COMMON FUND FOR COMMODITIES

Technical Paper No. 17

Improvement of the Marketability of Cotton Produced in Zones Affected by Stickiness

Final Report of the Project CFC / ICAC / 11

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GOURLOT J.-P., FRYDRYCH R., Scientific Editors

Project funded by the Common Fund for Commodities
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Foreword

The cotton sector is of major economic and social importance to many developing countries. It provides employment, income and export earnings. As a natural product, cotton is subject to the uncertainties inherent in agricultural production. While chemicals are being applied to contain pests to a certain extent, there is no all-effective protection. The project concentrated on how best to deal with a specific problem, namely stickiness in cotton caused by the sugary excretions of aphids and whiteflies (Aphis gossypii and Bemisia tabaci). Stickiness affects about one-fourth of all cotton production.

Research is being undertaken on how best to protect cotton against stickiness when in the field (e.g. in the framework of a completed CFC-financed project, entitled Integrated Pest Management for Cotton with a focus on Whitefly and Aphids). Less work has been done on what use can still be made of cotton which is affected by stickiness. As stickiness disrupts the modem, high-speed spinning processes, cotton producers are faced with severe price discounts when selling cotton that originates from an area which is suspected to be contaminated. As stickiness is difficult to identify by visual inspection, price discounts are applied indiscriminately, thus also affecting clean cotton produced in an affected area.

The current project specifically aimed at developing reliable methods to determine the level of stickiness in cotton bales and to establish, under factory conditions, different thresholds for spinning cotton with different levels of stickiness. An economic evaluation of the process of "grading" stickiness in cotton bales for use in day-to-day operations of a cotton trading company was included in its design.

The project started in 1997 and has been implemented under the overall responsibility of the Sudan Cotton Company Ltd, working in very close collaboration with the Cotton Technology Laboratory of the Centre de cooperation internationale en recherche agronomique pour le developpement (CIRAD). Technical supervision and guidance was provided by the International Cotton Advisory Committee (ICAC).

This Technical Paper is a reflection of the results obtained during the project. It is being published, in line with the Fund's practice, in order to share the experiences gained in this project with other Common Fund Member Countries that have an interest in this matter.

It is the hope of the Common Fund for Commodities that this publication will be of practical use to parties in both the Government as well as the private sector, who are active in the field of cotton production and trade.

Dr. Rolf W. Boehnke
Managing Director
Common Fund for Commodities

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Executive summary

A bale is declared "sticky" if, during a particular processing step, e.g. spinning, its stickiness level disrupts the spinning process, leading to reduced performance of the spinning machines and/or poorer quality final products. To assess stickiness, a reliable and rapid measurement device is necessary, giving results that are well correlated with the efficiency and the breakage incidence in an industrial-scale spinning mill and the quality of the yarn produced. In this study, we put forward production management methodology and draw up a classification for marketing.
It should be mentioned that a classification requires a measuring tool, proper conditions for that tool, and appropriate cotton production organization. Thus, four steps were initiated to evaluate the feasibility of cotton classification for stickiness:

1. It was first necessary to determine whether any measuring devices were efficient in a classification process. Among the tools evaluated, namely Thermodetector SCT, HPLC and H2SD, H2SD seems to be the most adapted to measure stickiness in these classification conditions, since it is predictive of disruptions spinning processes (OE, RS, combed RS), it is fast and does not show an operator effect. However, the thermodetector SCT can still be used at a laboratory scale.

2. During investigations into the extend and variability of stickiness in Sudanese bales, lots, gin areas, we observed:

– A wide range of within-bale, within-lot, within-block and within-gin stickiness. Among the production zones, some production areas in Sudan could be considered as non to slightly sticky.
– The sticky points distribution does fit a agregative statistical distribution law. However, due to the production conditions in Sudan, no specific law could be deduced from the collected data.
– It was thus impossible to deduce any possible level of litigation risk between seller and purchaser.

3. A qualitative classification procedure requires a threshold above which a cotton could be considered as sticky. Thus investigations were conducted into the effect of stickiness on productivity and quality in a spinning process. It was deduced that a unique global threshold to separate non-sticky from sticky cottons for all the processing conditions in any spinning mill in the world cannot be found since knowledge, processing technologies, … are too different. This threshold will have to be negociated for each contract between seller and purchaser Economical incidence should be discussed accordingly.

4. The economical viability of a stickiness classification was studied. This qualitative classification is viable if the stickiness distribution is more centered on low percentage levels of contaminated fibers and if the assumptions we made are proven to be solid.

Two other experiments were designed to ways to reduce the consequences of stickiness.

– Decreasing relative humidity during the spinning process: this improves productivity and quality with a greater improvement in productivity. However, at lower humidities, other problems could appear.
– A binary mix of non-sticky cotton with contaminated cotton: this reduces the level of stickiness for spinning as seen from stickiness measurement on H2SD. The stickiness of a mix was deduced to be the mean of the stickiness levels shown by each constituent weighted by their proportion in the mix, if the sticky cotton has no more than 50 H2SD sticky points.

Combating stickiness requires a global approach where improvements in breeding, agronomy, pest control and technology have to be made in a parallel manner. Classification is one of the tools to combat stickiness. Measurement results through mapping, can help in other ways to reduce stickiness, such as breeding new varieties, developing new ways to manage the crops through integrated pest management programs, managing the seed-cotton flow, etc.

On a long-term basis, the classification tool should be economically viable, and should improve the image of Sudanese cotton.

Chapter 1. Introduction

This report is organized in line with Appraisal Report organization, and as follows:

- First, a global description of the project and its background are given by an extract from the Appraisal Report agreed between the participating bodies. Thus, some information about the cotton situation and its background described here may have changed since due to financial, economical or technical modifications.

- Each of the three components in the project is described through an extract of the Appraisal Report (same comment as above), and then through the different experiments conducted. For each of these experiments, a complete description of the materials and methods used is given, followed by results and their discussion, then by figures, slides or any useful information concerning that particular experiment. At the end of each component, concluding remarks and discussions are given with practical consequences for the organization of the cotton industry.

- Component A: Testing and evaluation of methods for establishing the degree of stickiness in cotton. The reader will want to know about the stickiness measuring devices used in this project: thus, we placed a full description of these in the component A chapter. This was rendered necessary since the reader must be aware of technical information concerning the different measuring devices prior to reading the discussion about their technical ability to characterize stickiness.

- Component B: Development of a threshold for economical processing of sticky cotton.

- Component C: Evaluation of the financial viability of the process, training, circulation of project results through presentations, publications and technology transfer.

At the end of this report, a final project conclusion gives the main results and their implications.

Note : The proceedings of the final seminar, which took place in Lille, France, July 2-4, 2001, are available as separate books and can be obtained from the Common Fund for Commodities or From Cirad.

1.1. Project Rationale and Objectives

The stickiness problem is very complex as the stickiness of the cotton can be due to *inter alia* the following factors: various contaminants (seed coat fragments, neps, insecticides, oil, etc.); physiological sugars, mainly composed of reducing sugars and nectary secretions; and entomological sugars composed of reducing and non-reducing sugars (honeydew). This latter cause of stickiness/contamination has, for the last few years, been by far the most prevalent form of contamination, and is subject of the research undertaken in the framework of the Fund-supported project in Israel, Egypt, Ethiopia and Zimbabwe, focusing on the reduction of stickiness through effective crop protection methods based on principles of effective integrated pest management. The present project had its focus on the post harvest stage of cotton production.

The occurrence of stickiness is not confined to one or a few countries. This phenomenon, which was of little importance in the beginning of the 1980s seems to have become generalized. A survey undertaken by the International Textile Manufacturers Federation (ITMF) involving 235 companies in 30 countries showed that the stickiness problem is increasing. According to the ITMF report "Cotton Contamination Survey 1995" 20% of the surveyed samples had some level of stickiness, and it continues to be the case in the latest reports. Stickiness has therefore become a worldwide problem. Over the last few years all those involved in the cotton industry, from the producer to the spinner, have become increasingly concerned about the problems related to stickiness and have attempted to find a remedy.

Sticky cottons cause disruptions in the spinning process, fouling the cards, the brush tables, the feed trays and the rotors in open end spinning. Apart from the frequent stoppages which require cleaning of the machines, these honeydew deposits also cause irregularities in the card web, slivers and threads, and lead to the production of poor quality yarn. Once sticky cotton is there, the only solution is to isolate the sticky cotton from non-sticky cotton in order to save heavy economic losses to the growers in areas where the problem exists. Stickiness cannot be detected by observation of the cotton during harvesting or during the ginning process. The stickiness problem is usually detected during spinning. It is a time when nothing can be done except to spin whatever is available. In order to avoid unexpected obstructions of the spinning process, cotton spinners only pay the regular price for ginned cotton when they are certain that the cotton lint is clean and does not contain impurities which affect the spinning process. In case of any doubt they will offer only discounted prices for the 'suspect' cotton. These discounts, ranging from 5-30% of the price, are mostly applied indiscriminately to all cotton originating from an area considered to be affected by stickiness. The development of a method to establish an acceptable level of stickiness in cotton bales and to establish operational thresholds in the processing of sticky cotton will have the dual benefit of protecting growers against unjustified price discounting, and it will enable spinners to spin such a cotton through adjustments in the machinery and spinning conditions or through mixing with non-sticky cotton.

The **central objective** of the project was therefore to increase the return on cotton to producers through the development of reliable methods to establish the level of stickiness in cotton bales, and the establishment (under factory conditions) of operational thresholds for the processing of contaminated, sticky cotton. The establishment of processes to successfully deal with the problems of stickiness in cotton will not only raise prices of cotton in currently affected regions but will increase their quantity of marketable cotton.

1.2. Consistency with the ICAC Strategy for Cotton Development

Stickiness in cotton is considered by the members of the ICAC as one of its key priority areas for study and research. As stickiness in cotton increases both production costs as well as processing costs (thereby also reducing producer prices), the Standing Committee of the ICAC has earlier recommended projects for financing by the Fund in the field of crop protection, while the present project is the highest ranked priority project focusing on the post-harvest side of combating stickiness and damage control activities. Problems associated with the processing of contaminated cotton need to be resolved if cotton is to remain competitive with synthetic fibers while producers still receive remunerative prices. It is recognized by the ICAC members that many developed cotton-producing and -consuming countries have the expertise and the means to address these problems. However, most developing countries do not have the research capacity and the financial means to solve these key problems. It is these countries that are most subject to losses in income and loss of markets if solutions are not found. The ICAC has therefore acknowledged the importance of the exchange of technical information between member countries and close cooperation in the solution of mutual problems. The proposed project is an example of both ICAC's prioritization of activities and the recommended international cooperation.

1.3. Description of Project Components

The project comprised the following three components:

(a) Testing and evaluation of methods for establishing the degree of stickiness in cotton production;
(b) Development of a threshold to enable economical processing of sticky cotton;
(c) Evaluation of the financial viability of the process developed under the project, training, dissemination of project results through presentations, publications and technology transfer.

Chapter 2. Component A: Testing and evaluation of methods for establishing the degree of stickiness in cotton

Studies were conducted to test, evaluate and monitor stickiness in cotton in order to separate sticky cotton from non-sticky cotton, and establish the degree of stickiness. The studies were conducted jointly by staff of the Sudan Cotton Company (SCC), the Cotton Program of the Agricultural Research Corporation (ARC) of Sudan; the Cotton Program of CIRAD-CA; and Institut Textile de France (ITF). The SCT-CIRAD thermodetector, developed by the Cotton Technology Laboratory of CIRAD-CA, was used to analyze stickiness. The detection of cotton stickiness using the thermodetection method is based on the deposit of sticky substances onto two aluminum sheets. The cotton sample is heated via a hot plate and releases its humidity. This humidity is absorbed by the honeydew which then sticks to the aluminum sheets during a second, cold-press, phase. The number of sticky points counted is a measure for the level of stickiness of the sample. This thermodetector has been recognized by the International Textile Manufacturers Federation as a reference method to measure stickiness in cotton. Six units were envisaged to be required for the purpose of the project. The units were placed in different locations in SCC and ARC premises in the country, in accordance with the minimum requirements for the necessary measurement capacity. Of these six units only three were financed by the Fund, the three other units were financed by the SCC.

Investigations and measurements focused on the determination of the level of stickiness in cotton from different production areas. Measurement and determination of the degree of stickiness was carried out for different qualities. The situation prior to the project for the cotton classification was:

– seed cotton: classification based on 3 grades for the Acala types and 6 grades plus half grades for the long and extra long staple. The seed cotton was ginned according to grades.
– lint: the bales were classified on the base of one sample per bale by human classers (grade and staple length).
– in addition around 1000 commercial samples per year were evaluated by ARC for length (with Fibrograph), strength (with Stelometers and Pressley), fineness and maturity (with FMT), and stickiness (with minicard). The SCC ordered an HVI (High Volume Instrument) Zellweger Uster to complete the equipment of the ARC cotton research laboratory.

The separation of sticky cotton from non-sticky cotton and the evaluation of the degree of stickiness was undertaken under different ginning methods (roller ginning and saw ginning). For each ginning method approximately 500 bales (a total of 1000 bales were therefore covered) were tested by taking and testing at least 16 samples per bale, for stickiness. Out of the 500 bales tested for each ginning method, 60 bales were selected for tests under component B below. For all bales tested, the relationship between the level of stickiness and the level of infestation by white flies and aphids (which are the main causes of stickiness) were investigated. Variations due to sampling techniques were analyzed and eliminated/minimized for both roller and saw ginned cotton. Once reliable measurements had been obtained, efforts were made to establish the minimum number of readings required to measure the stickiness levels for both roller ginned and saw ginned cotton with an acceptable level of accuracy. Based on the test results bales could be separated into low, medium and high stickiness and offered for sale. Ultimately the project findings will be used to formulate a strategy for the implementation of a stickiness determination program at the national level, through the testing of 5% each of the representative samples for both saw ginned and roller ginned cotton. About 30,000 bales were tested annually. Corroborative re-tests were undertaken on 2,000 to 3,000 samples by an independent laboratory (of *Cotton Incorporated, Cary, USA*) without charge to the project. Finally attention were given to the implications for cotton export management. Instead of one category of cotton now exported, at least two but possibly more categories of cotton could be offered

for sale (free of stickiness, and (in one or more grades) sticky cotton). In this way premiums will be obtained for high quality cotton which hitherto has been subject to generalized pricing and has suffered from unnecessary discounting for stickiness.
In order to achieve the objective of developing, testing and evaluating reliable methods for establishing the level of stickiness in cotton bales, the following outputs had to be produced through the implementation of the described activities.

Output 1.1 **Investigate stickiness in cotton coming from different producing areas** (Medium Staple, Long and Extra Long Staple areas for both roller and saw ginned cotton).

Activity 1.1.1 Bale samples from various areas famous for producing sticky cotton in Sudan were collected, for roller ginned cotton. Around 500 bales were tested using at least 16 samples per bale (one sample per layer of fiber).

Activity 1.1.2 Bale samples from various areas famous for producing sticky cotton in Sudan were collected, for saw ginned cotton. Around 500 bales were tested using at least 16 samples per bale (one sample per layer of fiber).

Activity 1.1.3 Using the thermodetector, samples were analyzed for stickiness.

Output 1.2 **Variation due to sampling techniques will be investigated and eliminated/minimized for both roller and saw ginned cotton.**

Activity 1.2.1 Methods will be determined and perfected to take samples and also take measurements of the samples in respect of stickiness of cotton for roller ginned cotton.

Activity 1.2.2 Methods will be determined and perfected to take samples and also take measurements of the samples in respect of stickiness of cotton for saw ginned cotton.

Output 1.3 **The minimum number of tests required to know the actual level of stickiness from a given sample or produce will be determined.**

Activity 1.3.1 For uniform measurements and better reproducibility of the results, the minimum number of readings required to measure the stickiness level will be established for the roller ginned cotton.

Activity 1.3.2 For uniform measurements and better reproducibility of the results, the minimum number of readings required to measure the stickiness level will be established for the saw ginned cotton.

Output 1.4 **Bales with low, medium and high stickiness will be separated and offered for sale accordingly.**

Activity 1.4.1 Studies will be undertaken to assess the extent of variability in the level of stickiness from one bale to the other.

Output 1.5 **A full package will be decided to determine the actual level of stickiness for all the produce in the country.**

Activity 1.5.1 A strategy to monitor and evaluate the stickiness will be finalized.

Activity 1.5.2 The results will be applied on representative sample of the produce for roller ginned cotton (around 5% of the roller ginned cotton bales will be tested).

Activity 1.5.3 The results will be applied on representative sample of the produce for saw ginned cotton (around 5% of the saw ginned cotton bales will be tested).

Activity 1.5.4 The Sudan cotton production is around 600 000 bales per year, the representative sample of the production (5%) will represent around 30 000 bales. Two to three thousand samples will be re-tested by an independent laboratory (Cotton Incorporated, Raleigh, USA) free of charge.

Activity 1.5.5 The bale management for export will be studied as the number of categories for sell will be at least multiplied by two (free of stickiness bales and sticky bales).

The following chapters give answers about the proposed outputs and activities. However, we will discuss the outcomes of this research after relating the scientific studies which were realized.

2.1. Equipments used in this project to measure stickiness

In this research, two measuring devices (Figure 2-1) were used to evaluate the stickiness potential of cotton fibers. In complement, some HPLC results have been used to describe more closely what types of sugars are involved in the ‘sticky sugars’

2.1.1. Stickiness Cotton Thermodetector SCT

A standardized procedure was designed to run the SCT. This procedure is the basis of the development of standards at different levels: AFNOR (French organization for standards), CEN (European organization for normalization) and ITMF (International Textile Manufacturer Federation, for which this method is the recommended measuring device for stickiness since 1994).
More information are given in the corresponding paragraph in the Final Technical Research Report and in the mentioned documents above.
We give here the procedure that have been used for this research for any individual measurement done.

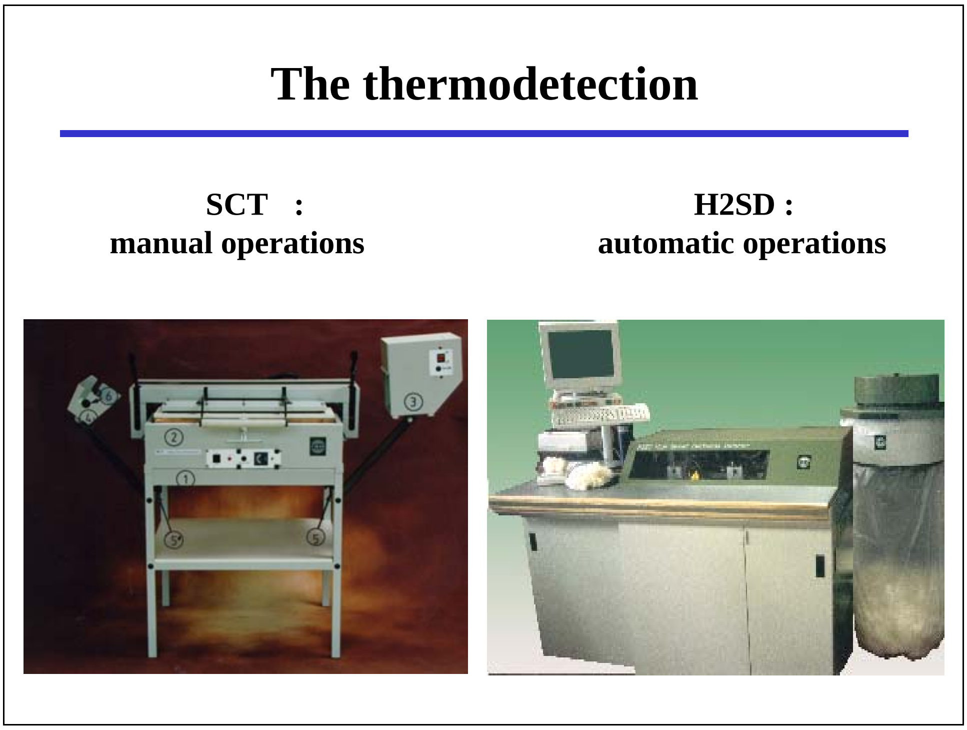

Figure 2-1: Two detection devices used to measure stickiness in this ICAC / CFC project.

After a pre-heating phase of the SCT, a aluminum foil is placed on the SCT copper plate. Then, using the specific fiber blender, a mass of 2.5 g of fiber is homogenized and transformed into a web that is placed on the aluminum foil. A second aluminum foil is placed over the cotton web to form an ensemble. The heating device is placed over the ensemble for a preset time. Then the ambient temperature pressure is placed over the ensemble for another preset time. When the SCT gives the signal, the ensemble is taken from the SCT to be placed in a storage place of about 60 minutes. After this storage time, the upper aluminum foil is removed, and a specific brush is used to remove the cotton web from the lower aluminum foil and the remaining attached fibers on the upper aluminum foil. A counting of apparent sticky points on both foils has to be done.
This operation can be repeated as many times as necessary to evaluate the stickiness potential in the fibers with accuracy. The conditioning of the samples and the measurements should be performed in normalized ambient atmosphere (21° C and 65% relative humidity).
A standard is in development under the supervision of the French and European standards committee. Thus, before any use of this SCT method, the latest version of this standard should be consulted in the CEN books.
This procedure was followed during testing conducted at Cirad.

In the classification test on a real-scale level as conducted in Sudan, the work was designed such that some technicians were preparing the specimen using the SCT while others were counting sticky points adherent to aluminum foils.

2.1.2. High Speed Stickiness Detector

As many cottons now show stickiness, the development of a rapid method for the detection of stickiness is more important than ever. The stickiness of cottons during the spinning process has become a selection criterion in the spinning industry. It would therefore be advantageous at the production stage to evaluate the stickiness of each bale. The analytical rate of the H2SD detector is compatible with that of HVI measurement lines and the results it gives correlate well with those obtained on the reference apparatus, the SCT thermodetector. The H2SD is therefore very promising for a bale-by-bale evaluation. The production machine has been improved for intensive use in an industrial environment and modified to provide easy maintenance.

A standard is in development under the supervision of the French and European standards committee. Thus, before any use of this H2SD method, the latest version of this standard should be consulted in the CEN books. The standard is nevertheless summarized here to describe as clearly as possible the operating procedure that should be followed for testing. This procedure was followed during testing conducted at Cirad.

A normal H2SD analysis is performed at 65% RH and 21°C. The H2SD (Frydrych *et al.*, 1994) is made up of five work stations:

– A sample of cotton (3 to 3.5 grams) is opened using a rotor to form a mass with a density of about 160 g/m². This is placed on an aluminum foil which passes successively in front of 4 stations.
– Hot pressure is applied to the sample. The combination of the water in the cotton and the temperature differential between the heat applied and the aluminum, produces a thin layer of wetness on the sheet of aluminum.
– The sticky points in contact with the aluminum foil are fixed in place by pressure exerted at ambient temperature.
– The cotton is then removed.
– The sticky points are then evaluated by an image analyzer which counts the points and determines their size using of a camera and image-processing software. As these stations are independent, four samples can processed simultaneously. Thus, the machine is able to analyze a sample each 35 seconds.

Information displayed on the screen includes a digital image of the sticky points, a histogram of sticky-point size, the results along with the sample reference name, the total number of sticky points and distribution in three size classes (small, medium and large).

2.1.3. High Performance Liquid Chromatography (HPLC)

International Textile Center in Lubbock runs the following method to determine the individual sugar contents in fiber samples:

– Sticky deposit samples were weighed and placed in plastic bags.
– Twenty ml of 18.2 megohm water were added. A sample of the aqueous solution was taken from the bag with a 10 cm^3 syringe on which a 0.2 micron filter (nylon membrane-polypropylene housing) was attached. A 1.5 ml filtered sample was deposited into the 1.5 ml autosampler vial.
– Sugars were separated on the columns (CarboPac PA1 Anion exchange Guard column and two CarboPac PA1 Anion exchange Analytical Columns) in series with a Gradient Eluent system: Eluent 1: 200 mM NaOH and Eluent 2: 500 mM Sodium Acetate and 200 mM NaOH.

This method is used to determine the following sugar contents: Inositol (*I*), Trehalose (*T*), Glucose (*G*), Fructose (*F*), Trehalulose (*W*), Melezitose (*M*) and Sucrose (*S*).

2.1.4. Standardization procedure for sampling

A standard (NF EN 12751 Textiles – Sampling of fibers, yarns and fabrics for testing) is designed to define a proper way of sampling so as to represent a population of textiles. Please refer to these standards for updated information.

Different cases are studied depending on fiber presentation (small amount, bales, lots …). Preparation of the sample prior to testing is also described.

It is stated that bales can be sampled by removing one sample at each end of the bale; however this sampling method can only be used if the variability between bales is higher than that observed between the different layers of any given bale for the considered characteristic to be evaluated. For instance, it is already known that ginning technique affects within-sample variability for some HVI measured characteristics.

This point will be considered in the following section in order to relate this standard to a commercial point of view. Thus, most of the experiments described hereafter were performed by sampling different layers in the bale so as to check the basic hypothesis: within-bale variability is lower than between-bale variability.

2.2. Discussion – Conclusion

Through this list of the measuring methods and operating procedures, we can already imagine the difficulties involved in maintaining such equipment in good shape.

It is of obvious to maintain the equipment so that no drift occurs due to machine settings.

