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EFFECT OF NIGHT TEMPERATURES ON BOLL GROWTH AND YIELD

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Abstract

Earlier research has shown a strong correlation between low yields and high temperatures during boll filling. Preliminary research comparing boll growth and yields in contrasting environments (Arkansas and Greece) indicated that an 8ºC higher night temperature during boll development in Arkansas may be a major contributory factor to lower yields. A field experiment was designed using plastic covering over replicated plots at night and heaters or air conditioners, to rise or lower, night temperature compared to the control. Results indicated that high night temperature decreased boll weight, with fiber weight per seed being the main yield component affected. There was no significant effect on respiration or photosynthesis. The one week temperature treatment period was too short and allowed sufficient time for compensation. The study will be repeated in 2003 with some modifications.

Introduction

Variability in cotton (Gossypium hirsutum L.) yield is associated with genotype and environment, water and temperature stress in particular. A strong correlation has been shown to exist between high temperatures during boll development and low yields in the Mid-South (Oosterhuis, 1995). However, the effects of high temperatures on boll growth and yield are not well understood. Furthermore, maximum and minimum temperatures are used to calculate heat units for use in the COTMAN crop monitoring program for predicting growth and determining production inputs. Some controversy exists about the real value of these heat units because although a lower threshold for growth is used, there is no such upper threshold for extreme temperatures. It is suggested that under conditions of high temperature, the calculated heat units may not correspond to measurable growth and yield, and therefore, may not be appropriate for predicting production inputs and decisions. This project was designed to investigate the effect of extreme temperatures on the calculation of heat units and the effect on boll growth and yield.

Cotton yield and total seed cotton production in Arkansas increased steadily during the eighties, but leveled off, or even declined slightly in recent years. Also, yields have fluctuated widely from year-to-year (Fig. 1). For example, the 1994 crop was a record high yield, whereas the 1993 and 1995 seasons were extremely disappointing with unusually low yields despite the promise of a good crop at mid-season. It has been suggested that this may be related to extreme weather conditions and insect infestations in July and August (Oosterhuis, 1995).

Variability in cotton yield is associated with many factors but temperature appears to play a major role (Burke et al., 1988). However, there is very limited data available on temperature and cotton yield, possibly because of the difficulty in conducting the research in the field with varying temperatures (See the long term temperatures showed in Fig. 7). Our preliminary work has indicated a strong correlation between high temperatures and low yields in Arkansas (Fig. 2). Information on cotton response to temperature is lacking particularly with regard to the upper temperature threshold and effects on physiological processes and yield. The current method of calculating heat units needs to be refined. We currently calculate heat units by [(maximum temperature + minimum temperature)/2] - 60F, where 60F is the lower limit for physiological activity. Most researchers worldwide do not use an upper limit for calculating heat units although there is strong evidence that cotton metabolism decreases dramatically at high day temperatures (Burke et al., 1988). Our hypothesis is that when periods of excessively high temperature occur during boll filling, there is a temporary shortage of carbohydrate, which leads to decreased boll weights. Currently, we do not account for this in our estimations of yield. In 1995 and 1996 the cotton crop showed great potential mid-way through the season but this potential declined dramatically during August (due to presumably to excessive temperatures and periods of carbohydrate stress).

Value of this information. Understanding the impact of higher temperatures on boll growth and yield would permit us to improve our heat unit calculations (i.e. make them more accurately related to real beneficial growth). Therefore, producers could make more accurate decisions about the value of additional management inputs based on heat units and predicted yield. Furthermore, if we know what is happening to our boll load, we can devise possible methods to counteract the problem, e.g. using earlier maturing varieties to escape the highest temperatures, breeding for temperature tolerance, irrigating at appropriate critical times, using new technologies such as an osmolyte spray to improve plant tolerance, etc.

