1809 Current Use of Instrument Technology in the Cotton Industry

Mrs. Anja C. Schleth , Uster Technologies, Inc., Knoxville, TN
Mr. David McAlister III , Uster Technologies, Inc., Knoxville, TN
Dr. Devron Thibodeaux , CQRS-ARS-USDA, Clemson, SC
Mr. Roger Riley , Uster Technologies, Inc., Knoxville, TN

Different sectors in the cotton industry have different application requirements for instrument technology. Cotton research organizations usually work with small sample sizes, but require detailed information on all cotton quality parameters. Cotton classing organizations play important roles in understanding what affects cotton quality and ensuring the grade (value) of the cotton. Cotton spinning mills have mixed application requirements, depending on their size and quality objectives. The objective of this paper is to highlight the use of existing instrument technology for a wide range of applications in the cotton industry. Examples of three case studies of the second author's (David McAlister, III) original work (published and unpublished) were reviewed as examples of how the technology can be used effectively in several sectors of the cotton industry. The results of the various case studies indicate that the HVI and AFIS are instruments capable in helping solve cotton fiber related issues and advancing the understanding of the influences on cotton fiber quality.

Introduction

General

Instrument measurement of fiber properties is more important today than ever before. The textile market has truly become global with respect to the trade of fiber, yarn, fabric, and apparel. There is a common interest among countries involved in global textile trade to have a common language when it comes to describing the quality and value of the goods traded. Typically, the cost of raw material consumes 50-70% of manufacturing cost for a yarn spinning mill. Therefore, knowing precisely the quality and value of a cotton bale is very important for managing costs in a mill. The value of a bale of cotton is determined by the length, strength, fineness, and color of the fiber of which the bale is made of. Depending on what these fiber properties yield will determine whether the owner of the bale will receive top price or not. Typically these fiber properties are measured on instruments. The measurement reliability of an instrument will influence how profitable a bale of cotton will be for the owner.

The United States, through the United States Department of Agriculture (USDA), was the first country to adopt a common language for cotton fiber trading. In 1937 the Smith-Doxey Act was signed into law in the US. This law requires that all cotton be classed for trading in the market by the USDA. This requirement still exists; however, all classification for fiber quality is now done by instruments rather than a human being. This is accomplished in 12 regionally located classing offices with a total of 295 USTER® *HVI*'s (High Volume Instrument).

Other countries have followed the path of USDA in adopting USTER® *HVI* as the standard instrument in classification of their cotton crop. The largest of these is the China Fiber Inspection Bureau (CFIB), which initiated the move to USTER® *HVI* classification of cotton in 2004 and will be completely online by 2010 with a total of approximately 350 HVI's.

There are currently approximately over 400 HVI's in use in various official classing organizations around the world. In total, there are more than 1900 HVI installations including Classing and Mill organizations.

The use of instrument generated fiber quality data does not end with the selling and purchasing of cotton bales. Once a mill takes ownership of the bales of cotton, the mill managers must decide how to efficiently consume the bales while maintaining consistent quality, high operation efficiency, and high yield of raw material (ensuring that most of the fiber becomes yarn). It is at this point that the fiber quality data generated by USTER® *HVI* is used for bale management. Bale management is the judicious selection of cotton to achieve acceptable economic spinning performance and consistent quality. Bales are selected for laydowns/ mixes in a mill according to HVI measured quality parameters such as length, strength, micronaire, and color. Mills that practice proper bale management procedures using USTER® *HVI* realize better operating efficiencies, quality, and yield of raw material than mills that do not.

Bale management is only the first step for a mill to utilize fiber quality data to manage the quality, efficiency, and cost. Once the cotton fiber is in-process, it is manipulated and formed into a yarn for a specific end-use (knits or wovens). However, the success of this manipulation is dependent on knowing the proper processing parameters required to successfully turn the cotton fiber into yarn with quality and efficiency at the required cost. Therefore, it is important to know the quality of the fiber as it is being processed through the mill. For this, most quality-conscious mills use the USTER® *AFIS* (Advanced Fiber Information System) which is able to measure single-fiber properties required for the determination of precise machine settings. The need for this fiber quality information is even more important today due to the impact of increased production speeds of textile machinery. The time required for a fiber to be formed into a yarn has been reduced drastically, putting much more stress on the fiber than ever before. This means that precise information of processed fiber is required in order to manage the machine settings according to the limitations of the fiber. The USTER® *AFIS* is able to determine length, fineness, maturity, neps, seed-coat fragments, and dust/trash, all of which have an influence on textile manufacturing processes. Currently, there are more than 850 *AFIS* installations worldwide.

Examples of three case studies were reviewed as examples of how the technology of *HVI* and *AFIS* can be used effectively in several sectors of the cotton industry. Each case is and example of a studies focused on Cotton Research (harvesting methodology), Cotton Classification (changes in cotton color), and Cotton Spinning (spinning performance of different quality cotton varieties). Each case will be discussed separately in the introduction, materials and methods, results and discussion, and conclusion sections of this paper.

Case Study 1 – Cotton Research

This first case is an example of how HVI and AFIS are used to evaluate the effect of treatments on cotton by the research. In particular, this case is focused on the effect of harvesting methods and row spacing of cotton on cotton quality and the subsequent spinning efficiency/quality.

Traditionally, cotton has been grown with a row spacing of 76.2 to 101.6 centimeters. Originally, a farmer gauged this spacing on the width of the mule plowing the field, hence the 76.2 to 101.6 centimeters. The desire and need to increase yield have led to new and different techniques and chemicals. One technique used to increase yield has been to adjust the spacing between cotton rows, which has led to the development of ultra-narrow row (UNR) spacing.

A producer's goal when using the UNR cotton system is to grow high quality, high yielding, short season cotton (Trehune, 1998). A major advantage to a grower using the UNR cotton system is increased yield. This is because of higher plant density and more uniform distribution of plants within a field. In a conventional field, a plant population of 100,000 plants per hectare is planted 101.6 centimeters apart between rows and 7.62 to 10.16 centimeters apart within the row. In contrast, a typical UNR field has a plant population of 300,000 plants per hectare with a configuration of about 25.4 centimeters by 12.7 centimeters (Dowling, 1996).

Over the past few years, BASF has conducted trials in the United States on UNR yield in five of the cotton belt states. UNR cotton averaged 15 % higher yield than the traditionally grown 101.6 centimeter cotton. Mississippi and Texas recorded the highest increases, 32 % and 37 % respectively. The largest yield gains have been in areas and fields which could be classified as poor or marginal (Dowling, 1996).

The areas of greatest concern with UNR cotton are in the harvesting and ginning methods. Because of the close spacing of rows, UNR cotton is harvested with a stripper harvester instead of the more commonly used spindle harvester. One result of using the stripper harvester is increased non-lint content. Plant densities can compound the effect of the stripper on the non-lint content of cotton. Lower plant densities can cause an undesirable branching which results in excessive removal of bark by mechanical strippers and serious operating problems in the field (Harris et al., 1999). One solution for reducing the higher levels of non-lint content is the addition of field cleaners to the stripper harvester, which allows the removal of some of the sticks, burrs, and other trash. This additional cleaning equipment presents harvested cotton to Southeast gins that more closely resembles spindle-picked cotton (Perkins and Atwell, 1996).

To overcome some of the problems in ginning created by UNR cotton, Mayfield (1999) suggests that the following methods be employed when one is ginning UNR cotton on a gin set up for spindle-picked cotton. The gin should include additional equipment to handle the extra foreign matter. A Southeast gin would require an additional stick machine or an additional combination burr and stick machine as the first cleaner. Also, a second stage of lint cleaning is recommended for UNR cotton. The trash handling system would have to be improved to handle the greater volume of trash from the individual cleaners on the way to the trash pile (Mayfield, 1999).

The presence of increased Visible Foreign Matter (VFM) should be expected in UNR cotton. Visible Foreign Matter is defined as "the sum of all the non-fibrous material that can be mechanically separated from the fibers" (McCreight et al., 1997). The impact of VFM on fiber quality varies. A study was conducted by Larson and English in 1997 involving stripper-harvested UNR cotton and spindle-harvested conventional cotton. The High Volume Instrument (HVI) test results from this study indicate that UNR cotton had a higher trash content and lower micronaire than conventional cotton (Larson and English, 1997).

