U. S. UPLAND COTTON: BELTWIDE AND MID SOUTH YIELD TRENDS, 1960 - 1998

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Abstract

Cotton yields have remained stagnant for the past 17 years. Yield data of the U.S. upland cotton crops between 1960 and 1998 was examined. This paper reports the findings of this investigation.

Introduction

Chaudhry (1997) reported that U.S. cotton yields have been stagnant for the last seventeen years. Meredith (1998) proposed that the rate of yield change was negative from 1982 -1996. Wessling *et al.* (1973) showed that weather and management practices played a significant role in year-to-year variations in cotton yields. Meredith (1995) indicated that genetic improvements in cotton yield peaked in about 1987. Meredith's report suggests that the long-term yield trend may have been influenced by genetic factors as well as variations in weather and management practices. These reports constitute significant reasons for concern as to the ability of U.S. cotton to remain competitive in global textile markets and indicate that we must reexamine our understanding of the physiological/genetic processes, which influence yield. The purpose of the present study is to reexamine the long-term trends in American upland cotton yields on both a regional and a Beltwide basis and to search for insights into the underlying cause, or causes, for these trends.

Procedure

Yield trends were determined by analyzing regional and national yield data as reported by USDA statistics reports for the years from 1960 through 1998. Fiber quality data were obtained from AMS, USDA for the years 1974 through 1997. Segmental rate analyses were done by dividing the yield trend curve into three overlapping segments around "bend points", calculating, by least squares, a quadratic equation which constituted a reasonable fit to each segment, taking the first derivative of the resulting quadratic equation and calculating the rate of yield change from the first derivative. Rates of yield change were then plotted against the years in the overlapping segments. This procedure provided for identification of the years when the rate approached zero, *i.e.*, the "bend points" in the polynomial describing the yield trend over the 39 year period, and the years when the rate changed direction.

Results and Discussion

Figure 1 shows the variation in the weighted average U.S. upland cotton yield from 1960 -1998 (1998 estimated). Both a linear and a curvilinear trend line are shown. (Note: All equations shown on the graphs use the earliest date shown on the graph as the base year; e.g. Figure 1 uses 1960 = 0 as the base for time.) The linear trend line has a slope of about 6 lb./acre/year and an R squared value of 0.58. These data indicate that the variations in U.S. upland cotton yields from 1960 to 1998 could be, at least, partially explained by the linear model. Nevertheless, the curvilinear trend line is a quartic equation with an R squared value of 0.72, indicating that this equation does a 14% better job of explaining the yield variation. When the curvilinear trend line was segmented around its three "bend points", the data shown graphically in Figures 2, 3 and 4 were obtained. Figure 2 is the graph of a convex parabola and indicates that the rate of yield change was negative between 1960 and 1967. Figure 3 is the graph of a concave parabola, which indicates that the rate of yield change was positive between 1970 and 1988. Figure 4 is a convex parabola, which indicates that the rate of yield change became negative, again, between 1980 and 1998. These findings and the three bend points in the quartic trend line equation constitute strong evidence that the rate of yield change approached zero at three times during the 1960 - 1998 period. The question is, when?

In order to estimate the time when the rate of yield change approached zero, the first derivatives of the three parabolic functions shown in Figures 2, 3 and 4 were determined and the rates calculated from the resulting linear equations. These rate values were then graphed with the designated overlaps from 1960 -1998. Figure 5 shows the results of this procedure, which indicates that the rate of yield change approached zero in 1968, 1974 and 1990. In addition, Figure 5 also shows that reversals in the direction of yield change occurred in 1973 and, again in 1983. This is in reasonably good agreement with the data published by Meredith (1995). These data also indicate that the current rate of yield change stands at approximately a minus 13 pounds of lint per acre per year. There was a dramatic increase in the rate of yield improvement between 1973 and 1983. Elucidation of this phenomenon could go a long way toward understanding the factor(s), which control yield variations.

Figure 6 shows least squares trend line analyses for Mid South yields from 1960 – 1998 (1998 estimated). Here, as in the case of Beltwide yield analysis, a quartic trend line was obtained. Even though the data presented in Figure 6 indicated that a linear regression model would be inappropriate for Mid South yield trends, a linear regression model was considered. The results of this model are also

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shown in Figure 6. The linear model indicated that yields have been increasing at a rate of 6 pounds per acre per year since 1960; however, with an R squared value of only 0.36 it is obvious that the linear model is truly inappropriate. The quartic regression model has an R squared value of 0.53 and, obviously, provides for a better accounting for Mid South yield variations from 1960 - 1998, as compared to the linear regression model.

