2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

SAMPLING ISSUES FOR COTTON FIBER QUALITY MEASUREMENTS ; PART 2 : IMPACT ON COTTON TESTING INSTRUMENT RESULTS

Jean-Paul Gourlot, Edward Gerardeaux, Richard Frydrych, Gérard Gawrysiak, Philippe Francalanci and Eric Goze
Cirad
Montpellier
Jean-Yves Drean and Rui Liu
ENSITM
Mulhouse

Abstract

The cut cotton sample used for the commercial evaluation of cotton bales is taken at a single point from one or two sides of the bale. It should be verified that this sample is sufficient to perform quality measurement that is adequately precise to avoid litigation. On one hand, the variability of the H2SD stickiness measurement within a bale has been addressed by Gozé (2002) and Frydrych (2004) who showed that stickiness was variable within a bale. On the other hand, the studies about the within-bale variability of the other fibre characteristics measurements, while available for US cotton, are very few in a small farmers context.

In another growing country where cotton is grown by small property holders, we achieved a study on technology of farmer's cotton fibre. Our study compared cotton technology of cotton farmer's samples, in four villages located in contrasted ecological conditions. Results show a broad range of quality between localities and between farmers. As in many producing countries, seed-cotton fed in the ginning plant comes from successive modules that may originate from different localities and farmers without taking into account the quality consequences; a strong variability of fibre characteristics inside a bale could result.

When preparing a bale, different layers of cotton are superimposed by a tramper before pressing. Our hypothesis is that within-bale variability is concentrated between the layers (vertically) whereas within-layer variability (horizontal) is lower. If such is the case, specially designed samples taken from the entire side of the bale, i.e. in the form of a superficial strip involving all the layers, should be more representative than a simple cut cotton sample that involves only few of the layers.

We tested this hypothesis by means of a sampling study involving 24 bales from 4 different origins. A three-dimensional matrix of 8x2x2 was used to study the variability in all 3 directions of the bales. Also, a comparison between the conventional cut cotton sample and the superficial vertical strips determined which method, in practice, gave the best results.

The H2SD results clearly showed in the first part of this study (Frydrych, 2004) that the new sampling method is interesting to reduce the H2SD measurements variability. This paper reports the results about other fibre technological measurements on the same samples.

Introduction

Most of the time, samples are drawn out from the bale with a rectangular punch, which cuts in one or both external layers of the bales to perform quality characterizations on cotton bales. One or two rectangular samples of approximately 100-150 grams, 180 * 80 mm wide and 50 mm thick are extracted from the bale for quality assessment. The fibres contained in these two samples are supposed to be representative of the whole bale.

Many articles have been published in the 90's in the United States of America to study the representativity of such samples for commercial purposes and its importance on measurement precision (Boyd, 1993; Moore, 1994; Sasser, 1992…). In these cropping conditions – large farms, mechanical harvest, module building, and module feeder at the gin, etc. – precision, accuracy, repeatability and reproducibility are satisfactory, as fibre bales can be considered as homogeneous.

The within-bale variability originates from the within-field variability, added to a part of the between-field variability in the case where seed-cotton from various field is mixed.

- In USA, the number *n* of bales per field may be very high. Then 1/*n*, the probability of mixing seed cotton from two different fields is very low. Plus the within-field variability is expected to be small.
- In other conditions, the within-field variability can be high, and as the fields are small, the number of bales per field *n* is small. Then the probability of mixing the cotton of at least two different fields in a bale is rather high.

In addition to that point, we may introduce another origin for the variability: some countries offer a wide choice of variety to be planted, while other only offer a few varieties.

As an example, concerning 2003-2004 crop in Florida, we observe that cotton seeds from Deltapine varieties are more than 97% of the total (Table 1). (sources: addresses 1, 2 and 3 in bibliography)

Table 1: Distribution of Deltapine varieties within Florida.

Variety	Percent
DP 436 RR	1.89
DP 449 BG/RR	0.42
DP 451 B/RR	10.30
DP 458 B/RR	33.47
DP 468 BGII/RR	0.49
DP 555 BG/RR	34.42
DP 655 B/RR	1.40
DP 5415RR	6.09
DP 5690RR	9.35
Total	**97.83**

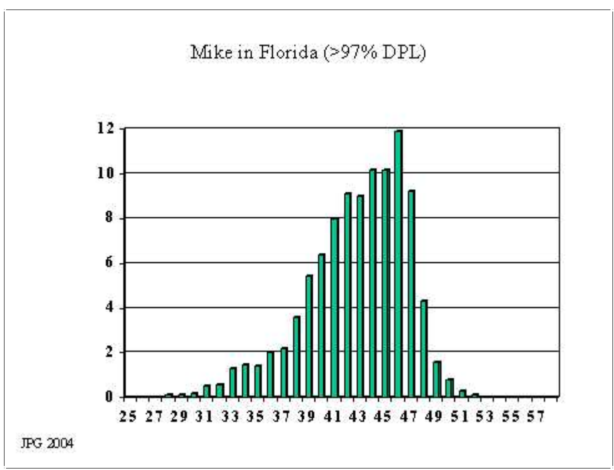

Figure 1: Micronaire distribution in Florida when DPL varieties cover more than 97% of the planted cotton.

