Continued Progress in Breeding for Yield in the USA?

W.R. Meredith, Jr.
United States Department of Agriculture, Agricultural Research Service, Cotton Genetics & Physiology P.O.Box 345, Stoneville, MS. 38776-0345

ABSTRACT

The objective of this study was to determine if lack of genetic progress was partially responsible for stagnating yields in USA cotton. A review of obsolete vs. modern cultivars indicated breeding progress for yield peaked in 1987. National cultivar test regression of yield on test year was negative (b=-05.1 kg ha^{-1} yr^{-1}) for the years 1982-1996. Two remedies are suggested. First, broaden the genetic base being used by breeders, and second, focus more on long term goals for increasing yields than on short term goals of just protecting existing yield potential.

Introduction

Increased cotton production per hectare is necessary if cotton is to keep up with world population growth. With an increase in population of about 80 million persons per year (Brown, 1998), world cotton production needs to increase by about 1.2 million bales per year to keep pace. Production increases need to come from greater productivity per hectare, as the net tillable land area is not likely to increase. The objective of this study was to evaluate the current effect of breeding on yield increases in the USA.

Procedure

Yield trends were evaluated by three methods. The first involves analyzing USA cotton yield trends. Data used were average yield results from the U.S. Department of Agricultural Statistical Reports (1960-1997). Regression of USA average yield on crop years since 1960 produces a regression coefficient of 7.7 kg ha^{-1} yr^{-1}. However, the average yields show little progress since 1982. Chaudhry (1997) reported that USA and world production per hectare has stagnated in the last 17 years.

The second approach involved review of obsolete vs. modern cultivar comparisons. Yield trends from six USA obsolete vs. modern studies are given in Table 1. Yield increases range from 6.1 to 11.5 kg ha^{-1}. Similar results using regression of new cultivars on check cultivars were reported by Meredith and Bridge (1984). The average yield increase due to breeding for the years 1950-1980, for the East, Delta, Plains, and West regions was 5.5, 9.6, 8.7 and 14.2 kg ha^{-1}, respectively. However, in the most recent study, Meredith, *et al.* (1997) reported the lowest yield increase of 6.1 kg ha^{-1} yr^{-1}. When yields in three of the Mississippi tests, Bridge, and Meredith (1981), Bridge *et al.* (1971), and Meredith *et al.* (1997) were combined into one analysis, the results showed a significant curvilinear effect. The yield analysis by Meredith (1995) suggested that genetic improvements peaked in about 1987.

The third approach was to use cultivar test averages from 6 regions and 15 locations that had been in USA National Cultivar Tests generally since 1960. The six regions and their test locations were: East: Florence, SC, and Auburn, AL; Delta: St. Joseph, LA, Portageville, MO, and Stoneville, MS; Central: College Station, TX, Weslaco, TX, and Bossier City, LA; Plains: Chickasha, OK, and Lubbock, TX; West: El Paso, TX, Pecos, TX, and Las Cruces, NM; and San Joaquin: Shafter, CA and Westside, CA.

Since USA yield trends showed a distinct change in about 1982, analyses of the regional tests were conducted on three time periods; 1960-1996, and partitioning the entire period into two components; 1960-1981 and 1982-1996. These tests were generally conducted with better than average management and thus yield trends may be due to both breeding and management. However, these results and those from obsolete vs. modern cultivar tests are similar (no yield increase in the last decade was due to breeding). Trends from the USA cultivar tests will be viewed as mostly due to breeding.

Results and Discussion

Regression of yield of regional test averages on year of tests are given in Table 2. Five regions showed significant regressions ranging from 6.7 to 9.3 kg ha^{-1} yr^{-1}. Only the Plains region showed no increase in yield, b = -1.93 kg ha^{-1} yr^{-1}. The environmental stresses in this region frequently conceal any genetic improvements.

