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UPDATE ON MICRONAIRE, MATURITY AND FINENESS RESEARCH

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Abstract

Fiber property research regarding the measurement of micronaire, maturity and fineness has been ongoing at the Southern Regional Research Center. This paper presents an update of the most recent advances in several aspects of this research. First, these fiber properties were measured with an upgraded Micromat Fineness and Maturity tester (FMT) as well as with a near infrared instrument (NIR). Cottons from two consecutive growing seasons (2001 and 2002) in fixed regions were evaluated from year to year and region to region. Secondly, the NIR was calibrated with over 200 cottons analyzed by the FMT. Prediction algorithms were generated and used to predict the fiber properties of a different set of cottons, the 2002 crop. Results were subsequently correlated with the FMT measurements. Thirdly, the experimental relationships between properties were investigated further and were determined to be governed by a family of continuous lines, rather than a single line.

Introduction

Recent advancements in micronaire, fineness and maturity measurements by the upgraded FMT and NIR (Montalvo and Von Hoven, in press; Von Hoven et al., 2001, 2002) allow for comparability studies of cotton. This paper provides updates on several comparability studies being conducted at Southern Regional Research Center.

First, cotton from two consecutive crop years, 2001 and 2002, was grown in various locations and was analyzed for micronaire, fineness and maturity by the FMT. Results are compared from year to year and from region to region. These cottons are included in the newly established Cotton Variety Processing Trials sponsored by the American Textile Manufacturers Institute (ATMI). The protocol for the ATMI study calls for the growing, harvesting, ginning, fiber analysis and processing on high-speed textile equipment of commercially available cotton varieties. First year trials were with crop year 2001 fibers.

For the second compatibility study, the ATMI crop year 2001 and 2002 cottons were analyzed by NIR and results are presented relative to the FMT data. To predict the fiber properties of the second crop year, the NIR was calibrated with over 200 other cottons to generate micronaire, fineness and maturity prediction equations.

The third investigation involved probing the relationships between the fiber properties by computing R^2 between paired variables. Using simplified methods, previous work (Montalvo et al., 2003) had suggested that the relationships between mirconaire and maturity, micronaire and fineness, and fineness and maturity are described by a family of lines instead of a single line. The experimental data in this paper is used to test the reported results.

Materials and Methods

A series of cottons were grown in West Texas, Mississippi and Georgia in the 2000 and 2001 growing seasons for the ATMI Cotton Variety Processing Trials. These cottons were cleaned with two passes on the Shirley Analyser and then tested on an upgraded FMT (Von Hoven et al., 2001, 2002). To ensure that the FMT was maintaining reproducibility during testing, a strict quality control protocol was followed that included physical standards that mimic mid-micronaire cotton used throughout the testing. Six replications of four-gram fiber samples were carded using Louete cotton hand cards with 100 picks per inch. The carded sample was then rolled into a sliver with a diameter of approximately 2 inches and inserted into the FMT with a specially designed mechanical device (Montalvo and Von Hoven, 2003). Replicate results were created to produce mean micronaire, fineness and maturity values for each cotton by the FMT.

The Shirley-cleaned cottons were also tested on a NIRSystems Model 6500 spectrophotometer (NIR Analysis software, 1990). Four spectra per sample were generated and averaged from two 24-gram cotton samples run with 2 spectral replications per sample. Each sample was placed off-center to a 12.7 cm diameter sample cell rotating at 2.2 rpm and over a quartz window. During one revolution of the sample cell, 32 scans were taken and averaged. Partial least squares analysis with one-out-rotation was used to correlate the spectral data with the fiber properties. Correlations, R^2, were then made between the NIR predicted fiber properties and the fiber properties as measured by FMT.

Three calibration trials were generated. First, only the ATMI 2001 crop year cottons were used for NIR calibration and validation. Second, only the ATMI 2002 crop year cottons were used for NIR calibration and validation. Third, the NIR was calibrated with 204 worldwide cottons. The independent validation set was the 2002 ATMI cottons, which were not in the 204-calibration set.

