COTTON RESPONSE TO IRRIGATION TIMING AND USE OF ENHANCED EFFICIENCY NITROGEN FERTILIZER AND BIOSOLIDS

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Abstract

Will cotton respond differently to N fertilizer sources if irrigation timing is varied? In this 2010 field study in NE Arkansas, we found that nitrogen fertilizer source did not significantly affect final lint yields, but irrigation timing did impact yield. Waiting until first flowers to start irrigation resulted in crop delay and reduced yields compared to an irrigation start time that was scheduled to avoid pre-flower water deficit stress. Overall highest yields were observed in early irrigated cotton fertilized with ESN, a polymer coated, slow release urea. Implementation of innovation technologies such as slow release fertilizers can lead to environmentally sustainable cotton system.

Introduction

Timing irrigation initiation to avoid pre-flower water deficits has been shown to improve earliness and increase cotton yields in Arkansas (Teague et al 1999, 2005a,b, 2006,Teague and Danforth 2009, 2010). Irrigation research was expanded in 2010 to examine how changes in timing of irrigation initiation could affect N use efficiency. This long term cotton systems study will assess agronomic, economic and environmental impacts of conservation practices and is part of a Cotton Inc. supported cotton sustainability project at the Judd Hill Foundation Research Farm in NE Arkansas.

Materials and Methods

The field study was carried out at the Judd Hill Plantation near Trumann, AR. The growing season is May through October, and the latest possible cutout date (that date with a 50% or 85% probability of attaining 850 DD60s from cutout) for this production area is 11 or 3 Aug, respectively (Zhang et al. 1994 and Danforth and O'Leary 1998).

The experiment was designed as a 3X4 factorial experiment with irrigation timing (3 factors) and N fertilizer (4 factors) arranged in a split plot with irrigation considered main plots. Furrow irrigation was initiated either during the 2nd week of squaring (early) or was delayed 2 additional weeks until first flowers (delayed start) (Table 1). A non irrigated control was included. Fertilizer was applied prior to planting at 100 lb N/acre either as urea, polymer coated urea (trade name ESN), or urea + 300 lb/ac biosolids (trade name Top Choice Organic). ESN is a polymer coated, controlled release fertilizer from Agrium, Inc. Top Choice Organic is a 4-3-0 soil amendment (biosolids) available from TopChoice Organic, Poinsett Fertilizer, Trumann, AR. An unfertilized check (0 N) also was included. Fertilizers and biosolids were broadcast by hand and incorporated using a disk bedders on 6 May. Beds were flattened at planting with a DO-All. Cruiser treated (thiamethoxam) Stoneville 4288 B2RF was seeded on 7 May 2010 in the Dundee silt loam soil at 3 to 4 seeds/ft. Row spacing was 38 inches. Production practices were similar across all treatments in-season including insect and weed control, plant growth regulator application and defoliation; only irrigation start timing and N fertilizer inputs were varied for the study.

The COTMAN crop monitoring system (Danforth and O'Leary 1998; Oosterhuis and Bourland 2008) was used to document differences in crop development among irrigation and fertilizer treatments from squaring until physiological cutout. Two sets of five consecutive plants in the center rows of each plot were monitored weekly using the Squaremap sampling procedure which includes measurement of plant height, number of main stem sympodia, and presence or absence of first position squares and bolls. After 1st flowers, Squaremap sampling of consecutive plants was continued to monitor square and boll retention and sympodial growth. End-of-season season plant mapping was performed each year using the COTMAP procedure (Bourland and Watson 1990). Ten plants in one row per plot were examined for node number of first (lowest) sympodial branch on the main axis, number of monopodia, and number of bolls on sympodia arising from monopodia. Bolls located on main stem sympodia (1st and 2nd position) were recorded, as well as bolls located on the outer positions on sympodial nodes (>2nd position). The highest sympodium with 2 nodal positions and number of bolls on sympodia located on secondary axillary positions were also noted. Plant height was measured as distance from soil to apex.

