POSSIBILITIES FOR MEASURING COTTON IN THE FIELD AND OUTSIDE THE LABORATORY: FOR BREEDING, PRODUCTION, GINNING, THE WAREHOUSE

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ABSTRACT

Cotton is often classified using high volume instrumentation. Although accurate, these laboratory systems require strict laboratory conditions, well trained operators, and are expensive. Much interest has been shown in non-laboratory measurements in situations not related to classing or commercial trade, especially for those processes/locations prior to fibre processing into yarns. Several recent developments in field, at-line, and on-line quality measurement systems are reviewed from breeding/field measurements to post harvest operations. In ginning, the main quality measurements are for fibre colour, trash, and moisture and for plastic contamination. In the warehouse/storage, systems for moisture and colour measurements are in place. Research on fibre quality properties for in/near cotton field analyses (seed cotton) is in its infancy. Seed cotton micronaire has been measured in/near the cotton field using portable NIR instruments. Trend analyses (high-medium-low micronaire) have been obtained with portable NIR units, and new units are under evaluation. Field trials with new, more cost and size effective NIR units are planned.

INTRODUCTION

Cotton is often classified (fibre quality assessments) using high volume instrumentation (USDA, 2005), such as the Uster® HVI™ and Premier ART2™ systems. Though very rapid, accurate, and capable of measuring several fibre properties (length, strength, micronaire, colour, trash, etc.), they are expensive and require tightly controlled laboratory conditions (temperature and relative humidity/RH; ASTM D1776-08); they are not suitable for quality measurements in remote locations (warehouse, gins, etc.) with insufficient temperature and humidity controls. Operating these units in non-standard conditions can lead to errors in the quality measurements and results, especially for length and strength (Thibodeaux et.al., 2006). Cotton is a global commodity, in which fibre from one country can be readily used in most other countries. This global competitiveness places increased demands on the quality of the cotton fibres, and in turn increased demand on fibre quality assessment and measurement systems. In addition, a need exists for new quality tools and measurements that can measure the fibre earlier in the manufacturing processes (prior to the laboratory) and in non-laboratory conditions—field, on-line, and at-line measurements. On-line measurements are those measurements that are performed directly on the manufacturing or processing equipment; at-line measurements are those measurements that are performed in the "manufacturing" area (e.g., next to the gin, in a greenhouse, in the warehouse); field measurements are those measurements performed in or next to the cotton field, directly on the cotton boll (seed cotton). These non-laboratory or remote location measurements can be used to integrate cotton fibre quality assessments from the field to final fabric ("dirt to shirt").

In this work, we will review a few of the latest developments in non-laboratory quality measurements, from breeding/field measurements to post harvest operations. Several technologies will be reviewed, with a special emphasis on quality measurements of seed cotton (e.g., micronaire).

GIN MEASUREMENTS

Extensive research has been performed on quality assessments of cotton fibre systems during the ginning process. These quality measurements consist primarily of on-line and at-line measurements. Gin monitoring measurements include primarily fibre colour, trash, moisture, and plastic contamination.

An example of measurement technology for on-line gin measurements of fibre properties is the Uster® Intelligin™ (Abbott, 2013). The Intelligin measures the fibre's colour, trash, and moisture (Figure 1). The Schaffner IsoTester™/Gin Wizard™ systems (no longer available) measures at-line (in the gin) fibre length, strength, colour, trash, moisture, neps, seed coat fragments, stickiness, and micronaire (the only gin-associated unit to monitor micronaire) (Figure 2).

Figure 1. Uster® Intelligin™.

Figure 2. Schaffner Gin Wizard™/IsoTester™ systems.

Recently, much research has been performed in the areas of fibre moisture and plastic contamination. In addition to fibre moisture measurements with the Intelligin (on-line) and IsoTester (at-line), “on-line” bale moisture content can be measured by the use of microwave technology. A microwave unit developed by Pelletier (2006) is continuing to be refined. Delhom and Byler (2008) measured the variations in bale moisture content with the Vomax 851-B microwave unit, and the commercial Samuel Jackson Tex-Max™ microwave unit also measures bale moisture (Figure 3). A recent study by Byler (2013) compared several portable and fixed bale moisture systems, and the Tex-Max™ was found to be the most accurate after a simple correction. Extensive evaluations of portable, hand-held, inexpensive moisture meters have been performed by several ARS ginning laboratories (Byler et.al., 2009; Byler, 2013). Though fast, the portable meters exhibited a 95% confidence interval for bale moisture measurements of ±0.9-1.8% moisture.

Figure 3. Samuel Jackson Tex-Max™ microwave instrument.

