HEAT, MATURITY, AND DEFOLIATION

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Abstract

Harvest aid timing is essential for timely harvest. Early harvest aid application can lead to delayed harvest, need for multiple harvest aid applications, decreased yield, reduced lint quality, and ultimately reduced cotton profitability. Harvest aid timing is based upon boll maturity, with many methods currently existing for determining the proper application timing of harvest aid materials. One method of determining time of harvest aid application is based on accumulated heat units after physiological maturity. Currently, 850 heat units after cutout is the guideline set for defoliant application without observing a reduction in yield. However, this recommendation may be premature in some cotton growing areas. A study was conducted in 2000 and 2001 to address the effects of early and late applications of harvest aids based upon varying accumulated heat units after cutout. A field study was conducted at the Texas Agricultural Experiment Station in Burleson County, in 2000, and a controlled environment (i.e greenhouse) study at the Norman Borlaug Crop Biotechnology Center at Texas A&M University in College Station. Two cotton varieties, DP 20B and DP 422 B/RR, were planted with each being treated with defoliants at 650, 750, 850, 950, and 1050 HU accumulated after cutout. In the field experiment, percent open boll counts at the day of harvest aid application ranged from 1 to 68 percent, in 650 and 1050 HU treatments, respectively. Treatments having less than 950 HU exhibited 25 percent or less open bolls. At 14 DAT, 650, 750 and 850 HU had less than 67 percent open bolls where 950 and 1050 HU had greater than 87 percent open bolls. At 14 DAT, all treatments had greater than 76 percent defoliation with 950 and 1050 HU showing greater than 90 percent leaf removal. These effects were furthermore realized with lint yields ranging from 354 to 867 lbs. lint /A with 650 HU yielding the least and 1050 HU being the most. In the greenhouse DP 422 B/RR yielded numerically more lint yield than DP 20B. However, the effects of HU treatments were identical and representative of the observed results from the field study in 2000. These data lead to three possible conclusions: 1) the definition for cotton 'cutout' of 5 NAWF cannot be applied uniformly to all cotton growing areas; 2) the use of 850 HU after 'cutout' is inadequate for timing harvest aid application without reducing lint yield; and 3) an upper limit threshold temperature of 90^{o}F is needed for calculating HU after physiological maturity.

Introduction

At 45 to 60 days after emergence cotton (*Gossypium hirsutum* L.) begins flowering and continues until it reaches physiological maturity, producing fruiting structures that potentially create economic biomass. After physiological maturity the cotton plant progresses toward senescence and an overall vegetative decline, leading to cotton defoliation. Physiological maturity is where vegetative carbon allocation equals reproductive demands. Cutout which is the point at which there are five nodes above the uppermost first position white flower (5 NAWF) (Bourland et al., 1986), has also been defined as physiological maturity. At this stage of development all economic yield has been established on the plant. This measurement assumes that the last effective boll that contributes to yield is set at this uppermost sympodial branch. However, the definition of 5 NAWF may not be a correct definition for establishing physiological maturity in all cotton growing areas (i.e. dryland versus irrigated).

After physiological maturity, grower need for determining proper defoliation timing is essential. Harvest aid timing is based upon boll maturity, with many methods currently existing for determining the proper application timing of harvest aid materials. One method of determining time of harvest aid application is based on accumulated heat units (i.e. HU; degree day units, DD60s) after physiological maturity (i.e. cutout, 5 NAWF). Once % NAWF is determined, HU are accumulated daily until the desired quantity has been met. Currently, 850 HU after cutout is the guideline set for defoliant application without observing a reduction in yield (Tugwell, et al., 1998; Benson, et al., 2000).

Growing degree days is currently obtained by adding the daily maximum and daily minimum temperature (^{o}F), dividing this value by two, and then subtracting a base temperature (60 ^{o}F for cotton) for the particular crop. At present, this method does not include an upper limit temperature threshold. Without establishing an upper limit threshold in areas where summer daily temperatures exceed 90^{o}F, and nighttime temperatures are also high, the calculated HU may be overestimated. These HU in excess of 90^{o}F may be more harmful than beneficial in effectively maturing the crop. Furthermore, addition of these excessive degree day units to the accumulated measurement may result in premature application of harvest aids to underdeveloped cotton bolls.

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 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^{o}F (Krieg, 1986). Therefore, an upper limit threshold temperature may be useful for calculating heat unit accumulation relative to fiber development and maturation.

Wallach and Kletter (1981) developed a method of accumulating growing degree days (i.e. heat units) utilizing day length, an upper limit threshold of 30^{o}C (~86^{o}F), and a base temperature of 12^{o}C (~54^{o}F). This method effectively reduces the time for heat unit accumulation and potentially serves as a more accurate estimate of maturity. However, Wallach and Kletter's method for calculating growing degree days is more complicated and time consuming than the method currently being used. This intensive method uses day length incorporated into a series of three formulas to determine degree days. The current method is more grower friendly and potentially could be more accurate if an upper limit threshold temperature were utilized.

Early harvest aid application can lead to delayed harvest, need for multiple harvest aid applications, decreased yield, reduced lint quality, and ultimately reduced cotton profitability. A study was conducted in 2000 and 2001 to address the effects of early and late applications of harvest aids based upon varying accumulated heat units after cutout.

