Ginning: a way of measuring its specific impact on fiber quality

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1 - Abstract

When classing cotton fiber quality, the results are governed by three sets of conditions: 1) production conditions, which may potentially be heterogeneous (variety, soil, climate, etc.); 2) ginning conditions at each ginning step, which have a positive or negative impact on final fiber quality. 3) testing conditions in the testing and classing laboratory.

Our objective was to develop a way of measuring the specific impact on fiber quality of ginning operations alone, which therefore cannot be deduced easily from classing results. A sampling and testing protocol was tested in Mali in four industrial ginning mills while processing seed-cotton modules over a cotton cropping season. During the ginning of each module, samples were taken at four stages: seed-cotton samples before and after seed-cotton cleaning, and fiber samples before and after lint-cleaning. To obtain a reference ginning, a micro-gin was used to gently process seed-cotton samples. The resulting fiber samples, as well as the corresponding fiber samples collected downstream in the industrial ginning process, were characterized within a single randomized design in two blocks including controls every twenty samples.

The fiber quality results thus made available at four stages of the ginning process were used to estimate the impact of each step, as well as the overall impact of ginning on the fiber quality characterization results. When significant overall ginning impacts were detected, the proposed protocol helped in finding the ginning step that lay behind fiber quality degradation, independently from the production and characterization sources of variations in classing results. Some technical and technological developments are still necessary for applying this protocol.

2 - Introduction

Cotton is the main natural fiber used in the textile industry. Many factors affect seed-cotton production and, thereby, the quality of the derived fibers. Of these factors, the following have a demonstrated effect on field productivity and fiber quality: variety, crop management practices (crop protection, sowing date, etc.), and the biotic (pests, diseases, weeds, etc.) and abiotic (soil, climate, etc.) environment. In addition, all these factors add up and/or interact together to lead to potentially variable production (Elsiddig, Abdalla, & Fadlala, 2003; Gérardeaux et al., 2013; Pettigrew, 2008).

When seed-cotton is mature, it is harvested manually or mechanically and grouped in seed-cotton modules, which are then transported to an industrial ginning mill (Curley et al., 1973; van der Sluijs & Delhom, 2016). The main goal of ginning is to separate the fibers from the seeds through various successive general processing steps (Anthony, 1977). Three steps will be considered here: i) a seed-cotton cleaning step to remove a maximum of trash, ii) a ginning step (by saws or by roller) for separating fibers from the seeds, and iii) a lint cleaning step to extract the remaining trash before a bale pressing operation to form cotton bales. All these steps affect the quality of the produced fibers in variable manners, intensity and direction (positive or negative) (Anthony, 1990; Columbus, Bel, & Robert, 1990).

At the end of the industrial ginning operation, fiber samples are taken from each bale using a cutter device for later evaluation of the technological characteristics of the fiber by taking measurements at the time of classing (hereinafter also referred to as fiber quality characterization). Fiber quality characterization is based on evaluating or measuring several fiber characteristics on the collected samples according to internationally harmonized rules (Drieling, Gourlot, & Knowlton, 2012). The results of this characterization are used to group the corresponding bales in ‘homogeneous quality classes’, which aims to respect specific quality criteria imposed by the international market, before being sold and delivered to spinners. Each of the testing conditions may affect the precision and the accuracy of the fiber quality characterization results.

As a consequence, fiber quality characterization results obtained from bale samples depend on the interaction between three major items (Figure 1): 1) production conditions from sowing to picking, 2) storage and ginning conditions, and 3) accuracy of the fiber quality characterization.

