

**VARIABLE RATE IRRIGATION ON COTTON LINT YIELD AND FIBER QUALITY****Jill D. Booker****Texas Agricultural Experiment Station  
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Lubbock, TX****Abstract**

During four years (2001-2004) the suitability of variable rate in a pivot irrigation system for cotton production was evaluated in the Texas High Plains (THP). The variable rate irrigation system delivers 75% ET replacement as the base rate (BR) and was compared to areas where BR-20% and BR+20% were applied. The effect of variable rate irrigation on water use efficiency (WUE), fiber lint yield and quality, and loan value were evaluated. Fiber quality parameters of interest were micronaire, strength, and length properties. In 2001 and 2003, BR+20% yielded more than the BR-20%, but micronaire was not affected by the water rate. Fiber strength improved with a decrease in water application in 2001, but was not affected in 2003. In 2002, the BR-20% rate was not evaluated, and BR+20% yielded more than the BR while fiber quality remained unaffected by irrigation rate. In 2004, due to excessive rainfall amounts, lint yield differences were not observed, but micronaire was negatively affected by increasing irrigation. Water use efficiency was only significantly different in 2003, where it increased with increasing water application. In each case and for every year, difference in fiber quality did not impact the loan value of cotton. Cotton, an indeterminate crop, seems too unpredictable to manage with variable rate irrigation especially under deficit irrigation practices and the short-growing season of the Texas High Plains.

**Introduction**

In 2003, the High Plains Underground Water Conservation District #1 reported that 122,238 irrigation pivots were in use within their 15 county region of the THP. Out of about 3,000,000 irrigated cropland acres, only 54% of those were irrigated with a high efficiency system such as Low Energy Precision Application (LEPA) pivots. Water is a limiting resource for crop production in this region, and farmers are facing decreased availability of irrigation water and increased energy costs. Using the available water in the most efficient manner is key to extend our limited water resources. In the THP few irrigation wells, due to limited pumping capacity, can provide the daily crop water use evaporative demand for most of the growing season. Over the past 50 years, great strides have been made in improving the efficiency of irrigation technology. LEPA irrigation systems can be up to 95% efficient if managed properly (Lyle and Bordovsky, 1983). However, improving irrigation efficiencies in this high evaporative demand environment should be a continual process. Variable rate irrigation (VRI) technology could be the next step in improving irrigation efficiencies and improvements in crop WUE.

At the NESPAL site in Georgia, VRI is proving successful. Their VRI systems can vary traveling speed across an area or cycle nozzles on or off to vary the water applied (Perry et al., 2002). Work is also being done on VRI technology in Australia, but thus far a commercial application system has not been developed. The VRI technology used in our experiment was developed at the TAES-Halfway station (Bordovsky and Lascano, 2003). On the Helms Farm 0.40 km pivot, a control system activates solenoid valves of each manifold unit relative to field location, thereby controlling irrigation quantities at specific sites. This system has been in use and evaluated for the past five years on a cotton-cotton-corn crop rotation.

Cotton is an ideal crop for the THP due to its heat tolerance and relative low water requirements as compared to other crops that grow well in this region such as corn or peanuts. However, irrigation is required to achieve any consistency in cotton production, and requires specific management practices to ensure adequate water levels throughout the growing season. In general, cotton yield is positively correlated with soil water content. Many have

determined that soil water deficits promote stunted growth, aborted bolls, and decreased leaf area leading to reduced photosynthesis (Pettigrew, 2004b; Johnson et al., 2002; and Elm et al., 2001). However, too much water can lead to rank growth and delayed development. Environmental factors including water availability also affect fiber quality.

Fiber quality is measured using High Volume Instrument (HVI) and consists of fiber length, fiber strength, micronaire, uniformity, trash content, and color parameters. These parameters are used to adjust the cotton prices according to the Schedule of Premiums and Discounts for Upland and Extra Long Staple Cotton. These price adjustments are given based on micronaire or maturity, fiber strength, uniformity, trash content and color. The 2002 schedule was the first to include new premiums and discounts on fiber length uniformity, and included an increase in the fiber strength base due to new standards required by the textile industry (Bednarz et al, 2004).

