought induced limitations to reproductive success in cotton. European Society of Agronomy meetings, Helsinki, Finland. Aug 2012.

Phillips, J. and Oosterhuis, D.M. 2012. Effect of 1-MCP application on heat-stressed cotton during reproductive development. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.

Snider, J.L., and Oosterhuis, D.M. 2012. Field-grown cotton cultivars exhibit genotypic and seasonal differences in photosystem ll heat tolerance. Beltwide Cotton Conferences. Orlando, FL. Jan 3-6, 2012. National Cotton Council of America, Memphis, TN.