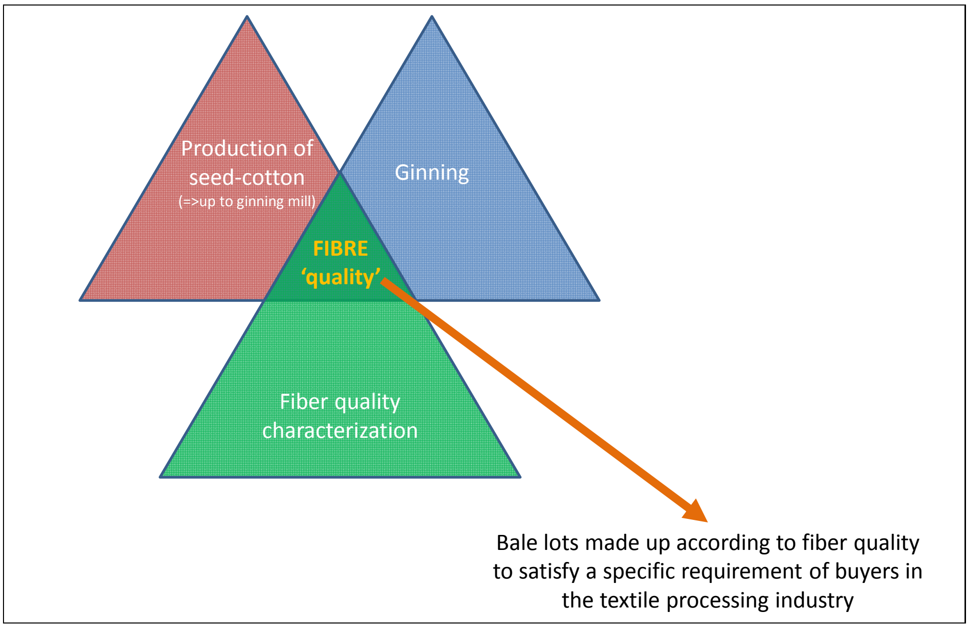

Figure 1: Fiber quality results from an interaction between production, ginning and characterization conditions.

Consequently, evaluating the specific impact of industrial ginning mills on fiber quality cannot be simply done by observing variations in fiber quality characterization results, when planning maintenance operations for instance. Indeed, any change in items 1), 2) and/or 3) listed above could lead to a change in fiber quality characterization results at any given moment in industrial ginning mill production. One of these three items could also be hidden by the other(s), leading to a loss of quality. This could be even more critical in areas where cottons are produced under different conditions: although this approach may work in countries where seed-cotton is grown in large homogeneous plots on entrepreneurial farms, it is more likely to fail in countries where seed-cotton is grown in numerous small plots on small farms with manual cropping and harvesting.

To summarize, changes in the results of fiber quality characterization obtained on bale samples depend on a combined effect of production and ginning conditions. For specific ginning use, our aim was to propose a way of measuring and tracking the specific impact of ginning alone, throughout the season, in order to ensure the production of top quality fiber at all times. Consequently, using fiber quality results from classing is not enough to detect potential ginning impacts because characterization is carried out off-line from a few hours up to several days after ginning, on the one hand, and because the results might be affected in any direction due to variations in seed-cotton quality and/or ginning performance, on the other hand.

In a part of this experiment, typical overall ginning impacts on fiber characteristics were demonstrated in eleven industrial ginning mills in Mali during the 2014-2015 cropping season (Togola et al., 2017). During that experiment, seed-cotton samples were taken from seed-cotton modules feeding the ginning mills, as well as fiber samples from the cotton bales made out of the corresponding feeding modules (Figure 2). Seed-cotton samples were processed using a reference micro-gin for producing fiber samples whose characterization results were compared to those of the bale samples to detect significant impacts. These characterization results were also used to calculate differences between bale samples and micro-gin samples to measure the intensity of the detected overall ginning impact.

3 - Objective of the method

The results of the fiber quality characterization on bale samples describe the combined effect of seed-cotton production and ginning, and fiber characterization. For specific ginning use, our objective was to propose a way of measuring and tracking the specific impact of ginning alone on fiber quality. This method, applied throughout the ginning season, was intended to ensure the production of top quality fiber at all times, and provide a measurement of the impact of each ginning step. The final goal was to propose a technical diagnosis for maintaining each ginning step of a ginning mill at its most efficient level.

4 - Proposed method for measuring the specific impact of ginning operations

All in all, an industrial ginning mill involves three major steps that directly and/or indirectly impact fiber characteristics: seed-cotton cleaning and ginning, and lint cleaning. Measuring the overall impact of ginning on fiber quality can only be worthwhile if the source of any observed quality losses is found.

To find the origin(s) of the detected overall impact, the sampling method meant taking samples from the material flows before and after each of the three major steps, then characterizing them to evaluate the impact of each step. The experiment was carried out in Mali in four industrial ginning mills (D, E, G, and I) chosen at random from eleven (Figure 2) and tested during the 2014-2015 season. The experiment was carried out on several dates (7 in D, 13 in E, 16 in G and 13 in I, hence 49 cases in total) throughout that cropping year. On each date, one seed-cotton module was ginned, during which seed-cotton samples (around 20 kg each) were collected from the module (SC_{in}, one representative sample per module), and from the feeder apron at the gin stand level (SC_{out}, one representative sample per module). Fiber samples (0.10 kg each) were also collected between the gin stand and the lint-cleaner (F_{in}, 1 sample each time a bale was produced, from 5 successive bales per module) and just after the lint-cleaner of the same ginning line (F_{out}, 1 sample each time a bale was produced, from 5 successive bales per module), (Figure 3).