Table 1. Irrigation timing dates for early start and delayed start irrigation timing for 2010 Judd Hill irrigation timing * N source field trial.

Irrigation Timing	Date of irrigation	Days after planting (DAP)
Early Start	12, 18 June	36, 42
Early Start & Delayed Start	24 June, 1, 8, 23 July, 3, 11 August	48, 55, 62, 77, 88, 96

Weekly insect sampling using drop cloths confirmed efficacy of insect control. All insect and crop monitoring activities were confined to specific rows during the season to avoid thigmonastic effects of sampling procedures on plant growth, fiber production and quality. A 2 row research cotton picker was used to harvest two center rows per plot. After defoliation, fifty consecutive bolls, hand-picked from adjacent whole plants in the plot sample row, were collected, ginned on a laboratory gin and submitted to the Fiber and Biopolymer Research Institute at Texas Tech University for HVI fiber quality determinations. Plant monitoring, yield and fiber quality data were analyzed using ANOVA with mean separation using protected LSD.

Results

Irrigation Timing Effects

The 2010 crop season featured hot summer temperatures with low levels of rainfall except for one series of rain events in mid-July (Table 2). Results from plant monitoring with COTMAN reveal significant differences in pace of pre-flower nodal development among irrigation treatments. We interpret these differences an indication of water deficit stress in delayed and rainfed treatments (Figure 1). The hot early season temperatures resulted in first flowers by the 52 DAP sample at which time there were significantly greater numbers of main stem squaring nodes per plant (main stem sympodia that have not yet flowered) in the early irrigation treatment (8.2 nodes) compared to delayed and rainfed treatments (6.5 and 6.6, respectively) (P=0.007; LSD05=0.78). When delayed irrigation start plants finally received water, plant terminal growth, which had stalled, was restarted. Small boll shed accompanied this revival (Figure 2). At about 65 DAP, the slope of the COTMAN growth curve for plants grown with delayed irrigation was flat compared to the reference curve. A reduced slope is interpreted as an indicator of lower metabolic stress from boll loading and indicates a delay in crop maturity ((Bourland et al 2008). Crop delay associated with irrigation timing is clearly evident in values for mean no. days from planting to physiological cutout (Figure 3).

Table 2. Average monthly heat unit (DD60s) and precipitation accumulation, 1960-2007 for Northeast Arkansas[1] summer months compared to 2010 on-farm measurements at Judd Hill.

	Heat Units (DD60s) [2]		Rain (inches)		2010 Deviation from Average	
Month	Average[1]	2010	Average[1]	2010	Heat Units	Rainfall
June	532	732	3.89	0.63	200	-3.26
July	644	721	3.67	7.02	77	3.35
August	583	730	2.85	0.30	147	-2.55
September	363	454	3.73	0.78	91	-2.95
				Total	515	-5.41

[1]Source: NOAA National Climatic Data Center, daily surface data for Keiser, AR
[2]Heat unit calculations were based on average daily temperature calculated using high and low temperatures (Daily Heat Units= ((High+Low)/2)-60)

