IMPROVEMENT OF HVI MEASUREMENT PRECISION PART 2: USE OF HVI FOR BREEDING PROGRAMS: MCI SAMPLING DEVICE IMPROVEMENT

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Summary

HVI data produced for commercial purposes is insufficiently precise for use by breeders. Improving the precision of the HVI data is studied on a wide range of saw- or roller-ginned cottons either of commercial origin or aquired from breeding programs. The effects of manually mixing the samples before analysis is tested. Different configurations: MCI-Universal-sampler, MCI-Fibrosampler and ZUS-Fibrosampler are compared. Measurement precision for the different types of cotton is given for each configuration in relation to the number of specimens per sample. Precision is expressed as confidence interval for Upper Half Mean Length, Mean Length, Uniformity Index and Strength. Certain configurations give precision values compatible with breeding work using less than 10 specimens per sample.

Introduction

High Volume Instrument (HVI) measurement lines have been developed to improve the commercial classification of cottons. These instruments furnish an objective measurement of several fiber characteristics, some of which are of particular importance for fiber behavior during spinning (spinability). This advantage, associated with the rapidity and reliability of the measurements, corresponds to the requirements of the cotton industry. Since they first appeared in 1980, the number of HVI lines in use has continually progressed and an increasing segment of world fiber production is now classified in this way.

The production of high quality fiber is one of the major aims of varietal improvement programs and over the last few years, researchers have been using HVI analysis of their vegetal material (Dever and Gannaway, 1987; Meredith, 1991) to:

- create true evaluation conditions. Some genotypes may analyse differently on conventional equipment and on HVI lines (Brown and Taylor, 1988)
- rapidly produce results and reduce analysis costs.

The HVI analysis method employed in the USA to classify commercial cottons (2 to 4 measurements per bale) gives precisions compatible with trading requirements (Sasser, 1992). By contrast, this precision is insufficient for breeders who need data of higher precision for cottons that are often less homogeneous (Cooper et al., 1988; Green and Culp, 1990).

The cotton technology laboratory at Cirad-CA analyses numerous cottons acquired from breeding programs. The HVI data it produces for these cottons must show the same precision as that furnished by conventional equipment (Table 1). A preliminary study conducted by the laboratory on the Zellweger Uster/Spinlab (ZUS) length/strength 910 B module showed that the precision required can be obtained when 10 measurements are taken for each cotton sample that has previously been opened manually (Gourlot and Héquet, 1994). A further study showed that the Motion Control Inc (MCI) 3500 system required far more measurements both with the Pinch sampler and the Universal sampler (Gourlot et al., 1996).

The study presented in this paper supplements those cited above. Its objectives were:

- to compare the two systems as regards their precision over a wide range of cottons.
- identify the reasons for the lower precision of the MCI 3500 system, if confirmed.
- develop a technique or a method to improve this precision.
- establish usage norms for the two systems using cottons acquired from breeding programs.

Materials and Methods

The Zellweger Uster system used was composed of a length/strength 910 B module and a Fibrosampler 192. The MCI 3500 system was composed of a full line fitted with a Universal sampler. The two systems used micronaire value to determine strength. For each sample, the same micronaire value is used for the two systems, for all the the specimens. This therefore eliminated any variation between strength results due to micronaire variations. The micronaire value was measured on the MCI system. The two systems were calibrated twice daily using the standard procedure. The two HVICC cottons used covered the range of cottons analyzed. The following characteristics were measured: ML and UHML length, Pressley 1/8 strength (STR) and elongation (EL). The maximum number of measurements authorized for each cotton was used systematically by the software, i.e. 10 for ZUS and 16 for MCI. The cottons were prepared for 48 h then analyzed under standard conditions of relative humidity (RH = 65 % ± 2 %) and temperature (T = 21°C ± 0.5°C).

Experiment 1

The primary objective was to compare the precision of the measurements made by the two systems. The secondary

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objective was to confirm the impact made by manually opening the samples before analysis on the precision of the measurements made by each of the two systems.

