HOW VARIETY AND WEATHER DETERMINE YARN PROPERTIES AND DYE UPTAKE

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Abstract

Both variety (genotype) and weather (growth-environment components) are accepted as important factors in determining cotton fiber yield. The relationships between cotton genotype and those fiber-quality characteristics considered most important by textile manufacturers have also been examined, and genotypes with *potential* for producing high yields of fiber with superior spinning properties have been developed. However, just as weather conditions during the growing season reduce fiber yields, the growth environment also alters important fiber-quality characteristics like micronaire and maturity (the fiber properties most closely related to dye-uptake success). Significant genotype-environment interactions further complicate both the maximization of yields and the achievement of cotton fiber properties demanded for modern textile processing. For example, when eight Upland cotton genotypes were grown in South Carolina in 1991 and 1992, fiber-quality quantitation by AFIS showed that genotype was a significant determining factor in fiber length, short fiber content, diameter, circularity, immature fiber fraction, area, fine fiber fraction, micronAFIS, and perimeter. However, growth environment also modified *all* AFIS fiber properties; and genotype interacted with environment to modify fiber length, short fiber content, circularity, immature fiber fraction and micronaire. When yarns spun from the eight genotype fibers were tested, genotype was a significant factor in yarn nep counts, strength, elongation percent, and breaking tenacity. Environment was a factor in yarn nep counts, uniformity, strength, elongation, and tenacity. Genotype and growth environment were significant factors in dye-uptake success.

Introduction

Each growth environment is a distinct composite of factors that can be controlled by the cotton producer (fertilization, planting date, irrigation) and uncontrolled weather factors (temperature, rainfall, and insolation). This 'quality' composite of the growth environment determines cotton fiber properties, both through modifications of metabolic rates during fiber development and through interactions between genotype and growth environment that limit realization of full genetic potential [Bradow, et al., 1996a]. Fiber maturity is particularly sensitive to growth environment, alone and in interaction with genotype [Bradow et al., 1996b], and maturation rates are particularly sensitive to the thermal growth environment [Johnson et al., 1996; Bradow et al., 1996b; Bradow and Bauer, 1997].

When the fiber properties of saw-ginned bulk samples of four Upland cotton genotypes [Bauer and Bradow, 1996] were determined by AFIS (Zellweger-Uster Advanced Fiber Information System), growth environment was a strong factor in determining those fiber properties most closely related to fiber maturity, *i.e.*, circularity, immature fiber fraction, cross-sectional area, fine fiber fraction, and micronaire [Bradow et al, 1996b]. Fiber maturity, in turn, is related to some yarn spinning properties and, more specifically, to dye uptake success [Smith, 1991; Pellow et al., 1996]. In this report, the significant effects of growth environment and genotype on fiber, yarn or dye uptake properties of four Upland genotypes are identified; and the roles of a single environmental factor, temperature, in determining those fiber, yarn and knit-fabric characteristics are discussed.

Materials and Methods

Four commercial Upland cotton (*Gossypium hirsutum L.)* genotypes were used: Deltapine 20 (DP20); Deltapine 50 (DP50); Deltapine Acala 90 (DP90); and Deltapine 5690 (DP5690). The experimental design has been described elsewhere [Bauer and Bradow, 1996]. In brief, the four genotypes were planted in randomized complete block designs with four replicates on Typic Kandiudult soils in Florence, South Carolina in 1991 and 1992. Planting dates, harvest dates, season lengths, total rainfall, and total and periodic heat-unit (DD16 or Degree-Day-16°C) data are shown in Table 1. All fiber was spindle-picked and saw-ginned before the analyses of fiber properties and spinning and dye-uptake testing.

Fiber properties were quantified by the AFIS airflow particle-sizer (Advanced Fiber Information System, Zellweger-Uster) [Bradow et al., 1996a; 1996b]. Definitions and abbreviations for AFIS fiber properties are listed in Table 2.

All AFIS fiber property, yarn-testing, and dye-uptake testing data were subjected to two-way analyses of variance with genotype and environment (crop year + planting date) as the main effects and data pooled over planting date (n = 12). Where significant effects of environment on a specific fiber property, yarn property or dye-uptake parameter were found, three-way analyses of variance were used to determine whether the environment-induced modifications in that property were related to crop year, planting date, or the interactions of those two environment components (n = 4). Where planting date was found to be a significant environmental factor, linear regression models were constructed for individual fiber properties versus heat-unit (DD16) accumulations at 50, 100, 150 days after planting (DAP) and at harvest.