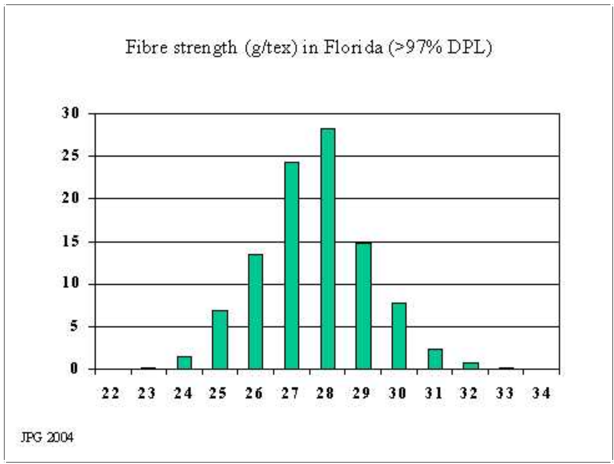

Figure 2: Strength distribution in Florida when DPL varieties cover more than 97% of the planted cotton.

The distributions of micronaire and strength measured on the harvested fibre show much variability (Figure 1 and Figure 2).

Thus, at this point, we may wonder about the within-bale variability for the same parameters. Indeed, as seen from outside USA, we do not know well the probability of feeding a single gin plant by mixing seed-cottons from different modules combining cottons from different varieties or growing locations or growing conditions which led to observe those between-bales distributions in Florida.

Otherwise, few papers have been published in the context of small scale cotton farming and gin plants fed by telescope that may induce larger variability than the one observed in the previous situation.

Material and Methods

We studied by a survey the variability originating from the within and between cotton fields in one producing country. In a consumer country, we made a sampling experiment to measure the within-bale variability and the precision of various sampling methods.

The survey can be used to quantify the possible between-bale variability that can be observed in another producing country than the USA, and one can compare its results to the information presented in introduction. The sampling experiment is designed to compare the merits of several sampling methods and check if the sampling error magnitude is acceptable.

Field survey

Cotton is produced in a small holder country in strict pluvial conditions. The average field measures 1.2 ha for an average yield of 1.05 ton of seed-cotton per ha. Thus, each producer sells an average of 1.26 tons of seed-cotton. Marketing is organized by the grower's association of the village by putting together seed-cotton produced by several farmers. Ginning companies buy the whole production of all the villages that they have been attributed by the national Cotton Association. Seed-cotton from all the growers in a village is dispatched in different modules according to its seed-cotton grade. When arriving at the ginning plant, seed-cotton 'modules' are stocked separately and successively ginned. As in many producing countries, seed-cotton feeding the ginning plant comes from successive modules. It may then happen that two modules contribute to the same bale. This can occur in the USA conditions as well.

The between field and within field variability were observed in four villages situated in contrasted areas of the country.

Description of climate conditions and cultural practices

We chose to study cotton fibre quality from four villages selected in the main region of cotton production. Location

(A) is at the centre of the cotton production area, yields are high and climate is very favourable (Table 2). Rainfall starts in June and stops in mid-October. Location (B) conditions looks like those of location (A).

Location (C) and (D) conditions are a little bit different: rainfall starts in May and stops in the end of October. Rainfall events are much more important than in (A) and (B). Weather is often cloudy in August. Sowing dates are extended in (C) and (D) due to a lack of mechanisation while (A) and (B) uses animal or motorized traction to sow.

Table 2: General information about the producing areas within the producing country.

	Rainfall in mm	Daily insulation from July to November in h	Sowing period durations in days	Average yield in kg/ha of seed-cotton
A	1046	8.2	40	1736
B	1000	NA	45	1479
C	923	6.8	60	1120
D	1080	5.9	55	1177

NA : data not available but should be between (A) and (D).

Sampling of the seed-cotton in the villages

Seed-cotton samples were taken in farmer's cotton fields. A typology of farmers exploitations were previously done in each village to cover the cotton cultivation practice variability, four to five categories were identified. Four to six farmers were chosen in each category according to the relative weight of each category. A sample of seed-cotton was taken in each farmer fields at a typical location. In case of an important visual within-field variability, two or three samples were taken instead of one. Each sample was harvested on 16m². The harvest of seed-cotton was split: the first took place 120 days after planting and the second was made 150 days after planting. Seed-cotton samples were ginned with a "20 saws" gin stand and 200 g of fibre were taken by picking 20 sub samples by hand. Fibre quality parameters were measured using an HVI® instrument at CIRAD Montpellier, France.