In order to fully represent the diversity of the cottons commonly analyzed in the laboratory, 99 cottons of various origins were selected from the Cirad-CA fiber bank. 49 of these come from roller ginning and 50 from saw ginning (Table 2). Saw ginned cottons included commercial cottons and cottons acquired from breeding programs conducted in various countries. Most of the roller ginned cottons were acquired from breeding programs. For each cotton, a mass of 300 grams of fiber was divided into 4 representative and independent samples. Two of these were opened manually. Each line received two samples of the same cotton, one opened, the other in its raw condition. The order in which the 198 samples (99 raw cottons, 99 opened cottons) were analyzed by the two lines was randomized. For practical reasons, the analyses were performed at a rate of 20 samples/day on both systems. The variance between the specimens was calculated for each of the samples analyzed (within-sample variance).

Experiment 2

The aim was to identify why measurements on the MCI system were less precise.

The analysis procedure on the two systems is composed of two main steps, i.e. sampling and measurement. Sampling comprised taking the specimen, then combing and brushing. The difference in precision between MCI and ZUS may have been due to the sampling procedure, the measuring method or both combined. To chose between these three possibilities, the precision of the systems was compared by using a common sampling device (ZUS) and the measurement unit inherent to each of the two systems. If the difference in precision is still present, this shows that the problem lies with the MCI measurement device. If the precision of the two systems are more similar, this shows that the problem lies with the MCI sampling device.

The MCI sampling system is different from that used by the ZUS. With the MCI, the fibers are removed from the surface of the sample using a comb (4 teeth/cm) then transferred into the clamp. The combing and brushing take place after the pinching. The ZUS system takes fibers using a comb (6 teeth/cm), and these are combed before pinching, and are then brushed.

Using a common sampling device required the construction of a special clamp, manufactured from a ZUS comb and an MCI clamp (Figure 1). The piece of ZUS comb used is essential for the Fibrosampler. Its length was compatible with the MCI measurement slit. The MCI clamp, shortened by the thickness of the comb, allowed the new device to be positioned on the MCI measurement heads. Specimens were taken by the Fibrosampler using the comb part. After closing and brushing on the ZUS, this part was placed on the clamp mounting for analysis on the MCI. Specimen width was 53 mm.

This study used the same cottons as the previous study. Only the samples opened by hand were used. The order in which the 99 samples were analyzed by the two lines was randomized. The variance between the specimens was calculated for each of the samples analyzed (within-sample variance). The following variables were compared : ML and UHML length and strength. Uniformity was not taken into account as this is calculated, not measured, by deduction from ML and UHML. Elongation was not taken into account as no calibrations had been performed for this parameter and the differences in levels between the two systems could have hindered any comparison of their precisions.

Results and Discussion

The precisions of the two HVI systems (or the two preparation methods) were compared by considering within-sample variances using an F test.

$$F_{obs} = \frac{\sigma^2_{(n-1)}\ (MCI)}{\sigma^2_{(n-1)}\ (ZUS)} \quad ou \quad F_{obs} = \frac{\sigma^2_{(n-1)}\ (Raw)}{\sigma^2_{(n-1)}\ (Open)}$$

If the observed F is greater than the theoretical F at the significance threshold selected, then the variances are considered to be different.If the variances between the different samples are homogeneous (Bartlett's test), the F test may be applied to the mean variances. This provides a precise comparison because of the large number of degrees of freedom.

When variance heterogeneity is noted, another statistical technique may be employed to take account of all the samples. The F value is calculated from the ratio of the variances of the two systems (or the two preparations), sample by sample. To each F value corresponds a Pi probability of exceeding the threshold. The Napierian log of Pi follows a Chi² (χ^2) rule with 2 degrees of freedom.

$$\chi^2_{obs} = \sum_{i=1}^{i=n} 2 * Ln\ (P_i)$$

with 2n degree of freedom,
n = number of samples

The probability of exceeding χ^2_{obs} provides an overall evaluation of the difference between the variances, and therefore between the precisions of the two systems. However, it is impossible to use the mean variance to calculate the mean confidence interval for each system.

Experiment 1

The comparison between the MCI-Universal sampler and the ZUS systems was conducted in relation to type of

ginning and type of preparation (4 cases). The effect of manually preparing the samples was determined for each system and each ginning type (4 cases). In all cases studied, Bartlett's test showed heterogeneity of the within-sample variances. The variances between the systems or between the preparations were therefore compared using the χ^2 technique.

Comparison of the HVI systems

When considering the saw- or roller-ginned cottons, either opened or raw, the probability of exceeding χ^2_{obs} was always less than p = 0.001 for all the characteristics measured. The MCI within-sample variance was in all cases significantly higher than for the ZUS. Therefore, on the range of cottons tested, the MCI data were significantly less precise than those furnished by the ZUS (Figure 2).