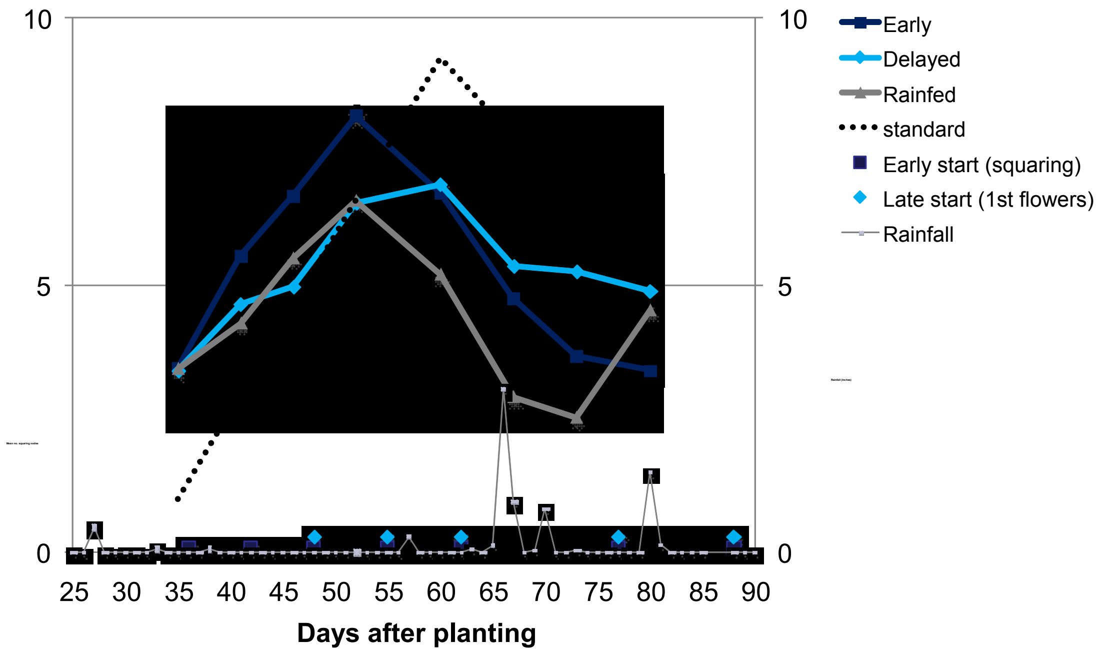

Figure 1. COTMAN growth curves for irrigation timing main plots and the COTMAN target development curve (standard). Irrigation timing for early start and late start are shown on the x-axis. Daily rainfall amounts are also shown for the 2010 season.

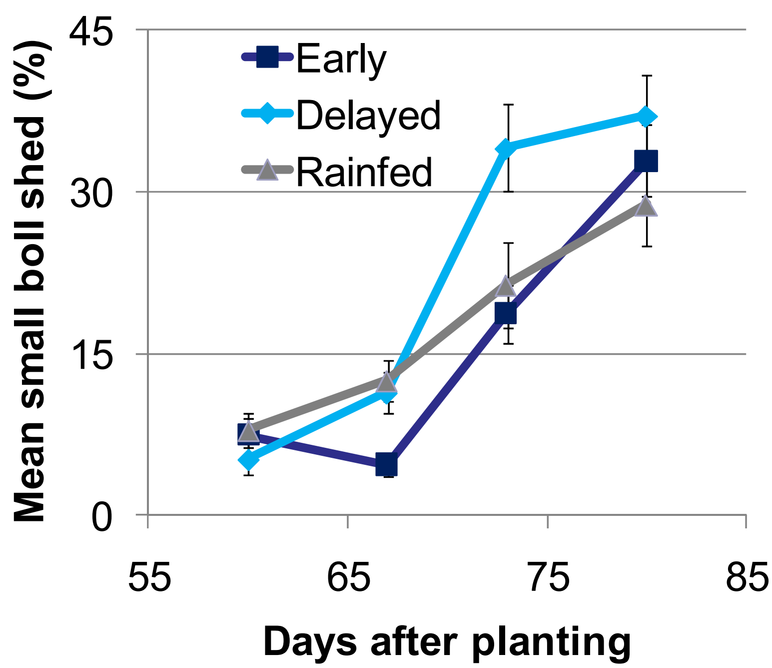

Figure 2. Small boll shed (three uppermost first position bolls), monitored using COTMAN was highest when irrigation was delayed until first flowers. Insects were not associated with this fruit loss; small boll shed was a physiological response associated with pre-flower water deficit stress relieved by late irrigation and rains.