There is a complicated relationship between fiber quality and environmental factors such as soil water content and soil nutrients. Johnson et al. (2002) found that cotton fiber quality had a positive correlation with soil P, organic matter (OM), pH, CEC, K, and Na, as well as water content. Primarily they found that strength and elongation factors were well correlated with soil water, pH, and OM. Davidonis et al. (2004) reported that adequate soil water along with high ambient temperatures before and during boll development increased fiber maturity. Maturity is reported as micronaire which is a composite measurement of maturity and fiber fineness. Micronaire often has a negative correlation with soil water content. This is explained by Elms et al.(2001) as increased boll retention on the 2<sup>nd</sup> and 3<sup>rd</sup> positions on the cotton plant due to increased soil water. It also increases the boll load further up the plant (Pettigrew, 2004a). These bolls tend to be less mature at harvest, and therefore, have a lower value for micronaire. If the number of immature bolls is high at harvest then the micronaire values is generally negatively affected. The desired values of micronaire are between 3.5 and 4.9, and measurements outside that range are discounted (TTU, 2005).

While increased soil water content may delay maturity, inadequate soil water can reduce fiber length (Ritchie et al., 2004). It has also been reported by Johnson et al.(2002) that too much water can reduce fiber length. Obviously adequate amounts of water are important for fiber quantity and quality development. Too much water has negative affects on yield, micronaire, and fiber length; too little water yields weaker fibers with non-uniform lengths. Cotton production management is critical to ensure adequate nutrient and water availability to the crop. Site-specific production practices such as VRI, may provide the producer with better tools for managing inputs or improving the efficiency of those inputs.

State-space analysis showed that crop yield variability at the landscape level in this area could be explained by soil texture, soil nitrate-N, and water available during the growing season (Li et al., 2001) and these factors were then used to delineate and define soil management units (SMU) within a field. Furthermore, based on previous research we hypothesized that removing water from low producing areas in the field and applying this water to higher yielding areas would increase overall economic production without negatively affecting the yield potential of the entire field (Watson et al., 2001; Officer et al., 2003). Our experimental objective was to test our hypothesis and a long-term objective of these experiments was to evaluate the rotation of cotton and corn in the THP under limited irrigation.

### **Materials and Methods**

This experiment was conducted at the Helm Farm, located one mile south of Halfway, TX on the Texas Agricultural Experiment Station. The circular field was equipped with a 0.4 km pivot instrumented with a LEPA irrigation system. The outer four spans of the pivot were outfitted with variable rate irrigation (VRI) technology. This equipment included a SNAP-LCSX-PLUS industrial controller (Opto 22, Temecula, CA), solenoid valves to activate individual manifold systems to deliver prescribed amounts of water, and a standard incremental encoder (Dynapar<sup>TM</sup> Series E15) was used to provide an input signal to the controller to determine pivot location.

The system used a series of 3 nozzles on each drop which are activated by the solenoids to provide differing levels of water. The water application amounts can vary every three degrees around the circle, however each manifold unit acts as a group, so that each 20-22 rows are watered with the same application rate. There are three manifold units within each span, providing 12 irrigation units along the four span length of the pivot.

The field consisted of an Olton clay loam (fine, mixed, superactive, thermic Aridic Paleustolls) with slight slopes and an overall change in elevation of about 4.3 m from West to East (Figure 1). The circle has been divided in to six uniformly sized wedges, and this experiment occupied 4 spans of fields 5B, 5C, and 5D (Figure 2).

Upon obtaining the Helm Farm in 1999, the TAES installed a LEPA pivot system and equipped the outer three spans with variable rate equipment. Veris® 3100 Electrical Conductivity (EC) Mapping System (Veris Technologies, Salina, KS) was used to measure EC on the farm to provide some baseline information about the soil and samples were obtained on the East side of the pivot to analyze for soil texture. In 2001, the pivot blew over during a wind-storm. That pivot had to be scrapped and replaced with a new one. Irrigation with the variable rate technology was delayed due to set up and calibration to ensure accurate positioning and water delivery of the new system. The initial VRI in 2001 occurred in August, which was too late to produce large differences between the water rates. Plant and soil measurements were made in 2001 to test the system and establish our sampling methods.

