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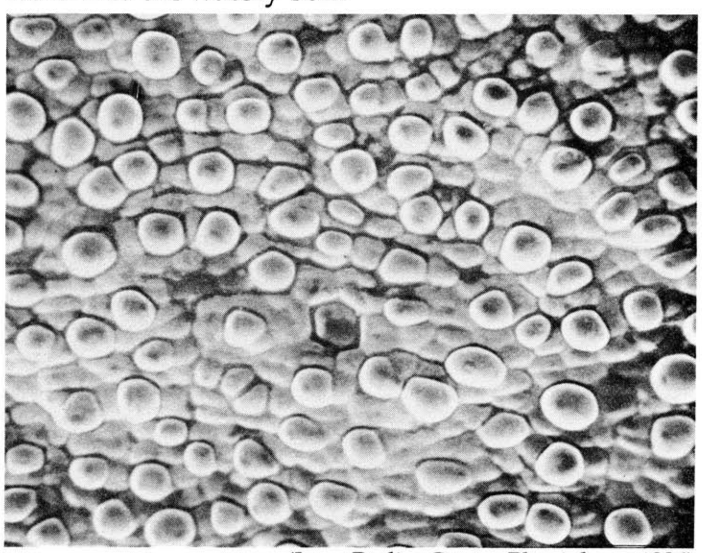
Fiber Development and HVI Quality

Weather and cultural practices that alter the development of the cotton fiber also alter the quality parameters measured by HVI. This issue of Cotton Physiology Today is extracted from the publication "Producing Quality Cotton", currently available from the National Cotton Council - Cotton Physiology Education Program. "Producing Quality Cotton" was written to help producers understand and maximize quality under the HVI system. For a free copy, please call or write. KH

1st Stage of Fiber Development: Elongation

The following pictures are electron micrographs. They utilize electrons instead of light waves to record the minute detail of the fiber. Although cotton fibers are exceedingly long for a single cell (1 to 1.5 inches) they have diameters typical of cells (.4 to .8 thousandths of an inch). These electron micrographs convey the orderly, precise pattern in fiber development. Starting the day of bloom, cells on the surface of the ovule (unfertilized seed) start to elongate outward into the watery boll.

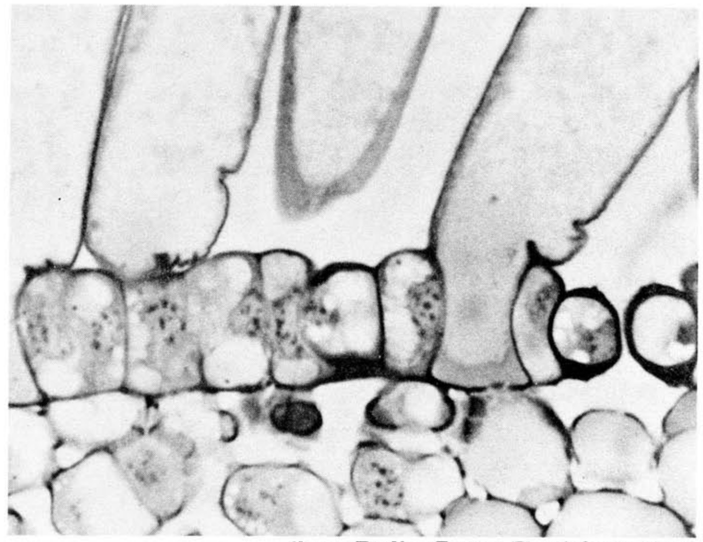


(Jerry Berlin, Cotton Physiology, 1986)

These elongating cells will reach their final length in approximately 16 to 20 days, at which time they start to thicken. The rapid elongation of these cells is driven by their internal water pressure which stretches the highly plastic primary wall, like an expanding balloon.

Management to Increase Length

Fiber length is controlled to a large degree by variety, although weather and management also can influence the final fiber length. Since maximum fiber length is determined during the elongation phase of fiber development in young bolls (the first 16 to 20 days after bloom), fiber length of young bolls will be effected most by weather and management.