As fiber quality characterization cannot be carried out on seed-cotton, in order to measure any overall ginning mill or ginning step impact, a reference micro-gin was used to process seed-cotton samples SC_{in} and SC_{out} in a stable manner. This reference micro-gin was considered as gentler for the fiber because it operated slowly, almost without a seed-cotton cleaner (just a feeder), and without a lint-cleaner. We expected these conditions to be the best for preserving intrinsic fiber properties. Consequently, the fiber characterization results obtained on samples collected at the end of this reference process ($F_{out}(SC_{in})$ and $F_{out}(SC_{out})$) represented a 'quality' reference to which the characteristics of the industrial ginning mill samples were compared (Figure 3).

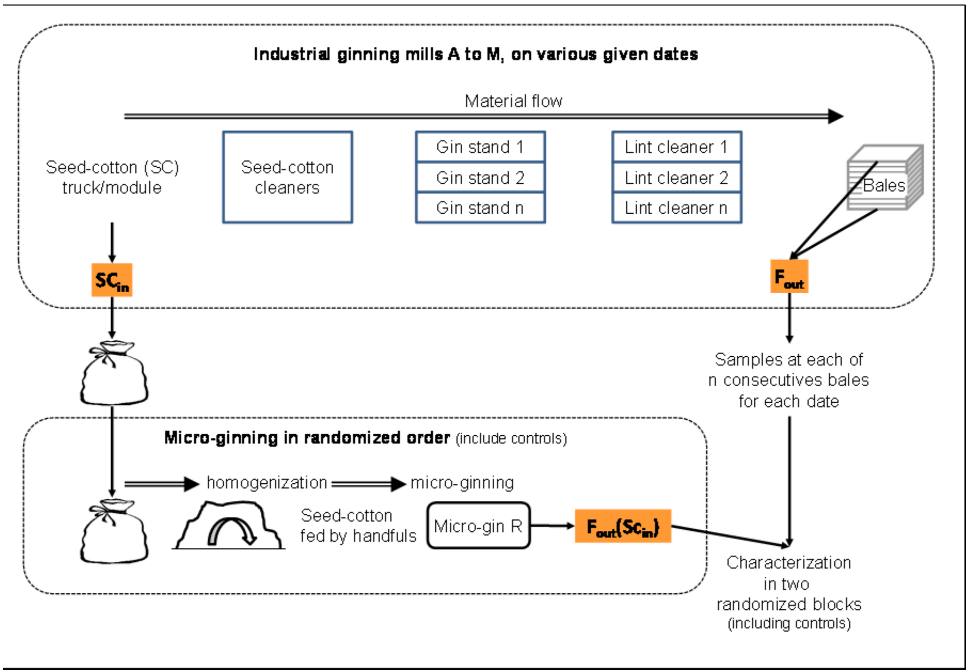

Figure 2: Overall impact of ginning; experiment in 11 industrial ginning mills, 2014-2015 crop.

