COMMON FUND FOR COMMODITIES

TECHNICAL DEVELOPMENTS FOR INSTRUMENT TESTING

CHAPTER 8.6

ANNEX A: COTTON HOMOGENIZER

Project CFC/ICAC/33

Commercial Standardization of Instrument Testing of Cotton with particular consideration of Africa

Cotton Testing in Africa
CSITC - Project

This project is co-funded by the European Union and the Common Fund for Commodities

Activity D.2.2. Development of a prototype of homogenizing machine, and production of simplified copies for RTCs, public information

Project CFC/ICAC/33

This project is co-funded by the European Union and the Common Fund for Commodities

Laura PAYET, Jean-Paul GOURLOT
CIRAD- UPR102-LTC Montpellier
June 2010

Report on Activity D.2.2. Development of a prototype of homogenizing machine, and production of simplified copies for RTCs

This report is dealing with a part of the Activity D.2.2. (Study of African cotton variability in the producing zones in order to choose the best operating methods), itself part of D.2. (Evaluation of cotton variability).

Extract from project document:

" Activity D.2 is aimed at achieving the optimal number of samples per bale and the optimal number of tests per sample. These numbers depend highly on the origin of the cotton production. Without knowing the basic variability of fibre characteristics in cotton bales, it is impossible to fix any operating method for testing that warrants that the results are in given tolerances. As the cotton is produced in small farms in Africa in comparison to the one produced in countries already using SITC for classification, there is no certainty that the operating methods already used are efficient enough for cotton trading without any claim.

The basic step is to study the within-bale variability of cotton characteristics to fix an operating method able to produce results in the expected precision and accuracy. We wanted to train specific persons by research activities to support trainers in their job. Another key to success is the organization of round test organized by the RTC and at the attention of the laboratories in the region. In order to only compare laboratories, the cotton samples (a large mass of cotton) sent out by the RTC to the laboratories for testing should be very homogeneous. It is then required to take profit of a cotton homogenizing device to be developed first (on Cirad and CFC funding) and then copied to the 2 RTCs (paid by CFC). The user institute will then be the RTCs (with an exemplary of the machine) and the laboratories as they will be confident in the round test to adjust their results at the proper level. [...] "

Bibliography: PAYET L., GOURLOT J-P., 2011, Rapport "D.2.2. Development of a prototype of homogenizing machine, and production of simplified copies for RTCs, Public information", Project CFC/ICAC/33, 38 p.

Content

List of annexes

1 - <u>Introduction</u>

A key to success of levelling out the results of fibre characterization from regional laboratories is the organization of round test organized by the RTC. In order to only compare laboratories, the cotton samples (a large mass of cotton) sent out by the RTC to the laboratories for testing should be very homogeneous. It is then required to take profit of a cotton homogenizing device to be developed first (on Cirad and CFC funding) and then copied to the 2 RTCs (paid by CFC). The user institute will then be the RTCs (with an exemplary of the machine) and the laboratories as they will be confident in the round test to adjust their results at the proper level.

A set of three mixing/homogenizing machines will be produced to prepare the samples to be sent to the laboratories for the regional round-test action [Extract from Project Document LT OV353.doc].

The overall approach was (Figure 12):

- to develop a prototype having a large flexibility in major instrument settings: pressure, speed, drawing constants;
- to test this prototype in order to find two or three set of best settings according to the types of cottons to be mixed (some cottons are easy to “open” and to homogenize, while others can be very difficult);
- to produce simplified copies of the machine for the African conditions;
- to test these simplified machines;
- to deliver these simplified machine to RTCs.

2 - <u>Description of the technical objective</u>

In their routine work, laboratories test samples for classing purposes; for instance, one sample is taken per bale of cotton fibre and is sent to the laboratory for evaluation of its “quality”. As every sample is taken from a different bale, any single sample is potentially different from the following one. It is then difficult to check the quality of the data produced by the laboratory.

However, it is probable that a customer will take another sample from the same single bale from which a sample was drawn for classing analysis and classing purpose. The customer will want to get the same result (or higher) as what was found by the classing laboratory, unless a claim may be issued.

The final objective is then to ensure that laboratories, at least in a same region, are finding the same results on the same cotton samples. To find the same result (within a tolerance), it is required that all laboratories use comparable procedures and techniques such as:

- the conditions of testing are alike in all laboratories,
- the equipments are properly maintained and properly calibrated against the Universal Standards,
- the procedures of testing are similar,
- the personnel is properly trained
- the procedures of testing are comparable.

One way to prepare laboratories to work toward common procedures is to register them to periodic inter-laboratory round-tests. In these round-tests, a central location the RTC in our case send out comparable samples coming from a homogeneous material to registered laboratories. These laboratories realize the analysis and send back result to the central location. All results from one laboratory are compared to the averaged results from all participating laboratories to prepare and send out a report to everyone.

The key issue in these round-tests is that the material SHOULD be homogeneous before drawing samples to be sent to the laboratories in order to only comparing the laboratory results and not an interaction between the impact of the material and the impact of the laboratory. In summary, smaller the variation in the material, higher is the efficacy of detecting variation in results due to the laboratory practices.

In addition, it is required that what ever the cotton poor or good "quality" to be measured, the laboratories will measure them at a common level. In order to check that hypothesis, most round-tests include several cottons having a wide range of characteristics. In the international round-test, such as the "CSITC round-test" and the "USDA HVI round-test", the number of cotton varies between 2 to 5.

For every cotton in every test, the required quantity of homogeneous material is given by the number of participating laboratories (around 150) multiplied by the individual mass per laboratory (around 150 grams): it is then 23 kilogram of homogeneous material that are required per cotton and per test!

In order to feed the round-test with fibres, CSITC and USDA are selecting homogeneous bales coming from homogeneous regions, where the seed-cotton was ginned gently. These bales first checked for their homogeneity prior to be sampled for participation in round-tests.

The CFC/ICAC/33 project planned to organize Regional Round Test by the RTCs. It has been expected that all laboratories in the Regions would participate both in providing material and in participating to the testing process. The number of participating laboratories was estimated to be in the range of 10 to 20, requiring around 1500 to 3000 grams of homogeneous material per cotton and per test.

As it is difficult to select homogeneous cotton bales in these regions, it was proposed to insure the homogeneity of the material thanks to a mixing technique. For its own round-test, CIRAD was used to "open and mix" prepare samples by hand as shown in Figure 1. This technique is very tedious and time consuming, while it is very gentle for the fibres in order not to modify their quality prior testing during round-tests.

Figure 1: "Opening and mixing" a cotton sample by hand (Picture CIRAD, 2008).

Blenders and openers can be used for homogenizing material, but they both use card clothes with teeth that have a high probability to damage the fibres during this operation, which is not expected.

CIRAD then developed a technique using a loose drafting system for separating the packs of fibres associated with a suction system to separate tufts of fibres to be mixed in a container thanks to an airstream. The cotton bale sample (600-800 grams), which can be a part of a layer in a bale, is initially very compressed (approx. volume 3 * 40* 50 cm) is opened and mixed to finally come to a volume of 40 * 70 * 150 cm) in the feasibility study instrument settings.

This device served CIRAD to define the technical requirements for manufacturing a compact prototype.

3 - Procedure to produce the prototype

3.1 - Definition of criteria for selection of manufacturer

In order to select the company producing the first prototype, several criteria were retained:

- A set of technical requirements was developed according to a CIRAD schematic based on its experience in mixing small to large quantities of cotton fibres for creating reference material for round-test and for other research experiments;
- Price should be consistent with the project budget;
- Manufacturer should have all means in order to produce such a prototype (visit on site by CIRAD expert)
- Manufacturer should accept a close follow-up from CIRAD's personnel;
- Distance should be limited between CIRAD experts and the Manufacturer in order to have a close follow-up during the development and during the production of the device.

3.2 - List of approached companies and final choice

On the basis of a "yellow page" listing based on a query with keywords "construction mécanique; électro-mécanique; prototype" in Montpellier surroundings, we found that there are very few existing companies interested in our project. However, we were able to get four manufacturers:

1- SYDEL-S.A., 625 rue de la croix verte, 34196 Montpellier cedex 5, daniel.fuentes@sydel-sa.com,

2- Plateforme technologique, Lycée Mermoz, 717, avenue Jean Mermoz 34000 Montpellier, pft34.montpellier@wanadoo.fr,

3- Mathec, ZAC Petite Camargue, chemin de Provence, 34400 Lunel, mathec@wanadoo.fr,

4- Atelier Alpha, ZAE Les Garrigues, 34380 Saint Martin de Londres, atelieralpha@wanadoo.fr.

Among them, only two (SYDEL and Atelier Alpha) were able to provide us with a proforma invoice, respectively 24 247 euros and 64 000 euros.

We then finally chose SYDEL-SA to develop and manufacture the prototype.

3.3 - Follow-up of the prototype manufacture

The first drawings were delivered by SYDEL-SA to CIRAD in June 2008, followed by a purchase ordered signed the 18th June 2008. The production of the prototype started in July 2008 and was delivered at CIRAD the 22nd October 2008.

4 - Test and improvement of the prototype

After previous tests of technical performance (check mechanics, smooth running, *etc.*), the real test of validation of the prototype started in April 2009, as part of the *"Research of the best settings"* sub-activity. The aim of the whole prototype validation study is to find the optimum protocol and the optimum settings leading to a well-performed homogenization with an easy use. It is described below, divided into two parts: experiments on homogenizing machine and fibre characterisation with results.

Prior to the experimentation plan, a preliminary experiment was realized to prove that the homogenizing machine is working with medium masses of cotton fibres to be homogenized. Thus, some settings were fixed in order to determine others in next experiments:

- The distance between pairs of cylinders was fixed as mentioned: L+15 between 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4, L being an estimation of the length of the fibre in millimetres (known for standard cottons).
- The speed of the pairs of cylinders was set as described in next table (speeds C):

Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
out	280	18,7	4	Maximum outlet speed, Lower inlet speed, Redistribution of drafting ratios.
	70	4,7	1,9	
	37,5	1,9	2,5	
in	15	1		

- The different types of cotton used independently were: Short-Weak (32142) and Long-Strong (27855), 800 grams each (total for this experiment).

Distance, speed and, cotton material being fixed, other settings (pressure deviation, pressure between cylinders, section of pipe) were also varying in order to determine their best level. It was observed that the homogenizing machine was correctly working with medium masses of cotton fibres for both short and long cottons independently, with settings fixed as described:

- pressure deviation: fixed at 7 bars,
- pressure between cylinders, regulated by a spring system: fixed at 20 kgf,
- section of pipe: constricted and to be reduced (prior to duplication).

The prototype was then considered to be operational and its delivery was approved. These settings being specified, next step is to mix cottons in order to fix the settings which determine whether or not the mixing effect of the machine is sufficient.

4.1 - Plan of experiments on homogenizing machine prototype

Blending can be considered as an extreme situation for homogenizing fibres. It is assumed that by mixing two types of cottons, it would easily represent the homogenizing effect of the machine, even if the actual aim of the project here is to homogenize one part of a cotton bale. It was then chosen to work with a mix of two cottons in proportions 50/50 w/w for the prototype validation. The objective of this part is to test the machine at different settings with different sampling protocols, as a basis for determining next the ones which give the best value for practicality. Experiments were lead into three situations, according to the protocol defining how cottons were fed into the opener:

- Situation 1: Two juxtaposed cottons to be mixed (experiments 1 to 10),
- Situation 2: Two superposed cottons to be mixed (experiments 11 to 20),
- Situation 3: Two superposed cottons to be mixed (experiments 21 to 30) and then piling up as many layers as obtained mixed samples (additional mixing)

The term « two juxtaposed cottons » refers to the sampling operation of bringing in two types of cotton, one beside the other on the feeding table, so that they both stands side by side on a half table width before the mixing operation. The term « two superposed cottons » refers to the sampling operation of bringing in two types of cotton, one above the other on the feeding table, so that they both stands stacked up on the full table width before the mixing operation.

Pressure deviation, pressure between cylinders and section of pipe being previously fixed, it was decided that two other settings would be varying: cylinders speed and distances between pairs of cylinders. Six combinations of speeds have been tested (see Annex 2 for details), as well as two combinations of distances between pairs of cylinders (see below) that will prevent the fibres from breaking up:

1. L+15 between 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4,
2. L+5 between 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4.

L is an estimation of the length of the fibre in millimetres (known for standard cottons). <u>When two cottons with different length characteristics are to be mixed, L stands for the length of the longest cotton.</u>

Every experiment is a combination of these two settings. The following table sums up the plan of experiments to realise.