Another study was conducted by Vories et al., 1999. This study also involved stripper-harvested UNR cotton and spindle-harvested conventional cotton. Their results indicate that none of the HVI properties were affected except for micronaire. The UNR cotton consistently had a lower micronaire than the conventional cotton. Advanced Fiber Information System

(AFIS) (Uster Technologies, Knoxville, TN) tests indicated that UNR cotton had significantly more neps, higher short fiber content, and more visible foreign matter that the conventional cotton (Vories et al., 1999).

Very little research has been conducted on the spinning efficiency of UNR cotton. In 1999, a study compared UNR and conventionally grown cottons on a ring spinning system. This study found no significant difference in processing efficiency between UNR and conventionally grown cottons (McAlister, 1999). While there was no significant difference in spinning efficiency, there were significant differences in the yarn quality between UNR and conventionally grown cottons. Yarn single-end strength variability, yarn neps, yarn thick and thin places, and Classimat minor defects were found to be statistically significantly worse for the UNR cottons, indicating that the differences are attributable to the production methods or the additional ginning required for UNR cotton (McAlister, 1999).

The stripper-harvesting method utilized for UNR cotton collects more trash with the cotton than the spindle-harvesting method, and increased trash in cotton has been found to correspond with increased ends down in spinning (McCreight et al., 1997). For this reason, stripper-harvested UNR cottons have not been well received by textile mills. Currently, no practical method of spindle harvesting UNR cottons exists. Therefore, past research has not studied the effect of spindle harvesting on the fiber properties of cotton grown in ultra narrow rows. It would be beneficial for producers, ginners and spinners of cotton to know the effects of harvesting method on fiber properties and on spinning performance of UNR cottons when they are ginned with two lint cleaners--as recommended for stripper harvested, ultra-narrow row, upland cottons.

This study was undertaken to evaluate the effect of harvesting method of cottons grown in ultra-narrow rows on the productivity of a spinning mill. The goal of this case study is to demonstrate how test results of the USTER® *HVI* and USTER® *AFIS* can be applied to address the needs of Cotton Research through the evaluation of improved harvesting techniques for UNR cotton.

Case Study 2 – Cotton Classification

This second case is an example of how HVI data can be used to monitor the changes in fiber color (+b in this case) as a result of environmental changes during warehouse storage. This is important because it highlights an issue that often will cause a dispute about the classification of cotton. In many cases, if the storage environment has been ignored when cotton is consumed many months after storage in hot, humid environments, color changes will have a serious impact on finished goods quality.

The effects of ageing on cotton fiber properties, especially color grade, have been studied by several researchers. The effect of field weathering on the fiber properties of cotton was studied by Hessler et al., (1954). Weathering effects were attributed to moisture, heat, and microorganisms. Since the cellulose of the primary wall is of lower degree of polymerization than what is inside the primary wall, it will respond more readily to the forces of decomposition (heat, moisture, microorganisms). The greatest damage to the cotton from weathering was increased color (grayness and yellowness). Color damage was not found to be severe until after at least two months exposure. Fortunately, graying caused by dirt or other contaminates is not permanent, and responds readily to kiering and bleach to gain whiteness equivalent to the brighter cottons. However, the same is not true when color is due to biological degradation. If sufficient moisture were present during exposure to weather, the color damage would be more of a problem because pigments produced by microorganisms are more difficult to remove (Hessler et al., 1954).

Simon and Harmon (1953) studied sources of color in cotton. The researchers classified four sources of color as follows: dirt, fiber morphology, intrinsic color, and extrinsic color. Trash, foreign matter, and other impurities were classified as dirt and were removable by mechanical cleaning. The presence or absence of dirt was found to have no effect on bleaching and was discounted as the cause of grayness of the cotton after bleaching. Fiber morphology was indicated as the degree of convolutions of the fiber. Exposed and unexposed fiber samples were dissolved and the colors of the solutions were found to be the same as the original cotton samples. Consequently, fiber morphology was discounted as a concern for the purpose of this research. The flavones, orange-yellow pigments, as suggested by Hess (1928), were defined as the intrinsic color of cotton. Flavones occur as the glucoside in cotton, and it was discovered that the flavones are removable by commercial bleaching and can be discounted as a concern. In order to study the effect of environment on the extrinsic color of cotton, fiber was secured straight from the field after varying periods of exposure. It has been suggested by Nickerson (1951) and Marsh et al. (1954) that fungi are the source of discoloration in cotton. Sui's (1951) conclusions on fungal attack are referenced in this research. Fungi attach themselves to the surface of the cotton fibers, next penetrate the fiber walls, and then infect the lumen of the fiber. The severity of weathering was found by Simon and Harmon (1953) to affect the penetration of the fungi. Samples of weathered (exposure to outdoor environment in sunlight and rain) and unweathered (stored in a controlled atmospheric environment in a laboratory) cottons after twelve weeks were obtained and the weathered samples were found to contain fungal growth. It was found that the color persisting after bleaching was due to fungi, which flourish under the correct weather conditions. The undesirable color, extrinsic color, is found to be achromatic and is the result of the fungi's presence itself.

Nickerson (1951) determined the extent of change in color (reflectance Rd and yellowness +b) of cotton samples caused by exposure in the field, and short and long term storage. High and low grade cottons were used in the study. The cottons exposed in the field showed a marked change in fiber color. Cottons subjected to storage were stored under various temperature conditions. Conditions of short term storage were: room temperature 18.3°C (65°F), 56.1°C (133°F) for three months, and 121.1°C (250°F) for five days. Room temperature samples showed just a slight change in color. Samples stored at 56.1°C showed a considerable increase in color change similar to that of cottons stored for seventeen years. The samples stored at 121.1°C showed a drastic change in color. For long term storage, cottons were stored in a warehouse and measured for color over seventeen years. There was considerable change in color as a result of this long term storage. It was also found that lower grade cottons tend to be more yellow than the higher grades.

A second study by Nickerson and Tomaszewski (1959) highlighted color changes due to cotton storage. The purpose of this research was to study the degree of color change associated with different treatments of storage temperature and relative humidity (RH). Samples were stored for three years under the following conditions: -17.78°C (0°F); 10°C (50°F), 50% RH; 37.78°C (100°F), 50% RH; and 37.78°C (100°F), 85% RH. Results indicated small changes in color for -17.78°C and 10°C, 50% RH treatments and large changes for the other two treatments. Nickerson concluded that a temperature of 10°C and RH of 50% induced the smallest change in cotton color and it was recommended that cotton standard samples used by the USDA be stored under these conditions. It was also discovered that a difference in +b of more than 0.15 is significant.

The intent of this study was to investigate what effects warehousing conditions (ageing) has on cotton fiber properties . Ultimately, this report will provide a better understanding of the effects of warehousing on cotton fiber and what may be done to better manage fiber properties. The goal of this case study is to demonstrate how the USTER® *HVI* can be applied to address needs of cotton classification through careful consideration of color measurement and storage conditions of cotton.

Case Study 3 – Cotton Spinning

This third case is an example of how HVI and AFIS data can highlight differences in processing during the spinning process. This is important because the HVI and A FIS are indispensable tools for engineering the spinning process.

The key to exploiting the productivity and quality advantages of the latest generation high-speed spinning systems is the development of germplasm with fiber properties that can be spun effectively with these systems (May, 2000). Previous work (Meredith et. al., 1991) concluded that cotton variety had the most effect on the resultant spun yarn tenacities. He demonstrated this by measuring the typical fiber property measurements available on the High Volume Instrument System (micronaire, length, strength, uniformity, color, and trash). Additionally, a more recent study of southeastern cotton varieties (Rogers, McAlister, and Boswell, 2000) again demonstrated that variety is the dominant factor in high-speed yarn processing performance and quality when only typical fiber property measurements used in marketing are considered. Historically, studies have been conducted at the ARS-USDA Research Unit at Clemson, SC since 1959 to determine the influence of fiber properties on yarn processing efficiency and yarn quality and documentation. The results of earlier studies were documented as early as 1967 (Newton, Burley, LaFerney, 1967).

The quality requirements placed on cotton is now greater than ever because these fibers are increasingly utilized in products where consumer preferences are becoming much more demanding with respect to product performance, quality, and aesthetics (natural fiber/synthetic fiber blends). In addition, production technology has made great improvements in output rates, thus placing greater demands on cotton and other natural fibers relative to their ability to process and perform efficiently at the higher production rates. Spinning technology has seen drastic increases in speed in the past ten years. These higher spinning speeds place new stresses and demands on cotton fiber. High-speed, high-draft spinning systems require fibers that are fine, long, uniform, strong and clean. Current High Volume Instrumentation utilized by industry and Classing organizations, as well as the Advanced Fiber Information System utilized by industry, are ideal tools for predicting the spinning consistency and process performance various cottons.