Since micronaire is accepted as a measurement that is influenced by maturity and fineness, the paired relationships, R^2, between the properties were studied. Using the FMT data on a set of 275 cottons and the 2002 crop year cottons, the relationships between micronaire and maturity, micronaire and fineness, and maturity and fineness were plotted. These relationships were also modeled using the fundamental properties of wall thickness and perimeter.

Results and Discussion

ATMI FMT Results

The averaged fiber properties of the ATMI cottons measured by the FMT for crop year 2002 were normalized relative to crop year 2001 fibers to allow for ease of comparability from year to year (Table 1). Micronaire and maturity values increased in 2002 for both West Texas and Georgia growing regions. Fineness increased in 2002 for the West Texas area but decreased in the Georgia region. The Mississippi cottons for the 2002 crop year were not available for the study.

The averaged fiber property values among regions within a crop year revealed interesting trends. For the 2001 crop: micronaire and maturity, MS>GA>WTX and fineness, GA>MS>WTX. For the 2002 crop year: micronaire, fineness and maturity, GA>WTX.

Mean differences from year to year and region to region are due to differences in genotypes, environmental conditions and farm management practices. In some instances, several producers supplied the cottons in a growing location. In others, the bale came from a single producer with similar growing, harvesting and ginning conditions. The genotypes were not the same in the three growing regions in the 2002 crop year study; the listing of genotypes was not available to aid in interpretation of results. In West Texas, the rain tends to be patchy so that it may rain in one field but not in the adjacent field. Also, about half of the cotton grown in West Texas is rain fed; the remainder is irrigated. As a consequence, differences in the properties are expected from year to year and region to region.

ATMI NIR Results

Table 2 shows the averaged ATMI NIR results for both crop years and results are also presented relative to the FMT. For the 2001 results, the NIR was calibrated and validated by cross validation, with only the 2001 cottons. For the 2002 results, the NIR was calibrated and validated by cross validation, with only the 2002 fibers.

Cross validation is the most intensive method of optimizing an NIR calibration model. In effect, cross validation attempts to emulate predicting “unknown” samples by using the training set data itself. Significant advances in the speed of PC calculations have made the cross validation technique universally accepted.

The cross validation procedure is initiated by selecting a sample from the training set and removing the cotton averaged spectrum and FMT data from the set. The remaining training set samples are used to develop a calibration model. Next, the model predicts the fiber properties of the removed sample and the residual error is noted. Next, the removed sample is placed back in the training set, a different sample is removed, and a new calibration model is developed and used to predict the fiber properties of the removed sample. The residual error is noted. Finally, after all samples have been left out and predicted, averaged fiber properties in the set and the R^2 between the FMT and NIR were computed.

The ratio values are very close to one, indicating no FMT or spectral outliers in the data sets. Note that the ratio values provide a quality control check of both measurement systems prior to: (a) combining the ATMI data with prior data to develop a larger master NIR calibration set or (b) analyzing the ATMI cottons by NIR as true unknowns, not included in the master NIR calibration set.

Figures 1-3 document the NIR prediction from 204 cotton calibration equations of micronaire, fineness and maturity for the 2002 ATMI crop cottons, which were not included in the calibration set. NIR does a very good job of predicting the fiber properties as seen with the high R^2 values in the correlations with the FMT data.

The NIR master calibration set was generated by combining spectra and FMT data from several sets of cottons. There was about one year lag between spectral acquisition of the first and last sample sets in the master calibration cottons. During this time period, a small change in NIR sensitivity was noted when the instrument was moved in the laboratory in order that modifications could be made to the room’s air conditioning system. This resulted in a small bias for the NIR fiber property calibration equations. As a result, the slope and intercept for the correlations between NIR and FMT data are non-ideal – i.e. not 1 and 0, respectively, so that the mean NIR to FMT ratios show small deviations, Figures 1-3. After correction for the effects, the mean NIR to FMT ratios are within 2% of the FMT values.