In 2002, cotton variety Paymaster 2326 was planted on 11 May at a rate of 138,000 seed ha<sup>-1</sup> on field 5B. The irrigation was applied in strips along the circle (Figure 2) at two rates, a base rate (BR) and BR+20%. The available water at this location is not adequate to supply 100% potential evapotranspiration (PET) replacement; therefore BR was calculated at 75% replacement of PET. An additional 20% was applied on alternate strips providing 6 strips of each water treatment. The following year, Paymaster 2326 was planted at the same seeding rate on 8 May 2003 on field 5D. Irrigation was applied in the same manner as the previous year but with an additional application rate of BR-20%. In 2004, planting occurred on 14 May on field 5C at the same seeding rate with the same three irrigation application rates. Typical farming practices were used to establish and maintain the crop.

Soil samples to a depth of 90 cm were taken at the beginning and end of each growing season to establish residual NO<sub>3</sub>-N and P levels within the field. These soil samples were divided into 0-15, 15-30, 30-60 and 60-90 cm increments and sent to Ward Laboratory for NO<sub>3</sub>-N on all sampled depths and Mehlich III P on the 0-15 and 15-30 cm depths. Soils were also analyzed for electrical conductivity (EC) and pH, and soil texture was obtained using the Beckman-Coulter Laser Analyzer.

In 2003 and 2004, 36 locations were established at the beginning of the growing season. These points were central to the 100-m<sup>2</sup> area sampled throughout the growing season. Plant samples were taken monthly and evaluated for leaf area, height, dry matter, and number of green and open bolls as the season progressed. Neutron probe measurements were taken at each location every two weeks after initiation of irrigation which generally started around the first of July. Cropscan radiometer readings were taken periodically to evaluate the growth of the crop. Two hand collected yield samples were taken from each location, weighed, ginned, and subsampled for fiber quality analysis with HVI at the Texas Tech International Textile Center.

Water use efficiency (WUE) was calculated as lint yield per unit of crop water use, in kg ha<sup>-1</sup> mm<sup>-1</sup>. Yield, WUE, and fiber quality comparisons were made using SAS Proc GLM and SAS Proc Mixed. Differentiation was assessed using Least Significant Difference & Duncan's Multiple Range Test (SAS Institute, 1985).

## Results

The weather has been extremely variable over the span of this experiment. The THP gets an average of 468 mm year<sup>-1</sup> with the majority of that falling during the summer months. In 2002, total rainfall was fairly typical but most of it fell outside of the growing season (Figure 3). The year 2003, was the second driest year on record with 219 mm of rainfall (Figure 7), while 2004 was the wettest year on record and had cool air temperatures throughout the growing season (Figure 13 and 14). These conditions were conducive for highly variable results throughout the experiment. Table 1 shows the planting dates, harvest dates, total rainfall during the growing season, and irrigation applied for each water treatment for each year of the experiment.

In 2002, lint yield was above average for the Halfway, TX area. There was a significant improvement of yield with the addition of more water. The BR+20% irrigation rate yielded 265 kg ha<sup>-1</sup> above the BR (Figure 5). However, the WUE was not significantly different indicating the additional water did not improve the amount of yield per unit of water used (Figure 6). Likewise, the fiber quality data showed no differences between water rates.

Overall, lint yields were lower in 2003 due to the extreme heat and low rainfall amounts (Figures 7 and 8). The irrigation system was unable to keep up with the water demand later in the growing season. This led to significant differences at every level of irrigation where the BR+20% had the highest yield and the BR-20% had the lowest yield (Figure 9). In addition, WUE showed the same trend. The BR+20% treatment yielded the most lint per unit of irrigation while the BR-20% had the lowest yield per unit of irrigation water applied (Figure 10). The BR+20% had a micronaire value less than the other two irrigation treatments (Figure 11). However, all three treatments had micronaire values outside of the premium range, but within the tolerance range meaning they did not earn a discount either. The improvement in the micronaire value did not improve the loan value as it was above the target range. As

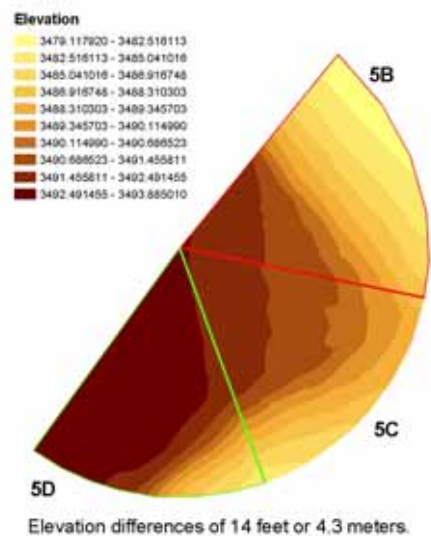
the water rate increased, the strength values decreased (Figure 12), which is contrary to the reports by Johnson et al (2002).