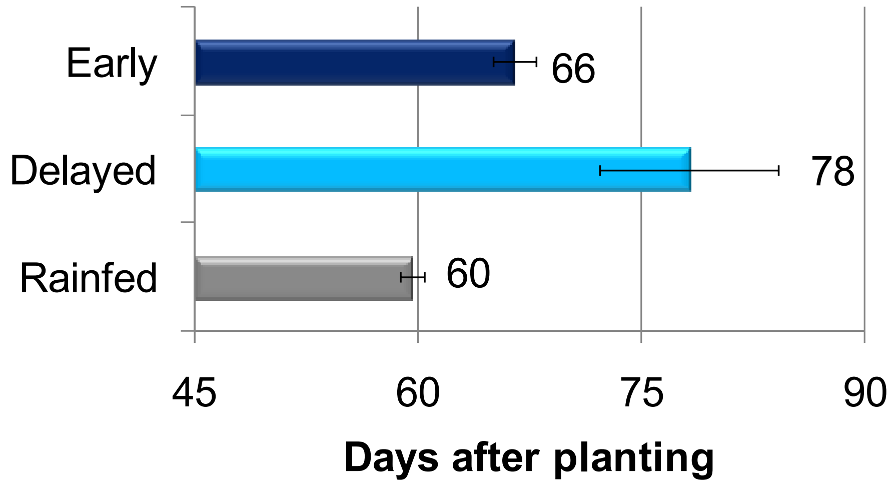

Figure 3. Mean no. days to physiological cutout (NAWF=5) for cotton in three irrigation timing main plots. When irrigation initiation was delayed two weeks, physiological cutout (NAWF=5) was delayed by 12 days. Water stress resulted in cutout at 60 DAP for rainfed cotton.

Fertilizer Effects

COTMAN growth curves also provided in-season evidence of variation in crop nodal development among fertilizer treatments (Figure 4). Unfertilized plants grown with early irrigation, produced fewer mean no. squaring nodes (±SEM) by first flowers compared to fertilized treatments. Unfertilized plants reached physiological cutout (NAWF=5) earlier than fertilized plants. When plants were subjected to pre-flower water stress either in delayed or rainfed treatments, differences in pace of pre-flower nodal development among the different N fertilizer treatments were not as apparent as compared to early irrigated plants. Soil N from fertilizer applications likely was not as available to those plants because of reduced soil moisture. Following irrigation, late season rank growth in was observed in delayed irrigation treatments, particularly for urea fertilized cotton. Results from petiole sampling as well as other in-season measures of plant N and biomass are not yet complete.

Conclusions

Irrigation: Using standardized COTMAN plant monitoring procedures, we recorded changes in fruiting dynamics resulting from pre-flower water deficit stress. Results from delayed irrigation initiation included:

- Fewer main stem sympodia (fruiting branches) at first flowers
- Greater small boll shed in the 2nd and 3rd week of flowering
- Later maturity – an extra12 days to reach physiological cutout (NAWF=5)
- Result: 16% yield penalty

Fertilizer: Fertilized treatments outperformed non-fertilized checks; however, there were no significant differences in yield among fertilizer sources.

- Fiber quality measures for length, uniformity and strength were reduced in unfertilized checks
- Addition of biosolids at 300 lb/ac with urea had no impact on yield in the first year of the study
- Properly irrigated cotton fertilized with polymer coated, slow release urea produced highest mean yields

Producers should time irrigation applications to avoid pre-flower water deficits that can delay the crop and reduce yields. COTMAN growth curves are useful in monitoring effects on pre-flower crop development pace as well as late season crop maturity following pre-flower water deficits. Growth curves aid in interpreting causes of late season crop growth. In season crop monitoring also will aid in proper implementation of innovative technologies such as slow release fertilizers which ultimately may benefit cotton production as well as help protect the environment and lead to a more sustainable cotton system. This study will be repeated in 2011 with expanded evaluations of irrigation and fertilizer effects on farm profit and measures of environmental impact.