Benefits of NIR

The FMT measures cotton micronaire, fineness and maturity. This reference method is very labor intensive, extensive training is required, and is a destructive test in the short term. A one to two week delay is necessary between reuse of the same specimen to retain the property values and precision observed with the original measures (Montalvo and Von Hoven, 2003).

NIR offers substantial savings in time and cost to measure what the FMT measures. Other benefits of NIR include greater accuracy, ease of use and non-destructive testing. NIR may also improve the measurements of other fibers properties (Montalvo and Von Hoven, in press). These include organic matter, such as wax, plant matter (trash), sugars (plant and stickiness caused by aphids and white flies), fibrous and seed coat reps, color (yellowness, brightness and dyeability), moisture, strength and length.

R^2 Between Paired Fiber Properties

Previous work (Montalvo et al., 2003) based on simplified models suggested that because the relationships between micronaire and maturity, micronaire and fineness, and fineness and maturity are described by a family of lines, fitting the data to a single line model leads to variability in R^2.

The FMT data supports this hypothesis. Figures 4-9 are example plots illustrating the wide variability in R^2 for the two sets of cottons -- the 2002 crop year fibers, Figures 4-6 and the larger set of 275 cottons, Figures 7-9. A summary of the R^2 values is listed in Table 3. The R^2 varied among sets from 0.268 to 0.831. Within a sample set, the poorest correlations were between fineness and maturity. The best correlations were between fineness and micronaire. Thus, the R^2 values vary greatly between paired fiber variables for independent sample sets.

For this reason, the relationships were modeled by using the fiber's wall thickness (T) and perimeter (P) as independent variables since micronaire, maturity and fineness are functions of T and P (Montalvo, submitted for publication, 2003). The typical range for wall thickness is 1.4 to 3.4 µm while the typical range for perimeter is 35 to 60 µm as calculated from fineness values (Ramey, 1982) and maturity ratio values (Lord, 1988). Instead of observing one line per relationship, a family of lines became apparent, Figure 10. For example, at a fixed wall thickness of 1.5 µm, as perimeter increases, the range of correlations with micronaire remains small. At a wall thickness of 3.5 µm, as perimeter increases, the range of correlations with micronaire increases. Thus, there is inherent variability in the correlations of the fiber properties. This indicates that one measurement, such as micronaire, is not representative of both the fineness and maturity of a cotton and therefore both measurements are needed.

Conclusions

In this study, micronaire, maturity and fineness were measured on cottons grown in several regions over two consecutive years, 2001 and 2002, by an upgraded and calibrated FMT. The values of micronaire, maturity and fineness generally increased for the 2002 cottons and those cottons grown in Georgia had higher values of these properties than those grown in West Texas. When the NIR was calibrated with over 200 cottons, this analysis method predicted the fiber properties of the 2002 set of cottons very well. When plotting paired fiber properties, poor correlations emerged. This supports the theory that micronaire is not sufficient to quantify maturity, and that another independent measure of maturity is needed, such as FMT or NIR.

References

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Table. 1. Averaged FMT Fiber Properties, Crop Year 2001 and 2002.

Area grown	Mic	Mat	Fin (mtex)
2001 Crop Year			
W TX	3.21	0.68	160
GA	4.35	0.80	205
MS	4.62	0.85	203
2002 Crop Year			
W TX	3.66	0.79	167
GA	4.63	0.94	191
2002 Relative to 2001			
W TX	1.14	1.16	1.04
GA	1.06	1.11	0.93

Table. 2. Averaged NIR Fiber Properties, Crop Year 2001 and 2002, each year independent evaluation sets.