Distances	L+15 / L+10 / L+10			L+5 / L+10 / L+10		
Situation	1	2	3	1	2	3
Speeds A	E1	E11	E21	E6	E16	E26
Speeds B	E2	E12	E22	E7	E17	E27
Speeds C	E3	E13	E23	E8	E18	E28
Speeds D	E4	E14	E24	E9	E19	E29
Speeds E	E5	E15	E25	E10	E20	E30

First Plan of Experiments
Combination of distances between cylinders and speeds of pairs of cylinders

The commercial characteristics of the fibres were analyzed later by Standardised Instrument for Testing of Cotton, SITC. Every sample were to be tested: the raw ones – meaning not mixed by the homogenizing machine, as well as the mixed ones, in order to assess the mixing effect on variability results.

4.1.1 - <u>Type of material used</u>

Two HVICC standard cottons were used in this study: Short-Weak SW and Long-Strong LS (see Annex 1 for number of standards and their characteristics). They were expressly chosen to be drastically different on their length and strength properties. Thus, their variability would be significantly high if they are raw (not mixed), whereas an intimate mixing of these fibres could result in reducing this variability.

4.1.2 - Quantity of material to be tested, number of samples

For each combination cylinders speeds/distances between pairs of cylinders, protocol was made twice (total of two repetitions) in order to get the results more representative. A total of 800 grams of cotton (400 grams each) was used per experiment. For each repetition, samples were collected and placed into convenient envelopes for further testing (especially for raw samples, the whole cotton mass must be collected once, without preparation), as following sampling procedure:

<table>
<tr><th>Experiments</th><th>Raw cottons sampling
(at way-in)</th><th>Mixed cottons sampling
(at way-out)</th></tr>
<tr><td>E1 to E10
(situation 1)</td><td>Five 40g samples were taken at the way-in of the homogenizing machine (two cottons side by side on feeding table).</td><td rowspan="2">Five 40g samples were taken at the way-out of the homogenizing machine (mix of two cottons gathered in plastic bag). Each sample was spread on a flat surface: fibres were then drawn three times transverse to get four samples.</td></tr>
<tr><td>E11 to E20
(situation 2)</td><td rowspan="2">Five 40g samples were taken at the way-in of the homogenizing machine (two cottons stacked up on feeding table).</td></tr>
<tr><td>E21 to E30
(situation 3)</td><td>Five 40g sub-samples were taken at the way-out of the homogenizing machine (mix of two cottons gathered in plastic bag). At each step of processing a sub-sample, the mixed fibres from the bag were piled up as a layer in order to get one large piece. Fibres were then drawn four times transverse to the layers to insure a doubling while constituting five samples.</td></tr>
</table>

Figure 2 and Figure 3 illustrate the sampling protocol of experiments of situation 2 and situation 3 respectively (two cottons stacked up fed on the table).

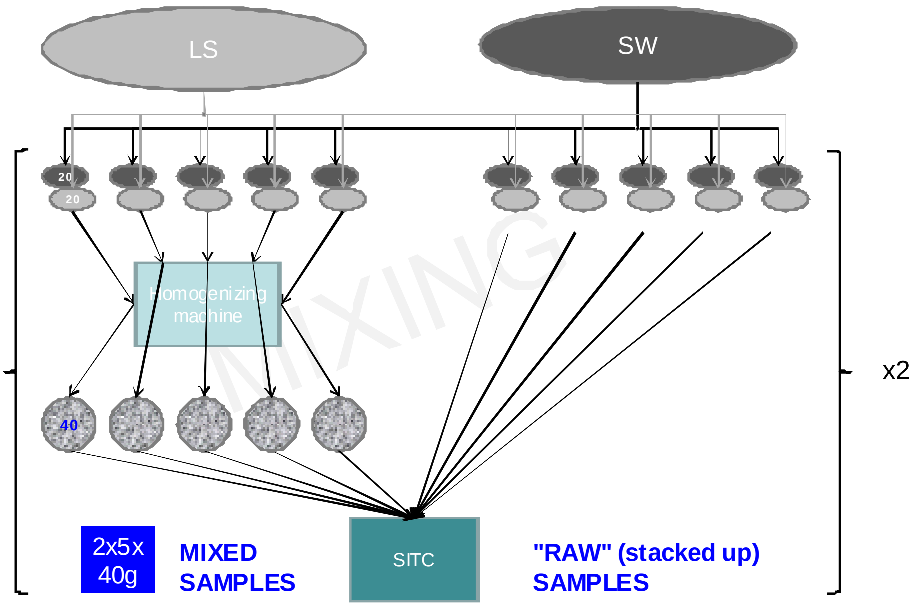


Figure 2. Sampling protocol for mixing cottons (situation 2)

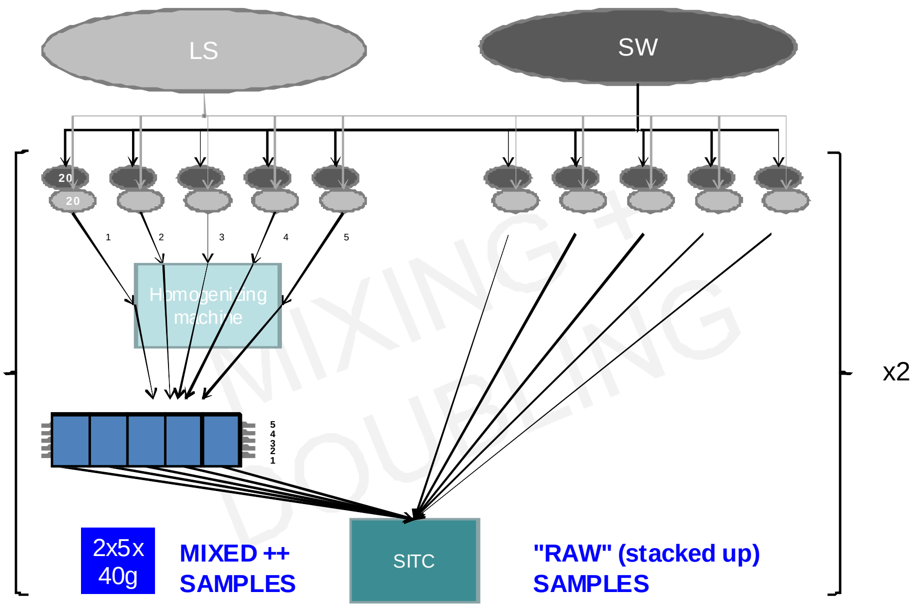


Figure 3. Sampling protocol for mixing cottons and process doubling (situation 3)

4.1.3 - Restrictions on further experiments

Situation 1 was first realised with two juxtaposed cottons feeding the table. Experiments E1 to E10 were all carried out complying with previous sampling instructions, but were not all managed. Indeed experiments E1 and E6 (speeds ratio A); E4 and E9 (speeds D); and E5 and E10 (speeds E) showed many difficulties at use: rolling up of the fibres onto the bottom drafting rolls and fibre overloading at the constricted section of pipe. As for an explanation, the combination of speeds D was not operational as the first motor was not powerful enough to drive the first couple of cylinders. Besides, especially for speeds A and E, total drafting ratio was considered to be too low (last motor too slow) to allow a correct homogenizing performance. Regardless, experiments E1 and E6 (speeds A) were analyzed as a reference, and the conclusion is that the variability of their results is very high (see 4.2.3.1 - for more information).

For experiments of situations 2 and 3, it was decided to filter out the combinations of speeds A, D and E, related to low feasibility in experimentation from the plan of experiments. Finally, only two combinations of speeds are remaining over five: speed B (maximum outlet speed, no other modification), and speed C (maximum outlet speed, lower inlet speed and redistribution of drafting ratios), since experiments linked to them are practically executable for both distances 1 and 2. The only experiments E12, E13, E17 and E18 were therefore realised for situation 2 and experiments E22, E23, E27 and E28 for situation 3.

4.1.4 - Comments

It has to be noted that different couples of cotton had to be used during the plan of experiments (see numbers of cottons in Annex 1). This issue came from the fact that quantities expected in stock differed from reality, so it had to be compensated by changing the cottons, so all results could not be compared that easily from one experiment to another. To avoid this issue for validation of duplicate machine, only one cotton couple will have to be set aside for the study.

During experimentations, some points or dysfunctions were observed to be improved prior to duplication:

- the section of pipe was found to be too large: it would need to be reduced in order to allow enough suction power to the Venturi system and to avoid overload masses of cotton at the constricted section of pipe,
- the 2nd motor was used at low engine speed compared to its capacity: it would need to be replaced by a slower one. The opportunity can also be taken to change the 3rd and 4th motors for a faster running while keeping the same drafting ratios.

4.2 - Fibre characterisation of samples from plan of experiments

4.2.1 - Testing procedure

Cotton fibres benchmark properties were analysed in a conditioned textile laboratory, according to ASTM 1776-04: standard atmospheres having a temperature of 21°C and a relative humidity of 65%, with tolerances of ± 1°C and ± 2%. The six current commercial characteristics of the fibres were tested:

- Micronaire (Mic),
- Upper Half Mean Length (UHML),
- Length Uniformity Index (UI),
- Strength (Str),
- Reflectance (Rd),
- Yellowness (+b).

These properties were analyzed on High Volume Instrument Zellweger Uster HVI 1000 (Model M700), with software system HVI SW Version 3.1.3.18. The three modules of the high volume instrument were used. Micronaire module (MIC) is used for Mic, while Length/Strength module (L/S) is used for UHML, UI and Str and Color/trash module (C/T) is used for Rd and +b.

For each sample, it was decided to do 2 tests on MIC Module and 6 tests on L/S and C/T modules. Indeed, from practical experience at CIRAD cotton laboratory, it was observed that the variability for each characteristic is acceptable for such an amount of tests. From the 40g samples in the envelop, it is possible to use two times the 10g ± 0.5g needed for MIC module by cutting transverse to cotton flow without preparation sampling procedure. The rest is also taken cut transverse to cotton flow (no preparation) for L/S and C/T modules.

Two results were then obtained for Mic and six results for UHML, UI, Str, Rd and +b.

Both **MIC Module Testing** and mode 4 of **System Testing** were used, setup with 1 repetition per module and Manual Mic entry allowed. Practically, each sample is first tested 2 times with MIC Module Testing so that the average of 2 is entered afterwards manually in System Testing for 6 tests on same sample.

4.2.2 - Data analysis

Data from SITC tests were imported in Excel and JMP (SAS Institute Inc.) for statistical interpretation. For each sample, average of 2 measurements of Mic remained from value entered, while means of 6 measurements are calculated for UHML, UI, Str, Rd and +b. The first step in the variability study is to compare the results among repetitions, for each experiment individually. This was achieved by using Student's t test in JMP. When repetitions (5 samples) of an experiment are too different in variability, it is assumed that it cannot be significant to go further in the interpretation; the settings of this experiment are then considered as non operational. Afterwards the study proceeds in calculating standard deviations and variances within experiments. Each experiment was the result of 10 raw samples (2 repetitions of 5 samples) and 10 mixed samples.

4.2.3 - Results and discussions

4.2.3.1 - Results of cottons mixed samples in the first situation

The first part of this study is to analyse the results from samples of the 4 operational experiments over 10 in situation 1: E2, E3, E7 and E8, in comparison to reference results of E1 and E6.

It is initially expected that the mixing effect of the homogenizing prototype on juxtaposed cottons would have an impact on variability of the results: the variance of the six characteristics of mixed samples should be lower than the ones of raw samples. This assumption is verified for every characterisation criteria of experiments E1, E2, E3, E6, E7 and E8.

However, for experiments E1 and E6 (speed ratio A), it is observed that the variability of some of the commercial characteristics of fibres is varying from one repetition to the other. It was checked that temperature and hygrometric conditions did not have an influence on the cotton benchmark properties sensible to changes in conditioning, since variations were not significant along one experiment (see Figure 4 for strength properties of two universal calibration standards: LS 32274 and SW 33045, used as a basis for testing). The high disparity could then be explained by the manipulation of the fibres, resulting from fibre rolling up or overloading issues. This situation actually appears as an outcome of wrong combinations of cylinders speed. There is indeed a connection between the difference of variability among repetitions and the difficulties that occurred during experimentation involving agglomerate formation. Finally, the speed settings which do not allow an easy use of the equipment consequently lead to high variability of the fibre characteristics results among repetitions.

