A REVIEW OF YIELD AND QUALITY TRENDS AND COMPONENTS IN AMERICAN UPLAND COTTON

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Abstract

The U.S. cotton/textile industry is facing very difficult times. Helms (2000), in his report of the findings of the American Cotton Producers "Blue Ribbon Committee on Cotton Yield" stated that, "clearly a significant problem exists with current cotton yields". "The problem is best characterized by stagnant yields, which have become increasingly variable and highly unstable in recent years." In addition, fiber quality has deteriorated during the 1990's and the prospect for 2000 is not good. These developments present a serious challenge to the cotton research community, both public and private, and demand immediate attention that most likely will require a significant deviation from business as usual if meaningful solutions to these problems are to be had.

In order to plot an intelligent course of progress into the future, it is essential to know where you are at the present. Understanding where you are at the present requires an in-depth knowledge of how you arrived at your present position from the past. The objective of this paper is to examine, with regard to cotton yield and quality, where we have been, where we are and where we need to go in order for the U.S. cotton/textile industry to remain profitable and durable.

Yield Trends

Culp and Green (1992) reported that during the 70-year period from 1866 to 1935, average lint yields in the South Atlantic states (Georgia, North Carolina and South Carolina) increased at the rate of 1.8 kg/ha/year. Yields declined or plateaued, however, across the southeastern states from 1920 through 1935 because of the boll weevil infestation. A similar decline in Mississippi yields was reported by Bridge and Meredith (1983). The national average yield from 1866 to 1936 was reported by Miller (1977) to fluctuate around a mean of 213 kg/ha with no upward or downward trend. Culp and Green (1992) also reported that yields increased in the South Atlantic states during the period from 1936 to 1960 at a relatively slow rate of 4.0 kg/ha. Meredith and Bridge (1982) indicated that national cotton yields rose rapidly from 1936 through 1960 at an average rate of 10.4 kg/ha/yr. Meredith and Bridge (1982) also reported a slight decline in national yields from 1961 to 1980 at a rate of -0.9 kg/ha/yr. Figure 1 presents a graphical representation of the historical yield trends for U.S. upland cotton as reported by various investigators including those referenced above.

Chaudry (1997) reported that U.S. cotton yields had been stagnant for the previous seventeen years. Meredith (1988) proposed that the rate of yield change was negative from 1982 - 1996. Meredith (1995) indicated that genetic improvements in cotton yields peaked in about 1987. This report suggests that the long-term yield trend may have been influenced by genetic factors as well as variations in weather and management practices.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1447-1453 (2001)
National Cotton Council, Memphis TN

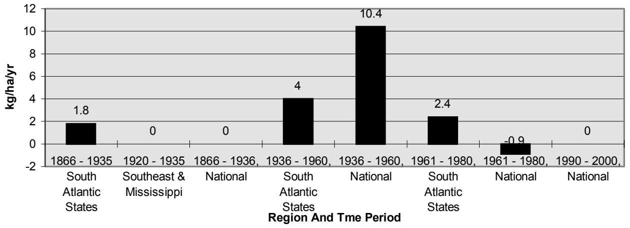

Figure 1. Historical survey of rates of yield improvement for U.S. Upland Cotton, 1866-2000 (kg/ha/yr).

Lewis and Sasser (1999) analyzed the yield data for the U.S. upland cotton crops from 1960 through 1998 and determined how the rates of yield change occurred during this time period. Their analyses showed the rate of yield improvement changed from an annual increase of about 5 lb/acre/yr in 1960 to zero increase by 1968. Then the U.S. crop experienced annual losses in yield from 1968 through 1974. From 1975 through 1983 the yield of the crop increased each year to an average annual increase of about 15 lb/acre/yr in the mid 1980's. Since that time, the annual change in yield has decreased each year and since 1990 has actually sustained yield losses on a national, annual basis. Figure 2 summarizes these data. Lewis and Sasser (1999) also examined the yield data from the Mid South region and found it to be highly correlated with the national yield data.

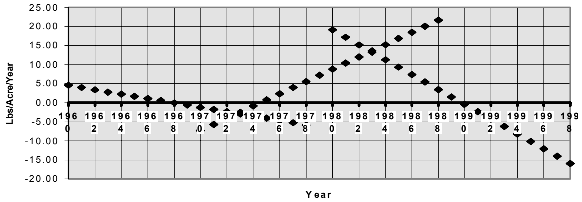

Figure 2. From Lewis and Sasser, 1999, U.S. Upland Cotton yield trends: 1960-1978, 1970-1988 and 1980-1998; "Overlapping Segmental Rate Analysis."

As suggested by Lewis and Sasser (1999) this situation deserves further investigation. Whatever was going on with yields in the earlier period (1970-1985) is what we would like to have happen and whatever was going on in the later period (1985 - 1998) is what we would prefer not to have happen. Thus, it seems worthwhile to investigate these two time periods in an attempt to discover any significant difference that may have occurred.

