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THE DYNAMICS OF DRY MATTER PARTITIONING IN THE COTTON BOLL OF MODERN AND OBSOLETE CULTIVARS

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Abstract

Yields across the Cotton Belt increased steadily throughout the 1980's, but leveled off and even decreased in the 1990's. Of more concern, however, is the increased year-to-year variability. A clear understanding of why yields have leveled off the past decade and why increased variability from year-to-year has occurred is urgently needed. It is speculated that the reason for this decrease in yield is a combination of adverse environmental conditions, particularly during boll development, coupled with changes in breeding directions over the past few decades. To test this assumption a randomized slit-plot study was designed and conducted in northeast Arkansas to evaluate yield development of modern versus obsolete cultivars as influenced by the environment. Two years data has shown differences in yield and components of yield as related to contrasting cultivars, but no significant correlations to irrigation has occurred. This is due in part to adequate rainfall during peak boll development.

Introduction

Cotton yields in Arkansas as well as much of the U.S. increased steadily during the 1980's, but in the 1990's there has been a leveling off and lately a decrease in yields (Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the extreme year-to-year variability. Three out of five seasons from 1995 to 1999 were extremely disappointing with unusually low yields (Oosterhuis, 1999). The 1998 and 1999 crop yields were the poorest in recent history and much of this was related to extreme weather conditions and less on insect pressure. Generally, each year the cotton crop appears to have good potential at mid-season, but this potential is not always achieved at harvest due to combinations of moisture stress and high temperatures during the critical first three to five weeks of flowering and boll development. Besides environmental conditions, changes in breeding objectives over the past few decades may also be an underlying reason for yield variability. Increased yield variability may be the result of differential partitioning of carbohydrate and energy pools between fiber and seed of modern and obsolete cultivars as a result of environmental stress during early boll development. To test this hypothesis the following research objectives were initiated. The first objective was to study dry matter and carbohydrate partitioning at the whole plant, boll and fiber level in relation to genotype and environment. The second objective was to study various physiological and biochemical parameters associated with yield in order to better understanding boll development and yield as affected by environmental stresses.

Materials and Methods

A field study was designed in northeast Arkansas in 2001 and 2002 to test the impact that contrasting environmental conditions coupled with genotypic differences had on partitioning in field-grown cotton. The study contains two factors which are water and cultivar. Water is the whole-plot factor, split for either well-watered or water-deficit conditions. The sub-plot factor is cultivar and consists of eight cultivars which include four modern and four obsolete cultivars. The modern cotton (*Gossypium hirsutum L.*) cultivars are ST 474, SG 747, DP 33B, and Acala Maxxa and the obsolete cultivars include ST 213, DP 16, REX, and SJ2. Each of these eight cultivars was subjected to both water treatments and was replicated six times. Numerous in-season physiological and end-of-season agronomic measurements were evaluated to explain yield variability. End-of-season measurements included lint yields, as well as yield and boll components. Boll components consisted of average boll weight, seed weight, and fiber per seed. Yield components consisted of bolls per acre and seeds per acre.

Results and Discussion

Lint Yields

Yield results from the 2001 field study indicated there was a significant difference ($P<0.05$) in yield between modern and obsolete cultivars when averaged over water, with the modern cultivars showing a significantly higher yield than the obsolete cultivars (Figure 1). A more important result was that there was a significant interaction between water and cultivar levels indicating that different cultivars responded differently to water in terms of yield potential. However, there was no difference in lint yields between water treatments averaged over cultivars.

Yield and Yield Components

When averaged over water in 2002, the modern cultivars numerically out yielded the obsolete cultivars (Table 1). Boll component values indicated that the higher yields by the modern cultivars was due to significant improvements in gin turnout and fiber per seed. The obsolete cultivars had significantly larger bolls with significantly larger seeds (Table 1). In terms of yield components, there were no differences between boll number or seed number per acre at either the cultivar or water level. There were no differences in yield, yield components or boll components at the water level (Table 2).

Photosynthesis and Canopy Temperature

There were no statistical differences ($P<0.05$) between modern and obsolete cultivars for increasing net photosynthesis or reducing canopy temperature at either water level when measured three weeks after first flower (Figure 2). However, canopy temperature and photosynthesis were the most efficient for crop growth and development for modern cultivars under well-watered conditions but numerically reduced under water-deficit.

Specific Leaf Weight (SLW)

There were no differences at either the cultivar or the water level for altering SLW at the first flower plus two week stage (FF2). However, by four weeks after first flower (FF4), obsolete cultivars had a significantly lower SLW than modern cultivars under both water levels (Figure 3).

Chlorophyll Content

Chlorophyll content was numerically higher for modern cultivars than for obsolete cultivars under both water levels at each sample time (FF2 and FF4) during the season (Figure 4). This numerical increase in chlorophyll by the modern cultivars was significant at the FF4 stage.

