NATIONAL COTTON COUNCIL

Cotton Physiology Today

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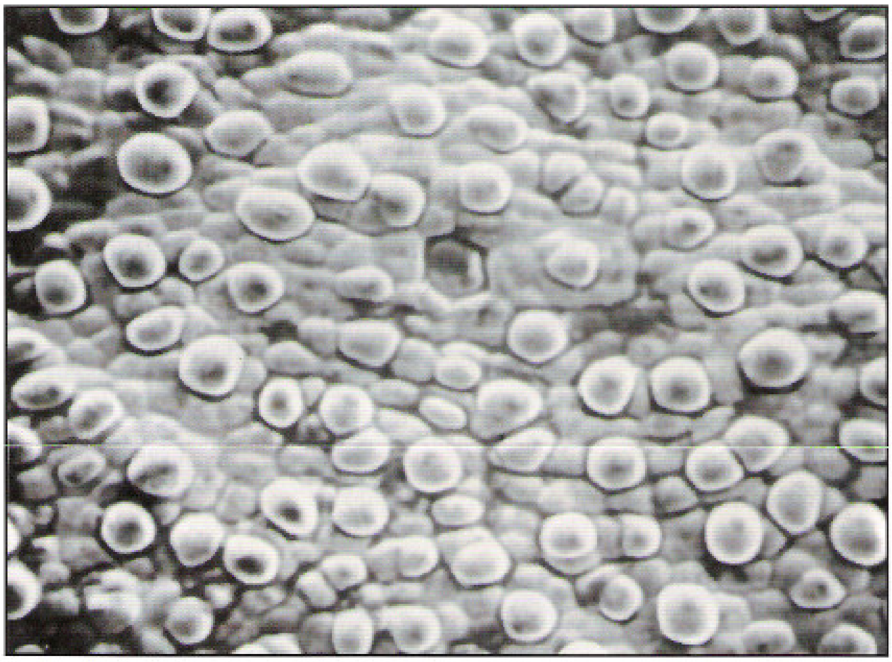
Producing for Quality

The Cotton Physiology Education Program (CPEP), now in its 13th year, is funded by a grant to the Cotton Foundation by BASF, makers of PIX®PLUS plant regulator. CPEP's mission is to discover and communicate more profitable methods of producing cotton.

Introduction

The role that quality plays in a healthy cotton industry continues to grow in importance with ever increasing demands of modern high-speed processing equipment and a more discerning consumer. In recent years, US cotton has been hit by unusually hot, dry weather during the growing season. In bales from 1999 and 2000 crops, the aggregate losses from staple length, strength and high micronaire discounts were about $180,000,000, nearly double those for the 1995-97 crops.



J. Berlin

Figure 1. Scanning election micrograph of cotton seed surface.

How do farmers' decisions influence quality? Is there anything a farmer can do to minimize quality discounts? Can a farmer assure top quality? To get a clue on these questions, I looked through back issues of *Cotton Physiology Today.* The contents of this newsletter are composed of excerpts taken from previous editions authored by Kater Hake and Dave Guthrie.

While the factors of length, length uniformity, strength, micronaire, color, trash, bark, grass and preparation all are factors that establish quality, this paper deals with length, strength and micronaire.

INSIDE:

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Andrew G. Jordan, National Cotton Council. The contents of this newsletter are composed of excerpts taken from previous editions authored by Kater Hake and Dave Guthrie.

Importance of Variety

Of all the decisions a producer makes during the year,; the most critical for yield and quality is varietal selection. Inherent qualities of strength, length and fineness are strongly controlled by genetics. However, variety alone does not assure quality, nor does it guarantee yield. But variety is the starting point and the most important single decision affecting yield and quality.

After the variety is selected and seeds are planted, cotton must be managed throughout its entire growing season. Ideally, production decisions are matched to the developing crop and weather to maintain a stress-free crop. As expected, a system of non-stress production makes healthier plants. Likewise bolls produced on healthy plants produce longer, stronger and more completely developed mature fiber.