In 2004, the large amounts of rainfall (Figure 13) and cooler ambient temperatures (Figure 14) eliminated any differences in cotton lint yield between the irrigation treatments (Figure 15). There were also no significant differences in WUE between the treatments (Figure 16). However, there were differences in micronaire (Figure 17). As suggested by Elms et al.(2001), the increased availability of soil water led to decreased micronaire values at each irrigation treatment. The decrease in maturity level was also due to the cooler ambient temperatures experienced during 2004 (Figure 14). The heat units (HU) never reached 2000 for the growing season. The fiber strength was also adversely affected by increasing water levels. The BR+20% showed significantly lower micronaire and fiber strength results than the BR, and BR expressed significantly lower values of these parameters than the BR-20% treatment.

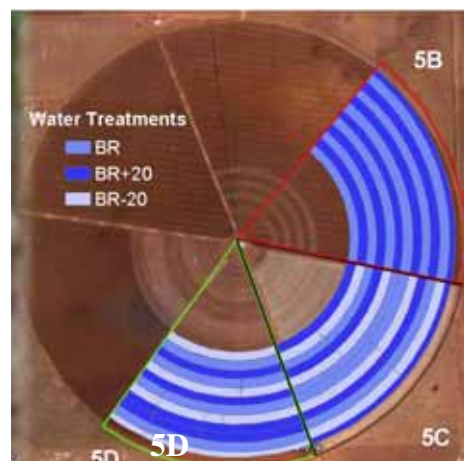
### **Conclusions**

In 2003, applying additional water in the BR+20% was cost-effective. However, in the 2004 crop year, income was negatively affected due to applying additional irrigation leading to discounts in cotton pricing based decreased fiber quality as irrigation costs increased. A mixed statistical model was used to evaluate 2003 and 2004 crop years together and no significant differences were exhibited. The data from 2002 was eliminated because the BR-20% treatment was not used during that year. The results indicated that with the right weather conditions VRI can improve WUE, however, the weather conditions are too variable to ensure this result every year. These results suggest that for the THP with a short growing season, semiarid weather, and the indeterminate growth pattern of cotton, the use of site-specific irrigation is not necessarily advantageous. However, VRI may show some advantage in use in grain crops in this area.

In 2002, water was applied to the corn section of the rotation according to prescribed SMU's. At the conclusion of that growing season, the determination was made to water in strips across the landscape during the following years. Applying the water according to SMU did not allow for the assessment of each water application within a particular soil condition. There was no way to evaluate whether the BR+20% area would have benefited more from the BR application. It was surmised that if water rates were equally distributed across the experimental area and sampled accordingly, then SMU could be evaluated after the data was collected according to differing delineation methods. Currently, the soil parameter data such as EC, texture, pH, and elevation are being evaluated with discriminate statistics to determine if groups can be identified to delineate SMU. This method is showing some promise, but the results were too late to include in this paper.



**Figure 1.** Study area on the Helm Farm in Halfway, TX.



**Figure 2.** Water treatments within fields 5B, 5C, 5D.

**Table 1.** Planting and harvest dates with rain and irrigation amounts.

Year	Planting Date	Harvest Date	Rainfall Total (mm)	Irrigation (mm)		
				Base Rate (BR)	BR + 20%	BR - 20%
2002	11-May	15-Nov	104	342	386	--
2003	8-May	26-Nov	256	274	322	226
2004	14-May	11-Nov	707	230	264	194

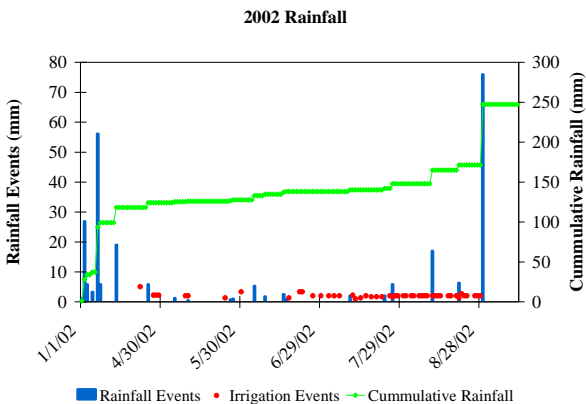


Figure 3. 2002 Rainfall and irrigation data.