The Plant Variety Protection Act was passed by the U.S. Congress in 1970. This law seems to have prompted an increased input of resources into the development and release of new commercial cotton varieties, which may have contributed to the rapid increase in the rate of yield improvement in the 1970's and early 1980's. By the mid 1980's a movement was well underway in the cotton breeding industry, both public and private, directed towards the discovery of genes that could be patented and the genetic transformation of cultivated upland cotton varieties with these patented or patentable genes. In fact, Galau (1985) published the first disclosure for patent of cultivated cotton regenerated from tissue culture. This movement was precipitated by an apparent change in policy by the U.S. Patent and Trademark Office which allowed the issue of patents on sexually reproduced plants and individual plant genes, and may have diverted critical resources away from the development of new varieties into the discovery of patentable genes and transgenic varieties. One result of this change appears to have been a reduction in the development of broadly different new varieties based on segregation and recombination of the complete genomes of the parental lines. Indeed, during recent years, backcross breeding of transgenic varieties has dominated the cotton breeding industry. According to USDA, AMS, Cotton Division (2000), these transgenic varieties are now approaching 50 percent of the commercial planting cottonseed trade. This technology has focused on "input" traits, that is, resistance to insects and herbicides and not on "output" traits such as yield and quality. In addition, an amendment to the U.S. Plant Variety Protection Act was passed in 1994 that added the "essentially derived" provision to the law that appears to have significantly influenced the free exchange of germplasm among cotton breeders.

Study of the descriptive yield statistics for U.S. upland cotton for the periods 1960 - 1979 and 1980 - 1998 revealed that mean and maximum yield levels were improved in the more recent time period. In contrast, the minimum yield produced in recent years is lower than the minimum yield produced in earlier years by approximately 17 pounds of lint per acre. More importantly, the variance in yields for the recent time period compared to the earlier time period increased nearly four fold. Similarly, the standard deviation nearly doubled. Additionally, the skewness in yield distribution about the mean was negative for the recent time period, whereas it was positive for the earlier time period. This latter finding indicates that there were more low yielding years in the recent time period than in the earlier time period. The percent coefficient of variance in yield for 1980-1998 was 4.32 percent higher than the 1960 - 1979 era. These findings constitute incontrovertible evidence that upland cotton yields have become much more variable and less stable in years between 1980-1998, as compared to years between 1960-1979.

Yield Components

Cotton lint yield is probably best understood in terms of the components that make it up. Fiber or lint yield in cotton is determined by two (2) major components, i.e., the number of seeds produced per acre and the weight of fiber produced on the seed. Cotton fibers are elongated epidermal cells of the outer integument of the seed coat. No seed - no fiber. The structure and dimensions of the fibers determine their quality.

Cotton is like most of the important field crops in that a major component of yield is the reproductive potential, or the number of seeds produced per unit of land surface. However, it differs from most of the other field crops, where seed yield is the prime determinant of economic yield, in that if no fiber or a reduced amount of fiber is produced on the seed surface, the lint yield may be severely reduced

Lint Yield = [(No. of Seeds/Acre)(Weight of Fiber /Seed)]
Seed Yield = [(No. of Seeds/Acre)(Weight/Seed)]

The number of seeds per acre is determined by the number of plants per acre, the number of bolls per plant and the number of seeds per boll. This suggests that the number of seeds produced per acre is influenced to a high degree by management and environmental factors and to a lesser extent by genetic considerations.

Seeds per Acre = [(Plants/Acre)(Bolls/Plant)(Seeds/Boll)]

The weight of fibers per seed is a function of the number of fibers per seed and the average weight per fiber.

Weight of Fiber per Seed = [(Number of fibers per seed)(Average weight/fiber)]

From a cell physiology perspective, the number of fibers per seed is determined by the number of epidermal cells in the outer epidermis of the seed coat that initiate elongation and develop into lint fibers. Physically, the number of fibers per seed is a function of the weight of fiber per seed divided by the mean weight per fiber.

Number of Fibers/Seed = Weight of fiber per seed/Mean weight per fiber

The mean weight per fiber is a function of the mean length of the fibers on the seed multiplied by the mean linear density of the fibers.

Average Weight per Fiber = (Mean fiber length)(Mean linear density of the fibers on the seed)

Physiologically, the average weight per fiber is determined by the degree and extent of primary and secondary cell wall growth. Primary wall growth is equivalent to fiber elongation. As long as a plant cell is increasing in volume it is considered to be producing primary cell wall. After a plant cell stops increasing in volume but continues to increase in weight it has entered the secondary cell wall phase of growth. Secondary wall growth is equivalent to an increase in the linear density (micronaire tex, etc.) of the fiber or the thickness and, perhaps, the density of the secondary cell wall. Thus, the mean weight per fiber is a function, physiologically speaking, of both primary and secondary cell wall growth. This constitutes strong evidence that the weight of fiber per seed is heavily influenced by genetic considerations, especially in so far as the number of fibers per seed is concerned.