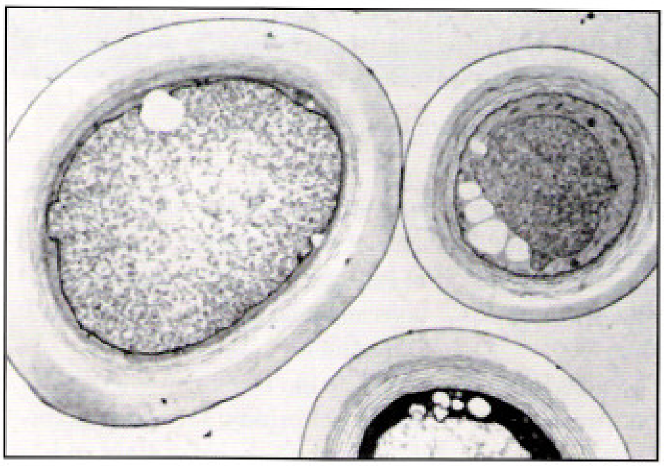
Fiber Development

Cotton fiber develops in an orderly, precise pattern. Starting the day of bloom, cells on the surface of the ovule, or unfertilized boll, start to elongate outward into the watery boll (Figure 1).

These elongating cells will reach their final length in approximately 16 to 25 days, at which time they start to thicken. The rapid elongation of these cells is driven by internal water pressure that stretches the highly plastic primary wall like an expanding balloon. Thickening of lint occurs from the daily deposition of cellulose strands in the cell wall (Figure 2). Unlike tree growth where annual rings are deposited outside of last year's growth, cotton's daily growth rings occur inside the previous day's growth.

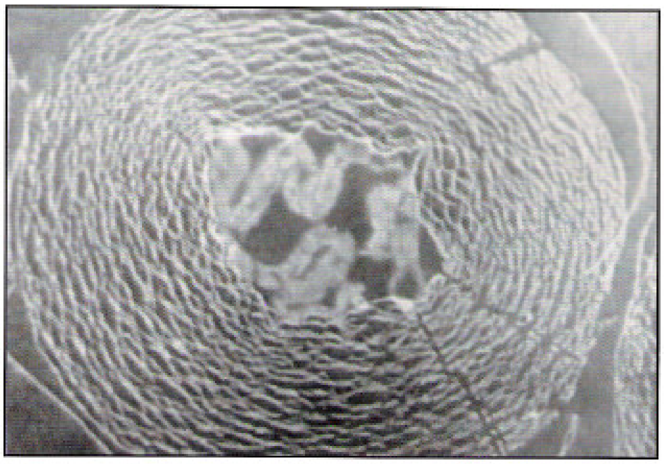
These daily rings of cellulose strands are deposited at slightly different angles, becoming aligned with the fiber length and building in fiber strength similar to plywood. If the boll develops to maturity, these layers partially close in the center of the cell or lumen in another 20 days (Figure 3).

Once the fiber has reached full thickness or maturity, the last stage in fiber development is drying, during which the fiber collapses and shrinks approximately 1/3 in diameter. This shrinkage causes twist and crimp created from the reversals and contortion between the daily layers of cellulose (Figures 4 and 5). As these layers dry, they shrink inward pulling in different directions resulting in the crimping that allows cotton fibers to intertwine and be spun into thread.



J. Berlin

Figure 2. Cross section of developing cotton fibers.

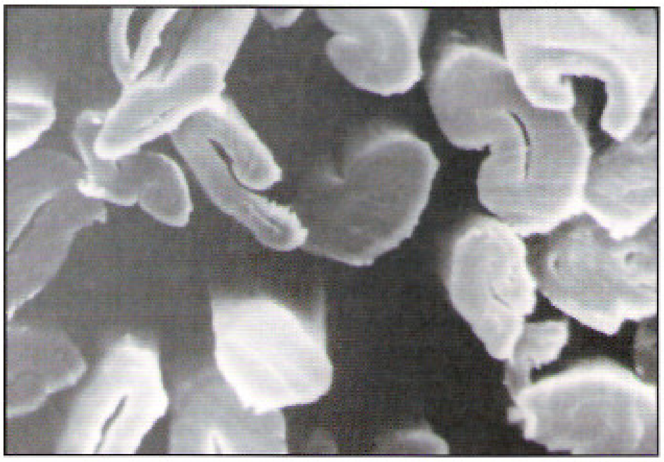


B. Goynes

Figure 3. Cross section of a fully mature cotton fiber before boll drying.