Comparison of the preparation methods

Table 3a and 3b present the probabilities of exceeding χ^2_{obs} for the different HVI system-ginning combinations.

On the MCI system, it can be seen that the within-sample variances for roller-ginned raw cottons were statistically higher than for the opened cottons. Manually opening the samples before analysis therefore improves the precision of the measurements taken after roller ginning. As far as saw ginned cottons are concerned, only uniformity of length and strength showed significantly better precision after opening.

On the ZUS system, opening the roller-ginned cottons significantly improved measurement precision for all the characteristics considered. This same effect was seen for saw-ginned cottons for all the characteristics excepting uniformity of length. A general improvement was therefore noted in precision after opening.

Only opened cottons were used in experiment 2.

Experiment 2

A rigorous comparison of the two systems using a common sampling device presupposed that the specimens used were of the same size. In fact, the length of the MCI measurement slit required a narrower specimen than those analyzed on the ZUS, i.e. a ratio of 0.75. For the type of variables studied (length and strength) proportionality exists between the inter-specimen variance and the size of the specimens. This ratio must therefore be taken into consideration when comparing the within-sample variances of the two systems. To do this, the within-sample variances given by the MCI were multiplied by 0.75. The F ratio observed thus becomes:

$$F_{obs} = \frac{0.75 * \sigma^2_{(n-1)}\ (MCI)}{\sigma^2_{(n-1)}\ (ZUS)}$$

Comparison of the MCI and ZUS systems when fitted with a common sampling device

Table 4 presents the probabilities of exceeding χ^2_{obs} for the two types of ginning and the 3 variables considered. In 4 cases out of 6 the probability of exceeding χ^2_{obs} was far greater than the p = 0.05 threshold, thus indicating that the two systems gave similar within-sample variances (Figure 3). In these 4 cases, replacing the MCI sampler by the ZUS sampler gave the same measurement precision with the MCI as with the ZUS. The MCI sampling system is therefore responsible for the lower precision observed in previous studies for these 4 cases.

MCI within-sample variance remained significantly higher than that observed with the ZUS for ML after roller ginning and STR after saw ginning.

The two systems use different calculation methods to evaluate ML. MCI uses the entire fibrogram whereas ZUS uses span length. The MCI calculation may be more sensitive to the considerable inter-specimen variability shown by cottons that have been roller ginned.

The length-strength module on the MCI is covered by a hood. A study conducted in the laboratory using 2 HVICC (bales 27985 and 28484) showed that a strength drift occurs over time when measurements are taken with the hood closed. After operating for 30 to 60 minutes, the strength level exceeds the tolerance required for calibration. No drift is observed when measurements are taken with the hood open (Figure 4). The fact that the elevator motors are close to the strain gauge leads to considerable heating of the gauge when the hood is closed. The gauge's characteristics are changed whereas the calibration curve remains the same. This therefore has an impact on the quality of the strength measurements given:

- the strength of cottons analyzed during and after the drift is underestimated.
- within-sample variance is increased for samples analyzed during the drift phase (performing 16 measurements for a sample on the MCI using a Fibrosampler takes about 15 minutes).

In the study presented here, the cottons that had undergone saw ginning were analyzed with the hood closed. By contrast, those that had been roller ginned had to be analyzed with the hood open as the operator checked that the specimen presented correctly in relation to the measurement slit (long fibers).

Comparison of the within-sample variances obtained on the MCI fitted with a Fibrosampler or a Universal sampler

Replacing the Universal sampler with the Fibrosampler produced an overall decrease in within-sample variance. This was the case for both types of ginning and for the 3 characteristics measured. Figures 5 and 6 show the UHML

obtained after saw ginning and strength after roller ginning.

Determination of the confidence intervals in relation to the number of specimen per sample

To calculate the confidence interval for a mean of n measurements valid for all the samples, it was necessary to determine mean within-sample variance. Calculation of the mean variance is only possible if the individual within-sample variances are homogeneous. Bartlett's test was used to test the homogeneity hypothesis for p variances by calculation of $\chi^2_{observed}$ compared with a $\chi^2_{theoretical}$ at p-1 degrees of freedom and for a given α risk.

