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# AGRONOMY AND SOILS

## Water Use Efficiency and Irrigation Response of Cotton Cultivars on Subsurface Drip in West Texas

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### ABSTRACT

**The High Plains Aquifer is the source of nearly all agricultural irrigation water in the Texas High Plains, and its resources are being depleted due to withdrawals that greatly exceed recharge; therefore, expanding the use of deficit irrigation in this region. Some drought-tolerant crops, including cotton (*Gossypium hirsutum* L.), can adapt well to deficit irrigation, but this adaptation might be cultivar- and environment-specific. The objective of this study was to determine if the response of commercially available cultivars to differential irrigation was influenced by the environment. Seven cotton cultivars (DP0912B2RF, DP0924B2RF, DP0935B2RF, DP1028B2RF, DP-1032B2RF, DP1044B2RF, and FM9160B2F) were evaluated in 2010 and 2011 at three irrigation levels, ranging from severe-deficit to full irrigation in West Texas. In-season soil moisture content, yield, and water use efficiency were compared by cultivar and irrigation level. In 2010, which was wet and cool, the earlier-maturing cultivars, particularly DP0912B2RF, performed favorably compared to the later-maturing cultivars at the highest irrigation levels. In 2011, which was hot and dry, later-maturing cultivars, such as DP1044 and DP0935, had the highest yields. There was also a strong interaction between study year, irrigation rate, and cultivar performance. In 2010, later-maturing cultivars such as DP0935 and DP1044 had lower yields at the highest irrigation, but higher yields in the deficit treatments. DP1044, the latest maturing cultivar in the study, was a top yielding cultivar in both seasons, suggesting that a cultivar with later maturity characteristics can be successful in both hot and heat-limited environments on the Texas High Plains.**

In recent years the Texas High Plains has annually produced 25% of the entire crop of U.S. cotton (*Gossypium hirsutum* L., Rundle and Staples, 2011). The cotton production region within a 130-km radius around Lubbock, TX is semiarid, and about one-half of the area is nonirrigated, with yields that vary with rainfall (Wanjura et al., 2002). Nearly all irrigation on the High Plains comes from withdrawals from the Ogallala (High Plains) Aquifer.

The High Plains Aquifer is one of the largest aquifer systems in the world (Torell et al., 1990) and is the source of nearly all irrigation water in the Texas High Plains. More than 90% of the withdrawals from the High Plains aquifer are for agricultural irrigation, which has resulted in a severe decline in groundwater levels over the past several decades (Colaizzi et al., 2009). Decreases in water availability also have altered irrigation strategies in the Southern High Plains; irrigation is used primarily to supplement rainfall, and irrigation alone is often not enough to sustain the growth necessary for maximum yields. In many cases, irrigation is limited by well capacity, and even irrigated cotton suffers water deficit effects based on environmental conditions (Colaizzi et al., 2009). Therefore, cotton in the Southern High Plains can face both environmental and production water limitations.

Decreasing water availability has led to research on the water use requirements of most agronomic crops, as well as the yield and quality impacts of deficit irrigation (Basal et al., 2009; Dagdelen et al., 2009; DeTar, 2008; Howell et al., 2004; Pettigrew, 2004; Tolk and Howell, 2001).

**Water Use Efficiency.** Depletion of water resources has led to improvements in water use efficiency (WUE) through enhanced management practices (Jenkins et al., 1990) and irrigation (Howell, 2001). Defined physiologically, WUE is calculated as the ratio of carbohydrate fixation to transpiration. However, instantaneous measures of biomass are difficult to obtain, so agronomic WUE is often

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calculated as the unit of economic yield produced per unit of water used (Loka et al., 2011). In production, this definition is often summarized as the unit yield per unit of irrigation. WUE improvements have been observed through changes in tillage practices, irrigation method, cultivar advances, and selection of crop based on environmental conditions (Howell et al., 2004). Irrigation can increase WUE through increased crop yields, especially in semiarid and arid environments (Howell, 2001). Models to simulate the effects of these factors on WUE have been proposed and tested by Evett and Tolk (2009) and Baumhardt et al. (2009).