A standard is simply a means whereby different parties agree to measure a given parameter in the same way. Thus, even if the procedures have been standardized, anyone can use any method the way he wishes. However, it is always better to use a measuring method according to a well-known standard, especially when results will be compared to other laboratory information.

The sections given above are extracts from the future European Standards that are on the way to be validated according to the rules of this committee. We wish thank M. Laurent Houillon, Convenor on Stickiness Working Group within the TC 248, for letting us present these extracts of the standards as they are at the present time.

A lot still remains to be done in the standardization procedure. Indeed, in the same way as for other devices, stickiness measuring devices will require internal and external calibration. At that point, the above standards give some information about the internal calibration: this mainly concerns equipment settings.

Concerning external calibration, we will need reference samples with very precisely determined stickiness values to check whether the measuring devices installed in different locations are able to ‘read’ the same stickiness level. This measurement reproducibility for well-known reference bales is directly dependent on how well the cotton is mixed and/or how well the sampling procedure is performed prior to testing.

A classification procedure would require the same within-bale cotton homogeneity for the different characteristics. However, it is necessary to know the actual level of within-bale stickiness variability in order to prepare the classification procedure, and if necessary, to adjust the production parameters, e.g. the seed-cotton collection.

In the next chapter, we will attempt to evaluate the variability of within-bale stickiness. With this information, it should be possible to determine:

– the number of samples to be taken per bale;
– the number of measurements per sample, this information is required to try to deduce the breadth of the confidence intervals, and to give stickiness readings within these given restricted confidence intervals;
– the risk that a reading made during classification is different from that determined in the purchaser’s laboratory. This evaluation has a direct link with the number of possible complaints between a seller and a purchaser.

2.3. Experiment on 5% of Sudanese production using the SCT

2.3.1. Objective

An experiment was performed to determine the stickiness level of Sudanese cotton based on a 5% sample of the production.

2.3.2. Introduction

Two complete crops were sampled at a 5% level in the most important production zones in Sudan. In the normal organization in Sudan, seed cotton bags come to the gin after a visual classification for color, trash and length and a classification into 3 grades. Each grade is ginned separately. Bags of the same visual grade are mixed without taking account of the production origin (block). After proper conditioning of the seed-cotton, the bags are emptied behind the gin stands, and seed-cotton is manually fed to the roller ginning machines. The lint is collected and mixed on a conveyor belt which drives the lint to the bale press. One group of 100 bales (or 300 bales in some factories) is called a lot.
In this experiment, seed cotton from different production blocks was ginned separately (i.e. the opposite from that described above) for the following reasons. The objective of the project was to separate the sticky part from the non-sticky part of the production. If we consider that a block is quite homogeneous and that some blocks are free of stickiness, mixing different blocks solely on the basis of the seed-cotton grade (as is done under normal conditions) will certainly result in mixing sticky with non-sticky cottons. Mixing bags of a same block should be acceptable since we assumed that cotton in the block production was homogeneous, but nonetheless depends on within-block stickiness variability.

2.3.3. Materials and methods

On that cropping year, this experiment represented the collection and analysis of 15885 bales with 2 samples per bale. Five bales uniformly selected (bales 20, 40, 60, 80, 100 …) from each lot of 100 bales were sampled (2 samples per bale). One SCT measurement was performed on each of the 31770 samples.
This experiment corresponds to true 5% sampling, and showed considerable variation factors since it represents the routine way of working in Sudan. The sampling covered 5 production zones where 1 or 2 variety groups were grown. Each zone could contain both roller and saw gin factories to process the seed cotton. Seed cotton can be produced by 2 varieties. For these reasons, the analysis of such an experiment is somewhat difficult in a standard statistic model.

2.3.4. Results and discussion

The data analysis was performed on the averages of the 2 measurements made for every bale. Figure 2-2 represents the quantile boxes for the 3 factors variety * factory * ginning methods (roller or saw) combined into. This is the best way to summarize the important information extracted from the experiment. It was assumed that the observed data is close to a Poisson distribution. The data was square root transformed.
First, we can see that the stickiness means for the 7 combinations were different, and that the stickiness ranges were very different one from another. A marked effect may be exerted by one of the three factors merged in the codification “Variety / Factory / Ginning type” that is kept encoded for commercial purpose.
Then, in view of the analysis of variance (factory * variety * gin * lot * bale), the most important effect (highly significant for each gin) in this experiment was found to be the lot effect.
In these experimental conditions, we demonstrate that the variability of within-lot stickiness is low (non significant effect of the bale within the lot). This means that the operating conditions, prior to and during ginning, enable the production of homogeneous lots having defined stickiness levels.

When comparing the data from two different crops where the same sampling procedure was applied, we observe an interesting decrease in stickiness within Sudanese production. This trend decreased average stickiness from 40 sticky points during the 1997/98 season down to 20 SCT sticky points during the 1998/99 crop season (Figure 2-3).

2.3.5. Conclusion

In this experiment, production organization was altered compared to normal routine practices, so that seed-cotton bags were not mixed all together with bags from different production zones (blocks). In these production conditions, we expected to see a loss of homogeneity between lots and an increase in within-lot homogeneity of results.
The data analysis confirmed our expectations through a highly significant effect on the lot (differences between lots are notable) while the 'bale' effect within the lot was not significant (no stickiness difference between the bales of a single lot).
These conclusions could lead to a modification in Sudanese production organization, to produce cotton lots with a specific stickiness level, as assessed by a classification process.
This organization would allow non-sticky cottons to be removed from the production for sale at the international market price. Later in this document, we will review the conditions to be respected in order to ensure "certification" of the stickiness level determination for each lot and consideration of the litigation risk between a seller and a purchaser for these raw materials.
The information collected in such a production organization (no grouping together of seed cottons from different production zones + classification process) could also be used to improve our knowledge about the true production zones. When seed cotton from different zones is mixed, this result in "bulk" seed-cotton from a large production zone area, without locating exactly the "sticky part". Thus it becomes difficult to determine the source of the problem and verifying measures are therefore impossible. By contrast, the ginning of seed-cotton from given production blocks renders it easier to find which zones furnish 'sticky cotton', where corrective measures should be applied.
In short, specific production methods could result in more homogeneous lots (at least for stickiness). This organization should also integrate a classification process to assess the stickiness of the bales, and these results could also be used to link stickiness data to pest infestation on limited production zones in order to draw conclusions concerning crop management (in general terms).

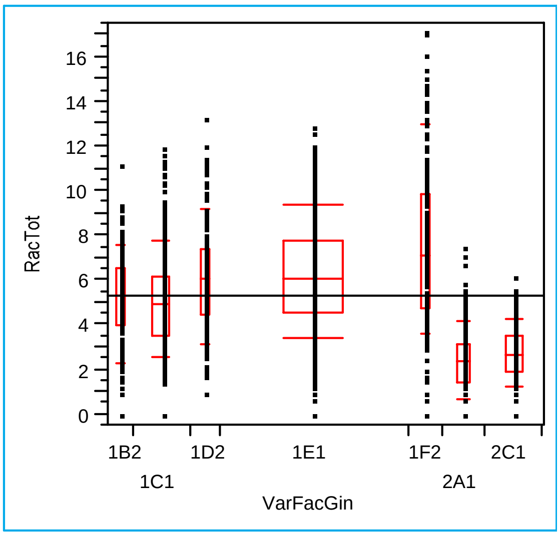

Figure 2-2: Distribution of SCT-measured stickiness for different Variety / Factory / Type of ginning combinations.

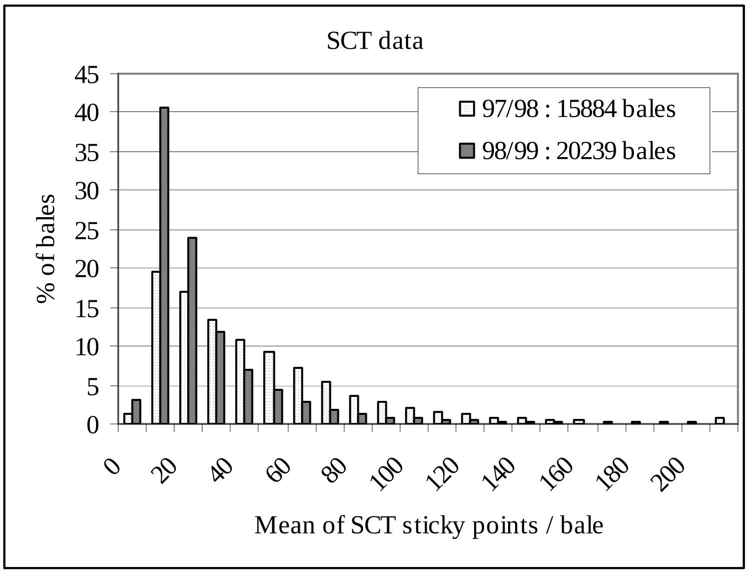

Figure 2-3: Comparison of stickiness distributions in 2 crops.

2.4. Testing and evaluation of methods for establishing the degree of stickiness in cottons. Stickiness sampling methods in cotton bales: Application to the commercial classification of Sudanese cotton production using SCT

2.4.1. Introduction

This study was conducted as part of section a/ of the project entitled: “Testing and evaluation of methods for establishing the degree of stickiness in cotton”, and corresponds to outputs 1.2 and 1.3, and part of output 1.1, i.e. activities 1.1.1, 1.1.2, and 1.1.3.

Its final objective is to establish sampling and measurement methods to assess the stickiness degree of cotton bales produced in Sudan, enabling the sticky bales to be separated from the others. This will allow the uncontaminated cotton to be sold at a higher price on the international market. In other terms, the study seeks to determine methods for classifying bales according to their potential stickiness.

Two types of bale classification may be envisaged:

- quantitative classification, i.e. each bale is attributed a guaranteed stickiness score,
- qualitative classification, where the bales are separated into two categories (sticky or non-sticky) with respect to a fixed value, called the critical stickiness threshold.

At the present time, bale classification for potential stickiness would enable producers to offer spinners lots that are guaranteed trouble-free during processing. To achieve this, the bales must simply be separated into two quality categories: sticky and non-sticky. A quantitative classification system based on the number of sticky points is technically possible, but it involves a not inconsiderable cost related to the constitution and management of batches of homogeneous stickiness. On the other hand, a qualitative classification system can determine the grade of a very sticky bale after a single measurement, thus restricting the number of measurements per bale, and in consequence reducing the cost of the classification. The qualitative classification system is therefore recommended, based on the use of a critical stickiness threshold.

Before continuing with this description, it is appropriate to clearly define the notion of critical stickiness threshold. If this were to be defined as the spin-ability limit for sticky cottons, it could be extended beyond a simple measurement of the number of sticky points to other parameters, such as the size of these points, and possibly the type of sugars they contain. A spin-ability limit defined in this manner is currently under study in association with the ITF institute in the context of the second part of the project. However, the instrument used to evaluate the within-bale distribution of stickiness is unable to determine the type or the size of the sticky points. This instrument (the SCT thermodetector) was selected by the CFC when the project was ratified for at that time the SCT was the only instrument recommended by international bodies for the measurement of cotton stickiness. For these reasons, and while awaiting the results of the second part of the project, the work conducted and described in the first part of this report was based on a critical stickiness threshold defined solely by the number of sticky points measured using the SCT thermodetector.

2.4.2. Materials and methods

If cotton is to be effectively classified with regard to its stickiness, it is necessary (as explained below) to evaluate the within-bale variability of this stickiness. To do this, an investigation was conducted in samples drawn from 1000 bales: 500 roller ginned and 500 saw ginned bales were selected from the 1996 production of 100 cultivation blocks of the Sudan Gezira board. Each block was ginned separately whereas the normal procedure is to sort production before ginning using a manual grading system, rather than by block. This change was made to ensure that the bales showed a more homogeneous potential stickiness, assuming that each block is infested in a homogeneous manner by the insects responsible for the stickiness. Ten bales per block were selected. Sixteen 80g samples per bale were drawn at the lint-slide along the pressing time.

The blocks were not chosen at random, but according to a pre-defined method. Thus, the conclusions concerning the general stickiness are applicable solely to these blocks in 1996, not to the entire cotton production of Sudan.
A 2.5g specimen was taken from each sample for a SCT test at the ARC laboratory. The 16 specimens from each bale were tested one after another by the same operator.
Unlike continuous measurement methods, sticky point counts cannot be assigned a Gaussian distribution. Repeatability does not merely relate to a variance, and within-bale probability distribution must be assessed from repeatability studies.
In brief, this distribution was inferred from theoretical considerations and the mean-variance relationship; its parameters were estimated by maximum likelihood. Likelihood ratio tests were used to check the homogeneity of the parameters. The litigation risk for bale classification was calculated from this probability distribution.
To go into deeper details, the number of sticky points is a discrete random variable obtained by the counting of points on a relatively small area of the aluminum foil. In the hypothesis of a fully randomized distribution and homogeneous sticky points density within a bale, the number of sticky points per sample, as expressed by the theory of punctual processes (Cressie, 1991; Saporta, 1990), follows a Poisson distribution with a mean for each bale. In the opposing hypothesis, the probability distribution is over-dispersed compared to Poisson's distribution. A one-sided Chi² test allows a choice to be made between these two hypotheses. Indeed, in the case of a Poisson distribution, the ratio of the sum of squares of deviates *(SCE)* to the mean of *n* measurements asymptotically follows a Chi² distribution with *n-1* degrees of freedom (Dagnelie, 1975; Fisher, 1938). For *p* bales and n_j measurement per bale resulting in a mean $x_{j.}$, equation B-1 gives the expression of the observed χ^2_{obs} with $\sum_{j=1}^{p}(n_j - 1)$ degrees of freedom.

$$\chi^2_{obs} = \sum_{j=1}^{p}\left(\frac{SCE_j}{x_j.}\right) \qquad \text{(Equation 2-1)}$$

When the Poisson hypothesis is rejected, the ratio of the Chi² to its number of degrees of freedom gives an estimate of the over-dispersion compared to Poisson's distribution.
The relation of the variance to the mean on a log-log scale was used as a guide to choose a probability distribution.
Among the over-dispersed distributions, the negative binomial was investigated because it can be created by a wide variety of process (Johnson, 1992), and it has been observed for stickiness counts in other Cirad collaborating countries.
The negative binomial distribution with mean *m* and shape parameter *k*, is the distribution of the random variable *X* for which

$$P(X = x) = \frac{\Gamma(k+x)m^x k^k}{\Gamma(x+1)\Gamma(k)(m+k)^{(k+x)}} \qquad \text{(Equation 2-2)}$$

with gamma (Γ) being the generalized integral defined by:

$$\Gamma(k) = \int_0^\infty x^{k-1}\exp(-x)dx \qquad \text{(Equation 2-3)}$$

Its variance is $\sigma^2 = m + m^2/k$

Each bale has its own mean stickiness m_j, whereas the parameter *k* is supposed to be the same for all bales.
When estimating the parameters on a set of *p* bales, the arithmetic mean $x_{j\bullet}$ is a good estimate of the parameter m_j. On the other hand, the shape factor *k* can be estimated using different ways, from which the method of the maximum of likelihood is the most precise. This method consists in evaluating the maximum of the function *L*:

$$L = \prod_{j=1}^{p} \prod_{i=1}^{n_j} \frac{\Gamma\left(k + x_{ji}\right)(x_j.)^{x_{ji}} k^k}{\Gamma\left(x_{ji}+1\right)\Gamma\left(k\right)\left(x_j.+k\right)^{\left(k+x_{ji}\right)}} \qquad \text{(Equation 2-4)}$$

In practice, it is easier to estimate the inverse of *k*, because the estimation of the quantity $\alpha = 1/k$ is less biased and gives more symmetrical confidence intervals around α.than that of *k*
A one-sided maximum likelihood ratio test allows to check for the homogeneity of the *k* coefficient within a group of *p* bales. Indeed, if *L* is the maximum of likelihood which is obtained considering that all the bales have the same *k* coefficient, and L_j the one obtained with a k_j for every bale or group of bale taken separately, then the quantity $-2\left(log\, L - \sum log\, L_j\right)$ is a Chi² with $p - 1$ degrees of freedom.

2.4.3. Results

An analysis of variance on the square root of the mean number of sticky points was performed to detect any difference of mean level between counters. It showed clear differences between counters (P<0.0001). Although bales were not alloted at random between the different counters, this suggests that some counters may detect more sticky points than others. As a consequence, SCT does not seem fully adapted to commercial classification, as countings made by a person may differ from those made by another person. However, we investigated the within-bale variability.
The scatter plot of log-transformed variance against log-transformed mean shows that variance increases with the mean (Figure 2-4). On the opposite, if sticky points were randomly distributed within a bale, the number of sticky points for any given bale would follow a Poisson distribution for each bale with a variance equal to its mean. This Poisson hypothesis was also rejected at the 0.0001 level by the Chi² over-dispersion test.
The scatter plot of log(variance) versus log(mean) (Figure 2-4) shows that the relationship between mean and variance, as modeled with a negative binomial distribution, is not satisfactory. Here, two sub-clouds of points may be observed: one above the curve, the other below. The second is even below the bisecting line (dashed), which corresponds to the most restricted dispersion that can be imagined in a situation where the sticky points are distributed in a completely random fashion on the fiber of the entire bale. This under-dispersion phenomenon should not be observed, even with a completely random distribution of sticky points. No explanation of this phenomena can be brought by the ginning method which is used as displayed in Figure 2-5 where 'roller' and 'saw' ginned clouds results are superimposed.
However, under-dispersion can be observed when all stickiness measurements for the same bale are made one after another. This phenomenon may be attributed to observer memory, i.e. each time the points are counted, the operator remembers the counts he/she has just determined for other samples from the same bale.
No conclusion can therefore be drawn from the measurements made in the 1000 bales concerning the probability distribution of SCT counts, apart from the hypothesis of an operator memory effect.
In order to test this hypothesis and to evaluate the within-bale distribution of SCT sticky points even in the presence of memory effect, two other experiments were conducted at CIRAD on a sub-set of the 1000 bales. The first involved the first 30 bales and was not randomized. The second, conducted during the placement of Dr Abdel Rahman in Montpellier, involved 30 other bales chosen at random. In this experiment, 16 measurements of each bale were distributed at random between two operators and were analyzed in a random order.
In the randomized experiment, a possible difference of level between the two operators was tested with an appropriate log-linear model. This does not affect much the over-dispersion index that drops from 5 to 4.86. The operator effect is not significant (P=0.15), when taking into account the operator effect. Therefore, the within-bale variances were estimated ignoring this difference of level.
When considering the measurements made at CIRAD, the scatter plot of log(mean) against log(variance) shows that the over-dispersion is more pronounced in the randomized experiment (Figure 2-6) than in the non-randomized experiment (Figure 2-7). The less pronounced over-dispersion noted for the non-randomized measurements was attributed to the operator memory effect.

The counts made by the ARC were even less dispersed than those observed at CIRAD in the absence of any randomization. This suggests that the operator memory effect introduced substantial bias into the results in routine conditions.
This calls for the following recommendation: when performing several measurements on the same sample with SCT, it is important to interleave the specimen from the same sample with specimen from other samples in a randomized order, in order the operator ignores what sample he is analyzing at the time he counts.
No level difference between operators was detected in these later experiments thanks to the good training of the operators and the periodical check of their readings on reference cottons. We recommend these precautions to be used as well in routine tests.
When considering the randomized measurements, an adjustment using a negative binomial distribution gives satisfactory results for the relationship between the mean and the variance. Thus, although a likelihood ratio test showed that the *k* parameter is heterogeneous (Chi^2=6.7322 for 1 df, P=0.0095), a negative binomial distribution of parameter k=10.8 is the best approximation that can be established by this study.

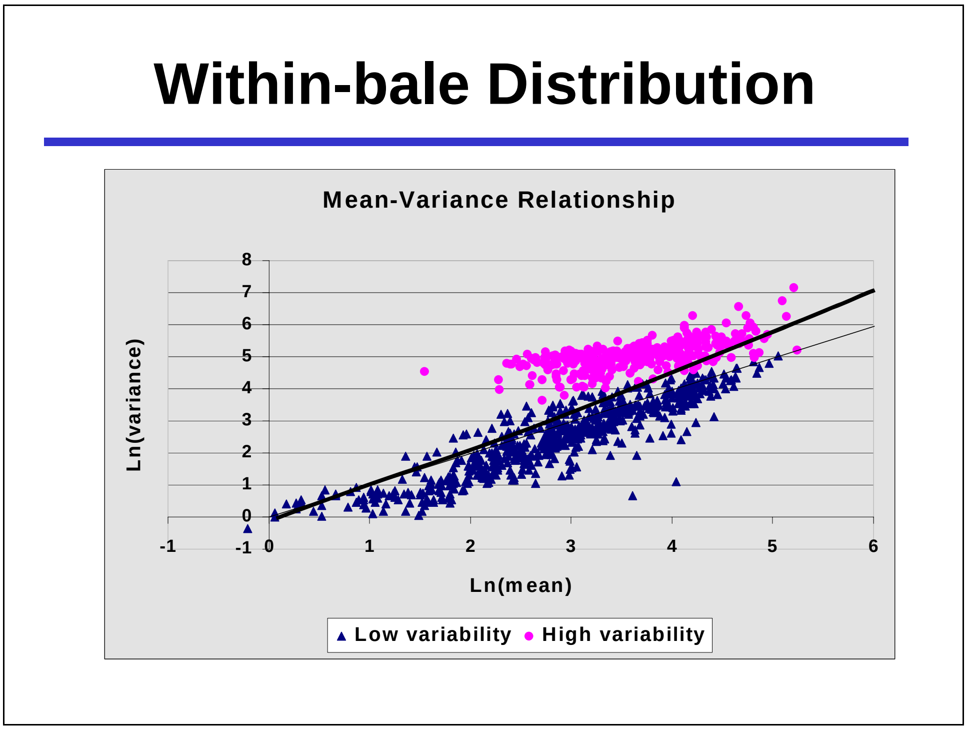

Figure 2-4: Relationship between within bale variance and bale mean on SCT measurements on 1000 bales sampled from 1996 production of 100 blocks of the Sudan Gezira board. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on all the bales.

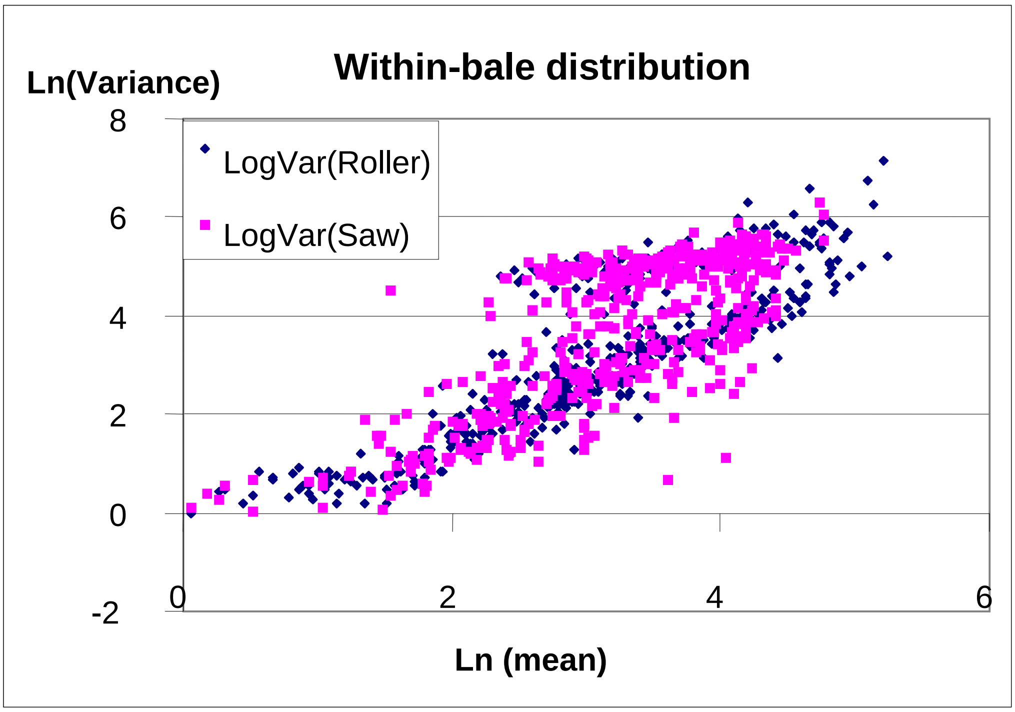

Figure 2-5: Same relation as previous figure with a classification according to the ginning method (roller / saw).

