EFFECTS OF MODERATE WATER DEFICIT STRESS ON FOUR DIFFERENT COMMERCIAL COTTON CULTIVARS

Henrique Da Ros Carvalho
Texas A&M University
College Station, TX
Carlos J. Fernandez
Texas A&M AgriLife Research and Extension Center
Corpus Christi, TX
J. Tom Cothren (*in memoriam*)
Texas A&M University
College Station, TX
Juan C. Correa
Texas A&M AgriLife Research and Extension Center
Corpus Christi, TX
Glen Ritchie
Texas Tech University
Lubbock, TX
Nithya Rajan
Texas A&M University
College Station, TX
Mourad Krifa
University of Texas
Austin, TX

Abstract

Water deficit is a major limitation for cotton yield in drought-prone Texas croplands. Cultivars that use water more efficiently can significantly impact yield and the sustainability and stability of crops grown under water-limited environments. This paper describes a study designed to characterize the effects of moderate water stress (imposed by deficit irrigation) on the water economy, growth and yield of four commercial cotton cultivars grown in the Drought Tolerance Laboratory at the Texas A&M AgriLife Research and Extension Center in Corpus Christi. Results indicated that cultivars DP912 and PHY499 showed better yield performance and higher water use efficiency under water deficits.

Introduction

The effect of drought on plants is complex, and they respond to it with many protective adaptations (Henckel, 1964). In general, plants conserve by limiting leaf area growth and/or closing stomata (McCree and Fernandez, 1989). Due to its perennial habit (Cothren, 1994), it is possible to argue that different cotton genotypes may manifest different responses when subjected to water deficit conditions, which may indicate how efficiently they allocate and partition their resources. Therefore, identifying differences between cultivars may help determine morphological and physiological characteristics that affect water use by cotton plants.

The objective of this study was to assess the effects of water deficit stress on the performance of four cotton commercial cultivars in terms of whole-plant transpiration, dry biomass accumulation, yield and yield components, and water use efficiency indexes.

Materials and Methods

The study was conducted in 2014 at the Drought Tolerance Laboratory in the AgriLife Research and Extension Center at Corpus Christi. This facility consists of two joined modified greenhouses structures converted to rain shelters equipped with computerized systems for controlling irrigation regimes in sets of individual plants and continuously monitoring whole-plant transpiration using a lysimetric method.

Cultivars Deltapine 912 (DP912), Deltapine 1044 (DP1044), Phytogen 375 (PHY375), and Phytogen 499 (PHY499) were planted on April 9th, in 13.5-L pots filled with fritted clay soil. Fritted clay was chosen as the soil medium because

of its large volumetric water holding capacity, 0.46 L L^{-1} (VanBavel et al., 1978). The four cultivars were subjected to two irrigation regimes: continuous full irrigation (2.4 L day^{-1}) and deficit irrigation (1 L day^{-1}) from first bloom (June 7th) through maturity. All irrigations were scheduled at night, when transpiration values can be assumed to be negligible. The experimental set up consisted of a complete randomized design with four replications. Nutrients were provided according to a modified version of Hoagland's solution (Fernandez, 1989). Other management practices such as pest control were performed as needed. All pots were fully irrigated until plants reached first bloom, when the treatments were applied. Whole-plant transpiration was monitored on a daily basis. Plants were harvest on August 15th for measuring growth and yield parameters. No harvest aid agrochemicals, such as defoliants and boll openers were applied prior harvest. Irrigation was stopped once the majority of the bolls were mature (open). Plants were mapped before harvest. The data were analyzed by the analysis of variance (ANOVA), and means separated by Fisher's LSD at $\alpha = 5\%$ using SAS.

Results and Discussion

Daily transpiration data for the full and deficit irrigation treatments (L day^{-1}) are shown in Figures 1 and 2. Cultivars didn't exhibit major differences in the daily rate of water loss. Daily variations were caused by weather conditions. Deficit irrigation decreased cumulative plant water use by 35%, but no significant differences were observed in cumulative transpiration among cultivars in both water regimes (Table 1).