Segmental rate analyses of the Mid South data were done as described above for the U.S. data. The results of these studies are shown graphically in Figures 7, 8 and 9. These data show that the rate of yield change was negative from 1960 - 1967, positive from 1970 - 1988 and became negative, again from 1980 - 1998, much like the Beltwide data shown above.

Figure 10 shows the overlapping segmental rate analyses from the data derived from Figures 7, 8 and 9. In this case, the rate of change in Mid South yields appeared to approach zero in 1966, 1975 and 1992. Figure 10 also provides for an estimate of when a change in the direction of the rate of yield increase or decrease occurred. The rate of yield change reversed from a decreasing rate to an increasing rate in 1972 and from an increasing rate to a decreasing rate in 1983. The current rate of yield change appears to be approaching a minus 15 lb./acre/year, slightly greater than the Beltwide rate of yield loss. Here, as in the case of Beltwide yields (Figure 5), the rate of yield improvement was dramatic from 1972 - 1983. Insight into the underlying cause(s) of this event could greatly improve our knowledge of factors, which control year-to-year variations in yield.

Detailed examination of the data presented above concerning U.S. and Mid South yield trends reveal many similarities. Figure 11 shows both sets of yield data plotted together on the same graph with a hand drawn, putative, trend line superimposed. It is amazing how closely the two sets of data follow each other. Figure 12 shows the least squares regression of the Mid South yield data against the U.S. yield data, 1960 - 1998. A 0.9 correlation coefficient resulted with an R squared value of 0.81. This illustrates, unequivocally, that U.S. and Mid South yields from 1960 - 1998 are highly correlated with each other and suggests that whatever the causative factor(s) for the variation, there is a high probability that most of them are held in common. Subsequent statistical analyses revealed a mean value of 539.5 pounds per acre (1960 - 1998) for the U.S. and 597.5 pounds per acre for the Mid South. One standard deviation for U.S. yields over the 39-year period was 89.4 pounds per acre, whereas one standard deviation for Mid South Yields over the same 39 years was 114.2 pounds per acre. These data clearly show that while average Mid South yields were higher than U.S. yields, they were also a great deal more variable.

The question now arises concerning the underlying cause, or causes, for the variation in U.S. and Mid South yields. Lewis (1998) reported that the prime components of cotton lint yield are the number of seeds produced per acre and the weight of fibers produced per seed. Variation in lint yield is, undoubtedly, associated with the weight and/or numbers of fibers produced and their dimensions. With this in mind, analyses were done concerning fiber properties and lint (fiber) yield, since fiber data are available for the years under study. No significant correlation was found between micronaire value and yield or year. However, Figure 13 reveals a strong correlation between Upper Half Mean (UHM) fiber length and yield. In fact, the R squared value for this linear regression was 0.60, which corresponds to a correlation coefficient (R) of 0.77. This finding suggests that some of the yield variation may be due to fiber development anomalies and supports the concept that investigations of this nature could be productive in addressing the yield decline problem (Lewis *et al.*, in press). This may be especially relevant, since UHM fiber length has not improved since about 1991 and if anything has decreased in the recent past.

Figure 14 adds further credence to this proposal by showing that while UHM fiber length has increased at a rate of a little more than 0.002 of an inch per year, it appears to have done so in a stepwise progression since 1975 and has been on a plateau since about 1991, dropping to an estimated 1.07 inches in 1998, with a corresponding disastrous yield.

Summary

We have analyzed the yield data of the U.S. upland cotton crops between 1960 and 1998 to determine how the rates of yield change have occurred during this time period. This analysis shows that the rate of yield changed from an annual increase of about 5 pounds/acre/year in 1960 to zero increase by 1968. Then the U.S. crop experienced annual losses in yield from 1969 through 1973. From 1974 through 1983 the yield of the crop increased each year to an average annual increase of almost 15 pounds/acre/year in 1983. Since that time, our annual change in yield has been declining each year; and since 1990, we have actually been losing yield on a national annual basis. The factors that can influence cotton yields such as variety changes and other genetic factors, environmental and weather conditions, crop management practices, pest population trends, etc. should be carefully studied for the 1973–1983 period since the crop sustained steady yield increases during that time.

