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Boll Weathering

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Tremendous gains have been made recently in the quality of U.S. cotton. Strength, length and grade have improved dramatically due to modern varieties, use of modules, and management practices that minimize plant stress while promoting short season cotton. However, despite these gains, boll weathering still costs the industry in yield, quality and profit. In 1991, Texas cotton suffered severe boll weathering, in 1992, South East fields were held hostage by late fall rains and in 1993, a change in the grading of cotton will focus producer attention even closer on boll weathering.

Fiber Surface

The cotton fiber is an epidermal cell, the same type of cell that covers leaves; and like leaves, fibers have a thin waxy cuticle on the outside. Just below the cuticle is the very thin primary wall, composed of cellulose and protein. Inside the primary wall is the thick secondary wall, which is 98% cellulose. Cellulose is built from plant sugars that are moved to the fiber from the leaves. As bolls mature and open, these plant sugars in the fiber disappear.

Athough cellulose is highly resistant to degradation by microorganisms, the plant sugars can provide starting points for fungi to feed and decay the lint. Some San Joaquin Valley Acala varieties have higher natural sugar contents and are thus more vulnerable to boll rot when grown in the rainbelt. In addition, when cotton fiber development is terminated prematurely the natural sugar content can remain high, predisposing the fiber to fungal infection.

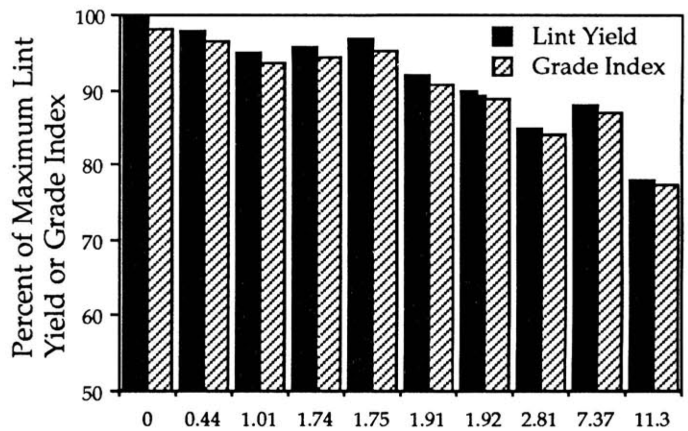
Physical Act of Weathering

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. 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.

Immediately after a boll opens, exposure to the environment allows bacteria and fungi to rapidly multiply on the fiber. When the boll opens under favorable drying conditions the natural sugars on the fiber disappear, probably being fixed in the cellulose or degraded by sunlight. When the boll opens under humid conditions the microbes begin to feed on the sugars and on the surface of the fibers. The dark color of the microscopic spores give the lint a dull or gray color. This gray color is increased when the supply of sugar on the lint is high due to deposits by aphids and whiteflies. Under very humid or rainy conditions the fungi continue to multiply on the lint creating "hard" or "gray lock" bolls.

The damage to yield and quality by heavy rain on open bolls is illustrated by the following figure, data from Stoneville MS, 1983-1987. Delaying harvest for 4 to 6 weeks did not significantly reduce yield or quality in years when rainfall of less than 1 inch occurred after the cotton was open. When rainfall exceeded 2 inches, significant yield and quality loss resulted. The quality reduction was caused by loss of color and to a lesser degree the addition of trash.

Effect of Rainfall on Yield and Grade Index



Weight loss

Boll weight loss from weathering is a controversial subject, because reported numbers vary widely and because fall weather strongly controls the degree of loss.

Mid-South: In Mississippi a 0.09% per day yield loss was reported when cotton was left in the field over a 50-day period. Another Mississippi report from 22 locations indicated an average boll weight loss per day of 0.64% with a range of 0.45% to 1.75%. In Arkansas, a 0.21% loss per day over a 5 week period was recorded in a crop severely delayed by early thrips. Another Arkansas study conducted during a more favorable season showed no reduction in yield.

Arid West: In the San Joaquin Valley, no significant loss of boll weight was measured, only a slight trend of 0.06% per day. An Arizona study of weathering also showed no decline in yield from weathering.

Southwest: In West Texas, a 3-year study demonstrated a moderate decline in open boll weight loss (0.19% per day over an 8 week period), with the greatest loss occurring in the early weeks after opening.