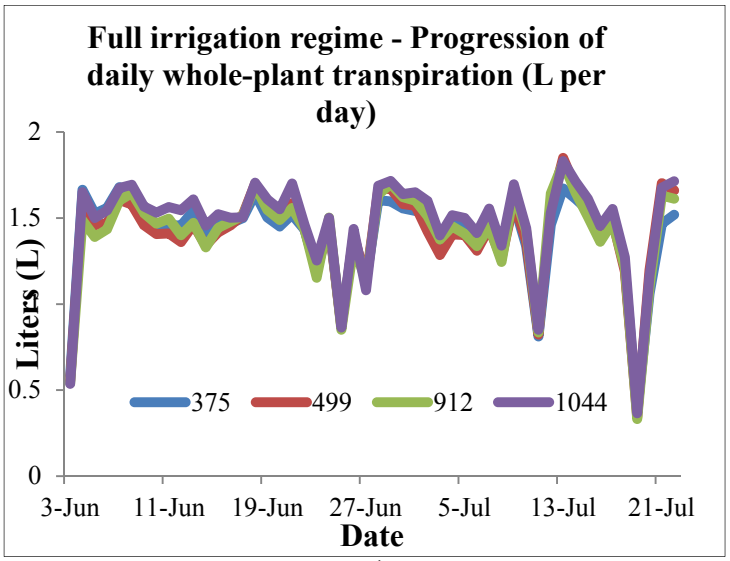

Figure 1. Average daily whole-plant transpiration (L day^{-1}) data for the four cultivars under full irrigation regime during the test.

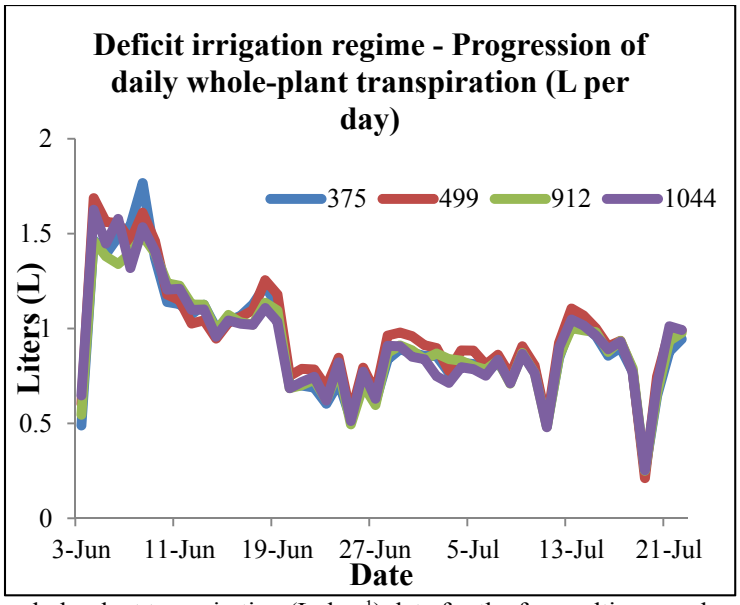

Figure 2. Average daily whole-plant transpiration (L day^{-1}) data for the four cultivars under deficit irrigation regime during the test.

Table 1. Cumulative whole-plant transpiration (L) for the four cultivars under the two irrigation regimes.

	Cumulative whole-plant transpiration (L)	
Cultivars	Full irrigation regime	Deficit irrigation regime
DP912	70.509 a	45.939 b
DP1044	73.459 a	46.319 b
PHY375	70.479 a	46.117 b
PHY499	73.459 a	46.319 b

Means with different letters are significantly different at the 5% probability level.

There were no significant differences in total dry biomass among cultivars in both water regimes (Table 2). Under the full irrigation regime PHY499 accumulated more main-stem and roots and less leaf mass, whereas DP912, DP1044, and PHY375 had smaller main-stem and root mass, but greater leaf dry weight. Under water deficit conditions, PHY499 showed higher production of roots and lower production of leaves than the other cultivars.

Table 2. Dry biomass production and its components for the four cultivars under the two irrigation regimes.

	Dry biomass (g plant^{-1})					
Cultivar	Main-stem	Branches	Leaves	Burs	Roots	Total including seedcotton
Full irrigation						
DP912	33 c	36 a	42 ab	55 a	32 b	300 a
DP1044	37 bc	45 a	47 a	45 b	40 b	311 a
PHY375	38 b	37 a	41 b	51 ab	36 b	304 a
PHY499	48 a	46 a	24 c	59 a	59 a	324 a
Deficit irrigation						
DP912	36 a	32 a	37 a	30 a	33 b	197 a
DP1044	34 a	35 a	33 ab	22 b	32 b	235 a
PHY375	34 a	28 a	27 bc	28 a	37 b	207 a
PHY499	42 a	37 a	20 c	30 a	53 a	247 a

Means with different letters are significantly different at the 5% probability level.