The combined analyses (Table 3) over all regions produced a significant increase in yield for the 37-year period of 6.8 kg ha^{-1} yr^{-1} which is similar to the USA yield change of 7.7 kg ha^{-1} yr^{-1}. Within partitioned periods the regression was –2.0 and –5.1-kg ha^{-1} yr^{-1} for the 1960-1981 and 1982-1996 periods, respectively.

Yield components generally followed a similar trend within regions (Table 2). All regions except the Plains showed significant increases in lint percentage. Over the 37-year period, all regions showed decreases in boll and seed weight, which was similar in both partitioned periods (Table 3).

Average performance of yield, yield components, and fiber properties are given in Table 4 for the three periods. "F" tests show highly significant differences between the two partitioned periods for all traits except micronaire. Yield increased 193 kg ha$_{-1}$ or 19.8%. Lint percentage increased 2.9% and boll and seed weight decreased 9.9% and 9.2%, respectively. Fiber 2.5% span length decreased 1.4% and bundle strength (T1) and miniature yarn strength increased 6.7% and 4.8%, respectively.

These results indicate that despite major breeding and management efforts, USA yields are not increasing. The genetic explanation can be due to, (1) a lack of useful genetic variability, and (2) breeding priorities may have changed. Van Esbrock *et al.* (1998) investigated the genetic diversity of USA cultivars in use from 1970-1995. They concluded that much of the genetic variability available to breeders remains unused and that many of the recent cultivars have common ancestors. The yield plateau that ended in about 1981 was partially due to the introduction of genes from triple hybrid and *G. barbadense* germplasm (Meredith 1991). Compounding this problem, many USA public germplasm enhancement programs have been discontinued or seriously reduced.

Breeding objectives also have changed with greater emphasis being placed on fiber strength and added value traits. Transgenes conferring resistance to insects and herbicides have been added to established varieties by the backcross method. Breeding has focused on short-range goals at the expense of long term breeding for yield improvement.

Unless breeders broaden the genetic base and focus again on yield, it is this author's opinion that little increase in USA yield will occur.

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Table 1. Review of published reports on USA breeding progress as measured by regression analyses.[1]

Reference	Lint increase yr^{-1} $kg\ ha^{-1}$
Bridge, *et al.*, 1971	10.2
Bridge and Meredith, 1983	9.5
Wells and Meredith, 1984	6.4
Culp, 1984	11.5
Bassett and Hyer, 1985	8.0
Meredith, *et al.*, 1997	6.1

[1] Regression coefficient (b) for yield on year of cultivar release computed from modern vs. Obsolete cultivar tests. All regression coefficients are highly significant, P>0.01

Table 2. Lint yield and yield components regressions[1] on year of cultivar tests (x)[2] for six USA regional tests.