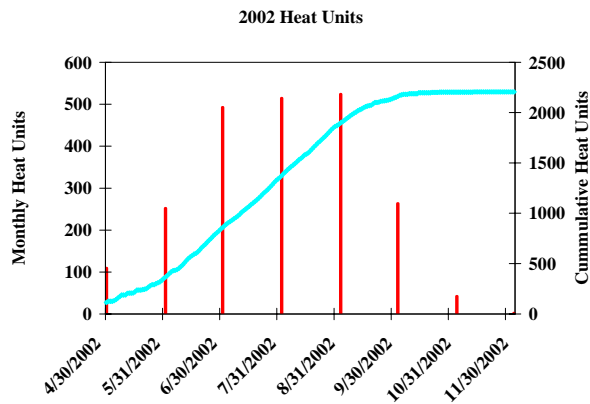


Figure 4. 2002 Heat unit data.

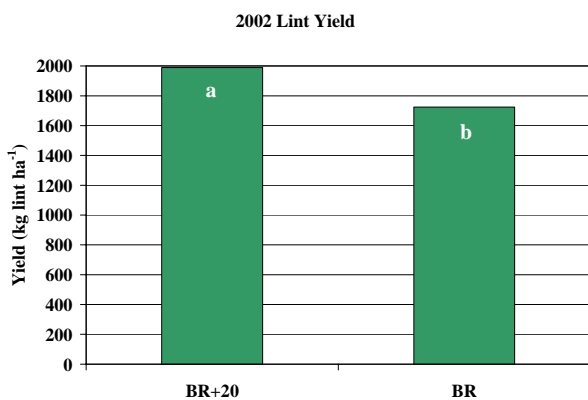


Figure 5. 2002 Lint Yield

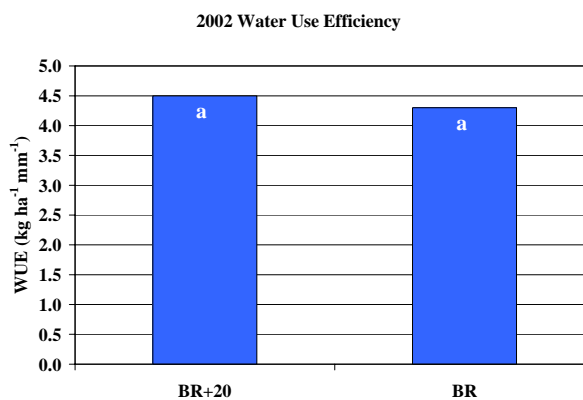


Figure 6. 2002 Water use efficiency

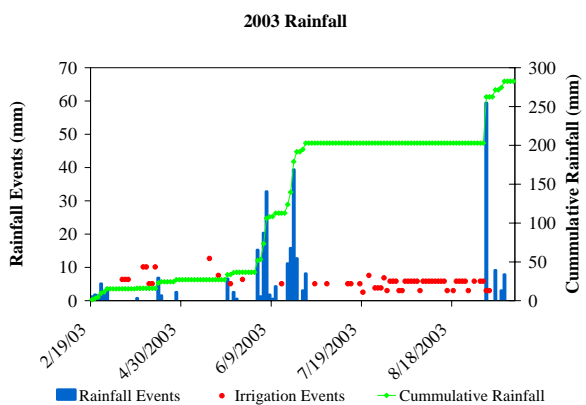


Figure 7. 2003 Rainfall and irrigation data.