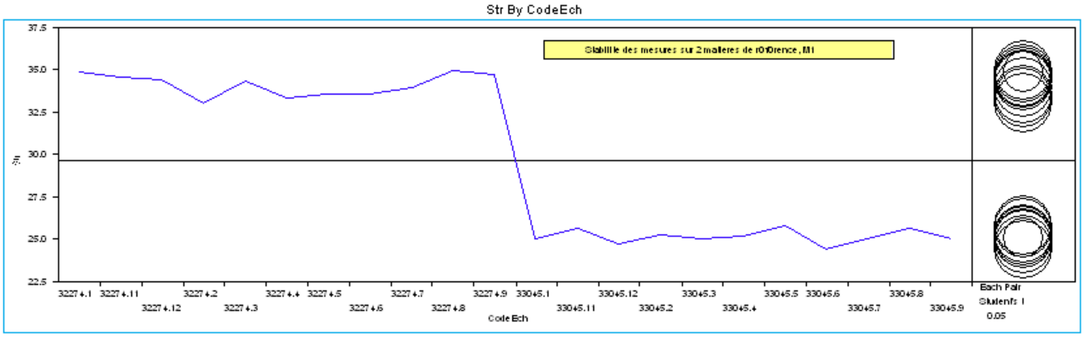


Figure 4. Strength results for strong and weak standard cottons, during check tests realised along time (several days)

On the other hand, experiments E2 and E3 (distances 1) fulfil the assumption of mixing effect on variability AND there is no significant variation between repetitions. Same conclusions can be drawn for experiments E7 and E8 (distances 2). For these reasons, it is decided to restrict further experimentation to experiments settings linked to E2, E3, E7 and E8.

Next figures illustrate strength property of cottons samples from E7: mean line and standard deviations are represented per repetition, and per group of raw or mixed samples. For charts of the other criteria, see Annex 3 and Annex 4. From repetition R1 to R2, the average is similar, as well as the standard deviation, as shown in Figure 5. From raw to mixed samples, the average also stays similar, while the standard deviation of mixed samples is reduced (see Figure 6).

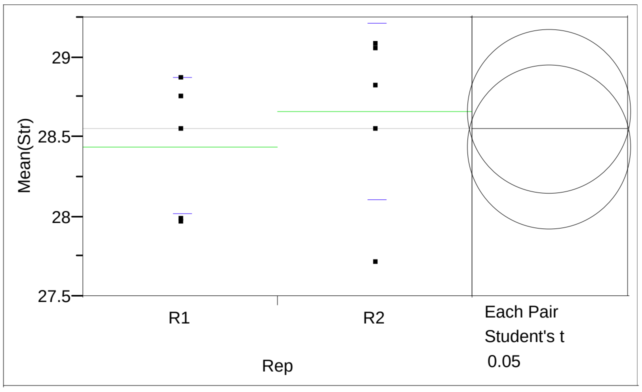


Figure 5. Analysis of Strength By Repetition R1 or R2 for mixed samples of E7

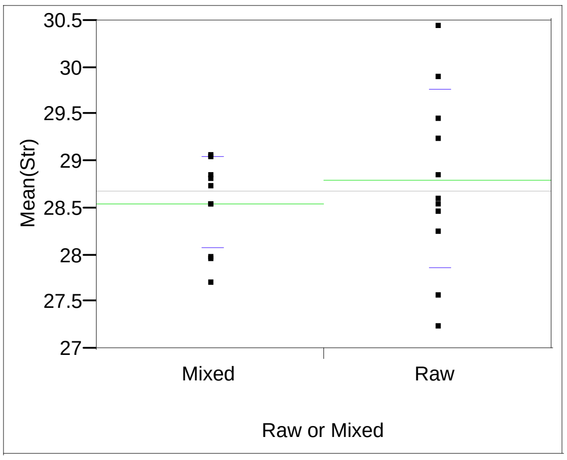


Figure 6. Analysis of Strength By Raw or Mixed for all samples of E7

4.2.3.2 - Experiments comparisons

The second part of this variability study aims at determining the settings of the homogenizing machine which enable the fibres to be mixed a specific way, so that the variability of the results in characterising the fibres is reduced. Experiments will be compared one to another for each characteristic, according to their variance, calculated from the data of a batch of 10 (20 or 40) samples. For raw samples only, it can be decided to group the results of different experiments with similar sampling procedure at way-in into: a batch of juxtaposed raw cottons and a batch of superposed raw cottons.

Calculating variance (raw)/variance(mixed) ratios is a way to appreciate the mixing effect of the experiment. The bigger the ratio, the more the variability between raw and mixed samples is lowered, and the more the settings of the experiment have an impact on the mixing. In this study, high ratios would be an indication of fibres well mixed.

Conclusion on a specific setting for distances

This first study aims to compare groups of four experiments set with distances 1 and distances 2, in order to determine whether or not there is a setting of distances that gives largely better variability results than the other. It is suggested to analyse situation 1 in this part (see situations 2 and 3 in Annex 5).

Variance results of E2 and E3 (distances 1) and E7 and E8 (distances 2) for situation 1 are presented in Table 1, as a basis for next calculations.

	N Rows	Var(Mic)	Var(UHML)	Var(UI)	Var(Str)	Var(Rd)	Var(+b)
E2-raw	10	0.0086	15.4	3.73	4.75	0.47	0.067
E3-raw	10	0.0045	1.35	2.61	6.31	0.31	0.23
E7-raw	10	0.0020	3.09	2.15	12.8	0.94	0.78
E8-raw	10	0.00080	0.90	1.08	2.40	0.14	0.44
E2-mixed	10	0.0087	2.24	1.36	0.63	0.28	0.039
E3-mixed	10	0.0017	0.54	0.67	3.30	0.20	0.11
E7-mixed	10	0.0016	0.33	0.55	1.55	0.31	0.10
E8-mixed	10	0.0029	0.086	0.26	0.58	0.062	0.056

Table 1. Variance between 10 samples per experiment for E2, E3, E7 and E8 (From means of 2 tests: Mic or 6 tests: UHML, UI, Str, Rd, +b)

A sorting was then elaborated individually from the variance(raw)/variance(mixed) ratios of the six characteristics (see Table 2). The ratios of characteristic x are mentioned as [x] in next tables.

	[Mic]	[UHML]	[UI]	[Str]	[Rd]	[+b]
E2-raw / E2-mixed	0.99 £	6.88 **	2.75 $	7.50 **	1.67 $	1.70 £
E3-raw / E3-mixed	2.63 $	2.50 $	3.87 *	1.91 $	1.54 £	2.06 $
E7-raw / E7-mixed	1.23 $	9.30 **	3.94 *	8.22 **	3.00 *	7.47 **
E8-raw / E8-mixed	0.28	10.4 **	4.22 *	4.15 *	2.35 $	7.85 **

Table 2. Variance(raw)/variance(mixed) ratios [x] per criteria x for E2, E3, E7 and E8

Legends: Test F 10/10

** level of significance 1% > 4,85
$ level of significance 25% 1,55 < < 2,98
* level of significance 5% 2,98 < < 4,85
£ level of significance 50% 1,00 < < 1,55

Each experiment was then given a grade from 1 to 4 according to its performances for each of the six characteristics (see Table 3). It was chosen to use the ratio data rounded to the first decimal, ranking with the following ratio tolerance: when ratio δ equals ratio γ ± 0.5, then δ and γ are associated to the same grade (average of two ranks, e.g. grade 3.5 for ranks 3 and 4).

Experiment	[Mic]	Grade
E3	2.6 $	1
E7	1.2 $	2
E2	1.0 £	3
E8	0.3	4

Experiment	[Str]	Grade
E7	8.2 **	1
E2	7.5 **	2
E8	4.1 *	3
E3	1.9 $	4

Experiment	[UHML]	Grade
E8	10.4 **	1
E7	9.3 **	2
E2	6.9 **	3
E3	2.5 $	4

Experiment	[Rd]	Grade
E7	3.0 *	1
E8	2.3 $	2
E2	1.7 $	3.5
E3	1.5 £	3.5

Experiment	[UI]	Grade
E8	4.2 *	1
E7	3.9 *	2.5
E3	3.9 *	2.5
E2	2.7 $	4

Experiment	[+b]	Grade
E8	7.9 **	1.5
E7	7.5 **	1.5
E3	2.1 $	3.5
E2	1.7 £	3.5

Table 3. Grades per criteria x, based on ratios [x] for E2, E3, E7 and E8

From Table 3, it can be deduced that E7 gets better grades than E2 for any criterion. Likewise, E8 always gets better grades than E3, except for Micronaire. Consequently, it can be drawn that experiments using setting distances 2 allow a greater reduction of the variability of many more criteria than experiments using setting distances 1 in this situation.

Same conclusions also can be drawn for E2, E3, E7 and E8 (situation 2) in the one hand and for E22, E23, E27 and E28 (situation 3) in the other hand (see details in Annex 5). Therefore it is possible to conclude that no matter the speeds setting and no matter the situation (feeding protocol), a specific setting of the distances enables to get high ratios, so fibres well mixed. It is then recommended to use the homogenizing machine by setting the distances between pairs of rolls as following: L+5 between 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4.

Conclusion on a specific setting for speed ratios

Now that experiments distances 1 have been set aside, the study aims to organize the six experiments set with distances 2 (E7, E8, E17, E18, E27 and E28) into a hierarchy. Variance results are presented in Table 4, as a basis for next calculations.

	N Rows	Var(Mic)	Var(UHML)	Var(UI)	Var(Str)	Var(Rd)	Var(+b)
RAW-jux	20	0.0044	0.16	0.31	0.83	0.058	0.034
RAW-sup	20	0.0022	0.20	0.37	1.2	0.057	0.018
E7-mixed	10	0.00069	0.045	0.12	0.24	0.0084	0.0077
E8-mixed	10	0.0024	0.071	0.076	0.32	0.022	0.0044
E17-mixed	10	0.0011	0.060	0.095	0.26	0.016	0.0027
E18-mixed	10	0.00042	0.055	0.15	0.25	0.048	0.0049
E27-mixed	10	0.00041	0.063	0.233	0.53	0.012	0.0023
E28-mixed	10	0.00049	0.017	0.034	0.19	0.031	0.0054

Table 4. Variance per criteria x between 10 or 20 samples per experiment for E7, E8, E17, E18, E27 and E28
(From means of 2 tests: Mic or 6 tests: UHML, UI, Str, Rd, +b)

The sorting was first elaborated individually from the variance(raw)/variance(mixed) ratios of the six characteristics. For experiments E7 and E8, 'raw' refers to 'RAW-jux' since cottons are fed juxtaposed before mixing, while 'raw' refers to 'RAW-sup' for experiments E17, E18, E27 and E28 since cottons are fed superposed before mixing. This distinction between raw juxtaposed and raw superposed samples within the variance ratios enable to compare directly the mixing effect of the machine due to the different settings, and not the interaction between the influence of sampling and the impact of mixing. Each experiment was then given a grade from 1 to 6 according to its performances for each of the six characteristics (see Table 5).

Experiment	[Mic]	Grade
E7	6.3 **	1
E27	5.4 **	2.5
E18	5.2 **	2.5
E28	4.5 **	4
E17	2.1 $	5
E8	1.8 $	6

Experiment	[Str]	Grade
E28	6.5 **	1
E18	4.8 **	2.5
E17	4.7 **	2.5
E7	3.4 *	4
E8	2.6 $	5.5
E27	2.3 $	5.5

Experiment	[UHML]	Grade
E28	12.2 **	1
E18	3.7 *	3.5
E7	3.5 *	3.5
E17	3.4 *	3.5
E27	3.2 *	3.5
E8	2.2 $	6

Experiment	[Rd]	Grade
E7	6.9 **	1
E27	4.9 **	2
E17	3.6 *	3
E8	2.6 $	4
E28	1.8 $	5
E18	1.2 £	6

Experiment	[UI]	Grade
E28	11.0 **	1
E8	4.1 *	2.5
E17	3.9 *	2.5
E7	2.5 $	4.5
E18	2.5 $	4.5
E27	1.6 $	6

Experiment	[+b]	Grade
E27	7.9 **	1.5
E8	7.6 **	1.5
E17	6.9 **	3
E7	4.4 **	4
E18	3.8 *	5.5
E28	3.4 *	5.5

Table 5. Grades per criteria x, based on variance(raw)/variance(mixed) ratios [x] for E7, E8, E17, E18, E27 and E28

Legends: Test F 20/10

**	level of significance 1%	> 4,41	*	level of significance 5%	2,77 < < 4,41
$	level of significance 25%	1,52 < < 2,77	£	level of significance 50%	1,03 < < 1,52

For example, experiment E28 gets the first grade for UHML, UI and Str raw/mixed ratios, with are by the way much higher than the ones of the other experiments.

Figure 7 and Figure 8 illustrate results of strength variability, with a distinction between mixed samples obtained from juxtaposed (blue) and superposed (green) cottons fed into the homogenizing machine. Reduction of variability from raw samples to mixed samples is easily observable in Figure 7. Charts for all criteria are presented in Annex 6 and Annex 7.