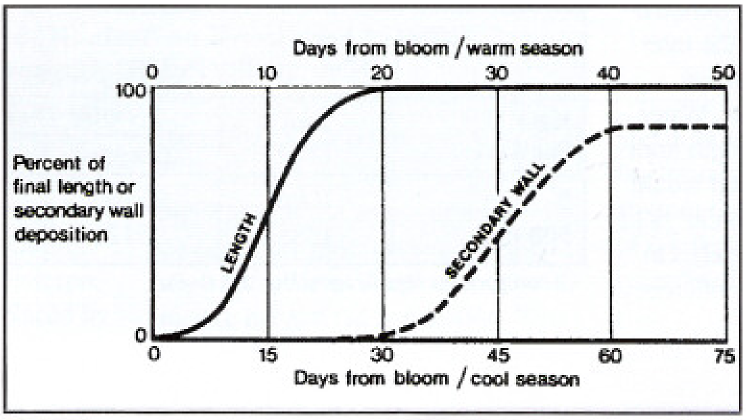
B. Goynes

Figure 4. Crimp in fully mature dried cotton fiber.



B. Goynes

Figure 5. Cross section of dried cotton fibers of varying maturities.



Ramey

Figure 6. Fiber length and wall deposition curves.

The Management of Quality

The complex impact of environment and management on fiber quality is made more complicated because of the diverse fiber developmental stages at any one time throughout the plant. On the same day, some bolls may be just starting fiber elongation, others starting to thicken and others may be completely mature (Figure 6). Whether it is water stress or extremes in temperature that impact the bolls, these influences will have a totally different effect on each stage of boll development. The quality that results from a specific environmental or management input is difficult to predict without detailed knowledge of the boll development stage during the disruption of fiber development.

Quality is built during the entire production season. Many factors that influence quality, such as weather, are beyond the control of producers. Yet some such as variety, fertilization, irrigation and harvest aids are under direct control.

Management to Increase Length

Fiber length is controlled to a large degree by variety, although weather and management also influence the final fiber length. Maximum fiber length is determined during the elongation phase of fiber development (the first 16 to 25 days). Hence, fiber length of young bolls will be most effected by weather and management.

High temperatures during the elongation phase of fiber development result in shorter fiber. Fiber length is also decreased by severe water stress and potassium deficiency. Both of these decrease the internal water pressure or expansive force of the elongating fiber. Water deficit will not decrease length until the stress reaches a level that would cause a 25 to 50% reduction in yield (-24 bars, leaf water potential). On the other hand, potassium deficiency can reduce fiber length even at moderate levels of yield loss due to the very sensitive nature of fiber quality to potassium levels in the boll. The table below shows yields and quality for K deficient and sufficient plots.

Moderate temperatures during the first 3 weeks of a boll's development increase fiber length in that boll. The same cotton variety grown in mild or wet climates usually has longer fiber and lower micronaire than from hotter or dryer regions.

Ginning Influence on Length

Fiber length also can be influenced by ginning and lint cleaning, especially when the moisture is below recommended levels. Gin cleaners will remove more trash at low moisture, but more fiber damage will result. The ideal ginning moisture range is 6-8%. For each 1 percent reduction in fiber moisture below 5%, the staple length would be reduced approximately 1 hundredth of an inch.

Effect of Fertilizer-K on Acala GC-510 lint yield and fiber quality in 1987, Cassman 1990.

K2O Per Acre	Lint Yield	Fiber Quality Characteristics		
		Length	Mike	Strength
0	1006	1.10	3.85	27.7
500 lbs	1385	1.12	4.21	29.1

All comparisons significant at the .001 level.

Management to Increase Strength

Researchers have known for many years that fiber strength is highly controlled by variety, but only recently has this relationship been understood. Recent biochemical research into fiber strength has shown that varieties with strong fiber tend to produce longer cellulose molecules.