The goal of this case study is to demonstrate how the USTER® *HVI* and USTER® *AFIS* can be applied to determine the processing success of different cottons treated with the same methods and equipment for processing.

Material and Methods

Case Study 1 – Cotton Research

The equivalent of six bales of Paymaster 1220 BG/RR cotton were grown in ultra narrow rows 19.05 centimeters apart on a commercial farm in Kingstree, SC in 1999. During the growing season, the crop was managed as is typical for a UNR cotton production system. At harvest, half the cotton was spindle-picked with a conventional, six-row spindle-picker and the remaining half was stripper-harvested with a conventional finger-stripper with a field cleaner. The field cleaner was employed to overcome the lack of an additional stick machine and incline cleaner at the gin. The spindle harvester was set for 30" rows, which only allowed for 1 out of every four rows to be picked. The remaining rows were driven-over by the picker as it picked each fourth row. These cottons were harvested in late December due to unusually wet weather during the harvest period.

The cotton was ginned at a commercial gin near where the cotton was grown. The gin was setup for handling spindle-harvested cottons which included a combo separator, fountain dryer, split to two incline cleaners and back to a stick machine (3 saw), incline cleaner, gravity cleaner, feed control, gin stand, and two lint cleaners. Cotton fiber from each of these treatments was then tested to determine the influence of harvest method on fiber properties.

Once the bales of cotton had been conditioned, they were tested for micronaire, upper half mean length, uniformity index, strength, elongation, length distribution, maturity, and non-lint content. These tests were conducted with the following instruments: HVI & AFIS (Uster Technologies, Knoxville, TN). Details of the tests with these instruments are provided in Table I.

After the cottons from the two treatments were ginned, there were three bales of cotton for each treatment (a total of six bales). For processing purposes three lots were used for each of the two treatments to give a total of six spinning lots. In other words, each treatment had three replications in textile processing. Each lot consisted of 68.04 Kg. of cotton. To emulate a mill environment where several bales of cotton are blended together, each lot was composed of a mixture of the three bales from each harvesting condition.

The cotton for each lot was processed through the opening and cleaning line at the Cotton Quality Research Station (CQRS), USDA, at a throughput rate of 45.36 Kilograms per hour. The processing equipment used in the card room consisted of three tandem opening hoppers, an Axi-Flo opener/cleaner, a GBRA big bin hopper, a RN coarse cleaner, a RST multi-roll cleaner, a DX de-duster, and a DK-740 card (all Truetzschler, Monchengladbach, Germany). A 227 gram sample of the card mat was taken from each lot and tested on the AFIS for length distribution and non-lint content. The waste suction for the opening line was turned off in order to collect waste from the Axi-Flo, the RN, the RST, and the DK-740 card. Waste removed from the cotton for each lot at each location was placed into separate bags, individually weighed, and the waste percentage calculated by dividing the weight of the waste collected at each point by the total amount of ginned cotton fed to the opening line.

After carding, six cans of 4,252 - Tex grain sliver were processed through a Rieter RSB (Rieter, Winterthur, Switzerland) (one pass) leveled finisher draw frame, resulting in 24 cans of 3,898 Tex sliver for rotor spinning. For rotor spinning, 24 cans per lot of 3,898 - Tex sliver were fed into a Schlafhorst SE-11 (Schlafhorst, Monchengladbach, Germany) rotor spinning frame to spin a 29.53 Tex yarn. The following process parameters were used: a twist multiple (TM) of 3.85, a rotor speed of 90,000 revolutions per minute, and a combing roll speed of 8,000 revolutions per minute. Stops for each lot were visually monitored and recorded. Each lot ran approximately 9-10 hours on a 24-position rotor spinning frame. Upon completion of each lot, the frame was thoroughly cleaned and prepared for the next lot.

Case Study 2 – Cotton Classification

Raw Material

One trailer of Deltapine 5415 was spindle harvested and ginned the next day at Sampson Gin in Newton Grove, NC. Six bales were ginned for this study with a dryer temperature of 72.22°C, a moisture content of 5.5%, measured after the tower drier, and one lint cleaner. Micronaire, length, strength, color Rd (reflectance) and color +b (yellowness), and trash (%Area) for each cotton sample were measured on a HVI High Volume Instrument (Uster Technologies, Knoxville, TN). The cotton properties are listed by ageing treatment in Table IV.

Ageing Process

The bales were placed immediately upon arrival to the warehouse in conditioning chambers similar to the one illustrated in Figure 3. Four chambers were set to simulate the four seasons of the year using data from the National Weather Service for the Charlotte, NC area (location of the conditioning chambers). The door on each unit was fitted with a chart recorder for recording the temperature and humidity over a 24 hour period. In addition, a 7,800 BTU heating/cooling window unit with a thermostat was utilized for maintaining the proper temperature, while a humidifier with humidification control was utilized to maintain the proper relative humidity. The target atmospheric conditions of each chamber were: Fall, 16.6°C (62°F) and 62% Relative Humidity (RH); Winter, 6.1°C (43°F) and 43% R.H.; Spring, 15.5°C (60°F) and 60% R.H.; Summer, 25.5°C (78°F) and 77% R.H. Temperature was controlled within +/- 2.8°C and relative humidity within +/- 5%.

All but two bales were covered with woven polypropylene bagging and the remaining two were covered (one each) with woven burlap and a polyethylene film bagging. The polyethylene bagging used had holes on 406.5 mm centers. Three bales with different coverings were placed in the summer conditioning chamber to test the effect of bale covering on the fiber properties during ageing. Samples of 50 grams from each bale were taken as described in ASTM D-1441-00 on the Monday of each of the twelve weeks of storage for testing.

Case Study 3 – Cotton Spinning

Cotton varieties were selected based on the experience and knowledge previously gained in USDA's National Variety Test programs on small plots. A total of fourteen different cotton varieties were selected and planted in three different growth areas. Different varieties were planted in West Texas (9 different varieties), Mississippi (8 different varieties), and Georgia (7 different varieties). Three bags of seed of each variety were given to each producer -- enough to cover 15 acres of each variety, if needed.

Planting and Harvesting

Planting and harvesting were conducted following the producer's typical practices. Enough acres of each variety were planted to yield a full module of seed cotton for each variety. Any resulting yield losses compared to the producers' normal production were accounted for at harvesting. Harvesting method used was what was typical and customary for the growing location.

Ginning

Ginning of each module took place at the gin customarily utilized by the respective producers. It was preferred that one lint cleaner be utilized during ginning of all varieties to minimize the possibility of fiber damage. Each module was ginned as a separate block of bales and appropriately identified.

Fiber Testing

All fiber testing was conducted at the Cotton Quality Research Station (CQRS) of the Agricultural Research Service in Clemson, SC. Bales of each variety were transported to CQRS for testing and spinning. Official HVI Classification (AMS) (Color, Trash, Length, Strength, Mic, Uniformity) was obtained for each bale produced for each variety (Table VI). The Spinning Consistency Index (SCI) was calculated at USTER from the HVI classing data for every bale (Table VI). All AFIS data was generated by CQRS.

Spinning

All spinning was conducted at CQRS in ring spinning producing a 20/1 Ne yarn count. Yarns were spun applying a weaving twist since these yarns are placed under much higher stress than knitting yarns during fabric formation. Two 150-pound replications were processed per variety from each growing location. All yarns were produced from carded sliver. Table VII details the spinning information.

Yarn Testing

All yarn testing was conducted at CQRS. The list of tests performed on all yarns included yarn evenness, yarn imperfections, yarn appearance, and yarn strength (Table VIII).

Results and Discussion

Case Study 1 – Cotton Research

Fiber Properties

Micronaire: Much can be determined about a cotton fiber simply by analyzing its micronaire, maturity, and fineness values. Textile manufacturers utilize the micronaire value as one of the properties for determining if the cotton is worthy of being purchased for the processing of yarns and fabrics for specific end uses.