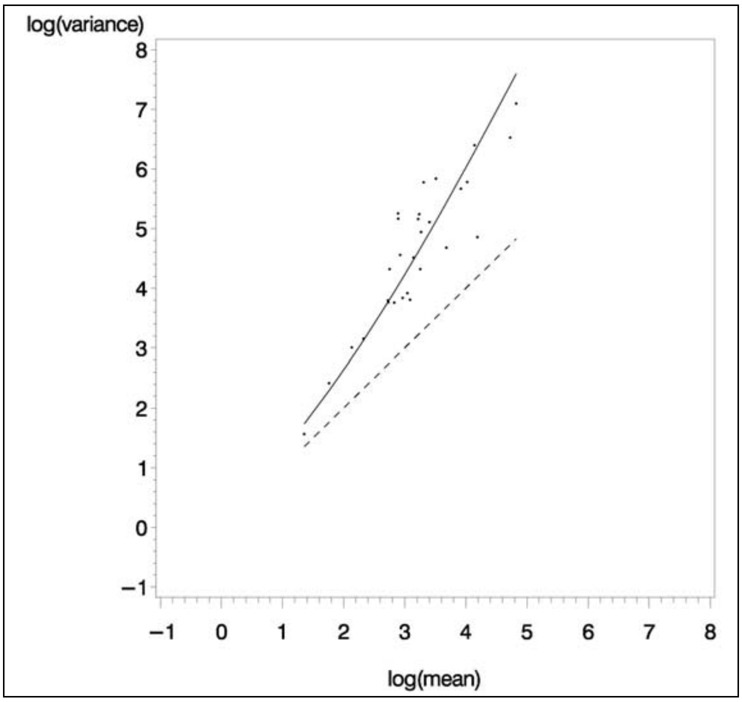

Figure 2-6: Relationship between within-bale variance and bale mean on SCT measurements in a randomized experiment carried out at Cirad on 29 bales of Sudanese cotton. The bisecting line shows the theoretical variance x mean relationship for Poisson distributions. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on the 29 bales.

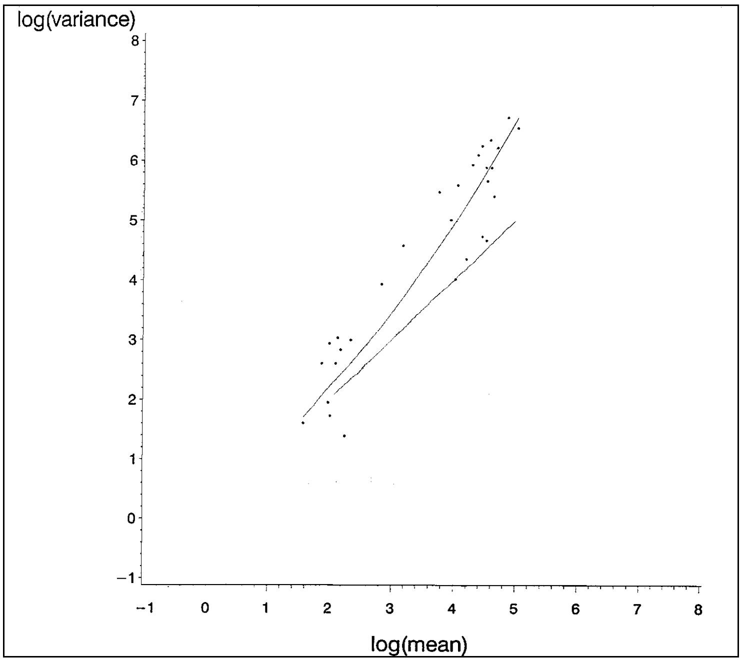

Figure 2-7: Relationship between within-bale variance and bale mean on SCT measurements in a non-randomized experiment carried out at Cirad on 30 bales of Sudanese cotton. The bisecting line (dashed) shows the theoretical variance x mean relationship for Poisson distributions. The solid line shows the theoretical variance x mean relationship for negative binomial distributions with a common k estimated on the 30 bales.

2.5. Stickiness variability and feasibility of a commercial classification using H2SD

2.5.1. Objective

This experiment was designed to highlight the within-bale stickiness distribution and its parameters in order to evaluate the number of samples and the number replicates required for a representative estimate of the stickiness potential of a given cotton bale.

2.5.2. Materials and methods

To evaluate this distribution, 100 bales were selected from Sudanese production: 50 were roller-ginned and 50 were saw-ginned. During the ginning process of these bales, 16 layers of cotton were sampled in every bale
It is important to note that these bales were selected to represent a broad stickiness range and are therefore not representative of the actual extend of stickiness in Sudanese production. We will highlight later the importance of sampling representativity in this procedure. After been conditioned in normal conditions (65% relative humidity and 21°C), the samples were H2SD tested using a fully randomized design.

2.5.3. Results and discussion: Within-bale distribution of stickiness

Probability distribution of the number of sticky points

Considering the 100 test bales with 16 measures each, apart from some missing samples, the observed χ^2 is equal to 7213 with 1492 degrees of freedom. The hypothesis of within-bale Poisson's distribution is then rejected at 0.01% level. The over-dispersion index, which is the ratio of the variance to the mean, is around 4.84.
This relation seems quadratic when observing the regression logarithm of the variance to the one of the mean (Figure 2-8). Such a relation suggests a negative binomial distribution.
The maximum likelihood estimation of k, as using SAS software, converged to an homogeneous value of $k = 9.43$.
The within-bale distribution of the number of sticky points is then negative binomial with shape parameter $k = 9.43$ for the 100 bales sample we tested.
As we evaluated the within-bale distribution, we will now see its application to a qualitative classification of the bales.

2.5.4. Litigation risk in qualitative classification: definition and control method

The variability of the measurements made determines the risk involved in commercial classification, i.e. the risk that a bale classified as non-sticky by the supplier is then evaluated as sticky by the purchaser. This risk can be reduced to an acceptable level by classifying more strictly than in subsequent evaluations.
A bale is classified by reference to a classification threshold: if the stickiness measured is less than or equal to the threshold, the bale is classified as non-sticky. If the stickiness is greater than the threshold, the bale is classified as sticky. However, the different measurements made for the same bale do not always give the same results, as already noted in the variability study. Therefore, the same bale could be classified at some point as non-sticky and at another as sticky. This is a potential cause of litigation between the seller and the purchaser.
This idea is illustrated in Figure 2-9. Here, the classification threshold is set at 10, i.e. bales with 11 points or more are classified as sticky. If we consider a bale with a true potential stickiness

corresponding to a mean of m=12 sticky points, and showing a negative binomial distribution (as seen in the randomized experiment), equation 1 can be used to calculate the probability of observing exactly X=0, 1, 2, etc. sticky points. These different probabilities are plotted against X.
In this precise case, it can be seen that the probability of classifying the bale as non-sticky (solid bars) is nearly the same as the probability of classifying the bale as sticky (dashed bars). To be more precise, the probability of classifying the bale as non-sticky is 0.428.
If the purchaser adopts the same classification threshold and the same number of measurements, he will have a probability of 1–0.428=0.572 of classifying the same bale as sticky. To result in litigation, the supplier must have classified the bale as non-sticky and the purchaser must have classified the same bale as sticky. As these two classifications are independent, the probability of both events corresponds to the product of their individual probabilities. The risk of litigation is therefore 0.428 x 0.572 = 0.24.
Such a risk can have considerable economic consequences and is therefore unacceptable. It can even be demonstrated that the risk may reach a maximum of 0.25. This occurs when the classification threshold is exactly equal to the distribution median. This result is independent of the probability distribution.
The risk for any given threshold varies in relation to the potential stickiness of the bale, as shown in Figure 2-10.
In practice, the potential stickiness of the bale is unknown when it is classified. When classifying an entire production of bales, the litigation risk is the mean risk over all the bales, which depends on the probability distribution of the stickiness in the population.
As this distribution is unknown, no calculations can be made based in advance on this overall risk, but we do know that its upper limit is the maximum risk. Therefore, as we are unable to base calculations on this overall risk, we can use the maximum risk. If this is set at a reasonably low value, a low litigation risk can be expected.
One method of lowering the maximum risk is to be more strict when classifying than when evaluating. To guarantee that an evaluation of the bales will practically never give a stickiness reading higher than the limit required by the spinner (called the evaluation threshold), the producer must classify his bales using a lower threshold (called the classification threshold).
For example, if the evaluation threshold is always set at 10 sticky points, but the classification threshold is set at 3 sticky points, the risk of litigation for a bale with potential stickiness of 12 points is only 0.0237 x (1–0.428) = 0.0086, i.e. 1.4%.
The maximum risk has been calculated with respect to both the classification and evaluation thresholds, with one or two replications. Figure 2-11 and Figure 2-12 show isolines for this risk in relation to the classification and evaluation thresholds.
For example, if the valuation threshold is set at 15 sticky points, then a classification threshold of 3 sticky points would result in a maximum risk of approximately 1%. With 2 measurements per bale, the classification threshold can be safely raised to 6 sticky points without any increase in the maximum risk.
To make calculations more formal, the litigation is the conjunction of two independent events: A: the bale is classified as non-sticky;
$\overline{B}$: the bale is evaluated as sticky.
The litigation risk, as defined above, can be calculated as follows: expressing the mean from the total *X* of the *r* measurements, we get the probability of events A and B:

$$P(A) = P(M \le t_s) = P(X \le rt_s)$$
$$P(B) = P(M' \le t_s) = P(X \le rt_s) = P(A)$$
(Equation 2-5)

Hence, P($\overline{B}$) = 1 – P(A).
The total *X* follows a binomial distribution with parameters *rm* and *rk,* since the counts are independent [Johnson, Kotz et Kemp, 1992]. This gives:

$$RL(m) = F(rt_s)(1 - F(rt_s))$$
(Equation 2-6)

The litigation risk *RL* in this formula depends on the mean *m*, the number of measurements *r* and the stickiness threshold t_s. For a given threshold t_s and a given number of measurements *r*, this risk varies

with the mean m and goes through a maximum as given in the example (Figure 2-10). This risk is specific to each individual bale.
Its maximum with respect to m is the same as the maximum with respect to *P(A)* because this probability is a strictly decreasing function of m. The derivation of *RL* gives:

$$\frac{\partial RL(m)}{\partial P(A)} = -2P(A) \qquad \textbf{(Equation 2-7)}$$

from which we can deduce a maximum $RL_{max} = 0.25$ when the threshold is a median of the distribution. This risk is too important for a classification because the cost of the claims by the purchasers would be too high.
One way to limit this maximum risk for the producer is to fix a classification threshold t_c lower than the one imposed by the purchaser that we called evaluation risk l_v. In these conditions, the litigation risk expression, $RL(m) = P(A)[1-P(B)]$, becomes**:**

$$RL(m) = \sum_{x=0}^{rt_c} \frac{\Gamma(r\,k+x)(r\,m)^x\,(r\,k)^{r\,k}}{\Gamma(x+1)\Gamma(r\,k)(r\,m+r\,k)^{(r\,k+x)}}\left[1-\sum_{x=0}^{rl_v} \frac{\Gamma(r\,k+x)(r\,m)^x\,(r\,k)^{r\,k}}{\Gamma(x+1)\Gamma(r\,k)(r\,m+r\,k)^{(r\,k+x)}}\right]$$

(Equation 2-8)

Litigation risk for an entire production

We are interested by the averaged litigation risk for a complete production, this average is weighted by the probability density function of the averaged level of per bale *f(m)*.
The global risk *RG* is**:**

$$RG = \int_0^{\infty} RL(m)\, f(m)\, dm \qquad \textbf{(Equation 2-9)}$$

This risk *RG* should be evaluated by a specific study for each country and to its production environment. This specific study require a sampling procedure taking in account the statistical representativity of the entire crop production.

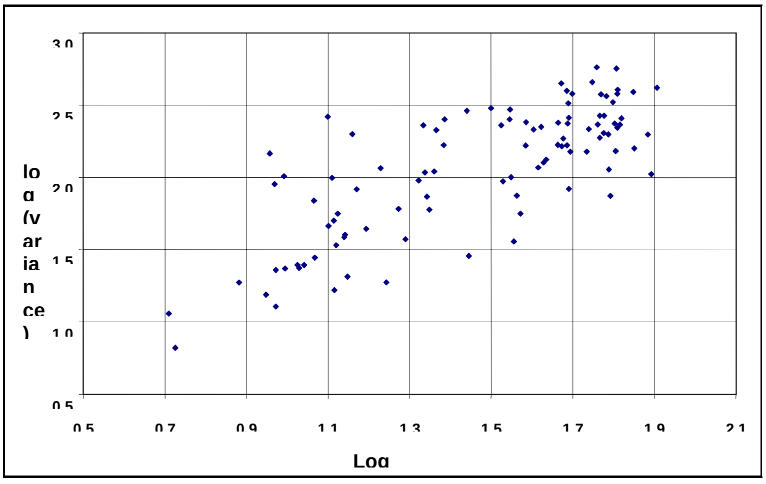

Figure 2-8**:** Relation Variance vs Mean of the number of sticky points as measured by H2SD.

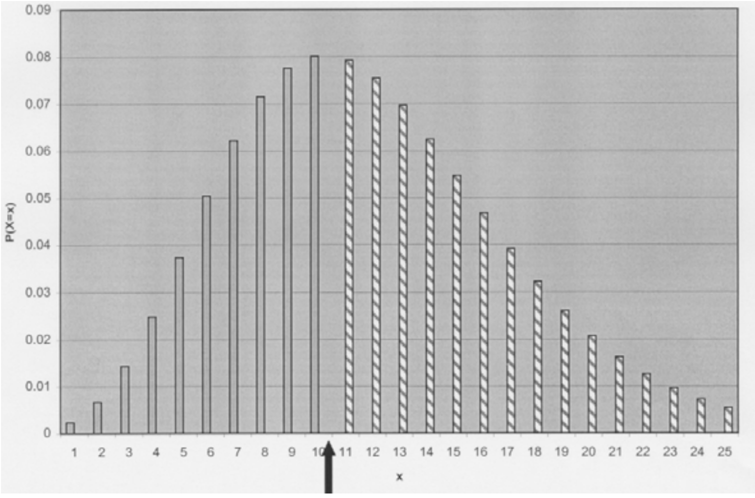

Figure 2-9: Negative binomial probability distribution of sticky point numbers, mean = 12 and k = 9.43.

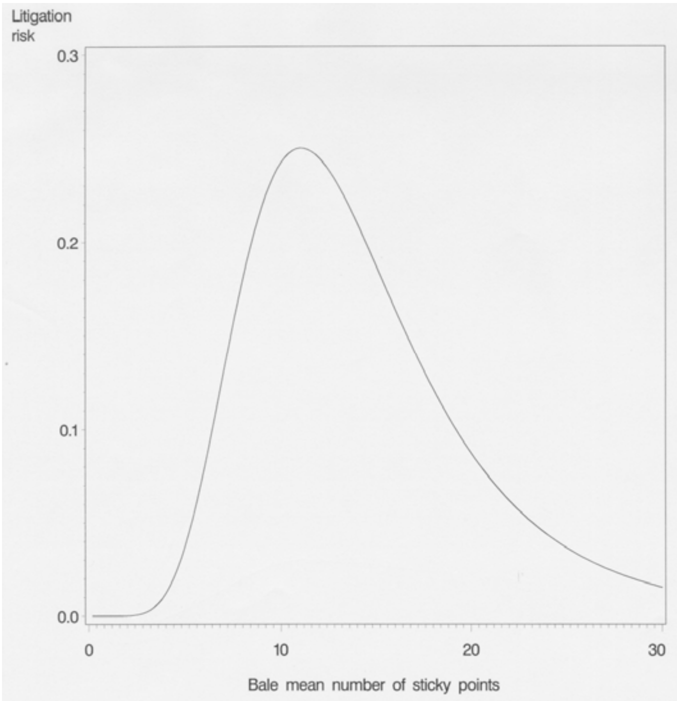

Figure 2-10: Litigation risk when classification threshold = evaluation threshold = 10 sticky points. Negative binomial distribution, k = 9.43, R=1 measurement per bale.

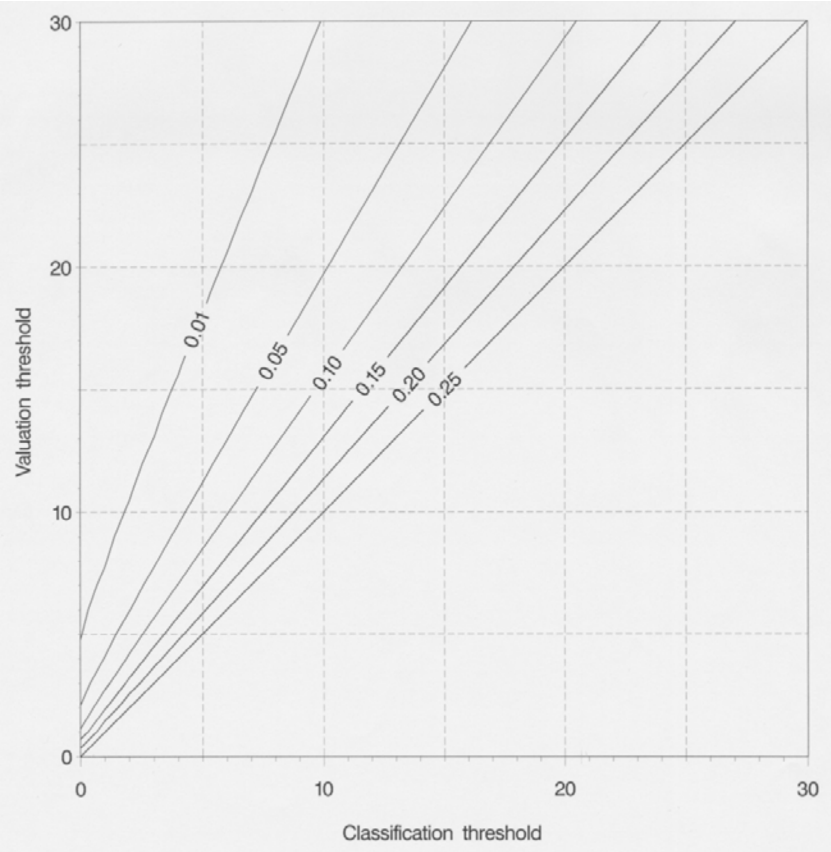

Figure 2-11: Evaluation threshold lv as a function of the classification threshold ts in the case of a negative binomial distribution with k = 9.43 and two H2SD measurements per bale (r=1).

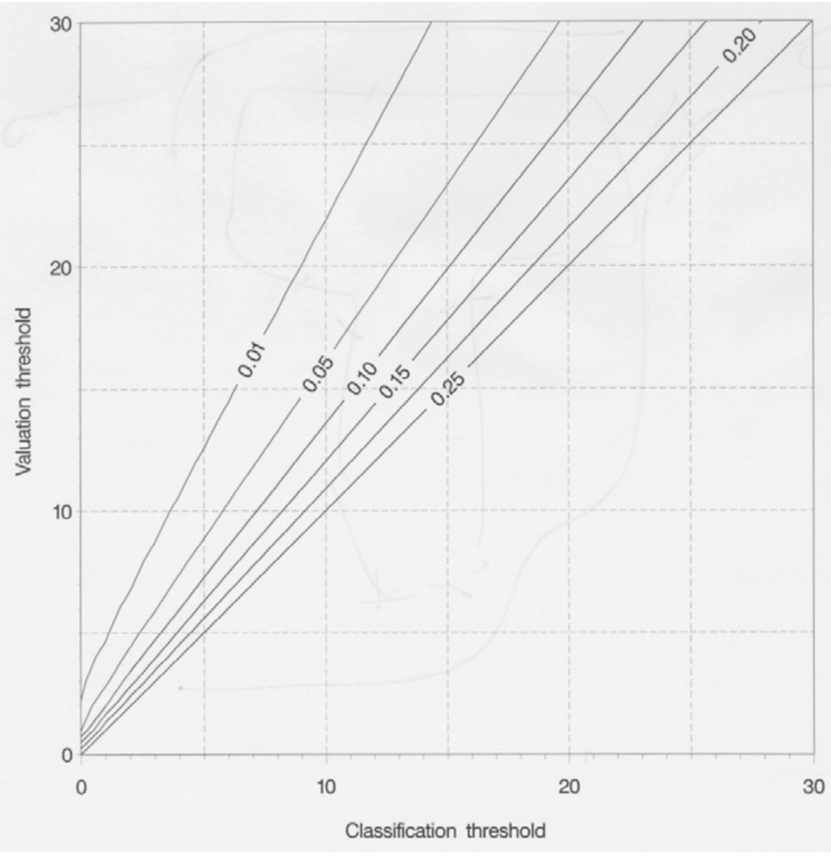

Figure 2-12: Evaluation threshold lv as a function of the classification threshold ts in the case of a negative binomial distribution with k = 9.43 and two H2SD measurements per bale (r=2).

2.6. Complementary experiment: Extra experimentation with 7680 samples taken in the whole country

2.6.1. Objective

To study the within-bale variability of stickiness, as well as other sources of variability and deduce a possible litigation risk for applying it during a classification process.

2.6.2. Materials and methods

The next step is now to confirm these information through a large scale testing. Thus, during our visit to Sudan in December 1998, we proposed and agreed the following experiment with all the persons that are concerned with the Project. The following choices have been made to represent the Sudanese cotton production. Table 2-1 gives the information which serve as basis for our final choice.
In the following text, the gin factories will be called ‘gins’ (even if some counting 96 or more gin-stands in case of roller ginning for instance).
The main information concerning the Sudanese cotton production are given in Table 2-1 and Table 2-2.

Table 2-1:Cross tabulation by variety and geographic zone:

	Geographic zone			% of the production
	Zone1	Zone 2	Zone 3	
Production	25%	25%	50%	
Variety 1	17%	17%	66%	75%
Variety 2	0%	0%	100%	25%

Table 2-2: Repartition if the gins within the cotton area:

	Geographic zone		
	Zone1	Zone 2	Zone 3
Type of ginning and Total number of gins	Saw 3	Saw 4	Saw: 1 Roller: 12

To get a representative sample of the Sudanese production, in our experiment, and with respect to an economical limit, we chose the following protocol:

– Eight gin factories were sampled among the 20 installed in Sudan, taking care of the variety and of the repartition roller vs saw gin. The selected gins have been chosen to have the highest production levels to meet a better representativity of the production.
– In each gin, we selected 30 lots within their production during the ginning crop 1998/1999.
– We made the assumption that any lot counts exactly 100 bales in all cases.
– For each lot, we sampled 1 bale every 50 bales. In practice, the bales labeled as 25, 75, 125, 175, ..., (every 50 bales) were sampled.
– For each bale retained, 16 different layers were sampled taking one sample of 50 grams on every layer.
– For each of these sample, we got the relevant information to properly analyze the collected data.

To make the sampling easier, samples were taken in the lint slide prior to bale packing. When all the samples are taken, we got 8 gins * 30 lots/gin * 2 bales/lot * 16 samples/bale = 7680 samples.

These samples were sent to CIRAD in Montpellier. CIRAD tested all these samples using H2SD device in a randomized design per gin. Reference cottons were also randomly analyzed in the series of Sudanese samples to check the H2SD's consistency in the results.

2.6.3. Results and discussion

No significant trend appears in the results for the reference cottons (Figure 2-13). This indicates that H2SD reads the same (within the confidence intervals) for given cottons along the time as it is expected for such instrument. Thus, a good confidence can be assumed for the following results.

Detailed analysis of the stickiness has been done per gin. We can observe that some production zones are non-sticky while other are sticky at different degrees.

In summary, we can conclude that:

- Some producing zones induce higher levels of stickiness while some other keep a low level of stickiness.
- There is a highly significant varietal effect.
- The type of ginning do not explain any variation in the level of stickiness.

Important notice: Fibers from one variety are mainly used for combed process, while fibers from the other variety are used in carded spinning. Thus, even if the fibers used in the combed process have a low stickiness level compared to the other variety ones, problems can appear during the specific processing for the longest fibers, and deteriorate its image in terms of stickiness.

It appears that around 34% of the bales for that crop, assuming that this sampling is representative of the production, has a stickiness level under 30 points H2SD (which is already sticky).

Comparable conclusions can be drawn concerning the within-bale stickiness variability. Different patterns appear indicating that a unique statistical distribution cannot describe the observed data. In consequence, a litigation risk for the entire country cannot be deduced.

The observed data could be fitted with a binomial negative distribution for this set of data as well as it was possible for the 100 bales data set. The shape factor was changed to $k = 9.78$.This means that it would be possible to establish tables to set both classification and evaluation threshold. The k shape factor value changes according to the within-bale stickiness distribution, which depends on production conditions.

Further sampling and testing will be necessary to set this shape factor. Since significant differences appears between gins (Figure 2-14) in the actual production conditions, it may be necessary to improve these production conditions prior first, then a new sampling and testing operations will be required to finally fix the law and its parameter in order to assess classification and evaluation thresholds.

2.6.4. Conclusion

These results demonstrate that a wide range of stickiness can be recorded within Sudan. Some areas seems to have greater sensibility to insect infestation, that may be explained by the location and the variety, even if other factors can interact.

Since significant differences appears between gins in the actual production conditions, it may be necessary to improve these production conditions prior first, then a new sampling and testing operations will be required to finally fix the law and its parameter in order to assess classification and evaluation thresholds.

The early picking appears to be the most effective solution as deducted from discussion in Wad Medani end of 2000. However, this will require appliance of different combined solutions to fit against stickiness.