Longer cellulose molecules provide fewer break points in the lint and greater cross linkages between fibers. This relationship is perfectly analogous to the benefit of longer fibers in yarn strength. Long fibers can extend through more twists in the yarn with fewer breaks between fibers. Since short fibers are loosely inserted into the yarn, the load or strain is carried primarily by the long fibers. Since short fibers are loosely inserted into the yarn, the load or strain is carried primarily by the long fibers. Other characteristics of cellulose deposition may also be important in fiber strength.

Variety

Variety is by far the dominant factor in strength, contributing 80% of the total variability in strength. If one compares strength of different varieties over several years it is clear that selecting a variety with high strength last year is the best way to insure high strength this year.

Growing Environment

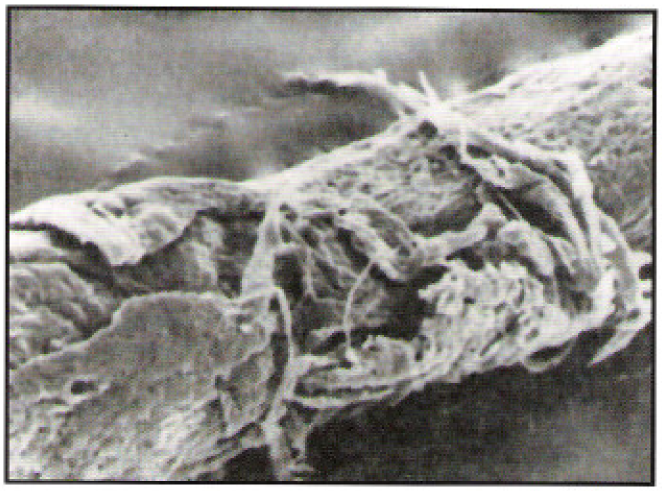
Environment does have a small effect on strength, although the environmental factors that influence strength are unknown.

Cultural Practices

Potassium deficiency can decrease strength by up to 2 grams force per tex, under a severe deficiency that would cut yield by 40%. Any factor such as extreme weathering that causes either physical or microbial damage to the fiber will reduce its strength (Figure 7).

Ginning Effects on Fiber Strength

The effects of ginning on fiber strength are minimal except in the case of excessive heating, which decreases strength.



B. Goynes

Figure 7. Electron micrograph of severe fungal deterioration on the fiber surface.

Managing Micronaire

Historically micronaire (mike) has been used as a measure of maturity, but with the diversity in varietal fineness and refined needs of high-speed spinning this simple interpretation of mike has been replaced by a more complete understanding based on fiber properties.

Both high and low mike cottons are limited in range of use by the textile industry. Low mike cotton can be fine fiber but usually is immature fiber that does not readily absorb dye and thus creates an uneven dye pattern in the finished cloth. Low mike cotton is more likely to form neps (small knots of tangled fiber) in the ginning and yarn manufacturing processes.

High mike cotton also has limited use by the textile industry because it cannot be spun efficiently into fine yarns. A minimum of 100 cotton fibers per cross section of yarn are required in the spinning process to hold yarn together and give it strength. If coarse, high mike cotton is used; these 100 fibers can only make a coarse, thick yarn.

Coarse fibers are used to make denim, polyester blends and nonwovens such as batting, in which fineness is not critical. Thus coarse fiber rarely receives a premium in the marketplace even if extra strong or extra long.

Season Cut Short

An early termination of the growing season is the most common cause of low mike cotton, whether it's frost or Verticillium wilt or premature harvest aid application. When the leaves are removed, fiber development stops in 2 to 3 days. Even following a defoliant application, fiber develops for only 5 days, half of the time drawing nutrients from the treated leaves, the other half of the time from the stem and roots. The following figure represents the development of the bottom, mid and top crops, both the elongation phase and thickening phase. In the following example, the season is cut short. Bottom bolls would be fully mature (4.6 mike). Mid bolls would not complete full development (3.5 mike). And top bolls would either not develop enough to open or would be very immature lint and very low mike (2.5 mike) (Figure 8).