**Yield.** Cotton yields in the Texas High Plains have benefited substantially from irrigation (Wanjura et al., 2002). DeTar (2008) concluded that decreases in irrigation to a certain level would have no impact on yield, but that a 5% reduction of water below the critical level of 654 mm of total water applied would produce a 4.6% reduction in yield. Wanjura and Upchurch (2000) compared yield reduction differences with deficit irrigation between corn and cotton. They concluded additional irrigation resulted in a 60% yield increase for corn but only provided a 17% yield increase for cotton. Basal et al. (2009) showed in cotton that decreasing water application by 25%, 50%, and 75% reduced yield by 8%, 20 to 30%, and 40 to 45%, respectively. Other studies have also demonstrated varying decreases in seedcotton yield under water-stress (Cook and El-Zik, 1993; Dagdelen et al., 2006; DeTar, 2008; Lopez et al., 1995; Pettigrew, 2004; Saranga et al., 1998).

**Cultivar Differences.** Deficit irrigation has been reported to significantly affect WUE and yield; however, differences between yields and WUE among cotton cultivars are less documented. DeTar (2008) tested two cultivars and concluded no significant difference in yield and WUE between cultivars over six application rates of 33% to 144% of daily Class A pan evaporation. Pettigrew (2004) compared lint yields among eight different cultivars at irrigated and dryland moisture treatments in Mississippi and concluded that the response to the two moisture treatments was similar among genotypes. However, cultivar performance can be related to environment, as evidenced by differences in predominant cultivars from one region of the Cotton Belt to another.

The purpose of this study was to determine the interaction between cultivar and irrigation for WUE and yield among cotton cultivars with different relative maturity ratings.

## MATERIALS AND METHODS

Research was conducted over a two-year period at the Texas Tech Research Farm in New Deal, TX. The soil type was Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll). The experimental design was a split plot design with three replicates, with irrigation as a main plot and cultivar as the split plot. Seven cotton cultivars were compared: Deltapine 0912 B2RF (DP0912), Deltapine 0924 B2RF (DP0924), Deltapine 0935 B2RF (DP0935), Deltapine 1028 B2RF (DP1028), Deltapine 1032 B2RF (DP1032), Deltapine 1044 B2RF (DP1044), and FiberMax 9160 B2F (FM9160). Although maturity characteristics are not standardized among seed companies, based on advertised maturities and our experience with these cultivars in West Texas, the cultivars were grouped as follows: early to early-mid maturity (DP0912, DP1028, and DP0924); mid maturity (FM9160 and DP1032); and mid to late maturity (DP0935 and DP1044).

Planting dates were 26 May 2010 and 17 May 2011. The seeding rate was 18 seeds per linear meter, and row spacing was 1.02 m for both years of the study. The cotton was planted in four-row plots that were 10.6 m long in 2010 and 12.2 m long in 2011. Harvest was completed on 16 November 2010 and 7 October 2011. The accumulation of thermal heat units during each growing season was calculated using 15.6°C growing degree days ($GDD_{15.6}$): the average of the high and low temperature each day minus a baseline of 15.6°C. Reference evapotranspiration and calculations of accumulated thermal units were both calculated from an on-site GRW100 weather station (Campbell Sci., Logan, UT).

Conventional tillage was used in both years, and insecticide and herbicide production practices were based on Texas A&M AgriLife extension recommendations. All plots were fertilized at a rate of 80 kg N $ha^{-1}$ using 28-0-0-5 liquid fertilizer applied through the irrigation system in both years. The study was defoliated using 1.5 l $ha^{-1}$ ethephon + cyclanilide and 73 ml $ha^{-1}$ thidiazuron + diuron at 60% open boll on the fully irrigated treatments.

**Irrigation.** The subsurface drip irrigation system consisted of drip tape under every row, 20 to 24 cm below the surface and 61 cm emitter spacing. The irrigation treatments in 2010 and 2011 were severe-deficit, mild-deficit, and fully irrigated. Water was applied daily, and the individual irrigation treatments were replicated three times on independently irrigated 8-row drip zones. Irrigation output for each irrigation zone in the trial was monitored using flow meters throughout the season, and all irrigation zones were adjusted to limit variation to less than 5% of total irrigation rate per week. The crop was irrigated uniformly from emergence to first square at a rate of 5 mm per day, and irrigation treatments were initiated at first square. The irrigation treatments were applied based on percent daily evapotranspiration (ET) replacement. In 2010 and 2011, the severe deficit treatment received no irrigation after treatment initiation, the mild-deficit treatment received 2.5 mm per day, and the fully irrigated treatment received 5 mm per day.

