U.S. COTTON BELT

Cotton Yield Progress – Why Has It Reached a Plateau?

By W.R. Meredith, Jr.

Cotton, like most U.S. crops, is experiencing severe economic stress. Relief will come in the form of higher commodity prices, lower production costs, and higher yields. Some progress in improving fiber quality and reducing expensive production inputs has been made. However, further improvements need to be associated with yield increases. Yields of most field crops have been increasing during the last several decades.

Average U.S. cotton yields per acre are indicated in **Figure 1**. The yield curve from 1961 to about 1999 indicates an average increase of 5.99 lb/A/year. However, inspection of the yield curve shows a plateau from 1961 to 1979. This was followed by 10 years of increasing yields/A, as a result of better insect control, crop management, and the introduction of new germplasm into breeding programs. However, quadratic analysis of the yields from 1980 to 1999 shows that yields peaked in about 1992 (**Figure 2**).

> Despite many changes in cotton technology, it is evident that yields in the U.S. are at a plateau and have been for about 15 years. Some, but not all, of the causes for this lack of yield increases have been identified.

Dr. Hal Lewis, an independent cotton breeder working with the American Cotton Producers Association, analyzed cotton yield trends and reached a similar conclusion. He also showed that the year to year variation within the last 20 years, is four times greater than within the previous 20-year period. **Figure 1** shows the great year to year variation.

What are the major factors impacting yield? They include weather, management, rise of new pests, and variety improvement.

Weather. Certainly year to year variability has a big impact on yield, but is it responsible for the yield plateau? Abnormal weather would need to cover the entire Cotton Belt from Carolina to California. Such weather patterns also would have to negatively affect other major crops. Weather scientists have indicated that the earth's climate has gradually been getting warmer. Higher temperatures could have plus and minus effects

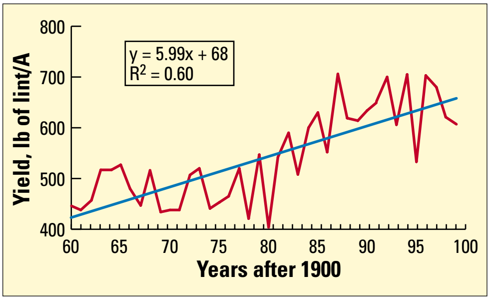

Figure 1. Average yield of U.S. cotton from 1961 to 1999.

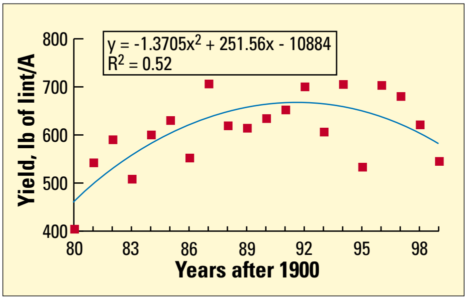

Figure 2. Average yield of U.S. cotton from 1980 to 1999.

on yield. Higher temperatures with drought would decrease yields, but also would extend the growing and harvest season. The increase in carbon dioxide (CO_2) would be expected to increase photosynthesis. There has been no definitive model that accurately associates weather variability with the yield plateau.

Management. The change in management can be addressed as changes in mechanization, agronomy, pest control, and communications. Improvements in equipment have resulted in greater crop management efficiency and handling ease. Precision planters, combined with better seed quality and seed treatments, have resulted in earlier plantings with less plant stand losses and need for replanting. Better placement and timing of fertilizer, pesticides, growth regulators, and crop terminators occur because of better equipment. Modern cotton pickers and strippers result in faster, more efficient harvesting. Modules for storing unginned cotton prevent the loss of harvesting time due to gin overloading.

Agronomically, more management attention is paid to crop development. Crop growth is managed with growth regulators. More acres are irrigated, especially in the Midsouth. Pest control due to precise consulting, area-wide pest control programs, and use of transgenic varieties has resulted in less crop losses and need for pesticides. The rapid transmittal of technology and information has allowed better timeliness in applying technology.