Summary

Our preliminary research has shown some differences between modern and obsolete cultivars in terms of both physiology and yield potential. We have shown that modern cultivars yield higher than obsolete when averaged over well-watered and water-deficit conditions. This increased yield achieved by modern cultivars appears to be related to improvement in the partitioning of carbohydrate (and therefore energy pools) to the developing fiber compared to the obsolete cultivars. However, to better explain the yield variability problems experienced in recent years a significant stress during boll development is needed to better compare the obsolete to modern cultivars from a physiological and boll development standpoint. To date, our research efforts have been solely accomplished in the field and we have yet to achieve a noticeable stress event during boll development due to favorable weather patterns during that time. Therefore, future research efforts will include controlled growth chamber studies to accompany our field efforts.

References

Lewis, H.L. and P. Sasser. 1999. U.S. Upland cotton: Beltwide and Mid-South yield trends, 1960-1998. Proc. Beltwide Cotton Prod. Conf. National Cotton Council of America, Memphis, TN.

Meredith, W.R. Jr. 1998. Continued progress in breeding for yield in the USA? Proc. Cotton Biochemistry Conf., Cotton Incorporated, Raleigh, NC.

Oosterhuis, D.M. 1999. Yield responses to environmental extremes in cotton. *In*. D.M. Oosterhuis (ed.) 1999. Proc. Cotton Res. Meetings and Research Summaries, Univ. of AR, Ark. Agri. Exp. Sta. Special Report 193:30-38.

Table 1. Genotypic effect on yield, boll components, and yield components averaged over water treatments.

Trt.	yield	Boll Wt.	Gin T.O.	seed wt	Bolls	Seeds	fiber/seed
	lb lint/A	g/boll	%	g/100seed	#/A	#/A	mg/mg
Modern	656	3.59	**36.8***	8.94	219,000	8,220,000	**0.59***
Obsolete	622	**3.95***	34.7	**9.94***	192,000	7,890,000	0.52

Treatment means followed by * are significantly different at $P<0.05$.

Table 2. Environmental effect on yield and components of yield averaged over cultivars.

Trt.	yield	Boll Wt.	Gin T.O.	seed wt	Bolls	Seeds	fiber/seed
	lb lint/A	g/boll	%	g/100seed	#/A	#/A	mg/mg
Irrigated	637	3.69	35.9	9.46	209,000	8,370,000	0.56
Dryland	641	3.86	35.6	9.41	202,000	7,740,000	0.55

Treatment means followed by * are significantly different at P<0.05.

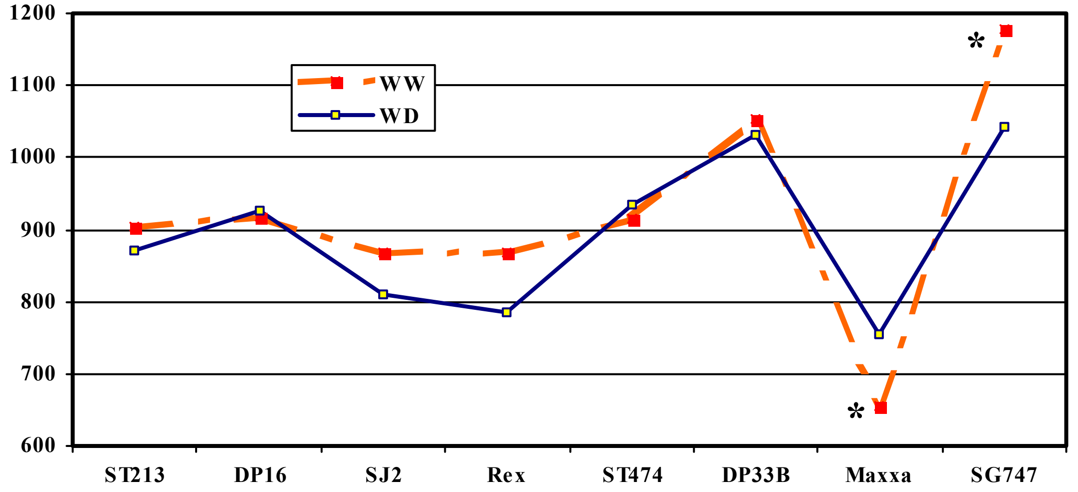

Figure 1. Lint yields of selected genotypes under different water regimes. *indicates a significant water x cultivar interaction at the P<0.05 level.