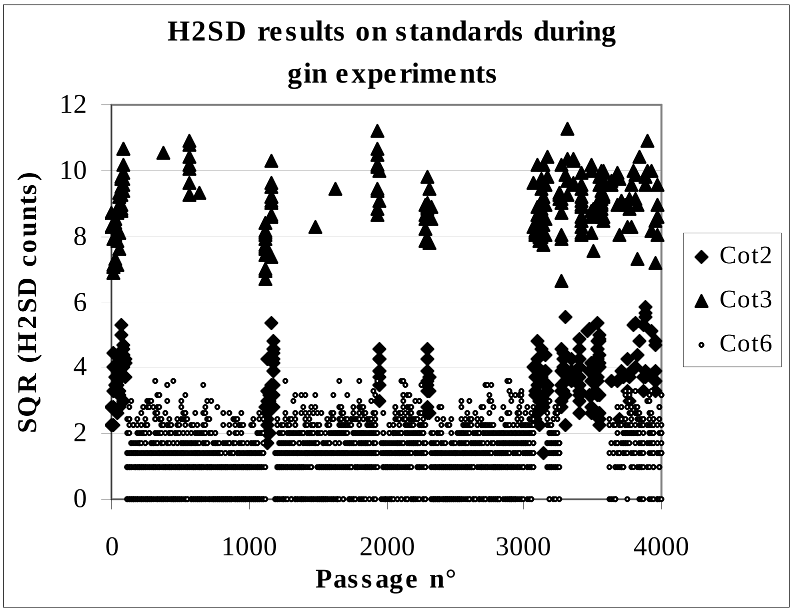

Figure 2-13: Results on 'reference cottons'.

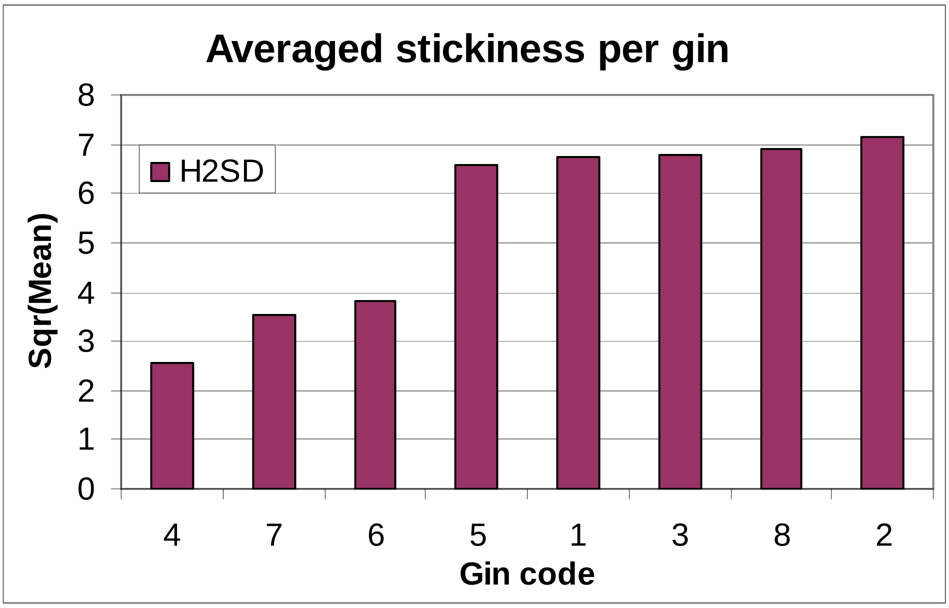

Figure 2-14: Factory location effect on the H2SD stickiness level.

2.7. The extent and variability of stickiness in the Sudanese 1998 crop using SCT and H2SD devices

2.7.1. Objective

An evaluation is required of the stickiness potential of Sudanese production along with an estimate of the proportion of the cotton which could be marketed as non-sticky. This evaluation was made using SCT purchased for that purpose, and confirmed by an independent laboratory.

2.7.2. Materials and methods

Five per cent of the bales produced in the 1998-1999 cotton crop were sampled for stickiness measurements.

Several blocks were selected in every gin factory. A block corresponds to a set of 100 bales produced successively. A sample was taken every 20 bales in each block. All the samples were tested in the ARC laboratory using SCT. An independent laboratory, Cotton Incorporated in USA, received 2300 samples for re-testing. Since SCT analysis was too time consuming, this re-testing was performed on CI's H2SD. Only the confirmed data is shown hereafter.

These samples were re-tested in a randomized order to avoid possible drift in the measurement could affect the variability estimations between gin factories. Samples were sorted in accordance with this randomization, but the machine was sent to Montpellier and the samples repacked in boxes in an approximate order compared to the randomization order. As the order of packing the samples was done without taking care of their origin (gin), the final order of testing can be considered as independent of the studied variations factors. In consequence, samples analysis are considered as randomized. Since a randomization of such number of samples in an experiment is a huge work, we take the assumption that samples were randomized for testing on SCT in ARC laboratory.

Internal Cirad reference cottons were analyzed at regular intervals among the Sudanese samples to check the machine response against time.

2.7.3. Results

2.7.3.1. Frequency distribution of the counts

No repetition was available within each bale to check the within probability distribution. Taking care of previous research work on SCT as well as H2SD measurements, a square root transformation was applied before regressions and variance analysis, to approximately stabilize the variance of the measurement error.

Probability distributions of the SCT and H2SD were separately described for each gin factory, using histograms, empirical cumulative distribution charts, moments and quantiles. Distributions of SCT measurements are always asymmetrical to the left, of more pronounced manner for some gins than for others. Distributions of H2SD measurements are more symmetrical, and we observe the same symmetry difference between gin factories as for SCT. In one gin, distribution is almost symmetrical. For 3 out of the 4 gin factories, extremes of the distributions are approximately the same for SCT and H2SD. For an other gin on the contrary, SCT measurements spread from 0 to 235, while H2SD measurements spread from 0 to only 128.

Average stickiness clearly varies from gin to another gin. With SCT, bales from one gin have an average of 8.5, and 31, 39 and 34 sticky points for the other gin factories. With H2SD, the same gin also shows the least stickiness with 16 points, the one from the other gins being 39, 44 and 45 sticky points. However, among these 3 gins, one gin seems the most sticky with H2SD and the least with SCT. Differences between gins are significant.

From a practical standpoint, **IF** we arbitrarily fix a threshold of 10 H2SD sticky points to get a moderate stickiness and 20 H2SD sticky points for a sticky cotton, only one gin gives an interesting percentage of non-sticky bales (Table 2-3). It is however very important to notice that the representativity of the collected samples is unknown.

Table 2-3: Number of samples per gin and stickiness grade.

	H2SD			All
	Non-sticky	Moderate	Sticky	
Gin 1	172	93	115	380
Gin 2	19	16	131	166
Gin 3	5	16	120	141
Gin 4	77	137	671	885

2.7.3.2. Variability between measurements in a same bloc

With SCT or H2SD, a precise measurement can only be reached with several repetitions. Thus, a classification process using a single measurement is automatically severe if a litigation risk has to be limited (Tamime, 2000; Gozé et al, 2000). However, taking in account the production process, it is possible that the bales from a single bloc which are produced altogether, could have nearer stickiness potentials than bales that are produced on different days intervals. If this would be true, man take in account the within-bloc variability to propose a more powerful classification operating method.
A variance analysis with one factor shows a highly significant bloc effect, on SCT as well as H2SD. Thus the within-bloc variability is lower than the within-gin variability for stickiness.
A mixed model allows the within and between bloc variance estimation. A likelihood test shows that these variances are not the same depending on the gin. In the square root scale, the different variances estimations are given in Table 2-4.

Table 2-4: Variance estimations of SCT and H2SD results (square root transformation) depending on the gin.

	Within blocks variance		Between blocks variance	
Factory	$\sqrt{SCT}$	$\sqrt{H2SD}$	$\sqrt{SCT}$	$\sqrt{H2SD}$
Gin 1	1.34	1.28	1.44	1.91
Gin 2	0.90	1.62	2.44	2.49
Gin 3	3.99	1.82	2.20	1.66
Gin 4	5.81	3.52	1.70	1.84

2.7.3.3. Relationship between SCT and H2SD measurements

SCT and H2SD work on almost the same thermodetection principle, but they are different devices working with sample size, sample mass, …, and temperature that are different. Thus, they generally do not give similar results, but statistic links exist between their results (Frydrych, 1996). The objective if this paragraph is to check the relationship between the results of these devices.
As said earlier, SCT as well as H2SD results were transformed to stabilize their variances through a square root transformation, rendering feasible the regressions calculations.
Relationship between SCT and H2SD is highly significant ($p<0.01$) using the all set of data, but somewhat loose ($R^2 = 0.29$). As the ranking of the gins are not the same for the 2 devices, we checked the effect 'gin' in the regression SCT vs H2SD. Thus, we checked the gin effect and the gin x H2SD interaction in a linear model of SCT:

$$Sct = f(gin) + H2sd \cdot g(gin) \qquad \text{(Equation 2-10)}$$

These tests shows that the regression slope is affected by the gin. Thus we calculated the regression for every gin. On bales from gin 3, the slope is not significantly different from 0, and there is no significant relation between SCT and H2SD. By the contrary, the other 3 gins show a relationship between SCT and H2SD, with a low R^2 between 0.17 and 0.28. If we take care of the relation Sqr(SCT) as a function of Sqr(H2SD) on the blocks where all 5 samples were present, the coefficient of correlation is $r = 0.70$.

These results indicate that the quality of the sampling procedure and of the randomization has a great effect on the relation between SCT and H2SD. Strict sampling procedure has to be performed in order to get a reliable stickiness measurement, as it is done in some countries to perform HVI testing and classification.

2.7.3.4. Contamination from sample to sample on H2SD

Here the question is: is there any contamination from sample to sample in H2SD which can affects the machine reading ? Indeed, it would be possible that some sticky fibers from a previous sample could be transferred to the following non-sticky cotton and thus affects its result.
The method used to detect such effect consists in studying the linear regression which exists between the number of sticky points for the non-sticky reference cotton as a function the number of sticky points of the preceding cotton. It exists a significant relationship (P=0.0014), but it is very loose (R^2=0.0063) based on square root transformed data.
Y=1.0099 + 0.0804 X
In this formula, the constant represents the noise (1 sticky point), while the slopes gives the dependency relation. We have to take care that this regression line is based on results on the X axis are variable as those on the Y axis.
If we forget this limitation, a cotton having 100 sticky points will increase the results on the following non-sticky cotton sample by 10 x 0.08, or 0.8 in square value scale. That becomes, in the normal scale, 1 + 1.6 + 0.64 or 3.24 sticky points, which corresponds to an increase of 2.24 points in average.
If we do not forget this limitation, and according to Snedecor and Cocheran, it is possible to correct the slope following a specific statistical method to obtain the following formula which is also significant with a loose R^2:
Y = 1.05 + 0.089 X'
Thus would it be necessary to correct the data ?
It is thus significant, and a moderate bias may exist onto the results on a cotton following a highly sticky cotton. However, its consequence is not too important, since it increases the risk of classifying a non-sticky bale as sticky which render the H2SD tests more reliable as it could be expected. We can add that this bias decreases if more than one replication is made for each cotton sample since such contamination will concern mainly the first replication of the measurement.
This represents a financial loss on the producer side, but it improves confidence in the measurements itself and in the cotton producer.

2.7.4. Discussion

The absence of relation between SCT and H2SD is troublesome for the gin 3 results (SCT and H2SD). Results were all obtained in the same conditions, during a same set of analysis where the order of the samples analysis were randomized. Thus, if these results are valid for 3 gins, they also should be valid for the 4th one. We envisage a mistake in the sample identification for the gin 3.
Among the 4 concerned gins in this experiment, only gin 1 give an interesting part of non-sticky cotton. It is important to notice that the representativity of the Sudanese cotton crop cannot be asserted. However, these results confirm the previous results we have for an earlier crop, and can be explained the non-coincidence between insect presence in the field and the boll opening phase for one variety.

2.7.5. Conclusion: Practical recommendations for cotton classification

Among the gins taken in account in this experiment, gin 1 appears to be the most concerned by a valorization effort: with the same number of bales produced, this gin furnishes the highest number of non-sticky cottons. More generally, strategies should be adopted to concentrate classification efforts depending on short / long term objectives based on economical basis.

Concerning the utilization of a lower within-bloc variability, a finer analysis of the routine data should provide a more economical procedure to classify cottons. At this point, the within-bloc variance being variable from gin to gin, no general rule can be found. The principle of using tables to evaluate litigation risk can be envisaged to deduce the rules to follow during the classification process in order to get a better return on investment for such a tool.

Strict sampling procedure are necessary to provide reliable information about stickiness at all the different levels in the production (within-bale, within-lot and between lots, …)

2.8. General conclusions for component A

The objective of this component was to find a way to estimate the stickiness potential of cotton fibers, its variability at different levels (bale, lot, …), to devise a sampling procedure and to define a procedure for a complete annual crop production classification.

As planned in the Appraisal Report, which constitutes an agreement for funding by the International Cotton Advisory Committee and the Common Fund for Commodities, some of the tools available were tested during this project on Sudanese cotton production.

At the beginning of the project, two main measuring tools were used to characterize the stickiness potential of cotton fiber samples and to which we added extra experiments to determine the feasibility of their use:

- The Stickiness Cotton Thermodetector (SCT) was first used at the beginning of the project. It is important to note that at the time this project was agreed, SCT was the 'state of the art' device to measure stickiness, as the machine was the stickiness measuring method recommended by the International Textile Manufacturers Federation (1994). At that time, new developments were ongoing to design other methodologies, but they were not taken into account or used in this project since they were not completed.
- High Performance Liquid Chromatography (HPLC) was used in parallel to assay all individual sugars contained in the 'sticky deposit' of some samples. This method was only used for "Component B".
- In 1998, however, it was decided to move on by using a newly developed measuring technique called High Speed Stickiness Detector (H2SD) because SCT is too time consuming in classification procedures. Some characteristics were described to demonstrate its advantages, and results during this project contributed to its improvement and to defining its advantages compared to SCT technique.

Standard texts exist to describe the operating procedures for taking samples and the operating procedure for the two commercial measuring devices mainly used in this project. Once again, it is important to note that the enclosed standard documents are drafts which cannot be used as it is. Reference to official documents should be made if these techniques are to be used.

Even if these standards are on their way to being adopted (after some further modifications), we have already noted that they may or may not be used in normal commercial testing, especially concerning the sampling procedures, without taking care of the variability of stickiness at different levels of the production (i.e. within bale, within lot, …). The studies reported here focused primarily on evaluating this within-bale variability. With that knowledge, it is then possible to devise the operational conditions of classification (number of samples per bale or lot and / or the number of measurements per sample) to insure the 'certification' of the stickiness level determination for each lot taking care of the litigation risk between a seller and a purchaser for these raw materials. Thus a low level of complaints could be expected.

Many experiments were designed with such an idea in mind. The first one was based on the SCT's that were installed at the beginning of the project in the Agricultural Research Corporation laboratory in Wad Medani. After a training of all the personnel, six technicians run the six installed SCTs to prepare the aluminum foils. These foils were then transmitted to two other persons who are in charge of counting the sticky points that stuck to the foils.

Based on a large sampling (one sample from 16 layers from 500 bales coming from roller gin plants and 500 from saw gin plants), this experiment showed that the distribution of the sticky points does not follow the typical Poisson statistical law which was expected. Moreover, the stickiness is not homogeneously distributed within the bales.

This specific distribution of the SCT sticky points was mainly due to an operator effect and to an interaction between the counter effect and the real stickiness level of each bale. In other words, the stickiness level labeled to a given bale is dependent on who counts the sticky points, and the real stickiness level of that given bale. Some independent experiments confirmed this hypothesis.

In these conditions, it is not possible to evaluate stickiness (as well as any other characteristics) since results can be biased at anytime, and this bias is not acceptable in a commercial use due to the important risk of complaints it could induce. In complement, we were not able to deduce a simple

statistical law from the collected data, rendering impossible the establishment of a specific operating procedure for a classification process.
At that point, it was decided to give up SCT as a tool for such a type of classification process since it introduces an operator effect. However, it is important to note that SCT is able to separate bales having different stickiness level but only at a laboratory scale.
We decided to begin to use H2SD to characterize 100 bales because its automation induces no operator effect and no interaction in the measurement. One hundred other bales were analyzed with H2SD to achieve the goal of finding a statistical law for the sticky points repartition in the bales. An hypothesis concerning the statistical within-bale distribution law of the stickiness was brought based on the analysis of these bales: it would be a negative binomial distribution with shape factor $k = 9.43$.
Based on this assumption, this report described a method for calculating litigation risk from the probability distribution of sticky point measurements, and the method employed was illustrated using the results concerning within-bale variability. It was shown that a single classification threshold would lead to a maximum litigation risk equal to 25%. Thus the application of a classification threshold (producer side) lower than an evaluation threshold (buyer side) was recommended to lower the maximum litigation risk. Some table were designed to estimate the risk of litigation depending on the two different thresholds that are fixed in the commercial procedure. It should be remembered that a specific organization of the production could have a large effect on the within-bale distribution for stickiness, and could somewhat affect the way of isolating sticky bales from non-sticky bales.
To confirm this hypothesis, an extra experimentation was planed to study the within-bale distribution of the Sudanese production with respect to the geographical representativity of the gins and the proportion of the two main grown varieties, Acala and Barakat. A specific sampling procedure was designed to represent the Sudanese production. The stickiness characterization was made on H2SD measuring device.
The corresponding results demonstrate that a wide range of stickiness can be recorded within Sudan as represented by the gin factory locations assuming that the seed-cotton is collected in their respective surroundings areas. Some areas seem to have greater sensibility to insect infestation, that may be explained by the location and the variety, and their interaction. However, it has also been showed that a part of the Sudanese production is affected at a low degree by stickiness. In average, the within-bale stickiness variability remains non-significant, i.e. there was no difference of stickiness reading depending on the layer in which a sample was taken in the bale.
Among the gins taken into account in this experiment, some appear to be the most concerned by a classification effort: with the same number of bales produced, these gins furnish the highest number of non-sticky cottons. More generally, this conclusion leads to find strategies to concentrate classification efforts depending on short / long term objectives based on economical basis.
Some information can be deduced from this data in order to elaborate an organization for the collection and the ginning of seed-cotton based on blocks in place of grouping bags from different blocks. We already can see that such a classification for stickiness in these production conditions could bring another use of the measurement results. This information, collected in such a production organization (no grouping of seed cotton coming from different production zones + classification process) would allow a better knowledge about the production areas. Indeed, when seed cotton from one single block is ginned separately, any stickiness problem is mainly related to its origins, i.e. the production block. With such an information, a map can be drawn to locate the major locations where insect stickiness appears, and thus researches of its cause(s) could be implemented. This map could be used in relation with pest infestations ones to deduce varietal sensitivities where some varieties could escape from the insect infestation peak, soils effects, … or other interaction with production methodologies. The early picking also appears to be the most effective solution as deducted from discussion in Wad Medani end of 2000. However, this will require appliance of different combined solutions to fit against stickiness.
From the previous experiment, we pointed out that a specific organization of both the production, the collection of seed-cotton, its ginning and its classification could permit to improve the stickiness situation of the Sudanese production. However, the actual condition has to be also considered to devise the operating methods and the sampling conditions for the classification process.
Concerning the utilization of a lower within-bloc variability, a finer analysis of the routine data should provide a more economical procedure to classify cottons. At this point, the within-block variance being variable from gin to gin, no general rule can be found. The principle of using tables to evaluate

litigation risk can be envisaged to deduce the rules to follow during the classification process in order to get a better return on investment for such a tool.
To sum up, it exists a variability of stickiness depending on the variety, the producing blocks that can be partially solved by a proper organization of the seed-cotton collection and ginning practices. A classification process can be implemented at least to know more about some kind of mapping to solve the insect infestation or limit its effect.
The other use of the classification would be to warrant a given quality to homogeneous lots in terms of stickiness level. The conditions of testing are not clear since variability of stickiness on the case of the actual organization do not allow to find a statistical law to define precision and accuracy of the measurements which could be valid for the entire country. However, a measurement can be done to isolate highly contaminated lots from the rest of the production, and begin to stabilize an effective organization, and begin to market the fibers based on this measurement.
Method to evaluate the litigation risk depending on two thresholds – at the classification and at the evaluation steps – are now available and could be applied as soon as a statistical law will be deduced from the data after a proper organization of the cotton production.
From these numerous experiments, we learned that SCT is not fully adapted for a classification process since a human effect occurs during the measurement that remove part of the confidence we can make in the results during a classification process. Thanks to its automation, H2SD has not this bias and could be used for a classification process as it brings no human factors interacting with the measurement.

Chapter 3. Component B: Development of a threshold for the economical processing of sticky cotton

Methods for neutralizing stickiness are under development at CIRAD. The laboratory work carried out so far has indicated that stickiness may be largely neutralized without affecting the quality of the cotton. Employing a neutralizing process requires additional time and cost and should only be used if financially advantageous. Establishment of thresholds for spinning sticky cotton will therefore be of a major advantage to the spinning industry. The main focus of this component is to establish such a threshold.

The operations envisaged in this component will take place in France at Institut Textile de France, where, in close consultation with CIRAD, research activities will focus on the impact of varying degrees of stickiness on the spinning process (at factory scale) and the variables that affect this impact. Sticky cottons disrupt the spinning process by sticking to various parts of the spinning machines. It seems that the problem varies depending on the stage of the process leading to the production of the yarn. Cotton fiber preparation (beating, mixing, opening, cleaning) is affected greatly if the quantity of sticky cotton involved is very large (several hundred kilograms). Stickiness has a considerable effect during carding and leads to irregularities in card slivers or, in extreme cases, renders carding impossible. The machines must then be stopped and cleaned. As far as the drawing frames, brush frames and spinning machines are concerned, the honeydew is deposited onto the rollers (feed, draw, etc.) and causes yarn irregularities and breakages. Rotor spinning suffers from problems such as the frequent fouling of the feed tables and rotors, which requires machines to be stopped repeatedly and cleaned. The result is lower yarn quality and higher production costs.

Activities related to developing post-ginning measures as foreseen in the project will be largely based on experience gained by CIRAD in earlier work on the neutralization of stickiness in cotton (in particular the impact of pressure, heat and humidity, as studied and applied under laboratory conditions). Research that made use of the SCT-Thermodetector has revealed that the number of sticky points in the test samples fluctuates depending on the relative humidity of the ambient air. Results in the 55% to 65% range seem to be stable. Outside this range there is a marked fall in the number of sticky points. The maximum sticky potential is therefore expressed between 55 and 65% relative humidity. This points to 2 ways of neutralizing stickiness: drying or humidification. The so-called TNCC9 of neutralizing stickiness developed by CIRAD uses the same combination of factors as the thermodetector, i.e. pressure, heat, humidity. The results have shown the importance of studying the impact of stickiness in a real-scale environment.

The studies to be undertaken in the framework of the project will determine the effects of sticky cotton on the spinning process and on the quality of the yarn and the resulting product. The threshold level of sticky cotton that will still yield end-products of acceptable quality will be established. Tests will also be undertaken to assess to what extent sticky cotton can be blended with non-sticky cotton to obtain an acceptable level of quality, i.e. allow spinning without disrupting the regular spinning process. The tests will differentiate between conventional (ring) and rotor spinning, and will be performed different under atmospheric conditions in order to establish the impact of different moisture and temperature levels. All tests will be performed under industrial conditions and will use the lint from 60 bales classified as to degree of stickiness in component (a) (approximately 13 500 kg). Quality tests will be undertaken in the ITF and CIRAD laboratories using certified measuring equipment and standard procedures for the establishment of the properties/deficiencies to be determined.

In the framework of this component, the following outputs will be produced through undertaking the described activities.

Output 2.1 The effects of sticky cotton on the spinning process and quality of the yarn or resulting product.

About 400 kg of each cotton (about 2 bales) will be required from preparation to drawing. 100 kg of lint will be sufficient for the spinning process. All tests (on 30 x 2 bales) will be performed under industrial conditions. Breakages at different steps in the process will be counted and the production process will be evaluated through spinning. Laboratory tests will consist of measuring:

-fiber length and strength characteristics on an HVI Zellweger-Uster line (on raw fiber and card sliver), and maturity and fineness on a Shirley Maturity Meter;

-level of stickiness using an SCT sticky cotton detector at each step in production from bale to the second drawing, to evaluate any variations in the course of the production process;

-regularity at each step in the production process (card sliver to yarn) using an Uster Tester II evenness tester, and the strength of the yarn produced (Super web apparatus);

-Classimat, to classify the different defects (Uster, Classimat II);

The level of stickiness during spinning will be evaluated by qualitative analysis of stickiness during different steps in the production process and by the quantitative analysis of the laboratory tests in comparison with non sticky cottons.

The same cotton batches will be used in rotor spinning. The controls performed during the production process and the laboratory tests carried out will be the same as for the conventional spinning process. The quality of the yarn from the resulting product will be determined by making use of the method (developed by the Cotton Technology Laboratory of CIRAD-CA) that differentiates between neps according to their different origins: seed coat fragments, fiber neps, sticky neps and stem or leaf fragment neps. This method will be used to count the number of neps induced by stickiness in the industrial yarn and consists of regularimetry tests performed on a Uster UT3 regularimeter. The settings chosen will be as follows: speed 50m/mn, thin (-50%), thick (+50%), neps (200%). These settings will be used for the two regularimeter tests, i.e. normal test (for the total number of neps) and detailed analysis which will be performed to identify the different neps observed. Each imperfection is examined in detail using a magnifying glass and strong lighting. The yarn is stopped over a given period of time (20 seconds), then is loosened in order to stabilize for 5 seconds before the reading. Imperfections will be classified as seed coat fragments, fiber neps (entangled fibers and sticky neps) and fragments such as leaves. Percentages obtained for each type of imperfection will be adjusted to total neps on 1000 m to obtain the number of neps per type of imperfection over 1000 m.