Region	Period 19--	Lint yield on XI -kg ha^{-1}-	Lint % -%-	Boll weight -g-	Seed weight -mg-
East	60-96	792 + 8.46X1 (3.57)	38.02 + 0.063X1 (0.019)	6.90 – 0.051X1 (0.006)	121.3 – 0.57X1 (0.085)
	60-81	925 - 3.78X1 (6.92)	37.97 + 0.069X1 (0.039)	7.15 – 0.085X1 (0.015)	121.8 – 0.67X1 (0.185)
	82-96	1031 + 10.60X2 (15.97)	39.45 + 0.051X2 (0.076)	6.13 – 0.081X2 (0.021)	111.6 – 0.86X2 (0.376)
Delta	60-96	1051 + 8.34X1 (2.20)	36.92 + 0.075X1 (0.014)	6.81 – 0.051X1 (0.004)	127.3 – 0.70X1 (0.054)
	60-81	1147 - 4.15X1 (4.39)	36.70 + 0.092X1 (0.029)	6.93 – 0.065X1 (0.007)	127.0 – 0.69X1 (0.106)
	82-96	1387 - 6.11X2 (8.16)	39.37 - 0.036X2 (0.049)	5.63 – 0.033X2 (0.014)	109.8 – 0.43X2 (0.196)
Central	60-96	890 + 6.72X1 (2.78)	36.64 + 0.043X1 (0.012)	6.19 – 0.036X1 (0.004)	121.4 – 0.68X1 (0.057)
	60-81	968 - 5.54X1 (5.28)	36.51 + 0.060X1 (0.028)	6.30 – 0.049X1 (0.009)	121.8 – 0.68X1 (0.133)
	82-96	1382 - 31.37X2 (9.27)	37.36 + 0.064X2 (0.048)	5.50 - 0.045X2 (0.014)	102.0 – 0.11X2 (0.170)
Plains	60-96	749 - 1.93X1 (2.77)	35.74 - 0.004X1 (0.021)	6.56 - 0.026X1 (0.006)	126.6 – 0.37X1 (0.100)
	60-81	900 - 18.93X1 (5.22)	36.33 - 0.063X1 (0.045)	6.62 - 0.035X1 (0.015)	123.7 – 0.05X1 (0.250)
	82-96	651 + 11.69X2 (10.81)	35.23 + 0.087X2 (0.075)	6.16 - 0.043X2 (0.023)	120.2 – 0.73X2 (0.251)
West	60-96	922 + 9.30X1 (3.08)	36.73 + 0.069X1 (0.014)	6.87 - 0.051X1 (0.004)	130.7 – 0.84X1 (0.067)
	60-81	906 + 10.42X1 (6.50)	36.86 + 0.084x1 (0.025)	6.84 - 0.046X1 (0.007)	131.4 – 0.88X1 (0.154)
	82-96	1389 - 21.88X2 (12.90)	37.75 + 0.125X2 (0.049)	5.91 - 0.071X2 (0.017)	112.6 – 0.84X2 (0.253)
SJ3	60-96	1158 + 7.78X1 (3.62)	35.46 + 0.130X1 (0.021)	7.18 - 0.023X1 (0.008)	131.3 – 0.46X1 (0.125)
	60-81	1225 - 0.16X1 (8.86)	35.74 + 0.108X1 (0.079)	7.78 - 0.076X1 (0.028)	148.0 – 1.94X1 (0.249)
	82-96	1349 + 7.74X2 (13.16)	37.70 + 0.207X2 (0.050)	6.74 - 0.025X2 (0.018)	115.7 + 0.47X2 (0.333)

[1] Standard error for regression coefficient indicated in parenthesis.

[2] X_1 = years after 1960, and X_2 = years after 1982.

[3] S.J. = San Joaquin

Table 3. Regression[1] of lint yield and yield components on test years (X)[2] for average over six USA regions.

Period	Lint yield on Xi	Lint % on Xi	Boll weight on Xi	Seed weight on Xi
19--	kg ha^{-1}	Lint %	g	mg
60-96	932 + 6.78X1 (1.40)	36.66 + 0.061X1 (0.008)	6.76 – 0.040X1 (0.003)	126.7 – 0.61X1 (0.004)
60-81	998 – 2.00X1 (2.66)	36.67 + 0.061X1 (0.018)	6.85 – 0.053X1 (0.006)	127.8 – 0.73X1 (0.009)
82-96	1118 – 5.05X2 (5.83)	37.90 + 0.074X2 (0.029)	6.03 – 0.053X2 (0.009)	112.0 – 0.44X2 (0.013)

[1] Standard error for slope indicated in parenthesis

[2] X_1 = Years after 1960, and X_2 = years after 1982

Table 4. Average yield, yield components, and fiber property performance for three periods over six USA regions.

Period	Lint yield	Lint	Boll Weight	Seed Weight	50% span length	Micronaire	Strength (T1)	Yarn Strength
19--	%	%	g	mg	mm	value	mNtex^{-1}	mNtex^{-1}
60-96	1054	37.8	6.02	115	28.4	4.39	199	129
60-81	975	37.3	6.28	120	28.6	4.42	193	126
82-96	1168	38.4	5.66	109	28.2	4.35	206	132
F test	44.4	39.8	84.4	181.2	7.54	3.18	38.3	23.0

[1] F test for (60-81) period vs. (82-96) period using variation within periods as error.