EFFECT OF AN UPPER TEMPERATURE THRESHOLD ON HEAT UNIT CALCULATIONS AND DEFOLIATION TIMING

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Abstract

Crop managers need to determine the most profitable time to defoliate cotton in different environments across the U.S. Cotton Belt. In cotton production, delaying defoliation exposes open bolls to a higher probability of rainfall, thus reducing lint yield and fiber quality. However, premature defoliation has detrimental effects on lint yield and fiber quality.

Several traditional methods exist to determine defoliation timing, including determining percent open bolls, counting nodes above highest cracked boll, and examining the highest harvestable bolls to determine their maturity. However, these methods rely on subjective judgment; therefore, effectiveness may be reduced.

A more recent method to determine defoliation is based on heat-unit or DD60 accumulation after physiological cutout or five nodes above white flower. This method recommends initiating defoliation at 850 heat units have accumulated from date of cutout. However, results have been inconsistent across a wide range of field environments when utilizing heat unit accumulation past cutout; therefore, adoption of this method has been limited. Many regions of the Cotton Belt have maximum day time temperatures during the growing season that above optimum for maximum growth. In these environments, crop managers may be over estimating daily heat units without the use of an upper temperature threshold.

To test this hypothesis, field studies were conducted at Uvalde, Texas; College Station, Texas; and Florence, South Carolina. At College Station and Florence, significant differences were observed in nodes above cracked boll and percent open boll values at defoliation between the two upper temperature thresholds; however, no significant differences were found at Uvalde. All three locations observed a significant difference in percent open boll at harvest between the two upper temperature thresholds. All three locations observed a significant difference in final lint yield at harvest between the two upper temperature thresholds. Lint yield was significantly higher for the 1050 heat unit treatments at Uvalde and College Station. At Florence, lint yield for the 1050 heat unit treatment was significantly higher than all other treatments except for the 950 treatment. All three locations required more than the benchmark of 850 heat units to obtain maximum lint yields. For fiber quality, the use of an upper temperature threshold did not have an effect on micronaire, length, uniformity, strength, and elongation.

Introduction

Since 1998 researchers from across the Cotton Belt have come to different conclusions on the optimum defoliation time based on heat unit (HU) accumulation from cutout (NAWF=5). COTMAN, a cotton-management expert system based on in-season plant monitoring, recommends that defoliation be initiated at 850 accumulated HUs from cutout. Utilizing an upper limit temperature threshold could possibly explain differences in results of defoliation timing and recommendations from across the Cotton Belt. An upper limit temperature threshold would impact the number of daily HUs that is accumulated in the southern areas of the Cotton Belt.

Cotton, a C_3 plant, utilizes an enzyme (rubisco; ribulose-1, 5-bisphosphate carboxylase/oxygenase), to fix atmospheric CO_2. The dual affinity of this enzyme for O_2 (photorespiration) and CO_2 (photosynthesis) results in less net carbon fixation at higher temperatures. Higher temperatures promote oxygenation, and hence photorespiration, in two ways. First, the solubility of CO_2 in water declines more rapidly than that of O_2 as temperature increases. Also, because of the specificity factor of rubisco, oxygenation is more sensitive to temperature and increases faster than the carboxyl ion as the temperature rises. Cotton growing areas with high daytime temperatures may have reduced plant efficiency due to the enhanced level of photorespiration; subsequently, net carbon availability may be decreased. This reduction in net photosynthesis has been shown to occur at approximately 90°F (Krieg, 1986). Heat units accumulated as a result of higher temperatures without an upper limit threshold may not be contributing in a positive manner, but rather in a negative manner to maturation. This may result in premature timing of harvest aids. Therefore, utilizing an upper limit temperature threshold may be useful for calculating HU accumulations relative to boll development and maturation.