Plastic contamination in lint cotton is a recurring concern. Often, the contamination is obtained from the field during the harvesting of the cotton (grocery bags, plastic mulch, module covers, etc.). There are several commercial contamination opticallybased sensors for gins, opening, and carding systems, and they can be classified into 6 general types or methods (Gordon et.al., 2012):

- Method 1—Acoustic sensor combined with optical reflective sensor. Examples include Loptex Italia S.r.l (Italy/Switzerland) and Vetal (India) systems.
- Method 2—Visible light with UV and polarized light and multiple detectors. Examples include Trutzschler GmbH (Germany) systems.
- Method 3—Diffused illumination. Examples include the BarcoVision (Italy) systems.
- Method 4—Optical-reflective techniques that compares different reflective surfaces. Examples include the Jossi Systems AG (Switzerland) systems.
- Method 5—Infrared (IR) and Near Infrared (NIR) spectroscopy. Most of these systems are in the research phase and can be used for laboratory analyses.
- Method 6—Balanced illumination. This method was developed by CSIRO for gins and uses the principles of the Loptex and Trutzschler systems.

In addition, research is underway on processing (heating) seed cotton samples and detecting plastic contamination by Ion Mobility Spectrometry (IMS; Funk et.al., 2008).

WAREHOUSE MEASUREMENTS

Research into at-line fibre measurements in/at the warehouse is limited. The main at-line warehouse measurements are bale moisture and bale colour. Bale moisture measurements using portable moisture meters have been discussed above. Bale colour measurements have been performed at-line using portable colour spectrophotometers, as shown in Figure 4 (Rodgers et.al., 2013a). Equations/relationships for Rd and +b were developed for the HunterLab MiniScan EZ™ portable colour unit, and the colour results interfaced with the MILLNet™ software. Comparative evaluations on over 400 samples demonstrated very good colour agreement between the portable colour unit and HVI™ colour results.

Figure 4. HunterLab MiniScan EZ™ colour spectrophotometer.

BREEDING and PRODUCTION MEASUREMENTS

As noted above, the main fibre properties monitored on-line and at-line in the gin and warehouse are colour, trash, and moisture. With the exception of the IsoTester, other fibre properties—such as micronaire—are not measured routinely outside of the laboratory. Interest has been expressed in rapid and precise measurements that can be used to monitor key fibre properties—such as micronaire—and applied both in the laboratory (complement to HVI-type instruments) and outside the laboratory. These new measurements would be applicable for both cotton lint (e.g., gin and warehouse) and seed cotton (e.g., field and gin). Near Infrared (NIR) technology meets most of these needs, and recent advances in NIR portable instruments could lead to new remote location measurement techniques, especially for seed cotton. Several studies have demonstrated the NIR method's ability to measure cotton lint micronaire in the laboratory with both bench-top and portable units (Montalvo and Von Hoven, 2004; Rodgers et.al., 2010a and 2010b).

Research is continuing on field measurements of key fibre properties, with emphasis on seed cotton micronaire. Preliminary field trials on 15 cotton varieties with a portable Brimrose Luminar™ 5030 NIR unit (Figure 5) successfully demonstrated the method's ability to detect differences between "high-medium-low" micronaires (HVI™ reference) for over 80% of the samples using laboratory NIR calibrations for micronaire (trend and outlier analyses; Rodgers et.al., 2010c; Figure 6). Protocols were developed for both field measurements and near field/"at-line" measurements, and all in/near field measurements were made directly on the cotton boll.

Figure 5. Brimrose Luminar™ 5030 portable NIR unit.