Methods and Materials

A field study was designed and conducted to investigate the effects of elevated night temperature on boll weight. The experimental plots were located at the University of Arkansas Main Experiment Station on a Captina silt loam. Cotton (Gossypium hirsutum L.) cultivar Suregrow 215 BR was planted on May 23, 2002 at a row spacing of 0.9 m with 10 plants/m. The experiment was laid out in a randomized blocks design with three replications. Cultural inputs followed University of Arkansas recommendations for cotton production and were consistent across all plots. Temperature shelters (4x5x1m) were constructed from PVC tubes to support a plastic covering over the top. The elevated night temperature treatments were achieved using "factory" heaters blowing hot air up the middle two rows of the plots (Plate 1). Similarly, the decreased temperature treatment was achieved using large "window" air conditioners blowing cool air up the center of the plots. Temperatures in each plot were monitored every 15 minutes using Watchdog temperature sensors (Spectrum Tech. Inc.) located in the center of the plot at mid canopy on the main stem of plants. The temperature treatments were imposed during the fourth week of flowering using the PVC shelters with plastic drawn over the plots at night at approximately 8:00 p.m. each night and removed at approximately 6:00 a.m. each morning (i.e. after sun down and removed just before sunrise).

About 50 bolls (white flowers) were tagged at the same fruiting position in all plots during the first, second and third week of flowering to give three ages of bolls when the temperature covers were placed over the plots at end of week 3 (i.e., at this time the tagged bolls were 3, 2 and 1 week old when the temperature treatment was imposed). Half the tagged bolls were harvested one week after removal of the covers and the remainder of the tagged bolls were measured at harvest. Seed number, fiber weight and fiber weight/seed were recorded.

Measurements were also made of leaf area, dry weight, leaf wax, and specific leaf weight one week after the temperature treatments were imposed. The effect of temperature treatment on photosynthesis and respiration was recorded in the middle of the week of temperature treatment and again one week after treatment using a LICOR 6200 portable photosynthesis system (Licor Inc, Lincoln, NE). Records were made of boll weight, weight of fiber/seed, leaf area, dry weight, and specific leaf weight.

Results and Discussion

Preliminary Temperature Study in Contrasting Environments

A comparative study of yields and temperatures was carried out in 2002 to determine why Greece has considerably higher cotton yields (1300 lb/acre) compared to Arkansas (750 lb/acre) despite many production factors being similar. A comparison of the two production systems revealed that the main factor accounting for the large yield difference was 8ºF cooler night temperatures in Greece compared to the Mississippi Delta during boll development (Fig. 3). Greek cotton did not experience elevated night temperatures and increased respiratory loses, which can be detrimental to optimum boll growth. In addition, humidity is lower in Greece during the summer so that on average evaporation keeps the leaves cooler during the day than is possible in the humid US Mid-South.

Night Temperature Study

Night temperatures were raised (space heater) and lowered (air conditioner) compared to the ambient temperature in the control (Fig. 4) The resulting effect on plant growth, physiology and boll growth did not show many significant differences (P=0.05). However, some interesting variations were observed among treatments in the parameters measured.

Effect of High Temperatures on Photosynthesis, Respiration and Plant Growth

Raising or lowering the night temperature four weeks after first flower had no significant (P=0.05) effect on respiration during the night or on photosynthesis the following day. Similarly there was no subsequent effect on these parameters one week after the night temperature treatment. The lack of effect on respiration was unexpected due to the sensitivity of these processes to temperature.

Effect on Boll Development

Similarly there was no significant effect of the night temperature treatment on leaf area and plant dry matter although the cooler night temperature treatment had numerically higher values of leaf area and dry matter. Fiber weight per seed is a fundamental component of yield (Lewis et al., 2000) but this parameter was not significantly reduced (P=0.05) by the seven-day period of altered night temperature treatment. This applied to bolls 1, 2, or 3 weeks of age experiencing the altered night temperature. In accordance with our hypothesis we expected a decrease in fiber weight from the elevated night temperature. Similarly, we expected an increase in fiber weight per seed from the cool temperature treatment but this was not observed.

The week duration of elevated or lowered night temperature may not have been sufficient for a lasting effect due to subsequent compensation during the remainder of the boll development period. Furthermore, the control temperature was cooler than expected, closer to the low temperature treatment. Unfortunately, the temperature sensors in the control treatment failed to work properly and the data was not recorded.