A relatively small increase in the weight of fiber per seed may have a highly significant impact on lint yield. For example, in the south central and southeastern US cotton belt, the long-term average number of seeds per acre produced is approximately 7 million. Thus, if the weight of fiber per seed were increased by only 5 milligrams, this could result in a yield increase of a little more than 75 pounds of lint per acre.

Benedict et al. (1999) reported that Stoneville 213, a widely grown variety during the 1970's, produced 80 milligrams of fiber per seed. Lewis et al (2000) found that DP 50 and Suregrow 125, two very popular varietes grown in the mid south in the late 1980's and 1990's, averaged about 60 milligrams of fiber per seed, whereas Stoneville 213 and DPL 16, two very popular varieties grown in the mid south in the 1970's, produced an average of about 72 milligrams of fiber per seed, a difference of 12 milligrams of fiber per seed. If the number of seeds per acre is held constant at 7 million seeds per acre, a change in the weight of fiber per seed of 12 milligrams represents a potential yield change of about 185 pounds of lint per acre. These workers also found that Stoneville 213 and DPL 16 produced about 5.5 million seeds per acre, while DP 50 and Suregrow 125 produced approximately 8.5 million seed per acre, a highly significant difference of about 3 million seeds per acre or about 600 pounds of seed per acre. These data constitute highly significant findings regarding the stability or reliability of lint yield.

Gravimetrics

It take an average of about 1.6 pounds of seed per acre to yield 1 pound of lint. If a variety depends heavily on the number of seeds per acre to produce an acceptable lint yield, then, it must fix a great deal more carbon to achieve this result as compared to a variety that produces a greater weight of lint per seed.

Energetics

Cottonseed contain approximately 20 percent triglyceride, or oil. It takes about 2.25 times as much energy to synthesize a pound of triglyceride as compared to a pound of cellulose (West and Todd, 1956). Thus, on an energy equivalency basis, cotton plants must fix nearly twice as much carbon to produce a pound of seed as compared to a pound of lint.

Culp and Green (1992) reported the performance of 29 obsolete and current cotton varieties and lines for yield and yield components. Their data show that the lint yield of these genetic materials released or first tested between 1945 and 1978 increased at a rate of 9.2 kg/ha/yr. When Earlistaple 7 was selected as the representative of the oldest obsolete variety tested and Acala SJ-5 and Paymaster 303, which are not adapted to the region of production, were excluded from the analysis, lint yields were found to have increased at the rate of 10.5 kg/ha/yr. These data were found to be in excellent agreement with those of Bridge et al. (1971) and Bridge and Meredith (1983) for variety improvement in Mississippi. These authors concluded that the "increased yield potential can be attributed to higher lint percentages and more bolls per plant"

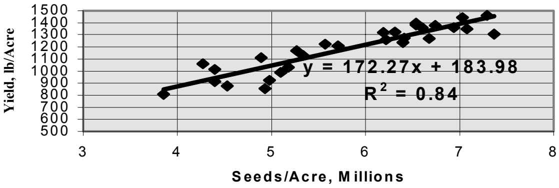

Figure 3. From Culp and Green, 1992: Change in lint yield with change in number of seeds per acre, 1945-1978.

Least squares regression analysis of Culp and Green's (1992) data showed that lint percent did increase at the rate of 0.0078 percentage points per pound of lint yield increase, however, the R squared value for the regression line was 0.43. An additional least squares regression analysis (Figure 3) of their data revealed that the lint yield increased at the rate of 172.27 pounds per acre per million seeds per acre with an R squared value for the regression line of 0.84. Thus, it appears that the greatest portion of the yield increase could be better explained by the increase in the number of seeds produced per unit of land surface, which agrees well with the findings of Lewis et al. (2000). In fact, further regression analysis (Fig. 4) of the Culp and Green (1992) data showed that there was no significant change in the weight of lint per seed (R squared = 0.0037) over the 1945 - 1978 period.

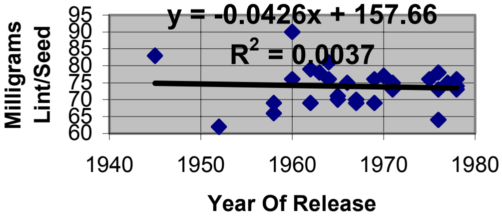

Figure 4. From Culp and Green, 1992: Change in milligrams of lint per seed over time, 1945-1978.

Additional regression analysis (Fig. 5) revealed that the seed index trended downward over the 1945 - 1978 time period at a rate of -0.0699 seed index units per year but with an R squared value of only 0.34.

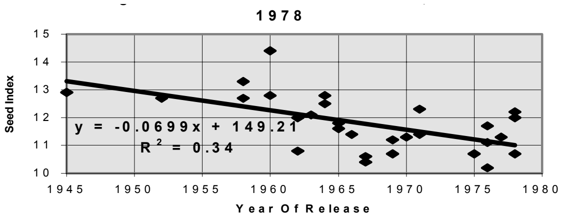

Figure 5. From Culp and Green, 1992: Change in seed index over time, 1945-1978.