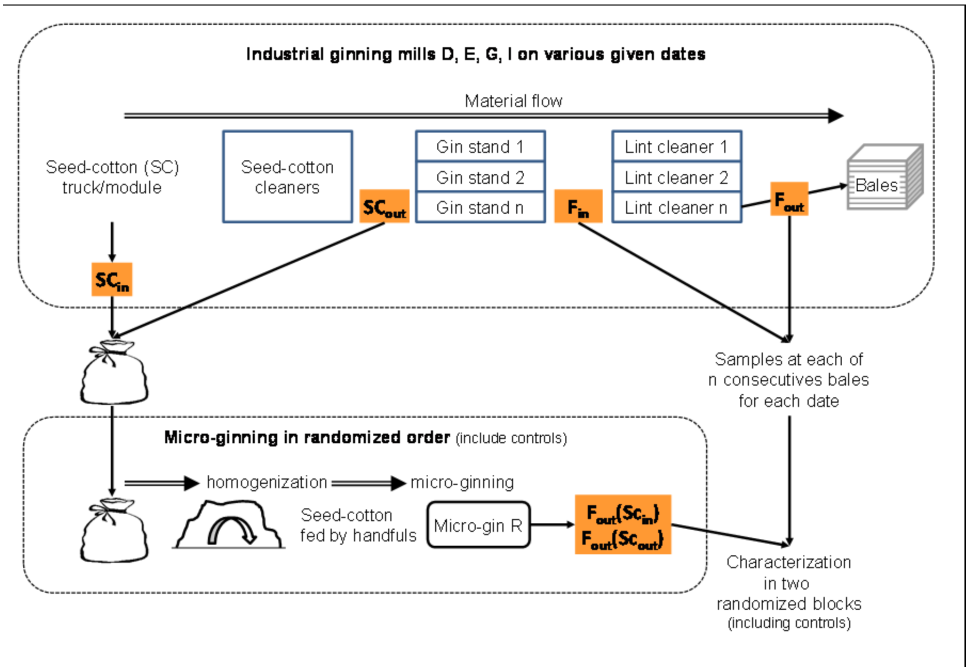

Figure 3: Collected samples in this experiment for detecting ginning step impacts on fiber quality characteristics.

All the collected fiber samples were grouped in the CERFITEX laboratory (Ségou, MALI) and arranged for their fiber characterization in two randomized blocks. Appropriate testing conditions were applied in this laboratory using a Standardized Instrument for Cotton Testing (SITC), Uster technologies HVI® 1000/700 calibrated to Universal High Volume Instrument Calibration Cottons (UHVICC). Each testing series comprised one measurement of micronaire and two measurements of length, uniformity, strength, reflectance (Rd%), yellowness, trash area and trash count per tested sample. Hereafter, we only consider Rd%.

Notes on the methods used to check the reliability of the acquired data:

- The stability of the performance of the reference ginning method was checked by the micro-ginning of two homogeneous seed-cotton materials (SC_{Ref}) available in large quantities, from which representative samples (20 kg each) were periodically ginned during the micro-ginning tests (Togola, Gourlot, Gozé, & Traoré, 2016) and over several ginning seasons. Fiber samples resulting from the micro-ginning of all the SC_{in} and SC_{out} samples (noted $F_{out}(SC_{in})$ and $F_{out}(SC_{out})$) were included with the other experimental fiber samples in the randomized testing design.
- The stability of the characterization performance was checked by the periodic testing of two fiber controls every 20 experimental fiber samples. These two fiber controls were Universal High Volume Instrument Calibration Cottons (UHVICC) ‘short-weak’ and ‘long strong’ cottons under the same conditions as the experimental samples.

As fiber quality characterization results depend on three sets of conditions (production, ginning, and characterization), we assumed that their effects added up, thus allowing a linear model of variation to estimate the parameters for a variance analysis. Technically, the model used was a linear mixed model that included fixed effects (those studied) and random errors (all sampling and measurement errors).

Differences in ‘quality’ at each ginning step were calculated from these model parameters. With four sampling positions in the industrial ginning mill, six Delta values (Figure 4) could be calculated as differences in the fiber quality characterization results (each time with $\Delta_x = \text{quality}_{out} - \text{quality}_{in}$) for seed cotton (SC) and/or fibers (F). Of course, if an industrial ginning mill bypassed or did not have a lint-cleaning operation (for gins D and I), then the Δ_3, Δ_5 and Δ_6 values were not calculated, and Δ_4 was considered as a measurement of the overall impact of that industrial ginning mill in place of Δ_6. We concentrated on Δ_1, Δ_2 and Δ_4 for mills D and I without lint-cleaners, and Δ_1, Δ_2, Δ_3, and Δ_6 for mills E and G with lint-cleaners.