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Location	Year	Boll wt. %loss per day
Arizona	1970's	no loss
Arkansas	1986	0.21%
Arkansas	1988	no loss
Mississippi	1980's	0.09%
Mississippi	1985 to 1988	0.64%
San Joaquin Valley	1986	0.06%
Texas High Plains	1969 to 1971	0.19%
Australia	1988	0.50%

Clearly, the environment during the fall season dramatically influences weathering losses. Several causes of lint weight loss due to boll weathering are possible:

- **Open cotton blown to the ground**. When cotton bolls open, the lint continues to fluff outward due to changes in humidity that cause the fiber to contort and twist. When high winds are combined with rain, fluffed seedcotton in defoliated fields is highly susceptible to being blown on the ground. "Storm proof" cotton varieties grown in West Texas and Oklahoma minimize physical loss of cotton because the burs do not fully open, the lint does not fluff, or an edge of each lock is stuck to the inside boll wall.
- **Cotton locks falling to the ground.** When bolls opens under humid conditions, fungi can feed on the slowly opening bolls, wrapping the locks in fungal mycelium. These grey or hard lock bolls readily fall out of the boll either prior to harvest or as pickers move through the field.
- **Loss of cotton weight due to leaching** is minimal. Cellulose is insoluble in water and thus resistant to leaching loss. Some partially soluble constituents of fiber could be leached, however, the rainfall necessary to do so would be substantial.
- **Loss of weight due to microbial degradation** is slight. When fungi feed on cotton, they degrade the fiber, reducing total weight. Weight loss directly due to fungi is probably very slight. However, few boll rots are picked clean by spindles and do represent a substantial loss, especially in tall cotton. Work by Don Baker during the wet 1992 Mississippi fall demonstrated a 24 pound lint loss for every inch that the final plant height exceeded 40 inches. Some fields with tall plants suffered a 500 pound lint loss due to boll rot.
- **Ginning loss of weathered cotton** can be significant. Late picked cotton that has severely weathered often requires greater lint cleaning to improve the grade. A second lint cleaner can remove 10 lbs of material normally left in the bale. In addition, the greater fiber breakage could result in shorter staple length.

Fiber Discoloration from Damage

An early frost can degrade the color of cotton. Injury to moist boll walls by freezing disrupts the tissue and allows gossypol to stain the seedcotton. Plant bugs and boll weevils also will cause a spotty stain of injured bolls. While spindle pickers will only grab a few of these stained locks, stripper harvesters often salvage most of them. Spindle harvesters have lower harvest efficiencies than stripper harvesters and leave many of the damaged, immature or partially opened bolls that can detract from premium quality.

Fiber Length

Field weathering and ginning have a dramatic effect on length uniformity and short fiber content. Open bolls which has weathered due to excessive rain (2 inches or more) deteriorates and is more susceptible to fiber breakage during processing. Weathered cotton suffers increased short fiber content and reduced length uniformity in the gin and textile mill, not in the field. Late harvested fields also suffer increased short fiber content from the tendency of late set bolls to have more short fiber. Weathered cotton may suffer a measurable reduction in fiber length. The 3-year Texas study indicated an average reduction of 1/32nd in staple length due to 7 weeks of weathering. However, other studies showed no significant effect on length.

Weathering Reduces Strength

Exposure to fungi and ultraviolet radiation (UV) can weaken fibers, reducing fiber strength. The role of UV light is currently being investigated, but appears to be associated with dry climates where bolls opening during the summer are exposed to long hours of bright sunlight. Absorption of the UV light by certain minerals in the fiber may break some cellulose molecules and weaken fiber strength. Strength is highly dependent on both the average length of cellulose molecules in the fiber and uniformity of the cellulose molecules. The studies from California, Arizona and West Texas (all bright sunlight environments) show a reduction in fiber strength with weathering. Locations in the Mid-South show no consistent reduction in strength.

Weathering Reduces Micronaire

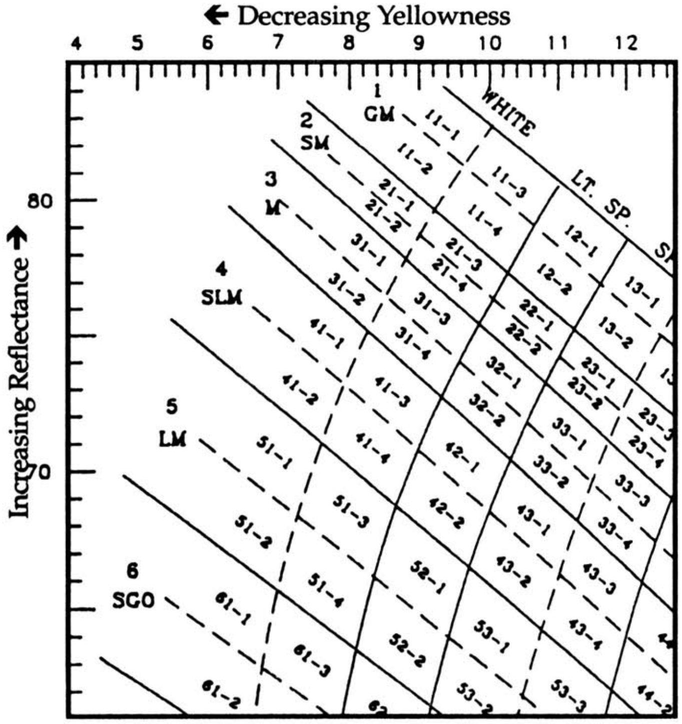
When lint grays and darkens due to weathering, it is because fungi are feeding on the lint. This feeding creates a rough surface that can retard air movement in the micronaire chamber, causing weathered cotton to occasionally suffer a slight reduction in micronaire reading. Also when wet weather removes non-cellulosic components, more fibers would be included in the micronaire chamber, further retarding air flow and lowering mike.