Total Boll Weight and Fiber Yield at Harvest

There was no significant (P=0.05) effect of raised or lowered night temperatures on final boll weight or fiber weight (Figs. 5 & 6). However, there was a numerical trend for elevated night temperature to decrease fiber and boll weight, which, although not statistically significant, supports our hypothesis of high night temperatures being detrimental to developing boll weight. Decreased boll weight would presumably be related to a shortage of carbohydrates for boll growth. It has been suggested that this would partly account for lowered yields in Arkansas during periods of high night temperature, but additional research with modifications to the protocol are needed to prove this hypothesis. High temperatures would be further compounded when coupled with periods of water shortage as invariably occurs in the Mississippi Delta at sometime during boll development in July and early August.

Conclusions

There was no significant (P=0.05) effect of raised or lowered night temperatures on final boll weight or fiber weight. However, there was a numerical trend for elevated night temperature to decrease fiber and boll weight, which supports our hypothesis of high night temperatures being detrimental to developing boll weight. Decreased boll weight would presumably be related to a shortage of carbohydrates for boll growth. It has been suggested that this would partly account for lowered yields in Arkansas during periods of high night temperature, but additional research with modifications to the protocol are needed to prove this hypothesis. There were no significant effects of altered night temperature on night respiration.

The field study will be repeated with some modifications in 2003. The night temperature treatment will be extended to two weeks as one week did not appear to be sufficient and allowed subsequent compensation. Actual boll temperature will be monitored in addition to canopy temperature. The sides of the PVC canopies may also be covered to ensure a more uniform temperature under the plastic covers. The study will be repeated in the growth chamber using two similar chambers with contrasting night temperatures during boll development. Emphasis will be placed on measurements of boll temperature, respiration and carbohydrate accumulation in bolls.

References

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Lewis, H., May, L. and Bourland, F. 2000. Cotton yield components and yield stability. pp. 532-536. Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council. Memphis, TN.

Oosterhuis, D.M. 1995. A postmortem of the disappointing yields in the 1993 Arkansas cotton crop. Proc 1994 Arkansas Cotton Research Meeting and Summaries of Research. Univ. Arkansas Agri. Exp. Sta., Special Report 166:22-26.

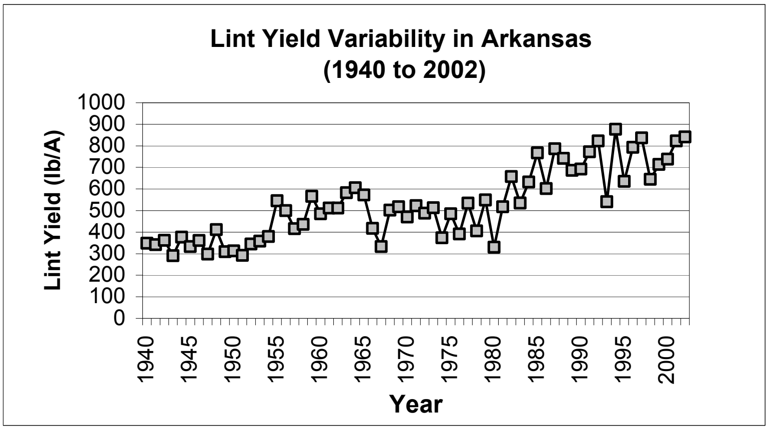

Figure 1. Lint yield variability in Arkansas from 1940 to 2002.

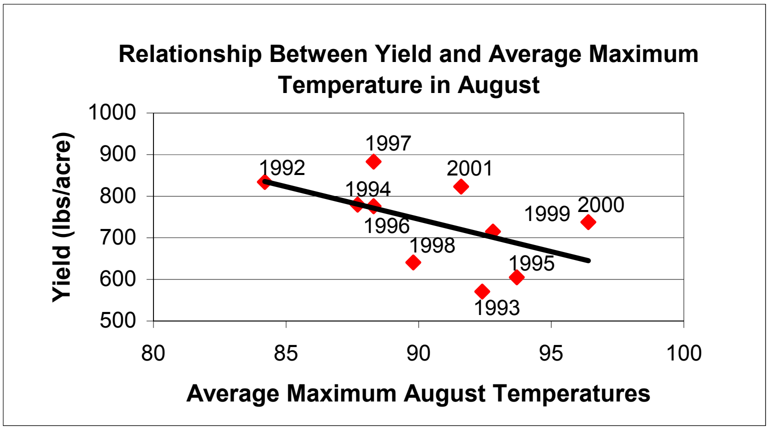

Figure 2. Relationships between yield and average maximum temperatures in Arkansas from August from 1992 to 2000.