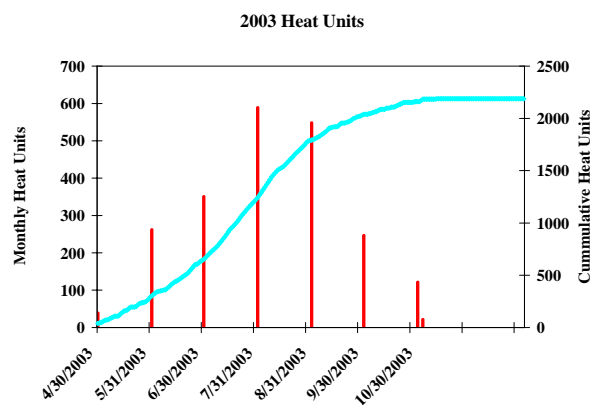


Figure 8. 2003 Heat unit data.

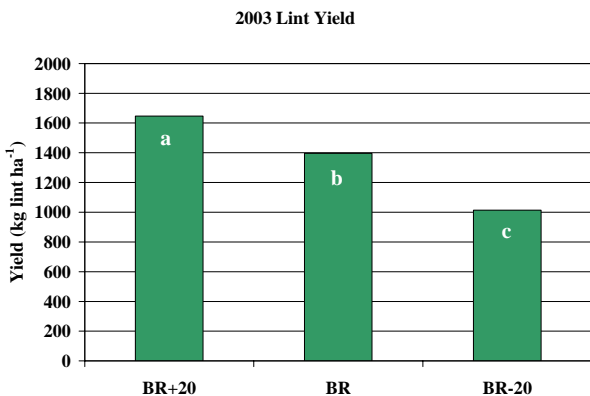


Figure 9. 2003 Lint Yield

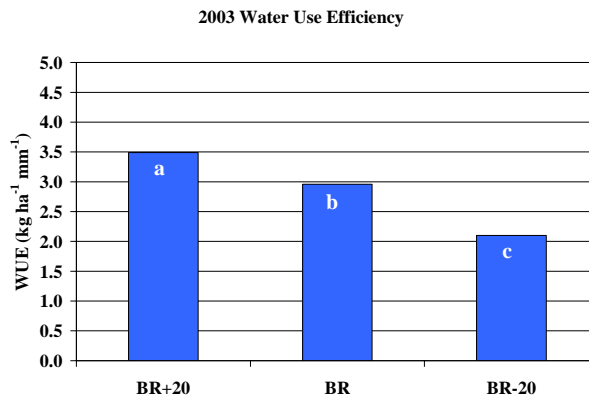


Figure 10. 2003 Water use efficiency

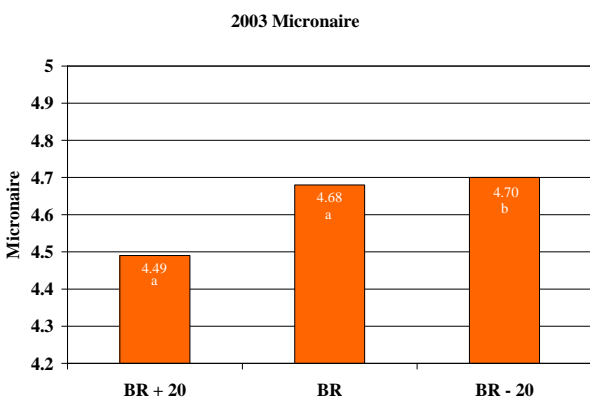


Figure 11. 2003 Micronaire

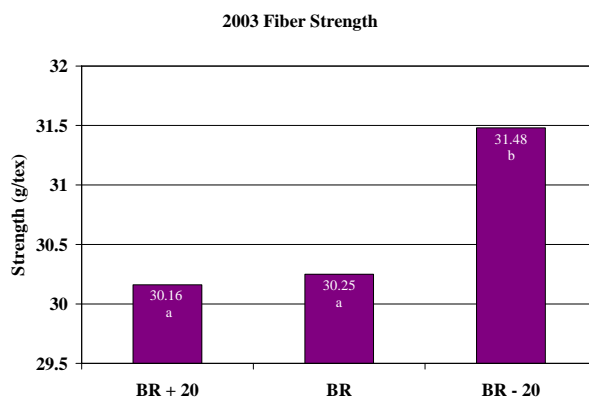


Figure 12. 2003 Fiber Strength

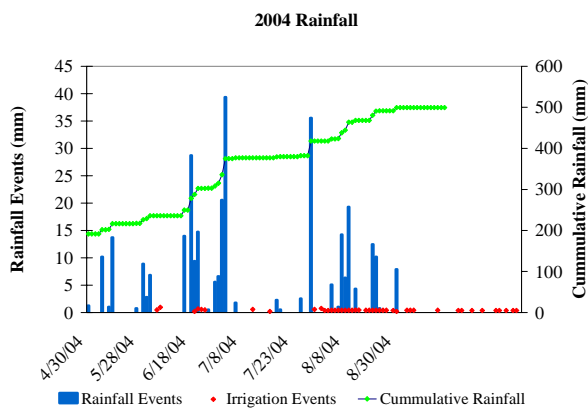


