GENOTYPIC AND ENVIRONMENTAL EFFECTS ON PARTITIONING IN THE COTTON PLANT AND BOLL FOR EXPLAINING YIELD VARIABILITY

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RESEARCH PROBLEM

Cotton yields in the U.S. increased steadily throughout the 1980s, but leveled off and even decreased in the 1990s. 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 cotton genotypes due to changes in breeding objectives over the past few decades. This is a preliminary report of a study to explain yield variability by evaluating cotton yield components as influenced by genotype and environment to .

BACKGROUND INFORMATION

Cotton yields in Arkansas as well as much of the U.S. increased steadily throughout the 1980s, but leveled off and even decreased in the 1990s (Chaudry, 1997; Meredith, 1998; Lewis and Sasser, 1999). Of more concern, however, is the increased year-to-year variability in which record yields occur one year followed by disastrous yields the next year. Generally, each year the cotton crop appears to have good yield potential at mid-season, but high yields are not always achieved at final harvest. One reason for poor yields is related to subtle genotypic changes in modern cultivars due to the way in which carbohydrate and energy are partitioned between seed and fiber within the boll. However, the main reasons for poor yields in recent years may be due to extremely hot temperatures, coupled with drought, during the crucial first three to five weeks of flowering and boll development (Oosterhuis, 1995, 1997, 1999).

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The current hypothesis is that modern cultivars produce smaller bolls with smaller, more numerous seeds. Under adequate growing conditions this allows for more seed per acre and the potential for more fiber aiding in higher lint yields. However, under adverse environmental conditions (mainly drought) the modern cultivars are unable to tolerate the added carbohydrate stress associated with trying to appropriately fill seed and produce fiber. To test this hypothesis, the following research objectives were designed for an ongoing field trial. The main objective was to investigate dry-matter partitioning at the whole plant, boll, and seed level in relation to genotype and environment. A second objective will include future investigation of night temperatures as related to boll development. Collectively, this information should help in the development of an "early warning" signal for detecting low boll-weight development in the field before yields are adversely affected.

RESEARCH DESCRIPTION

In 2001, a field study was designed in northeast Arkansas to test the impact of contrasting environmental conditions coupled with genotypic differences on dry matter partitioning in cotton. The study was planted 10 May 2001 in a randomized split-plot design consisting of 16 treatments replicated six times. The whole-plot factor was irrigation and consisted of either well-watered (WW) or water-stressed (WD) conditions, and the split-plot factor represented cultivar consisting of four obsolete (ST 213, DP 16, Rex, SJ2) and four modern (ST 474, SG 747, DP33B, Acala Maxxa) cultivars. Each of the eight cultivars was subjected to both well-watered and water-stressed conditions to account for the 16 treatments tested in the study. The cultivars were chosen with the collaborative effort of breeders across the U.S cotton belt to insure that current germplasm pools from each region were represented. To evaluate dry-matter partitioning at the boll and seed levels, approximately 80 first-position bolls were tagged at upper and lower canopy positions. From these tagged bolls, 10 bolls were collected at two, four, and six week intervals and are currently being processed in order to determine dry matter of boll component parts, lint and seed indices, and seeds per boll. At final harvest, mature bolls were collected from a 2-m^2 harvest area to determine the same boll parameters measured on the tagged bolls, and final lint yields were recorded from mechanically harvesting the center two rows of each four-row plot.

RESULTS

Lint Yields

There were no differences in lint yields between well-watered and water-deficit treatments when averaged over cultivars (Fig. 1, Table 2). The 2001 cotton season experienced below normal temperatures with normal rainfall, which resulted in similar yields between wet and dry plots. However, there was a significant difference in yield between modern and obsolete cultivars when averaged over water, with the modern cultivars showing a significantly higher yield than the obsolete cultivars (Fig. 1, Table 1). The only exception to this was Acala Maxxa, a modern cultivar, which yielded less than the obsolete cultivars tested because of an inability to mature all of its bolls within the short Mississippi Delta season. 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 (Fig. 1).

Boll Number and Weight (Whole Plant Analysis)

Immediately prior to mechanical harvest, all mature bolls were collected from a two-meter row length within each plot to estimate average boll weight, bolls per acre, seeds per acre, seeds per boll, seed weight, and fiber per seed. Final boll harvest supported the hypothesis that modern cultivars had more bolls and seeds per acre than obsolete cultivars when averaged over water treatments (Table 1). As expected, the obsolete cultivars also had larger bolls with larger seeds. We had anticipated that the obsolete cultivars would have fewer seeds per boll and more fiber per seed than the modern cultivars due to modern cultivars investing less energy in seed development. However, the replicated field study indicated that the modern cultivars produced more fiber per seed and had less seeds per boll (Table 1). Over the last few decades plant breeders have increased gin turnout (the amount of fiber relative to the amount of seed,) therefore this result appears to make sense. However, field results showed fewer seeds per boll in modern compared to obsolete cultivars, which still remains an unanswered question. Table 2 summarizes the effect that the environment, i.e. water deficit, had on modern and obsolete cultivars. There were no differences between wet and dry plots in the 2001 season as a result of appreciable rainfall during peak squaring and boll development. This boll component data also helps to explain why there were no differences in yields between wet and dry plots.