These findings indicate that the lint percent increased because seed size decreased while the weight of lint per seed remained essentially constant. Thus, yield increased as a consequence of an elevated reproductive potential or more seeds per acre. It is noteworthy that the more current varieties, released between 1967 and 1978, were nearly twice as variable in yield and had a more negative skewness than the more obsolete varieties, released between 1945 and 1967.

As mentioned above, Lewis *et al.* (2000) reported that the 1970's era varieties relied on more fibers per seed and fewer seeds per acre to produce their yield as compared to the 1990's era varieties. These findings are supported by the data in Figure 6, which show the weight of lint per seed produced by 13 commercial varieties grown in northeast Arkansas in 1996. Furthermore, Figure 7 illustrates that change in the weight of lint per seed is largely accounted for by change in the number of fibers per seed.

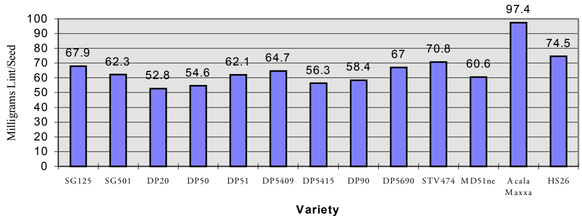

Figure 6. Wighted average weight of lint per seed: 13 commercial varieties, NE AR, 1996.

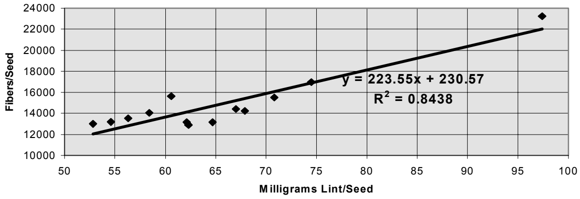

Figure 7. Change in number of fibers per seed with change in weight of fibers per seed, NE AR, 1996.

If the weight of lint per seed is reduced, the plant must produce more seed per acre to yield the same weight of lint per acre. Since cottonseed contain twice as much energy as lint, this places an extremely high demand for energy production on the plant and makes it much more susceptible to stress. Only a casual review of cotton belt weather patterns reveals that we are more likely to have stressful than ideal growing season weather. Perhaps this is the reason our yields have become stagnant and more variable. Recent deterioration in fiber quality may also be related to this increased susceptibility to stress.

Quality Trends

In 1930, approximately 75 percent of the cotton acreage in the U.S. was planted with short staple varieties, measuring 1 inch or less. By 1950, the short staple varieties accounted for only about one third of the total production (Poehlman, 1959).

Culp and Green (1992) reported the fiber properties of 29 current and obsolete varieties and lines released or first tested between 1945 and 1978. Figure 8 shows, with reference to the varieties and lines studied, that the upper half mean fiber length (staple) was not improved over this period of time.

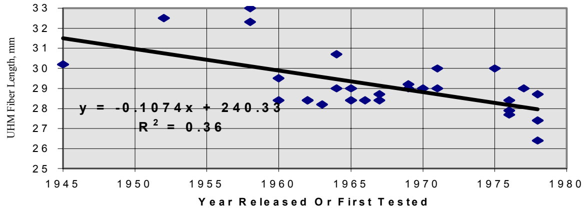

Figure 8. From Culp and Green, 1992: Change in upper half mean fiber length of current and obsolete varieties and lines over time, 1945-1978.

Lewis (1999) reported that staple was improved by about 0.05 of an inch over the 25 year period, 1974 -1999. Least squares regression analysis indicated that the rate of improvement was a little over 0.002 of an inch per year. However, only casual inspection of the data revealed that this improvement in staple was not a continuous phenomenon as the regression line suggests but, in fact, occurred *via* two rather distinct vertical changes. Between 1979 and 1984, the staple increased from about 1.05 inches to about 1.08 inches, and between 1990 and 1991 from about 1.08 to about 1.10 inches. These changes may have been influenced by technological changes in the classing system (personal communication from Dr. Preston Sasser). The most noteworthy aspect of this report is that the staple has been more or less static since 1991, with the exception of a precipitous drop to a near 1983 era level of 1.07 and 1.06 inches in 1998 and 1999, respectively (Figure 9).

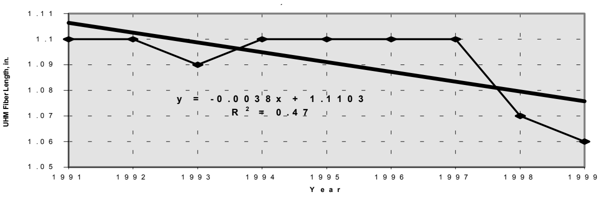

Figure 9. U.S. Upland Cotton, 1991-1999; variation in UHM fiber length - regression analysis, source, AMS/USDA.