Spectral range:	400-2500 nm			1100-2500 nm		
Area grown	Mic	Mat	Fin	Mic	Mat	Fin
2001 Crop Year by NIR[a]						
W TX	3.21	0.68	162	3.22	0.68	161
GA	4.33	0.80	200	4.30	0.81	199
MS	4.63	0.85	212	4.65	0.84	213
Relative to FMT						
W TX	1.00	1.00	1.01	1.00	1.00	1.01
GA	1.00	1.00	0.98	0.99	1.01	0.97
MS	1.00	1.00	1.04	1.01	0.99	1.05
2002 Crop Year by NIR[b]						
W TX	3.66	0.79	166	3.66	0.79	166
GA	4.63	0.94	192	4.63	0.94	192
Relative to FMT						
W TX	1.00	1.00	0.99	1.00	1.00	0.99
GA	1.00	1.00	1.01	1.00	1.00	1.01

[a] cross validation, ATMI 2001 crop only

[b] cross validation, ATMI 2002 crop only

Table 3. Correlation Summary.

Data Set	R^2
ATMI Crop year 2002: NIR prediction from 204 cotton calibration equations	
NIR vs. FMT	
Mic	0.987
Mat	0.941
Fin	0.965
FMT Data	
Fin vs. Mic	0.764
Mat vs. Mic	0.578
Fin vs. Mat	0.268
Set of 275 cottons analyzed by FMT	
Fin vs. Mic	0.831
Mat vs. Mic	0.723
Fin vs. Mat	0.327

Table 4. Modeling the Relationships at Constant Perimeter.

y-axis[a]	x-axis[a]	curved	straight
H	T	☑	
M	T	☑	
Mic	T	☑	
H	M		☑
Mic	H		☑
Mic	M		☑

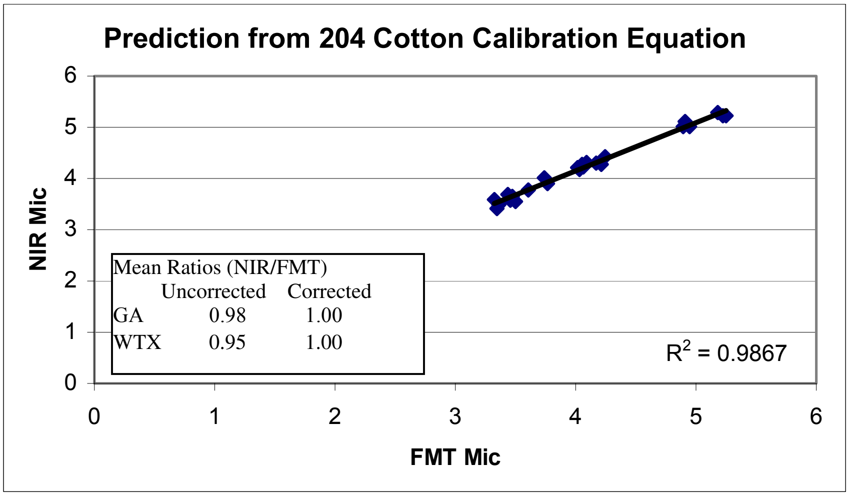

Figure 1. 204 Cotton NIR Prediction of 2002 crop micronaire values.

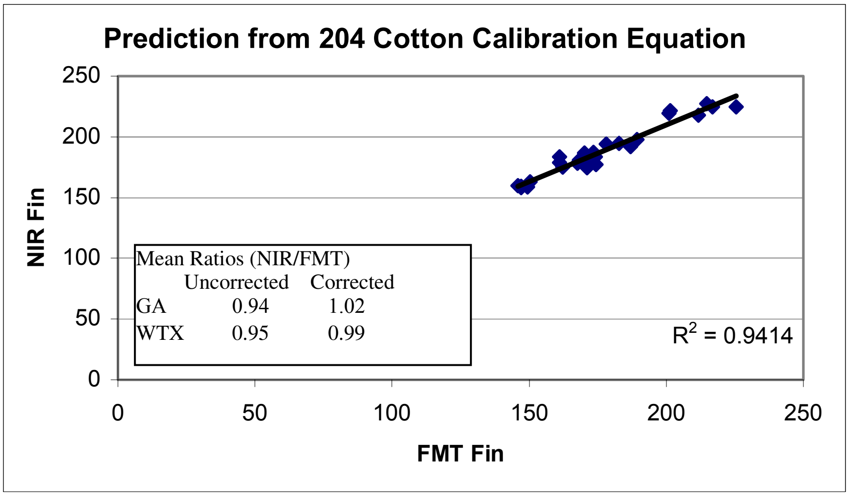

Figure 2. 204 Cotton NIR Prediction of 2002 crop fineness values.