Activity 2.1.1 Cotton with known levels of stickiness will be spun on **ring** and **rotor** spinning machines (industrial scale).

Activity 2.1.2 The effects of sticky cotton on the spinning process and resultant yarn quality will be established.

Output 2.2 Establishment of stickiness thresholds for spinning.

Activity 2.2.1 The economically acceptable level of stickiness on ring and rotor spinning machines (industrial scale) will be determined. A level of stickiness that prohibits spinning without prior processing will be established.

Output 2.3 Blends of sticky cotton with non-sticky cotton will be prepared such that stickiness will not be a problem during spinning.

One way of using sticky cottons would be to mix them with non sticky cottons in order to obtain a mix whose stickiness is below the critical spinning threshold. The proportions of each type of cotton would depend upon the potential stickiness of the contaminated cotton which itself depends on at least 2 factors, namely the number of sticky points measured on the sticky cotton detector and the distribution and size of these sticky points. Five types of cotton (among the 30 employed in the industrial spinning tests) will be used (for example with 25, 50, 75, 100 and 150 sticky points). These cottons will be mixed in various proportions with non sticky cotton. The number of sticky points along with their size and distribution will be studied.

Activity 2.3.1 Mixes of cottons from different origins (sticky and non sticky) will be prepared.

Activity 2.3.2 Cotton mixes will be measured on the stickiness detector and standards will be established to help spinners to mix sticky cotton with non-sticky cotton without affecting the spinning process (ring and rotor) or yarn quality.

Output 2.4 The effect of atmospheric moisture on cotton stickiness will be established.

The relative humidity of the air is known to have an effect on the spinning of sticky cottons. Spinners use this property in an empirical manner. The aim of this study is to determine the critical threshold for the relative humidity of the air during spinning cottons of different stickiness levels (number of sticky points and their sizes). Six types of cotton (among the 30 employed in the industrial spinning tests) will be used. The study of the spinning process (micro-spinning) under different relative humidity conditions, will be performed using conventional and rotor spinning techniques for three types of yarn counts. All the disruptions that occur during the yarn production process (carding, drawing, spinning, rotors) will be evaluated (deposit of sticky points on various parts of the machines, yarn winding, yarn breakage, etc.). Yarn strength and regularity will be measured. Different types of neps will be identified, counted and studied.

Activity 2.4.1 The effect of atmospheric humidity on the spinning of sticky cotton and on yarn quality will be established.

3.1. Carded spinning of sticky cotton: Effect of stickiness on productivity and yarn quality

3.1.1. Objective

Which type of stickiness measurement is the most suitable to predict fiber behavior during spinning ? What is the exact relationship between breakages, efficiency and stickiness ? These questions, and many others required to address the stickiness problem, have yet to be answered with precision. It is therefore difficult to evaluate accurately the economic effects of stickiness on the spinning industry (Floeck, 1998) and in consequence it is impossible to determine in a rational manner the discount that should be applied to sticky cottons (Hoelscher, 1998).
To address these questions and gain a more precise understanding of the effects of stickiness in spinning we conducted a quantitative study using a broad range of sticky cottons (Fonteneau-Tamime, 2000) to record different qualitative and quantitative parameters.

3.1.2. Materials and Methods

3.1.2.1. Materials

Sixty bales from the 1996-1997 Sudanese cotton crop were available for the study. The ARC (*Agriculture Research Corporation*), in collaboration with SCC (*Sudan Cotton Company*), selected these bales on the basis of stickiness measurement using a mini-card test. Acala fibers of medium length were used for the carding spinning experiment, while Barakat fibers were used for the combing spinning study.
About 30 bales were selected to cover a range of stickiness while keeping the range of the other fiber parameters as tight as possible. A sampling procedure in 10 equidistant layers in each bale, was completed in order to measure their fiber characteristics. The following measurements were made:

– HVI (*High Volume Instrument* ZELLWEGER USTER 900), for Mean Length (ML) and Upper Half ML (UHML), length uniformity UI%, HVI strength and elongation;
– FMT (*Fineness Maturity Tester* SDL3), for micronaire, fineness and maturity;
– SCT (Thermodetector SCT), for the number of sticky points;
– H2SD (*High Speed Stickiness Detector*), for the number of sticky points and their sizes.

Twenty-four bales were finally selected for the carded spinning tests. Ten of these were roller ginned. Their characteristics were relatively homogeneous and covered a wide range of stickiness (from some points to 50 sticky points as measured using the H2SD). All of the bales showed some stickiness. Two non-sticky bales from Central Asia were added as references. Carded spinning tests were then performed using 26 bales (10 being roller ginned).

3.1.2.2. Fiber quality determination

Fiber quality characteristics are given in
Table 3-1, while stickiness data is given in Table 3-2.

Table 3-1: Fiber quality characteristics for selected bales in the spinning tests.

Ginning*	Stat	ML mm	UHML mm	UI %	Strength g/tex	Elong %	IM	MR	PM %	H mtex	Hs Mtex	Rd %	b
R (roller ginned)	Mean	22.2	26.9	82.6	27.0	4.8	3.6	0.8	69.4	165	213	73.5	11.5
	Max	23.2	27.7	84.4	28.4	5.2	4.0	0.9	76.5	176	230	75.0	12.8
	Min	20.5	25.5	80.4	25.3	4.5	3.2	0.7	63.5	153	201	71.9	9.4
	STD	0.8	0.7	1.2	0.8	0.2	0.3	0.0	4.5	9	8	0.9	1.1
S (saw ginned)	Mean	21.8	26.7	81.4	27.3	4.8	3.7	0.8	70.2	168	214	75.3	11.6
	Max	23.2	28.1	82.7	30.7	5.2	4.2	0.8	73.2	188	252	79.6	12.3
	Min	19.9	24.8	80.0	24.7	4.4	3.3	0.7	65.9	150	192	72.6	10.0
	STD	0.8	0.8	0.8	1.4	0.2	0.3	0.0	2.2	13.4	17	2.0	0.7
AC	mean	23.9	28.7	83.3	29.6	5.7	4.7	0.9	81.5	198	215	70.8	10.7

The remaining 24 corresponded to various varieties of Acala type and had been produced in Sudan in 1996-1997.

Table 3-2: Stickiness data for the raw cottons.

Apparatus	Sample type	AC	R	S
SCT	Mean	0.4	26	26.1
	Max	0.4	52.5	62.8
	Min	0.3	12	7.3
	Std	0.1	13.6	18.2
H2SD	Mean	0.7	27.1	32.1
	Max	0.8	42.3	61.2
	Min	0.5	9.3	13.1
	Std	0.2	11.8	16.2

Once each of the 26 bales had been characterized, the cotton was processed by industrial-scale carded spinning. The spinning facility was composed of two rooms with independent conditioning: a preparation room and a spinning room. The cotton fiber was processed successively by the following machines:

– Bale breaker (LAROCHE)
– Opener-cleaner (TRÜTZSCHLER RN)
– Opener-mixer (TRÜTZSCHLER RSK)
– Card (TRÜTZSCHLER DK 715)
– Drawing frame (RIETER D1/1)
– Roving frame (RIETER F1/1a)
– Ring spinning frame (SACM CF-6)
– Rotor spinning frame (SCHLAFHORST SE-9)
– Winder

3.1.2.3. Conditions and operating procedure

The order in which the bales were processed was randomized to avoid any bias in the interpretation of the results. Before actually starting the processing, the bale was homogenized by recycling between the RN opener and the LAROCHE breaker. This reduced the natural variability within each bale and thus improved the precision of the relationships between stickiness and spinning incidents. Then, the bale entered production at a temperature of 25 ± 2°C and a relative humidity of 47.5 ± 2.5%. These hygrometric conditions correspond to those generally recommended for preparation. The sliver and roving were then transferred to the spinning room where atmospheric conditions consisted of a temperature of 25 ± 2°C and a relative humidity of 57.5 ± 2.5%.

During the spinning of each bale, the number of breaks, fiber wraps and stoppages for cleaning were recorded for each machine used. These incidents were then listed with respect to the part of the machine where they occurred and their cause. Observations were made to deduce the nature and the origin of the incidents to complete these checks and samples.
The processing equipment was cleaned thoroughly after each test to avoid contamination between consecutive tests.
The results were used to calculate the breakage incidence and the efficiency of the different machines. These productivity parameters were then compared with stickiness results determined using three different methods:

- SCT thermodetector measuring the number of sticky points (*SCT*),
- H2SD measuring the number of sticky points (*H2SD*), their total size (*Size-H2SD*) and their size category (*Small*, *Medium* and *Large*),
- HPLC measuring the content of the different sugars: Inositol *(I)*, Trehalose *(T)*, Glucose *(G)*, Fructose *(F)*, Trehalulose *(W)*, Melezitose *(M)* and Sucrose *(S)*.

3.1.3. Results and Discussion

It should be noted that 2 bales (AS15 and AR17) could not be processed under these normal conditions. The results were therefore based on 24 bales. A specific study was conducted on 2 bales in very low relative humidity. The results of this experiment are described in paragraph 3.2.

3.1.3.1. Choice of the best predictor of stickiness problem during spinning

We attempted to define a stickiness indicator based on quantitative determinations. We then compared the three main methods of measuring stickiness (SCT, H2SD, sugars by HPLC) and matched these to productivity and quality criteria. First, the data from these three techniques was analyzed and compared.

3.1.3.2. Relations between SCT, H2SD and HPLC results

Table 3-3 gives the results and the correlation coefficients observed between stickiness and sugar measurements on samples taken at the RSK opener:

- *H2SD*: number of sticky points measured by H2SD (*H2SD* counting);
- *Small*: number of sticky points whose size, measured by H2SD, is in the range [1.7; 9] mm²;
- *Medium:* number of sticky points whose size, measured by H2SD, is in the range [9; 18] mm²;
- *Large:* number of sticky points whose size, measured by H2SD, is larger than > 18 mm²;
- *TMH2SD* : mean size of the sticky points as measured by H2SD;
- *TTH2SD* : total size (sum of the sizes measured by H2SD);
- *SCT:* number of sticky points as measured by SCT (*SCT* counting);
- *I* : percentage of inositol (% of the fiber mass) measured by HPLC;
- *T* : percentage of trehalose (% of the fiber mass) measured by HPLC;
- *G* : percentage of glucose (% of the fiber mass) measured by HPLC;
- *F* : percentage of fructose (% of the fiber mass) measured by HPLC;
- *W* : percentage of trehalulose (% of the fiber mass) measured by HPLC;
- *S* : percentage of saccharose (% of the fiber mass) measured by HPLC;
- *M* : percentage of melezitose (% of the fiber mass) measured by HPLC;
- *Stotal* : total percentage of sugars *I*, *T*, *G*, *F*, *W*, *S* and *M* (% of the fiber mass) .

Table 3-3: Correlation coefficients between H2SD (RSK samples), SCT et HPLC results.

Variables	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT
H2SD	1						
Small	0.991	1					
Medium	0.974	0.961	1				
Large	0.949	0.904	0.910	1			
TMH2SD	0.577	0.503	0.573	0.728	1		
TTH2SD	0.940	0.897	0.910	0.982	0.705	1	
SCT	0.891	0.873	0.836	0.887	0.521	0.892	1
I	NS	NS	NS	NS	0.629	NS	NS
T	NS	NS	NS	NS	NS	NS	NS
G	NS	NS	NS	NS	NS	NS	NS
F	0.533	0.534	0.519	0.487	0.420	0.517	0.589
W	0.754	0.772	0.721	0.672	NS	0.703	0.818
S	0.862	0.872	0.847	0.768	0.429	0.786	0.835
M	0.659	0.677	0.664	0.564	NS	0.590	0.721
Stotal	0.600	0.597	0.608	0.548	0.445	0.584	0.687

Critical R at the 5% level = 0.4044 NS: non significant

We chose the RSK samples because the samples here are more homogeneous and give more precise HPLC measurements.

The results confirmed the significant relationship between H2SD and SCT measurements. These relationship also are significant on raw cotton samples as illustrated by the following equation where the offset is not different from 0 and the slope is almost not different from 1.

$$SCT_{Raw} = 0.99 \times H2SD_{Raw} - 3.16$$

Concerning sugar contents, inositol, trehalose and glucose contents did not correlate with SCT and H2SD results. Fructose was lightly correlated with the number of sticky points. On the other hand, melezitose, trehalulose and mainly saccharose were well correlated with SCT and H2SD measurements. The total percentage of sugars showed a low, but significant, correlation with *SCT* and *H2SD* results.

The correlation coefficients showed comparable trends for the different methods used to measure stickiness . However, the inter-connection between the different variables limited the complementarity of these measurements. Thus, we will probably have to choose only one criterion to measure stickiness and predict its effect during spinning.

3.1.3.3. What is the actual best indicator ?

By best indicator, we mean the measurement that gives the best correlation coefficient with the disruptions observed during spinning, for both productivity and quality parameters.

Efficiencies and breakages and quality parameters were matched to the stickiness determination performed on RSK samples. The fibers are well mixed at this point and these samples are therefore representative of the raw material with low variability of the stickiness within the fibers. This can be observed in Table 3-4 where the dispersion indexes (ratio of the variance to the mean) are reported for each step in the process where samples can be taken for stickiness measurements. The best place to get samples for both measuring devices is the RSK opener-mixer.

Table 3-4: Over-dispersion index of the SCT and H2SD number of sticky points at different operating levels.

	SCT	H2SD
Raw cotton	3.01	4.40
Laroche Opener	2.11	2.71
RN Opener Cleaner	2.27	2.13
RSK Opener mixer	1.75	1.93
Card sliver	2.44	1.20

Correlation coefficients between stickiness measurements and productivity parameters are given in Table 3-5. Correlation coefficients between stickiness measurement and quality parameters are given in Table 3-6.

The correlation coefficients show that the number of sticky points measured by SCT, the number measured by H2SD and the percentage of melezitose, trehalulose and saccharose are correlated with most of the productivity parameters in the spinning mill. Concerning the sticky point sizes, the 3 classes (small, medium and large) and the total size of the sticky points (*TTH2SD*) show a comparable to the number of sticky points measured by *H2SD*. On the other hand, the average *TMH2SD* size was rarely significantly linked to spinning parameters.

The total amount of sugar (Stotal, expressed in percent of the fiber sample) was distributed for the cottons used in this experiment as illustrated by Figure 3-1. The darker bars corresponds to the cotton considered as non sticky from Central Asia.

All cottons in this project contained Melezitoze and Trehalulose. This indicates that these cottons were contaminated by whiteflies at least, and maybe by *Aphids* + whiteflies. Only one bale was possibly contaminated by *Aphids* alone. Thus, conclusion cannot be drawn about the type of infestation solely from the sugar contents, without any information available from the field. It should be noted that physiological sugars may disappear over time (Hequet, 1999).

A comparison of the number of H2SD sticky points with the melezitose and trehalulose contents underlined the advantages of the H2SD readings. Indeed, the best correlation coefficients to productivity and quality parameters were obtained with H2SD. Correlation coefficients with melezitose and trehalulose contents were rarely higher than with the H2SD count, and these sugars did not correlate to all the parameters that correlated with H2SD

As far as disruptions during spinning are concerned, the HPLC results did not provide any supplementary information beyond that furnished by the H2SD and SCT counts. In view of the time and cost of the HPLC and SCT analysis, H2SD seems to be the most appropriate method for measuring stickiness in our research.

3.1.3.4. Contribution of sticky point sizes in the expression of stickiness during spinning

Based on the assumption that a large sticky point will not induce the same disruption as a small point, the sticky point were divided into 3 categories (small, medium and large). We have already observed that this classification of the sticky points according to size does not provide any helpful information in explaining the problems encountered during the spinning operations. To improve the quality of the predictive models, we tried to use the individual sizes of sticky points to explain the problems encountered during the spinning operations.

To conclude, the fact that we did not succeed in using the individual sticky point size in the definition of the best stickiness predictor does not mean that this variable has no effect on the spinning process. In fact, if the H2SD image analysis principle is considered carefully, the measured size does not always correspond to the real size on the aluminum foil. Indeed, the measurement is an apparent size estimation due to scattered illumination of the fibers and the sugars that stay on the aluminum foil. This induces an over-estimation of the size of the sticky points. Thus, the evaluation of the smallest sticky points is biased. Some research is currently ongoing outside this project so that future measurements are more accurate and this could modify all the conclusions drawn here.

3.1.4. Conclusions

3.1.4.1. Effect on productivity

The performance of spinning machines is dependent upon the stickiness of the cotton starting material they use. In this study, machine performance decreased when sticky cottons were processed under the hygrometric conditions generally recommended, i.e. 45 to 50% RH during opening and carding, and 55 to 60% RH during spinning. The effects of the stickiness on machine productivity were quantified. The results of the regressions showed that the number of sticky points determined by H2SD is a more reliable predictor of stickiness effects than the SCT count or the sugar content measured by HPLC.

Here, although the SCT count correlates with productivity parameters, the correlation coefficients obtained with H2SD are even better. As far as the sugar contents are concerned, not all correlated with the breakage incidence and machines efficiency. In fact, only trehalulose, melezitose and sucrose could be correlated with these two parameters, but not for all the machines, and here, when a correlation was detected, this was generally no better than that obtained with the H2SD sticky points count.

The blocking threshold for the spinning of sticky cottons under the relative humidity conditions described above was about 50 H2SD sticky points. The spinning process is blocked at the card when the count exceeds this value. In addition, stickiness affects the machines and seriously reduces productivity well below this blocking limit. The roving frame is the most sensitive to stickiness.

The relative humidity appears to be of prime importance. The very sticky bales (50 H2SD sticky points) that initially required machine stoppage were subsequently processed successfully at 40% relative humidity. However, the breakage rate even under these conditions was prohibitively high and machine efficiency was very low. A study to evaluate the effects of stickiness at different relative humidity values is presented in paragraph 3.5. Some results were also presented in paragraph 3.2.

3.1.4.2. Effect on quality

This study concerning the carded spinning of sticky cottons showed that stickiness has effects both on the productivity and the quality of industrial spinning under the temperature and relative humidity conditions usually recommended. Here, the cotton was prepared and carded at 25 °C and 47.5% RH and was spun at 25 °C and 57.5% RH. These conditions were maintained within ± 2 °C and ± 2.5% relative humidity throughout the study.

Although card and drawing frame productivity was reduced by stickiness, this stickiness had no effect on sliver quality at this point. It was only from the roving frame onward that a stickiness-induced decrease in regularity was observed. The CV% of the roving mass was slightly higher, thus increasing the irregularity of the yarn on the ring-spinning frame.

When considering the actual spinning, the quality of ring-spun yarn was more susceptible to stickiness than that of rotor-spun yarn. Monitoring of regularity, imperfections and tensile properties clearly highlighted this difference between the two processes where the CV% of mass, number of thin places, number of thick places and number of neps in the ring-spun yarn increased significantly with the number of H2SD sticky points. The tensile properties of this ring-spun yarn, and particularly its tenacity and work-to-break capacity, decreased as stickiness increased. By contrast, most of the quality characteristics of the rotor-spun yarn were unaffected by cotton stickiness. Thus, the CV% of mass, the number of thin places, the number of thick places and the number of neps were unrelated to cotton stickiness. Only the tenacity and hairiness of the rotor-spun yarn were affected by the stickiness, i.e. a slight decrease in tenacity and a slight increase in hairiness. The same difference between the two types of yarn was also observed for the number of CLASSIMAT® defects.

It has been recognized that relative humidity plays an important role in the effects of stickiness on productivity. By contrast, its impact on the effects of stickiness on yarn quality have not yet been correctly evaluated. A study to evaluate the effects of stickiness at different relative humidity values is presented in paragraph 3.5. However, some results are also presented in paragraph 3.2.

Most of these conclusions are represented in Figure 3-2 to Figure 3-12.

Table 3-5: Correlation coefficients *r* between stickiness measurements and productivity criteria.

Variable	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT	I	T	G	F	W	S	M	Stotal
C-CT100km	0.591	0.578	0.580	0.555	NS	0.532	NS	NS	NS	NS	NS	NS	NS	NS	NS
C-Efficiency	-0.726	-0.735	-0.705	-0.634	NS	-0.677	-0.657	NS	NS	NS	-0.528	-0.738	-0.721	-0.572	-0.603
E1-CT100km	0.786	0.755	0.789	0.774	0.443	0.835	0.812	NS	NS	NS	0.560	0.662	0.764	0.644	0.643
E1-Efficiency	-0.603	-0.585	-0.631	-0.557	NS	-0.578	-0.608	NS	NS	NS	NS	-0.498	-0.580	-0.464	-0.461
E2-CT100km	0.719	0.703	0.680	0.704	NS	0.771	0.851	NS	NS	NS	0.642	0.774	0.750	0.680	0.735
E2-Efficiency	-0.535	-0.519	-0.497	-0.531	-0.442	-0.567	-0.645	NS	NS	NS	-0.508	-0.394	-0.615	-0.452	-0.564
B-CT100km	0.746	0.771	0.659	0.675	NS	0.712	0.757	NS	NS	NS	0.588	0.782	0.754	0.707	0.652
B-Efficiency	-0.763	-0.791	-0.744	-0.638	-0.475	-0.628	-0.638	NS	NS	NS	-0.556	-0.626	-0.768	-0.627	-0.613
CAF-TC1000BH	0.816	0.832	0.749	0.763	NS	0.728	0.755	NS	NS	NS	0.440	0.697	0.746	0.691	0.505
OE- Efficiency	-0.659	-0.671	-0.660	-0.565	NS	-0.529	-0.674	NS	NS	NS	NS	-0.645	-0.585	-0.512	-0.420
OE-Y-P240BH	0.654	0.678	0.689	0.532	NS	0.487	0.476	NS	NS	NS	NS	0.572	0.526	0.463	NS
OE-LR240BH	0.737	0.760	0.711	0.638	NS	0.564	0.710	NS	NS	NS	NS	0.607	0.615	0.612	NS

Risk α	r critical
0.1%	0.6402
1%	0.5256
5%	0.4132

SCT: number of SCT sticky points
H2SD: number of H2SD sticky points
Small: number of sticky points whose size is included between 1.7 and 9 mm²
Medium: number of sticky points whose size is included between 9 and 18 mm²
Large: number of sticky points whose size is larger than 18 mm²
TMH2SD: average size of the H2SD sticky points
TTH2SD: total size of the H2SD sticky points
I: inositol
T: trehalose
G: glucose
F: fructose
W: trehalulose
S: saccharose or sucrose
M: melezitose
Stotal: percentage of total sugars
C-CT100km: total nb. of breaks per 100 km of card sliver
C- Efficiency: card efficiency (efficiency = rendement)
E1-CT100km: total nb. of breaks per 100 km of drawing frame sliver (1° draft)
E1- Efficiency: drawing frame efficiency (1° draft)
E2-CT100km: total nb. of breaks per 100 km of drawing frame sliver (2°draft)
E2- Efficiency: efficiency of the drawing frame (2°draft)
B-CT100km: total nb. of breaks per 100 km on the flyer
B- Efficiency: efficiency of the flyer
CAF-TC1000BH: breakage per 1000 spindles/hour on the ring spinning frame
OE- Efficiency: efficiency of the Open-end machine
OE-Y-P240BH: number of piecings per hour for 240 pen end positions
OE-LR240BH: number of interventions per hour for 240 open end positions.

Table 3-6: Correlation coefficients *r* between stickiness determinations and quality criteria.