When all of these boll stages are mixed together at harvest, the result is not only reduced mike but also highly non-uniform lint. This greater non-uniformity in micronaire from low mike bales increases breakage and dye problems in the textile mill.

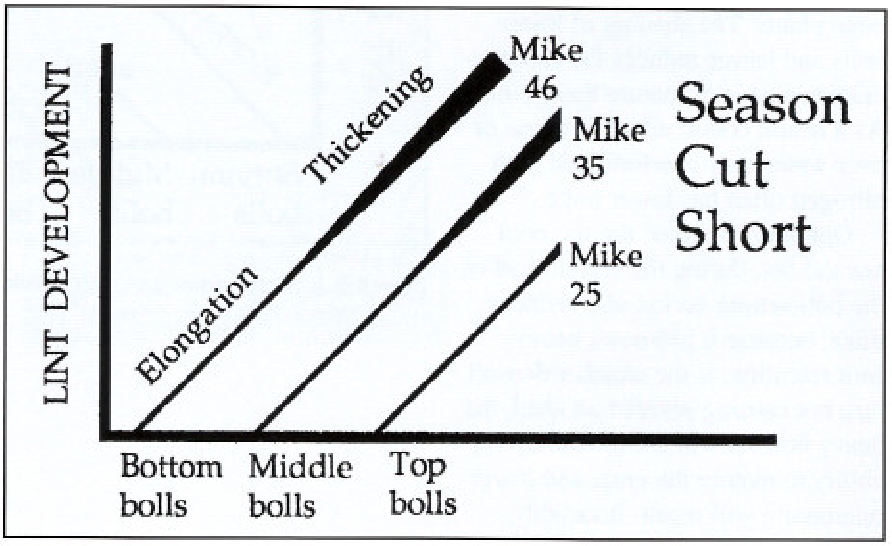


Figure 8. Fiber development with season cut short.

Low Mike Cotton: Insufficient Carbohydrate to Meet Boll Demand

When the cotton plant sets more bolls than it has carbohydrate supply to fill, low mike often results. Potassium (K) deficiency is just one example. Unlike nitrogen deficiency, a condition under which the crop will compensate for the lower nutrient level by adjusting the boll load downward, potassium deficiency is created by the crop set on the stalk. Potassium deficient plants set bolls normally, but once on the plant, the bolls' high demand for K exceeds the infertile soil's ability to supply K. The K demand of the developing bolls then strips the potassium from the leaves causing them to bronze and senesce prematurely. Thus K deficient cotton has insufficient carbohydrate supply to mature the bolls and often has extremely low mike (reduced maturity). Potassium is directly involved in the physiology of fiber elongation and thickening, thus K deficiency reduces not only maturity be also strength, length and uniformity.

Other factors that create a condition of low carbohydrate in relation to boll demand include: dense stands, high nitrogen, excess irrigation or favorable fruit set. Dense stands and excess nitrogen or irrigation promote vegetative growth and large plants. The shading of lower bolls and leaves reduces the carbohydrate available to mature these bolls. As a result, cotton which is dense or over-watered or overfertilized with nitrogen often has lower mike.

Optimum weather, not too cool nor too hot, during the second half of the boll-setting period also reduces mike, because it promotes heavy fruit retention. If the weather doesn't turn hot causing severe boll shed, the heavy boll set will exceed the leaves' ability to mature the crop, and lower micronaire will result. Invariably, years with excellent boll retention are lower mike years.

High Mike Cotton: Ample Carbohydrate to Mature Bolls

The mike of cotton tends to increase when there is ample supply of carbohydrate to mature the bolls set on the plant. When supply is greater than demand for carbohydrate, the daily rings of cellulose are thicker thus resulting in fiber that fills in the lumen more completely. The most common causes of high mike cotton are poor boll set or small boll size due to hot weather or water stress. High temperatures cause small bolls to shed, and the remaining bolls often have low seed counts; yet the supply of carbohydrates is often increased. We see this in the high temperature years when irrigated cotton gets very tall due to ample carbohydrate and reduced boll load. Water stress often causes high mike because boll retention is very sensitive to water stress, while fiber thickening is much less sensitive. Boll retention is reduced when water stress level drops below -19 bars , while fiber thickening and elongation is not affected until the severe level of -24 bars is reached . When a plant experiences water stress, it sheds young bolls leaving the few older bolls on the plant with ample carbohydrate to fully thicken.