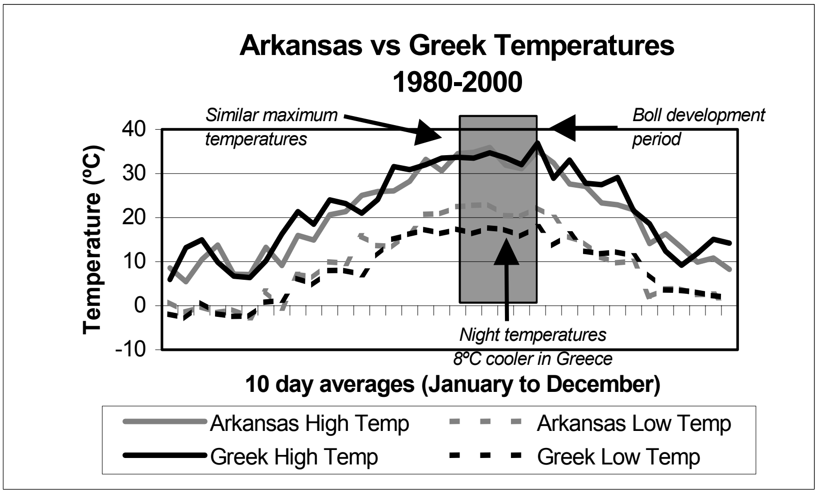

Figure 3. Arkansas versus Greek temperatures.

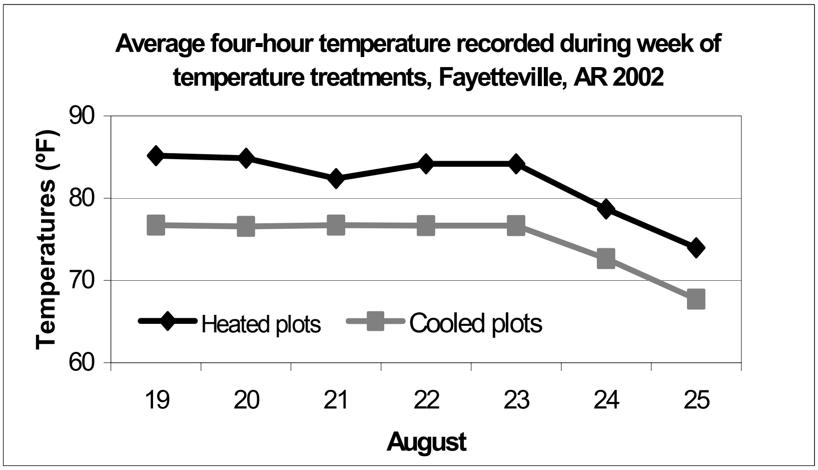

Figure 4. Daily four-hour temperatures recorded from August 19 to August 25, 2002.

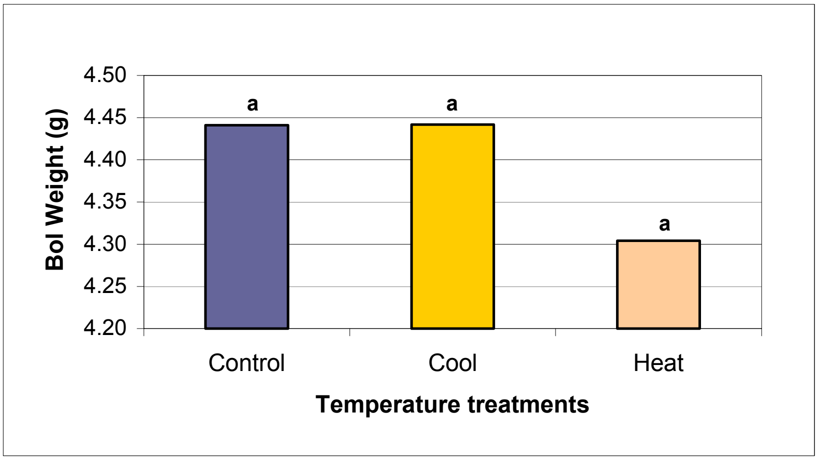

Figure 5. Average boll weight from 2m lengths of row at harvest. Fayetteville, AR, 2002.