Feller et al. (1998) found that the enzyme rubisco activase, which activates rubisco, is inhibited by temperatures greater than approximately 90°F that subsequently leads to reduced photosynthetic productivity. Depending on genotype, temperatures between 86 to 90°F have been shown to increase boll-fill period (Yfoulis and Fosoulas, 1978). Due to the extreme maxima and minima temperatures in the western Cotton Belt, 86/55°F threshold is used to increase the precision of growth monitoring and management (Unruh and Silvertooth, 1997). Plants gained more total biomass and partitioned more of it to bolls and squares at 86/68°F day/night temperatures than any other temperature regime examined (Reddy et al., 1991).

This study was designed to test the hypothesis that the existence of an upper limit temperature threshold could influence the optimum time to defoliate with accumulated HU from cutout and explain the variability in results and timing recommendations from across the Cotton Belt.

Objective

To compare the effects of utilizing different upper limit temperature threshold levels to calculate HU accumulation after cutout and the subsequent impact on defoliation timing, yield, and fiber quality.

Materials/Methods

Identical studies were conducted in 2007 at the Texas Agricultural Experiment Station in Uvalde, Texas; the Texas Agricultural Experiment Station near College Station, Texas; and at Clemson University in Florence, South Carolina. Treatments consisted of two different upper limit temperature thresholds (86°F and no upper limit) and defoliation at five maturity stages based on accumulated HU from date of cutout. Plots were four rows wide (40-inch centers) by forty feet in length. The study was arranged as a 2x5 split-plot design, with the main plot being upper limit temperature thresholds of 86°F and no upper limit temperature and the sub-plots were 650, 750, 850, 950, and 1050 accumulated HUs. Each treatment was replicated four times. State Extension guidelines were followed regarding insect control, weed control, and fertility. Statistical analysis used was the Proc GLM procedure in SAS (9.1.3) and means were separated using the LSD method at the $P \leq 0.05$ significant level.

Beginning at first bloom, nodes above white flower (NAWF) counts were taken on a weekly basis until cutout was reached. Ten plants per plot were sampled in order to obtain an accurate NAWF count. At cutout (NAWF=5), daily heat units were recorded until the day of defoliation. Heat units were calculated by the following equation [(daily high °F + daily low °F/2)] – 60°F. Each day, heat units were calculated using the two upper limit temperature thresholds. For example, if the daily high was 101°F; then 86°F and 101°F would be used in the heat unit equation to determine the daily heat units for the three upper limit temperature thresholds. Daily temperatures were obtained from a weather station located nearby. Nodes above cracked boll (NACB) counts were recorded on the day of defoliation application. NACB measurements were recorded from 10 plants per plot. Percent open boll at defoliation and harvest were determined by plant mapping (PMAP 4.0) ten plants per plot. Defoliation applications consisted of a tank-mix of Dropp 6SC (1.6 oz/A) + Def 6EC (6 oz/A) + Prep 6EC (21.33 oz/A). All treatments were harvested 10 to 14 days after defoliation. Fiber quality measurements were determined by sending samples to the International Textile Center in Lubbock, Texas. Fiber quality measurements for the Florence, South Carolina location are not included in this report. Statistical analysis was conducted by using SAS (Proc GLM) and mean separation with Fishers Protected LSD.

Results

Nodes Above Cracked Boll

At College Station and Florence, significant differences were observed in nodes above cracked boll values between the two upper temperature thresholds; however, no significant differences were found at Uvalde. As expected, nodes above cracked boll values decreased in value as accumulated heat units from cutout increased . A significant upper temperature threshold by heat unit interaction was observed at the College Station and Florence locations Table 1).

Table 1. Nodes above cracked boll values at defoliation. Uvalde, Texas; College Station, Texas; and Florence, South Carolina, 2007.