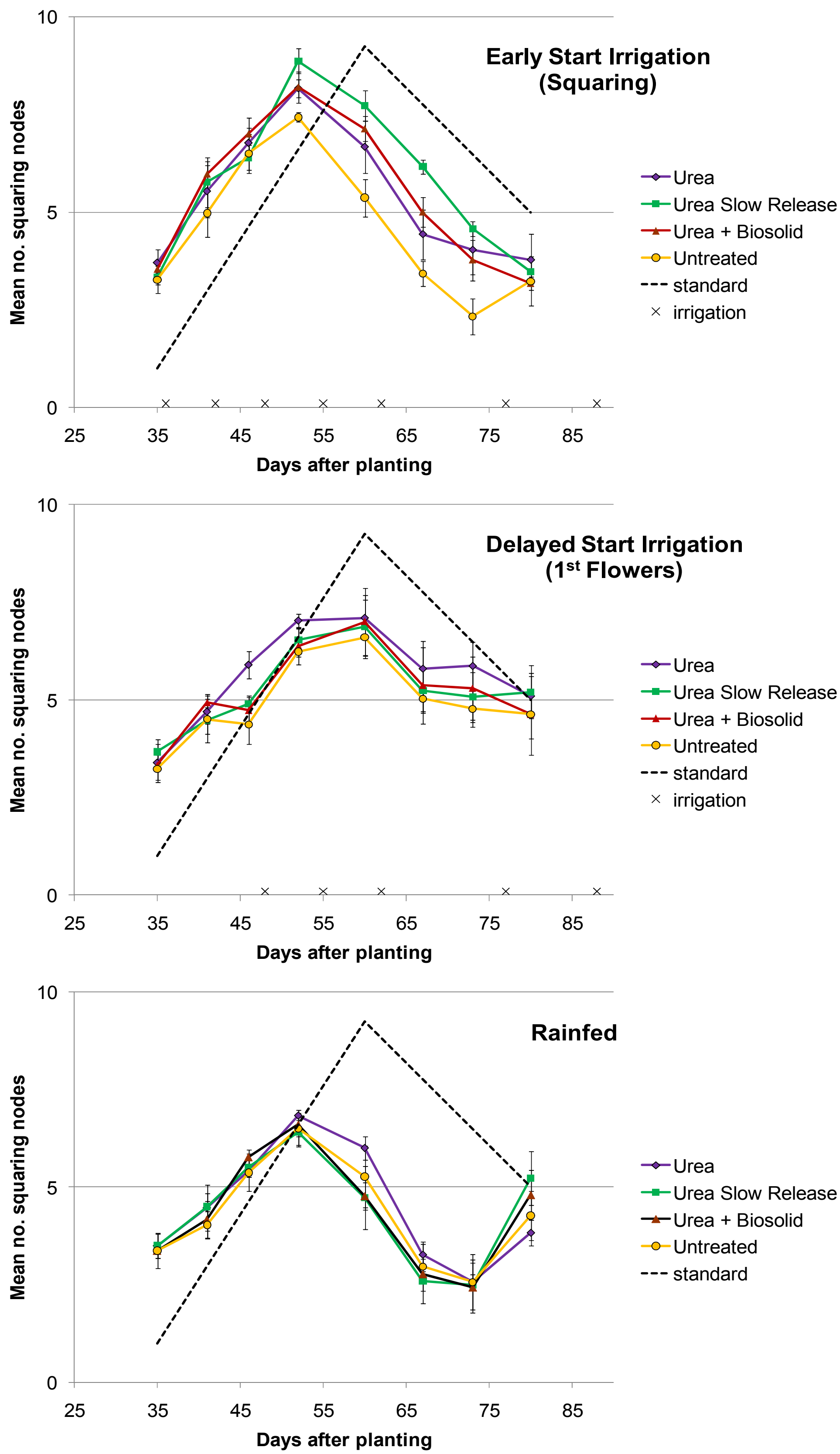

Figure 4. COTMAN growth curves for N fertilizer treatments for each irrigation timing..

Table 3. Results from final end-of-season plant mapping using COTMAP for irrigation timing main plot effects- 2010[1].