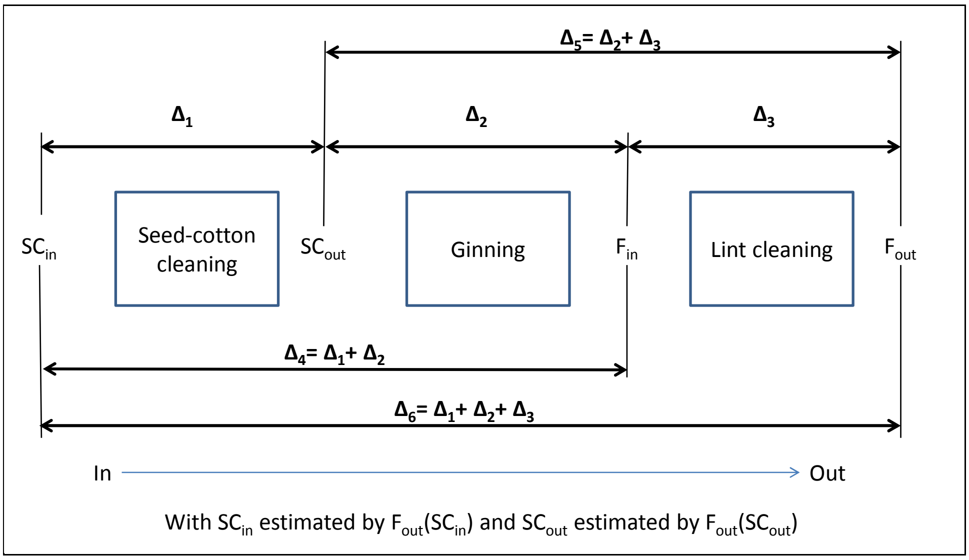

Figure 4: Examples of six differences in quality Δ (‘Deltas’) (Δ_1 to Δ_6) to be evaluated when sampling is performed before and after each major ginning step. SC stands for seed-cotton; F for fiber; $_{in}$ and $_{out}$ for the place where samples were taken. Δ_4 to Δ_6 combine several processing step impacts and can be deduced from Δ_1 to Δ_3 which represent single ginning step impacts.

5 - Results and discussion

The testing conditions were verified as reliable and stable throughout the experiment, and the micro-ginning conditions were also proven to be stable over the time all the SC_{in} and SC_{out} (all test dates for all tested industrial ginning mills) were micro-ginned. The available fiber characterization results were therefore assumed to be reliable under the aforementioned appropriate micro-ginning and testing conditions, allowing the calculation of all the Delta values and of their respective confidence intervals (alpha=5%) in each industrial ginning mill on each date (Figure 5 represents Delta values for Reflectance Rd%). In this chart, the vertical bars represent the confidence intervals for each of the calculated Delta values. When Delta was not significant, meaning that there was no significant difference in quality between the quality entering and the quality leaving a given (combination of) ginning step(s), then the corresponding vertical bars crossed the Delta=0 horizontal line. Otherwise, when Delta was significant, the corresponding vertical bars did not cross the Delta=0 horizontal line, which is a practical way of graphically showing significant ginning impacts.

Δ_1, Δ_2, and Δ_4 for industrial ginning mills D and I (no lint-cleaner installed), on the one hand, and Δ_1, Δ_2, Δ_3, and Δ_6 for industrial ginning mills E and G (with lint-cleaners), on the other hand, indicated no trend over time during the season. Occasionally, some of the Delta values could be significant, as shown hereafter together with a rapid interpretation between brackets:

- Out of 49 cases, Δ_1 showed 16 values statistically higher than 0 (seed-cotton cleaning operations improved Rd%), 33 values not different from 0 (no seed-cotton cleaning impact), and 0 values statistically lower than 0 (no deterioration of Rd% by seed-cotton cleaning).
- Out of 49 cases, Δ_2 showed 1 value statistically higher than 0 (gin stand improved Rd%), 34 values not different from 0 (no gin stand impact), and 14 values statistically lower than 0 (Rd% decreased at the gin stand).
- Out of 29 cases, Δ_3 showed 11 values statistically higher than 0 (lint-cleaning improved Rd%), 18 values not different from 0 (no improvement of Rd% by lint-cleaning when installed), and 0 values statistically lower than 0.
- Out of 49 cases, Δ_4 (overall impact for gins without lint-cleaning) showed 8 values statistically higher than 0 (seed-cotton cleaning and gin stand improved Rd%), 38 values not different from 0 (no impact of any combined effect of seed-cotton cleaning and gin stand), and 3 values statistically lower than 0 (Rd% decreased with a combined impact of seed-cotton cleaning and gin stand).
- Out of 29 cases, Δ_6 (overall impact for gins with lint-cleaning) showed 17 values statistically higher than 0 (the overall ginning process improved Rd%), 12 values not different from 0 (no impact of the overall process), and 0 values statistically lower than 0.
- The above cases where Δ_4 and Δ_6 were significant, indicating an impact of the overall ginning process on Rd%, were those which were already significant and have been published (Togola et al., 2017).

Some comments can also be made when considering the individual ginning mills. For instance, in mill I, Rd% was improved at the seed-cotton cleaning step, with Δ_1 between 0.3 and 2.2% significant for 4 out of 13 dates, with a mean of +0.9%. However, Rd% deteriorated at the ginning step, with Δ_2 between -1.3 and 0.7% significant for 6 out of 13 dates, with a mean of -0.7%. In mill D, Rd% was less improved than in mill I at the seed-cotton cleaning stage with Δ_1 between -0.1 and 1.1% significant for 2 out of 7 dates, with a mean of +0.6%. Rd% also deteriorated at the ginning step, with Δ_2 between -1.3 to 0.1% significant for 1 out of 7 dates, with an equivalent mean of -0.7%.