If the variances are homogeneous, the mean confidence interval valid for all the samples is calculated by:

$$Confidence\ interval = Mean \pm \frac{t_{(1-\alpha/2)} * \sigma}{\sqrt{n}}$$

t = Student's distribution variable, p(n-1) df
α = type I risk
σ = mean standard deviation (n-1 df)
n = number of measurements per sample

The confidence interval is an expression of the precision of the mean of the measurements. It changes with the number n of measurements taken.

If the variances are not homogeneous, one of the following methods may be used to calculate the confidence interval:

- transformation of the basic data to render the variances homogeneous
- constitution of subsets of cottons showing homogeneous variances
- consideration of a level of variance corresponding to (100-x) % of the cumulated distribution of the variances as the basis of the calculation.

Choosing 95 % of the distribution gives a very wide safety margin (Figure 7).

Table 5 presents the results of Bartlett's test when applied to the different configurations (MCI Universal sampler, MCI Fibrosampler, ZUS Fibrosampler), using manually opened cottons. With only a few exceptions, the within-sample variances were heterogeneous. The confidence interval could not therefore be calculated directly.

None of the basic data transformations was able to homogenize the variances.
The cottons tested were of very varied origins and of different types. It is therefore not surprising that, when considered as a set, their within-sample variances appear as heterogeneous. Four cotton subsets were identified:

- 18 roller-ginned cottons, species *G. barbadense* (long, fine and resistant fibers)
- 31 roller-ginned cottons, species *G. hirsutum* (medium long, fine and resistant fibers)
- 39 saw-ginned cottons, commercial type produced by industrial ginning
- 11 saw-ginned cottons, research type, produced by varietal tests, ginned in a micro-mill.

These 4 groups of cottons may behave differently during HVI analysis.

Bartlett's test was applied to the non-transformed data for each of the 4 groups and for each of the 3 configurations used. The results obtained are presented in Tables 6, 7 and 8.

The probability of exceeding the threshold was not significant for a considerable number of cases. The two groups produced by roller ginning and the research-type cottons that had been saw-ginned generally gave homogeneous variances.

The group of commercial saw-ginned cottons showed generally heterogeneous variances. The diversity of their growing conditions and the industrial ginning processes employed may in part explain this.

When the variances were homogeneous, the confidence interval was calculated from the mean variance. In other cases, the confidence interval was calculated from the variance corresponding to 95 % of the cumulated distribution for the variances in the group.

Table 9 presents the precision of the measurements in the form of confidence intervals for each of the 4 cotton groups, for each HVI configuration used and for each variable measured (ML, UHML and STR). The confidence intervals calculated using 95 % variance are marked with a (*).

Variations in the confidence interval in relation to the number of measurements taken per sample are presented in Figures 8 to 11 (UHML and STR for commercial saw-ginned cottons and research roller-ginned *G. hirsutum* cottons).

The precision obtained on the MCI 3500 was markedly improved by use of the Fibrosampler. If an equivalent number of measurements per sample is considered, the precision obtained on the MCI-Fibrosampler was very similar to that obtained on the ZUS.

Conclusion

The following conclusions may be drawn from the two experiments conducted in the course of this study to improve the precision of HVI measurements:

Opening the cotton samples by hand before the analysis improved measurement precision regardless of the type of cotton and the HVI system employed.

The MCI 3500 system fitted with the Universal sampler taking 16 measurements per sample, gave less precise results than the ZUS system taking 10 measurements per sample. The sampling device used by the MCI system (Universal sampler + combing and brushing) is the main cause of this.

Replacing the Universal sampler with a Fibrosampler followed by brushing on the ZUS system improved MCI precision to that of the ZUS.

With MCI system, a strength drift over time occurs, when measurements are taken with the length-strength module covered.

The study determined confidence intervals for each of the main cotton groups commonly used in the laboratory. These intervals were established for the different HVI configurations studied.

Analysis of the MCI system fitted with the Fibrosampler, as used in this study, requires repeated handling operations. Under these conditions, the time required to analyse a sample, taking 16 measurements, is about 15 minutes. To render its use more practical, the MCI line would need to be fitted with an automatic Fibrosampler-type sampling device.