Three soil cores were collected at planting in 2011 to determine initial soil volumetric water content for the study site. Samples were collected using a tractor-mounted hydraulic probe (Giddings Machine Company, Windsor, CO) to a maximum depth of 1 m, at which point penetration was inhibited by an underlying calcic horizon. The collected samples were divided into 0 to 30 cm, 30 to 60 cm, and deeper than 60 cm. The soil was oven-dried for 48 h, and bulk density and initial water content were determined for each depth.

Soil moisture was monitored weekly using neutron probe readings for soil volumetric water content, beginning at pin-head square and continuing until cutout on cultivars DP0912 and DP1044 at all irrigation levels in two replicates. Measurements were conducted to a depth of 100 cm in 20-cm increments.

**In-season Data Collection.** Emergence was measured at or before the 4-leaf stage by counting plants in a 4 m section of row. During the season, plant height and total nodes were measured on cultivars DP1044 and DP0912 on a weekly basis on five consecutive plants, with initial, mid-season, and final measurements conducted on all cultivars. At harvest, the middle two rows of each plot were harvested using a cotton stripper equipped with load cells. Samples were ginned by personnel at the Monsanto Cotton Research Megasite in Lubbock, TX.

**Data Analysis.** Water balance and crop water use were estimated using volumetric calculations, based on the initial soil samples and in-season neutron probe measurements. Volumetric water content measurements were compared among irrigation treatments in both years using proc GLIMMIX (SAS 9.2, Cary, NC).

Within each year, cultivar effects, irrigation effects, and cultivar by irrigation interactions were analyzed for significance for both lint yield and water use efficiency. Within the software, Pdiff calculations were made to compare cultivars within each irrigation rate. Irrigation and cultivar were both treated as fixed effects, and the random effects were the blocking factor (replicate) and the interaction of replicate by irrigation.

Agronomic water use efficiency was calculated as the lint yield (kg) per unit irrigation ($m^3$). Because individual replicates with the same irrigation regime had slightly different measured watering rates, WUE measurements were nearly identical to, but varied slightly from, lint yield measurements when compared from one irrigation treatment to another. All data were analyzed using SAS proc GLIMMIX (Littell et al., 2006).

## RESULTS AND DISCUSSION

**Irrigation.** In 2010 most of the total water available to the crop came as rainfall, with 330 mm of effective rainfall falling during the growing season. Rainfall amounts greater than 13 mm occurred six separate times during the season. Irrigation amounts were 28 mm for the severe-deficit treatment, 121 mm for the mild-deficit treatment, and 206 mm for the fully irrigated treatment. Total water available for the fully irrigated treatment did not reach the total water supply amount of 740 mm that is recommended on the Texas High Plains to reach maximum yield (Wanjura et al., 2002), due to rate limitations on the irrigation system. The total water applied corresponded to crop evapotranspiration ($ET_c$) replacements of 71% for the full irrigated treatment, 60% for the mild-deficit treatment, and 48% for the severe-deficit treatment based on reference ET and crop coefficients proposed by Allen et al. (1998). Heavy rainfall occurred 38 and 39 days after planting (DAP) and all irrigation treatments were commenced late in the season, due to high soil moisture throughout the month of July.

There were 1181 cumulative growing degree days ($GDD_{15.6}$) in 2010 (Fig. 1), similar to the environmental conditions described by Howell et al. (2004). These conditions are considered adequate for most cultivars grown in the region, but they are slightly below adequate heat units required for later maturing cultivars to reach maximum yield. Cumulative $GDD_{15.6}$ was much higher in 2011 than 2010, with 1415 $GDD_{15.6}$ accumulated, due to the hot temperatures experienced during the growing season. Other climatic data for 2010 and 2011, including temperature, rainfall, radiation load, and wind speed are shown in Table 1.