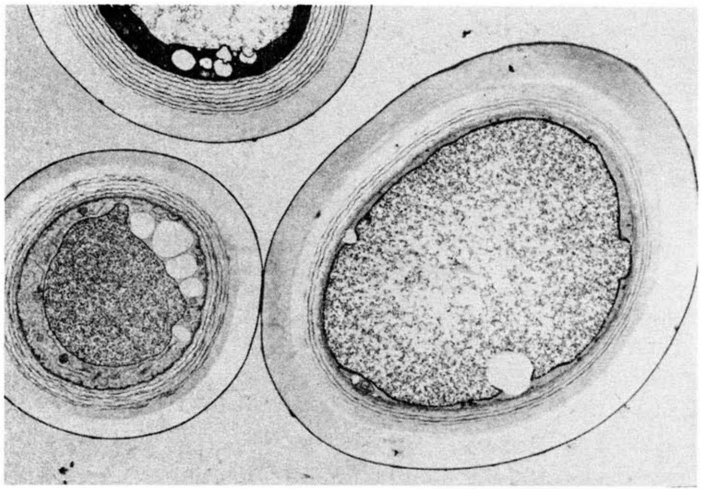
(Jerry Berlin, Cotton Physiology, 1986)

Water stress and potassium deficiency decrease fiber length because the water pressure or expansive force in the elongating fiber is decreased. High temperatures during the elongation phase of fiber development also result in shorter fiber, due to earlier termination of fiber elongation. Bales of long staple cotton are produced from varieties with the genetic potential for long fiber when grown under moderate temperatures and moist conditions.

2nd Stage of Fiber Development: Thickening

After the elongation phase, fiber thickening occurs from the daily deposition of cellulose strands in the secondary cell wall. Unlike tree growth where annual rings are deposited <u>outside</u> of last year's growth, cotton's daily growth rings occur <u>inside</u> the previous day's growth. These daily rings of secondary wall are almost pure cellulose strands that are deposited at different angles, building in fiber strength similar to the construction of plywood. It has been known for many years that fiber strength is controlled by variety, but only recently has part of this relationship been understood. Recent biochemical research into fiber strength has shown that varieties with short cellulose molecules tend to have low strength fiber. This relationship is analogous to the impact of short fibers on yarn strength.

Yarn produced from cotton with a high short fiber content contains more fibers that can not carry a load. That's because short fibers are loosely inserted in the yarn and they extend through only a few twists in the yarn. In yarn with many short fibers, the longer fibers must carry the load and thus are more likely to break.



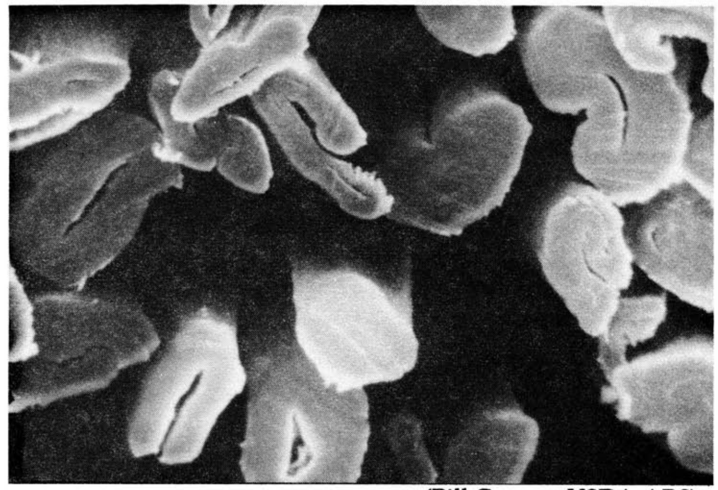
(Jerry Berlin, Cotton Physiology, 1986)

Managing for High Strength

Variety is the dominant factor in strength. Avoiding low strength varieties is the best way to insure higher strength bales. Environment does have an effect on strength, although the environmental factors that influence strength are unknown. For example, the central Mid-South 1990 crop was 1.7 g/tex weaker than the 1989 crop from those same 3 classing offices; even though the varieties planted were virtually the same (44% DPL50 and 23% DPL20 in 1989 versus 49% and 19% in 1990). Severe potassium deficiency can decrease strength by up to 2 grams per tex. Any factor that causes either physical or microbial damage to the fiber will reduce its strength. Extreme weathering or over-heating at the gin are two examples.