One would assume that the combined effects of these modern management tools and information would have a positive effect on yields.

New Pests and Problems. Since yields have not been increasing when they were expected to increase, are there new pests or problems that we have not detected? There have been cases of new weeds and isolated cases of outbreaks of insects, generally referred to as minor insects. These problems are not sufficiently large on a national basis to explain the observed plateau. The occurrence of "bronze wilt" has mystified many growers and researchers. The sudden wilting and subsequent severe loss of yield have not been adequately explained by pathologists, physiologists or geneticists. Such losses have been primarily on varieties descending from one genetic background and have been confined to a few acres. Shifting to other varieties has essentially reduced the losses to zero, but the so-called susceptible varieties do not always exhibit the syndrome. The increase in reniform nematodes is believed to affect a much wider production area. It is more difficult to research this problem than that of many other pests. The direct evidence associating the presence of reniform nematodes with yield losses is limited. However, the circumstantial evidence of the increase in reniform populations in grower fields with a yield decline is great. Another problem, also not yet resolved, is the low organic matter level of many soils where continuous cotton has been grown for many years.

Variety Improvement. Two methods have been used to measure yield changes due to variety improvement. The first method was to use the average yield of 15 tests conducted as part of the National Cotton Variety Tests and involved six U.S. cotton growing regions. As indicated in **Table 1**, the combined regression analysis over all six regions shows a regression coefficient (slope, or m, in the equation with form of Y = mX + intercept) for yield on test year of 6.05 lb lint/A/year. This is almost identical to the national average yields (**Figure 1**) with a slope of 5.99 lb lint/A/year. A segmented regression analysis of the variety tests partitioned the data into two time periods: 1960 to 1981 and 1982 to 1996. Inspection of **Figure 1** shows a similar national trend with a major increase in yield

Weather, management, new pests, and variety improvement are some of the factors affecting cotton yield.

TABLE 1. Regression equations for average cotton yield (lb lint/A) on year of test for six U.S. regions involving 15 locations.

Region	Years	Intercept	Slope or reg. coef. (SE)	Average yield, lb lint/A	2nd period - 1st period
East	1960-96	707	+ 7.55 X (1.25)*	877	
	1960-81	826	– 3.38 X (6.18)	798	
	1982-96	921	+ 9.47 X (14.25)	987	189
Delta	1960-96	938	+ 7.45 X (1.96)**	1,072	
	1960-81	1,024	– 3.70 X (3.92)	986	
	1982-96	1,238	– 5.45 X (7.28)	1,204	218
Central	1960-96	795	+ 6.00 X (2.48)*	908	
	1960-81	864	– 4.95 X (4.71)	815	
	1982-96	1,233	– 28.01 X (8.28)	1,041	226
Plains	1960-96	669	– 1.72 X (2.48)**	637	
	1960-81	804	– 16.90 X (4.66)	625	
	1982-96	581	+ 10.44 X (9.65)	654	29
West	1960-96	823	+ 8.30 X (2.76)**	1,001	
	1960-81	809	+ 9.31 X (5.80)	914	
	1982-96	1,240	– 19.53 X (11.51)	1,104	190
Far West	1960-96	1,034	+ 6.94 X (3.23)*	1,169	
	1960-81	1,094	– 0.15 X (7.91)	1,082	
	1982-96	1,204	+ 6.91 X (11.75)	1,253	171
Combined analysis	1960-96	832	+ 6.05 X (1.25)**	941	
	1960-81	891	– 1.78 X (2.37)	870	
	1982-96	1,075	– 4.51 X (5.21)	1,043	173

X = Years after the initial year of the period (1960 or 1982).
SE = Standard error of regression coefficient.
*, ** = Indicates significantly different than 0.0 at the 0.05 and 0.01 probability levels, respectively.