Micronaire is an indirect measure of cotton fiber gravimetric fineness (mass per unit length), and both biological fineness and maturity influence this micronaire value. Micronaire is commonly used as an indicator of cotton fiber maturity, although care must be applied when doing this. For marketing purposes, a micronaire value of 3.7 to 4.2 is considered premium with regard to price. Values of 3.5, 3.6, and 4.3 through 4.9 are considered normal. Values of 3.4 and below and 5.0 and above are considered to be of lesser value and are in the price discount range. Table II shows that the micronaire values for the cottons in this study were in the discount range since the test results were on the low side of the micronaire scale. Adverse weather and row spacing more than likely contributed to these low micronaire values.

Color: Cotton color can be described with two descriptors: degree of reflectance (Rd) and degree of yellowness (+b). The range values for reflectance are 40% to 85%, with 85% being very reflective. The range of values for yellowness is 4 to 18 units, with 18 being very yellow. U.S. upland cotton is typically creamy white. Exposure to various environmental conditions can cause the color to become more yellow and gray with late harvesting. Harvesting and ginning have been found to also influence cotton color. As shown in Table II, the spindle-harvested treatment exhibited a lower +b value than its stripper-harvested counterpart. The spindle harvested treatment also exhibited a numerically lower Rd value than the stripper-harvested treatment, although it was found of no statistically significance in this case.

Tensile Strength: In HVI testing, a strength measurement is made on the same beard of cotton that is used for measuring fiber length. As might be expected from the stripper-harvested treatment's lower micronaire value, the fiber strength of this cotton was significantly weaker than the spindle-picked treatment as shown in Table II.

Length: Previous studies comparing UNR cottons to those grown with conventional spacing indicate that UNR cottons have lower uniformity index values (McAlister, 1999). The Upper Half Mean Length (UHML) results in this study indicated that the spindle-harvested treatment had a higher UHML than the stripper-harvested treatment tested (Table II). These results can be explained by the fact that plants grown in ultra-narrow rows support fewer bolls and therefore are able to provide 1^{st} and 2^{nd} position bolls with more growth-related nutrients. This would mean that the fibers in those bolls would have a chance to more fully develop. When spindle harvesting UNR cotton, only the locks from the open bolls are harvested, making it more selective in retrieving fiber from the plant than the stripper harvester.

Length Uniformity Index (UI) is a measure of the fiber length distribution in a sample. A low uniformity index value would indicate that there are more short fibers (fibers < 12.7 mm in length) present in a given sample than in one with a high uniformity index value for cottons of the same upper half mean length. The stripper harvested treatment exhibited a significantly lower uniformity index value than the spindle-picked treatment (Table II). Upon further investigation, it was discovered that the stripper-harvested cotton exhibited a significantly higher amount of short fiber content (SFC) by weight as measured by the AFIS than the spindle-picked treatment (Table III).

Neps: Neps are a collection of one or more fibers occurring in a tangled and unorganized mass. The AFIS nep count results indicated that the stripper-harvested cotton had a significantly higher nep level than its spindle-harvested counterpart (Table III), which is consistent with the more aggressive picking method.

Non-lint Content: The non-lint content of cotton includes stalk, leaf particles, dirt, dust, micro-dust, and respirable dust. Much concern exists over the non-lint content of UNR-spaced cottons compared to cottons grown with conventional spacing and spindle harvesting. The stripper-harvested cottons received extraneous matter classifications for bark level 1 as shown in Table II. AFIS dust levels were higher for the stripper-harvested treatment (Table III). In addition, the stripper-harvested treatment exhibited a higher trash count level than the spindle-harvested treatment (Table III). Although a field cleaner and two lint cleaners were employed as recommended, the weathering of the cotton could have had an adverse effect on the stripper treatment. Moisture content of plant at harvest has been cited as a cause of increase in bark content for stripper picked cottons (Brashears, 1984).

Raw Stock Processing

Waste: The results shown in Figure 1 indicate that the stripper-harvested treatment generated a higher waste amount (minimum significant difference = 2.15 @ 0.05 level). This is not surprising as it is expected that cotton with a higher trash level will process with a higher level of waste in a spinning mill.

Spinning: Ends down are a measure of spinning efficiency with lower numbers indicating a higher efficiency. The ends down level for both treatments (Figure 2) was not statistically different (minimum significant difference = 60.0 @ 0.05 level). This is surprising since higher short fiber and higher trash levels were determined in the stripper harvested treatment. High levels of short fiber and trash are known to negatively influence spinning efficiency. However, since the stripper harvested treatment resulted in a significantly lower micronaire, the higher number of fibers per cross-section in the OE yarn in the stripper harvested treatment (332 fibers vs. 216 for spindle harvested cotton) could have overcome the effects of the high short fiber content and trash.

Case Study 2 – Cotton Classification

Fiber Color +b

The ranking of least to most porous bale covering is polyethylene film, woven polypropylene, and woven burlap. To investigate the effect of surface area exposure, it is reasonable to assume that the more porous a bale covering is the more fiber surface area will be exposed. Fiber color +b values were significantly affected by bale covering type and atmospheric condition over time, which is important because stored bales are used to form mix laydowns for mills to produce even colored yarns and fabrics. Work by Nickerson (1951) indicates that a change in color +b of 0.15 or more has significant consequences. As illustrated in Figure 4, there was a significant change in +b values (averaged across the bale covering types) as the ageing time increased in storage conditions similar to summer. However, the differences were statistically significant only in changes of more than 0.38 +b units which is more than double the level observed by Nickerson (1951).

Under summer conditions (25°C (78°), 77% R.H.,), the more porous burlap (BP) covering underwent the most color +b change (Table V) and was significantly more yellow than the polypropylene (PO) or polyethylene (PE) covered bales, which were visually not significantly different after twelve weeks of ageing. The woven burlap covering tends to expose the cotton more to the atmosphere than the woven polypropylene and the polyethylene film. Woven polypropylene and woven burlap covered bales showed the highest and most significant correlation with HVI color +b changes over the twelve week storage period under summer conditions (R^2 = 0.677 and 0.610 respectively). There was no significant correlation between the polyethylene film covering and HVI color +b changes for the same period of time under the same storage conditions. Under conditions of Fall, 16.67°C (62°F) and 62% R.H.; Winter, 6.11°C (43°F) and 43% R.H.; Spring, 15.56°C (60°F) and 60% R.H., no significant changes occurred to the fiber color +b values (Table V). It is, therefore, the effect of moisture at the treatment temperature of 25°C (78°F) that showed the dominating effect on the color changes. This trend is supported in research by Anthony and Herber (1991), in which a polyethylene covered bale gained less moisture in humid conditions than did a bale covered in woven polypropylene.

Nickerson (1941) documented in her research the atmospheric conditions of high temperature and high humidity work in conjunction to produce changes in fiber color +b.

Hessler et al. (1954) have documented that pigments produced by microorganisms are a source of cotton fiber discoloration. It is noted by Marsh et al (1954), that one species of microbe that occurs frequently in cotton in humid storage conditions is the fusarium fungus. Staining tests performed to detect microbial growth indicated positive detection of fusarium in summer conditioned bales covered in burlap and polypropylene. Also, pH test showed increases in pH, which approached a value of 8 for all treatments. The bale covered in polyethylene showed the least change in pH over the twelve week ageing period and no positive response in staining. It is known that pH over 8 is indicative of microbial damage (Marsh, 1954). Although the increases began to approach a pH level of 8, the results are inconclusive as evidence of microbial damage. The relationship between fungus growth on fibers and their response to temperature as described by Sui (1951) and Wolf (1947) explains why the summer ageing chamber (25.56°C, 77% RH) underwent significant changes in yellowness +b in this study.

Case Study 3 – Cotton Spinning

HVI Test Results

The measured properties of HVI were used to calculate the Spinning Consistency Index (SCI) for all cottons. SCI is calculation based on the most important HVI measurements of length, length uniformity, micronaire, strength and color and it is an indication of the spinning ability of the fiber. A high SCI value indicates good spinning ability while a low value indicates lesser spinning ability. In the case of this study, the SCI is a very strong predictor (R^2= 0.931) as shown in figure 5. It is common knowledge that variations in fiber micronaire, length and length uniformity, and strength all interact to affect the resultant yarn strength. The variations of the HVI properties are indicated in Table VI. In this case, the SCI quickly indicates this effect. This is important because it is a quick indicator of which cotton would be suitable for weaving applications

Yarn Evenness and imperfection defects

Analysis of the AFIS data indicates strong correlations between the short fiber content in the finisher drawing sliver and yarn CVm (R^2= 0.763), yarn imperfection thick places (R^2= 0.755) and yarn imperfection thin places (R^2= 0.749). This is reasonable and expected given the wide variation in fiber length and length uniformity which, in conjunction can be an indicator of short fiber. This reasoning is consistent with the variation in SCI as discussed in the previous segment.