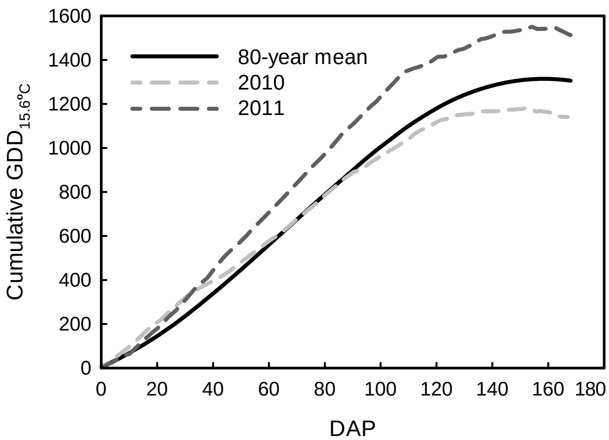


**Figure 1. Cumulative GDD by days after planting (DAP) for 2010 and 2011.**

The 2011 season was extremely hot, windy, and dry, and total irrigation water applied for 2011 was higher than 2010, although the growing season was 25 d shorter. Virtually all of the available water came from irrigation, compared to the majority coming from rainfall in 2010. Total in-season rainfall was 46 mm, and the total amount of irrigation applied in 2011 was 355 mm for the severe-deficit, 527 mm for the mild-deficit, and 638 mm for the fully irrigated treatment. Fully irrigated treatments were limited to a maximum daily irrigation input of 4 h and therefore were restricted from reaching the total water supply amount for maximum yield suggested by Wanjura et al. (2002). The $ET_c$ replacement percentages were similar to the three treatments in 2010

**Table 1. Monthly climatic data for 2010 and 2011 daily mean values compared with 30-yr mean data for Lubbock, TX**

| Month | Avg. Temp (°C) | Max Temp (°C) | Min Temp (°C) | Rain (mm) | Wind (m $s^{-1}$) | Total Radiation (MJ $m^{-2}$ $day^{-1}$) |
|---|---|---|---|---|---|---|
| ***2010*** | | | | | | |
| **May** | **20.8** | **28.1** | **13.6** | **29** | **4.5** | **24.0** |
| **June** | **27.2** | **34.4** | **20.0** | **65** | **3.9** | **26.1** |
| **July** | **25.2** | **30.3** | **20.1** | **181** | **2.9** | **22.6** |
| **August** | **26.8** | **34.0** | **19.6** | **34** | **2.5** | **24.5** |
| **September** | **23.8** | **31.1** | **16.6** | **24** | **2.9** | **19.6** |
| **October** | **17.6** | **26.3** | **8.8** | **66** | **2.6** | **16.7** |
| **November** | **10.4** | **19.4** | **1.5** | **2** | **3.3** | **13.6** |
| **Average** | **21.7** | **29.1** | **14.3** | **57** | **3.2** | **21.0** |
| ***2011*** | | | | | | |
| **May** | **21.5** | **30.6** | **12.5** | **1** | **4.8** | **28.7** |
| **June** | **29.9** | **38.2** | **21.6** | **0** | **4.7** | **29.2** |
| **July** | **30.0** | **37.3** | **22.7** | **1** | **2.9** | **27.0** |
| **August** | **29.9** | **37.3** | **22.6** | **9** | **2.5** | **25.1** |
| **September** | **22.1** | **30.1** | **14.1** | **32** | **2.7** | **19.3** |
| **October** | **16.9** | **24.9** | **8.8** | **34** | **3.4** | **16.9** |
| **November[z]** | **10.4** | **17.9** | **2.8** | **7** | **3.7** | **12.7** |
| **Average** | **23.0** | **30.9** | **15.0** | **12** | **3.5** | **22.7** |
| ***30-year Average[y]*** | | | | | | |
| **May** | **21.0** | **28.8** | **13.3** | **58** | **NA[x]** | **NA** |
| **June** | **25.2** | **32.6** | **25.2** | **77** | | |
| **July** | **26.8** | **33.8** | **19.8** | **49** | | |
| **August** | **26.1** | **32.9** | **19.2** | **49** | | |
| **September** | **22.1** | **29.2** | **14.9** | **64** | | |
| **October** | **16.4** | **24.0** | **8.8** | **49** | | |
| **November** | **9.9** | **17.6** | **2.2** | **22** | | |
| **Average** | **21.1** | **28.4** | **14.8** | **53** | | |

**[z] Cotton was harvested on 7 October 2011.**

**[y] Based on weather.gov (National Weather Service) data for average temp, rain, and 30-yr average (1981-2010) for Lubbock with wind and radiation for 2010 and 2011 from weather station data at New Deal, TX location.**

**[x] NA, Not applicable.**

with 48% for the severe-deficit, 69% for the mild-deficit irrigation, and 83% for the fully irrigated treatment.