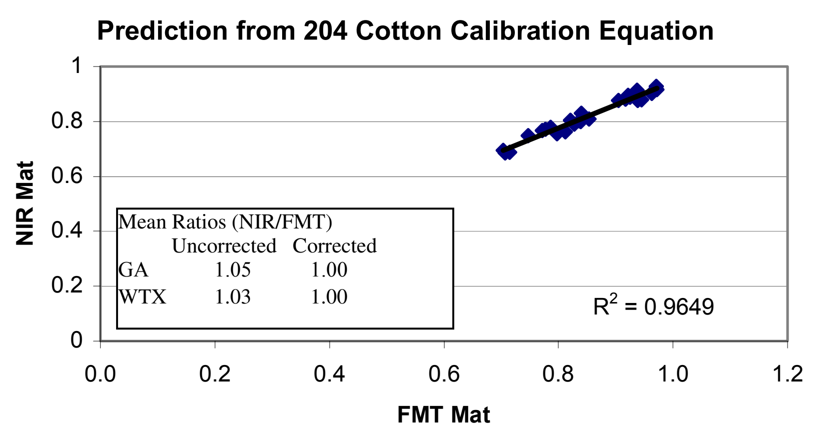

Figure 3. 204 Cotton NIR Prediction of 2002 crop maturity values.

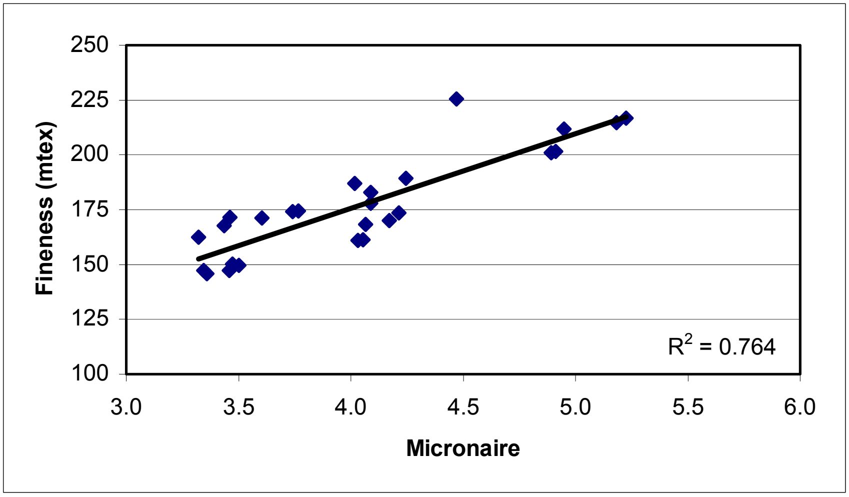

Figure 4. FMT Fineness vs Micronaire for 2002 crop year.