We also examined the yield data from the Mid-South region and found it to be highly correlated to the national yield data.

A correlation analysis between fiber quality properties and yield resulted in a good correlation between fiber length and yield. Because fiber length and strength are correlated within the upland crop, there is also a fairly good correlation between fiber strength and yield. However, a

low correlation was found between average crop micronaire and average crop yield.

References

Chaudhry, M. R. 1997. Cotton yields stagnating. The ICAC Recorder XV (1):3-7.

Lewis, Hal, 1998. Challenges and opportunities for adjuvants for agrochemicals for transgenic crops. *In* Patrick McMullan (ed) Proc. Adjuvants for Agrochemicals Challenges and Opportunities, Vol. I. Fifth International Symposium on Adjuvants for Agrochemicals. Memphis, TN. p. 495-499.

Lewis, H.L., C.R. Benedict and P.E. Sasser 1998. Cotton fiber strength: variability and development. Proc. Cotton Biochemistry Conf. (in press)

Meredith, W. R., Jr. 1995. Strengths and limitations of conventional and transgenic breeding. Proceedings Beltwide Cotton Prod. Research Conference. p. 166-168.

Meredith, W.R., Jr. 1998. Continued progress in breeding for yield in the USA? Proceedings Cotton Biochemistry Conf. (in press)

U.S. Department of Agriculture Statistics (1960 - 1997). U.S. Government Printing Office, Washington, DC.

USDA, AMS Cotton Fiber Properties (1974 - 1997). Cotton Division, USDA, AMS, Memphis, TN.

Wessling, W.H., G.A. Slater and H.L. Lewis 1973. 1972 crop log study in the San Joaquin Valley, Cotton Incorporated, Raleigh, NC.

Figure 1. U.S. Upland Cotton Yield Trends, 1960 - 1998

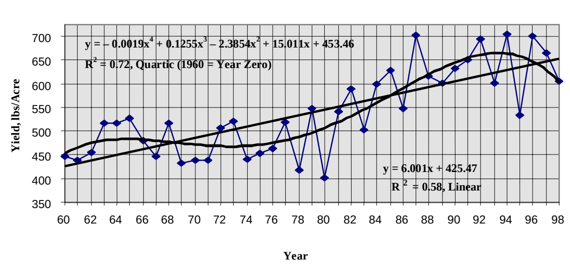


Figure 2. U.S. Upland Cotton: Segmental Trendline Analysis, 1960 - 1967

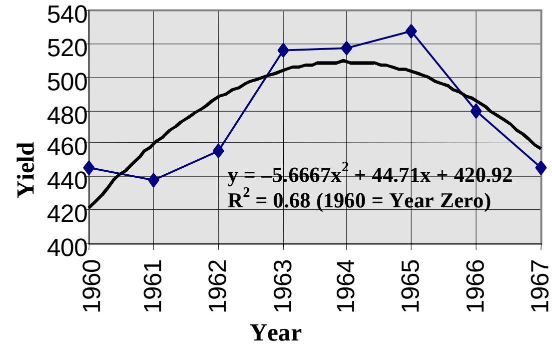


Figure 3. U.S. Upland Cotton: Segmental Trendline Analysis, 1970 - 1988

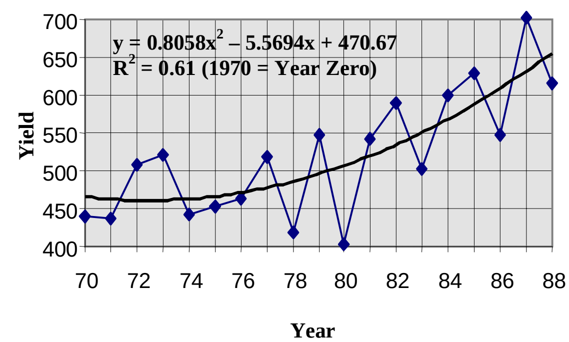


Figure 4. U.S. Upland Cotton: Segmental Trendline Analysis, 1980 - 1998

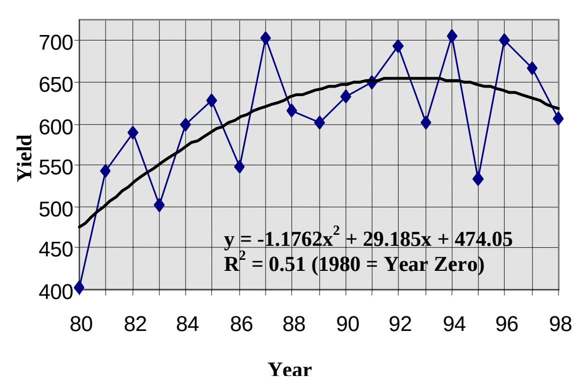


Figure 5. U.S. Upland Cotton Yield Trends: 1960 - 1978, 1970 - 1988, and 1980 -1998; Overlapping Segmental Rate Analysis