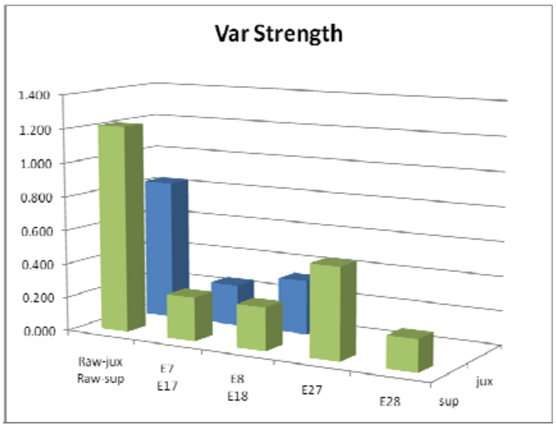


Figure 7. Variance obtained from 10 samples (mixed) or 20 samples (raw) for strength properties for E7, E8, E17, E18, E27 and E28

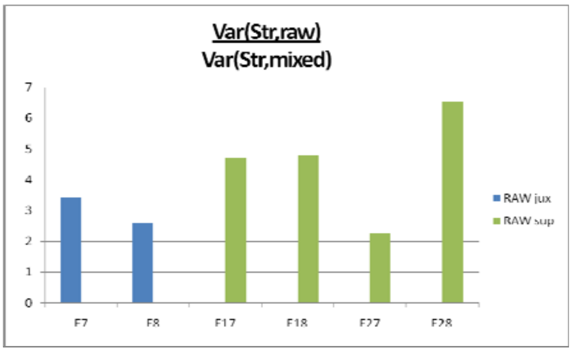


Figure 8. Variance(raw)/variance(mixed) for strength properties for E7, E8, E17, E18, E27 and E28

Finally, the average of these six grades allows establishing a general ranking (see Table 6), without any consideration of the weight or the significance of each criterion. What is considered as the best experiment is the one that allows a reduction of the variability for as many criteria as possible compared to other experiments.

Final Rank	Experiment	Grades sum
1	E28	17.5
2	E7	18
3	E17	19.5
4	E27	21
5	E18	24.5
6	E8	25.5

Table 6. General ranking

For UHML, UI and Str, experiment E28 is at the first rank since it allows a reduction of the variability of the greatest number of criteria of the whole experiment plan.

4.2.4 - Comments

When testing "raw" samples, it was observed an influence of the operator during SITC testing, probably due to its way of sampling. In this variability study, evaluating the effect of mixing of the machine involved a comparison between "raw" samples (as the reference material) and mixed samples. It was then important to establish a sampling protocol for testing "raw" samples.

4.3 - Conclusions on prototype validation: optimum settings and protocol

Regarding the variability results obtained from this experiments on prototype validation, it is important to remind that the two HVICC standard cottons used in this study (Short-Weak and Long-Strong) were expressly chosen to be drastically different on their length and strength properties, so that their mix would result in high variability between raw and mixed cottons. Finally the settings and procedure of an experiment which lead to high variance(raw/mixed) ratios for many properties can be considered as the best solution to obtain a correct mixing. Since experiment E28 allowed a reduction of the variability of more criteria than the other experiments (and particularly length and strength criteria), this would lead in deducing that the better way to mix two cottons is to use the homogenizing machine with following settings and procedure:

- pressure deviation: fixed at 7 bars,
- pressure between cylinders, regulated by a spring system: fixed at 20 kgf,
- distances set at L+5 between cylinders 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4,
- speed ratios so that outlet speed is maximum, inlet speed is lower and drafting ratios are redistributed,
- two cottons in superposition (way-in procedure) are feeding the table,
- piling up as many layers as obtained mixed samples in order to ensure an additional mixing effect.

These requirements remain a basis for elaborating and using the duplicated homogenizing machine. Besides, some technical adjustments have to be made before copying the prototype into simplified machines.

5 - Procedure to produce the copies

5.1 - Definition of criterias for selection of manufacturer

In order to select the company producing the first prototype, several criterias were retained:

- Price should be consistent with the project budget;
- Manufacturer should have all means in order to produce such a prototype (visit on site by CIRAD expert)
- Manufacturer should accept a close follow-up from CIRAD's personnel;
- Distance should be limited between CIRAD experts and the Manufacturer in order to have a close follow-up during the development and during the production of the device.

5.2 - List of approached companies and final choice

SYDEL provided us with a proforma invoice, 24 000 euros for two machines, including transportation but not assurance for transportation.

We then finally chose SYDEL-SA, 625 rue de la croix verte, 34196 Montpellier cedex 5, to develop and manufacture the copies for both RTC East and RTC West.

5.3 - Follow-up of the copies manufacture

The modified drawings were delivered by SYDEL-SA to CIRAD in July 2009, followed by a purchase ordered signed the 17th July 2009. The production of the copies started in August 2009. A first copy was pre-delivered at CIRAD the 18th December 2009 and the second the 4th February 2010 for running tests.

During experimentation stage, it was observed that some modifications had to be made on the machine in order to make it work according to requirements. First of all, the section of pipe was reduced in order to allow more suction power to the Venturi system. Referring to a second observation, maximum engine speed was lowered for cylinder 2 (for a better adaptation to the drafting system), while it was boosted for cylinders 3 and 4 (for a faster running of the machine):

Pair of cylinders	Way	Motor speed max (rpm)	From prototype to copy	Motor speed max (rpm)
4	out	280	→	412
3		280	→	412
2		280	→	91
1	in	91	idem	91

In the same topic, another important point was to simplify the speeds possibilities. The prototype was elaborated so that we could easily change the speed of independent cylinders with independent buttons (with electronic display). Now that combinations have been defined, the system for the copies can propose 2 pre-set programs for routine work (positions 1 and 2, see characteristics below). The speeds were changed from the prototype in order to be at the maximum capacity at the way-out while remaining the same drafting ratios as speeds C (position 1) and speeds B (position 2). The possibility to change the independent speeds is still available (position 3), but the access to the electronic board is restricted by a key and the electronic display is replaced by graduations. Machines were delivered with all motors set at 0 for position 3.

Position 1				
Pair of	Way	Motor speed	Total drafting	Partial drafting

cylinders		(rpm)	ratio	ratio
4	out	400	18.2	4
3		100	4.5	1.9
2		54	2.5	2.5
1	in	22	1	

Position 2				
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio
4	out	400	14.3	5.3
3		75	2,7	1,5
2		50	1.8	1.8
1	in	28	1	

Furthermore, independently from the technical specifications, other modifications were made for an easier use of the machine or for achieving conformity to security criteria:

- the system for applying the correct pressure between upper and bottom cylinders was made more practical for an easy setting,
- the system supporting the cylinders was made more practical for an easy move,
- the screws fixing the brushes were replaced by magnets in order to clean them easier and the dust is no longer possibly in contact with electronics,
- the feeding table is correctly fixed for security issues,
- the type of sensors was changed, so that not only the alert but also the security was guaranteed.

6 - Test of simplified machines

One simplified machine was pre-delivered at CIRAD on the 18th December 2009 with modifications from the prototype. Similarly with what was done on the prototype, a complementary protocol was implemented on the simplified machine and started the 28th December 2010. It is described below, divided into two parts: experiments on homogenizing machine and fibre characterisation and results. The aim of this next study is to test the protocol and settings optimally designed from the prototype for a well-performed mix with an easy use and to observe variability results.

6.1 - Experiment on simplified homogenizing machine

In this experiment, large masses (4 kg) made of 2 layers of cottons fed superposed were mixed. Every sample was tested: the "raw" ones – meaning not mixed by the homogenizing machine, as well as the mixed ones, in order to assess the mixing effect on variability results. It is expected that homogenizing machine would reduce the variability of two cottons chosen to be drastically different on their length and strength properties when mixed together.

The homogenizing machine was used in this study for mixing a part of a cotton bale. It was set as following:

- pressure deviation: fixed at 7 bars,
- pressure between cylinders, regulated by a spring system: fixed at 22 kgf at way-in and 17 kgf for the other pairs of rolls,

- distances between pairs of cylinders: L+5mm between 1 and 2, L+10mm between 2 and 3 and L+10mm between 3 and 4. L is an estimation of the length of the fibre in millimetres (known for standard cottons). When two cottons with different length characteristics are to be mixed, L stands for the length of the longest cotton,
- speeds of pairs of cylinders: set at position 1 (maximum outlet speed, lower inlet speed and distribution of drafting ratios).

Similar to the prototype validation, the objective of the following experiment is to mix two different types of cotton in proportions 50/50 w/w and conclude on the quality of the mixing effect of the homogenizing machine.

6.1.1 - Type of material used

Again, two HVICC standard cottons were used in this study: Short-Weak SW and Long-Strong LS, expressly chosen to be drastically different on their length and strength properties (see Annex 1 for number of standards and their characteristics).

6.1.2 - Quantity of material to be tested, number of samples

Large quantities of two types of cotton were continuously brought in, one above the other on the feeding table. The machine was then operating with settings described above, with the following sampling protocol:

- Mixing two cottons stacked up: five 800g samples were taken at the way-out of the homogenizing machine (mix of two cottons gathered in plastic bag). Each sample was spread on a flat surface: fibres were then drawn three times to get four samples. Finally there were twenty 200g samples.
- Mixing two cottons stacked up with additional doubling: five 800g sub-samples were taken at the way-out of the homogenizing machine (mix of two cottons gathered in plastic bag). At each step of processing a sub-sample, the mixed fibres from the bag were piled up as a layer in order to get one large piece. Fibres were then drawn three times transverse to the layers to insure a doubling while constituting four levels and then drawn four times in the other direction to finally get a total of twenty 200g samples.
- Raw cottons stacked up: for comparison purposes, twenty samples were also taken at the way-in of the homogenizing machine (two cottons stacked up on feeding table).

Samples were collected and placed into convenient envelopes for further testing (especially for raw samples, the whole cotton mass was collected once, without preparation).

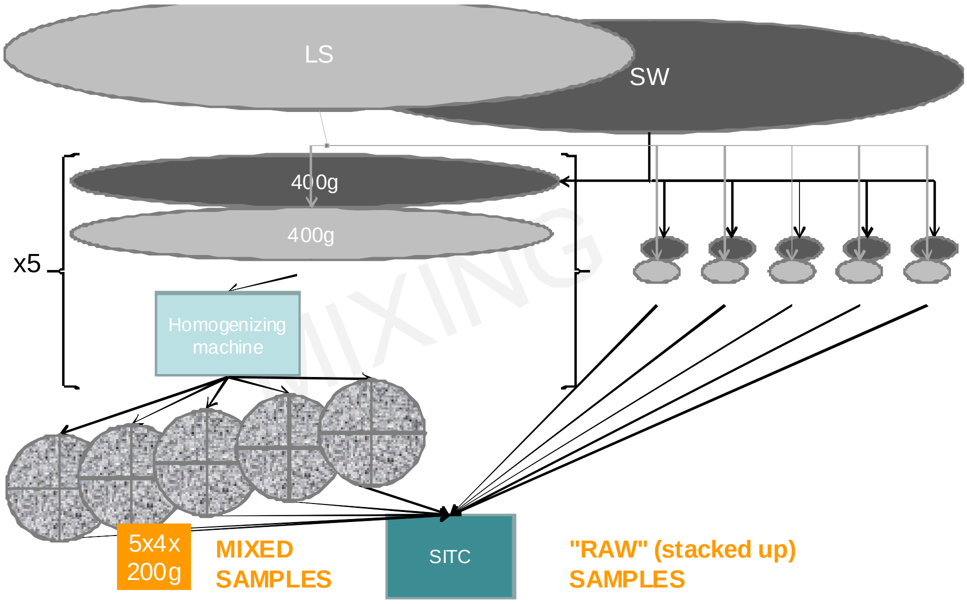


Figure 9. Sampling protocol for mixing cottons (large amounts)

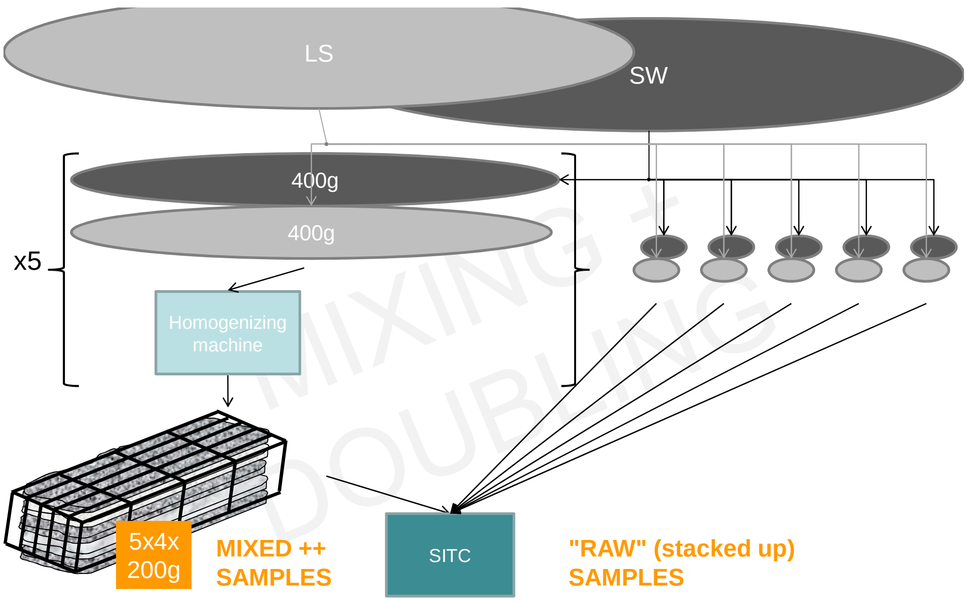


Figure 10. Sampling protocol for mixing cottons and process doubling (large amounts)

6.2 - Fibre characterisation of samples from experiments

6.2.1 - Testing procedure

Cotton fibres benchmark properties were analysed in a conditioned textile laboratory, according to ASTM 1776-04: standard atmospheres having a temperature of 21°C ± 1°C and a relative humidity of 65% ± 2%. The procedure was mainly based on SITC measurements; however complementary tests on Advanced Fiber Information System (AFIS) are also presented in Annex 10 to complete length analysis.