Discussion

The fiber samples tested in this study were bulk samples grown under prevailing weather conditions with cultural inputs (fertilizer and pest control applications) recommended for the growing region and season. Staggered harvest dates resulted in minimal weathering of the field opened bolls. In short, *each* of the 96 fiber samples was randomly selected from a well-grown crop and could be considered the equivalent of a bale sample such as would have been sent to the USDA, AMS classing office in Florence, SC in 1991 or 1992.

Yarn production and testing were done with replication under standard opening, carding, and spinning conditions. Dye testing was also done under standardized conditions with replication, as were the Hunter colorimeter readings. Significant differences were found between the color components means for the smooth and looped sides of knits, and results have been reported separately for the two sides of the knit swatches. No white specks were found in *any* of the 192 dyed knit swatches examined in this study, but color variations among and within the dyed swatches were readily detected with the unaided eye. Easily visible examples of barré were found in some, but not all, dye swatches.

Effects of Genotype and Environment on Fiber and Yarn Properties. Genotype was a significant factor in determining all 11 AFIS-quantified fiber properties (Table 1). The most pronounced environmental effects were upon the variability of those fiber properties most closely associated with fiber maturity, *i.e.*, θ, IFF, A[n], micronaire and Pc. (The definitions and abbreviations for AFIS fiber properties are found in Table 2.) There were also significant interactions between genotype and growth environment in the short fiber content, θ, and IFF data.

Genotype had no effect on yarn nep counts or uniformity, and yarn breaking strength and breaking tenacity, and count strength product (CSP) were determined by genotype alone (Table 3). Yarn elongation percent was determined by both genotype and environment, and a strong interaction existed between genotype and environment in the CSP data.

Significant relationships existed between DD16 heat-unit accumulations and yarn nep counts, yarn uniformity, breaking strength, elongation percent, breaking tenacity, and CSP (Table 4). Heat-unit accumulations before flowering affected nep counts, and elongation percentages only. Higher DD16 accumulations in the spring decreased nep counts and increased yarn elongation percentages. Higher temperatures during flowering (roughly 50 to 100 DAP) increased yarn breaking strength, elongation percent, and breaking tenacity. Increased DD16 accumulations between cutout and harvest decreased nep counts and increased yarn uniformity coefficients of variation and elongation percentages. Higher fall temperatures decreased yarn CSP. Correlations between DD16 and yarn elongation percent accounted for as much as 67% of the variability, depending on year and genotype.

Relationships between DD16 heat-unit accumulations at different stages in the growing season and fiber properties have been discussed elsewhere [Bradow and Bauer, 1997]. Here, the correlations between DD16 accumulations and yarn properties are noteworthy for three reasons: (1) thermal environment before and during flowering significantly modified cotton fiber characteristics at harvest; (2) the effects of those modifications persisted through yarn processing as significant differences in the properties of yarn made from those environmentally modified fibers; and (3) linear relationships between DD16 accumulations and yarn properties are independent of any individual fiber property. Linkages between fiber properties and spinning success and the effects of temperature on fiber maturation rates do appear, particularly in yarn elongation percent, the yarn property found to be most closely associated with fiber maturity.

Effects of Genotype and Environment on Undyed Fiber Color Components. Genotype and genotype response to the growth environment were the main factors in determining yarn properties, but growth environment determined the color of the undyed fiber (Table 5). There were no significant genotype-related differences in fiber whiteness (+L), redness (+a), or yellowness (+b) in the Hunter colorimeter assays.

Heat-unit accumulations during the first 50 days after planting had significant effects on all three color components of *undyed* fiber (Table 6). Higher temperatures before flowering increased the 'whiteness' and 'redness' color components while decreasing the yellowness component. Temperature during the blooming period had no effect on fiber 'redness', but higher temperatures during the period from 50 to 100 DAP produced whiter (higher +L) fiber with less of a yellow tinge (lower +b). Higher temperatures during the period between cutout and harvest also produced fiber with higher +L and lower +b, but +a was also increased by higher DD16 accumulations during that period. The correlations between DD16 and undyed knit color components accounted for as much as 83% of the variation in greige knit color, depending on color component considered and independent of genotype. Undyed fiber whiteness (+L) and yellowness (+b) were most closely correlated with DD16 accumulations.