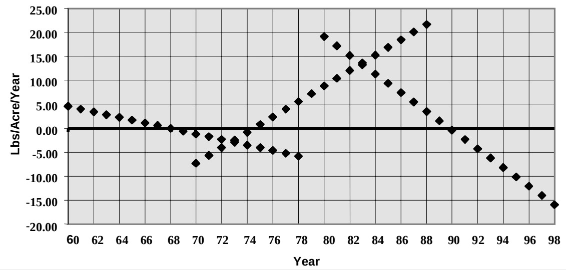


Figure 6. Mid South Long Term Yield Trends: 1960 - 1998

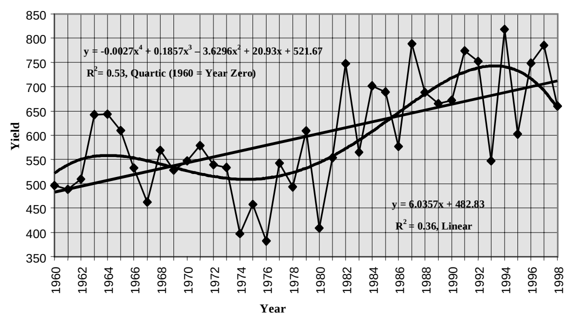


Figure 7. Mid South Segmental Trendline Analysis, 1960 - 1967

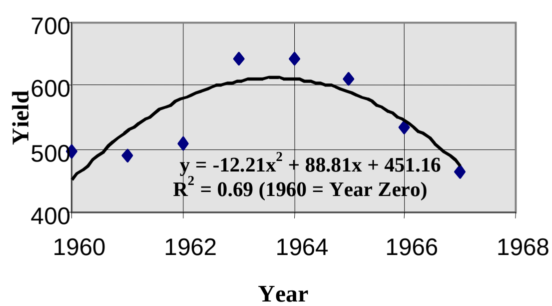


Figure 8. Mid South Segmental Trendline Analysis 1970 - 1988

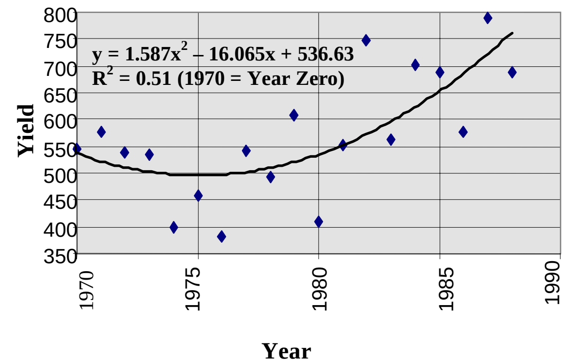


Figure 9. Mid South Segmental Trendine Analysis, 1980 - 1998

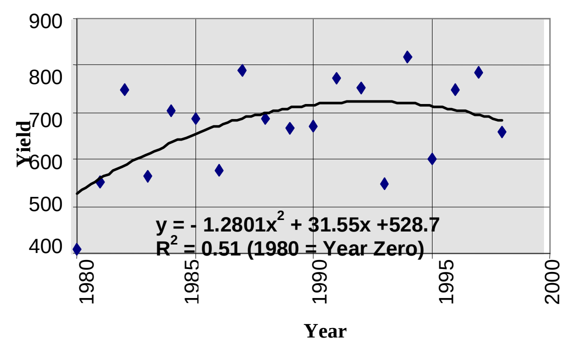


Figure 10. Mid South Yield Trend: Overlapping Segmental Rate Analysis; 1960 -1978, 1970 - 1988; 1980 - 1988