Managing for Dye Uniformity

After approximately 20 days of fiber thickening the layers of secondary wall cellulose partially close in the center of the cell. Since the secondary wall has a different dye uptake than the primary wall, dyed fabric spun from cottons with a mixture of mature and immature fibers will have uneven color. Immature fibers with thin secondary walls also are prone to form neps in the gin and textile mill. In the following electron micrograph of a slice through a bundle of fibers, the normal variability in secondary wall thickness is evident.



(Bill Goynes, USDA-ARS)

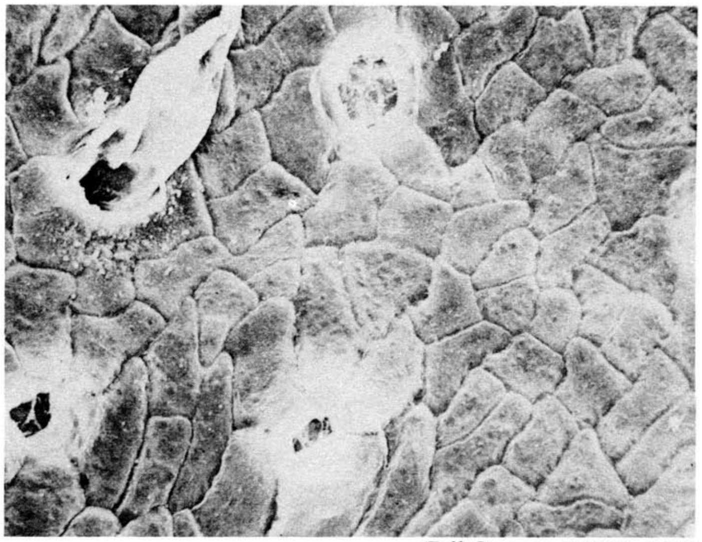
3rd Stage: Opening and Drying

Once the fiber has reached full thickness or maturity, bolls open and dry, and the fiber shrinks approximately ⅓ in diameter. Cotton bolls open due to the formation of separation zones between the burs and the drying of the boll wall. As the boll wall drys, it bends backwards exposing the lint and seed to air.

The seed surface then oxidizes, turning black, the lint dries and crimps. Crimp derives from the reversals in cellulose orientation and contortion between the daily layers of cellulose. As these layers dry, they shrink inward pulling in different directions, resulting in the crimp that allows cotton to intertwine and be spun into thread.

(Bill Goynes, USDA-ARS)

Most of the fibers break at the point of seed attachment, where the secondary wall is the thinnest, when pulled by the saws or roller in the gin stand. Although 15% of the fibers break at points other than the seed attachment site, resulting in short lint fibers. Varieties differ as to the force required to separate the lint from the seed, with Pima lint being relatively easy to separate. Some of the upland varieties also are suitable for roller ginning, having a loose fiber-to-seed attachment. The following electron micrograph shows the surface of a seed after ginning.



(Bill Goynes, USDA-ARS)

Cotton Fibers Are Not All the Same Length

One of the major differences between synthetic fibers and cotton is the presence of short fibers in ginned cotton. Not only does fiber length on one seed vary widely, but ginning and cleaning also break fibers into shorter segments. Length uniformity index, referred to as "Uniformity", is important to the textile industry because it is an indication of the short fiber content. Uniformity is the ratio of the average length of all the fibers to the average length of the longest fibers.