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Table 1 : precisions sought by the laboratory

Characteristic	95 % confidence interval
2.5 % Span Length	± 0.5 mm
Uniformity ratio	± 1.5 %
Stelometric strength	± 1.0 g/tex
Stelometric elongation	± 0.6 %
Micronaire	± 0.1

Table 2 : origin of the cottons used in the study

Roller ginned	Saw ginned
Africa	Africa
Central America	Central America
North America	North America
South America	South America
Asia	Central Asia

Table 3a : probability of exceeding χ^2_{obs} for the comparison between RAW and OPEN samples MCI 3500 Universal sampler

Ginning	Parameter	ML	UHML	UI	STR	EL
Roller	χ^2_{obs}*(98 df)*	182.0	186.1	166.2	146.3	137.1
	$P > \chi^2_{obs}$	<0.001	<0.001	<0.001	0.001	0.006
	Signific.	***	***	***	**	**
Saw	χ^2_{obs}*(100 df)*	118.5	95.1	138.6	131.5	119.1
	$P > \chi^2_{obs}$	0.10	0.62	0.006	0.02	0.09
	Signific.	n.s.	n.s.	**	*	n.s.

n.s. = non significant, * = significant at the O.O5 probability level, ** = significant at the O.O1 probability level, *** = significant at the O.O01 probability level

Table 3b : probability of exceeding χ^2_{obs} for the comparison between RAW and OPEN samples ZUS 910 B Fibrosampler

Ginning	Parameter	ML	UHML	UI	STR	EL
Roller	χ^2_{obs}*(98 df)*	150.6	133.8	124.2	219.0	157.4
	$P > \chi^2_{obs}$	0.001	0.01	0.04	<0.001	<0.001
	Signific.	***	**	*	***	***
Saw	χ^2_{obs}*(100 df)*	141.9	140.4	117.4	166.1	164.6
	$P > \chi^2_{obs}$	0.004	0.005	0.11	<0.001	<0.001
	Signific.	**	**	n.s.	***	***

Table 4 : probability of exceeding χ^2_{obs} for MCI fitted with Fibrosampler compared with ZUS

Ginning	Parameter	ML	UHML	STR
Roller	χ^2_{obs} *(98 df)*	133.91	95.76	70.57
	$P > \chi^2_{obs}$	0.01	0.55	0.98
	Significance	**	n.s.	n.s.
Saw	χ^2_{obs} *(100 df)*	91.35	55.99	129.02
	$P > \chi^2_{obs}$	0.72	1.00	0.03
	Significance	n.s.	n.s.	*

Table 5 : Bartlett's test applied to within-sample variances for different systems (open cottons). probability of exceeding $\chi^2_{observed}$ and significance

System	Ginning	Parameter	ML	UHML	STR
MCI 3500 Universal sampler	Roller	χ^2_{obs}*(48 df)*	60.83	76.26	72.55
		$P > \chi^2_{obs}$	0.10	0.006	0.013
		Signific.	n.s.	**	*
	Saw	χ^2_{obs}*(49 df)*	103.76	99.07	59.89
		$P > \chi^2_{obs}$	<0.001	<0.001	0.14
		Signific.	***	***	n.s.
MCI 3500 Fibro sampler	Roller	χ^2_{obs}*(48 df)*	108.86	134.53	69.05
		$P > \chi^2_{obs}$	<0.001	<0.001	0.024
		Signific.	***	***	*
	Saw	χ^2_{obs}*(49 df)*	82.08	82.32	94.52
		$P > \chi^2_{obs}$	0.002	0.002	<0.001
		Signific.	**	**	***
ZUS 910B Fibro sampler	Roller	χ^2_{obs}*(48 df)*	69.11	51.66	90.78
		$P > \chi^2_{obs}$	0.025	0.33	<0.001
		Signific.	*	n.s.	***
	Saw	χ^2_{obs}*(49 df)*	70.37	82.99	151.88
		$P > \chi^2_{obs}$	0.024	0.002	<0.001
		Signific.	*	**	***

Table 6 : Bartlett's test applied to within-sample variances for different cotton groups. MCI system fitted with a Universal sampler

Ginning	Group	Parameter	ML	UHML	STR
roller	*barbadense*	χ^2_{obs} *(17 df)*	18.25	30.86	23.32
		$P > \chi^2_{obs}$	0.37	0.02	0.14
		Significance	n.s.	*	n.s.
	hirsutum	χ^2_{obs} *(30 df)*	32.87	42.80	45.93
		$P > \chi^2_{obs}$	0.33	0.06	0.03
		Significance	n.s.	n.s.	*
saw	commercial	χ^2_{obs} *(38 df)*	79.38	80.17	49.21
		$P > \chi^2_{obs}$	<0.001	<0.001	0.11
		Significance	***	***	n.s.
	research	χ^2_{obs} *(10 df)*	23.01	16.99	9.78
		$P > \chi^2_{obs}$	0.01	0.08	0.46
		Significance	*	n.s.	n.s.