Variable	H2SD	Small	Medium	Large	TMH2SD	TTH2SD	SCT	I	T	G	F	W	S	M	Stotal
C-CV%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
E1-CV%	NS	0.420	0.389	0.316	NS	NS	NS	NS	NS	-0.522	NS	NS	NS	NS	NS
E2-CV%	NS	0.144	0.037	0.113	NS	NS	NS	NS	NS	-0.481	NS	NS	NS	NS	NS
B-CV%	0.466	0.469	0.410	0.444	NS	NS	NS	NS	NS	NS	NS	NS	0.506	NS	NS
CAF-UT3-CV%	0.801	0.797	0.776	0.763	0.586	0.748	0.757	NS	NS	NS	NS	0.542	0.779	0.508	NS
CAF-UT3-50%	0.628	0.615	0.625	0.621	0.607	0.597	0.536	NS	NS	NS	NS	NS	0.535	NS	NS
CAF-UT3+50%	0.819	0.815	0.791	0.776	0.523	0.776	0.831	NS	NS	NS	0.504	0.615	0.875	0.680	0.561
CAF-UT3-Neps	0.843	0.861	0.826	0.755	NS	0.757	0.841	NS	NS	NS	0.422	0.730	0.874	0.752	0.512
CAF-Hairiness	0.520	0.537	0.487	0.487	0.515	NS	NS	NS	-0.457	NS	NS	NS	NS	NS	NS
CAF-Elongation	NS	-0.326	-0.260	-0.313	NS	NS	NS	NS	NS	0.413	NS	NS	NS	NS	NS
CAF-Strength	-0.570	-0.560	-0.540	-0.594	-0.619	-0.566	-0.486	NS	NS	NS	NS	NS	NS	NS	NS
CAF-work	-0.462	-0.464	-0.409	-0.469	-0.510	-0.444	NS	NS	NS	NS	NS	NS	NS	NS	NS
OE-UT3-CV%	-0.725	-0.733	-0.728	-0.649	-0.547	-0.623	-0.528	-0.522	0.513	NS	-0.502	-0.592	-0.717	-0.474	-0.534
OE-UT3-50%	-0.794	-0.815	-0.738	-0.706	-0.454	-0.652	-0.623	-0.420	NS	NS	-0.460	-0.595	-0.769	-0.502	-0.462
OE-UT3+50%	-0.710	-0.719	-0.706	-0.633	-0.645	-0.577	-0.542	-0.740	0.651	NS	-0.589	-0.524	-0.660	-0.484	-0.611
OE-UT3-Neps	-0.612	-0.609	-0.601	-0.568	-0.654	-0.518	-0.488	-0.778	0.583	NS	-0.641	-0.423	-0.576	-0.444	-0.630
OE-Hairiness	0.477	0.493	0.467	0.432	0.590	0.425	NS	0.554	-0.563	NS	0.439	NS	0.469	NS	0.415
OE-Elongation	NS	-0.185	-0.189	-0.172	NS	NS	NS	NS	NS	0.428	NS	NS	NS	NS	NS
OE-Strength	-0.549	-0.541	-0.603	-0.514	-0.548	-0.522	-0.443	NS	NS	NS	NS	NS	-0.483	NS	NS
OE-Work	-0.472	-0.464	-0.495	-0.455	-0.478	-0.465	NS	NS	NS	NS	NS	NS	-0.474	NS	NS

C-CV%: CV% mass variation on card sliver
E1-CV%: CV% mass variation on 1st draft drawing frame
E2-CV%: CV% mass variation on 2nd draft drawing frame
B-CV%: CV% mass variation on flyer yarn
CAF-UT3-CV%: CV% mass variation on ring spun yarn
CAF-UT3-50%: Nb of thin places per km of ring spun yarn
CAF-UT3+50%: Nb of thick places per km of ring spun yarn
CAF-UT3-Neps: Nb of neps on km of ring spun yarn
CAF-Hairiness: Hairiness of the ring spun yarn
CAF-Elongation: Elongation of the ring spun yarn
CAF-Strength: Strength (=strength, cN/tex) of the ring spun yarn
CAF-Work: Work to break (N.cm) of RS yarn
OE-UT3-CV%: CV% mass variation of the OE yarn
OE-UT3-50%: Nb of thin places per km of OE yarn
OE-UT3+50%: Nb of thick places per km of OE yarn
OE-UT3-Neps: Nb of neps per km of OE yarn
OE-Hairiness: Hairiness of OE yarn
OE-Elongation: Elongation (%) of OE yarn
OE-Strength: Strength (cN/tex) of OE yarn
OE-Work: Work to break (N.cm) of OE yarn

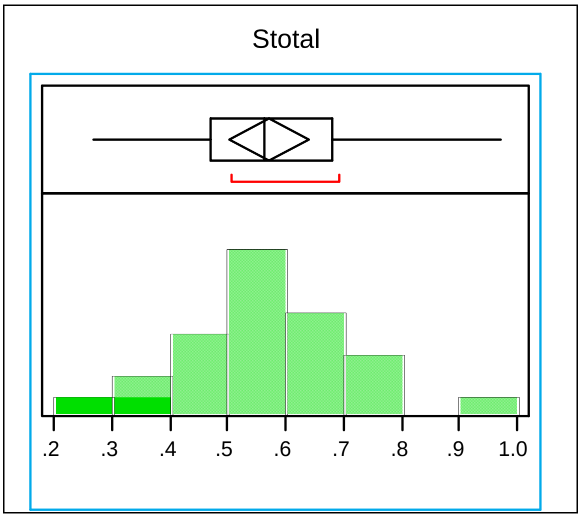

Figure 3-1: Total sugar (%w/w) distribution for all cottons.

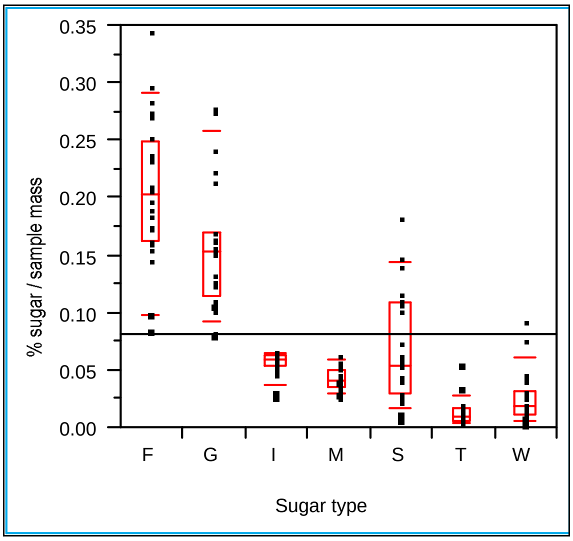

Figure 3-2: Repartition of the sugar types (%w/sample weight).

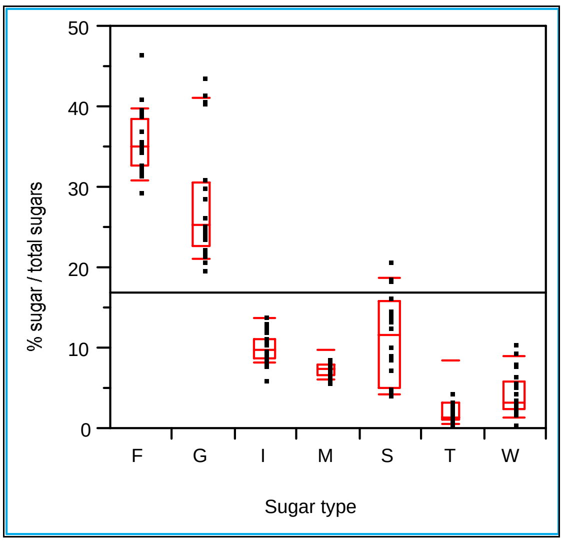

Figure 3-3: Sugar repartition in proportion of total sugars, without Central Asia cottons.

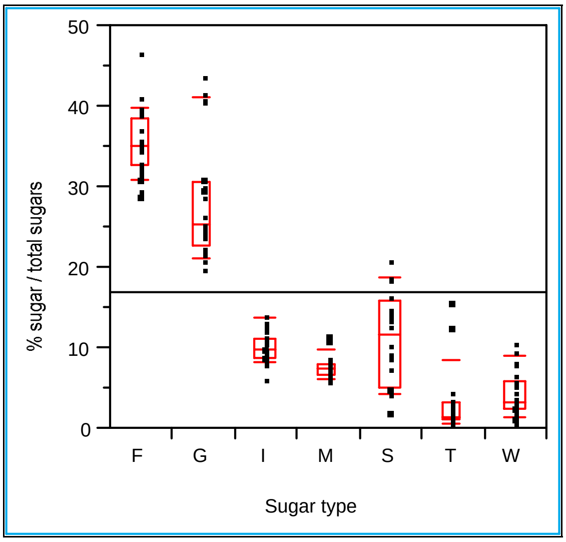

Figure 3-4: Sugar repartition in proportion of total sugars, with Central Asia cottons.

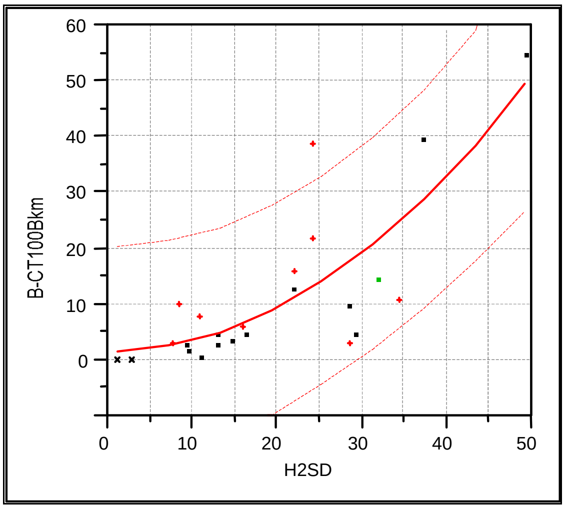

Figure 3-5: Total number of breakage per 100 km of roving material at the flyer vs H2SD.

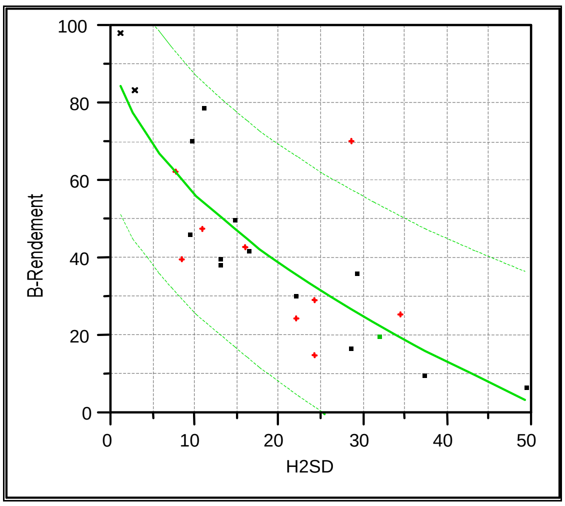

Figure 3-6: Flyer efficiency vs H2SD.

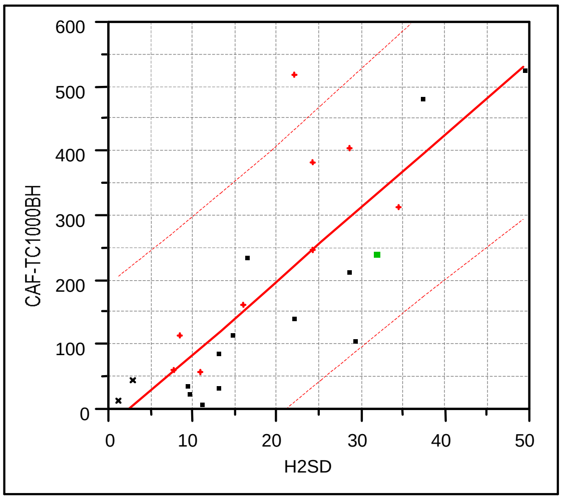

Figure 3-7: Ring spinning frame breakage ratio per 1 000 spindles/hour vs H2SD.

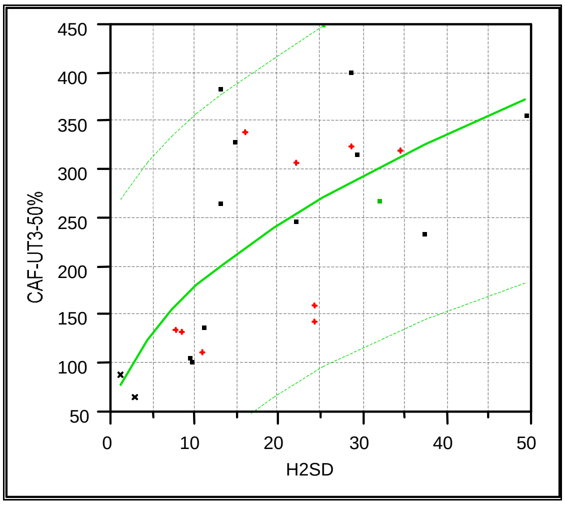

Figure 3-10: Number of thin places (50%) per km of RS yarn vs H2SD.

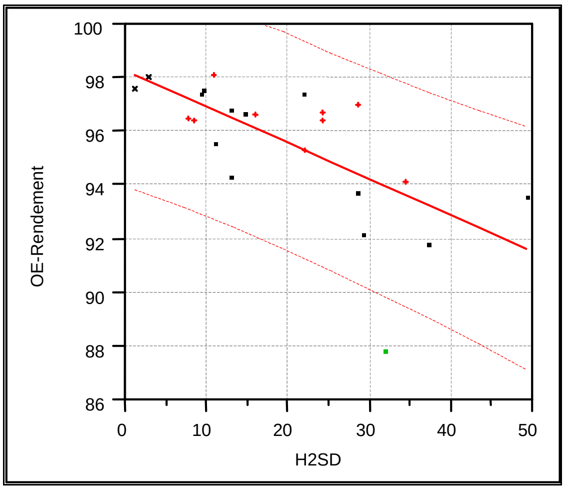

Figure 3-8: Open-end efficiency vs H2SD.

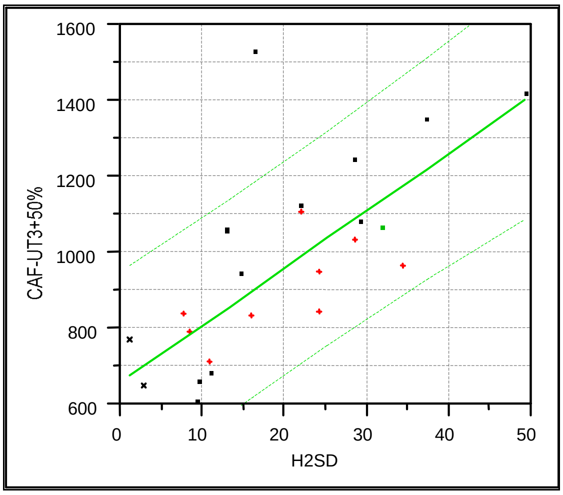

Figure 3-11: Number of thick places (+ 50%) per km of RS yarn vs H2SD.

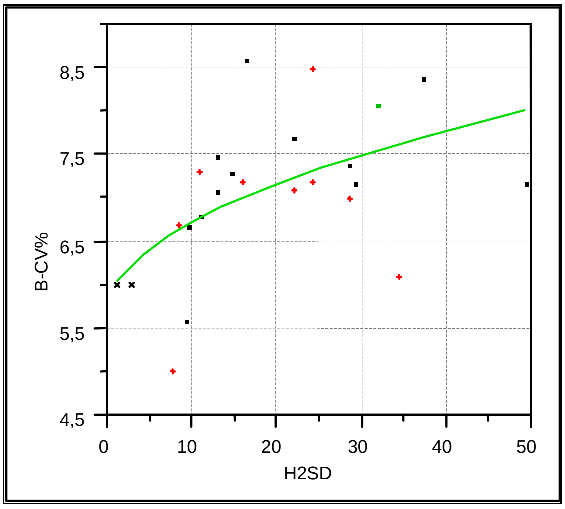

Figure 3-9: Mean mass CV% of the flyer fleece vs H2SD.

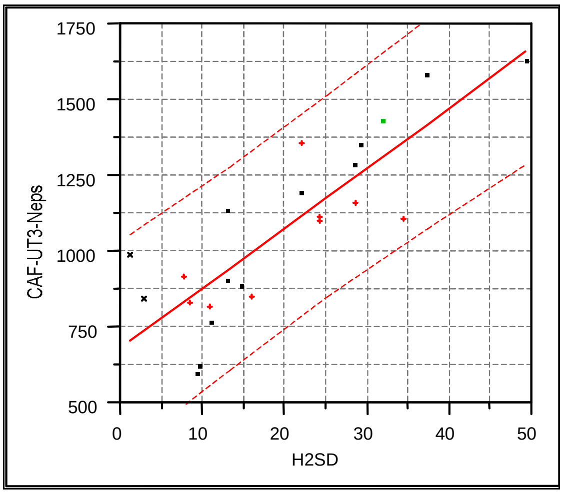

Figure 3-12: Number of neps per km of RS yarn vs H2SD.

3.2. Specific experiment at low relative humidity in ITF

To try to transform into yarn some bales with a high stickiness level, they were processed through the same industrial frame and settings as the previous experiment, but under lower relative humidity conditions (RH, 38.5 ± 2.5%).
The acquired results show that decreasing the relative humidity allows the processing of sticky cottons. At each step, from the card to the ring spinning, the effects of a lower RH are observed on the number of breaks, on the productivity of the process and on the quality of the yarn.
These results are conclusive but need to be confirmed on an extended range of cotton under different humidity conditions (see paragraph 3.5).

3.3. Stickiness effect on the combing process

3.3.1. Objective

This experiment was designed to evaluate the effect of stickiness under specific production conditions used to obtain finer yarn in the combing process.

3.3.2. Materials and methods

The Barakat variety used in our experiments did not show a wide range of stickiness levels. Thus, only a few bales showed more than 10 SCT sticky points (on raw cottons). Therefore, the effect of stickiness on the combed process cannot be evaluated quantitatively.
We therefore decided to conduct this experiment on only 5 bales (quality parameters given in Table 3-7) to obtain a descriptive study of the effect of stickiness.

Table 3-7: Quality results for Barakat cottons

Bale	Ginning*	ML Mm	UHML Mm	UI%	Strength g/tex	Elong. %	IM	MR	PM %	H mtex	HS mtex	Rd %	+B
BR12	R	28.3	33.8	83.8	36.1	6.3	3.5	0.83	73.8	150	181	68.0	12.7
BR07	R	28..4	33.6	84.5	35.7	6.2	3.6	0.84	75.0	154	183	70.7	12.3
BR16	R	28.9	34.2	84.6	37.0	6.5	3.4	0.83	73.5	147	178	69.0	12.6
BR03	R	29.6	34.8	85.1	38.6	6.8	3.7	0.85	75.5	158	186	67.9	13.1
BR14	R	27.5	33.1	83.1	34.7	6.0	3.2	0.78	69.4	141	181	68.8	13.0

3.3.2.1. Steps in the test

The same operations as for carding were retained for the blowing room and card tests (Figure 3-13).
After these cleaning operations, the material was processed to form slivers in the DK 715 card. The slivers then went across the D1/1 drawing frame. Cans of slivers were then transferred for a combing process in the ‘Caulliez Frères’ spinning mill.
The sliver was prepared for combing on a sliver lap machine with 3 heads. The obtained fleeces then fed the E7/5 combing machine.
After this operation, slivers went on the 2° draft D1/1 of auto-regulated drawing frame, and were transformed in flyer yarn on F1/1a flyer. The material was then used to prepare 16.7 tex yarn on a ring spinning frame (100 positions).

3.3.2.2. Hygrometric conditions

These experiments were performed in 3 separate workshops. Preparation to carding operations were conducted at ITF (same conditions as for the carded process tests), then combing was performed in ‘Caulliez frères’ mills (hygroscopic conditions were kept identical to those used in the mill), and spinning was performed at ITF. To summarize:
Preparation and carding: 45 to 50% relative humidity and 23 to 27 °C
Combing: 40 to 45% relative humidity and 26 to 30 °C
Spinning: 55 to 60% relative humidity and 23 to 27 °C.

3.3.2.3. Sampling, problem records and planned analysis

The same procedures as in the carded process tests were used for the preparation and carding operations. During the combing operation, samples were taken from the fleeces at the sliver lap machine level, from slivers and combing noils at the combing machine. The same procedure as for the carded process tests was followed for spinning.
All breaks, incidents, cleanings were recorded in the same manner as for the carded process experiments for the corresponding machines, and new recording forms were designed to record events at the combing operation taking care of the specificities of these equipment.
All the samples collected were analyzed in the same way as for the carded process experiment, to which were added tests on samples collected at the combing level using SCT and H2SD measurements to trace stickiness in their products.

Figure 3-13 : Operation steps in the combed spinning tests.

3.3.3. Results and discussion

3.3.3.1. Evolution of stickiness along the process

In the same manner as for the carded process experiments, the number of sticky points remained constant from the bale to the combing machine sliver. At this point, the number of sticky points decreased because the comb removes some sticky points that are then transferred to the combing noils.

3.3.3.2. At the card level

A moderate effect occurs during the carding of the Barakat bales at the card level. These results are comparable to those obtained in the carded process for bales with a comparable level of stickiness. This could be different with more sticky bales.

3.3.3.3. First draft, drawing frame

Breakage were at the same level as Acala cottons processed in the carded process, i.e. bales with a similar level of stickiness. On the other hand, efficiencies are substantially lower than those noted in the carded process. This is due to the large number of machine stoppages during feeding. Indeed, a doubling of 36 at the sliver lap machine requires a large number of cans compared to the one required in the carded process. Thus the efficiency ratios are more affected by these feeding times than by stickiness.

3.3.3.4. Sliver lap machine

Except for one bale with low stickiness level, all bales suffered from a high number of breaks at the drafting zone level, most often accompanied by rolling up on the cylinders. This explains the relative efficiency decreases compared to bale BR14 (80%).
This operation seems to be very sensitive to stickiness which decreases machine efficiency, even if the stickiness level of the fiber is low.

3.3.3.5. Combing machine

The number of breaks is higher at the comb level than elsewhere. The fibers are almost treated one per one at this step in the operation. This implies maximum contact between the fibers and the metallic parts of the machine (mainly the combs). This induces low efficiency numbers for the most difficult bales (73% efficiency down to around 40%).

3.3.3.6. Drawing frame: 2° draft

Except for one bale, which showed a large number of breaks at the creel level unrelated to stickiness, breakage were at the same level as in the carded process for the same level of stickiness.

3.3.3.7. At the flyer level

The flyer seems to be unaffected by stickiness. Indeed, the number of breaks and the efficiencies were comparable to those obtained in the carded spinning of non-sticky cottons.

3.3.3.8. Ring spinning frame

Breakage were at the same level as for the carded process at equivalent stickiness levels. These levels are acceptable and often met in spinning mills. Please note that, since the stickiness range here was rather restricted, the true measure of the effects of stickiness were not fully expressed during the spinning operation.

3.3.4. Conclusion for the combing process

Low levels of stickiness do not substantially disrupt the machines used in the carded process (card, drawing frame, flyer and ring spinning frame), but are difficult to transform at the sliver lap machine and the combing machine, these machine being used in somewhat low relative humidity conditions.
The range of stickiness for the bales we studied is not wide enough to precisely define relations between stickiness and the quality and productivity parameters in the combed process. However, a few points of stickiness will make the difference in the combing operations.
Some information already were already discussed concerning the effect of the size of the sticky points.

3.4. Properties of H2SD measurements: proportionality between percentage of sticky cotton and H2SD results, drift over time and independence of successive measurements

3.4.1. Objective

The number of sticky points as measured by H2SD is a density measurement of the sticky points within the sample. The thermodetection principle requires and assumes sufficient cleaning of the card clothing between each sample and the next, without which a contamination effect may be suspected: remaining sticky fibers would contaminate the next sample and increase its count: measurements are no longer independent.
Furthermore, some sticky points next to others may be grouped by the image analysis software and appear as only one sticky point. This problem has a greater chance of appearing when the density of sticky points increases, and a saturation effect may occur with heavily contaminated cottons. It was considered important to check whether this saturation was of practical importance. If it is negligible, the number of sticky points as counted by H2SD is proportional to their density in the sample.
Thus a mix in proportions a and b ($a + b = 1$) of cottons with stickiness potentials X and Y (H2SD readings) should give a cotton mix with a stickiness potential of $aX + bY$: the measurement is linear.
Then, as thermodetection is based on a combination of heat and humidity, it is important to determine the stability of the measurement over time under normal conditions in a fiber laboratory. We attempted to check these three properties: independence, absence of drift and linearity on a complete set of samples with a wide range of stickiness levels.

3.4.2. Conclusion

The over-dispersion observed in this experiment seems to be in contradiction with the binomial negative distribution observed with H2SD (Tamime et al, 1999). Indeed, for the binomial negative law, the over-dispersion is not constant, but increases with the mean. However, the negative binomial distribution is observed between the different layers of a bale (227 kg), whereas the less dispersed distribution is observed within a fiber sample of 1 kg, thoroughly mixed by the Cirad laboratory opener.
The existence of a slight drift induces a need for a periodical check or calibration of the H2SD using reference cottons of known stickiness. The quality of the mix for these reference cottons is essential to obtain homogeneous reference cottons.
The measurement is not subject to saturation up to 40 sticky points. If the goal is to classify stickiness into 2 classes (sticky or not), the threshold would be anyway far lower than 40 sticky points, and there is no need to envisage corrections.
By contrast, if the stickiness potential of highly contaminated cottons needs to be evaluated, an extra experiment would be necessary with a range of highly sticky cottons, to specify the observed non-linearity.
To sum up, the stickiness of a binary mix can be tabulated as a function of H2SD data on individual cottons and their percentage in the mix. It would be necessary to check the effect of stickiness from that binary mix onto the spinning process and yarn quality, and match the conclusion to that obtained in the industrial spinning experiment.
In conclusion, these results confirm that mixing cottons with different stickiness potentials is an appropriate solution to decrease the stickiness level of the mix, and this should reduce disruption during spinning.

3.5. Effects of relative humidity on the spinning process and yarn quality

3.5.1. Objective

It is possible, through measurement of the stickiness of raw cotton, to predict the disruption that may occur during spinning. Now, this experiment is designed to answer the question: what is the effect of relative humidity on the spinning process and the quality of the yarn ?

3.5.2. Materials and methods

Seven cottons were selected from the 24 cottons spun at ITF during the industrial spinning study to cover a range of stickiness. These cottons were obtained from the Laroche mix. One spinning test was performed for each cotton with two types of spinning – open-end or rotor spinning (OE) and ring spinning (RS) in three relative humidity conditions (40, 45, 55%).
For industrial carded varieties of cotton, the procedure is as follows: first opening and blending of cotton, then carding, condensation of the web in a sliver, drawing steps, flyer and spinning. As far as the micro-spinning is concerned, the previous procedure was adapted in line with the quantity of the cotton fibers to be spun (Frydrych and Dréan, 2000).
The organization of this experiment is displayed in Figure 3-14 and discussed hereafter.
Cirad uses Platt micro-spinning equipment which consists of a mini-card, a drawing frame and an eight-spindles spinning frame with double drawing, as well as six Suessen open-end rotors.
The randomization designed to work at 45% humidity first, then at 55%, and finally at 40% RH. Within each humidity experiment, the order to spin the seven cottons was randomly organized.
After a mixing of the samples, stickiness level was evaluated during the carding according to 4 grades. The evaluation time was up to rolling-up while recording the time required to get them. Then, in case of sticky cottons, after 3 rolling up, the cotton was considered as highly sticky, and the upper cylinder of the card was removed to continue the carding process of the remaining cotton sample.
At the drawing frame level, all the incidents, interventions concerning the rolling-up were noted.
For ring spinning, observations made during spinning, and mainly at the back drawing of the spinning concerned:

- spinning disruptions or breakages (induced or not by stickiness);
- presence or absence of sticky points deposited on the back draught roller (in some case, we also noted deposits on the front roller) causing the fiber to wrap around the roller;
- manual interventions or cleanings to prevent spinning from being interrupted.