Sampling experiment on commercial bales

On the commercial bale experiment, bales from 4 worldwide cotton origins (different from the first experiment) were sampled in four different ways in order to check the homogeneity of fibre characterization results. In order to keep a good level of confidentiality for the results, the origins of these bales were encoded by numbers: 1 (8 bales), 2 (5 bales), 3 (5 bales) and 4 (6 bales). Previous results using these bales were presented during the Beltwide Cotton Conferences in 2004 by Frydrych who was checking the within-bale variability of stickiness.

Four ways of sampling were used:

- One sample was taken in the bales as the rectangular punch would do on bottom and top layers of the bale (total : 2 samples per bale, Figure 3) ;

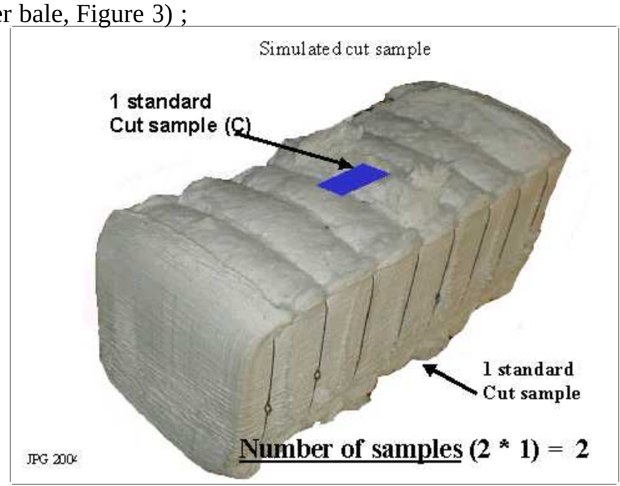

Figure 3: Sample taken as a rectangular punch would do.

- Two other samples from the top and two from the bottom of the bales were taken to check the variability of parameters within those layers of the bales (total: 4 samples per bale, Figure 4) ;

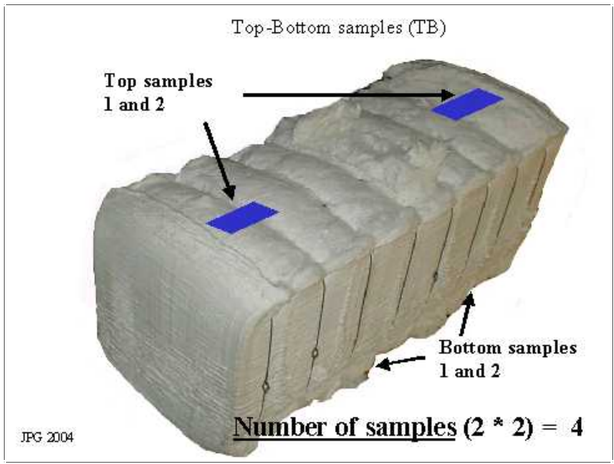

Figure 4: Top and bottom complementary samples.

- Eight layers regularly spaced were selected. In each layer, a sample was taken from each of the four corners (total: 32 samples per bale, Figure 5); these 32 samples allowed the most precise estimation of the bale mean characteristics, therefore they played the role of the reference sample in this study.

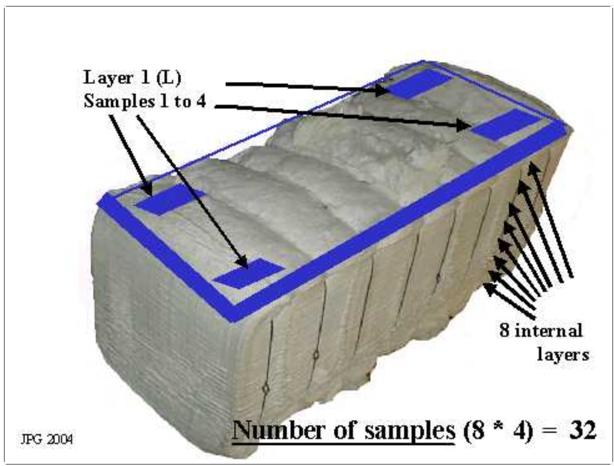

Figure 5: Layout of eight-layers of four samples

- Four samples were taken from 4 strips along the sides of the bales using a specific sampling device. This sampler is made of a cylinder covered by a card wire that grabs fibres along the sides of the bales. The fibres are then removed from that cylinder with an air-stream that drives the collected fibres into a collecting can (Figure 6 and Figure 7).
-