Effects of Genotype and Environment on Color Components of Blue-Dyed Knits. Genotype was not a factor in the color of the undyed fiber, but genotype, independent of growth environment, did affect the lightness (+L) of the blue-dyed knits (Table 7). Genotype was also a factor in the green (-a) and blue (-b) color components. Growth environment, which did not interact significantly with genotype, modified the green (-a) component of the looped side only of the dyed knits and the blue (-b) component of both the looped and smooth knit faces.

Although there were no significant environmental effects on blue-dyed knit +L in Table 7, thermal-environment effects upon fiber maturity [Bradow and Bauer, 1997] suggested that DD16 accumulations that decrease fiber maturity might also alter apparent fiber dye uptake by increasing the +L color component of the dyed knits. This positive relationship between higher temperatures and higher dyed-knit +L (lighter color) was indeed found for DD16 accumulations between 0 and 50 DAP and 50 and 100 DAP (Table 8). Higher temperatures early in the season and during flowering increased boll loading, yield, and, thus, competition for resources [Bauer and Bradow, 1996; Bradow and Bauer, 1997]. That competition for metabolic resources resulted in higher immature fiber fractions and, in the case of dyed knits, lighter colors. Higher temperatures from 0 to 100 DAP increased dyed-knit +L, *i.e.*, lightened the color of the knit swatches. After cutout, increased temperatures resulted in greater fiber maturity and improved dye uptake (negative slope in the DD16 versus +L regression equation).

Higher temperatures during the first 100 days after planting increased the depth of color or the 'blueness' (-b) of the dyed knits. This DD16 effect was particularly pronounced during the 50 to 100 DAP period (Table 8). Thus, higher DD16 accumulations modified the physical characteristics of cotton fibers so that blue-dyed knits made from the modified fibers produced were a 'truer' blue (more negative -b) but a lighter shade of blue (more positive +L). The reversals of the early-season regression slope directions in the period from 100 to 150 DAP were similar to those reported in a study of the effects of thermal environment on fiber maturity characteristics [Bradow and Bauer, 1997]. None of the DD16-based regression equations accounted for more than 30% of the variation in the blue-dyed knit color components.

Effects of Genotype and Environment on Dye Uptake Success. Dye uptake success was more easily quantified by using vector geometry to compare the differences in the color components before and after dye application [Hunter, 1975]. The three-dimensional Total Color Difference (TCD) vectors allowed comparison of the differences in all three color components before and after dye application (Table 9). The two-dimensional Chromaticity Difference (CD) vectors allowed comparison of only the differences in ±a and ±b (also Table 9).

Environment was the only significant factor in either TCD or CD analyses of variance. Higher DD16 accumulations resulted in higher TCD (Table 10), and the thermal environment during the period between 50 and 100 DAP had the greatest positive effect on dye uptake quantified as TCD. Chromaticity Difference, which does not include the whiteness/lightness +L component, decreased with increased temperatures, regardless of post-planting time period. Since the absolute values of the ±b color component were much larger than those of the ±a color component, thermal effects on CD agreed with those reported for ±b in Tables 6 and 8. Depending on the crop year and post-planting interval within the year, the DD16 regression equations accounted as much as 73% of the variation in TCD and 64% of the variation in CD.

Environment (year + planting date), but *not* genotype, was an important factor in the significant Total Color Differences and Chromaticity Differences of the blue-dyed knits and in fiber maturity. This report examined the effects of the thermal environment alone, but thermal environment was not, of course, the sole determinant of fiber maturity nor of the dye-uptake and yarn properties related to fiber maturity. Neither were extrapolations from properties of field-matured fiber the best descriptors of fiber maturity and maturation rates. However, these effects of the overall thermal environment on fiber maturation and variability are consistent with those described in another time-line study of cotton fiber maturation [Johnson, et al., 1996; Johnson et al., 1997] in which are described the effects of micro-environment factors, including DD16, on the properties of fiber collected at 21, 28, 35, 42, and 56 days post floral anthesis.