Methodology

A field study was conducted at the Texas Agricultural Experiment Station in Burleson County, in 2000, and a controlled environment (i.e greenhouse) study at the Norman Borlaug Crop Biotechnology Center at Texas A&M University in College Station. Two cotton varieties, DP 20B and DP 422 B/RR, were planted with each being treated with defoliants at 650, 750, 850, 950, and 1050 HU accumulated after cutout. The field study was arranged as a split-plot design, with whole plot being variety and sub-plot being treatment. Due to greenhouse logistics, the experiment was designed as a randomized complete block design, utilizing the same HU treatments. All treatments were defoliated with a tank-mix of Dropp® (0.1 lb/A), Folex® (1.0 pt/A), and Prep™ (1.33 pt/A) and picked 14 days after application.

Results – Field Experiment

No differences were observed in any of the parameters measured between the two cotton varieties. Furthermore, there was no variety by treatment interaction, meaning that both varieties exhibited the same response to all treatments. DP20B yielded significantly more lint per acre, when averaged across treatments, than DP 422 B/RR with 641 compared to 543 lbs./A, respectively. Percent open boll counts at the day of harvest aid application ranged from 1 to 68 percent, in 650 and 1050 HU treatments, respectively. Treatments having less than 950 HU exhibited 25 percent or less open bolls. At 14 DAT, 650, 750 and 850 HU had less than 67 percent open bolls where 950 and 1050 HU had greater than 87 percent open bolls. At 14 DAT, all treatments had greater than 76 percent defoliation with 950 and 1050 HU showing greater than 90 percent leaf removal. These effects were furthermore realized with lint yields ranging from 354 to 867 lbs. lint /A with 650 HU yielding the least and 1050 HU being the most. The most staggering effect of premature defoliant application is visualized when monetary values are added toward lint yield (Table 1). Additionally, some of the observed price reduction was due to discounts realized from lint quality reductions, not solely lint quantity (data not shown).

These data support the theory for an upper limit temperature threshold, of 90^{o}F, to be implemented from cutout until the prescribed heat unit accumulation is achieved. If this threshold was implemented the effect upon defoliation timing, in days, would have been as follows: 650 HU five days, 750 HU six days, 850 HU seven days, 950 HU eight days, and 1050 HU nine days later. This would in effect actually make the applications coincide with the each subsequent defoliation treatment. Therefore, applying an upper limit threshold would approximately establish 850 HU after cutout as really 950 HU using no upper limit threshold.

Results – Greenhouse Experiment

No differences were observed any of the parameters measured for either of the cotton varieties. In the greenhouse DP 422 B/RR yielded numerically more lint yield than DP 20B. However, the effects of HU treatments were identical and representative of the observed results from the field study in 2000. The influence upon yield and economic yield are shown in table 2; however, the effect of lint quality was not included and all prices were based upon the calculated CCC loan rates.

These data further support the need for an updated heat unit definition for defoliation application or for the implementation of an upper limit temperature threshold for calculation of growing degree days.

Conclusions

These data lead to three possible conclusions: 1) the definition for cotton ‘cutout’ of 5 NAWF cannot be applied uniformly to all cotton growing areas; 2) the use of 850 HU after ‘cutout’ is inadequate for timing harvest aid application without reducing lint yield; and 3) an upper limit threshold temperature of 90^{o}F is needed for calculating HU after physiological maturity. Therefore, a more extensive study should be conducted to determine the proper accumulation of heat units needed to ensure proper timing of harvest aids in Texas before this method can be used effectively.

Future Research

Accumulated heat units required to mature a given boll within the canopy should be determined. With this information the need for determining physiological maturity would be irrelevant in that the decision for application of harvest aids would be based upon the maturity of the last desired boll contributing to yield. This information would allow growers the ability to tailor the crop to fit the individual cost benefit analysis and desired yield. A ^{14}C translocation study also needs to be implemented to determine when carbon ceases to accumulate in developing cotton fruit and how many heat units were accumulated during this period.

Literature Cited

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Table 1. Lint yield and economic influence of heat unit accumulation – Field experiment.

Accum.	DP 422 B/RR			DP 20B		
Heat Units	**Lint / A**	**$ / lb.†**	**$ / A**	**Lint / A**	**$ / lb.†**	**$ / A**
650	263 D‡	0.0730	19.20	445 d‡	0.0730	32.49
750	434 D	0.3720	161.45	508 c	0.3720	188.98
850	468 C	0.4145	193.99	615 c	0.3990	245.36
950	728 B	0.4145	321.41	728 b	0.4145	350.99
1050	824 A	0.4275	352.26	909 a	0.4415	400.88

† Dollar per pound calculated using 2001 CCC loan value of SLM, 34 = $0.5165

‡ All analysis was performed using the General Linear Model in SAS (SAS Institute, 1999) with means separated using Fisher’s Protected LSD at a significance level of 5%.

Table 2. Lint yield and economic influence of heat unit accumulation – Greenhouse experiment.

Accum. Heat Units	**DP 422 B/RR**			**DP 20B**		
	Lint / A	**$ / lb.**[†]	**$ / A**	**Lint / A**	**$ / lb.**[†]	**$ / A**
650	602 B[‡]	0.5164	310.93	164 d[‡]	0.5164	84.71
750	680 B	0.5164	351.22	758 c	0.5164	391.51
850	1405 AB	0.5164	725.68	1157 bc	0.5164	597.59
950	1241 AB	0.5164	640.98	1483 ab	0.5164	765.97
1050	1826 A	0.5164	943.13	1624 a	0.5164	838.80

[†] Dollar per pound calculated using 2001 CCC loan value of SLM, 34 = $0.5165

[‡] All analysis was performed using the General Linear Model in SAS (SAS Institute, 1999) with means separated using Fisher's Protected LSD at a significance level of 5%.