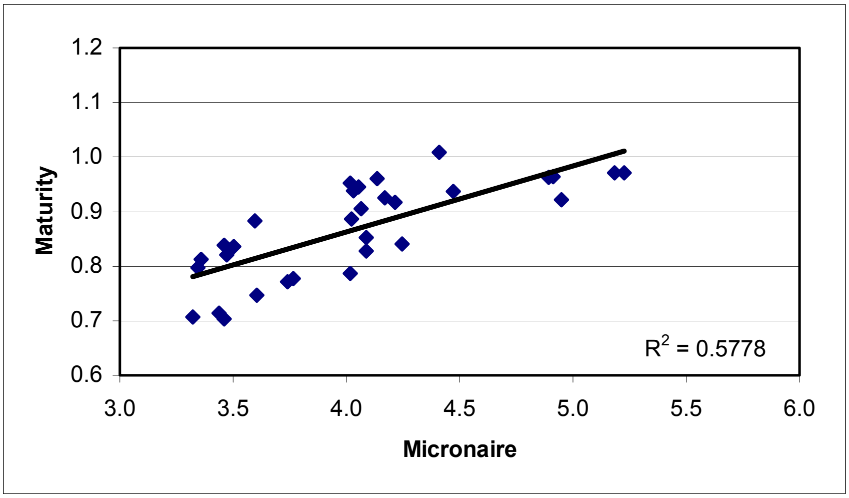

Figure 5. FMT Maturity vs Micronaire for 2002 crop year.

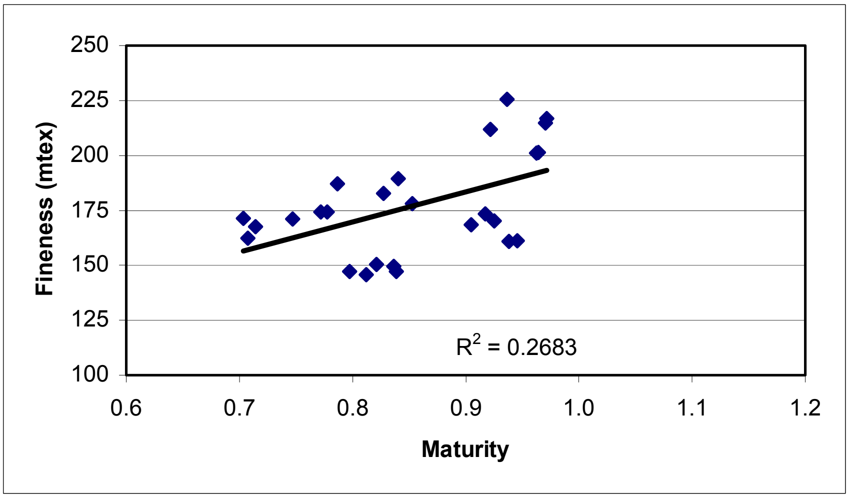

Figure 6. FMT Fineness vs. Maturity for 2002 crop year.

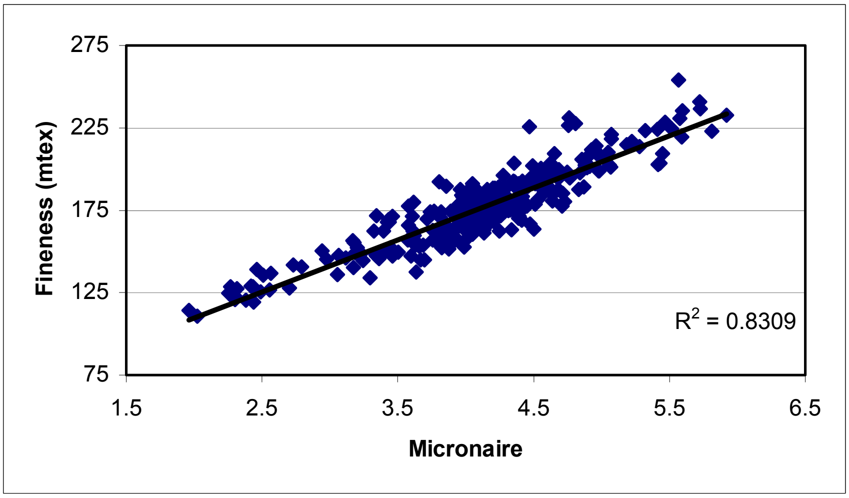

Figure 7. FMT Fineness vs Micronaire for 275 cottons.