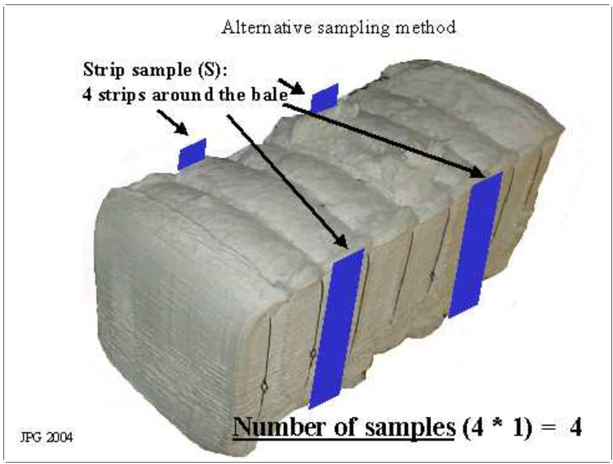

Figure 6: Four strip samples around a bale.

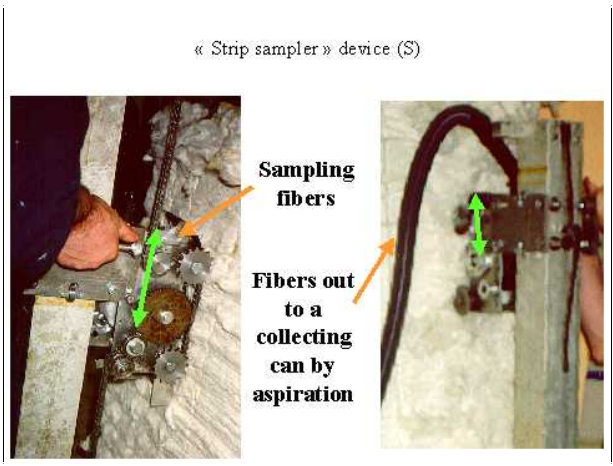

Figure 7: Strip sampler device used for the experiment.

The 1008 samples (42 samples per bale, 24 bales) collected were analysed using a Spectrum® equipment from Uster Technologies® (this use does not constitute any type of recommendation for this equipment). Samples from every bale and from every origin were analysed in a random order. We made two readings of micronaire and six readings of length, strength and colour parameters per sample.

Results and Discussions

Field survey

For every bale characteristic measured, the village means were compared at 5% level with a multiple comparison test. Because the sample sizes and standard deviations were different from one village to another, we used the Tukey test as modified by Kramer.

Micronaire

The Figure 8 shows data from that part of experiment. Location (A) has a high IM average and quiet uniform amongst farmers while location (D) has a low IM average with a high level of standard deviation. All differences are significant.

The two other situations, location (B) and location (C), can be considered as a transition between location (A) and location (D). These data can be linked with insulation and yield data in Table 2.

More mature fibres and longer fibres are produced in high insulation conditions: location A has a very high day insulation duration compared to other locations.

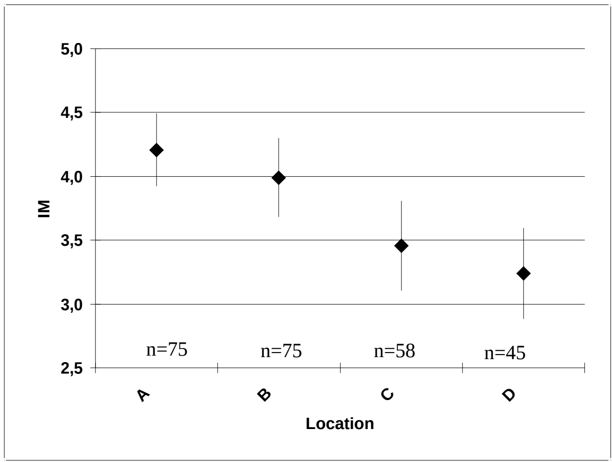

Figure 8 : Micronaire vs producing area: mean and standard deviations.

Fibre length

Data shows significant differences between averages of Mean Length (ML in mm). Location (A) produces fibres with ML exceeding by 2 mm those produced in location (D) (Figure 9). All villages are statistically different from one another, except B and C.