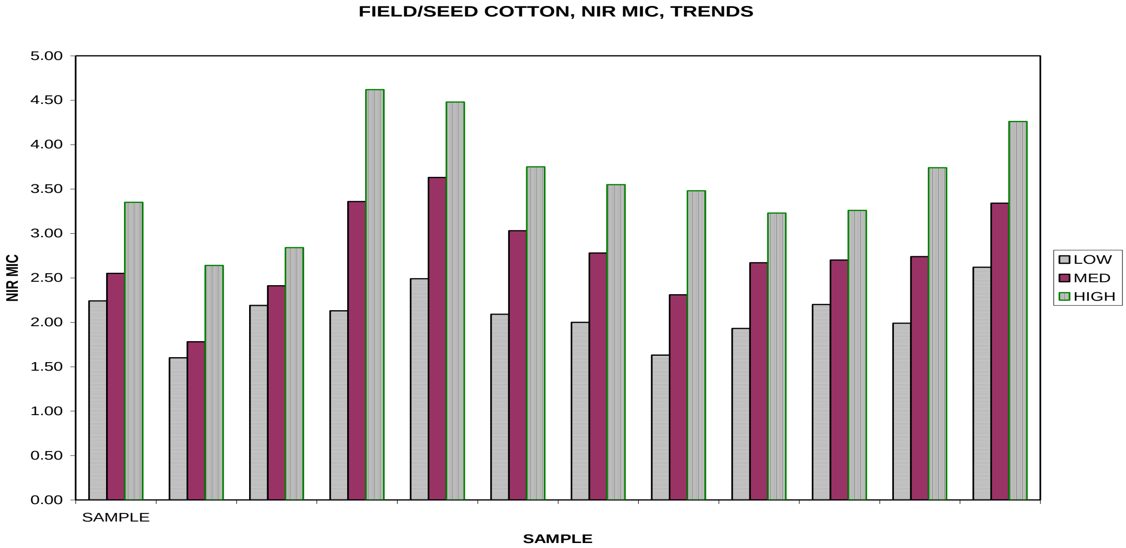

Figure 6. NIR micronaire, field measurements of seed cotton samples (Rodgers et.al., 2010c).

Evaluations were performed on the major sources of variability/differences between in/near field measurement of seed cotton micronaire and laboratory measurements of lint micronaire. The environmental conditions for field measurements were very variable—different weather conditions, different temperatures and RHs, different locations (3 fields in 2 states), different production practices, etc. (definitely not a controlled environment). To determine the impact of field measurement conditions and fibre type (seed cotton impact) on the NIR results, both seed cotton and ginned lint laboratory NIR measurements were made on each seed cotton sample measured in/near the field (field measurements/seed cotton vs. laboratory measurements/seed cotton vs. laboratory measurements/cotton lint). As shown in Figure 7, the average lot/variety range and variability was much higher for the field measurements/seed cotton measurements. Thus, the major source of variability in NIR field measurements was the field (environmental) conditions themselves and not the seed cotton nor cotton production practices. It is interesting to note that, even with the higher variability due to field conditions, good high-medium-low micronaire trend analysis was obtained. These results also demonstrated that the impact of seed cotton on the laboratory NIR micronaire measurements was small and could be easily offset by performing more measurements per sample.

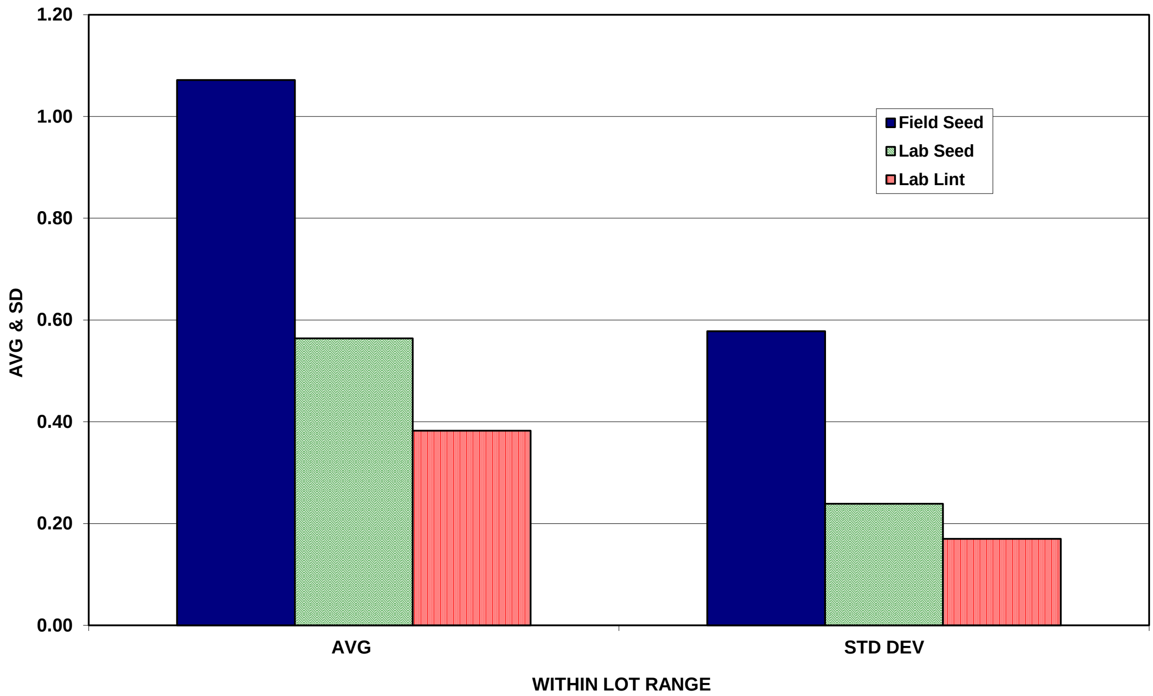

Figure 7. Field samples, field measurements/seed cotton vs. Laboratory measurements/seed cotton vs. laboratory measurements/cotton lint, average within-lot range difference and standard deviation (SD), all fields