Table 7 : Bartlett's test applied to within-sample variances for different cotton groups. MCI system fitted with a Fibrosampler

Ginning	Group	Parameter	ML	UHML	STR
roller	*barbadense*	χ^2_{obs} *(17 df)*	14.82	25.2	27.64
		$P > \chi^2_{obs}$	0.61	0.09	0.05
		Significance	n.s.	n.s.	n.s.
	hirsutum	χ^2_{obs} *(30 df)*	18.34	36.81	35.72
		$P > \chi^2_{obs}$	0.94	0.15	0.18
		Significance	n.s.	n.s.	n.s.
saw	commercial	χ^2_{obs} *(38 df)*	67.62	72.04	83.02
		$P > \chi^2_{obs}$	0.002	<0.001	<0.001
		Significance	**	***	***
	research	χ^2_{obs} *(10 df)*	12.17	8.99	11.41
		$P > \chi^2_{obs}$	0.27	0.53	0.33
		Significance	n.s.	n.s.	n.s.

Table 8 : Bartlett's test applied to within-sample variances for different cotton groups. ZUS system fitted with a Fibrosampler

Ginning	Group	Parameter	ML	UHML	STR
roller	*barbadense*	χ^2_{obs} *(17 df)*	21.10	18.82	30.34
		$P > \chi^2_{obs}$	0.22	0.34	0.02
		Significance	n.s.	n.s.	*
	hirsutum	χ^2_{obs} *(30 df)*	44.21	31.2	56.29
		$P > \chi^2_{obs}$	0.05	0.41	0.003
		Significance	n.s.	n.s.	**
saw	commercial	χ^2_{obs} *(38 df)*	47.66	58.72	132.42
		$P > \chi^2_{obs}$	0.14	0.02	<0.001
		Significance	n.s.	*	***
	research	χ^2_{obs} *(11 df)*	17.47	22.80	18.41
		$P > \chi^2_{obs}$	0.06	0.01	0.05
		Significance	n.s.	*	n.s.

Table 9 : Precision of the measurements made by the different HVI configurations and for the different types of cotton used in the study. Confidence intervals for 10 specimens per sample

System	Ginning	Group	ML	UHML	UI	STR
MCI 3500 Universal sampler	roller	*barbadense*	±0.96	*±0.99	*±2.10	±1.66
		hirsutum	±0.78	±0.64	±1.54	*±2.00
	saw	commercial	*±0.77	*±0.62	*±1.42	±1.02
		research	*±0.80	±0.50	*±1.56	±0.94
MCI 3500 Fibro sampler	roller	*barbadense*	±0.63	±0.46	±0.97	±1.01
		hirsutum	±0.52	±0.42	±0.93	±0.99
	saw	commercial	*±0.48	*±0.41	*±0.87	*±1.07
		research	±0.40	±0.32	±0.66	±0.73
ZUS 910B Fibro sampler	roller	*barbadense*	±0.48	±0.40	±0.71	*±1.41
		hirsutum	±0.42	±0.36	±0.74	*±1.22
	saw	commercial	±0.31	*±0.45	*±0.72	*±1.00
		research	±0.37	*±0.53	*±0.72	±0.88