Figure 10 shows that mean fiber length also suffered similar reductions over these same crop years. These reductions in fiber length parameters constitute matters of great concern to the U.S. cotton/textile industry.

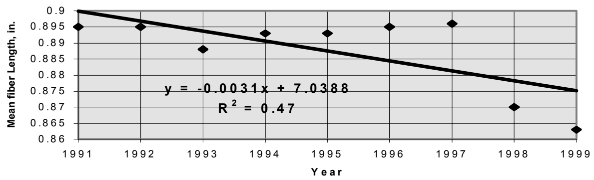

Figure 10. U.S. Upland Cotton, 1991-1999: Change in mean fiber length - regression analysis, source, AMS/USDA.

Culp and Green (1992) also reported the micronaire values of 29 obsolete and current cotton varieties and lines released between 1945 and 1978. Figure 11 shows the results of their study in this regard.

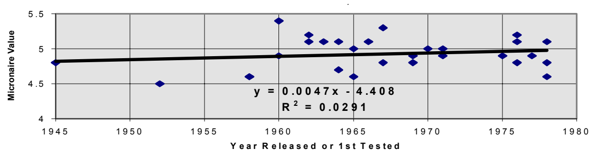

Figure 11. From Culp and Green, 1992: Change in micronaire value of 29 obsolete and current varieties and lines by year released or 1st tested, 1945-1978.

These data indicate that there was no significant genetic change in micronaire value of the varieties and lines covered by this study.

Lewis (2000) reported that the average micronaire value of the U.S. upland crop increased dramatically from 1991 - 1999. Figure 12 shows these results.

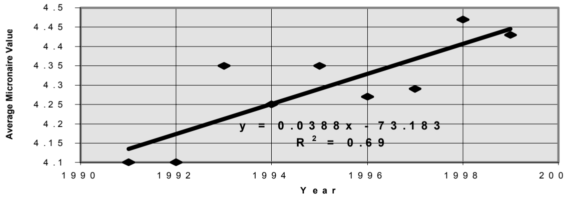

Figure 12. U.S. Upland Cotton, 1991-1999: Regression analysis - change in average micronaire value, source, AMS/USDA.

The increase in micronaire value of the crop shown in Figure 12 was well correlated with the decrease in the mean fiber length of the crop, as shown by Figure 10. This relationship is illustrated graphically by Figure 13.

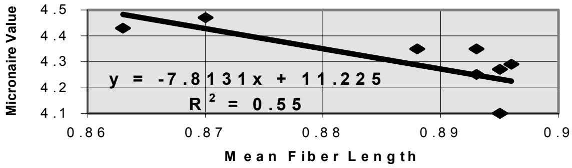

Figure 13. U.S. Upland Cotton, 1991 - 1999: Change in micronaire value with change in mean fiber length.

Culp and Green (1992) also reported fiber strength values for 29 obsolete and current varieties released between 1945 and 1978. Figure 14 shows the results of this study and indicates no significant genetic changes in fiber strength among these varieties and lines. In fact, the trend was toward lower fiber strength values over time of release but the regression coefficient of 0.29 does not allow for conclusive interpretation, other than no significant improvement.

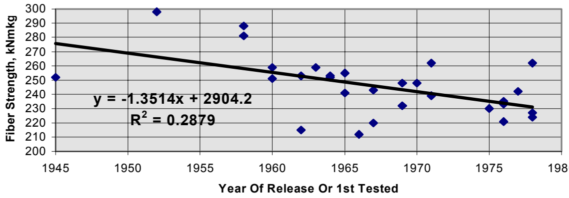

Figure 14. From Culp and Green, 1992: Change in fiber strength values of 29 obsolete and current varieties by year released or 1st tested, 1945-1978.

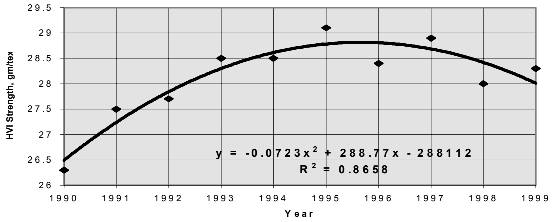

Figure 15. U.S. Upland Cotton, 1990 - 1999: Varieties in HVI fiber strength, source: AMS/USDA.

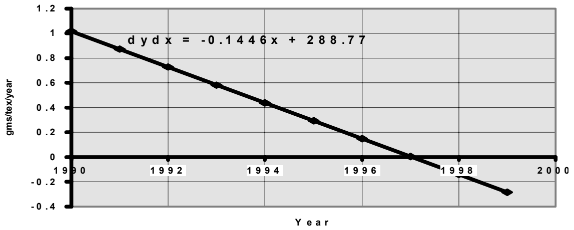

Figure 16. U.S. Upland Cotton, 1990-1991: Rate of change in HVI fiber strength, gm s/tex/year.