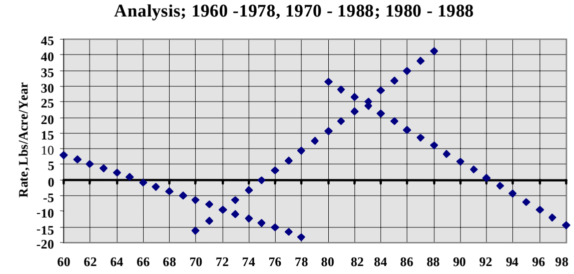
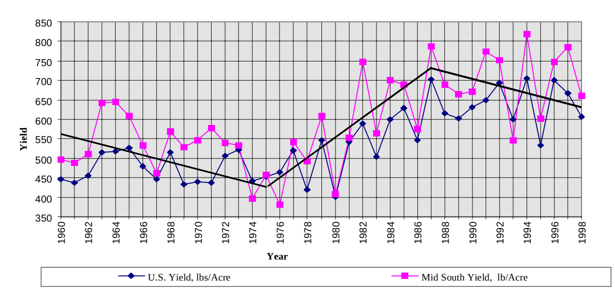


Figure 11. U.S. And Mid South Yields : 1960 - 1998



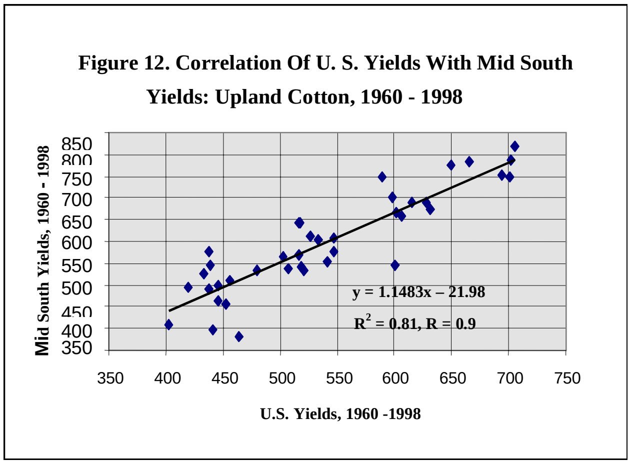


Figure 12. Correlation Of U. S. Yields With Mid South Yields: Upland Cotton, 1960 - 1998
Mid South Yields, 1960 - 1998
850
800
750
700
650
600
550
500
450
400
350
y = 1.1483x – 21.98
R^2 = 0.81, R = 0.9
350
400
450
500
550
600
650
700
750
U.S. Yields, 1960 -1998

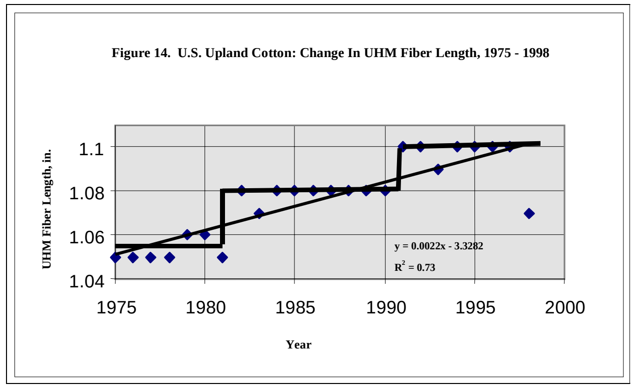


Figure 14. U.S. Upland Cotton: Change In UHM Fiber Length, 1975 - 1998
UHM Fiber Length, in.
1.1
1.08
1.06
1.04
y = 0.0022x - 3.3282
R^2 = 0.73
1975
1980
1985
1990
1995
2000
Year

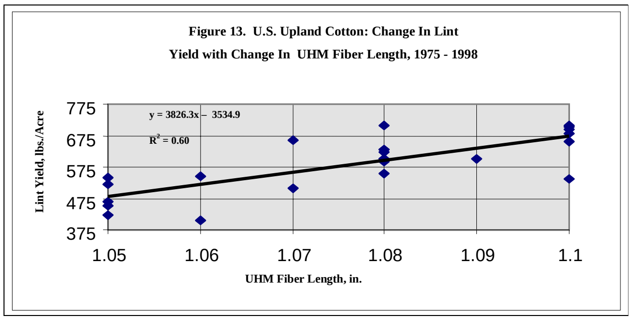


Figure 13. U.S. Upland Cotton: Change In Lint Yield with Change In UHM Fiber Length, 1975 - 1998
Lint Yield, lbs./Acre
775
675
575
475
375
y = 3826.3x – 3534.9
R^2 = 0.60
1.05
1.06
1.07
1.08
1.09
1.1
UHM Fiber Length, in.