**Soil Moisture Content.** The patterns of water uptake from soils were substantially different in 2010 and 2011 (Figs. 2 and 3). Soil moisture content was monitored to verify that differences in irrigation treatment resulted in differences in volumetric water content. Significant differences among irrigation treatments for both years are shown in Table 2.

As shown in Fig. 2, in-season volumetric water content measurements ($\theta_v$) in 2010 indicate that the only irrigation treatment with substantial decreases in soil moisture was the severe-deficit treatment. All decreases in soil moisture occurred deeper in the soil and toward the end of the growing season. Neither the fully irrigated nor mild-deficit treatment resulted in $\theta_v$ values that indicated significant water depletion, although soil moisture for the mild-deficit treatment was less than that of the fully irrigated treatment at the 60 cm depths and below (Fig. 2).

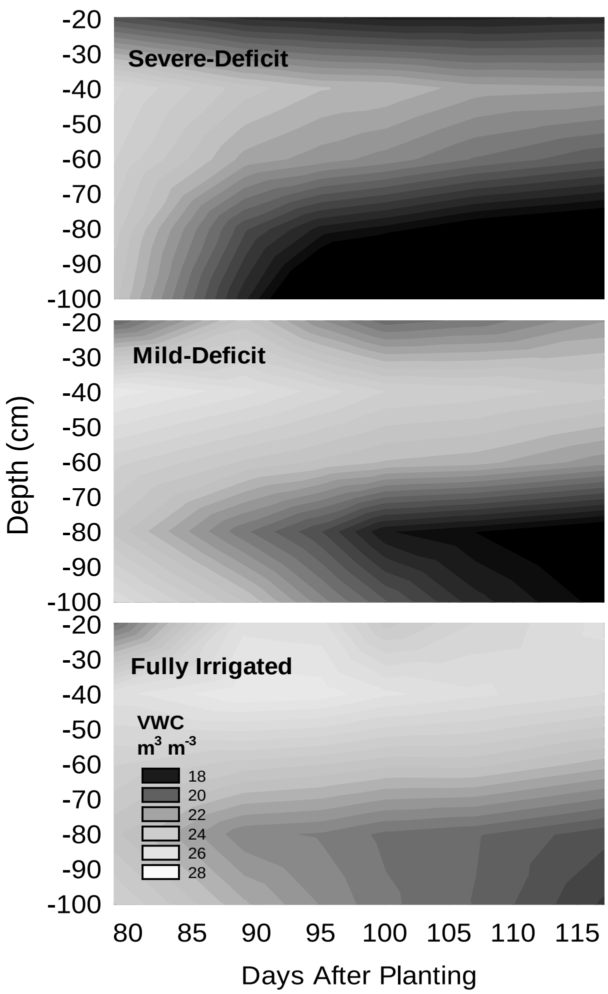


**Figure 2. Soil volumetric water content by soil depth for each irrigation treatment based on days after planting in 2010.**

**Table 2. Volumetric water content by days after planting (DAP) in 2010 and 2011**

| DAP | Severe-Deficit | Mild-Deficit | Fully Irrigated | LSD |
|---|---|---|---|---|
| *2010* | VWC ($m^3/m^3$) | | | |
| 68 | 0.228[z] | 0.237 | 0.233 | NS[y] |
| 78 | 0.200 | 0.228 | 0.235 | NS |
| 84 | 0.191 b[x] | 0.218 b | 0.234 a | 0.055 |
| 89 | 0.185 b | 0.208 b | 0.226 a | 0.051 |
| 96 | 0.176 b | 0.201 b | 0.222 a | 0.051 |
| 106 | 0.173 b | 0.198 ab | 0.219 a | 0.048 |
| *2011* | | | | |
| 63 | 0.257 | 0.259 | 0.279 | NS |
| 69 | 0.253 | 0.255 | 0.274 | NS |
| 87 | 0.207 | 0.206 | 0.224 | NS |
| 93 | 0.200 b | 0.201 b | 0.220 a | 0.015 |
| 108 | 0.191 c | 0.195 bc | 0.218 a | 0.014 |

[z] VWC averaged over 20 to 100 cm depth

[y] NS, Not Significant.

[x] Horizontal means followed by the same letter within a row are not significantly different ($p = 0.05$).