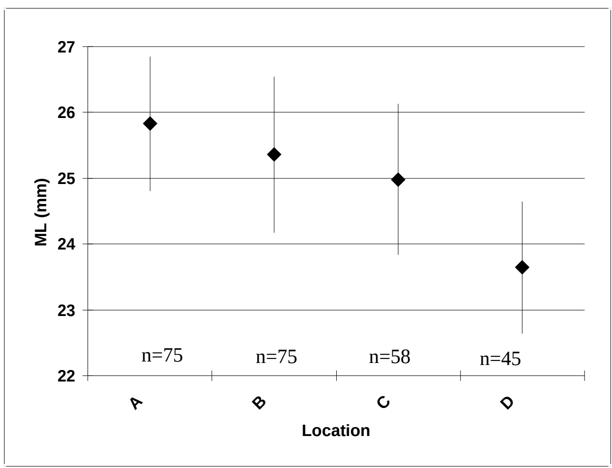

Figure 9: Mean Length (mm) vs producing location: mean and standard deviations.

With Upper Half Mean Lengths (UHML), the locations rank is the same order as for ML (Figure 10), with the same significant differences.

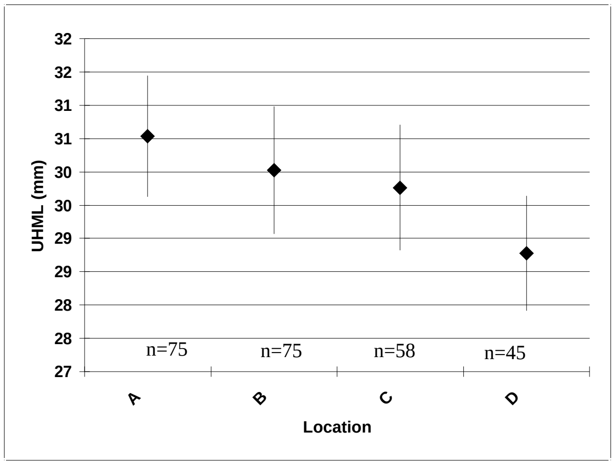

Figure 10: UHML (mm) vs producing location: mean and standard deviations.

Maturity ratio (MR)
IM is the fibre characteristic that varies the most between villages (Figure 11). The differences between villages can be explained by the cultural practices: in location (A) and location (B), the sowing period duration is 40-45 days while it is 55 to 60 days in location (C) and location (D). A multiple mean comparison test indicates that all villages differ from each other by their MR averages.

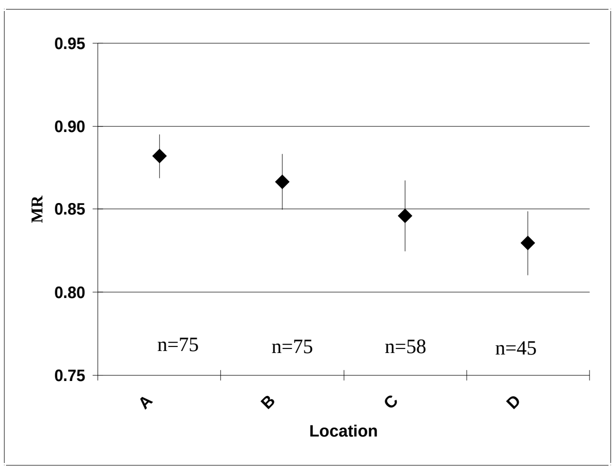

Figure 11: Maturity vs producing location: mean and standard deviations.

Evidence is shown that fibre technology is variable between villages because of climate conditions and cultural practices. Some villages have a low level of variability for fibre parameters while others have a larger one.

From this survey, we see that some heterogeneity of fibre characteristics may occur in bales from this country. This may be the case as well as in other small land holder countries.

Commercial bale sampling experiment.
The aim of this experiment is to answer two types of questions:

- For a given bale, do all kinds of samples yield the same average (apart from measurement errors) or are some samples biased?
- Are some sampling methods more precise than others? Do some sampling methods generally give estimations closer to the bale mean than other ones?

In fact, we do not know the exact bale mean, but we make the hypothesis that the 8 layers x 4 columns samples mean does adequately measure the bale mean.

As we have some replications, we can infer the precision of the method from the difference between the replicates, with a classical analysis of variance (ANOVA) scheme.

As the bale is made of successive layers, we model the within-bale variations with a hierarchical model: Y = mean + layer effect + column effect + error, with the column effect depending on the layer considered (the column effect is nested within the layer effect).

All the effects are considered random. Some covariance could arise between layers close to one another, but in fact we did not find any. We thus analysed the results with a plain variance components model.

The layer and column effects were estimated separately for the different kinds of samples, to allow some differences in variances due to the different shapes of the samples. Again, we did not find any heterogeneity of the layer effect variance between the different kinds of samples (this was tested with a likelihood ratio test). Nor was the case for the column effect. By contrast, all the variances would generally vary from one bale to another, thus making it impossible to infer a universal precision valid for all the bales: it generally had to be calculated separately for each bale.