Reliable data for fiber strength of the U.S. crop have not been available for as many years as staple data but good data from 1980 through 1999 indicate that average strength of the U.S. crop has improved over the 20 year period from approximately 24 gm/tex to about 29 gms/tex, with a rate of improvement of a little better than 0.25 gm per tex per year. These changes in fiber strength are highly correlated with changes in UHM fiber length. In the 1990's, average fiber strength of the U.S. crop increased from about 26 grams per tex in 1990, up to approximately 29 grams per tex in the mid 1990's and then decreased to about 28 grams per tex in 1999. These changes in fiber strength are illustrated graphically by Figure15. The quadratic equation characterizing these changes indicates that strength has been decreasing at a continuously changing rate over these years. The first derivative of this equation allows for analysis of the rate of strength change during the ten year period. The results of the rate analysis are shown in Figure16. The rate of change in strength was positive but decreasing from 1990 to 1996, approached zero in 1997 and became negative in 1998 - 1999.

Since there were no significant changes in the base genetics of upland cotton during the 1990 - 1999 time period, the quality changes reported above are estimated to have been caused by environmental forces.

Fiber Differentiation and Development

The structure and dimensions of cotton fibers determine their quality. The number of fibers per seed is a major determinant of yield. Thus, the differientiation and development of cotton fibers are thought to be primary processes controlling lint yield and quality. In plants many developmental processes can be either prevented or triggered at will by manipulation of environmental conditions. Plants offer, therefore, unique opportunities and advantages for studying the regulation and control of development. It is, perhaps, appropriate to recall that the German plant biologist Klebs (see Melchers, 1961) early in the 20th century formulated the problem of plant development in terms which are still valid today. In his concept the ultimate outcome of development is determined by *'spezifische Struktur'* and the *'innere und auszere Bedingungen'*. In modern terminology we can substitute for these expressions genome, cytoplasm and environment, respectively.

Among the environmental factors that influence plant development in a specific way, temperature and daylength are the most important ones (Zeevart, 1966). Low temperature induces a number of striking developmental processes. It overcomes physiological dwarfing, it can break dormancy and induce flower formation. Daylength controls the onset of dormancy in many woody species and flower formation in many herbaceous plants. The mechanism by which these two environmental factors exert their influence now appears to involve the activation of specific gene loci. Since American upland cotton is known to be day neutral, an investigation of the effects of temperature on fiber development seemed to be most appropriate.

Lewis (2000a) reported the effects of overnight low temperatures on fiber initiation and development in two varieties of upland cotton, the imim mutant and Texas Marker 1 (TM-1). The immature cotton fiber mutant (*imim*) is controlled by homozygous recessive alleles at a single locus. The mutant plant is characterized by having "tight-locked" bolls with immature fibers at boll opening. The mutation affects the dry weight of the secondary cell wall of the fiber and has little affect on the growth of the primary cell wall of the fiber. The imim mutant has a San Joaquin Valley Acala genetic background. Texas Marker 1 (TM-1) has a Delta Pine 14 genetic background and is homozygous dominant(*IMIM*) for the immaturity alleles, that is, it develops normal, open, fluffed bolls and fiber with well developed secondary cell walls at maturity (Kohel *et al*. 1974). During the spring of 1996, *imim* mutant and Texas Marker 1 (*IMIM*) cotton plants were grown in the greenhouse to the 2nd to 3rd true leaf stage prior to transplantation to the field. Overnight low greenhouse temperatures were maintained at 70 degrees F and daytime temperatures were controlled at 84 degrees F. Four sets of these plants were transplanted to the field at approximately one week intervals beginning on the 25th of April. These plants were allowed to grow to open boll maturity, at which time they were harvested by hand by fruiting zone, weighed, counted, ginned and subjected to intensive fiber analysis. The plants were mapped weekly from first square stage to open boll maturity.

Figures 17 and 18 show the results of this experiment with regard to the number of fibers per seed produced in the 1st four 1st position bolls at the four different transplant dates for *imim* and TM-1(*IMIM*), respectively. Figures 17 and 18 also show the average minimum daily temperature for the nine days immediately after transplanting(DPT). These data (Figures 17 and 18) indicate that the variation in numbers of fibers per seed for both the imim mutant and TM-1(IMIM) are influenced significantly by the average daily minimum temperatures to which they were exposed during the 9 days following transplanting. These findings are strongly supported by least squares regression analysis, as shown by Figures 19 and 20. Figure 19 clearly demonstrates that in the case of the imim mutant approximately 74% of the variation in the number of fibers per seed is accounted for by changes in the daily minimum temperature over the nine day period immediately past transplanting into the field. Figure 20 shows that in the case of TM-1 about 85% of the variation in the number of fibers per seed is accounted for by changes in the daily minimum temperature immediately following transplanting. In addition, these data also illustrate a quantitative difference in the imim mutant, homozygous recessive for the immaturity gene, and TM-1, homozygous dominant for the same gene. That is, the imim mutant responds to increases in the minimum temperature at a rate of approximately 465 fibers per seed per degree F. increase in average minimum daily temperature, whereas TM-1 responds at a rate of about 201 fibers per seed per degree F. increase in average minimum temperature, an approximate 2 fold difference in the level of response of the homozygous recessive form of the gene as compared to the homozygous dominant form. Since commercial cotton varieties have the phenotype of TM-1 plants, they are assumed to be either homozygous dominant or heterozygous for the fiber maturity gene.