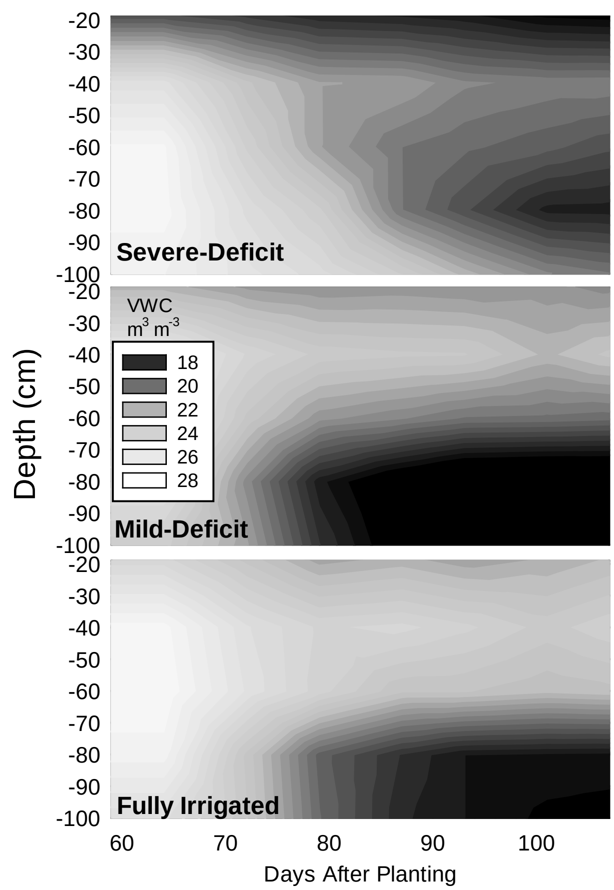


**Figure 3. Soil volumetric water content by soil depth for each irrigation treatment based on days after planting in 2011.**

In 2011, the loss of soil moisture at greater depths (60 cm and below) was again observed as the season progressed (Fig. 3). However, the treatments with the most changes in $\theta_v$ at greater depths were the mild-deficit and fully irrigated treatments.

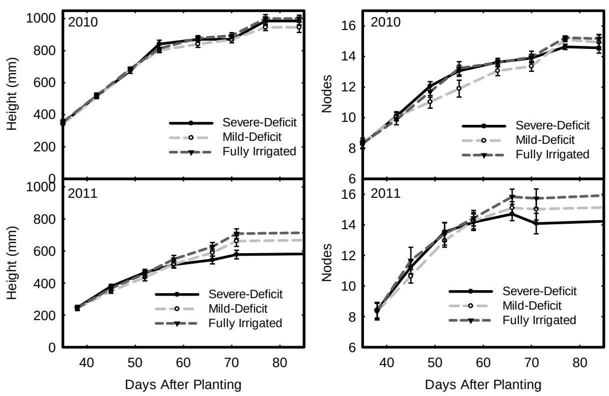


**Figure 4. Plant height and total nodes by irrigation treatment in 2010 and 2011. Error bars represent standard error of the mean.**

Significant decreases in deep soil moisture for the fully irrigated treatment began 90 DAP and continued throughout the season. The mild-deficit treatment was even more prone to soil moisture decreases lower in the soil profile.

The severe-deficit treatment did not have as much loss of deep soil moisture as the higher irrigation treatments. For the severe-deficit treatment, soil moisture at 100 cm was still higher than that in the higher irrigation treatments. The early water deficit in the severe-deficit treatments appears to have decreased water uptake within the rooting zone throughout the season.

These results are comparable to Whitaker et al. (2008), who observed soil moisture tension for subsurface drip irrigation and overhead irrigation treatments in Georgia. The fully irrigated treatments in Whitaker et al. (2008) had similar soil wetting patterns to the fully irrigated treatment in this study, which began in proximity of the drip tape at the 40 cm depth and extended up to the 20 cm depth and down to the 60 cm depth; however, irrigation in Georgia occurred less often and was of greater duration, and the Georgia study had much more rainfall than was experienced in this study (Whitaker et al., 2008). However, total water amounts were similar between the fully irrigated treatment in 2011 and the fully irrigated plots in their study.