Conclusions

Case Study 1 – Cotton Research

The purpose of this study was to evaluate the impact of harvesting method on ultra-narrow row grown cotton and the spinning mill performance and quality of rotor-spun yarns made from this cotton. Admittedly, it is not practical to utilize a spindle harvester designed to pick cotton from wider row spacing to harvest cottons planted in 19.05 centimeter rows. However, harvesting manufacturers like John Deere are already experimenting with narrow-row spindle harvesters. It is useful to investigate the need for a better harvesting technology for UNR cotton or a modified planting arrangement for UNR based on the resultant fiber properties and textile performance and quality. Therefore, this study was an attempt to investigate one of those needs to make UNR cotton more attractive to the textile mill consumer. All conclusions are based upon results achieved by following the experimental design of this study.

In comparing the fiber quality of the two treatments, the spindle-picked cotton fared better in color +b, fiber strength, fiber length, uniformity index, neps, and non-lint content. In textile processing, the spindle-harvested cotton resulted in lower processing waste and lower ends-down in rotor spinning, which benefits both yield and spinning efficiency at the textile mill. It is clear that there is some benefit from harvesting UNR cotton with some form of spindle-picker. This work provides a foundation for more in-depth research on the possibility of spindle harvesting UNR cotton.

Case Study 2 – Cotton Classification

The main objective of this study was to determine the effects of ageing, which simulate common cotton warehouse storage treatments on the color +b of cotton fiber.

Fiber exposed to a combination of high temperature and high humidity similar to summer environment tends to yellow cotton as the exposure time progresses. Changes in fiber color +b are minimal in conditions similar to winter, spring, and fall. Bales covered in woven burlap tend to allow rapid changes in fiber +b values, while bales covered in woven polypropylene cover do exhibit changes in fiber +b values but not as rapid. Bales covered in a polyethylene film did not exhibit any changes in fiber +b for up to eight weeks. Changes in fiber color +b of aged cotton are significant only after five weeks of ageing under summer conditions with either woven burlap or woven polypropylene covering. Fiber color +b yellowness changes in this study are due to the presence of fusarium fungus which grows well under summer conditions and turns yellow as detected by the staining of the fungus on the fiber.

Case Study 3 – Cotton Spinning

The main objective of this study was show the relationship between HVI measurements and yarn quality as well as the AFIS measurements and yarn quality. The results indicate that these instruments provide valuable information that can be used in selecting proper cotton for consumption in spinning as well as determining acceptable cotton quality levels given specific customer requirements for yarn evenness and defects level.

Summary

Examples of three case studies were reviewed as an indication of how the technology of *HVI* and *AFIS* can be used effectively in several sectors of the cotton industry. In each case the data provided by these instruments were able to show the treatment effects on the resultant fiber or yarn quality. For fiber testing, the HVI and AFIS are indispensable tools for investigating changes in fiber quality from bale all the way through the processing up to yarn spinning.

References

Case Study 1 – Cotton Research

ASTM, Standard Practice for Conditioning and Testing Textiles, (D-1776). 2001. Vol. 07.01: 431-434.

Anthony, S., W. Mayfield, and T. Valco. 1999. Results of 1998 ginning studies of ultra narrow row cotton. p. 1484-1488. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Bader, M., S. Smith, and R. Reed. 1999. UNR farm trials in Georgia 1998. p. 1482-1483. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Brashears, A. 1984. Modification of stripper rolls to reduce stick content in burr cotton. P. 155-157. In Proc. Beltwide Cotton Conf., Atlanta, GA, 8-12 Jan. 1984. Nat. Cotton Counc. Am., Memphis, TN.

Dowling, D. 1996. Ultra narrow row cotton shows promise. *Australian Cotton Grower*, 17(6):18-21.

Harris, H., W. Vencill, and J. All. 1999. Influence of row spacing and tillage upon western flower thrips and tobacco thrips in cotton. p. 974-976. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Larson, J., and B. English. 1997. Economic feasibility analysis of ultra-narrow-row-cotton in Tennessee. p. 315-317. In Proc. Beltwide Cotton Conf., New Orleans, LA. 6-10 Jan. 1997. Natl. Cotton Counc. Am., Memphis, TN.

McAlister, D. 1999. Textile performance study results on UNR and conventionally grown cottons. *The Cotton Gin and Oil Mill Press,* 100(22):10-12.

McCreight, D., R. Feil, J. Booterbaugh, and E. Backe. 1997. *Short Staple Yarn Manufacturing*. Carolina Academic Press, Durham, NC.

Mayfield, W. 1999. Overview of UNRC situation from a ginner's perspective. p. 1414-1416. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Perkins, W., and S. Atwell. 1996. Ultra narrow row harvesting approaches. p. 69. In Proc. Beltwide Cotton Conf., Nashville, TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.

Trehune, R. 1998. Ginners get results with new stick machine. *Cotton Farming Management.* 42(11), 30.

Vories, E., R. Glover, and K. Bryant. 1999. A three year study of UNR cotton. p. 1480-1482. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Williams, G., and J. Yankey. 1996. New developments in single fiber fineness and maturity measurements. p. 1287. In Proc. Beltwide Cotton Conf., Nashville, TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.

Case Study 2 – Cotton Classification

American Association of Textile Chemist and Colorists (AATCC) 1984a. Congo red staining. p. 44-45. *In* Analytical Methods for a Textile Laboratory. AATCC, Research Triangle Park, NC.

American Association of Textile Chemist and Colorists (AATCC) 1984b. Harrison's silver test. p. 50. *In* Analytical Methods for a Textile Laboratory. AATCC, Research Triangle Park, NC.

American Association of Textile Chemist and Colorists (AATCC) 1984c. Muller test. p. 51. *In* Analytical Methods for a Textile Laboratory. AATCC, Research Triangle Park, NC.

American Society for Testing and Materials (ASTM) 2000. Standard practice for sampling cotton fibers for testing (D-1441-00). p.351-353. *In* Annual Book of ASTM Standards. Vol. 07.01. ASTM, West Conshohocken, PA.

American Association of Textile Chemist and Colorists (AATCC) 2000. Fluidity of dispersions of cellulose from bleached cotton cloth (AATCC Test Method 82-1996). p. 104-107. *In* Technical Manual of the American Association of Textile Chemist and Colorists. Vol. 75. AATCC, Research Triangle Park, NC.

American Association of Textile Chemist and Colorists (AATCC) 2000. Extractable content of griege and/or prepared textiles (AATCC Test Method 97-1999). p. 139-140. *In* Technical Manual of the American Association of Textile Chemist and Colorists. Vol. 75. AATCC, Research Triangle Park, NC.

Anthony, S. and Herber, D. 1991. Moisture Transfer of Cotton Bales Covered with Experimental Bagging. p. 978-980. *In* Proc. Of the Beltwide Cotton Conf., San Antonio, TX. 8-12 Jan. 1991. Natl. Cotton Counc. Am., Memphis, TN.

Aspland, R.J. and Williams, S.A. 1991. The Effect of Cotton Color Grade on Color Yield of Dyed Goods. Association of American Textile Chemist and Colorist. (2): 23-25.

Campbell, K.S. 1955. To Prevent Dye Streaks in Cloth-Check Raw Cotton with Ultraviolet Light. Textile World. March. pp. 128-129.

Hess. 1928. Die Chemie der Zellulose.

Hessler, L.E., Towery, J.D., and Power, B.K. 1954. The effect of weathering in the field on fiber properties of cotton. Textile Res. J. 11:1010-1014.

Hoechst Celanese. 1990. Dictionary of Fibers and Textile Technology. Hoechst Celanese Corp., Charlotte, NC.

Marsh, P.B., Bollenbacher, K., Butler, M.L. and Merola, G.V. 1954. The relative responsiveness of certain properties of cotton fiber to microbial action. Textile Res. J. 1:31-38.

Nickerson, D. 1941. Color stability in raw cotton II – storage tests. United States Department of Agriculture. Washington, D.C.

Nickerson, D. 1951. Effect of exposure and storage on color and other factors of quality in raw cotton. United States Department of Agriculture. Washington, D.C.

Nickerson, D. and Tomaszewski, J. 1959. Cotton grade studies – color changes in storage. United States Department of Agriculture. Washington, D.C.