Calculations then allowed the detection of the ginning steps causing quality alteration. In mill G, three cases existed where the observed Delta values would lead to technical investigations (Figure 5, marked in orange shading in mill G):

- Negative value of Δ_1, when Rd% was lower after seed-cotton cleaning than before (Figure 6, January 13, 2015): a non-significant but large negative impact of seed-cotton cleaning was observed (Δ_1 = -0.88). One reason might be that the initial trash content was low, and therefore no improvement in Rd% was possible.
- Negative value of Δ_2, when Rd% was lower after ginning than before (Figure 7, March 9, 2015): a significant negative impact of the gin stand (Δ_2 = -1.46), compensated for by a significant positive seed-coat cleaning impact (Δ_1 =+1.80) and a significant positive lint-cleaning impact of (Δ_3 =+1.96), induced a significant positive overall impact Δ_6 on Rd% (+2.30%). The reasons for this gin stand impact might involve the settings of the moting and grids inducing trash fragmentation and therefore a change in Rd%.
- Negative value of Δ_3, when Rd% was lower after lint-cleaning than before (Figure 8, February 5, 2017): an almost significant negative Δ_3 was observed, and, as Δ_1 and Δ_2 were at zero, there was no improvement in Rd% during the processing of that seed-cotton as both color and trash parameters were stable. Some investigation may be required on the lint-cleaner settings.

In these examples and in a general manner, using an off-line micro-gin, Delta values and fiber quality characteristics could help in understanding the reason(s) for any improvement or degradation in quality throughout the process. The same analysis was extended for each date in each industrial ginning mill for all the measured fiber characterization results on the collected samples before selecting the above examples.

As any transformation step may affect various fiber characterization results in opposite ways, the proposed experimental protocols could help in solving the 'ginning impact compromise' based on measured properties. Certainly, seed-cotton quality parameters (such as opposite examples: with/without large trash, with/without pepper trash, etc.) have an impact on how to set detection thresholds to alert gin operators.

However, before that, the basic conditions are to measure all fiber characteristics in a reliable way, on representative samples, and at the production rate in several places in industrial ginning mills, to replace the use of a micro-gin which creates delays in the application of the proposed protocol. This requires the creation and/or the use of 'on-line sampling and testing devices' - which do not exist at this level of desired development. Those devices need to be installed on-line in the industrial ginning mills and connected together by specific software for compiling data and calculating Delta values. In comparison with acceptable thresholds, Delta values will alert mill managers and technicians to quality problems during the ginning of each seed-cotton module.

6 - Conclusion

In all, three sets of conditions affect the image we might have about fiber quality when observing classing results:

1) To obtain cotton fibers, seed-cotton produced under potentially heterogeneous conditions (variety, soil, climate, etc.) is harvested from various fields and may be grouped in modules.

2) In industrial ginning mills, the materials are processed in various machines, each having a positive or negative impact on the final fiber quality.

3) The conditions of fiber characterization may affect the fiber quality results obtained.

With a view to measuring the specific impact of ginning operations alone on fiber quality, an experimental sampling and testing protocol was proposed and tested in Mali in four representative industrial ginning mills when processing (altogether) 49 representative modules over the 2014-2015 cotton cropping season. During the ginning of each module, seed-cotton samples were taken from the module and after seed-cotton cleaning, while fiber samples were taken before and after lint-cleaning. Seed-cotton samples were processed using a reference micro-gin to obtain fiber samples. Lastly, all the collected fiber samples were characterized in a randomized design in two blocks including controls every twenty samples.

To measure any overall and specific ginning impacts or ginning step impacts (three main steps tested here: seed-cotton cleaning, ginning, lint-cleaning), the calculation of quality differences, called Delta, was proposed. Among cases showing significant overall ginning impacts, the Delta values calculated at each ginning step level helped to pinpoint the specific steps giving rise to fiber quality degradation, independently from other sources of variation.

Subsequently, technical causes of such degradation can be sought. To make headway in any industrial application, technical and technological developments are necessary. With these tools installed in industrial ginning mills, on-line fiber quality characterization results will be available at each ginning step and will allow rapid detection of problematic losses in quality, by comparing all the ginning lines in the ginning mill with one that is well-maintained, serving as a reference.

7 - Disclaimer

The citation of any trademark or registered product or brand does not constitute any kind of recommendation for their use.