**Lint Yield and Water Use Efficiency in 2010 and 2011.** The differences in the growing conditions in 2010 and 2011 resulted in significantly different in-season growth habits in 2010 and 2011 (Fig. 4). In 2010, plants were taller and produced more total nodes, and the differences in height and nodes among irrigation treatments were less noticeable. There were highly significant cultivar-by-year interactions for lint yield and WUE (Table 3), suggesting that some of the cultivars performed differently between years. These differences are shown in Table 4.

**Table 3. *P*-values for lint yield and WUE**

| Effect | DF | F Value (Yield) | F Value (WUE) | P Value (Yield) | P Value (WUE) |
|---|---|---|---|---|---|
| **Pooled** | | | | | |
| **Cultivar** | 6 | 2.18 | 2.79 | 0.054 | 0.016 |
| **Irrigation** | 2 | 926 | 237 | <.0001 | <.0001 |
| **Year*Cultivar** | 7 | 14.1 | 19.3 | <.0001 | <.0001 |
| **Year*Cultivar*** | 26 | 2.81 | 3.27 | 0.0002 | <.0001 |
| **Irrigation** | | | | | |
| **2010** | | | | | |
| **Cultivar** | 6 | 2.90 | 3.24 | 0.021 | 0.012 |
| **Irrigation** | 2 | 271 | 114 | <.0001 | 0.0003 |
| **Cultivar*Irrigation** | 12 | 1.11 | 1.14 | 0.38 | 0.36 |
| **2011** | | | | | |
| **Cultivar** | 6 | 3.70 | 4.99 | 0.0012 | 0.0005 |
| **Irrigation** | 2 | 256 | 33.6 | <.0001 | 0.0004 |
| **Cultivar*Irrigation** | 12 | 0.92 | 1.12 | 0.58 | 0.36 |

DP1044 had the most consistently high yields in both 2010 and 2011, and some other cultivars (DP0935, DP0924, DP1028, and DP1032) performed consistently from 2010 to 2011. Conversely, FM9160 and DP0912 were top performers in 2010 and were near the bottom in 2011. DP0912 is an early-maturing cultivar, so it would be expected to perform comparatively well during a season with limited heat units, compared to a season where heat units were not limiting. On the other hand, FM9160 is classified as a mid-maturing cultivar, so differences based solely on maturity might not offer a complete explanation of the differences in yield from one year to the next. Due to the interaction between cultivar and year on yield, 2010 and 2011 were analyzed separately.

**2010 Yield and Water Use Efficiency.** In 2010, DP1044 produced significantly higher yields than all other cultivars, except FM9160 and DP0935, which are all mid- to late-maturing varieties (Table 4). DP1044 also produced the highest WUE and was significantly higher than DP1028, DP0912 and DP0924. Irrigation treatments also produced significant differences (Table 3). FM9160 and DP1044 had the two highest averages for yield and WUE and were significantly higher than all other cultivars except DP0912.

Yields and WUE increased with water application, and each irrigation treatment resulted in significantly different yields and WUE among each treatment. Out of the three irrigation treatments in 2010, significant differences among cultivars for yield and WUE only occurred in the mild-deficit treatment. DP1044 had significantly higher yield and WUE than all other cultivars except FM9160 (Table 4).

There were no significant cultivar-by-treatment interactions for yield or WUE in 2010. The lack of a significant interaction indicates that the cultivars within this study had similar overall responses to different irrigation levels: some cultivars did not perform better at lower irrigation levels compared to higher irrigation levels. Therefore, any of the cultivars tested could be expected to perform similarly within defined irrigation treatments with only numerical differences in yield performance.

**2011 Yield and Water Use Efficiency.** Lint yield averages in 2011 were 75 kg ha$^{-1}$ lower in the deficit treatments and 130 kg ha$^{-1}$ lower in the fully irrigated treatment than in 2010. WUE was 0.04 kg m$^{-3}$ lower in the severe-deficit treatment, 0.07 kg m$^{-3}$ lower in the mild-deficit and 0.08 kg m$^{-3}$ lower in the fully irrigated treatment in 2011 (Table 4). The highest averages were produced by DP0935 and DP1044 for both lint yield and WUE, where DP0935 had significantly higher yields than all other cultivars except DP1044. The only irrigation treatment that had significant cultivar differences for yield and WUE was the severe-deficit. In this treatment, DP0935 had significantly higher yield and WUE than FM9160 and DP0912.