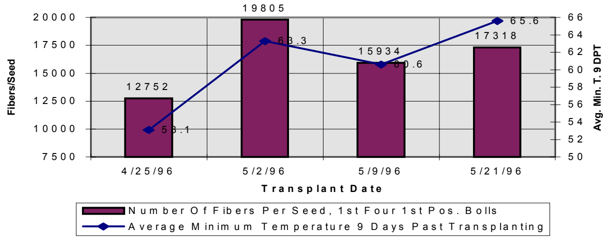

Figure 17. Number of fibers per seed (1^{st} four 1^{st} position bolls) and average min. Daily temperature (deg. F.) 9 days past transplanting (DPT) imim cotton plants, NE AR, 1996.

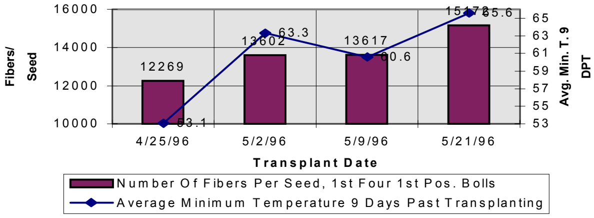

Figure 18. Number of fibers per seed (1st four 1st position bolls) and average min. Daily temperature (deg. F.) 9 days past transplant (DPT) TM-1 cotton plants, NE AR, 1996.

These data constitute strong evidence that the differentiation of primordial cells which give rise to outer epidermal cells of the cotton egg sac apparatus to become fiber cell initials occurs very early in seedling development at or about the 2nd to 3rd true leaf stage and then proceeds in a predictable manner as the plant continues to elaborate its fruiting apparatus according to the arithmetic progression through which it develops. These data also represent strong evidence that the environmental signal that evokes this process is the overnight minimum temperatures to which the newly expanding leaves are exposed. This finding suggests that, while cotton is day neutral, it does respond to an environmental stimulus which is analogous to the dark period stimulus of photoperiodic plants, and that the newly expanded leaves receive the stimulus which is then transmitted to the meristem, again, much like the well studied photoperiodic response. These findings have great significance for improving fiber yield and quality in cotton.

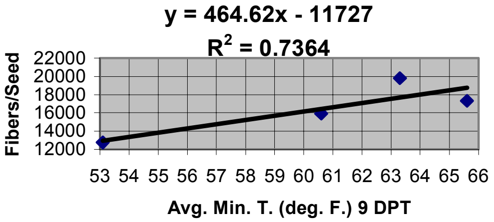

Figure 19. Regression Line: Change in fibers per seed with change in avg. Min. Daily tempt. (Deg. F.) 9 DPT, imim cotton plants, NE AR, 1996.

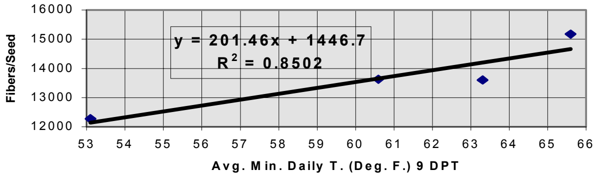

Figure 20. Regression Line: Change in fibers per seed with change in avg. Min. Daily tempt. (Deg. F.) 9 DPT, TM-1 cotton plants, NE AR, 1996.

Lewis (2000a) also conducted controlled growth chamber experiments to verify the field-transplant studies. These experiments not only confirmed the transplant results but also demonstrated that brief exposure, at 2nd - 3rd true leaf stage, to 45 and 50 degree F. conditions for four hours on three consecutive nights also significantly impacted fiber length distribution, linear density and weight per fiber. Furthermore, brief low temperature exposure at 2nd - 3rd true leaf stage had a profound influence on Afis percent short fiber content as shown by Figures 21 and 22. Short Fibers are defined as fibers shorter than 1/2 inch. Long Fibers, therefore, are defined as fibers 1/2 inch and longer. Figure 23 provides more detail concerning the effects of low temperatures on fiber length distribution. While percent short fiber content is significantly affected by low temperatures early in seedling development, the overwhelming effect is on the total number of fibers per seed. These findings have profound importance concerning how cotton fiber length distribution is regulated, however, using this information to minimize the variance in fiber length has even greater importance to the cotton textile industry. Thus, there can be little doubt that this phenomenon is of great significance in determining lint yield and quality in commercial cotton production.