Summary

The strong effects of genotype on fiber and yarn properties were expected. So too were the significant effects of growth environment on fiber characteristics, particularly those properties most closely associated with fiber maturity. Somewhat less predictable were the significant effects of growth environment on yarn uniformity coefficients of variation and nep counts. Higher temperatures after cutout decreased nep counts by increasing fiber

maturity, and the mechanisms by which higher spring temperatures decreased nep counts and higher fall temperatures increased yarn uniformity coefficients of variation have yet to be determined. Higher temperatures during flowering also increased yarn breaking strength, tenacity and elongation percentage even though the first two yarn properties were not significantly affected by growth environment.

The color components of undyed fibers were determined by environmental, not genetic factors. Higher temperatures during any part of the growing season increased fiber whiteness and decreased fiber yellowness. Higher spring and fall temperatures also increased the red color component. Genotype was a factor in the 'lightness' and 'blueness' color components of blue-dyed knits. Environment affected only the 'blue' and 'green' color components of the dyed knits. However, environment, not genotype, was the significant factor in dye uptake success quantified as Total Color Difference or Chromaticity Difference. Environmental factors associated with decreased fiber maturity and increased yield were also linked to lighter, less true colors in the dyed knits.

The anticipated linkage between yarn elongation percentage and fiber maturity was found and quantified, as was the anticipated relationship between fiber maturity and dye-uptake success. The pre-bloom thermal environment was found to be an unexpectedly significant factor in fiber maturity levels at harvest. Even less foreseen was the persistence of early-season thermal-environment effects through yarn and dyed-knit production and the significance of those effects on dye take success in particular.

Disclaimer

Trade names are necessary for reporting factually on available data. The USDA neither guarantees nor warranties the standard of the product or service, and the use of the name USDA implies no approval of the product or service to the exclusion of others that may be suitable.

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Table 1. Significant effects of genotype and growth environment on cotton fiber properties.

Fiber Property [Quantified by AFIS]	Mean Square and Significance Level		
	Genotype	Year	Genotype X Year
L[w]	0.002 **	ns	0.001 *
SFC[w]	38.07 ****	6.83 *	7.42 **
L[n]	0.001 ****	ns	0.002 *
SFC[n]	154.16 ****	ns	17.29 **
D[n]	12.30 ****	ns	ns
θ	0.019 ****	0.017 ****	0.001 **
IFF	40.53 ****	27.31 ***	7.13 **
A[n]	258.48 ****	295.65 ***	ns
FFF	67.59 ****	13.24 *	ns
micron-AFIS	1.59 ****	2.95 ****	0.236 *
Pc	87.57 ****	11.54 ****	1.43 *

ns = $p > 0.1$; *, **, ***, **** indicate $p < 0.1$, 0.05, 0.01, and 0.001 respectively.

Table 2. AFIS fiber property definitions and abbreviations.

Fiber Property	Abbreviation	Definition
Length by Weight	L[w]	Staple length by weight
Short Fiber Content by Weight	SFC[w]	% L[w] < 12.7 mm.
Length by Number	L[n]	Staple length by number
Short Fiber Content by Number	SFC[n]	% L[n]< 12.7 mm
Diameter by Number	D[n]	μm
Circularity	θ or Theta	Wall thickening, fiber maturity
Immature Fiber Fraction	IFF	% θ < 0.25.
Cross-sectional Area by Number	A[n]	Fiber cross-section in μm^2.
Fine Fiber Fraction	FFF	% A[n] < 60 μm^2.
micronAFIS	micronAFIS	Micronaire analog
Perimeter	Pc	Calculated from A[n] and Theta

Table 3. Effects of genotype and growth environment on yarn properties.

Yarn Property	Mean square and significance level		
	Genotype	Year	Genotype X Year
Nep Count	ns	1528.01 ***	ns
Uniformity CV%	ns	29.32 *	ns
Breaking Strength	27421.99 ****	ns	ns
Elongation Percent	7.44 ****	6.33 ****	ns
Breaking Tenacity	40.92 ****	ns	ns
CSP	9215.81 ****	ns	9683.49 ****

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 4. Relationships between yarn properties and heat-unit [DD16 accumulations at 50 and 100 days after planting [DAP] and at harvest. [1991 and 1992 data pooled for four genotypes, DP20, DP50, DP90, and DP5690.]

