MAPPING VARIABILITY IN COTTON FIBER MATURITY

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Abstract

The fiber processing characteristics of a cotton crop are determined by the maturity and variability of the individual fibers within the crop. Immature fibers are finer, flatter, and more elastic than fully mature fibers of a genotype because the fiber walls are thinner and the fibers are incompletely 'filled' with secondary wall cellulose. Consequently, immature fibers tend to stretch elastically, rather than break, when tension is applied and can recoil into tangled snarls when tension is released. The snarls and knots formed during fiber processing often contain entrapped mature fibers, and these tangled fiber masses appear in yarn and finished fabric as neps visible to the unaided eye. Further, the lower cellulosic content of the cell walls of immature fibers results in decreased dye uptake, which is seen as undesirable color shadings or barré when fibers of markedly different maturities are combined or in 'white' specks when the immature and mature fibers in a nep mass do not dye evenly and to the same degree.

Cotton fiber maturity can be defined as *chronological* maturity or days post floral anthesis. However, within a single plant and within a field or crop, quantitations of fiber maturity as days post floral anthesis are confounded by variations in flowering date introduced by the indeterminant flowering habit of cotton. The bloom period can extend over six to eight weeks, depending upon genotype, temperature, and other environmental factors. In contrast, fiber *physiological* or *biochemical* maturity can be defined as the ratio of fiber primary cell wall to the almost 100% cellulosic secondary cell wall. Measurements of primary:secondary wall ratios are quantitative and relatively insensitive to real time elapsed after fiber initiation, but such chemical methods are destructive and intensive in both instrument cost and labor. Fiber *physical* maturity can be quantified as the degree of secondary cell wall thickening resulting from fiber filling. Such measurements of fiber filling made using

the AFIS particle sizer are rapid, reproducible, and nondestructive.

AFIS-quantified fiber circularity [*theta*] and the corresponding circularity distribution function, Immature Fiber Fractions [IFF] were used to map fiber maturity and the dependence of physical and, to some extent, physiological fiber maturity upon growth environment factors and genotype. (Fiber circularity or *theta* is defined by a ratio of the cross-sectional area to the perimeter [$\theta = 4\pi*area*perimeter^{-2}$] where $\theta = 1.0$ is the circularity of a perfect circle and IFF = the percentage of fiber with $\theta < 0.250$.)

Fiber maturity varies with seed location within the locule and with boll location on the plant. For example, the least mature [highest IFF] fibers were found nearest the locule apex in the 'low' [node 7] crop of DPL51 grown in Corpus Christi, TX. Within a single meter of row [seven PD3 plants grown in Florence, SC] IFF varied from 6.2% at branch position two of node 6 to 25.1% at branch position two of note 12. IFF tended to be higher at outer branch positions and, logically, at higher fruiting nodes.

Variations in temperature, insolation, and rainfall [or irrigation] also introduce variations in cotton fiber maturity. In a South Carolina growing season characterized by low rainfall during the month before flowering began and excessive rainfall during the peak bloom period, in-row irrigation increased PD3 boll load at the expense of fiber maturation and property homogeneity. Metabolic resource limitations linked to low insolation during peak bloom and excess rainfall in that same period resulted in higher IFF percentages in irrigated cotton plants, compared to the lower-yielding rainfed plants in the same study.

Temperature, particularly heat unit accumulation, is a major factor in cotton fiber maturation. Both fiber maturation rate and maturity at harvest depend on the cumulative number of degree days above 60°F [15.6°C]. In South Carolina, *total* degree days above 60°F [DD60] were not significantly different in 1991 and 1992, but total 1992 DD60 accumulations were slightly lower due to cool spring conditions that persisted through the normal early May planting date. Mid-season and late-season heat unit accumulations were similar in the two years. Higher DPL20 boll-set following the warmer 1991 spring let to elevated IFF levels, regardless of planting date. A two-week delay [mid-May] of the 1991 planting resulted in increased IFF levels in DPL20, DPL50, DPL90 and DPL5690. In 1992, when boll loads were lower, the delay of planting until mid-May increased IFF in DPL20 and DPL50 only.

Fiber maturation was modulated by *total* heat unit [DD60] accumulations and genotype responses to temperature. Heat unit accumulations during the first 50 days after planting had a significant influence on fiber maturation in the warmer spring of 1991, particularly in the case of DPL20

and DPL50, the earlier genotypes in this four-genotype study. In the cooler spring of 1992, DPL20 and DPL90 were more sensitive to heat unit accumulations during the first 40 days after planting. DPL5690 was the least sensitive to heat unit accumulations during the last 50 days before harvest. DPL20 and DPL90 maturation responded more strongly to late-season temperatures.

Heat-unit accumulation differentials were also factors in fiber maturity variations in bolls from July and August flowers of Upland and Pima genotypes grown in Starkville, Mississippi. Flowering date and the related differences in heat unit accumulations modulated both fiber maturation rate and maturity at harvest in DPL5415, DES119, and Pima S-6. Fiber maturation rates in bolls from August flowers were higher than those observed in bolls from July flowers, but this rate compensation did not lower IFF levels to those found in bolls from July flowers.

Cotton fiber maturity estimates and predictors based on heat unit accumulations are improved by the incorporation of additional environmental factors such as insolation and rainfall. In seasons when rainfall was not a limiting factor, inclusion of day-length and insolation in linear models of fiber maturation [IFF] on heat unit accumulations raised the linear regression coefficient above 0.80. The multi-factor predictors were somewhat more effective for Upland than Pima genotypes.

Other environmental factors, such as elevated CO_2 and ozone also modulated fiber maturity. Added ozone decreased DPL51 IFF when soil nitrogen was limited but increased IFF when nitrogen was sufficient or in excess. Doubling the CO_2 levels increased IFF when soil nitrogen was high and no ozone was added to the system. However, the separate effects on fiber maturity of both ozone and CO_2 disappeared when both gases were added to the growth chamber.

Finally, spatial variability within the field is a highly significant factor in determining fiber maturity. The high soil moisture in low areas of a South Carolina field correlated with nodes of high IFF [and low yield]. Lower-yielding areas with lower soil moisture produced more mature fiber. Further discussion of this Precision Agriculture study can be found in the companion abstract, "Influence of Soil Properties on Cotton Fiber Quality Variation" by R.M. Johnson, J.M. Bradow, P.J. Bauer, and E.J. Sadler.

These IFF data describe fiber maturity in crops from multiple years in coastal South Carolina, coastal Texas, the Mississippi Delta, and growth chambers. Predictive equations and growth environment X maturity relationships derived from data from one of these fiber sources have been found to be 'applicable' to fibers from another source. Further, the IFF patterns in these maps of fiber maturity are closely related to glycoconjugate maps of fiber grown in

northern California [Sacramento Valley], and other researchers' plant mapping studies in the High Plains of Texas suggest that the environment X fiber maturity relationships in that quite dissimilar part of the Cotton Belt are similar to those reported here.

Variability in cotton fiber maturity results in lost income of more than $70 million per year for produces because approximately 30% of the US cotton crop does not meet processing fiber quality requirements. Mapping fiber maturity [IFF] across time and space in the studies from which these data were drawn indicates that the spatial and temporal mapping techniques of Precision Agriculture can be used to generate predictors of fiber quality and improved definitions of the quantitative relationships between variations in growth environment and variability in fiber processing characteristics.

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