The six current commercial characteristics of the fibres were tested: Micronaire (Mic), Upper Half Mean Length (UHML), Length Uniformity Index (UI), Strength (Str), Reflectance (Rd), and Yellowness (+b). These properties were analyzed on a Standardised Instrument for Testing of Cotton (SITC): High Volume Instrument Zellweger Uster HVI 1000 (Model M700), with software system HVI SW Version 3.1.3.18. For each sample, it was done 2 tests on Micronaire module (MIC), 6 tests on Length/Strength module (L/S) and 6 tests on Color/trash module (C/T). Two modes were used: *MIC Module Testing* and mode 4 of *System Testing* (setup with 1 repetition per module and Manual Mic entry allowed). Practically, each sample was first tested 2 times with *MIC Module Testing* so that the average of 2 could be entered afterwards manually in *System Testing* for 6 tests on same sample. From the 40g samples in the envelop, it was possible to use two times the 10g ± 0.5g needed for MIC module by taking cotton without preparation sampling procedure (transverse to cotton flow for raw samples). The rest was also taken without preparation for L/S and C/T modules.

6.2.2 - Data analysis

Data from SITC tests were imported in JMP (SAS Institute Inc.) for statistical interpretation. For each sample, average of 2 measurements of Mic remained from value entered, while means of 6 measurements were calculated for UHML, UI, Str, Rd and +b.

The first step in the variability study was to compare means among groups of samples. This was achieved by using Student's t test in JMP. Afterwards the study proceeded in calculating variances within groups of samples:

Groups of samples	Number of samples
Raw	20
Mixed	20
Mixed+doubling	20

6.2.3 - Results and discussions

It is initially expected that the homogenizing machine would have an impact on the variability of the results. Within-cotton variance of mixed samples should be lower than the one of raw superposed samples for the measured characteristics, especially for length and strength properties since the two cottons were chosen to be drastically different on these properties when mixed together.

Next figure illustrates strength property of cottons samples: mean line and standard deviations are represented per group of samples. From raw to mixed samples, the average stays similar, while the standard deviation of mixed samples is reduced.

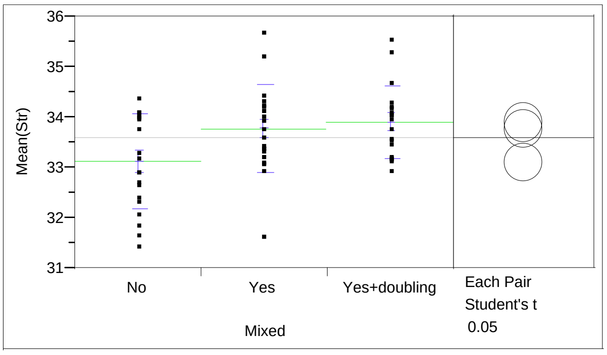


Figure 11. Analysis of Strength by Mixed? (no, yes or yes+doubling)

Calculating variance(raw)/variance(mixed) ratios is a way to appreciate the mixing effect of the experiment. The bigger the ratio, the more the variability from raw to mixed samples is lowered. In this study, high ratios would be an indication of fibres well mixed. Mean figures and variance results as a basis for calculating F-ratios are presented in Table 7. An interpretation of the table would be that the reduction of the variability from raw samples to mixed samples is easily observable and that the doubling procedure (constitution of layers) really offers better results.

	Parameter	Mean		Variance		F ratio	Pr>F	Trend to
Mixing		**Raw**	**M**	**Raw**	**M**			
	Mic	4.31	4.31	0.00234	0.00157	1.5	0.20	decrease
	UHML mm	29.70	29.57	0.20706	0.18532	1.1	0.41	decrease
	UI %	82.04	81.39	0.33311	0.74054	*2.2*	*0.04*	*increase*
	Str gf/tex	33.11	33.78	0.86485	0.75136	1.2	0.38	decrease
	Rd	79.39	79.68	0.04133	0.08167	*2.0*	*0.07*	*increase*
	+b	11.54	11.52	0.05980	0.04802	1.2	0.32	decrease
Mixing + Doubling		**Raw**	**M+D**	**Raw**	**M+D**			
	Mic	4.31	4.30	0.00234	0.00123	1.9	0.09	decrease
	UHML mm	29.70	29.52	0.20706	0.08164	2.5	0.02	decrease significantly
	UI %	82.04	81.38	0.33311	0.17115	1.9	0.08	decrease
	Str gf/tex	33.11	33.90	0.86485	0.50780	1.7	0.13	decrease
	Rd	79.39	79.68	0.04133	0.01154	3.6	0.00	decrease significantly
	+b	11.54	11.49	0.05980	0.01127	5.3	0.00	decrease significantly

Table 7. Results of mixing effect (M) and mixing associated to doubling effect (M+D)
F-ratio in italic: inverted from raw/M to M/raw in order to get F >1.

It is important to remind that the two HVICC standard cottons used in this study (Short-Weak and Long-Strong) were expressly chosen to be drastically different on their length and strength properties, so that their mix would result in high variability between raw superposed and mixed cottons. Since this is an extreme situation, it is assumed that next conclusions, drawn for mixing two types of cottons, would also be suitable for a part of a cotton bale to be homogenized for round tests.

The homogenizing machine enables to get high ratios for every criterion, particularly length and strength criteria, so the mixing effect can be considered as efficient: it ensures a decrease in within-cotton variability while mean values remain unchanged (gentle process). Furthermore, the additional doubling (layers piling up) offers possibility of greater variability decrease.

6.3 - Conclusion on simplified machine validation

It is essential that the raw material is homogenous before sending samples to laboratories. Establishing a homogenizing process is therefore necessary to reduce the variability of cotton which is going to be tested in different laboratories.

For CSITC Regional Round Tests in Africa, it is difficult to select homogeneous cotton bales. The results of the study showed that this can be solved by using the homogenizing machine in association with an easy doubling process. Indeed it ensures a decrease in within-cotton characteristics variability while mean values are stable: 4 kg of cotton fibre can easily be homogeneously sampled for participating laboratories.

All results were presented during the ITMF-ICCTM meeting in Bremen in March 2010.

7 - Deliver of the simplified machines to RTCs

A final CE conformity check for engine and low-voltage security was realised by a specialist from APAVE, France in the date of 18th January 2010.

The 2 machines could leave CIRAD, France on the 26th February 2010 for delivery to Regional Technical Centres. Transportation was made by a company subcontracted by SYDEL-SA. However, due to severe importation regulations in Mali and Tanzania, CIRAD was involved as the one exporting the goods for the project in contacting BIVAC International (Bureau Veritas in France) and TISCAN (COTECNA in France) for Mali and Tanzania respectively.

7.1 - RTC West: CERFITEX, Ségou, Mali

Inspection was done by Bureau Veritas before transportation on the 25th February 2010. The machine was confirmed to be out of customs clearance on the 19th March 2010 and confirmed to be received in laboratory premises on the 7th April 2010 by CERFITEX.

7.2 - RTC East: TBS, Dar Es Salaam, Tanzania

No inspection was asked to be done before transportation, but a commercial invoice was asked afterwards to CIRAD by COTECNA France when received in Dar Es Salaam airport. The machine was confirmed to be cleared at customs and received in laboratory premises on the 10th April 2010 by TBS.

In both situations, the machine was delivered together with the *User Manual* from the manufacturer SYDEL, and with a complementary *Operating Procedure* document given by CIRAD regarding the instructions of use and recommendations for preparing samples for Regional Round Trials.

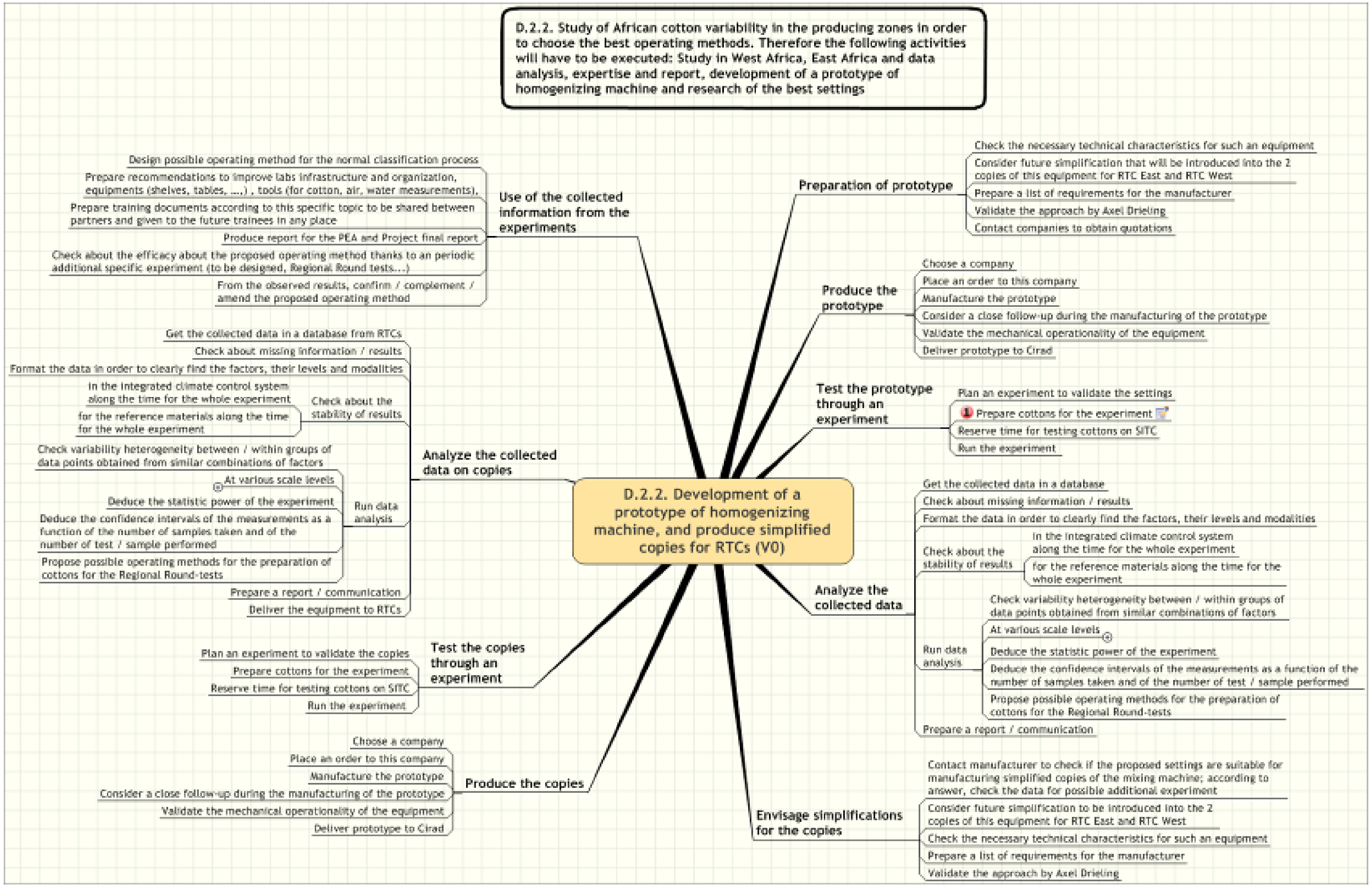


Figure 12: Overall sketch of procedure to achieve the production of two homogenizing machines.