HU	Uvalde, TX	College Station, TX	Florence, SC
650	7.18 a	7.25 a	9.75 a
750	6.23 a	6.66 ab	9.60 a
850	4.99 b	6.05 b	7.53 b
950	2.40 c	4.53 c	6.41 c
1050	1.55 c	4.03 c	4.58 c
Pr>f	0.0001	0.0001	0.0001
UTT			
86°F	4.21 a	5.32 b	5.75 b
No upper limit	4.73 a	6.09 a	9.22 a
Pr>f	0.1308	0.0007	0.0001
UTT x HU	0.2224	0.0053	0.0124

Percent Open Boll at Defoliation

At College Station and Florence, significant differences were observed in percent open boll at defoliation between the two upper temperature thresholds; however, no significant differences were found at Uvalde. A significant upper temperature threshold by heat unit interaction was observed at the Florence location (Table 2).

Table 2. Percent open boll at defoliation. Uvalde, Texas; College Station, Texas; and Florence, South Carolina, 2007.

HU	Uvalde, TX	College Station, TX	Florence, SC
650	3.29 c	21.13 e	1.00 d
750	10.43 c	38.50 d	5.42 d
850	32.21 b	45.88 c	26.20 c
950	52.28 a	53.88 b	39.44 b
1050	62.43 a	63.50 a	54.29 a
Pr>f	0.0001	0.0001	0.0001
UTT			
86°F	34.82 a	49.05 a	46.09 a
No upper limit	29.43 a	40.10 b	4.46 b
Pr>f	0.1029	0.0001	0.0001
UTT x HU	0.4586	0.0757	0.0001

Percent Open Boll at Harvest

All three locations observed a significant difference in percent open boll at harvest between the two upper temperature thresholds. However, a significant upper temperature threshold by heat unit interaction was found at all three of the locations (Table 3).

Table 3. Percent open boll at harvest. Uvalde, Texas; College Station, Texas; and Florence, South Carolina, 2007.

HU	Uvalde, TX	College Station, TX	Florence, SC
650	45.68 c	85.75 c	45.20 d
750	61.76 b	82.50 c	64.28 c
850	78.83 a	94.75 b	77.01 b
950	71.30 a	96.00 ab	84.76 b
1050	80.34 a	98.63 a	96.33 a
Pr>f	0.0001	0.0001	0.0001
UTT			
86°F	71.74 a	93.85 a	92.33 a
No upper limit	63.42 b	89.20 b	54.70 b
Pr>f	0.255	0.0005	0.0001
UTT x HU	0.0050	0.0118	0.0004

Lint Yield

All three locations observed a significant difference in final lint yield at harvest between the two upper temperature thresholds. Lint yield was significantly higher for the 1050 heat unit treatments at Uvalde and College Station. At Florence, lint yield for the 1050 heat unit treatment was significantly higher than all other treatments except for the 950 treatment. A significant upper temperature threshold by heat unit interaction was found at all three of the locations (Table 4).

Table 4. Lint yield in pounds per acre. Uvalde, Texas; College Station, Texas; and Florence, South Carolina, 2007.

HU	Uvalde, TX	College Station, TX	Florence, SC
650	616 d	671 e	308 d
750	887 c	960 d	433 c
850	1047 c	1137 c	498 bc
950	1282 b	1378 b	597 ab
1050	1504 a	1467 a	631 a
Pr>f	0.0001	0.0001	0.0001
UTT			
86°F	1156 a	1267 a	619 a
No upper limit	979 b	978 b	367 b
Pr>f	0.0033	0.0001	0.0001
UTT x HU	0.0008	0.0001	0.0212

Fiber Micronaire

At Uvalde and College Station, upper temperature threshold did not have an effect on micronaire values. There was a significant upper temperature threshold by heat unit interaction at Uvalde (Table 5).

Table 5. Micronaire values. Uvalde and College Station, Texas, 2007.