Rogers, C. 1992. Bale management to improve manufacturing performance and quality. p. 1240-1242. *In* Proc. Of the Beltwide Cotton Conf., Nashville, TN 6-10 Jan. 1992. Natl. Cotton Counc. Am., Memphis, TN.

Sheehan, W.C. 1951. Neppy cotton—methods of predicting cotton neppiness from raw stock. M.S. Thesis. Inst. of Textile Tech., Charlottesville, VA.

Simon, S.A. and Harmon, C. 1953. Color in cotton. Textile Res. J. 1:12-16.

Sui, R.G.H. 1951. Microbiological Decomposition of Cellulose. Reinhold, New York.

White, E.O. 1992. Bale management for the cotton yarn spinner. p. 1234-1239. *In* Proc. Of the Beltwide Cotton Conf., Nashville, TN 6-10 Jan. Natl. Cotton Counc. Am., Memphis, TN.

SYSTAT. 1992. SYSTAT for windows, version 5. SYSTAT, Inc. Evanston, IL.

Wolf, F.A. and Wolf, F.T. 1947. The Fungi. Wiley and Sons, New York.

Yankey, J.M. 1997. The solutions for controlling fabric barre´. p. 738-742. *In* Proc. Of the Beltwide Cotton Conf., New Orleans, LA 6-10 Jan. Natl. Cotton Counc. Am., Memphis, TN.

Case Study 3 – Cotton Spinning

Brushwood, D., “The Impact of Wax, Metals and Other Naturally Occurring Non-Cellulosic Materials on Yarn Processing Properties” National Cotton Council of America, Memphis, TN, In Publication (2003).

Gamble, G., Implications of Pectin on Cotton Fiber Processing, in “Proc. Beltwide Cotton Conferences,” National Cotton Council of America, Memphis, TN, In Publication (2003).

May, O. L., Keys to a Profitable U.S. Cotton Industry - Yield/Quality Issues to Address Through Breeding, 13th Annual EFS Conference paper, Cotton Inc., Raleigh, NC, April 17-19, 2000.

Meredith, W. R., Culp, T. W., Robert, K. Q., Ruppenicker, G. F, Anthony, W. S., and Williford, J. R., Determining Future Cotton Variety Fiber Quality Objectives, *Textile Res. J.* 61(12), 715-720 (1991).

Meredith, W.R., Genetic Characteristics of Cotton Varieties in Textile Variety Tests, in “Proc. Beltwide Cotton Conferences,” National Cotton Council of America, Memphis, TN, In Publication (2003).

Newton, F.E., Burley, S.T., and LaFerney, P.E., Does Cotton Price Reflect Use Value, Textile Ind. (1967).

Rogers, C. D., McAlister, D., and Boswell, J. S., Textile Processing Evaluation of Southeastern Cottons, in "Proc. Beltwide Cotton Conferences," National Cotton Council of America, Memphis, TN, 1528-1533 (2000).

Case Study 1 Data – Cotton Research

Table I. Fiber Testing Specifications.

Instrument	Sample Location	Sample Size	Samples/ Condition	Repetions/ Sample
HVI	Bale	50g	3	4
AFIS	Bale	0.5g	3	4

Table II. HVI and Classer Fiber Properties.

Property	UNR Spindle Harvested	UNR Stripper Harvested	MSD^{z}
HVI Micronaire	3.47	2.26^{x}	0.22
Strength (g/tex)	27.04	23.24^{x}	1.56
Rd	65.90	68.10	3.15
+b	9.04	10.60^{x}	0.46
Trash (%)	4.00	5.00	2.21
UHML (mm)	28.19	25.91^{x}	0.02
UI (%)	80.75	78.33^{x}	0.96
Color Grade	52	44	--
Extraneous Matter	0	11^{y}	--
Leaf Grade	3	4	--

^{z} MSD- Minimum Significant Difference at the 0.05 Level

^{y} 11 is the Extraneous Matter code for Bark Level 1 as determined by the classer

^{x}Significant difference exists between the treatments

Table III. AFIS Fiber Properties.

Property	UNR Spindle Harvested	UNR Stripper Harvested	MSD[z]
SFC (w)(%)	9.50	16.70[y]	2.39
Dust (cnt/g)	734.00	1952.00[y]	232.07
Trash (cnt/g)	84.00	263.00[y]	25.29
VFM (%)	2.12	5.70[y]	0.63
Neps (cnt/g)	385.00	1069.00[y]	78.19

[z]MSD- Minimum Significant Difference at the 0.05 Level

[y]Significant difference exists between treatments

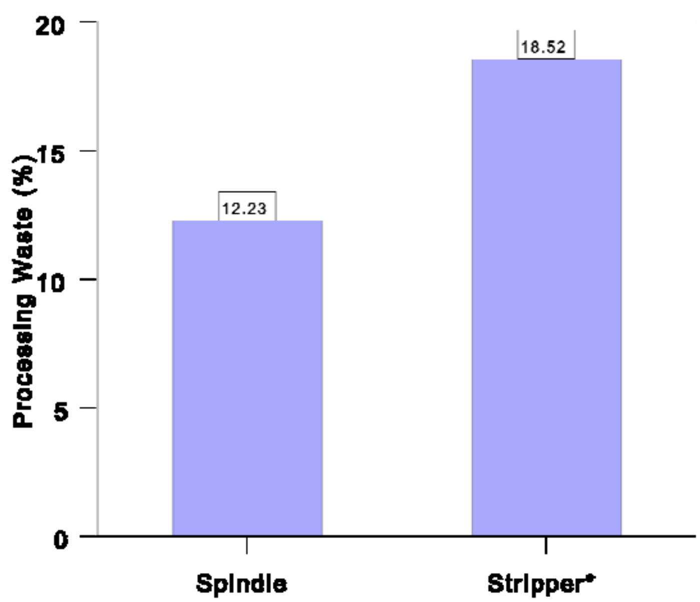

Figure 1. Comparison of % Waste Generated by Treatment (* = significantly different).

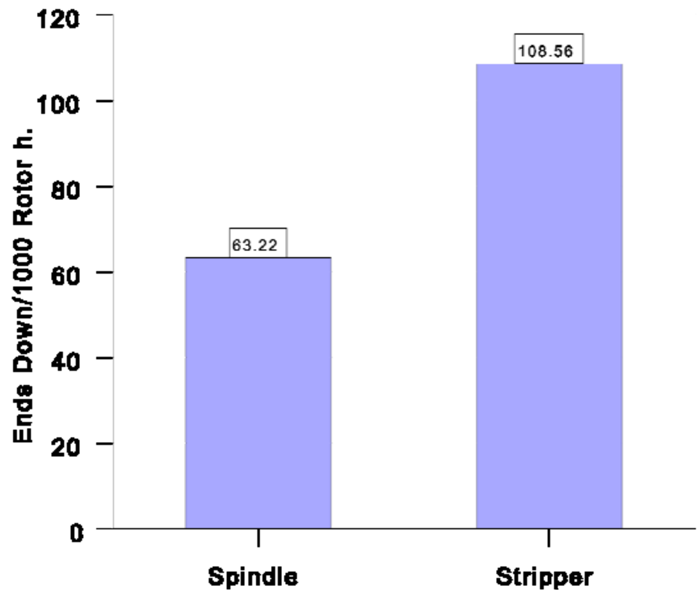

Figure 2. Comparison of Ends Down per 1000 Rotor Hour by Treatment.

Case Study 2 Data – Cotton Classification

Table IV. HVI fiber property list by treatment.

Properties	Winter	Summer Polypropylene	Summer Polyethylene	Summer Burlap	Spring	Fall
UHML (mm)	28.45	28.45	27.69	28.70	27.94	28.19
Micronaire (Units)	4.27	4.53	4.30	3.93	4.20	4.30
Uniformity Index (%)	82.33	81.60	81.00	82.60	80.67	81.67
Strength (g/tex)	26.97	25.43	25.47	26.93	27.87	26.30
Color Rd (Units)	74.50	74.17	75.67	76.00	74.83	75.00
Color +b (Units)	8.10	7.77	7.73	8.03	7.87	8.17
Trash (% area)	2.33	2.67	2.00	2.00	2.00	2.00

Figure 3. Conditioning Chamber.

Table V. HVI +b measurements for each treatment (averages)[z].