The sampling variance is inferred from the between layers and between column variances as follows: when a sample is taken from *p* different layers, with *q* different columns in each, and when *r* measurements are made overall, the variance of the result is (equation 1):

$$\sigma^2_{Layer} / p \quad + \quad \sigma^2_{Column} / pq \quad + \quad \sigma^2_{Error} / r \qquad \text{Equation 1}$$

Thus, when two length measurements are made on a double sided cut sample, the sampling variance of the result is readily calculated (equation 2):

$$\sigma^2_{Layer} / 2 \quad + \quad \sigma^2_{Column} /2 \quad + \quad \sigma^2_{Error} /2 \qquad \text{Equation 2}$$

For a “top+bottom” sample, with two columns in each layer, there are two layers and 4 column * layer combinations sampled, and the sampling variance becomes (equation 3):

$$\sigma^2_{Layer} / 2 \quad + \quad \sigma^2_{Column} /4 \quad + \quad \sigma^2_{Error} /2 \qquad \text{Equation 3}$$

A strip sample scans all the layers of the bale: the layer effect then cancels, so the layer variance component does not contribute to the sampling variance. For a double-sided strip sample, the sampling variance is then (equation 4):

$$\sigma^2_{Column} /2 \quad + \quad \sigma^2_{Error} /2 \qquad \text{Equation 4}$$

The sampling variances were calculated from these formulas. The variance component model parameters were estimated with the restricted maximum likelihood method (REML), using the mixed procedure of SAS software, version 8.2. Mean comparison tests with the usual Dunnet multiple comparison adjustment were carried out to detect any difference between each sampling method and the 8-layers samples taken as a control.

Three variables were analyzed: length (mm), strength (g/tex) and micronaire. The comparison of means shows some significant bias on some occasions for the strip sampler. However, this bias is always small and, though significant, can be neglected for commercial purposes.

<u>Variance components</u>

As an example, the square roots of the variance components of UHML are listed in Table 3 and Table 4.

Table 3: Standard deviation of the sampling error components listed by origin.

UHML	σ Layer	σ Column	σ Error
Origin 1	0.11	0.03	0.59
Origin 2	0.00	0.18	0.55
Origin 3	0.08	0.11	0.51
Origin 4 (*)	0.21	0.16	0.68

(*) the standard deviations vary from one bale to another. See table 4 for details

The layer component has a quite different contribution depending on the origin: not detectable for origin 2, it is 0.1 mm on origin 1 et 3, and 0.2 mm on origin 4. The column component also varies in magnitude from one origin to another. The residual standard deviation is roughly the same for every origin, although it is significantly higher for the origin 4.

This residual variation is dominant over all the other components. Remember that the squares of the standard deviations add up to the sampling variance: on the variances the difference in magnitude between components is even more important. Compared to the error component, the other components are almost negligible.

Table 4: Standard deviation of the sampling error components listed by bale in origin 4.

UHML	σ Layer	σ Column	σ Error
Bale 1	0.00	0.24	0.80
Bale 2	0.21	0.06	0.49
Bale 3	0.15	0.12	0.74
Bale 4	0.44	0.00	0.55
Bale 6	0.00	0.13	0.78

For origin 4 (Table 4), the variance components are more evenly distributed among layers, column and errors effects. Still, the error component is far higher than the other effects.

For micronaire and strength, the variance components differ from one bale to another for every cotton.

Sampling standard deviations

Figure 12 to Figure 14 compare the sampling standards errors of the strip sample with that of the cut-sample, computed from formulas 4 and 2 respectively. To perform the calculations, we retained the conditions of 2 measurements per sample for length and strength measurements, and one measurement for micronaire and modified the formulas accordingly.

To prepare the Figure 12, we checked that within-sample variances were homogeneous for UHML (Upper Half Mean Length). The origin (4) was heterogeneous, but we chose to represent its mean point anyway. The more detailed analysis of origin 4 is presented in Figure 13, where each point corresponds to one bale.

Figure 14 and Figure 15 show standard errors for strength and micronaire respectively, where each point represents one of the 24 bales from that research, as the variances components differs from one bale to another for every origin.

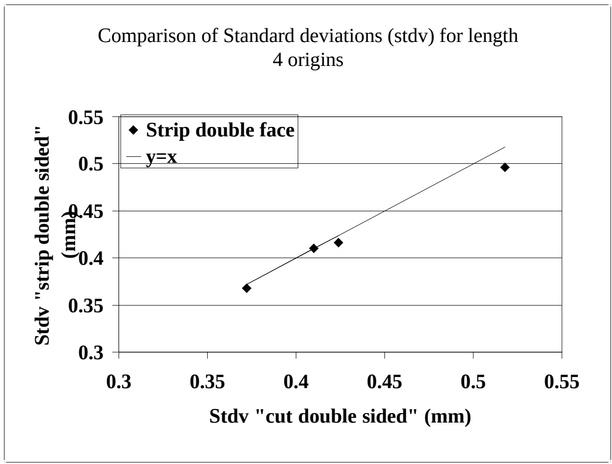

Figure 12: Comparison of standard deviations (mm) for UHML for the 4 origins of the bales.