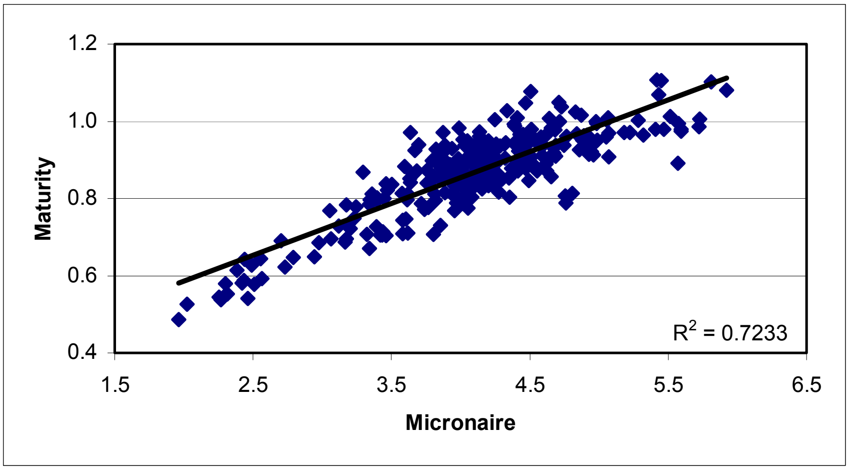

Figure 8. FMT Maturity vs Micronaire for 275 cottons.

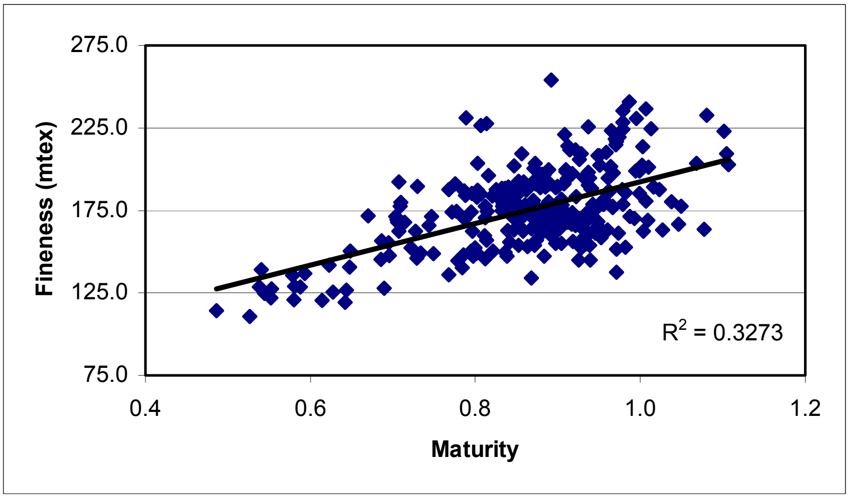

Figure 9. FMT Fineness vs. Maturity for 275 cottons.

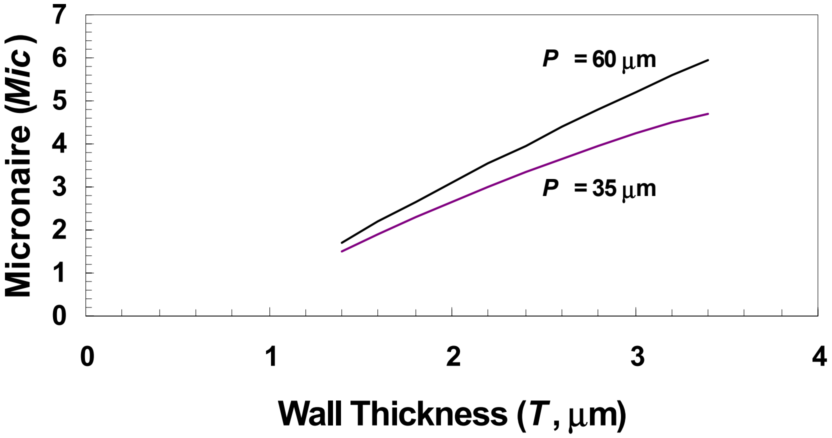

Figure 10. Micronaire vs. Wall Thickness at Constant Perimeter.