Although the results above were very encouraging, concerns have been expressed about the cost and size of the standard portable NIR instruments. Research is underway on new, very small, low cost portable NIR analysers, such as the JDS Uniphase (JDSU) MicroNIR™ (Figure 8). Prior to field trials, comparative laboratory measurements on cotton lint have been performed to determine the capabilities and potential of the MicroNIR to measure micronaire (Rodgers, 2013b). Comparisons were made between the portable Brimrose Luminar™ 5030 and new JDSU MicroNIR™. Instrumental specifics are given in Table I. The laboratory lint cotton NIR results are given in Table II. Very good agreement was observed between the two NIR units and for each NIR unit and the reference HVI™ results. Since very encouraging field measurement results for seed cotton micronaire have been obtained with the Brimrose unit, the very good agreement between the Brimrose and cost and size effective JDSU units are promising indicators for cotton field analyses of micronaire with the JDSU unit. Field trials for the JDSU unit are planned for the near future.

Figure 8. JDSU MicroNIR™ portable NIR unit.

Table I. Portable NIR unit instrumental specifics.

ITEM	NIR UNITS	
	BRIMROSE 5030™	JDSU MicroNIR™
TECHNOLOGY	AOTF	LVF
WAVELENGTH REGION (nm)	1100-2300	1150-2150
NO. OF SCANS	400	1000
INSTRUMENT ANALYSIS TIME (Sec.)	20	15
REPLICATES	5	10
RESOLUTION (nm)	2	8
SAMPLING AREA (mm Diameter)	6	15
SAMPLING METHOD	CONTACT	CONTACT

AOTF = Acousto-Optical Tuneable Filter; LVF = Linear Variable Filter.

Table II. Micronaire, HVI™ and portable NIR results

ITEM	PREDICTION, MICRONAIRE		
	HVI™ (Ref)	BRIMROSE 5030™	JDSU MicroNIR™
AVERAGE	4.01	4.06	4.05
SD	0.63	0.61	0.56
SDD	NA	0.19	0.25
R2	NA	0.91	0.85
No. > ±0.3 MIC	NA	12.1	15.1

SDD = Standard Deviation of Differences (residual analysis)

SUMMARY

Cotton is often classified using high volume instrumentation, such as the Uster® HVI™ and Premier ART2™ systems. Though very rapid, accurate, and capable of measuring several fibre properties, they require strict laboratory conditions, well trained operators, and are expensive; they are not generally suitable for non-laboratory cotton lint quality measurements. Much interest has been expressed in new quality tools and measurements that can measure the fibre earlier in the manufacturing processes and in non-laboratory conditions—field, on-line, and at-line measurements.

In ginning, gin quality/detection measurements include primarily fibre colour, trash, moisture, and plastic contamination. The Uster® Intelligin™ (fibre colour, trash, moisture) and Schaffner IsoTester/™Gin Wizard™ system (fibre length, strength, colour, trash, moisture, neps, seed coat fragments, stickiness, and micronaire) are the main instruments for measuring more than one fibre property. On-line microwave units (on-line) and small, portable conductance/resistance/ dielectric units (at-line) are used to measure bale moisture. Much interest has been shown in plastic contamination detection; the primary technologies used are acoustic, optical, and advanced spectroscopy (e.g., IR, NIR, IMS). In the warehouse, bale colour and moisture are the primary fibre properties measured (at-line).

Interest has been expressed in rapid and precise measurements to monitor key fibre properties—such as micronaire—that can be applied both in the laboratory (as a complement to HVI-type instruments) and outside the laboratory in remote locations (e.g., in or near a cotton field). Recent advances in NIR portable instruments could lead to new remote location measurement techniques, especially for seed cotton. Field measurements and sampling protocols have been developed for seed cotton micronaire, in which the NIR measurements are taken directly on the cotton boll. Preliminary field trails with a portable Brimrose Luminar™ 5030 NIR unit demonstrated the NIR method's ability to detect differences between "high-medium-low" micronaires for over 80% of the samples using laboratory NIR calibrations (trend and outlier analyses). The major source of variability was field conditions (environmental), not the seed cotton itself nor cotton production practices. Evaluations have been expanded to include new very small and cost effective portable NIR units (JDSU MicroNIR™). Very good agreement in the laboratory on lint samples was observed between the JDSU unit and the HVI™, with low residuals and <15% outliers, which are very promising indicators for cotton field analyses of micronaire. Field trials with portable NIR units are planned for the near future.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the outstanding work by Ms. Jeanine Moraitis in preparing and running the NIR samples.

DISCLAIMER

The use of a company or product name is solely for the purpose of providing specific information and does not imply approval or recommendation by the United States Department of Agriculture to the exclusion of others.

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