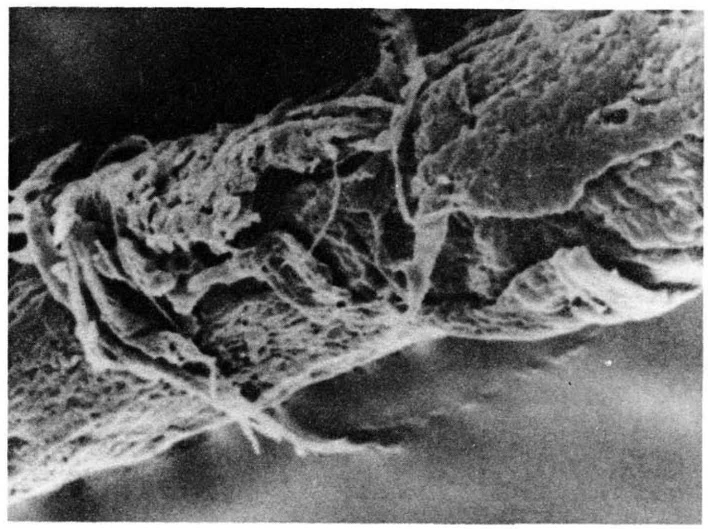
Management to Increase Uniformity Index

Unlike length or strength, uniformity index is controlled only slightly by variety. Fiber strength does have an effect on uniformity. Weak fibers are more vulnerable to breakage in the gin. Those same Mid-South classing offices with a drop in strength from 1989 to 1990 also suffered a decrease in uniformity index (81.2 in 1989 to 80.3 in 1990). Field weathered cotton is prone to breakage, suffering increased short fiber content and reduced uniformity in the gin and textile mill. Open bolls which have weathered due to excessive rain (greater than 2 inches) deteriorate turning gray and are more susceptible to fiber breakage during processing. Bolls set late in the season and bolls on vegetative branches also suffer increased short fiber content. High uniformity indexes (greater than 82) can be obtained by producing strong cotton for early harvest that avoids weathering, with a high percentage of the crop set early at 1st and 2nd positions on the fruiting branches.

Color is Determined by Yellowness and Reflectance

Historically, grade has been used to predict spinability and thus desirability by the textile industry. The whiter, cleaner grades have generally suffered less field weathering and biological deterioration of the lint surface. Although a classer still assigns a grade to each bale, HVI measures the trash content and the components of color, Yellowness (+b) and Reflectance (Rd), allowing a more precise determination of grade.

Cotton that has severely discolored is undesirable in the textile mill because the lint surface is deteriorated and because of perceived dye problems. Deterioration of the lint surface increases its roughness and alters the way fibers slide across each other in the spinning process. Light spot, gray or tinged cotton is more likely to result in weaker and uneven yarn. Discolored lint poses a marketing problem for certain yarn mills because of the potential for off color when dyed in lighter colors. Yellowness appears to be less important than reflectance in spinning. The following electron micrograph shows extensive fungal deterioration on the fiber surface. This sample was collected in 1988 from a Mid-South cotton field that was field weathered and demonstrates why field weathering not only affects reflectance but also vulnerability to breakage.



(Bill Goynes, USDA-ARS)

Field Weathering

When mature cotton bolls first open, the lint is white and clean due to the highly reflective nature of cellulose and the lack of microbial degradation. As cotton weathers it looses reflectance becoming more gray due to moisture, both humidity and rain - and to molds that grow on the lint or wash off of the leaves. If boll development is stopped prematurely by frost, drought or early application of harvest aids the lint often has a yellow color that varies in intensity.

When lint is exposed to moisture, fungi start to feed on the surface of the lint. The dark color of the microscopic fungal spores grays and dulls the lint. Cotton responds to weathering by graying and decreasing yellowness, just like a fence post. Production systems that minimize the exposure of open bolls, prior to harvest, are the greatest tools to increase color grade.

The Management of Quality

This article may have left you with the idea that understanding the effect of cultural practices and weather on quality is simple; you just compare the date of hot or cold weather to the stage of boll development and compute whether the length or micronaire or reflectance is altered. Unfortunately, when fiber in one boll is elongating, another is thickening and another opening. Further complicating quality prediction is fruit shed; since small bolls are more sensitive to shed, stress will alter the size distribution of bolls. Predictions regarding quality require knowledge of the boll size distribution when various plant stresses occur.

Variability is an inescapable fact of natural products such as cotton. This variability is a desirable characteristic because it gives cotton garments "depth" and "character", features that cannot be created with the high level of uniformity found in manmade fibers. Even within one bale, variability exists in all quality parameters.

Cotton quality is built into a bale during the entire production and ginning season. Many of the factors that influence quality, such as weather, are beyond the control of producers and ginners. Yet many factors are under direct control, such as variety and harvest aids. Producers have the opportunity to build in cotton quality that should be preserved through careful ginning and packaging.

The Cotton Physiology Education Program is supported by a grant from the Cotton Foundation, and brought to you as a program of the Technical Services Department of the National Cotton Council in cooperation with the State Extension Services.

The National Cotton Council (NCC) is the central organization representing all seven sectors of the U.S. cotton industry: producers, ginners, warehousemen, merchants, cottonseed crushers, cooperatives and manufactures. A majority of elected delegates from each sector must approve all NCC policies, thus assuring unity of purpose and action.

Cotton Physiology Today: Edited by Kater Hake