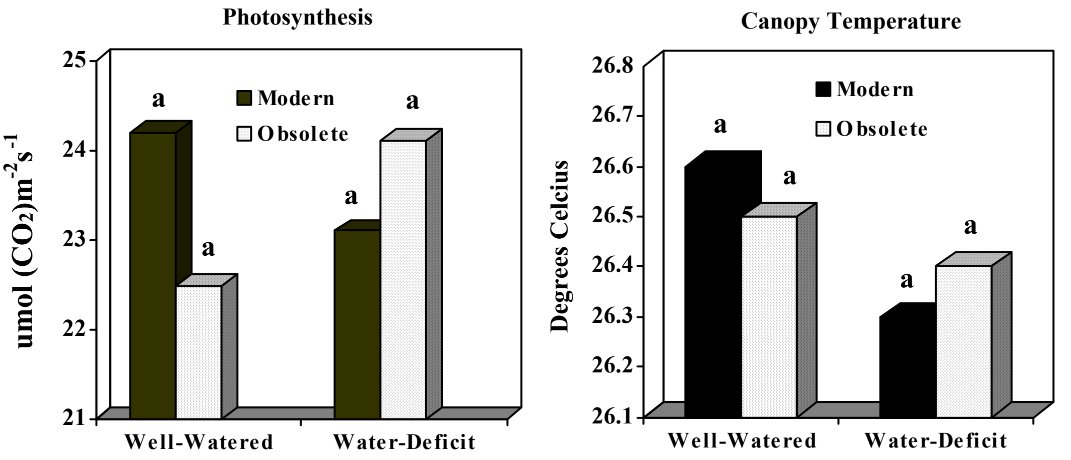

Figure 2. Photosynthesis and canopy temperature of modern and obsolete cultivars under well-watered and water-deficit conditions. Bars followed by the same letters are not significantly different at P≤0.05.

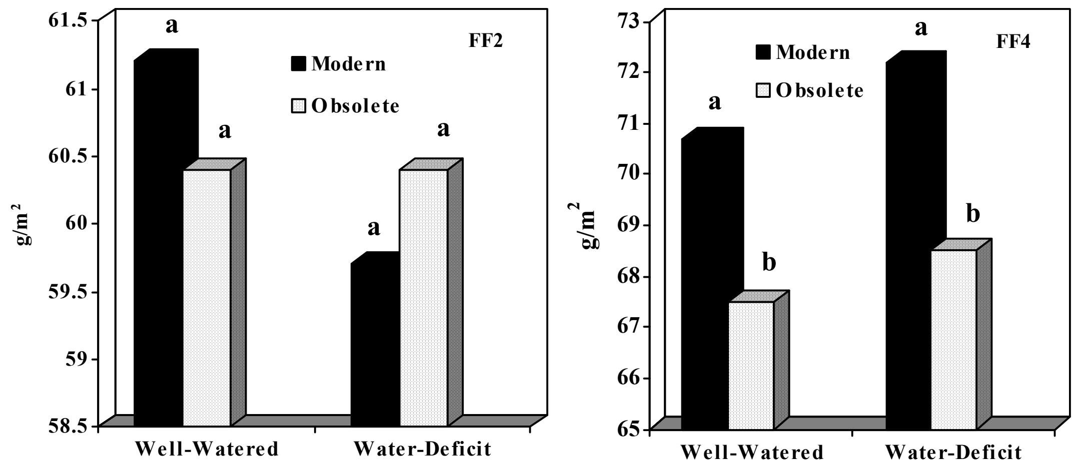

Figure 3. SLW comparisons of modern versus obsolete cultivars at FF2 and FF4. Bars followed by the same letter are not significantly different at P≤0.05.

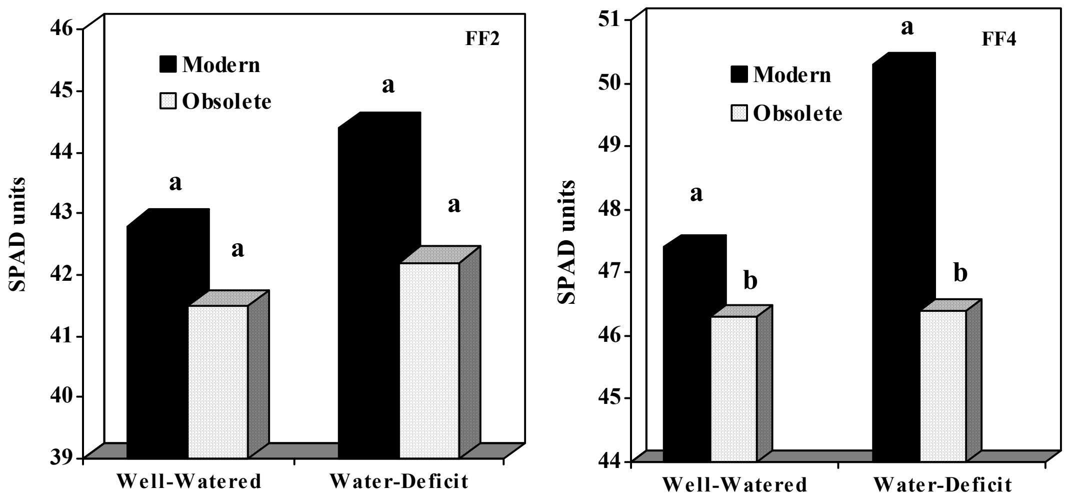

Figure 4. Chlorophyll content of modern versus obsolete cultivars at FF2 and FF4. Bars followed by the same letter are not significantly different at P≤0.05.