Week #	Winter	Summer Polypropylene	Summer Polyethylene	Summer Burlap	Spring	Fall
0	8.10	7.77	7.73	8.03	7.87	8.17
1	8.20	8.10	7.93	8.07	8.10	8.20
2	8.03	7.97	7.73	7.97	7.97	8.03
3	7.93	8.10	8.10	8.20	7.90	8.13
4	7.93	7.80	7.50	7.90	7.50	7.67
5	8.07	8.13	7.90	8.43	8.03	8.13
6	7.83	8.23	8.27	8.43	8.13	8.07
7	8.07	8.03	8.00	8.43	8.07	8.17
8	8.00	8.12	7.95	8.28	8.02	8.19
9	8.13	8.43	7.80	8.37	7.93	7.80
10	8.07	8.53	7.87	8.40	8.03	8.00
11	7.97	8.37	8.03	8.33	7.83	8.03
12	8.03	8.42	8.10	8.78	7.97	8.07

[z] The minimum significant difference between all means is 0.38 units.

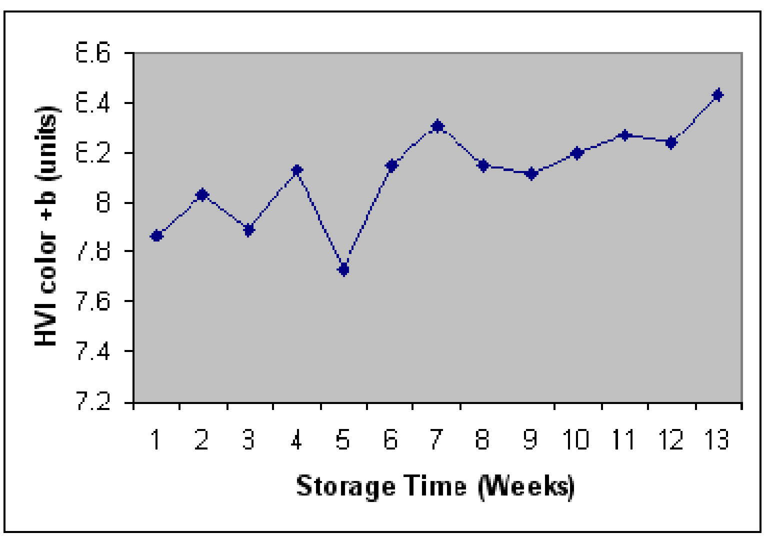

Figure 4. Relationship of storage time in summer conditions on HVI fiber color +b (averaged across the three bale coverings).

Case Study 3 Data – Cotton Spinning

Table VI. Average HVI Properties for Different Cotton Varieties and Growth Areas.

Growth Area	Variety	Mike	Strength	HVI Rd	HVI +b	Trash	Length	UI	SCI
G [z]	**DL PEARL**	4.74	27.63	71.83	7.28	6	1.095	79.42	101
M [y]	**DL PEARL**	4.68	29.58	75.25	7.63	5	1.156	81.33	121
G	**DP-491**	4.48	28.13	70.75	7.94	5	1.119	79.33	105
M	**DPL-491**	4.50	30.61	73.92	8.08	7	1.196	82.08	131
G	**DPL-555**	4.39	25.22	71.75	7.15	6	1.038	78.17	88
M	**DPL-555BR**	4.53	27.98	77.11	7.72	5	1.110	80.78	115
T [x]	**FM-5024**	3.70	28.45	74.91	8.95	8	1.076	80.64	120
T	**FM-819**	3.56	28.71	74.75	8.02	8	1.133	80.42	124
G	**FM-832**	4.36	28.15	70.58	7.91	6	1.094	79.92	108
T	**FM-832**	3.29	30.93	76.75	8.24	6	1.149	80.42	135
M	**FM-832**	4.07	32.97	75.00	7.48	6	1.197	83.11	147
G	**FM-958**	5.18	27.07	68.08	8.50	6	1.058	81.00	99
T	**FM-958**	3.71	29.63	77.33	8.28	4	1.120	80.42	126
M	**FM-958**	4.73	30.63	75.27	7.79	6	1.134	82.09	127
G	**FM-966**	4.58	30.57	70.83	8.01	5	1.073	80.75	116
T	**FM-966**	3.78	31.73	77.17	8.39	5	1.125	81.42	137
M	**FM-966**	4.56	33.53	74.17	7.66	7	1.150	83.58	144
T	**FM-989B/R**	3.30	28.98	77.00	8.26	7	1.113	79.83	125
T	**FM-989RR**	3.53	29.32	76.92	8.81	4	1.090	80.25	125
M	**PH-355**	4.90	28.78	71.45	8.31	8	1.120	83.27	122
T	**PM-2200**	3.85	28.04	76.63	8.78	6	1.087	81.31	123
T	**PM-2326**	4.38	28.23	75.13	9.05	6	1.071	82.19	121
T	**SG-521R**	3.51	25.75	74.00	9.20	8	1.072	80.75	114
G	**SG-747**	5.45	25.06	70.50	8.28	4	1.083	81.08	94
M	**SG-747**	4.78	26.58	71.33	8.68	5	1.113	82.42	113
	Min	**3.29**	**25.06**	**68.08**	**7.15**	**4**	**1.038**	**78.17**	**88**
	Max	**5.45**	**33.53**	**77.33**	**9.20**	**8**	**1.197**	**83.58**	**147**

[Z] Georgia

[Y] Mississippi

[X] Texas

Table VII. Detail of Spinning Production.

Detail	**Ring**
Drawing Passes	2
Yarn Count (Ne)	20/1
Twist (TM)	4.3
Lbs. Produced/Variety	450
Processing Speed	16,500 rpm

Table VIII. Average Yarn Properties.

	Yarn CVm	**IPI Neps**	**IPI Thick**	**IPI Thin**	**Yarn Strength (g/tex)**
Average	20.77	118	932	611	15.5
Min	17.20	24	308	103	11.2
Max	26.40	274	2168	2038	20.3

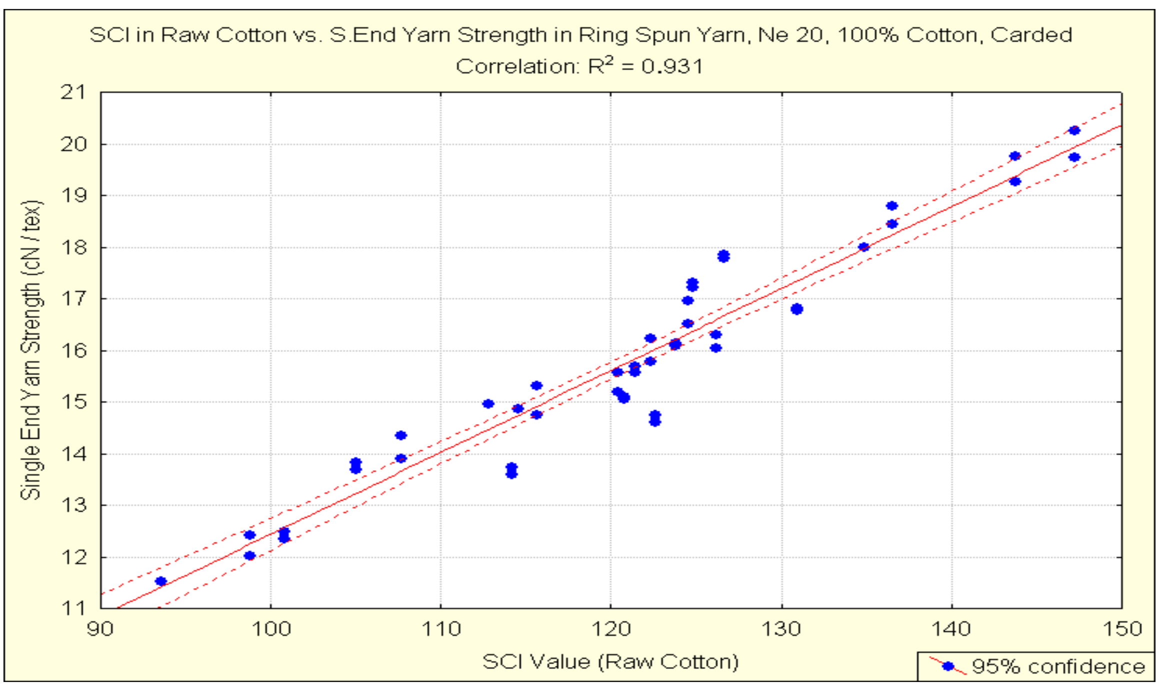

Figure 5. Correlation between Spinning Consistency Index (SCI) in Raw Cotton and Single-End Yarn Strength in Ring-Spun Yarn, Ne 20, 100% Cotton, carded.