Annex 1: List of cotton standards used for experiments

Cotton type	**SW**		**LS**		
Standard number	32142	31979	27855	28886	32415
IM	3.97	4.18	4.09	3.73	4.17
Strength	24.0	23.6	37.8	38.9	32.7
UHML mm	25.22	24.33	32.82	33.55	30.10
UI	80.2%	80.5%	84.3%	84.1%	83.9%
Experiment	Number used for SW		Number used for LS		
E0	x		x		
E1	x		x		
E2	x		x	x	
E3	x			x	
E4	x			x	
E6		x			x
E7		x			x
E8		x			x
E12		x			x
E13		x			x
E17		x			x
E18		x			x
E22		x			x
E23		x			x
E27		x			x
E28		x			x

Table 8. Cotton standards used for experiments for prototype validation

Cotton type	**SW**	**LS**
Standard number	33243	33389
IM	4.40	3.96
Strength	25.6	36.7
UHML mm	25.30	31.29
UI	79.9%	85.0%

Table 9. Cotton standards used for experiments for copies validation

Annex 2: Summary speeds tables for main experimentations

Pairs of cylinders speeds A - Applicable for Experiments 1, 6					
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
4	out	220	11	4,9	Same drafting settings as CIRAD micro-spinning machine
3		45	2,3	1,3	
2		35	1,8	1,8	
1	in	20	1		

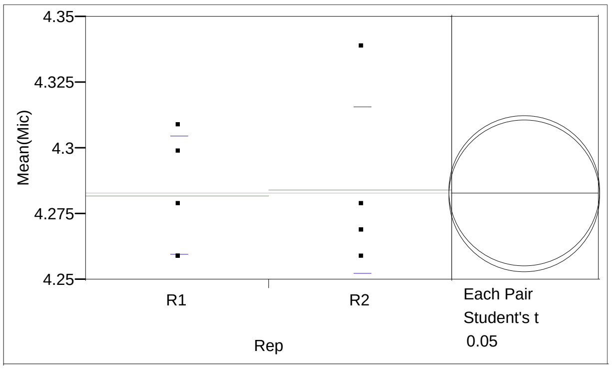
Pairs of cylinders speeds B - Applicable for Experiments 2, 7, 12, 17, 22, 27					
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
4	out	280	14	6,2	Maximum outlet speed, no other modification (compared with A)
3		45	2,3	1,3	
2		35	1,8	1,8	
1	in	20	1		

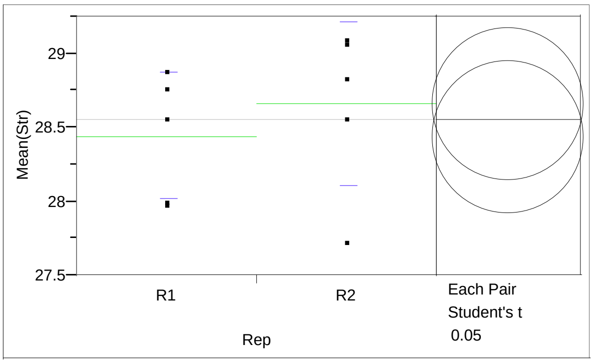
Pairs of cylinders speeds C - Applicable for Experiments 3, 8, 13, 18, 23, 28					
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
4	out	280	18,7	4	Maximum outlet speed, lower inlet speed and redistribution of drafting ratios (compared with A)
3		70	4,7	1,9	
2		37,5	1,9	2,5	
1	in	15	1		

Pairs of cylinders speeds D - Applicable for Experiments 4, 9					
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
4	out	280	28	4	Maximum outlet speed, lower inlet speed and redistribution of partial drafting ratios, increasing to outlet (compared with A)
3		70	7	2,8	
2		25	2,5	2,5	
1	in	10	1		

Pairs of cylinders speeds E - Applicable for Experiments 5, 10					
Pair of cylinders	Way	Motor speed (rpm)	Total drafting ratio	Partial drafting ratio	Hypothesis
4	out	220	11	3,1	Same inlet and outlet speeds, and redistribution of partial drafting ratios, increasing to outlet (compared with A)
3		72	3,6	2	
2		36	1,8	1,8	
1	in	20	1		

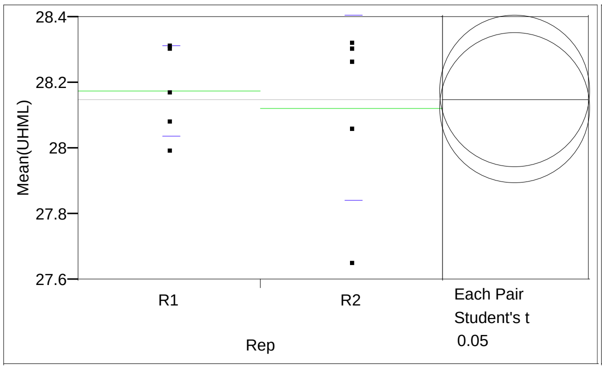
Annex 3: Analysis of all criteria By Repetition R1 or R2 for mixed samples of E7

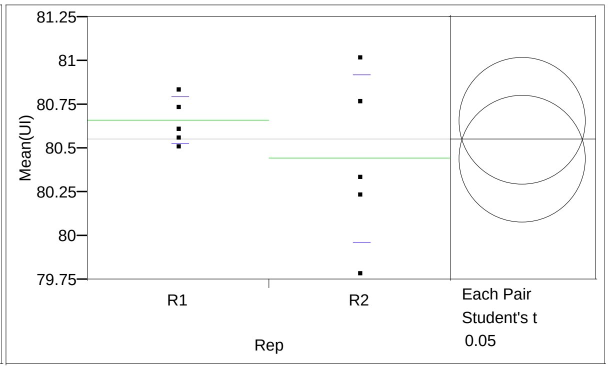




Oneway Analysis of Mean(Mic) By Rep

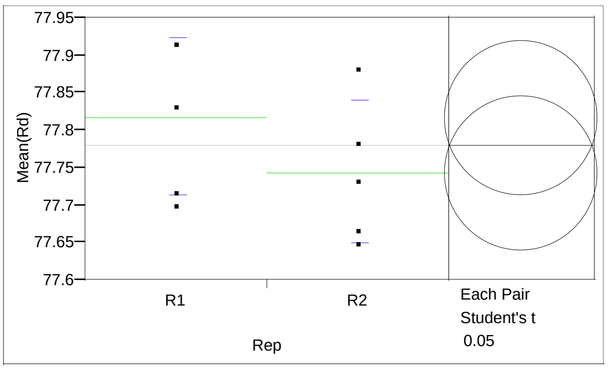
Oneway Analysis of Mean(Str) By Rep

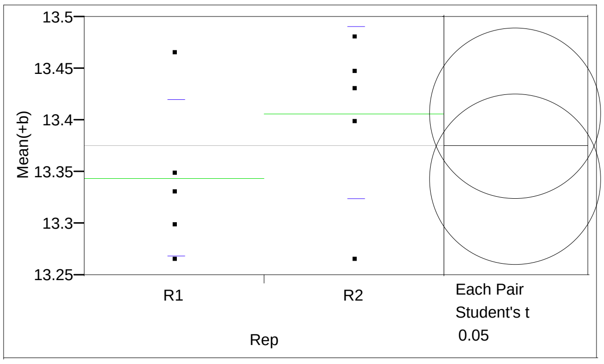




Oneway Analysis of Mean(UHML) By Rep

Oneway Analysis of Mean(UI) By Rep

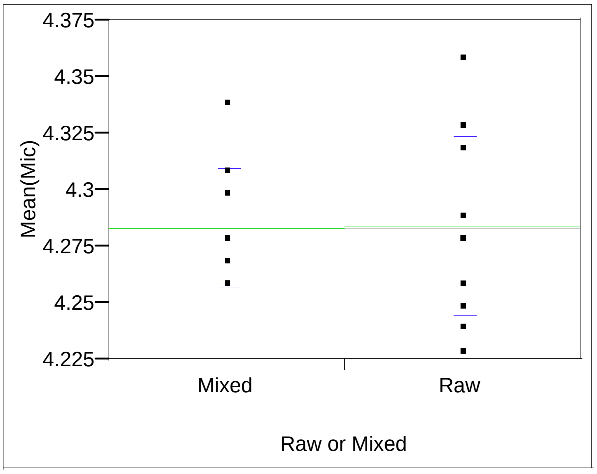




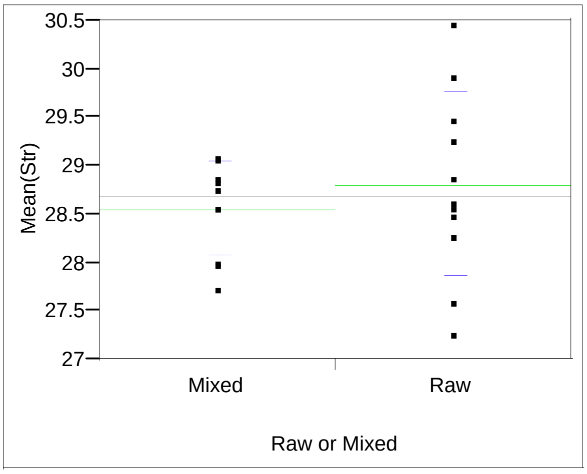
Oneway Analysis of Mean(Rd) By Rep

Oneway Analysis of Mean(+b) By Rep

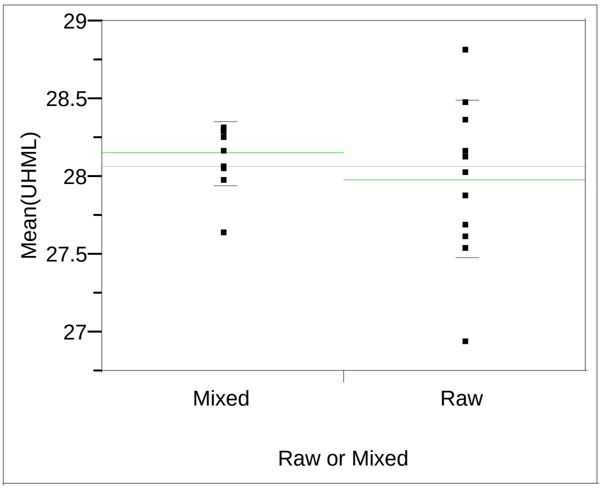
Annex 4: Analysis of all criteria By Raw or Mixed for all samples of E7



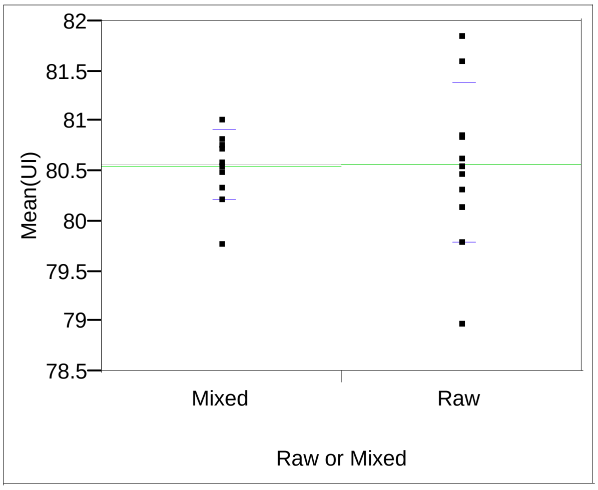
Oneway Analysis of Mean(Mic) By Raw or Mixed



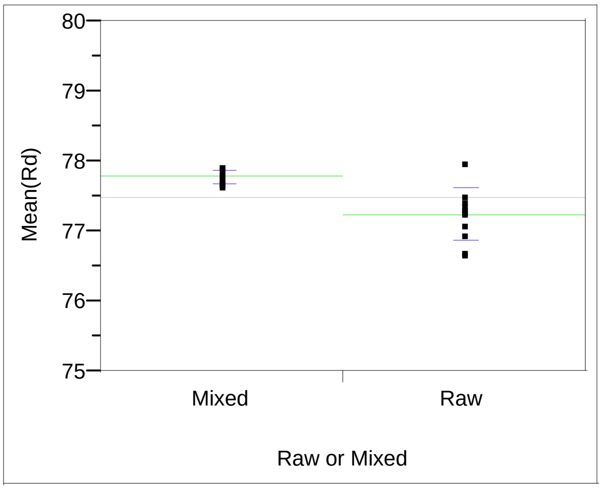
Oneway Analysis of Mean(Str) By Raw or Mixed



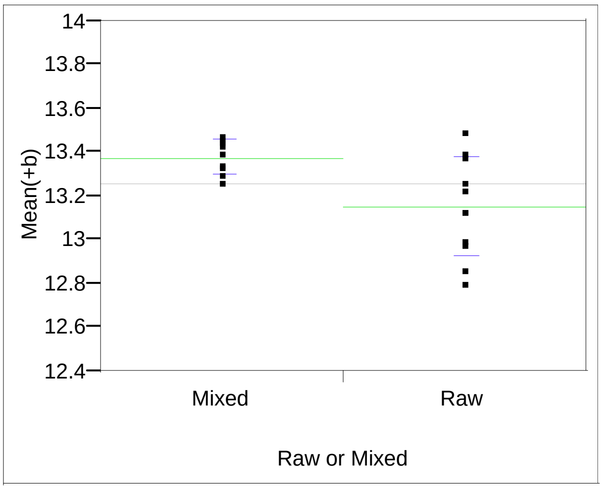
Oneway Analysis of Mean(UHML) By Raw or Mixed



Oneway Analysis of Mean(UI) By Raw or Mixed



Oneway Analysis of Mean(Rd) By Raw or Mixed



Oneway Analysis of Mean(+b) By Raw or Mixed

Annex 5: Comparison between groups of experiments of situation 2 and 3 to come to a conclusion on a specific setting for distances

The study aims to compare groups of four experiments set with distances 1 and distances 2, in order to determine whether or not there is a setting of distances that gives largely better variability results than the other. This was done for juxtaposed cottons. It is interesting to check that the conclusion is similar in other cotton feeding situations (superposed cottons).