Under the full irrigation regime, no significance was observed in terms of seedcotton and lint per plant, but PHY375 showed greater accumulation of seedcotton and lint per boll (Table 3). Under water deficits, DP1044 yielded lowest as to seedcotton and lint per plant, while PHY499 and DP912 yielded highest. No significance was found among the cultivars in terms of seedcotton and lint per boll under the water deficit regime.

Table 3. Yield and its components for the four cultivars under the two irrigation regimes.

	Yield and yield components (g)			
Cultivar	Seedcotton per plant	Lint per plant	Seedcotton per boll	Lint per boll
Full irrigation				
DP912	101.4 a	39.0 a	2.49 b	0.96 b
DP1044	95.9 a	37.2 a	2.63 b	1.02 b
PHY375	100.4 a	39.8 a	3.19 a	1.27 a
PHY499	86.5 a	35.0 a	2.20 b	0.89 b
Deficit irrigation				
DP912	67.8 a	26.5 ab	3.55 a	1.37 a
DP1044	41.5 b	16.8 c	2.35 a	0.96 a
PHY375	53.7 ab	22.4 b	2.96 a	1.23 a
PHY499	66.3 a	28.3 a	3.09 a	1.32 a

Means with different letters are significantly different at the 5% probability level.

Water use efficiency (g L^{-1}) was partitioned in three indexes: WUE_{total}, $WUE_{economic}$, and WUE_{lint}. WUE_{total} was calculated by diving the total dry biomass yield per the cumulative transpiration; $WUE_{economic}$ was calculated by dividing seedcotton yield per the cumulative transpiration; WUE_{lint} was calculated by dividing lint yield per the cumulative transpiration. There were no significant differences in the indexes among cultivars under the full irrigation regime (Table 4). Under water deficit conditions, DP1044 showed the lowest values in all three indexes, while DP912 and PHY499 showed the greatest values.

Table 4. Water use efficiency (g L^{-1}) indexes for the four cultivars under the two irrigation regimes.

	Water use efficiency indexes (g L^{-1})		
Cultivar	WUE_{total}	$WUE_{economic}$	WUE_{lint}
Full irrigation			
DP912	4.26 a	1.44 a	0.56 a
DP1044	4.24 a	1.31 a	0.51 a
PHY375	4.30 a	1.42 a	0.56 a
PHY499	4.61 a	1.24 a	0.50 a
Deficit irrigation			
DP912	5.13 a	1.47 a	0.58 ab
DP1044	4.26 c	0.89 c	0.36 c
PHY375	4.51 bc	1.16 b	0.48 b
PHY499	5.13 a	1.37 ab	0.59 a

Means with different letters are significantly different at the 5% probability level.

Conclusions

DP912 and PHY499 showed better yield performance and higher WUE under water deficits. The increased WUE showed by these two varieties under water deficits indicates possible higher photosynthetic rates under water stress than the other two varieties. A higher production of roots by PHY499 and lower partition to leaves may indicate an additional advantage of this variety when grown under water deficits in field conditions.

References

Cothren, J.T. 1994. Use of growth regulators in cotton production. pp.6-24. *In*: G.A. Constable and N.W. Forrester (eds). Challenging the future: proceedings of the world cotton research conference-1. CSIRO, Australia.

Fernandez, C.J. 1989. Analyzing drought resistance in plants by combining whole-plant experiments and computer modeling. Ph.D. Dissertation. Texas A&M University. College Station, TX.

Henckel, P.A. 1964. Physiology of plants under drought. Annu. Rev. Plant. Physiol. 15:363-386.

McCree, K.J. and C.J. Fernandez. 1989. A simulation model for studying physiological water stress responses of whole plants. Crop Science 29:353-362.

VanBavel, C.H.M., R. Lascano and D.R. Wilson. 1978. Water relations of fritted clay. Soil Sci. Soc. Am. J. 42:657-659.