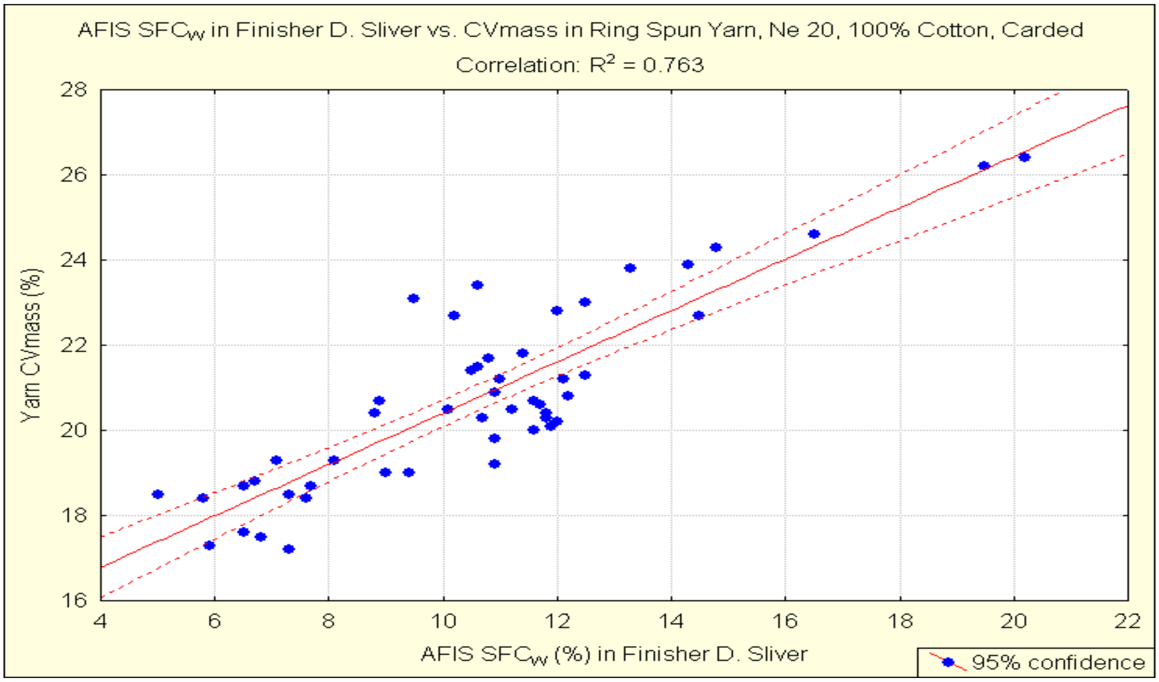

Figure 6. Correlation between finisher drawing AFIS short fiber content (w) and yarn evenness.

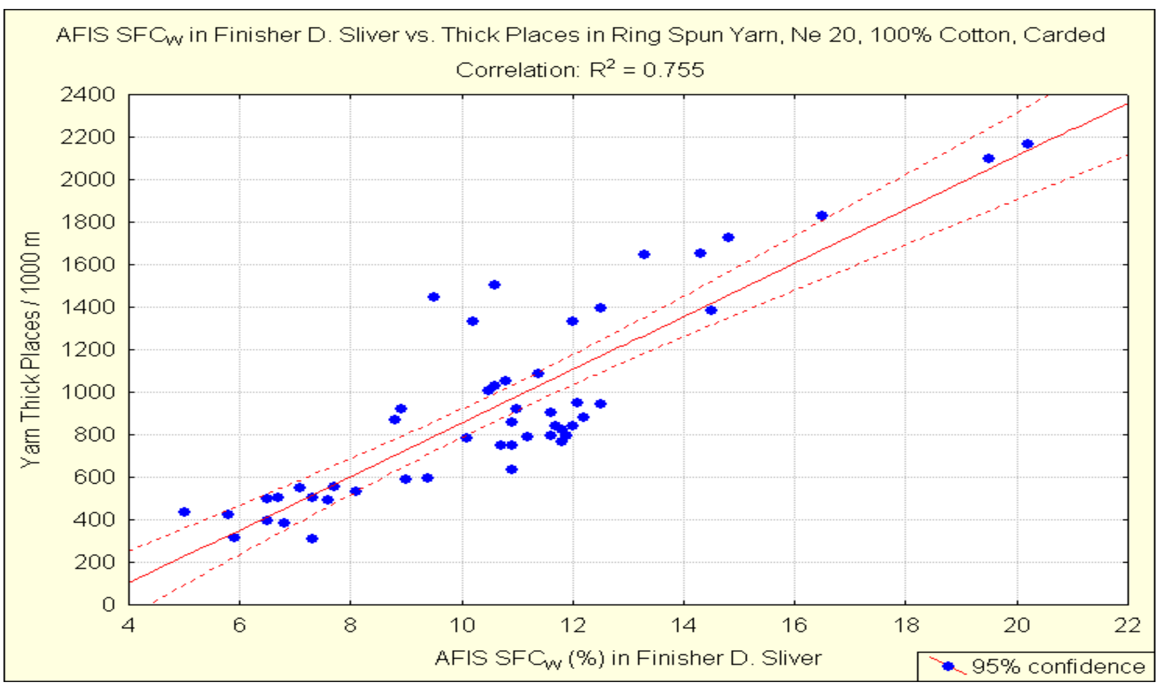

Figure 7. Correlation between finisher drawing AFIS short fiber content (w) and yarn imperfection thick places.

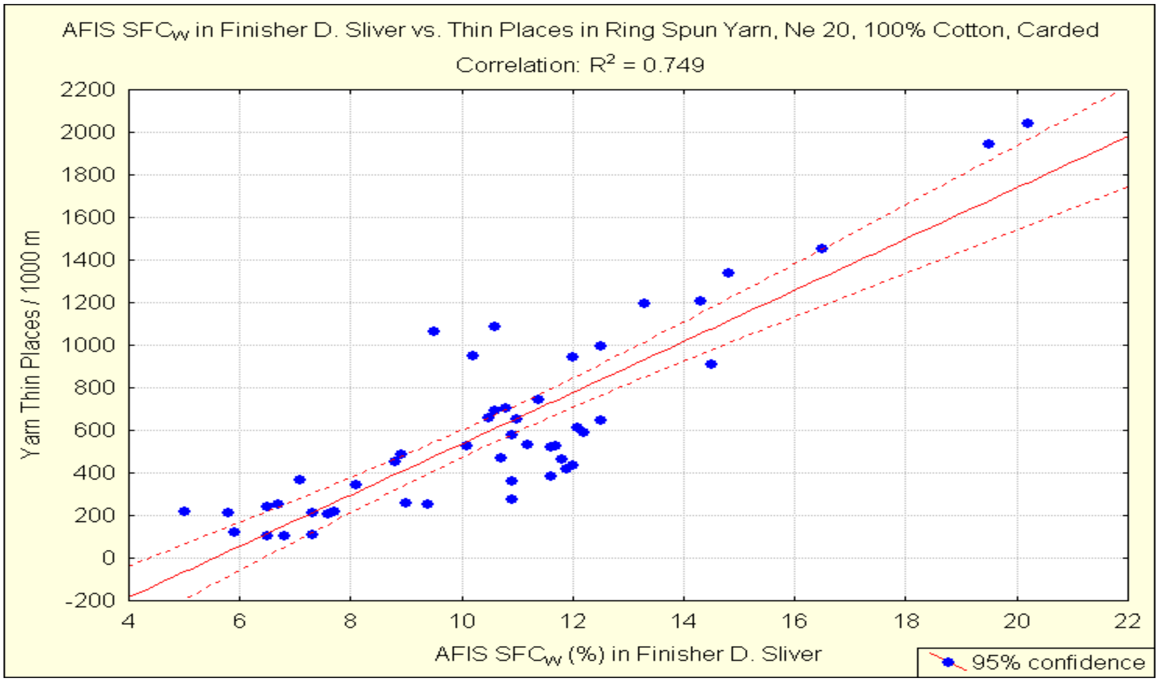

Figure 8. Correlation between finisher drawing AFIS short fiber content (w) and yarn imperfection thin places.