<u>Situation 2</u>

Variance results are presented in Table 10, as a basis for next calculations. 'RAW-sup' refers to raw samples of experiments E12, E13, E17 and E18 ; so it is 40 samples in a same group since cottons are fed the same way before mixing (in superposition).

	N Rows	Var(Mic)	Var(UHML)	Var(UI)	Var(Str)	Var(Rd)	Var(+b)
RAW-sup	40	0.0018	0.23	0.32	1.04	0.055	0.020
E12-mixed	10	0.00057	0.065	0.25	0.34	0.0062	0.0077
E13-mixed	10	0.00049	0.15	0.18	0.58	0.0084	0.0068
E17-mixed	10	0.0011	0.060	0.095	0.26	0.016	0.0027
E18-mixed	10	0.00042	0.055	0.15	0.25	0.048	0.0049

Table 10. Variance between 10 or 40 samples per experiment for E12, E13, E17 and E18 (From means of 2 tests: Mic or 6 tests: UHML, UI, Str, Rd, +b)

A sorting was elaborated individually from the variance(raw)/variance(mixed) ratios of the six characteristics (see Table 11). The ratios of characteristic x are mentioned as [x] in next tables.

	[Mic]	[UHML]	[UI]	[Str]	[Rd]	[+b]
RAW-sup / E12-mixed	3.20 *	3.57 *	1.27 £	3.10 *	8.80 **	2.60 $
RAW-sup / E13-mixed	3.75 *	1.52 £	1.74 $	1.80 $	6.48 **	2.94 *
RAW-sup / E17-mixed	1.72 $	3.91 *	3.37 *	4.05 *	3.49 *	7.48 **
RAW-sup / E18-mixed	4.33 **	4.23 **	2.18 $	4.12 *	1.15 £	4.08 *

Table 11. Variance(raw)/variance(mixed) ratios [x] for E12, E13, E17 and E18

<u>Legends</u>: Test F 40/10

**	level of significance 1%	> 4,17	*	level of significance 5%	2,66 < < 4,17
$	level of significance 25%	1,51 < < 2,66	£	level of significance 50%	1,05 < < 1,51

Each experiment was then given a grade from 1 to 4 according to its performances for each of the six characteristics (see Table 12). It was chosen to use the ratio data rounded to the first decimal, ranking with a tolerance of ratio ± 0.5, so that when ratio δ equals ratio γ ± 0.5, then δ and γ are associated to the same grade (mean of two ranks, e.g. grade 3.5 for ranks 3 and 4)

Experiment	[Mic]	Grade
18	4.3 **	1
13	3.8 *	2
12	3.2 *	3
17	1.7 $	4

Experiment	[UHML]	Grade
18	4.2 **	1
17	3.9 *	2.5
12	3.6 *	2.5
13	□.5 £	4

Experiment	[UI]	Grade
17	3.4 *	1
18	2.2 $	2
13	1.7 $	3.5
12	1.3 £	3.5

Experiment	[Str]	Grade
18	4.1 *	1.5
17	4.0 *	1.5
12	3.1 *	3
13	1.8 $	4

Experiment	[Rd]	Grade
12	8.8 **	1
13	6.5 **	2
17	3.5 *	3
18	1.1 £	4

Experiment	[+b]	Grade
17	7.5 **	1
18	4.1 *	2
13	2.9 *	3.5
12	2.6 $	3.5

Table 12. Grades per criteria, based on variance(raw)/variance(mixed) ratios [x] for E12, E13, E17 and E18

Conclusion for situation 2

From Table 12, it can be deduced that E17 gets better grades than E12 for 3 criteria over 6 (UI, Str, +b) and the same grade for UHML. Likewise, E18 gets better grades than E13 for any criterion except Rd. Consequently, it can be drawn that: no matter the speeds setting, experiments using setting distances 2 allow a greater reduction of the variability of many more criteria than experiments using setting distances 1 in this situation.

Situation 3

Variance results are presented in Table 13, as a basis for next calculations. 'RAW-sup' refers to raw samples of experiments E22, E23, E27 and E28 ; so it is 40 samples in a same group since cottons are fed the same way before mixing (in superposition).

	N Rows	Var(Mic)	Var(UHML)	Var(UI)	Var(Str)	Var(Rd)	Var(+b)
RAW-sup	40	0.0018	0.23	0.32	1.04	0.055	0.020
E22-mixed	10	0.00048	0.12	0.15	0.13	0.019	0.0068
E23-mixed	10	0.00040	0.076	0.24	0.15	0.020	0.0067
E27-mixed	10	0.00041	0.063	0.23	0.53	0.012	0.0023
E28-mixed	10	0.00049	0.017	0.034	0.19	0.031	0.0054

Table 13. Variance between 10 or 40 samples per experiment for E22, E23, E27 and E28 (From means of 2 tests: Mic or 6 tests: UHML, UI, Str, Rd, +b)

A sorting was elaborated individually from the variance(raw)/variance(mixed) ratios of the six characteristics (see Table 14). The ratios of characteristic x are mentioned as [x] in next tables.

	[Mic]	[UHML]	[UI]	[Str]	[Rd]	[+b]
RAW-sup / E22-mixed	3.79 *	1.89 $	2.18 $	7.82 **	2.92 *	2.94 *
RAW-sup / E23-mixed	4.54 **	3.07 *	1.36 £	7.00 **	2.72 *	2.99 *
RAW-sup / E27-mixed	4.48 **	3.71 *	1.37 £	1.95 $	4.74 **	8.55 **
RAW-sup / E28-mixed	3.74 *	13.95 **	9.48 **	5.58 **	1.75 $	3.66 *

Table 14. Variance(raw)/variance(mixed) ratios [x] for E22, E23, E27 and E28

Legends: Test F 40/10

**	level of significance 1%	> 4,17	*	level of significance 5%	2,66 < < 4,17
$	level of significance 25%	1,51 < < 2,66	£	level of significance 50%	1,05 < < 1,51

Each experiment was then given a grade from 1 to 4 according to its performances for each of the six characteristics (see Table 15).

Experiment	[Mic]	Grade
E23	4.5 **	1.5
E27	4.5 **	1.5
E22	3.8 *	3.5
E28	3.7 *	3.5

Experiment	[UHML]	Grade
E28	14.0 **	1
E27	3.7 *	2
E23	3.1 *	3
E22	1.9 $	4

Experiment	[Rd]	Grade
E27	4.7 **	1
E22	2.9 *	2.5
E23	2.7 *	2.5
E28	1.8 $	4

Experiment	[Str]	Grade
E22	7.8 **	1
E23	7.0 **	2
E28	5.6 **	3
E27	2.0 $	4

Experiment	[UI]	Grade
E28	9.5 **	1
E22	2.2 $	2
E27	1.4 £	3.5
E23	1.4 £	3.5

Experiment	[+b]	Grade
E27	8.5 **	1
E28	3.7 *	2
E23	3.0 *	3
E22	2.9 *	4

Table 15. Grades per criteria, based on variance(raw)/variance(mixed) ratios [x] for E22, E23, E27 and E28

Conclusion for situation 3

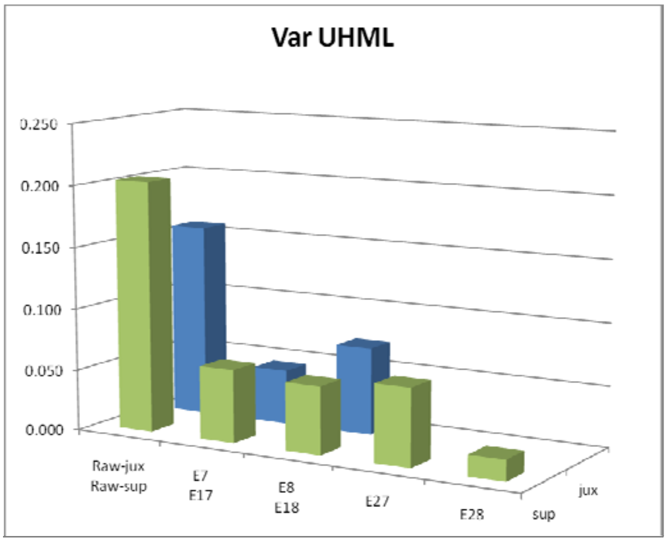
From Table 15, it can be deduced that E27 gets better grades than E22 for 4 criteria over 6 (Mic, UHML, Rd and +b). Likewise, E28 gets better grades than E23 for 4 criteria over 6 (UHML, UI, Rd and +b). Consequently, it can be drawn that: no matter the speeds setting, experiments using setting distances 2 allow a greater reduction of the variability of many more criteria than experiments using setting distances 1 in this situation.

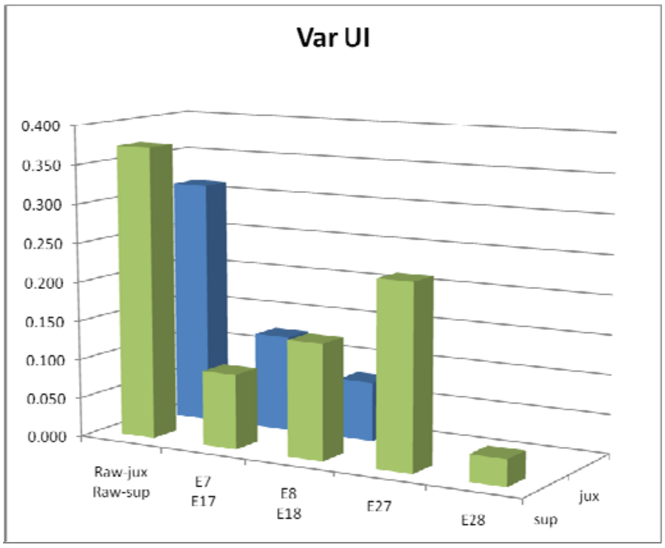
Final conclusion

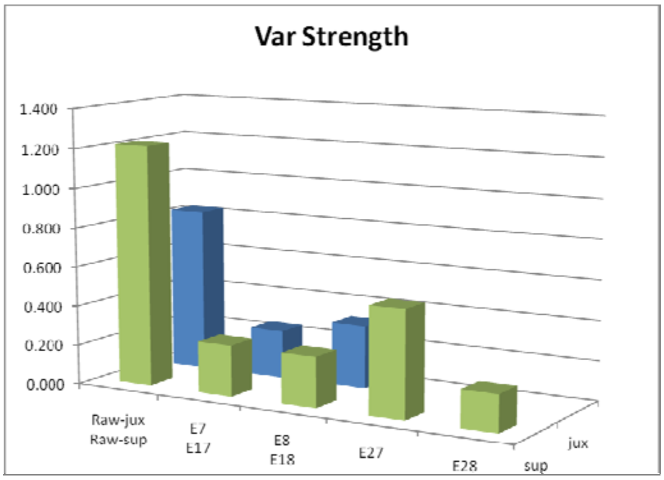
Therefore it is possible to conclude that no matter the speeds setting and no matter the situation (feeding protocol), a specific setting of the distances enables to get high ratios, so fibres well mixed. It is then recommended to use the homogenizing machine by setting the distances between pairs of rolls as following: L+5 between 1 and 2, L+10 between 2 and 3 and L+10 between 3 and 4 (distances 2).