Yarn Property	Slopes of DD16 versus Yarn Property Regressions and Regression s Equation Significance		
	0 to 50 DAP	50 to 100 DAP	At Harvest > 150 DAP
Nep Count	-0.033 *	ns	-0.047 *
Uniformity CV%	ns	ns	+0.010 **
Breaking Strength	ns	+0.299 *	ns
Elongation Percent	+0.0036 ****	+0.011 ****	+0.002 *
Breaking Tenacity	ns	+0.123 *	ns
CSP	ns	ns	-0.091 **

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 5. Effects of genotype and growth environment on undyed [greige] fiber color as quantified by Hunter Colorimeter assays of the smooth and looped sides of knitted swatches.

Color Component	Mean Square and Significance Level		
	Genotype	Year	Genotype X Year
+L [whiteness color component]			
+L, smooth	ns	282.56 ****	ns
+L, looped	ns	275.40 ****	ns
+a [redness color component]			
+a, smooth	ns	40.51 ****	ns
+a, looped	ns	41.61 ****	ns
+b [yellowness color component]			
+b, smooth	ns	188.16 ****	ns
+b, looped	ns	199.81 ****	ns

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 6. Relationships between undyed fiber color components and heat-unit [DD16 accumulations at 50 and 100 days after planting [DAP] and at harvest. [1991 and 1992 data pooled for four genotypes, DP20, DP50, DP90, and DP5690.]

Color Component	Slopes of DD16 versus Yarn Property Regressions and Regression s Equation Significance		
	0 to 50 DAP	50 to 100 DAP	At Harvest > 150 DAP
+L [whiteness color component]			
+L, smooth	+0.0186 ****	+0.0536 ****	+0.0169 ****
+L, looped	+0.0188 ****	+0.0563 ****	+0.0164 ****
+a [redness color component]			
+a, smooth	+0.0046 ****	ns	+0.0085 ****
+a, looped	+0.0046 ****	ns	+0.0087 ****
+b [yellowness color component]			
+b, smooth	-0.0133 ****	-0.0264 ****	-0.0154 ****
+b, looped	-0.0135 ****	-0.0250 ****	-0.0161 ****

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 7. Effects of genotype and growth environment on color of blue-dyed fibers as quantified by Hunter Colorimeter analyses of the smooth and looped sides of knit swatches..

Color Component	Mean Square and Significance Level		
	Genotype	Year	Genotype X Year
+L [Lightness Color Component]			
+L, smooth	1.57 ****	ns	ns
+L, looped	1.12 ****	ns	ns
-a [Greenness Color Component]			
-a, smooth	ns	ns	ns
-a, looped	0.02 *	0.20 ****	ns
-b [Blueness Color Component]			
-b, smooth	0.30 ***	0.48 ***	ns
-b, looped	0.36 ****	1.15 ****	ns

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 8. Relationships between blue-dyed fiber color components and heat-unit [DD16 accumulations at 50 and 100 days after planting [DAP] and at harvest. [1991 and 1992 data pooled for four genotypes, DP20, DP50, DP90, and DP5690.]

Color Component	Slopes of DD16 versus Yarn Property Regressions and Regression s Equation Significance			
	0 to 50 DAP	50 to 100 DAP	100 to 150 DAP	At Harvest > 150 DAP
+L [Lightness Color Component]				
+L, smooth	+0.0011 ***	+0.0043 **	-0.0013 ****	ns
+L, looped	+0.0012 ***	+0.0039 ***	-0.0012 ****	ns
-a [Greeness Color Component]				
-a, smooth	ns	ns	ns	+0.0004 ***
-a, looped	+0.0002 **	ns	ns	+0.0007 ****
-b [Blueness Color Component]				
-b, smooth	-0.0009 ****	-0.0032 ***	+0.0008 ****	-0.0006 *
-b, looped	-0.0011 ****	-0.0032 ****	+0.0007 ***	-0.0012 ****

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 9. Effects of genotype and growth environment on dye uptake success quantified as Total Color Difference [TCD] and Chromaticity Difference [CD] of smooth and looped sides of knit swatches.