Figure 13. 2004 Rainfall and irrigation data.

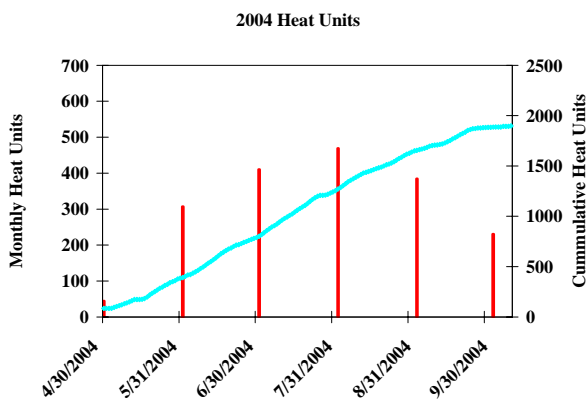
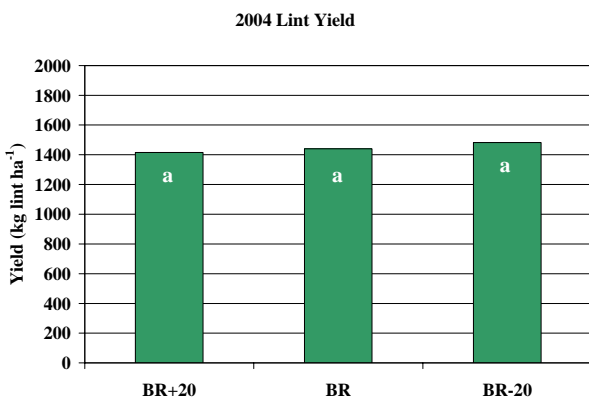
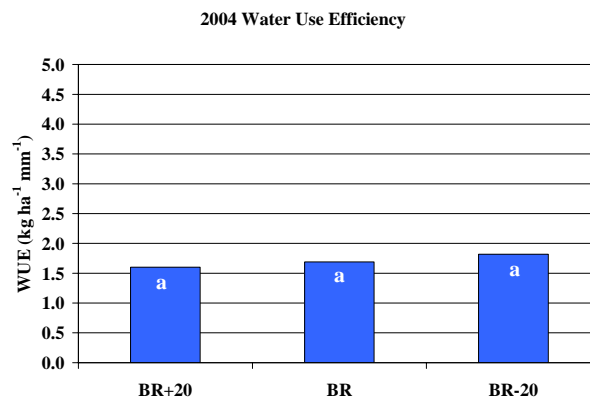


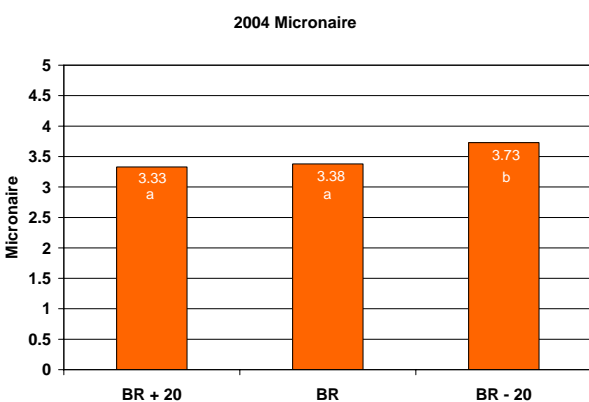
Figure 14. 2004 Heat unit data.



**Figure 15.** 2004 Lint Yield



**Figure 16.** 2004 Water use efficiency



**Figure 17.** 2004 Micronaire

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