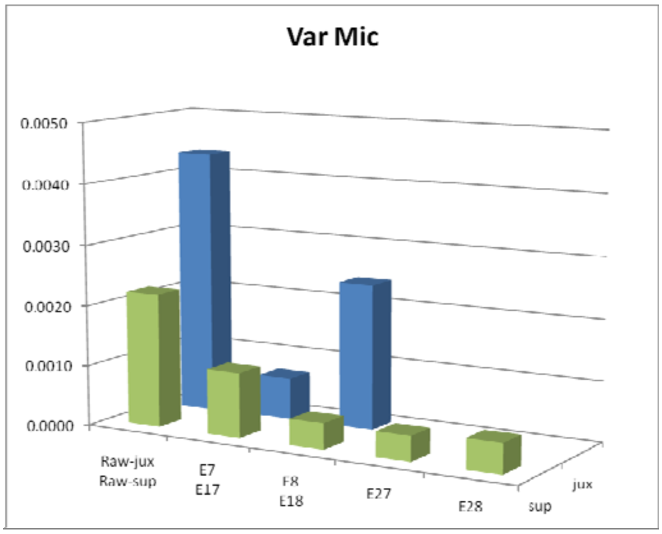
Annex 6: Variances between samples for main experiments (distance 2)

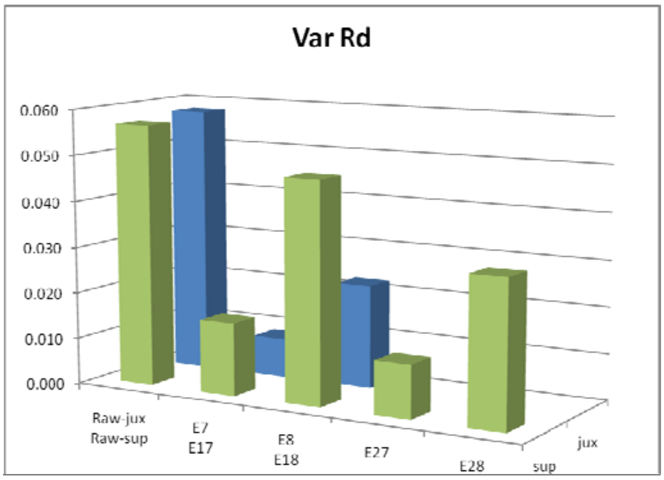
Calculated from means of 2 results (IM) or 6 results (UHML, UI, Str, Rd, +b) for 20 raw samples and 10 mixed samples

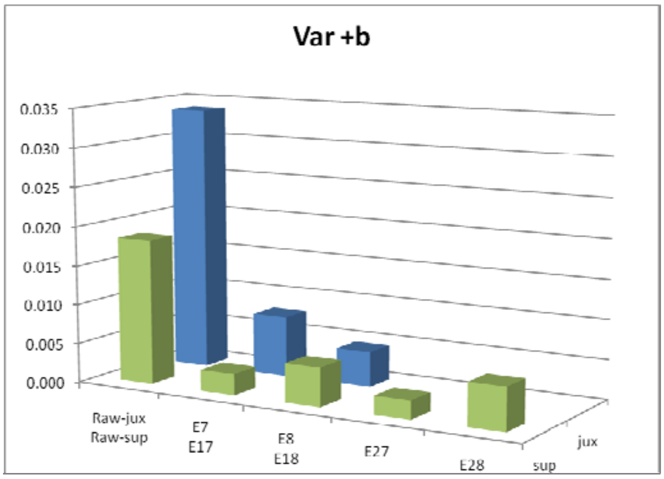






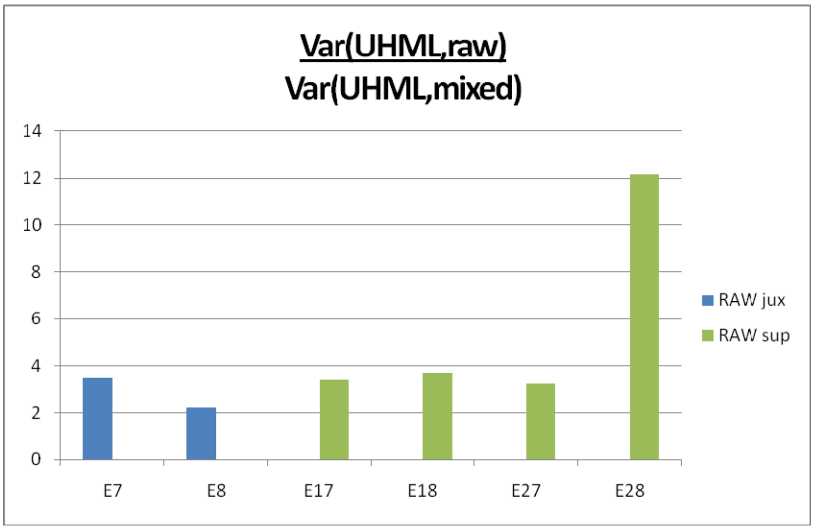

Var Mic
0.0050
0.0040
0.0030
0.0020
0.0010
0.0000
Raw-jux
Raw-sup
E7
E17
E8
E18
E27
E28
jux
sup

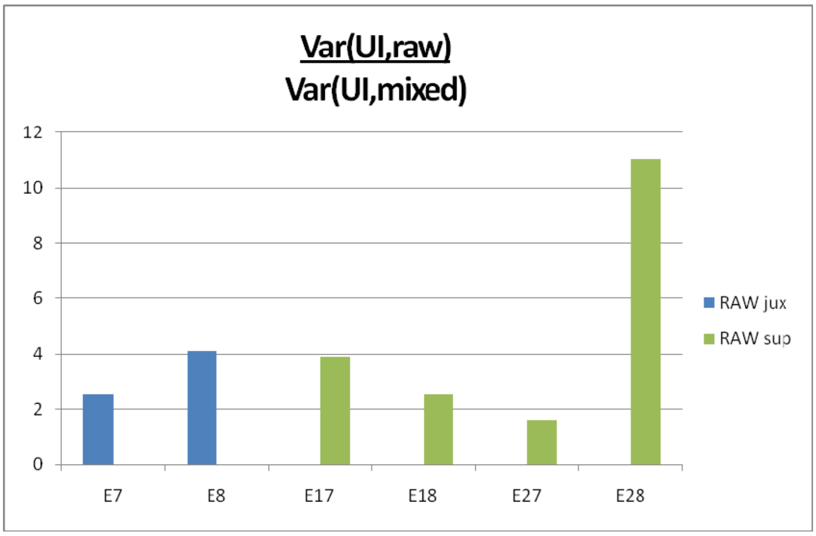

Var Rd
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Raw-jux
Raw-sup
E7
E17
E8
E18
E27
E28
jux
sup

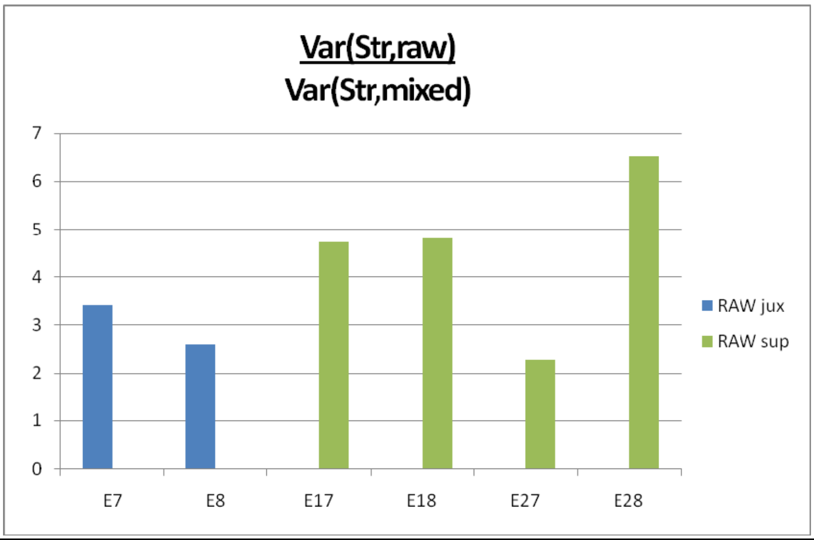

Var +b
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Raw-jux
Raw-sup
E7
E17
E8
E18
E27
E28
jux
sup

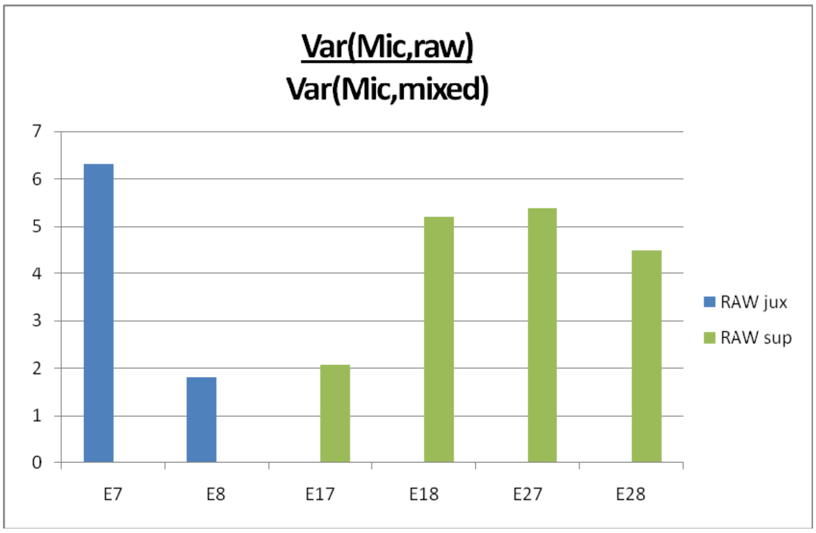
Annex 7: Variance(raw)/variance(mixed) ratios for main experiments (distance 2)

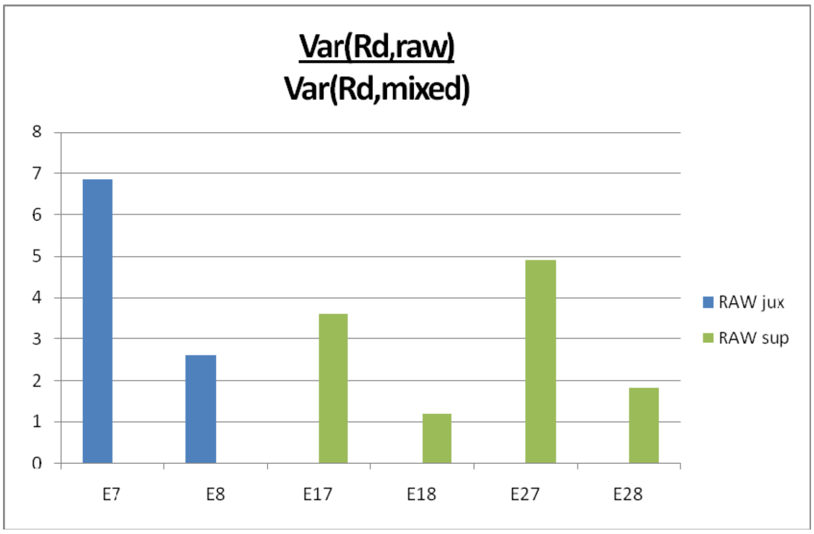
Calculated from previous calculated variances for 20 raw samples and 10 mixed samples

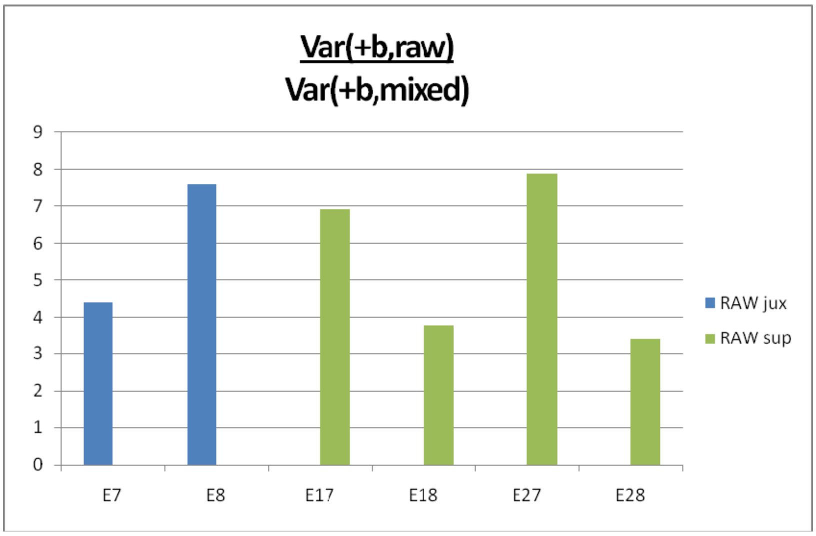







Var(Mic,raw)
Var(Mic,mixed)
7
6
5
4
3
2
1
0
E7
E8
E17
E18
E27
E28
RAW jux
RAW sup


Var(Rd,raw)
Var(Rd,mixed)
8
7
6
5
4
3
2
1
0
E7
E8
E17
E18
E27
E28
RAW jux
RAW sup


Var(+b,raw)
Var(+b,mixed)
9
8
7
6
5
4
3
2
1
0
E7
E8
E17
E18
E27
E28
RAW jux
RAW sup