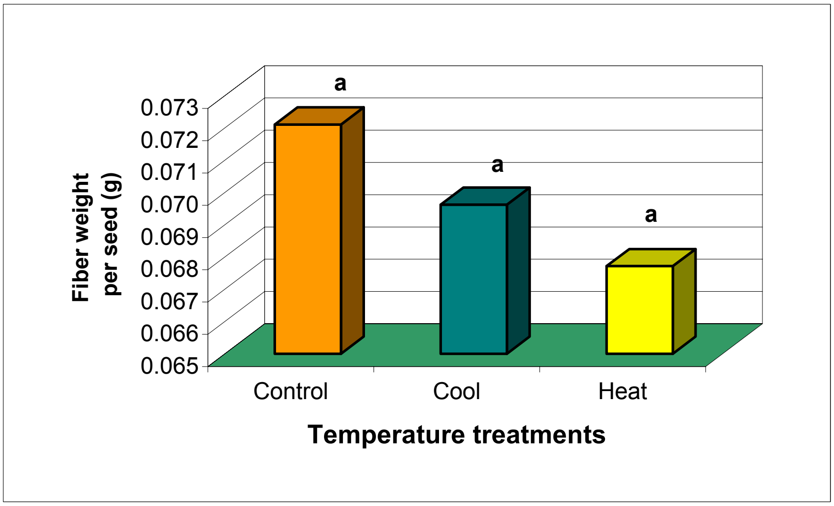

Figure 6. Weight of fiber per seed from 2m lengths of row at harvest. Fayetteville, AR, 2002.

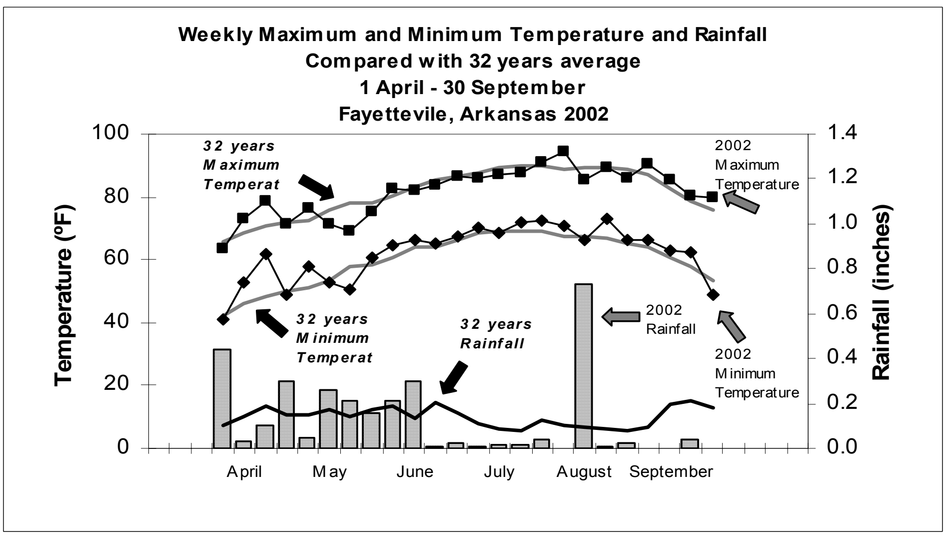

Figure 7. Long term temperature and rainfall, and current 2002 meteorological data for Fayetteville, Arkansas.

Plate 1. Temperature shelters set over the canopy of the two middle rows on each plot, Fayetteville, AR, 2002.