* = confidence intervals calculated from a 95 % variance distribution value

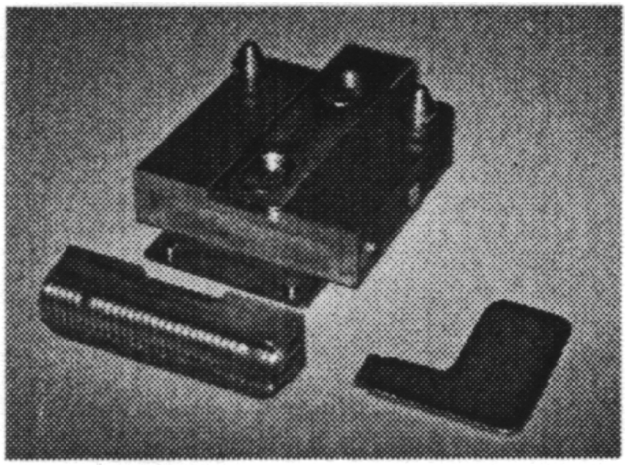

Figure 1. Modified Clamp for Sampling with Fibrosampler and measuring on MCI

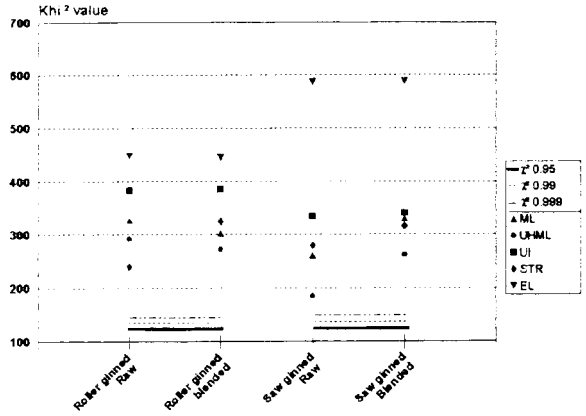

Figure 2: MCI system fitted with Universal sampler vs ZUS system; Within-sample variance cmparison based on a x^2 test.

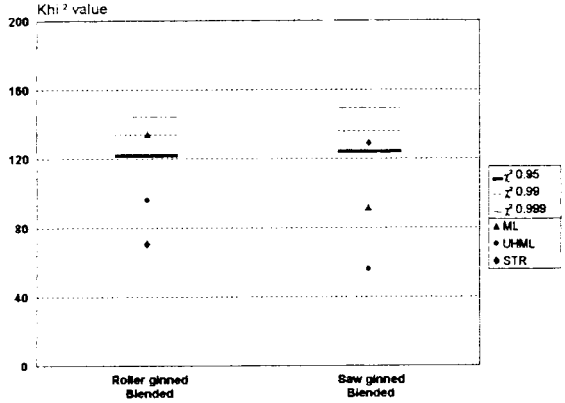

Figure 3: MCI system fitted with Fibrosampler vs ZUS system; Within-sample variance comparison based on a x^2 test.

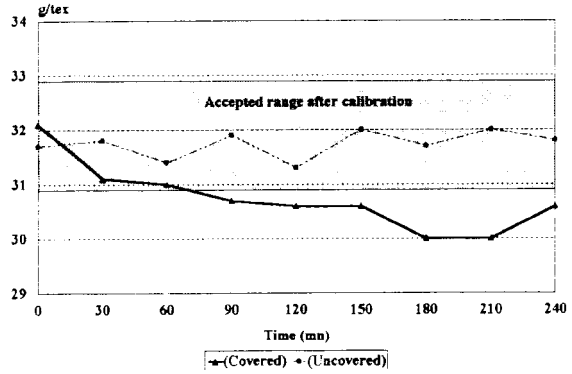

Figure 4: Strength measurement stabiity on MCI, as affected by the measuring unit covering, HVICC bale #28484.

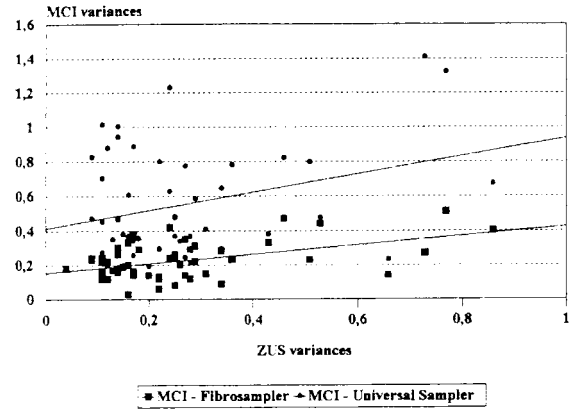

Figure 5: Sampling device effect on MCI within=sample variance; UHML measurements for saw ginned cottons.