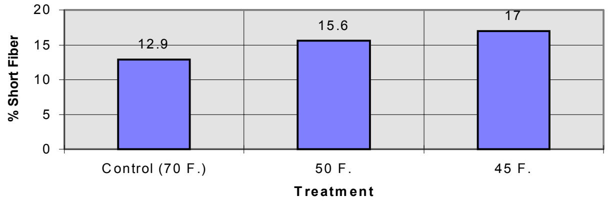

Figure 21. Effect of Growth chamber low temperature exposure on afis (N) short fiber content (1st four 1st position bolls) of field grown imim cotton fiber.

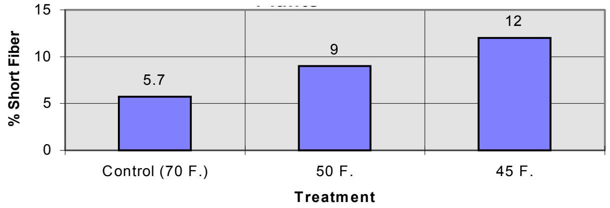

Figure 22. Effect of growth chamber low temperature exposure at 2nd - 3rd true leaf stage on afis (W) short fiber content (1st four 1st position bolls), greenhouse grown imim cotton plants.

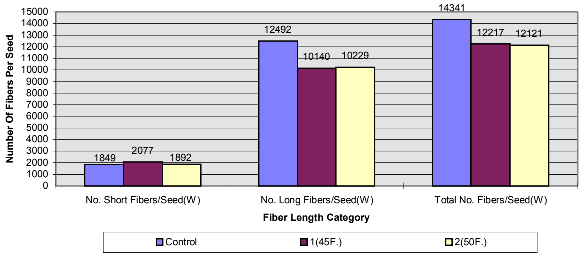

Figure 23. Effects of low temperature growth chamber treatments at 2nd to 3rd true leaf stage on fiber length distribution, 1st 4 1st position bolls, imim cotton plants, field grown.

Elevated short fiber content is a serious deterrent to utilization of modern, high speed, spinning technology such as the Murata Vortex spinning system, not to mention the cost of combing cotton to remove short fiber (noils) for classical ring spinning of finer yarn counts. An increase in percent short fiber content from 5.7% to 12% (see Figure22) would result in an increase from 28.5 pounds of short fiber to 60 pounds of short fiber per 500 pound bale of cotton. This short fiber must be removed as waste. The loss of 60 pounds of short fiber represents a direct cost approaching $50.00 per bale at current landed mill cotton prices. In addition, Figures 24 and 25 show that changes in percent short fiber with different temperature treatments at 2nd - 3rd true leaf stage is highly correlated with mean fiber length. This suggests that selecting for improved mean fiber length may be a practical way to reduce short fiber content. Reduced short fiber content has a tremendous potential for improving the competitiveness of the US cotton-textile industry.

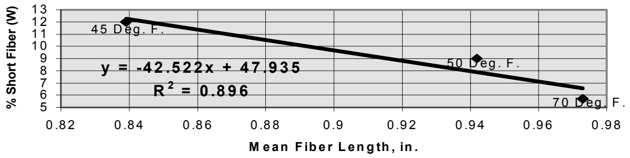

Figure 24. Imim mutant, greenhouse grown after low temperature growth chamber exposure at 2nd - 3rd true leaf stage: Change in percent short fiber [Afis (W)] with change in mean fiber length (1st four 1st position bolls).

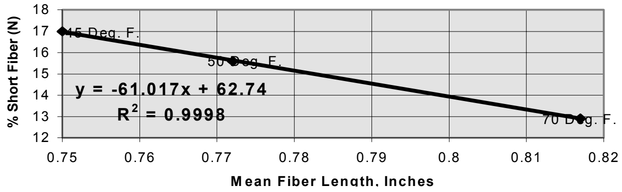

Figure 25. Imim mutant, field grown after low temperature growth chamber exposure at 2nd - 3rd true leaf stage: change in percent short fiber [Afis(N)] with change in mean fiber length (1st four 1st position bolls).

Summary

1. Most yield improvements in American upland cotton have resulted from increases in the reproductive potential of the plant or increases in the number of seeds per unit of land surface.
2. From 1945 to 1978 the weight of lint per seed remained relatively constant.
3. From 1975 to present the weight of lint per seed tended to decrease from approximately 75 milligrams per seed to about 55 milligrams per seed. If seeds per acre remained constant at 7 million/acre, this would result in a yield loss of about 300 pounds of lint per acre.
4. Based on gravimetric and energetic considerations, a decrease in weight of lint per seed requires an increase in the number of seeds per acre to maintain an equivalent yield level.
5. Increases in the number of seed per acre has resulted in increased demand for energy and increased susceptibility to stress and has probably resulted in less stable, more variable yields.
6. Breeding programs need to be reoriented to selection for genetic types which produce more lint per seed coupled with an optimum level of seeds per acre.
7. Increased fibers per seed may result in reduced short fiber content.
8. Increased mean fiber length appears to be highly correlated with decreased short fiber content.
9. Selection for improved short fiber content could result in improved fiber length uniformity which is critical to improvements in yarn forming efficiency.

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