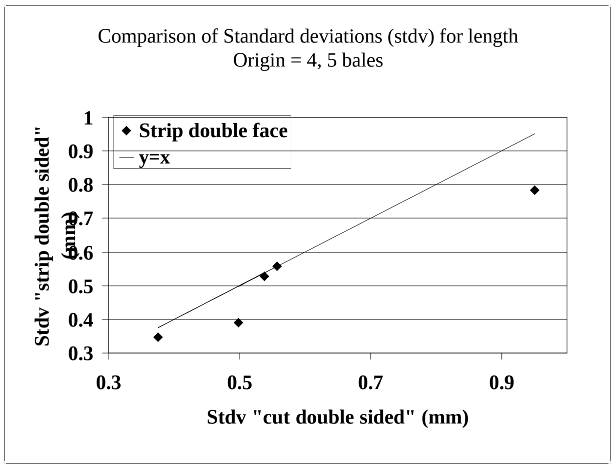

Figure 13: Comparison of standard deviations (mm) for UHML for the 5 bales from origin 4.

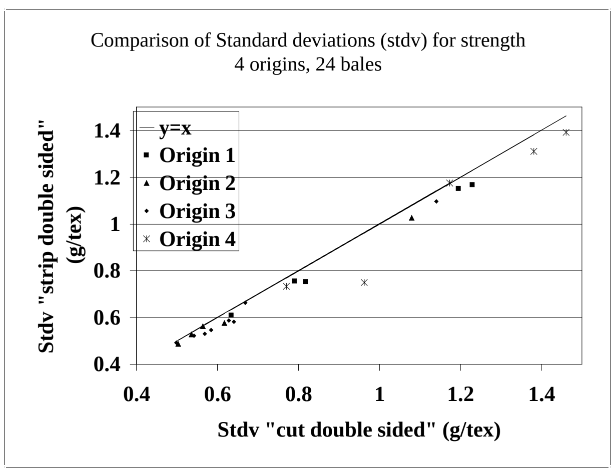

Figure 14: Comparison of standard deviations (g/tex) for Strength for the 24 bales from 4 origins.

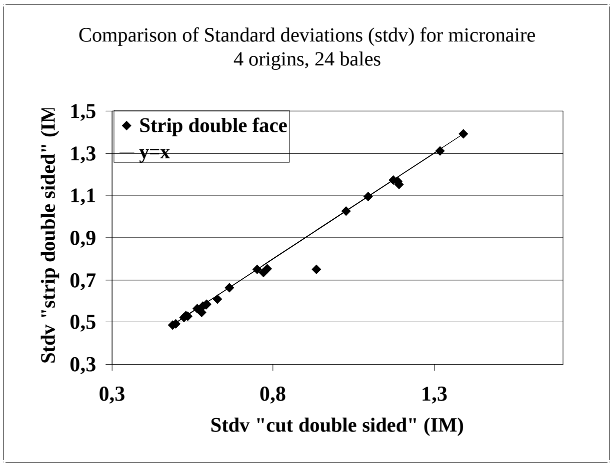

Figure 15: Comparison of standard deviations for micronaire for the 24 bales from 4 origins.

The computed standard error for the strip sample is always slightly inferior to that of the cut sample. This is to be expected from the cancellation of the layer effect. However, the dominating variance is the error variance, and the column and layer variances are much smaller. As a result, the sampling variance of the strip sampler is not very different from that of the classical cut sample: both share the "residual error" component of variance which can only be reduced by augmenting the number of measurements per bale.

<u>Comparison with the recognized acceptable error of the measurements</u>
An unexpected result is the high level of variability that is observed for all parameters.

For commercial purposes, internationally agreed tolerances for the measurements are given in Table 5.

Table 5: Internationally agreed tolerances for measurements.

	Confidence interval
IM	(+/-) 0.1 unit
Length	(+/-) 0.02 inch
	(+/-) 0.51 mm
Strength	(+/-) 1.5 cN/tex

From Sasser, 1992.

In the case of UHML, the norm for the confidence interval is +/- 0.02 inch that requires a standard error of 0.01 inch, that is to say 0.25 mm. From Figure 12, we can see that none of the two sampling procedures yield an acceptable precision, whatever the origin.