HU	Uvalde, Texas	College Station, Texas
650	3.99 a	4.85 a
750	3.94 ab	4.75 a
850	3.78 bc	4.68 a
950	3.69 c	4.61 ab
1050	3.81 bc	4.41 b
Pr>f	0.0105	0.0188
UTT		
86°F	3.83 a	4.66 a
No upper limit	3.86 a	4.65 a
Pr>f	0.5796	0.8978
UTT x HU	0.0045	0.1757

Fiber Length

At Uvalde and College Station, upper temperature threshold did not have an effect on fiber length values. For the accumulated heat unit treatments, there were no significant differences in length for the Uvalde location. At College Station, fiber length for the 850 treatment was significantly higher compared to all other treatments except for the 950 treatment. There was a significant upper temperature threshold by heat unit interaction at College Station (Table 6).

Table 6. Fiber length values. Uvalde and College Station, Texas, 2007.

HU	Uvalde, Texas	College Station, Texas
650	1.13 a	1.14 b
750	1.14 a	1.14 b
850	1.15 a	1.17 a
950	1.17 a	1.15 ab
1050	1.15 a	1.14 b
Pr>f	0.3328	0.0074
UTT		
86°F	1.15 a	1.15 a
No upper limit	1.15 a	1.14 a
Pr>f	0.577	0.1512
UTT x HU	0.7765	0.0009

Fiber Uniformity

Uniformity was not affected by the upper temperature threshold or accumulated heat unit treatment (Table 7).

Table 7. Uniformity values. Uvalde and College Station, Texas, 2007.

HU	Uvalde, Texas	College Station, Texas
650	84.06 a	81.36 a
750	83.41 a	80.96 a
850	82.76 a	81.24 a
950	84.41 a	81.64 a
1050	83.94 a	80.86 a
Pr>f	0.1105	0.6343
UTT		
86°F	83.70 a	81.17 a
No upper limit	83.70 a	81.26 a
Pr>f	0.9701	0.7864
UTT x HU	0.0860	0.4933

Fiber Strength

Fiber strength was not affected by the upper temperature threshold or accumulated heat unit treatment (Table 8).

Table 8. Fiber strength values. Uvalde and College Station, Texas, 2007.

HU	Uvalde, Texas	College Station, Texas
650	29.55 a	27.91 a
750	28.86 a	27.61 a
850	28.49 a	28.06 a
950	29.09 a	27.44 a
1050	28.73 a	27.00 a
Pr>f	0.5478	0.3972
UTT		
86°F	28.89 a	27.84 a
No upper limit	29.00 a	27.38 a
Pr>f	0.7804	0.2169
UTT x HU	0.1511	0.4647

Fiber Elongation

Fiber elongation was not affected by the upper temperature threshold or accumulated heat unit treatment (Table 9).

Table 9. Fiber elongation values. Uvalde and College Station, Texas, 2007.

HU	Uvalde, Texas	College Station, Texas
650	7.94 a	7.15 a
750	7.99 a	6.95 a
850	7.70 a	7.01 a
950	7.61 a	6.95 a
1050	7.75 a	7.25 a
Pr>f	0.0613	0.2756
UTT		
86°F	7.74 a	7.08 a
No upper limit	7.86 a	7.05 a
Pr>f	0.1701	0.7338
UTT x HU	0.7106	0.5258

Conclusions

At College Station and Florence, significant differences were observed in nodes above cracked boll and percent open boll values at defoliation between the two upper temperature thresholds; however, no significant differences were found at Uvalde. All three locations observed a significant difference in percent open boll at harvest between the two upper temperature thresholds. All three locations observed a significant difference in final lint yield at harvest between the two upper temperature thresholds. Lint yield was significantly higher for the 1050 heat unit treatments at Uvalde and College Station. At Florence, lint yield for the 1050 heat unit treatment was significantly higher than all other treatments except for the 950 treatment. All three locations required more than the benchmark of 850 heat units to obtain maximum lint yields. For fiber quality, the use of an upper temperature threshold did not have an effect on micronaire, length, uniformity, strength, and elongation.

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