For open-end spinning, observations made during the spinning concern:

- number of spinning disruptions or yarn breakages (induced or not by stickiness);
- number of rotor cleanings.

The Evenness tester UT3 and Tensorapid were used to measure the quality criterias on the yarn that were produced. A detailed neps analysis was performed on both RS and OE yarns to bring more information about the type of neps in the yarns.

3.5.3. Results and discussion

3.5.3.1. Effect on the spinning process

At the card level , a significant effect of stickiness was detected on the rolling-up when RH was 45% RH, while no trend was noted at 55%RH since it appeared to bring immediate troubles for any cotton stickiness level. None of the cottons caused disruption at 40%RH. A saturation effect was noted in the number of rolling-up at 55%RH because the operating procedure employed did not record any rolling-up after the third occurrence. It should be noted that these results take account of the accumulation of stickiness phenomenon occurring for a complete set of 10 fleeces except when more than 3 rollings-up occurred. As far as time till onset of rolling-up is concerned, the highest relative humidity levels

(45 and 55% RH) were seen to have a significant effect, as illustrated in figure C-67. Any rolling-up at 40% occurred after a very long time.
At the drawing frame level, a significant relation was noted between the number of rollings-up and the stickiness level at 55%RH.
At the OE spinning level, a trend was noted between breakages and stickiness for the highest RH, while no significant relation was found concerning the cleaning of the machinery.
At the Ring Spinning frame level, at 40%RH, almost no cleaning was required to maintain production, whatever the stickiness level of the raw cotton. At 45 and 55% RH, cleaning was required to maintain yarn production.

3.5.3.2. Effect on yarn quality

Quality of Ring Spun yarns:

As stated in many publications, yarn quality is dependent upon fiber quality. In this study, stickiness had difference effects on yarn quality depending on the relative humidity in the spinning room. However, since most of the cottons used in the study were of similar quality, most of the effects observed were considered to be due to stickiness. Nevertheless, care should be taken when considering the results and a check should be performed to verify whether the effect is due to stickiness or fiber quality parameters.
Relative humidity had a critical effect on most yarn quality characteristics, and in particular by a change in the evenness counting for irregularities.
A significant increase in Thin places exists in the RS yarn spun using cottons with a low stickiness level. For all humidity levels, the number of thin places showed a similar trend toward saturation when stickiness exceeded 20 sticky points. However, it was noted that more thin places occured at lower humidities compared to other conditions.
Only a significant relationship exists between the number of thick places dotted against RH% and stickiness. The only significant relationship was noted at 55% RH between the number of thick places and stickiness.
A significant effect of RH and stickiness had significant impact on the number of neps (200%) in the yarn. However, a significant interaction induced a greater sensitivity to stickiness at higher humidity. It was also observed that the number of neps was higher when slightly sticky cotton was spun at 40% RH compared to the results when the same cotton was spun in 45 and 55% RH.
A significant relationship was noted between yarn strength and stickiness at 40%RH, even though the pattern at other humidities was similar. This trend can be explained by the fact that stickiness induces irregularities that creates weak points in the yarn (as well as seed coat fragments, Krifa, 2001). This can be proven by counting the seed coat fragments present in the card fleeces, where both counts (on yarn and on card fleeces) follow the same trend.
Our interventions were made during the production to allow a yarn production, but they also indirectly improved the final yarn quality. Thus, the yarn quality results in this experiment were not only dependant on stickiness and RH% conditions: the number of cleaning/interventions was taken in account in our analysis. This assumption can be proven by looking at the relationships between the main criteria (such as the number of thin and thick places and yarn strength) and stickiness: when few interventions are required to spin (non sticky cottons), we observe significant relations between the 'yarn quality criteria' and stickiness; as soon as the number of interventions increases, the relation between 'yarn quality criteria' and stickiness becomes non-significant and a saturation effect occurs.

Quality of Open End spun yarns:

A significant relationship was noted at 55%RH on OE yarn. A significant relationship was found between the number of thick places and stickiness at 55%RH, while no significant relationship was noted in other RH conditions.
A significant relationship was noted between the number of neps places and stickiness at 55%RH, while no significant relationship existed for other RH conditions. The detailed analysis of the neps present in the yarn provided more information concerning the type of neps that had increased. Both

fiber neps and sticky neps contribute to the increase of the total number of neps in the OE yarn. It should be mentioned that the number of neps also increased significantly with stickiness at 40%RH condition but to a lesser extent.
Stickiness induced an increasing number of irregularities in the for OE yarns and RS yarn causing an increase in the number of weak points, which decreased yarn strength.

3.5.4. Conclusion

As proven in the real-scale experiment, stickiness affects both productivity and quality parameters. Thus, stickiness increases the number of cleanings and interventions during spinning.
The data collected during this experiment also provide new information about the effect of ambient conditions on yarn production. Stickiness increases the number of human intervention, especially when spinning is conducted at high relative humidities. During this experiment, our interventions were designed to allow yarn production to continue, and thus affected some yarn quality parameters. Trends were nevertheless noted for most of the parameters vs stickiness. The slopes of these relations are clearly affected by ambient conditions during spinning.
As a global conclusion, spinning under low humidity conditions will avoid most of the problem induced by stickiness, even if some yarn quality parameters are affected by such conditions.

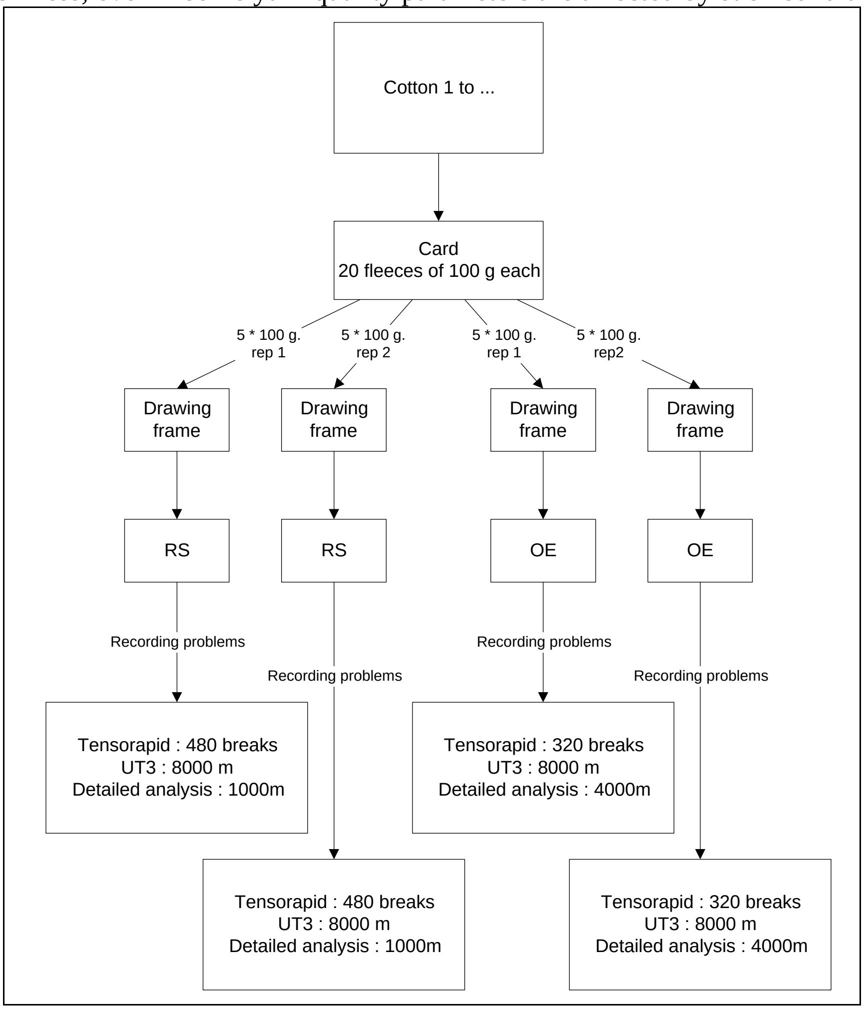

Figure 3-14: Organization of the test from the raw cotton up to the yarn testing.

3.6. General conclusion for component B

Component B was designed to evaluate the impact of stickiness on spinning productivity and quality parameters. The hope was to highlight a stickiness limit below which only manageable problems would occur during spinning while above it spinners would encounter real problems that could lead to financial losses. The intention was to use this 'spinning limit' as an evaluation threshold to fix rules in the commercial trading of cotton. Here the results from component A: the cotton producers being able to fix his own litigation risk as deduced from the within-bale and within lot variability, it would have been possible to fix the classification threshold to be respected in the classing offices.
From component A, we learned that it is difficult to derive a statistical law to match the data observed for all cotton produced in Sudan.
An industrial spinning test confirmed that stickiness induces disruption during spinning and leads to both productivity and quality losses. In general, this was already well known. However, we did expect to encounter a flat zone, even if a low degree of stickiness is present in the fibers, no significant disruption would occur. This is illustrated in Figure 3-15. Then, above a given stickiness limit, which could serve as evaluation threshold, increasing problems would appear as stickiness increased.

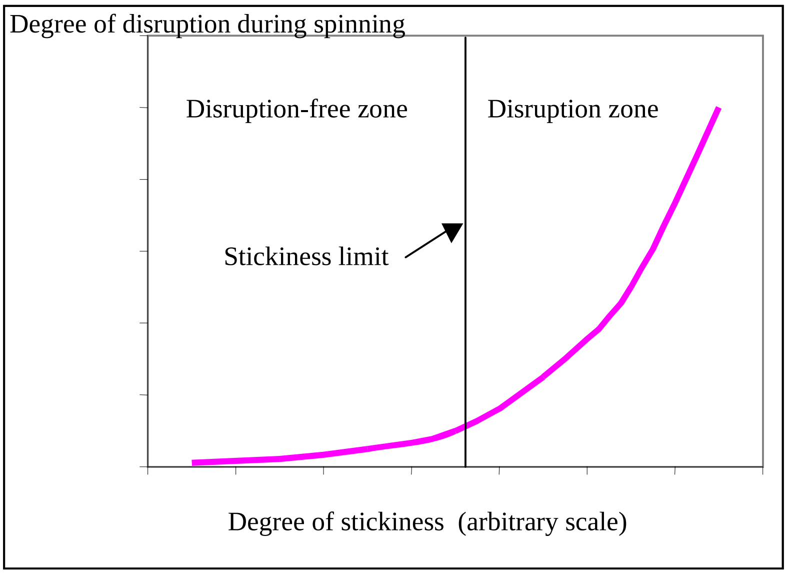

Figure 3-15: Problem vs stickiness expected relation.

From a practical standpoint, it was first necessary to find the best estimator of stickiness. This was done by taking account of the principle, the precision, the cost and the time consumption of the measuring method available in this project. Three methods, SCT, HPLC and H2SD were compared for their ability to predict problems during spinning both in terms of productivity and yarn quality.
The H2SD measuring device was retained because its results correlate more closely with all quality and productivity parameters. However, it should be noted that some sugar contents as measured by HPLC also correlated well with some parameters since they are directly related to the sugars that cause specific problems during spinning. SCT was not chosen, even if some relations are shown in this report, since a substantial operator effect was possible on the reading as seen in 'Component a' of this project.
After classification of the sticky points into size classes corresponding to "small", "medium" and "large" on H2SD, these experiments did not show any significant trend with the criteria recorded. This does not mean that this variable has no effect on the spinning process. Further development work is ongoing to improve the H2SD's image analysis system so that the measured size will be closer to that actuelly in the cottons. A more accurate measure of sticky point size might mean that all the conclusion of this research work would have to be revised. Indeed, it is probable that a change in sticky point size distributions may appear, and that this change may affect the existing relations with the spinning process. In this case, it may be possible that the different sticky point size classes will explain specific productivity or quality problems in the spinning mill.

The conclusions drawn in this document are highly dependent on the testing conditions of industrial scale experiments. Thus, the type of machines, their brand (assuming specific know-how by each textile machinery manufacturer), their settings, the ambient conditions, the type of work (extensive or intensive labor), the automation level, … can all play important roles in the way stickiness affects their operation, and therefore in the relations that have been described.

NB: **Any deductions made from the graphs given in this report, are only representative of our test conditions on specific samples.**

From the industrial scale experiment and its specific, restricted operating conditions, we learned that, as expected, the flat disruption free zone may exist for some quality and productivity parameters. However, its range may vary in width on the stickiness scale as measured by H2SD. This means that some productivity and quality parameters may be affected at low stickiness levels, while other parameters will not be as sensitive to a change in stickiness.

A specific stickiness level was found at the card where the fibers are cleaned almost individually. Here, the effects of stickiness were most marked and rendered impossible the carding of highly contaminated cottons.

This research cannot result in setting a critical threshold for worldwide spinning since the machine used are so different that some countries are specialized in processing heavily contaminated cottons, while other do not accept even traces of stickiness among the processed fibers.

Thus, if a classification procedure is implemented, classification threshold(s) will have to be set for every customer at a level that depends on his ability to process fibers of a given stickiness. This would be described in some kind of agreement between two parties. The organization of such a classification will lead to changes in the way bales are grouped according to homogeneous stickiness level.

Complementary experiments based on changes in relative humidities (RH) indicated possible solutions to combat stickiness. These experiments showed that productivity parameters improved by lowering the relative humidity level and some quality parameters were also improved or stabilized compared to the normal conditions met in the spinning mills. A clear effect of RH and stickiness on the micro-spinning process was observed as expected. An increasing first effect is observed on some productivity parameters for both ring and open-end micro-spinning when ambient conditions are becoming more humid in the spinning laboratory. It also exists an increasing effect of stickiness on yarn quality parameters which goes in the direction of worse quality for almost well-known parameters.

Since it is difficult to choose a range of cotton that differ only by their stickiness level, fiber quality parameters may interact with the conclusions drawn in this experiment. However, fiber quality was fairly homogeneous and most of the effects observed in this study can therefore be considered as mainly dependent on stickiness and the ambient conditions.

Yarn production sometimes required human interventions which had consequences on yarn quality. This is why we observed some saturation effects in the relationships between stickiness characteristics and RH conditions.

Neps numbers increased with stickiness and relative humidity as shown by the evenness tester that separated the different categories of neps: this increase was mainly induced by the creation of sticky and fiber neps in the yarn.

Mixing a sticky cotton with a non-sticky cotton is an appropriate method to decrease the stickiness level of the mix. A simple formula was derived from the data. However, this formula is limited since it is no longer predictive when stickiness becomes high. Two questions remain unsolved:

- large sticky points can be split into different smaller parts during the mixing operations: do these smaller points have the same behavior as ‘natural’ small points in terms of consequences on the spinning process ?
- is this formula valid for more than 2 constituents in the mix ?

This experiment was based on relatively small amounts of fibers which, after the mixing operation, showed comparable sticky points distributions (dispersion index 1.7) to that observed in industry (dispersion index 1.9).

It is essential to take this information into account when preparing cottons with a range of stickiness levels to check and/or calibrate the measuring devices. The mixing operation is increasingly difficult when cottons with low stickiness levels are mixed with a non-sticky cotton.

To sum up, it is now possible to relate the results from the two first components of this project. Methodologies were developed to evaluate the within-bale variability of stickiness, then evaluate, if

conditions remain stable, the number of samples taken per bale and the number of readings required on the measuring devices.
Next, statistical methodology was described to establish thresholds to categorize bales in different lots according to their stickiness level. In this report, the methodology was applied to 2 category classification for the separation of sticky cottons from non-sticky cottons. The method can also be applied to form more than 2 stickiness classes.
From the spinning experiment, we learned that no typical, single threshold can be set since each mill in the world has its own typical machinery and/or knowledge and/or economical conditions that enable some to process heavily contaminated fibers while others cannot.
In conclusion, classification thresholds can only be defined between producers and users in accordance with negociated agreements where the most important classification procedure steps can be discussed depending on the price of the material, the classification, etc … with respect to standards (meaning: documented methods). This approach complies with the fact that all standards mention that if test conditions differ from the recommended method, this must be mentioned in agreements between the parties.

Chapter 4. Component C: Evaluation of the financial viability of the process, training, dissemination of project results through presentations, publications and technology transfer

On the basis of relevant financial and production data obtained in the course of the project, a comprehensive financial analysis was prepared in the third project year. This analysis established the financial and economic viability of the processes using the Sudan situation as a practical case study. A model for making projections of benefits to other countries wishing to adopt the processes is included in the report. The risks are also clearly stated.

The achievements of the project was documented in regular progress reporting to the ICAC and the Fund, but above all in technical reports were presented at relevant meetings organized in the framework of global ICAC meetings or in workshops and seminars organized by other organizations (e.g,. the African Cotton Research Network-ACREN, the Conference des Responsables de la Recherche Agronomique Africain-CORAF and the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions).

In order to provide hands-on exposure to the methods used in the project, be it with regard to activities related to the determination of the levels of stickiness in cotton bales or to the processing of sticky cotton, a provision is made in the project budget for a training/visiting programme in the third project year for technicians from interested developing countries. The modality for the programme as well as the determination of the number of participants were determined by the PEA and the Supervisory Body in close consultation with the Fund in the course of the second project year. A provision has also been made for an international workshop to be organized in Sudan towards the end of the project for dissemination of the project results. Given the close link with the earlier mentioned Fund-financed Integrated Pest Management project in Israel, Egypt, Ethiopia and Zimbabwe, representatives from that project are envisaged to participate in the presentations and discussions of the results of the present project where considered relevant. In preparation for this workshop, a handbook describing the project results as well as the methodologies and techniques used in the project will be published in three languages (English, French and Spanish) and be made available, at a price to be determined, to commercial and non-commercial operators. This publication is the property of the Fund.

Output 3.1 **Providing information on project activities and results to other cotton-producing countries in Africa**

Activity 3.1.1 Dissemination of information on project activities and results annually through the network of cotton-producing countries in Africa.

Activity 3.1.2 Dissemination of information on project activities and results annually through the network of cotton-producing countries through the Mediterranean network.

Output 3.2 Providing information on project activities and results to cotton-producing countries outside of Africa

Activity 3.2.1 Annual workshop on efforts to combat stickiness and its effects conducted as a part of the meeting of the Committee on Cotton Production Research of the International Cotton Advisory Committee, held at Plenary Meetings, and attended by researchers from member countries and observers.

Activity 3.2.2 Organization of a training/visitors programme for groups of selected staff of interested organizations.

Activity 3.2.3 Organization of an international workshop to disseminate the results of the project.

Output 3.3 Financial Analysis Report

Activity 3.3.1 Throughout the duration of the project, data will be collected related to present production, grading, pricing and marketing of cotton as well as with regard to the use and cost of the new methodology resulting in different qualities of cotton in as far as related to stickiness levels.

Activity 3.3.2 Based on the data gathered through Activity 3.3.1, an all inclusive financial and detailed analysis will be prepared by the PEA, possibly in cooperation with an international specialist in this field, on the viability in economic/financial terms of the stickiness detection process and the development and application of the after-ginning methods to enable processing of sticky cotton.

Output 3.4 **Publication of a handbook for commercial utilization of project findings.**

Activity 3.4.1 In preparation for the workshop in Activity 3.2.3, a handbook will be prepared in English regarding procedures necessary for the separation of sticky cotton from non-sticky cotton.

Activity 3.4.2 The handbook will be translated into French and Spanish languages and be made available to all member countries of the Fund and the ICAC. The handbook will also be made available to all cotton-producing countries and organizations through the ICAC secretariat. The price of the book will be determined by the Fund, in close consultation with the PEA and the ICAC.

4.1. Economic viability of qualitatively grading cotton bales for stickiness measured by H2SD

4.1.1. Current situation in Sudan

In Sudan, approximately 300 000 families cropped cotton on 280 000 hectares in the 1996/1997 season. Irrigated crops account for 90% of fiber production (approximately 100 000 tons annually). Two principal types of cotton are cropped:

- *Acala*: medium fiber, *G. hirsutum*;
- *Barakat*: extra long fiber, *G. barbadense.*

Acala englobes several cotton varieties, the principal being *Barac*. Other varieties are produced in low quantities: *Shambat* for long fiber, *Albar* and *Acrain* for short fiber. Long and short fibers corresponded to only 1790 tons in 1996/1997, i.e. less than 2% of total production.

The growing area, with fairly dispersed plots, is situated between 10° and 16° North, and 30° and 36° East. Cotton growing areas are divided into blocks covering an average of 4000 ha. Average seed-cotton yield is nearly 1 ton/ha, i.e. 330 kg of fiber/ha. Two thirds of the seed-cotton produced is roller ginned. Ginning output corresponds to 34 to 35% for *Acala* and 32 to 33% for *Barakat*. The seed-cotton arrives at the ginning mills in 315 lbs bags. Bags containing highly sticky cotton, detectable with the naked eye, are removed. The others are sorted using a mainly visual grading system into 3 seed-cotton groups. Bags of the same grade are mixed regardless of their geographical origin and are ginned together. A mill containing 94 roller gins produces 1000 bales / 24 hours, with each bale weighing 191 kg (420 lbs). Four bales out of every 100 in each batch are graded visually and manually, and a single bale is tested by HVI.

The information given above can be used to estimate needs in terms of materials, laboratories, maintenance efforts, air conditioning, etc. It is noteworthy that these estimates are made on the basis of the hypothesis of a 'political' decision being made to grade the entire bale production for stickiness. At the end of the grading operation, the bales would then be grouped together into batches of "homogeneous" stickiness.

This paper attempts to evaluate the financial effect of this grading operation. It does not take account of the fact that Sudanese cotton has a reputation for being sticky since this image should improve thanks to the grading work which will thus have an impact on cotton sale price.

4.1.2. Estimating the cost of H2SD grading in Sudan

The cost of H2SD grading has been estimated in the United States to be US$1.5 per bale (Watson, 1998). This estimation, based on grading using two H2SD measurements per bale, includes depreciation of the instruments, labor and the cost of the different consumables and spare parts. The approach envisaged by the author is doubtless inspired by HVI grading of production since this has become well established in the United States over the last few years.

4.1.3. H2SD grading conditions

The cost of H2SD grading may be different in Sudan primarily because of the difference in labor costs. A bale-by-bale grading of the entire Sudanese production may thus be evaluated under the following conditions:

- annual production: 500 000 bales (400 000 Acala and 100 000 Barakat);
- sampling: 2 samples per bale;
- number of measurements: 1 H2SD measurement per sample;
- standard cottons: 2 reference cottons for daily verification of the machines;
- grading duration: 26 weeks (from January 1 to June 30 each season);
- workload: 2 teams working 8 hours / day x 5 days a week;
- workforce: 2 technicians for each H2SD machine.

4.1.4. Number of H2SD machines

With the capacity to process 100 to 110 samples/hour, it is theoretically possible for one H2SD machine to analyze 800 samples in one 8-hour shift. However, in view of the time required to analyze the standard cottons, breaks taken by the workforce and the different handling operations required for the sample, it is reasonable to limit analysis rate to 600 samples, i.e. 300 bales per machine and per 8-hour shift.

The number of H2SD machines necessary to grade 500 000 bales in 26 weeks is thus:

$$= \frac{500000}{300 \times 2 \times 5 \times 26} = 6.4$$

i.e. <u>7 H2SD machines</u> to grade 500 000 bales in 26 weeks.

4.1.5. Reference cottons (standard cottons)

A verification of each H2SD machine is necessary at the start of each shift, then every two hours, to guarantee constant readings. In the same manner as for HVI grading, two reference cottons (standards) of guaranteed stickiness (one slightly sticky and the other very sticky) need to be analyzed. Five verifications of the H2SD machines are therefore made using two standard cottons every 8 hours.

Three or four grams of cotton are necessary for each H2SD stickiness measurement. With two measurements per cotton, the total amount of standard cotton required is given by:

4 x 2 x 5 x 2 = 80 g of each standard cotton per day.

When considering the 26 weeks, this mass increases to 10.4 kg/cotton, i.e. a total of <u>20.8 kg for the two standard cottons</u>.

4.1.6. Consumption of aluminum foil

For each stickiness count, the H2SD instrument consumes 30 cm of aluminum foil.

The total number of counts (bale samples + standard cottons) is given by:

500 000 x 2 + 5 200 = 1 005 200 counts

Consumption of aluminum foil is given by: 0.3 x 1 005 200, i.e. <u>302 km</u>.

4.1.7. Workforce

With two operators per machine, the number of technicians in each 8-hour shift is 2 x 7, i.e. a total of 28 technicians.

With one person in each team to manage and prepare the samples, the total number of technicians is 30 persons.