occurring in the early 1980s. Five of the six cotton-producing regions show increases in yield (slopes) ranging from 6.00 to 8.30 lb/A/year for the entire 1960 to 1996 period. The exception is the Plains region where the year to year variability was of such magnitude that no clear trend was detectable. The average yield of the variety tests of the five regions for the early and late time periods was 919 and 1,118 lb/A, respectively, or an increase of 199 lb/A (**Table 1**). The increase in yield from 1982 to 1996, over the yield from 1960 to 1981, for the Plains region was 29 lb/A. The increase in yield in the early 1980s was due to the introduction of new pesticides and new germplasms. The new germplasm came from state and USDA Agricultural Research Service (ARS) enhancement programs. Within the two time periods, no progress for yield was made due to breeding. Analysis of the National High Quality Tests (data not shown), which involved nine Midsouth states, also showed a quadratic curve with yields increasing until about 1988 and then decreasing.

Since variety tests measure both genetic and management inputs, a second method of analysis was used to estimate breeding progress. This method relates yield to year of variety release. At Stoneville, we have conducted four such tests as indicated in **Table 2**. Average lint yield and the linear regression of lint yield on year of variety release, for six varieties common to all four tests, are indicated in **Table 2**. The average yield of the six common varieties was highest for the earliest test, 1,089 lb lint/A, and lowest for the latest test, 759 lb lint/A. The regression of yield on year of variety release (slope) shows a decline of 9.1 to 4.7 lb/A for the earliest to the latest tests. Statistical analysis indicates signifi-

TABLE 2. Annual lint increase due to breeding as indicated in tests comparing varieties with different variety initial release years.

Years of tests[2]	No. of varieties	Release years covered	Average yield of six common varieties[3], lb lint/A	Slope, lb lint/A/year[1]
1967-68	13	1922-62	1,089	9.1a
1978-79	17	1910-78	921	8.5a
1992-93	16	1938-93	780	5.4b
1998-99	38	1938-99	759	4.7b

[1]Significant differences between regression coefficients (slopes) indicated by different letter, as determined by "t" test.
[2]All variety tests conducted at Stoneville, MS.
[3]Six varieties in all tests were DPL Smooth Leaf, DPL 14, DPL 16, Stoneville 2B, Stoneville 5A, and Stoneville 213.

cance at the 0.05 probability level between the slopes of the first two and last two tests.

A subset of 23 varieties in the latest test released since 1983 is given in **Figure 3** and shows no significant trend due to variety improvement (slope = 3.5 lb lint/A/year).

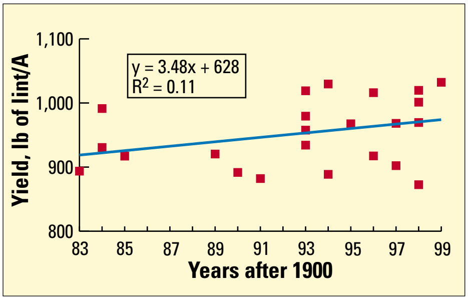

Figure 3. Increase in yield due to breeding from 1983 to 1999.

Summary

Current varieties have a very narrow genetic base with similar pedigrees. The narrowing of the genetic base has been associated with the decline in public germplasm enhancement programs. The use of transgenics with the major objective of "added value traits" has been very effective on the added value traits, but has had no effect on average yields. Research and grower experiences have shown that corn-cotton rotations will result in some yield increase. This practice reduces reniform nematodes and in some cases increases soil organic matter. In all likelihood, there are other factors limiting yield that have not been identified by research or grower experience. These factors probably encompass all areas of cotton production. If the U.S. cotton industry is going to survive in a competitive world, it cannot depend on a strategy of no yield increase. BC

Dr. Meredith is Research Leader, Midsouth Area, USDA-ARS, Crop Genetics and Production Research Unit, 141 Experiment Station Road, P.O. Box 345, Stoneville, MS 38776-0345; phone: 662-686-5322, fax: 662-686-5398.