Even in a dry climate, such as the San Joaquin Valley, micronaire and color can decline substantially due to weathering; micronaire dropped from 4.6 to 4.3, and grade dropped from Good Middling to Low Middling during an 80 day exposure period. Some rain did occur during this fall period. A reduction in micronaire due to weathering did not occur in all test locations.

Changes in Grade

In 1841 the Liverpool Cotton Brokers Association adopted the first official standards ever used for the uniform classing of cotton. With the introduction in 1914 of the Official Cotton Standards of the United States, a uniform system of grade was introduced into the U.S. Some of these initial grades have been eliminated, "Middling Fair", "Strict Good Middling" and "Blue Stained", but the basic system has carried through to the 1992 crop.

Starting with the 1993 crop, the traditional classers grade will be divided into a trash grade and a color grade. Separate designations for the presence of bark, grass, and rough preparation will be noted as additional codes. The color grade will still be determined by the classer but now assisted with HVI colorimeter readings of yellowness and reflectance and a Nickerson-Hunter diagram indication of color grade (part of which is drawn below).



The precision of HVI allows an increase in accuracy. Thus an additional digit or quadrant will be added to the HVI color grade. The grade 31, Middling White, will be split into 4 quadrants (31-1, 31-2, 31-3 and 31-4), with quadrant 31-1 being the whitest and least yellow in the Middling White grade, and quadrant 31-4 having the most amount of grey and yellow.

Measuring Color

Fiber color can be accurately measured on HVI systems using a colorimeter. Colorimeters determine both the reflectance or grayness (Rd) and degree of yellowness (+b). The reflectance is read off the vertical scale of the Nickerson-Hunter color diagram and the yellow is read off the horizontal scale. Normal ranges for reflectance and yellowness are 48 to 82 Rd and 5 to 17 +b, respectively, with increasing numbers referring to increasing reflectance and yellowness. Prior to field weathering, mature cotton lint typically has a reflectance (Rd) of 70 or higher and a yellowness (+b) of 9 or lower — color grade of 41-4 or better. As cotton weathers, it grays due to molds that grow on the lint. Even cotton classing standard boxes will change color as they age, especially if stored in warm, moist conditions.

The reduction in reflectance (more gray) is one of the most consistent quality losses due to weathering. With the identification of a separate color grade, both highly-weathered, clean cotton and non-weathered, trashy cotton will stand out, because no longer will the color grade be masked by the trash or bark content.

Alteration in Spinning Performance

Grade has historically been used to predict spinning performance and thus desirability by the textile industry. The whiter grades have generally suffered less field weathering and deterioration of the lint surface.

Cotton that has severely discolored is undesirable in the textile mill because the lint surface is deteriorated and because of occasional dye problems. Discolored lint poses a marketing problem for certain yarn mills because of the potential for off color when dyed in lighter colors. Although, dark colored dyes can mask uniformly discolored fiber. Discolored lint also can require more bleaching prior to dyeing. Deterioration of the lint surface increases its roughness and affects the way the fibers slide across each other in the spinning process. Spotted, tinged, or stained cotton is more likely to result in weaker and uneven yarn. Field weathered cottons suffer increased fiber breakage resulting in higher short fiber content, which lowers yarn evenness and quality.

Minimizing Weathering

In the rainbelt, limiting weather-related loss is a season long effort to "keep the plant on schedule"; and even then, the occasional year arises (such as 1984) when early and late fields suffer severe boll weathering. "Keeping the plant on schedule" requires season-long monitoring of plant development and avoidance of any stress that delays crop maturity, whether it is thrips, plant bugs, herbicide injury, excess nitrogen, or rank growth. Short season production practices have been discussed extensively in previous newsletters, however, several points need to be emphasized.