There were no significant cultivar-by-treatment interactions for lint yield or WUE in 2011, indicating that the cultivars performed similarly to one another within individual treatments. Yield values for the two years of the study do not differ greatly from those produced in other studies in the Texas High Plains by Wanjura et al. (2002) and Howell et al. (2004), both of whom examined yields and water use over multiple irrigation treatments.

Values for WUE in 2011 are similar to those produced in Howell et al. (2004); however WUE values for the 2010 season were numerically greater. DeTar (2008) also produced similar WUE averages on six irrigation treatments over four years, from 0.13 to 0.22 kg m$^{-3}$ in California.

**Table 4. Lint yields for each irrigation treatment and cultivar for 2010 and 2011. Water use efficiency values are in parentheses**

| Cultivar | Severe-Deficit | Mild-Deficit | Fully Irrigated | Average |
|---|---|---|---|---|
| *2010* | | Yield kg m$^{-3}$ (WUE kg m$^{-3}$) | | |
| DP0912 | 552 (0.15) | 1198 (0.27) bc[z] | 1743 (0.33) | 1164 (0.25) ab |
| DP0924 | 536 (0.15) | 1213 (0.27) bc | 1481 (0.28) | 1077 (0.23) b |
| DP0935 | 652 (0.18) | 1185 (0.26) bc | 1512 (0.28) | 1116 (0.24) b |
| DP1028 | 577 (0.16) | 1099 (0.24) c | 1612 (0.30) | 1096 (0.24) b |
| DP1032 | 559 (0.16) | 1213 (0.27) bc | 1571 (0.29) | 1114 (0.24) b |
| DP1044 | 656 (0.18) | 1436 (0.32) a | 1622 (0.30) | 1238 (0.27) a |
| FM9160 | 712 (0.20) | 1342 (0.30) ab | 1715 (0.32) | 1256 (0.27) a |
| Average | 606 (0.17) | 1241 (0.28) | 1608 (0.30) | 1152 (0.25) |
| | | | $LSD_{cultivar}$ | 121 |
| | | | $LSD_{irrigation}$ | 144 |
| *2011* | | | | |
| DP0912 | 459 (0.12) c | 1159 (0.21) | 1408 (0.20) | 1009 (0.17) cd |
| DP0924 | 533 (0.13) ab | 1164 (0.21) | 1527 (0.22) | 1075 (0.18) bc |
| DP0935 | 596 (0.15) a | 1274 (0.23) | 1537 (0.22) | 1136 (0.19) a |
| DP1028 | 576 (0.14) a | 1122 (0.20) | 1452 (0.21) | 1050 (0.18) bc |
| DP1032 | 557 (0.14) ab | 1137 (0.21) | 1433 (0.21) | 1042 (0.18) bc |
| DP1044 | 540 (0.14) ab | 1268 (0.23) | 1503 (0.22) | 1104 (0.19) ab |
| FM9160 | 508 (0.13) bc | 1087 (0.20) | 1452 (0.21) | 1016 (0.17) cd |
| Average | 538 (0.13) | 1173 (0.21) | 1473 (0.21) | 1061 (0.18) |
| | | | $LSD_{cultivar}$ | 71 |
| | | | $LSD_{irrigation}$ | 115 |

[z] Vertical means followed by the same letter within a column are not significantly different ($p$ = 0.05).

## CONCLUSIONS

Cotton cultivars are often chosen for a specific location because of their maturity characteristics. Early-maturing cultivars are chosen for areas with fewer potential heat units, due to the increased yield production during the limited growing season. Later-maturing cultivars are chosen for areas where limitations in heat units are not typically as much of an issue.

Our research suggests that an overlooked aspect of cultivar selection that is important in choosing the correct cultivar for the Texas High Plains is water deficit response. In 2010, a cool and wet season, a later maturing cultivar (DP1044) performed well, in part because of its excellent yield in deficit irrigation. In 2011, a hot and dry season, both of the later-maturing cultivars performed well. Despite climatic differences between the two years, later-maturing cultivars, particularly those that do well under limited irrigation, performed well in both years. This suggests that later-maturing cultivars would be good selections for areas in the Texas High Plains where water is limited and adequate heat units are available to reach genetic yield potential.

Unless water is not a limiting factor (an unlikely event in the Southern High Plains), cultivar performance under limiting conditions can be a useful indicator, in addition to maturity, for cultivar selection.

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