Dye Uptake Parameter	Mean Square and Significance Level		
	Genotype	Year	Genotype X Year
Total Color Difference [L ,a, and b vectors]			
TCD, smooth	ns	109.37 ****	ns
TCD, looped	ns	102.4 ****	ns
Chromaticity Difference [a and b vectors only]			
CD, smooth	ns	164.74 ****	ns
CD, looped	ns	165.90 ****	ns

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

Table 10. Relationships between Total Color Difference or Chromaticity Difference and heat-unit [DD16] accumulations at 50 and 100 days after planting [DAP] and at harvest. [1991 and 1992 data pooled for four genotypes, DP20, DP50, DP90, and DP5690.]

Dye Uptake Parameter	Slopes of DD16 versus Yarn Property Regressions and Regression s Equation Significance		
	0 to 50 DAP	50 to 100 DAP	At Harvest > 150 DAP
Total Color Difference [L ,a, and b vectors]			
TCD, smooth	+0.0119 ****	+0.0359 ****	+0.0107 ****
TCD, looped	+0.0119 ****	+0.0391 ****	+0.0099 ****
Chromaticity Difference [a and b vectors only]			
CD, smooth	-0.0122 ****	-0.0232 ***	-0.0146 ****
CD, looped	-0.0124 ****	-0.0218 ***	-0.0147 ****

ns = p > 0.1; *, **, ***, **** indicate p < 0.1, 0.05, 0.01, and 0.001 respectively.

AUSTRALIAN AND AMERICAN EXPERIENCE WITH RAPIDCON

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Abstract

Slow, passive and rapid, active conditioning concepts and developments are reviewed. RapidCon, a new rapid conditioning machine for HVI samples, is described. Observations based upon the initial year of experiences are given.

Introduction

It is known that the state of samples undergoing material property testing can affect test results. Rigorous sample preparation steps, which determine the sample state, are critical to obtaining precise and accurate test results. For HVI samples, environmental conditions in which these preparation steps take place are major factors in determining the testing precision and accuracies of the HVI readings of cotton quality. For most of this century, fiber, yarn and fabric tests, and preparations therefor, have been conducted in "standard conditions" of 65% RH, 70° Fahrenheit (21° Celsius). These conditions are sometimes referred to as ASTM conditions. What matters most, for good test results, is not just conditions in the laboratory but conditions within the samples and within the testing zones of the instruments at the time of testing. The various ASTM methods for fiber, yarn, or fabric samples include the requirement that the samples to be tested are to be stored or conditioned for 72 hours prior to testing in the standard environment. This storage time presumably allows the samples to "reach equilibrium." It is noted that the samples so conditioned are passively equilibrating and that equilibrium usually refers to sample moisture content. Moisture content is only one fiber property measurement whose equilibrium value is of interest. For HVI, others include tenacity and length, for fibers, and such material properties are much more important for selling, buying and using the fibers than moisture content. (However, we emphatically note that moisture content affects other fiber material properties, and is therefore an important, control variable.)

Whereas equilibration times of 72 hours yield consistent test results, as established for over 75 years, such periods are unacceptably long in today's intensely competitive and information-hungry market place. Even 48 hours, which the USDA deemed adequate when they introduced HVI, or 24 hours, which is commonly practiced in HVI classing operations, are unacceptable. Isn't it ironic that we have an instrumentation system that can provide data within less than a minute but you have to wait 48 hours to get the data?

Recognizing the severe conflict between promptly available results verses good results (meaning precise and accurate results), the USDA folks began their investigations in the early 90's into actively and rapidly conditioning cotton samples. These investigations were remarkably successful. Well-conditioned laboratory air, actively drawn through the HVI samples, proved to be equivalent to 48 hours of passive conditioning, for which diffusional mass and heat transfer mechanisms prevail. Rapid conditioning is now employed in most of the 14 USDA classing offices. We would like to acknowledge the excellent work done by James Knowlton, Darryl Earnest, and Roger Alldredge of USDA/AMS. Vice President Albert Gore complimented them on this and other work with the "Hammer Award" that they received last year.