With two team managers and two engineers, management personnel can be restricted to 4 persons.

Workforce composition is therefore:

- 30 technicians,

– 2 team managers,
– 2 engineers.

Table 4-1 presents our cost estimates for a single grading laboratory situated at Wad Medani close to Gézira (the most important production area in Sudan). This location would reduce the cost of sample collection and also provides pre-existing infrastructure in the form of an ARC laboratory (*Stickiness Testing Laboratory of ARC-Wad Medani*). Thus, if a different site is chosen, certain estimations would have to be modified, notably the cost of sampling (shipment and labor) and that of the different equipment already present in the ARC laboratory.

The overall cost of grading 500 000 bales is thus estimated to be $756 060, i.e. US$1.51 per bale. This result is slightly higher than the estimation made in the United States (US$1.25/bale). It should be noted that the American estimation does not detail the different costs and may not take account of the cost of collecting the samples and those relative to data processing. Here, the United States has already available a grading system (HVI) which includes the costs of the two supplementary operations we took into account in our estimation in Table 4-1.

Even if the estimated cost exceeded $1.5 per bale, the grading would still be cost-effective because of the discounting imposed on Sudanese cotton.

It is important to note that the true cost per sample for analysis purposes only (without sampling and transportation) is around **0.388 US$ / sample**.

Table 4-1: Estimated cost of H2SD grading, 2 counts/bale (500 000 bales).

Parameter	Unit price US $	Cost US $	Cost per bale US $
7 H2SD machines (depreciation over 5 years)	90 000	126 000	0.252
Aluminum foil consumed: 302 km (Price in France, exclusive of VAT)	120	36 240	0.073
Maintenance and spare parts		30 000	0.06
1 air-conditioning system (depreciation over 10 years)	100 000	10 000	0.02
Energy consumed (130 000 kwh) (Source: SCC)	0.35	45 500	0.091
Workforce wages (6 months): 30 technicians 2 team managers 2 engineers	 420 700 1100	97 200	0.194
Sampling (shipment, handling) (Source: SCC)		367 000	0.734
Data processing and communications (computer, tel., fax, etc.)		20 000	0.04
Standard cottons (21 kg)	200	4 200	0.008
Miscellaneous (approx. 2.7% of subtotal)		19 920	0.04
Total		756 060	1.51

4.1.8. Cost-effectiveness of grading

H2SD grading becomes cost-effective if the difference between sales with and without grading is greater than or equal to its cost. To formula to calculate the gain at the end of this operation is:

$$Gain = CA_{Classification} - CA - CC$$

$$= \sum_{I=1}^{n} P_i \; NB_i \left[\frac{X_i}{1-D_i} + (1-X_i)(1-D_i^{'}) - 1 \right] - CC$$

(Equation 4-1)

With

i the given type or class or grade of cotton.

P = Actual price of the bale.

NB = Number of bales.
i = bale ‘ quality ’ (Acala, Barakat, …).
X = proportion of non sticky bales.
D = Actual discount (without classification).
D ’ = Expected discount on sticky bales.
CC_{bale} = Classification cost per bale.
How does this gain vary as a function of the X_i proportions and the discounts D_i and D_i’ ? Unfortunately, in view of the number of variables, it is impossible to devise a graphical response to this question. We therefore simplified the expression for a tabular presentation. To do this, we reasoned by type of cotton sold *i* since the number of bales per type sold is sufficiently high for us to calculate precisely the gain produced by grading.
The gain by type of cotton is given by:

$$Gain_i = P_i \ NB_i \left(\frac{X_i}{1-D_i} + (1-X_i)(1-D_i^{'}) - 1 \right) - NB_i \ CC_{Balle}$$

(Equation 4-2)

4.2. Numerical application

The gain can be evaluated for total production of 500 000 bales made up of *n* = 2 types of cotton:

1: Acala (80% of total production), ***NB₁*** = 400 000 bales

2: Barakat (20% of total production), ***NB₂*** = 100 000 bales.

The price of a bale (420 lbs) can be set at the annual average listed in *Cotton Outlook* for 1998/99, i.e.: $0.5714/lb for Acala and $0.7574/lb for Barakat.
On the basis of $1.51/bale, (estimation given in Table 4-1), we evaluated the gain provided by grading for different proportions of non sticky *X* and the depreciation of those graded as sticky *D’* , and this for several *D* currently imposed on all Sudanese production in the absence of grading.

Table 4-2 and

Table 4-3 present the gains resulting from grading Acala and Barakat bales for different proportions *X* and depreciation *D’* if current discounting is considered to be *D* = 7%.

Bale grading is not always gainful since this is highly dependent upon the proportion graded as non sticky and the discounting applied to the bales graded as sticky.
As an example, if the proportion of non sticky bales in Acala production is *X* = 30% and the discounting imposed in the absence of grading is *D* = 7%, grading these Acala bales will lead to a loss even if the discounting of the 70% of bales graded as sticky is as low as *D’* = 3% (losses at *D’ = 3%* amount to $452 264).

Table 4-2: The gain (millions of US$) resulting from grading Acala bales into two categories, sticky and non sticky, for different proportions of non sticky bales *X* and discounting of the sticky bales *D’*. Discounting in the absence of grading *D* = 7*%* and grading cost CC_{Bale} = $1.51/bale.

	D’								
X%	3	5	7	10	12	15	20	30	35
0	- 3.5	- 5.4	- 7.3	- 10.2	- 12.1	- 15	- 19.8	- 29.4	- 34.2
20	- 1.5	- 3.0	- 4.5	- 6.8	- 8.4	- 10.7	- 14.5	- 22.2	- 26.0
40	0.6	- 0.9	- 1.7	- 3.5	- 4.6	- 6.3	- 9.2	- 15	- 17.8
60	2.6	1.8	1.0	- 0.1	- 0.8	- 2.0	- 3.9	- 7.8	- 9.7
80	4.6	4.2	3.8	3.2	2.8	2.3	1.3	- 0.5	- 1.5
100	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6

Table 4-3: The gain (millions of US$) resulting from grading Barakat bales into two categories, sticky and non sticky, for different proportions of non sticky bales *X* and discounting of the sticky bales *D'*. Discounting in the absence of grading *D* = 7% and grading cost CC_{Bale} = $1.51/bale.

	D'								
X%	3	5	7	10	12	15	20	30	35
0	- 1.1	- 1.7	- 2.4	- 3.3	- 3.9	- 4.9	- 6.5	- 9.7	- 11.3
20	- 0.4	- 0.9	- 1.5	- 2.2	- 2.7	- 3.5	- 4.7	- 7.3	- 8.6
40	0.2	- 0.1	- 0.5	- 1.1	- 1.5	- 2.1	- 3.0	- 5.0	- 5.8
60	0.9	0.6	0.4	0.0	- 0.2	- 0.6	- 1.2	- 2.5	- 3.2
80	1.6	1.4	1.3	1.1	1.0	0.8	0.5	- 0.1	- 0.4
100	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

It is essential, for a more precise evaluation of grading cost-effectiveness, to establish not only the proportion of non sticky bales and the discounting imposed in the absence of grading, but also the depreciation expected for the bales graded as sticky.

The discount currently imposed on Sudanese cotton is deduced from market data and is estimated by SCC to be 7 to 12% of the selling price. Evaluating the expected depreciation of bales graded as sticky is more difficult. This depends on several factors, particularly economic effects, and should be evaluated on the basis of objective criteria that take account of the damage caused by sticky cotton.

4.3. Conclusion

The results obtained show clearly the feasibility of a qualitative stickiness grading system by H2SD (*High Speed Stickiness Detector*). The cost per sample is around 0.388 US$ per sample to which should be added the sampling and transportation of samples to the laboratory. Once the stickiness of each bale has been determined, the producer can fix a stickiness threshold and thus guarantee that the stickiness of the bales he supplies is lower than the limits demanded by his clients. The effectiveness of such a grading procedure depends directly on the within-bale stickiness distribution. Thus, it is essential to evaluate this distribution locally since this could vary from one production zone to another.

It is also possible to adapt this procedure to H2SD grading into several stickiness categories. To do this, it would be sufficient to consider the upper limit of each stickiness grade as a critical threshold and proceed grade-by-grade in the same way as for grading into two categories, sticky and non sticky.

The cost-effectiveness of H2SD grading was estimated for different discounts applied to the selling price of bales graded as sticky and as a function of different proportions of non sticky bales and the discounting already imposed on cotton production with a reputation of being sticky.

The grading system would require several H2SD machines to process the entire production of the country. Between-machine repeatability should be evaluated to gain an appreciation of the precision of the results and their reproducibility. Studies concerning measurement repeatability are ongoing at CIRAD in partnership with several American and European laboratories.

A grading system into several stickiness categories can be envisaged (e.g. non sticky, sticky, very sticky). Here, it has been observed that the stickier the cotton, the more damage it causes. Because of this, the discount imposed on the price of sticky bales could be weighted for their degree of stickiness. This would oblige producers to grade the bales into several categories. The methodology is the same as that developed for grading into two categories, only batch management would be different, and above all more costly.

4.4. Dissemination of the findings

The following papers were published and presentations made in the course of the project. Other members of the project may have also made presentations of the data:

4.4.1. Publications

- Fonteneau Tamime O., Gozé E.,. Frydrych R., Dréan J.-Y. Qualitative Classification of Cotton Stickiness in H2SD High Speed Stickiness Detector. Accepted by Textile Research Journal.
- Fonteneau Tamime O., Frydrych R., Dréan J.-Y. Carded Spinning of sticky cotton. Part 1: Stickiness effects on productivity. Accepted by Textile Research Journal.
- Fonteneau Tamime O., Gourlot J.-P., Gozé E. Carded Spinning of sticky cotton. Part 2: Stickiness effects on quality. Accepted by Textile Research Journal.

4.4.2. Presentations

- Frydrych R., Tamime O., Gourlot J.-P., Gozé E., Le Blan T., Ahmed S. F., Abdin M. A, 2000, Sticky cotton effects on the carded spinning process, Cotton Beltwide Conferences, San Antonio (TX), USA, January 3rd to 10th, 2000.
- Chanselme J.-L., Fadlalla A.S., Goze E., Tamime O.F., Abdelatif A.H., 1998, Investigation of within-bale variability of stickiness measurement, World Cotton Conference 2, Athens (Greece), September 6th to 13th, 1998.
- Gozé E., Fonteneau Tamime O., Frydrych R., Gourlot J-P., Dréan J-Y., Nieweadomski J-C., Lassus S., Goebel C. et Francalanci Ph., 1999, Avancement du Projet Soudan: Improve the Marketability of the Cotton Produced in the Zones Affected by Stickiness, Actes des Journées Coton du Cirad, Montpellier, July 19th to 23th, 1999, pp. 259-262.

4.4.3. Posters

Tamime O., Gozé E., Frydrych R., Gourlot J-P., 1999, Dréan J.-Y., 1999, Classement des balles de coton selon leur potentiel de collage mesuré par le High Speed Stickiness Detector (H2SD), Doctoriales de l'Université de Haute Alsace in Mulhouse (France), Mai 1999.

4.4.4. Seminars

- PhD presentation by Fonteneau Tamime O., June 26, 2000.
- Seminar ‘ Journée d ’information sur la mesure et la lutte contre le collage des fibres de coton ’, June 26, 2000, Montpellier.
- Presentation of the results of the Project in Sudan, end of 2000: J.-P. Gourlot went to Sudan on December 2000 to present the information collected during the project to 75 persons representing SCC, ARC, ginners, farmers. A report was presented, in 190 slides, the results available at that time. New information that was not presented is contained in this report which attempts to provide all the necessary scientific background to understand our conclusions.
- Final seminar in July 2001 in Lille. Proceedings will be available on CD on request.

4.4.5. Other information

Stickiness is a worldwide problem that has been the subject of considerable research. A non exhaustive list of the groups currently working on the topic is given below:

– International Textile Manufacturers Federation (ITMF) :

Organization of a round test using stickiness measurement devices.

Probable recommendation of H2SD and/or other measuring device(s) by this Committee.

- Comité Européen de Normalisation (CEN):

Working Group on standardization for SCT.

Working Group on standardization for H2SD.

Working Group on standardization for FCT/FQT.

Chapter 5. Final conclusion

It would appear that stickiness is on the increase. Many authors in the bibliography give different reasons for this increase change e.g. changes in insecticides, possible resistance to insecticides, changes in processing machines etc. Many producing countries are affected by stickiness, and ICAC decided to sponsor a first project in 1993 to control insect-induced stickiness in the field. The project was known as « Sticky cotton: possible control methods from the plant to yarn ».

In parallel, some kind of stickiness evaluation was required to assess bale quality for commercial purposes. Thus, a new project, entitled « Improvement of the Marketability of the Cotton Produced in Zones Affected by Stickiness » was designed to address some of the basic questions and develop a method for characterizing stickiness.

This project, also sponsored by the International Cotton Advisory Committee, and funded by the Common Fund for Commodities, was carried out by ARC and SCC in Sudan, and by IFTH and Cirad in France with the support of ICAC.

The central objective of the project was to increase cotton producer revenues through the development of reliable methods to evaluate the stickiness of cotton bales, and determine (under factory conditions) the operational thresholds for the processing of contaminated sticky cotton.

A bale is declared as "sticky" if, during a processing step, e.g. spinning, its stickiness disrupts the spinning process, reduces spinning machines performances or decreases final product quality.

It should be noted here that classification requires a measuring tool, appropriate conditions for that tool, and good cotton production organization. All these conditions will impact on the success of such a classification system.

5.1. Qualitative classification of stickiness

In this part of the project, we investigated methods intended to manage the cotton and establish make a classification for its marketing.

As planned in the project, the SCT thermodetector, which was shown to be a good predictor of problems encountered during spinning and is the measuring device recommended by the International Textile Manufacturers Federation, was used to separate the sticky bales based on the number of sticky points. This method was shown to have its limits as a classification tool since it is slow and the results were biased by an operator effect. In the second part of the project, it was decided to use the H2SD instead of the SCT as it proved to be more reliable and faster.

The bales can be classified for stickiness in several manners, i.e.:

- a quantitative classification, namely each bale is labeled with a number of H2SD sticky points, and its associated confidence interval (tolerance);
- separation into two categories, "sticky" and "non sticky", according to a determined threshold called the "crucial stickiness threshold".

Both these methods require knowledge concerning the within-bale distribution of sticky points. The qualitative classification of the cotton bales was chosen to be more suitable for the situation.

From a specific experiment, it was shown that the sticky points were distributed in an aggregated manner: the number of sticky points in the tested bales followed a binomial negative statistical distribution whose shape factor and homogeneity was estimated for all the bales.

The aim of any classification is the guarantee a certain quality for a given bale. However, since fiber characteristics showed within-bale and within-lot variability, samples from one single bale or a single lot could show different results and this could result in complaints. This would be particularly awkward when producer results and purchaser results are different for the same bale

When classifying stickiness, at least qualitatively, this risk of complaints being made (i.e. risk of litigation) must be evaluated and sampling / classification conditions must be managed accordingly.

This is why tables were established on the basis of simulations that took account of:

– the statistical distribution observed
– producer requirements in terms of cotton production constraints

– the classification and grouping together of bales of homogeneous quality
– purchaser requirements
– and part of the economical cost of the operation.

Under these conditions, the classification method used by the producer must be based on a lower threshold than that employed by the purchaser, and thus reduce the risk of litigation.

The extent of stickiness was also evaluated within Sudan. Several thousand samples, produced by eight ginning plants located in different geographical zones were analyzed using the H2SD. The results showed that some zones are more affected by stickiness than others. It is therefore possible to consider developing a strategy for the follow-up and assessment of stickiness by concentrating the measurements on the zones where the classification is the most useful.

5.2. Stickiness measurement and relationship with technical hitches during spinning

Part of this study focused on the spin-ability of sticky cottons by processing several sticky cottons bales covering a wide range of stickiness. During the spinning of each of these bales, the breaks, stops and technical hitches were noted and used to calculate the output of each spinning machine.

Some cotton samples, taken from the opening of the bale up to the sliver, were used to monitor changes in cotton stickiness in the course of the processing. Different methods were used to measure the stickiness: SCT thermodetector, H2SD and HPLC chemical method. The sliver, roving-yarn and yarn quality were also monitored by analyzing samples taken at the different performed stages from cotton to yarn.

The spinning tests were performed in carded cycle for the two main types of spinning (ring and open-end spinning), under the temperature and relative humidity conditions usually recommended for processing in the absence of stickiness.

Some relationships were noted between the different stickiness levels and the production and quality criteria and were used to define the best indicator of stickiness, namely the number of sticky points measured by the H2SD fast detector.

This device, in addition to providing the result that correlated the most closely with the production criteria (breaks and output) and quality criteria (regularity, imperfections and properties of yarn strength) is the fastest and the most suitable for industrial application in the detection of stickiness in cotton bales.

The other measurements methods studied, i.e. SCT and sugar percentages measured by HPLC, were often correlated to the production and quality criteria, but the coefficients of determination (R^2) did not generally equal those obtained with the number of sticky points given by the H2SD. Moreover, the HPLC chemical measurement is unsuitable for an industrial application because it is costly and time-consuming.

The results of this study showed that the rowing frame was the most sensitive machine to stickiness. Considerable efficiency could be lost depending on the degree of stickiness because of breaks and the rolling-up of fibers around the rollers.

The open-end spinning seemed to be less sensitive to stickiness than the ring spinning. The loss of efficiency due to stickiness is gradual with a relatively gentle slope while the rate of breaks in the ring spinning process increased rapidly with stickiness potential.

Another noticeable difference between these two types of spinning processes concerned the yarn quality. Whereas the quality of ring spun yarn (coefficient of variation for mass, imperfections, tenacity) greatly depended on stickiness and deteriorated when stickiness increased, the properties of open-end yarn were only slightly sensitive to this problem.

It should be remembered that this experiment was conducted to determine a threshold to separate non-sticky and sticky bales. However, because of this gradual increase in the rate of incidents with stickiness, it was not possible to determine a single, overall threshold where spinning problems become too important.

In fact, the threshold depends on the number of incidents accepted by the customer. Also the rate of incidents remains rather variable from one bale to another for a same number of H2SD sticky points.

In view of the extensive work that would be necessary to list the incidents for every bale, the small number of bales could be used to establish only a rather imprecise relationship between the acceptable rate of breaks and the stickiness threshold.

Some tests on combed spinning were conducted in order to study the relationships between stickiness and disruptions of the specific machines used in this type of spinning process: the combing machine and the lap top machine. However, as the range of stickiness was rather limited, the study was conducted in a set of bales that all showed low stickiness potential.
Nevertheless, the few tests conducted showed that the combing machines we used in the project seemed to be very sensitive to stickiness, inducing a relatively large number of registered breaks. This proves that stickiness may be damaging for production in modern spinning mills.

5.3. Financial viability of a classification

The cost of grading all bales produced in Sudan was assessed along with the actual financial gains from such an operation, taking into account the discounts applied to cottons with the reputation of being sticky and the proportion of bales in the whole production. The results of this economic assessment showed the cost of grading to be about 1.5 $US per bale (almost 50**%** of this price for sample shipment to the testing laboratory since sample collection is not yet centralized) for an analysis cost of 0.388 $US per sample. A grading system is only economically viable if it results in some financial gain and this depends on the discount applied and the proportion of non-sticky bales. This study was conducted on the basis of many assumptions that need to be checked since it was almost impossible to obtain price and discount information from the market.

5.4. Solutions to reduce the consequences of stickiness

It is recognized that the higher the relative humidity, the most numerous the disruptions induced by cotton stickiness and the poorer the quality of the yarn. This negative effect was confirmed by reducing the relative humidity to 40% in a specific spinning experiment.
Three levels of relative humidity (40, 45, 55%) were tested to evaluate impact on productivity and the yarn quality in micro-spinning. Some tests conducted in an industrial spinning confirmed that very sticky bales which could be spun or were very difficult to spin under normal relative humidity (RH) conditions were spin-able without much disruptions at 38**%** RH. The quality of the yarns produced was also improved. Decreasing the relative humidity would appear to be a solution for the processing of sticky cottons.
In the scope of this study where each bale of cotton was spun individually, it was shown that the number of disruptions was related to the H2SD stickiness level. In industrial processing, cottons from different origins are often mixed together.
The linearity of H2SD counts in mixtures of sticky and non-sticky cottons was checked in samples containing 25, 50, 75 and 100**%** sticky cotton.
The stickiness of the mix was determined to be the mean stickiness of each constituent weighted by the proportion of this constituent in the mix (if the sticky cotton contains no more than 50 H2SD sticky points)..
Though there is no doubt that this observation needs to be confirmed in an extensive industrial spinning process and with respect to the quality of the yarn produced, it seems reasonable to imagine that mixing some sticky with some non sticky cotton could reduce the incidence of technical problems in the mill to an acceptable level.

5.5. Perspectives

Controlling stickiness requires a global approach where improvements in breeding, agronomy, pest control and technology have to be made in a parallel manner. Classification is one of the tools used to combat stickiness. Measurement results can help, through mapping, to make progress in all other ways to reduce stickiness, such as breeding new varieties, developing new ways to manage the crops through integrated pest management programs, managing the seed-cotton flow, etc.
On a long term basis, the classification tool should be economically viable, and would insure an improvement of the image of Sudanese cotton.

Abbreviations and acronyms

ICAC - International Cotton Advisory Committee, Washington (USA)
CFC - Common Fund for Commodities (Netherlands)
SCC - Sudan Cotton Company (Sudan)
ARC - Agricultural Research Corporation (Sudan)
ITF - Institut Textile de France (France) newly renamed as IFTH
CI Cotton Incorporated, Cary, NC (USA)
ITMF - International Textile Manufacturers Federation (Switzerland)
CIRAD-CA - Centre de Coopération Internationale en Recherche Agronomique pour le Développement - Département des Cultures Annuelles (France)
USDA - United States Department of Agriculture

LIST OF LABORATORY EQUIPMENT

FMT : Fineness Maturity Tester
H2SD : High Speed Stickiness Detector
HPLC : High Performance Liquid Chromatography
HVI : High Volume Instrument
SCT : Sticky Cotton Thermodetector
UT3 : Uster Tester 3
Tensorapid : Uster Dynamometer

DISCLAIMER

Mentions of equipment brands or models in this document do not constitute any form of recommendation for such equipment.

LIST OF VARIABLES

SCT: number of SCT sticky points
H2SD: number of H2SD sticky points
Small: number of sticky points between 1.7 and 9 mm²
Medium: number of sticky points between 9 and 18 mm²
Large: number of sticky points larger than 18 mm²
TMH2SD: average size of the H2SD sticky points
TTH2SD: total size of the H2SD sticky points
I: inositol
T: trehalose
G: glucose
F: fructose
W: trehalulose
S: saccharose or sucrose
M: melezitose
Stotal: percentage of total sugars
C-CT100km: total breaks per 100 km of card sliver
C- Efficiency: card efficiency (efficiency = yield)
E1-CT100km: total breaks per 100 km of drawing frame sliver (1° draft)
E1-Efficiency: drawing frame efficiency (1° draft)
E2-CT100km: total breaks per 100 km of drawing frame sliver (2°draft)
E2-Efficiency: efficiency of the drawing frame (2°draft)
B-CT100km: total breaks per 100 km on the flyer
B-Efficiency: efficiency of the flyer
CAF-TC1000BH: breakage per 1,000 spindles/hour on the ring spinning frame
OE-Efficiency: efficiency of the Open-end machine
OE-Y-P240BH: number of piecing per hour for 240 open end positions
OE-LR240BH: number of interventions per hour for 240 open end positions.
C-CV%: CV% mass variation on card sliver
E1-CV%: CV% mass variation on 1° draft drawing frame
E2-CV%: CV% mass variation on 2° draft drawing frame
B-CV%: CV% mass variation on flyer yarn
CAF-UT3-CV%: CV% mass variation on ring spun yarn
CAF-UT3-50%: No. of thin places per km of ring spun yarn
CAF-UT3+50%: No. of thick places per km of ring spun yarn
CAF-UT3-Neps: No. of neps per km of ring spun yarn
CAF-Hairiness: Hairiness of the ring spun yarn
CAF-Elongation: Elongation (%) of the ring spun yarn
CAF-Strength: Strength (cN/tex) of the ring spun yarn
CAF-Work: Work to break (N.cm) of RS yarn
OE-UT3-CV%: CV% mass variation of the OE yarn
OE-UT3-50%: No. of thin places per km of OE yarn
OE-UT3+50%: No. of thick places per km of OE yarn
OE-UT3-Neps: No. of neps per km of OE yarn
OE-Hairiness: Hairiness of OE yarn
OE-Elongation : Elongation (%) of OE yarn
OE-Strength: Strength (cN/tex) of OE yarn
OE-Work: Work to break (N.cm) of OE yarn
χ^2: Variable of the Chi² distribution
α: Confidence level (Type I error)
+B: Yellowness
H: Fiber linear fineness (mtex)
HS: Standard fineness (mtex)
IM: Micronaire
k: Shape factor for the binomial negative distribution
m: Parameter for the binomial negative law (mean)
ML: Mean length (mm)
MR: Maturity ratio
PM%: Percent of mature fibers (%)
Rd%: Reflectance (%)
RL: Litigation risk
SCE: Sum of squares of the deviates
UHML: Upper Half Mean Length (mm)
UI%: Uniformity index (%)