On the bale wise results from origin 4 (Figure 13), the precision with two replications is also not acceptable for commercial purposes. To obtain an acceptable precision one should increase the number of replications by a factor of 2, 5 or even 10 depending on the bale.

For strength (Figure 14), the precision is acceptable for commercial purposes for 17 out of the 24 bales. Doubling the number of measurements would have been enough to achieve an acceptable precision for all the bales.

For micronaire (Figure 15) also the acceptable precision is far from being achieved.

As the variability is not the same for every origin, and not even for every bale of the same origin, the classical notion of confidence interval should not be considered as an unchanging fixed quantity: rather, it should be viewed as a random quantity varying from bale to bale.

Thus our study seems now very modest: with only 4 origins and circum 6 bales per origin, we merely have a small sample of all the possible standard errors, and it is still difficult to infer a number of replications that would safely keep the standard error under the maximum acceptable value. For this we would need to widen this study to a more considerable number of bales.

However these few bales are enough for us to draw everyone's attention: in some occasions, the number of measurement usually made on commercial samples is not enough to achieve the expected precision.

As we noticed that it was not possible to get a general set of statistical rules for all bales in this study, it will probably be necessary to get rules for sampling and performing fibre analysis per producing area or country. We may also consider a trade off between the number of costly measurements needed to improve the precision and the commercial benefit gained from this improvement.

When this will be achieved, results from measurements can help in improving the organization of seed-cotton collection, seed-cotton ginning, and sampling procedures.

Conclusions

In this paper, we show that it may exist within-bale variability that could affect the representativity of samples drawn out from these bales.

Two examples helped in drawing this conclusion:

- For micronaire and strength measured on samples from one specific growing location within the USA, we saw that the distributions of these results can be wide when we look at the between-bale results. It is possible that, for some specific bales, fibre characteristics in these bales may vary.
- In another growing country, where seed-cotton was picked in various locations and ginned separately, fibre characteristics were also much variable from one place to another. Again, it is possible that fibres from various characteristics may be mixed in some bales.

It was then important to check if the samples yielded precise enough picture of the fibre characteristics in the bale.

A special experiment was set up to check various methods of sampling onto the within-bale distribution of fibre quality parameters. A new sampling device, the strip-sampler, was also tested. The fibres characteristics measured on samples from these sampling methods indicate that:

- It may exist a within-bale variability for all parameters measured in some origins; however, the dominant cause of sampling error is the lack of measurements
- With the standard number of replications, the cut-sample is not precise enough to avoid litigations.
- The strip sampler seems to provide samples that are more representative for variable bales than a cut-sample; however, the number of measurements per samples remains the important factor that improves the reliability of data produced per bale.
- Even though we assumed that the strip sampler grabs an equivalent amount of fibres in every layer of the bales, the prototype can be improved in order to insure that most of the layers of the bales are sampled, especially for origins, which encounter within-bale variability problems.

As a general conclusion, it will be important to check the within-bale variability level on a wider experiment made on a larger set of origins in order to prepare sets of rules defining better sampling procedures, and the best number of measurement per samples in order to respect some agreed trade tolerances.

Acknowledgements

We are particularly grateful to Valrupt Industries company (France) who let us sample bales in their facility and who provides us cotton samples for the "Sampling experiment on commercial bales" part of this article.

Bibliography

Internet address 1: http://www.ams.usda.gov/cottonrpts/MNPDF/mp_cn833.PDF.

Internet address 2:

http://www.ams.usda.gov/cnarchive/2003%2D04/mp%5Fcn833%20variety%20survey/2003varietysurveymp%5Fcn833.pdf.

Internet address 3 : http://www.ams.usda.gov/cottonrpts/MNPDF/mp_cn831.pdf.

Boyd, J. (1993). USDA report on module averaging -1992-. Beltwide Cotton Conferences, New Orleans, Florida, National Cotton Council of America.

Frydrych Richard, Gourlot Jean-Paul, Gozé Eric, Lebrun Bernard, Lassus Serge, Nieweadomski Jean-Charles, Dréan Jean-Yves and Lekcir Mohamed, 2004, Sampling Issues For Stickiness Measurements, Beltwide Cotton Conferences, Jan. 5-9, San Antonio, TX.

Gozé Eric, Krifa Mourad, Frydrych Richard and Nieweadomski Jean-Charles, 2002, Homogeneity of H2SD Counts Increase with Cotton Mixing - Consequences for Reference Cotton Preparation, ITMF International Committee on Cotton Testing Methods, Bremen 2002 Stickiness, pp. 42.

Moore, J. F. (1994). 1993 module averaging. Beltwide Cotton Conferences, San Diego, California, National Cotton Council of America.

Sasser, P. E. (1992). The repeatability of HVI data. International committee on cotton testing methods. Bremen (DEU): 1-5.