Category	Mean per plant for irrigation treatment				
	Early Start	Delayed Start	Rainfed	*P>F*	*LSD_{05}*
1st Sympodial Node	6.4	6.3	6.2	*0.19*	
No. Monopodia	1.8	1.3	1.1	*0.02*	*0.4*
Highest Sympodia with 2 nodes	9.5	11.3	8.4	*0.03*	*1.8*
Plant Height (inches)	33.4	33.4	23.6	*0.02*	*3.8*
No. Effective Sympodia	6.9	7.7	5.5	*0.01*	*1.0*
No. Sympodia	13.1	15.2	11.9	*0.03*	*2.1*
No. Symp. with 1st Position Bolls	4.6	3.8	3.4	*0.03*	*0.7*
No. Symp. with 2nd Position Bolls	1.0	1.0	0.3	*0.07*	
No. Symp. with 1st & 2nd Bolls	0.3	0.3	0.3	*0.92*	
Total Bolls/Plant	6.6	6.3	4.5	*0.003*	*0.7*
% Total Bolls in 1st Position	75.3	66.4	82.4	*0.013*	*8.1*
% Total Bolls in 2nd Position	18.2	20.4	13.1	*0.10*	
% Total Bolls in Outer Position	1.6	8.7	1.3	*0.04*	*5.9*
% Total Bolls on Monopodia	4.4	4.1	3.3	*0.81*	
% Total Bolls on Extra – Axillary	0.5	0.4	0.0	*0.23*	
% Boll Retention - 1st Position	37.4	27.3	31.3	*0.05*	*7.8*
% Boll Retention - 2nd Position	12.7	11.5	7.3	*0.13*	
% Early Boll Retention	43.8	35.1	35.6	*0.07*	
Total Nodes/Plant	18.5	20.5	17.1	*0.03*	*2.1*
Internode Length (inches)	1.8	1.6	1.4	*0.003*	*0.1*

[1] means of 10 plants per plot.

Table 4. Results from final end-of-season plant mapping using COTMAP for fertilizer effects- 2010[1].

Category	Mean per plant for N fertilizer treatment					
	Urea	Urea Slow Release	Urea + Biosolids	Untreated	*P>F*	*LSD_{05}*
1st Sympodial Node	6.3	6.3	6.3	6.2	*0.41*	
No. Monopodia	1.5	1.5	1.4	1.1	*0.10*	
Highest Sympodia with 2 nodes	10.5	10.5	9.9	8.1	*0.00*	*0.8*
Plant Height (inches)	32.8	32.9	29.7	25.1	*0.05*	*5.9*
No. Effective Sympodia	7.3	7.3	6.7	5.4	*0.001*	*0.1*
No. Sympodia	14.3	14.2	13.5	11.6	*0.001*	*0.2*
No. Symp. with 1st Position Bolls	4.3	4.0	3.9	3.5	*0.05*	*0.5*
No. Symp. with 2nd Position Bolls	0.9	0.7	0.8	0.6	*0.12*	
No. Symp. with 1st & 2nd Bolls	0.4	0.3	0.3	0.2	*0.40*	
Total Bolls/Plant	6.4	6.1	5.9	4.8	*0.003*	*0.8*
% Total Bolls in 1st Position	75.1	72.0	73.3	78.4	*0.49*	
% Total Bolls in 2nd Position	18.4	16.4	17.7	16.3	*0.89*	
% Total Bolls in Outer Position	4.5	5.9	3.5	1.5	*0.05*	*3.1*
% Total Bolls on Monopodia	1.8	5.1	5.1	3.9	*0.15*	
% Total Bolls on Extra – Axillary	0.1	0.7	0.3	0.0	*0.21*	
% Boll Retention - 1st Position	33.2	30.5	31.6	32.5	*0.62*	
% Boll Retention - 2nd Position	12.0	9.9	10.8	9.4	*0.65*	
% Early Boll Retention	40.3	37.9	37.9	36.6	*0.46*	
Total Nodes/Plant	19.6	19.5	18.8	16.8	*0.001*	*0.8*
Internode Length (inches)	1.7	1.7	1.6	1.5	*0.13*	

[1] means of 10 plants per plot.