Middle-set bolls also have higher mike because they are maturing when the days are longer and temperatures more favorable for photosynthesis. Additionally, bolls set at the first position on the main-stem are higher in mike because they have more leaves to feed them and they are less likely to be shaded. Thus early crops with high retention at the first position tend to be higher mike than later set crops farther out on fruiting branches . The following example shows the fruit shed from water or heat stress during peak bloom (Figure 9). The middle bolls shed, leaving ample carbohydrate to mature the bottom bolls or any late-set bolls.

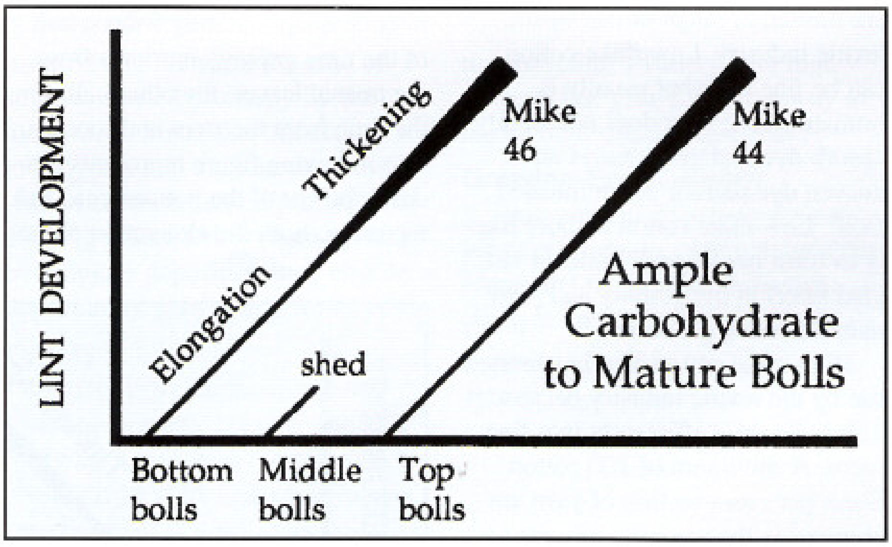


Figure 9. Lint development with ample carbohydrate to mature bolls.

High Mike Cotton: Short Fiber

When fiber is shortened, mike often goes up. If fiber elongation is limited, then during the thickening phase, the same quantity of carbohydrate will be spread over a shorter length and allow thicker daily rings. Most short fiber varieties, when fully mature, are coarser and have higher mikes than long fiber varieties. Within one variety the shorter staple bales will tend to be coarser mike. Even on one seed, the shorter fibers will be thicker. Water stress during bloom, a major cause of low yields in the 1990 crop, increases mike by both shortening fibers and shedding bolls.

Micronaire Changes: Surface Area Changes

The previous causes of high and low mike primarily influence the inside of the fiber and determine how well the fiber fills in. These control mike because they set the number of fibers necessary to make up the 3.2 gram sample in the micronaire chamber. But mike also can be controlled by changes in the surface of cotton lint. An example of changes in surface area is the microbial degradation of lint left ot weather in the field. When we see lint gray and darken, it is because fungi are feeding on the lint. This feeding creates a rough surface that retards air movement in the micronaire chamber, causing weathered cotton to suffer a slight reduction in micronaire.

Another example of surface area changes is in varieties with inherently fine fiber. Lint from these varieties, even when fully mature, have small diameters and perimeters. As fiber gets smaller, the ratio of surface to weight increases, placing more surface area in the 3.2 gram sample. We do not anticipate that producers will select varieties based primarily on their average micronaire, because unlike strength, the variety makes only a small contribution to micronaire.

Ginning and Micronaire

Ginning has little or no effect on micronaire. Gin cleaners may discard some immature seeds with their attached fibers, but the effect is minor. Micronaire does affect how cotton gins. Lower mike cottons are more susceptible to entanglement and nepping in the ginning and cleaning processes.