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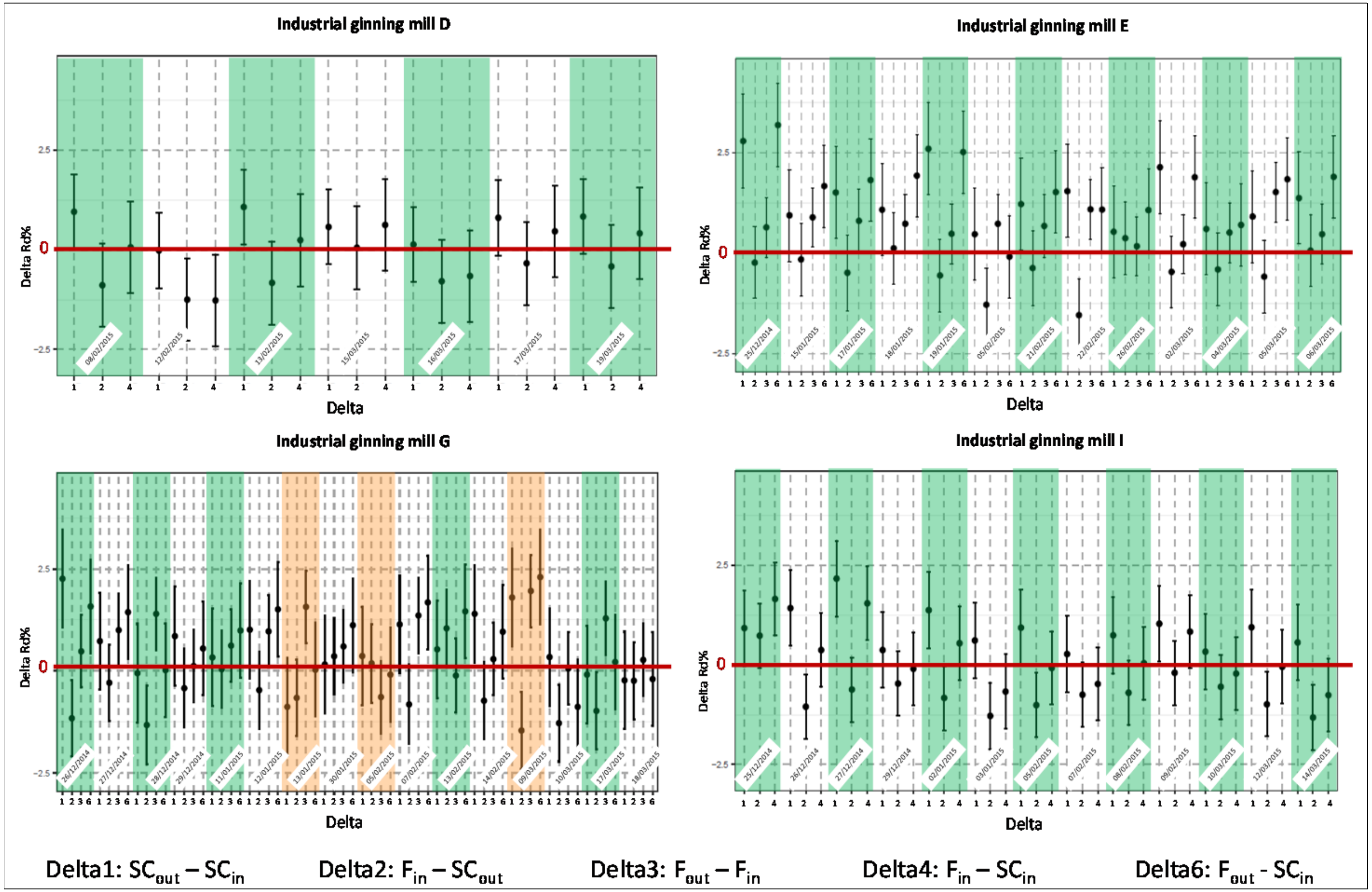

Figure 5 : For each industrial gin D, E, G and I, all available Delta values for Rd% were calculated together with their confidence intervals (vertical bars) for each date of the test. As a rapid reading, any vertical bar not crossing the 0 horizontal red lines indicates a significant impact effect (Delta different from zero). Among all the detected global ginning impacts (Delta6), three dates in industrial ginning mill G are focused on (highlighted by orange shading).