Compress the Boll Retention Cycle

When bolls are set over a short time period, they open over a short time period, especially if the temperatures are warm. Recent years have demonstrated that 3-bale per acre yields can be set over a 4 week period. No longer do we need a long effective flowering period to develop high yielding crops. The following inputs compress the boll setting cycle while maintaining yields.

- Avoid skippy stands and very low plant densities. The cotton plant adjacent to a large skip can use its branches to reach into the sunlight, setting bolls way out on fruiting and vegetative branches; these bolls develop much later than bolls set close to the mainstem.
- Narrow-row cotton, along with short season production practices, can compress the fruiting cycle by reducing bolls at the top of the plant and wide on the plant. Plant maps of well-managed conventional and narrow row fields clearly show this boll shift in Mississippi.
- Moderate to high plant densities can compress the fruiting cycle if plant height is kept under control. Boll retention on vegetative branches and further out on fruiting branches (position 3 or wider) is dramatically reduced at moderate to high densities.
- Plant growth regulators, such as Pix, shift bolls from the top of the plant to the bottom of the plant (see May, 1991, Cotton Physiology Today).

Shift Boll Opening Period to the "Dry" Months

Cotton production practices have been developed and refined over the last 50 to 100 years (depending on the region) to match the long term weather patterns, such as rainfall. Dryland cotton producers successfully manipulate planting dates so the rainy month coincides with the bloom period and the dry months with the harvest season. Listed below is the monthly rainfall averaged over the farming region of a state. As we move north in the Cotton Belt, the dry month shifts later in the year.

Monthly Rainfall for Cotton States

State	June	July	Aug	Sept	Oct	Nov	Dec
Texas (LRGV)	2.7	**1.5**	2.8	5.2	3.5	1.4	1.2
Texas (Central)	2.6	**1.8**	**2.0**	3.2	3.1	2.2	1.9
Texas (Plains)	2.8	2.3	2.2	2.1	1.8	**0.6**	0.5
Louisiana	4.3	5.2	4.4	4.2	**3.6**	4.5	5.7
Mississippi	3.7	4.5	3.2	3.5	**3.2**	4.8	5.6
Arkansas	3.6	3.7	3.2	3.7	**3.2**	4.8	4.6
Tennessee	3.9	4.5	3.5	3.6	**3.0**	4.7	4.9
Missouri	4.2	3.9	3.7	3.9	**3.2**	**2.9**	2.4
Georgia	4.3	5.4	4.6	3.9	**2.3**	2.8	4.0
Alabama	4.0	5.3	4.1	4.2	**2.9**	4.0	5.2
S. Carolina	4.7	5.5	5.2	4.3	**2.8**	2.7	3.4
N. Carolina	4.5	5.6	5.3	4.5	**3.2**	**3.2**	3.5

Defoliation Practices

Regardless of the time of harvest and length of the bloom period, rainbelt producers still have the ability to schedule harvest closely after defoliation. Some producers look at the temperature forecast, the expected response of the crop to harvest aids, and then back up their application from the anticipated harvest date.

Preconditioning applications of harvest aids do not fully prepare the crop for harvest, yet open some bolls; this increases the exposure time for weathering. Where weathering is a problem, producers often hit the crop hard with the 1st application of harvest aids and then follow with a 2nd for remaining leaves or bolls.

In stripper cotton, loss of grade by foreign material is severe following a freeze that terminates actively growing cotton. When a freeze injures green cotton, leaves desiccate and remain on the plant. In addition, cells in the moist stem of green cotton are ruptured by ice formation and the bark readily peals off and contaminates the stripped cotton. Applications of harvest aids to green cotton prior to a freeze can start the dry down and leaf shed process necessary for clean stripper harvest.

Harvest Practices

Cotton that has discolored due to moisture will bleach and lighten following bright sunny weather. Producers in the Mid-South will delay harvest for 2 to 3 days following a storm to allow the cotton to brighten, often recovering one full color grade.

In the rush to get the crop harvested, don't overlook the importance of keeping the harvester clean and in proper adjustment. As the crop is weathered, harvest efficiency will tend to decline. Worn or improper adjustment of the doffers will increase picker wrap and increase neps in ginned lint. It is a good practice to begin harvest in fields that usually remain wet and soggy after a rain and save the "high ground" until last.

WRAP-UP

Although some color can be lost from weathering even during a dry fall, yield and severe grade loss occur when open bolls are left out in the rain. We can't control the weather but we sure can control the plant. If we prepare it for a timely and rapid boll opening and then closely coordinate harvest with defoliation and crop status, we will have done our best to maximise yield and quality.