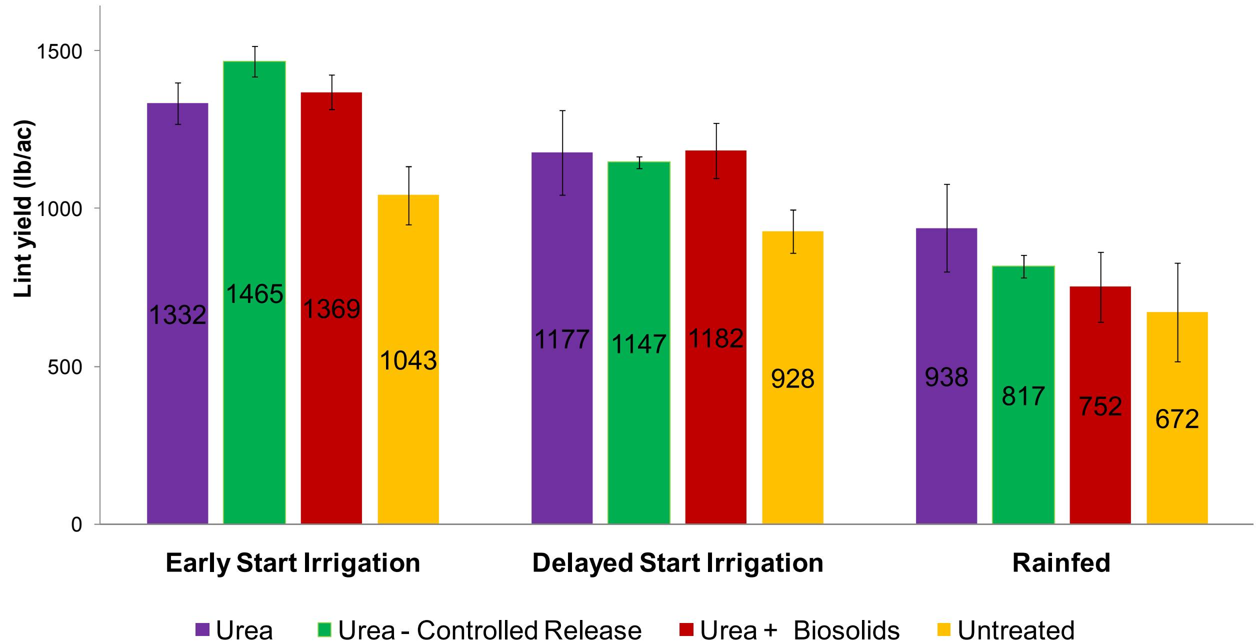

Figure 5. Mean (±SEM) lint yields for 4 fertilizer treatments when grown with irrigation start time at early square, at first flowers or with no supplemental irrigation. Irrigation and N fertilizer (P<0.01) significantly affected yields; there was no significant interaction (P=0.25).

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Table 5. Means for N fertilizer and irrigation timing effects for HVI classing data for 50 boll samples collected throughout consecutive plants on consecutive fruiting sites, Judd Hill 2010.

Treatment	Micronaire	Length	Uniformity	Strength	Elongation
Irrigation timing					
Early start	4.75	1.16	83.87	30.63	6.28
Delayed start	4.61	1.18	84.31	31.47	6.53
Rainfed	4.56	1.13	83.62	30.00	6.17
Nitrogen					
Urea	4.58	1.15	83.81	30.61	6.33
Urea - Slow Release	4.54	1.17	84.47	31.69	6.28
Urea + Biosolids	4.67	1.16	83.99	30.84	6.33
Untreated	4.77	1.14	83.46	29.64	6.36
P>F					
Irrigation (I)	*n.s*	*n.s*	*n.s*	*0.03*	*n.s*
Nitrogen (N)	*n.s*	*0.004*	*0.009*	*0.0001*	*n.s.*
*I*N*	*n.s*	*n.s*	*n.s*	*n.s.*	*n.s*

'1Determinations made at Fiber and Biopolymer Research Institute, Texas Tech University, Lubbock., TX.

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