Average Boll Weight and Seed Percentages (Boll and Seed Levels)

To better explain the yield results and boll development parameters measured at the whole-plant level, individually tagged bolls at upper and lower canopy positions are currently being analyzed for dry-matter allocations. This should help to explain partitioning at the boll and seed level as bolls of different genetic potential develop in the field under contrasting environments. The data presented in Fig. 2 constitute the harvested lower position bolls at the six-week stage of growth. It was anticipated that boll weight would be lower for the modern cultivars when compared to the obsolete cultivars. However, data collected from the lower position bolls at six weeks failed to show this trend. When averaged over water treatments, the performance of modern versus obsolete cultivars was quite variable in the detection of lower boll weights for the modern cultivars. It should be mentioned, however, that these data only reflect one position in the plant canopy and also only represent one sample time. The variation noticed in boll weight may be related to different tagging dates due to different maturities of the cultivars tested. Therefore, bolls may have experienced different weather conditions during the six-week boll development period. However, once we can calculate the amount of increase in boll weight per day per unit of water, we can better determine differences between modern and obsolete cultivars for developing boll weight.

PRACTICAL APPLICATION

This current and ongoing research project will continue to evaluate partitioning at the boll and seed level to gain insight into underlying principles of boll development as related to changes in genetics and the environment. Once all of the samples have been processed, analyzed, and weather data correlated back to the individual sampling, we anticipate being able to predict when bolls will begin to develop low boll weight in the field under different environments as related to genotypic differences. If this research is successful it will permit producers to be able to make management decisions to attempt to enhance boll development or reduce production inputs to save costs.

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Table 1. Dry-matter components of yield. Cultivar effect– averaged over water. Two-meter harvest from Clarkedale, AR. Summer 2001.

Treatment	Lint yield	Average boll weight	Seed/boll	Fiber/seed	Seed weight	Bolls/acre	Seeds/acre
	(lb/acre)	(g/boll)	(no.)	(mg/seed)	(g/100 seed)	(no./acre)	
ST 474 (new)	917	3.19	21.9	56.9	8.59	340,000	7,450,000
DP 33B (new)	1033	3.62	27.7	48.3	8.12	378,000	10,500,000
SG 747 (new)	1110	3.67	25.2	58.5	8.62	369,000	9,300,000
Maxxa (new)	691	4.05	22.9	68.2	10.51	250,000	5,640,000
New (Average)[z]	938[y]	3.63	24.2	58.0[y]	8.96	334,000	8,220,000
ST 213 (old)	870	3.48	25.4	50.3	8.39	336,000	8,520,000
DP 16 (old)	922	3.73	27.3	48.4	8.58	323,000	8,840,000
Rex (old)	815	3.82	26.2	50.7	9.25	286,000	7,490,000
SJ2 (old)	833	4.28	26.5	56.7	10.28	256,000	6,710,000
Old (Average)[z]	771	3.83[y]	26.3	51.5	9.13	300,000	7,890,000

[z] Indicates that the measurement for a given treatment was significant at the P<0.05 level.

[y] Statistics only compare significant differences between cultivars at the new vs. old level. Statistical comparisons were not made in regard to individual cultivars.

Table 2. Dry-matter components of yield. Water effect– averaged over cultivar. Two-meter harvest from Clarkedale, AR. Summer 2001.

Treatment	Lint yield	Average boll weight	Seed/boll	Fiber/seed	Seed weight	Bolls/acre	Seeds/acre
	(lb/acre)	(g/boll)	(no.)	(mg/seed)	(g/100 seed)	(no./acre)	
Well-watered (WW)	906	3.68	25.2	54.7	9.01	330,000	8,370,000 [z]
Water-deficit (WD)	891	3.78	25.6	54.8	9.07	303,000	7,740,000

[z] Indicates that the measurement for a given treatment was significant at the P<0.05 level.

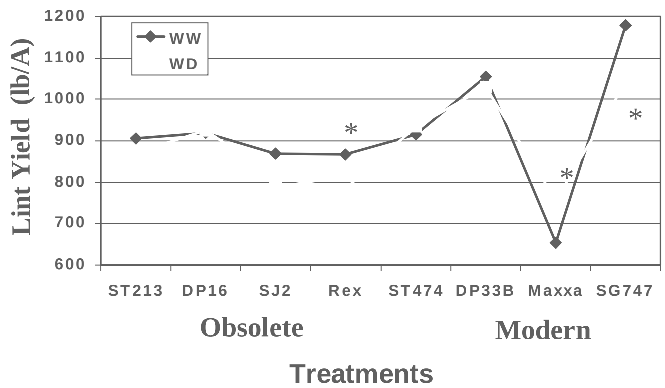

Fig. 1. Lint yields of four modern and four obsolete cultivars as affected by well-watered and water-deficit conditions. There was a significant cultivar x water interaction at the P<0.05 level.

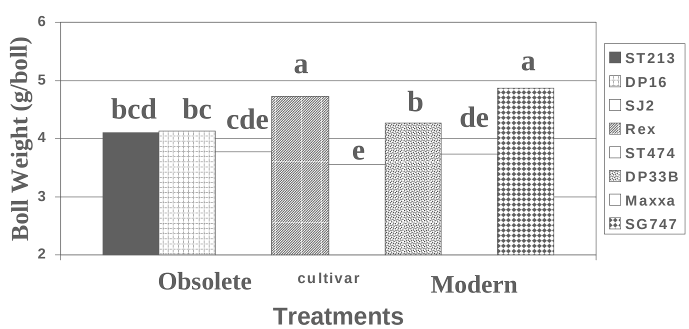

Fig. 2. Average boll weight of lower six-week-old bolls for four modern and four obsolete cultivars averaged over well-watered and water-deficit conditions. Bars followed by the same letter are not significantly different at P<0.05.