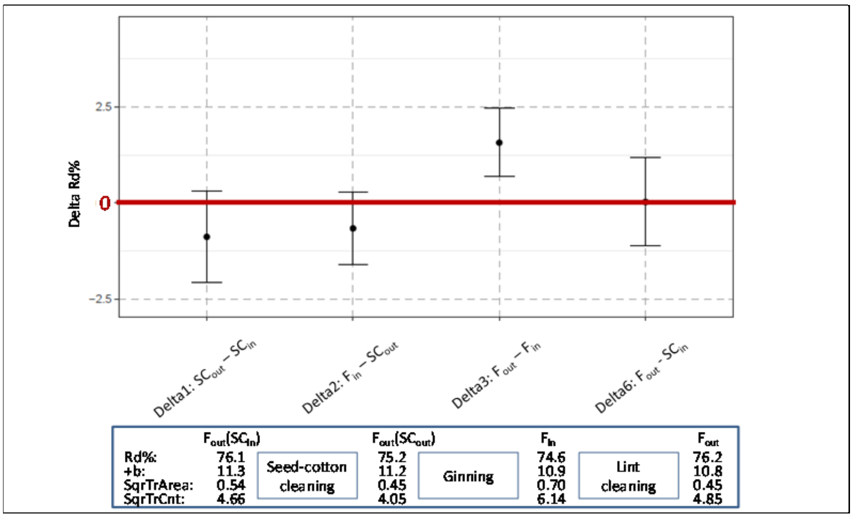

Figure 6: Delta values observed in industrial ginning mill G on January 13, 2015: discussion for Delta1.

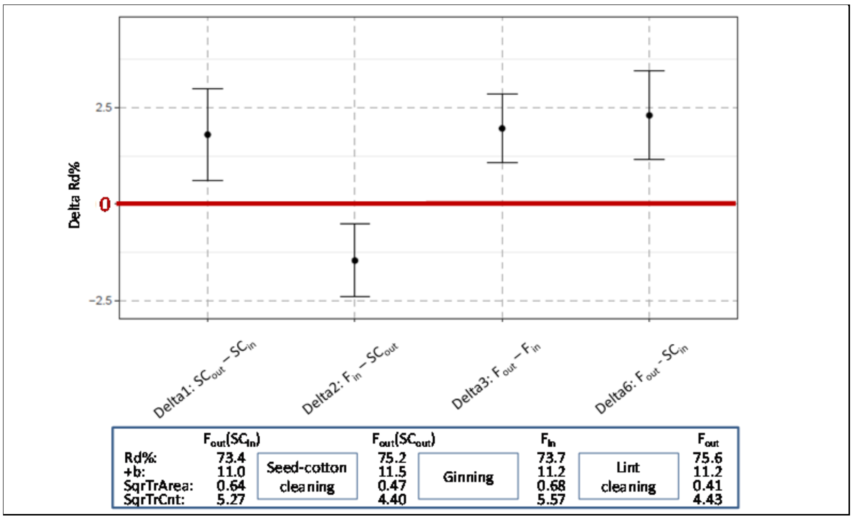

Figure 7: Delta values observed in industrial ginning mill G on March 9, 2015: discussion for Delta2.

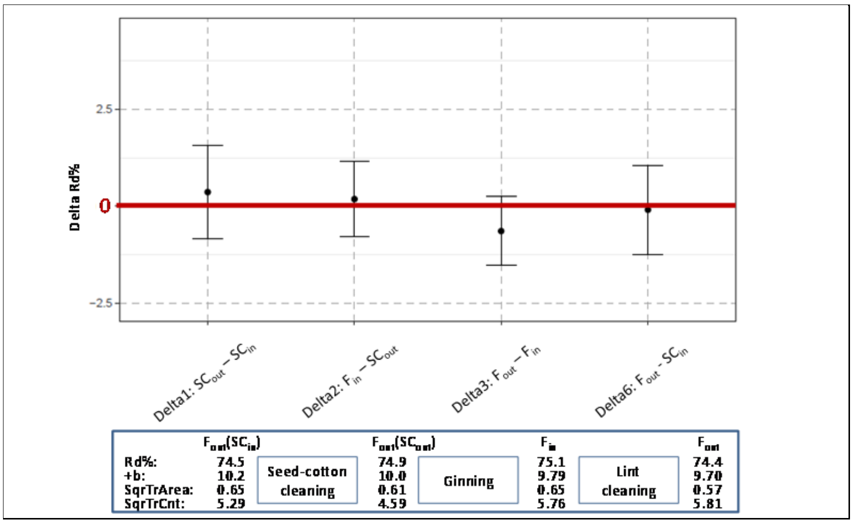

Figure 8: Delta values observed in industrial ginning mill G on February 5, 2015: discussion for Delta3.