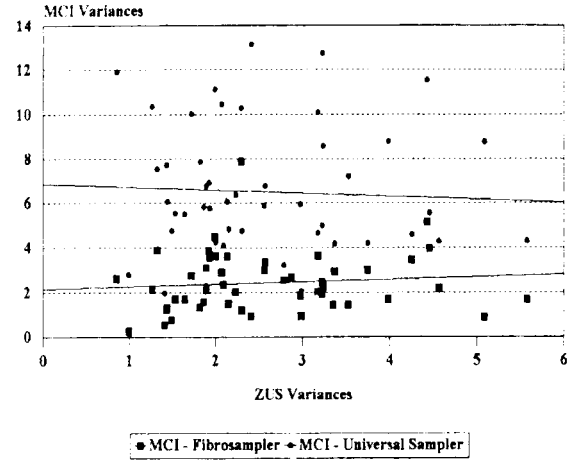

Figure 6: Sampling device effect on MCI within-sample variance; Strength measurements for roller ginned cotton.

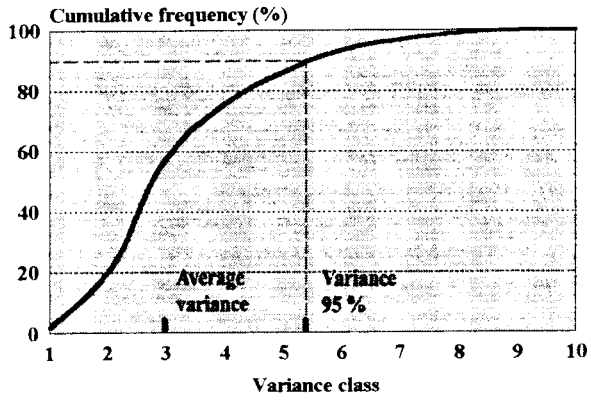

Figure 7: Choice of a variance level of 95%, using the within-sample variance distribution.

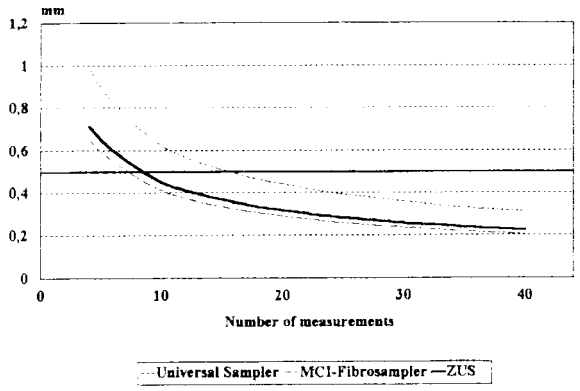

Figure 8: Confidence intervals for UHML, as measured by different HVI systems; saw ginned commercial samples.

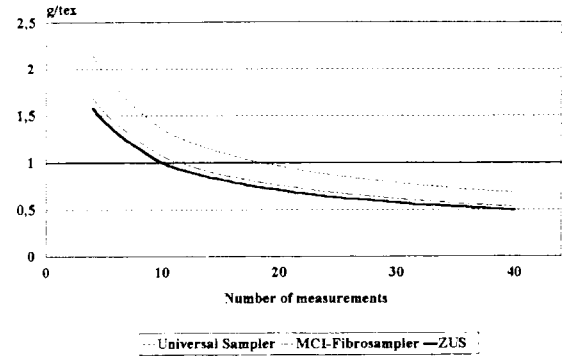

Figure 9: Confidence intervals for Strength, as measured by different HVI systems; saw ginned commercial samples.

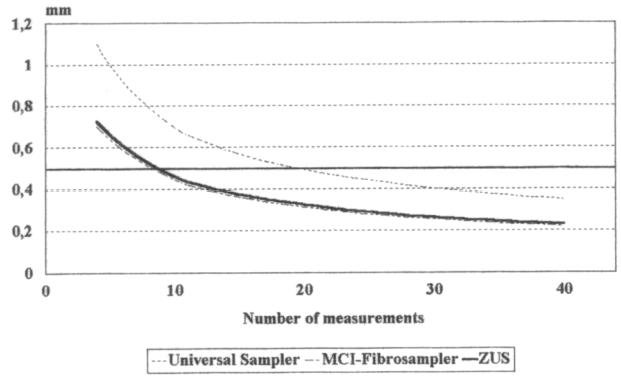

Figure 10. Confidence intervals for UHML, as measured by different HVI systems; roller ginned *Gossypium hirsutum* samples.

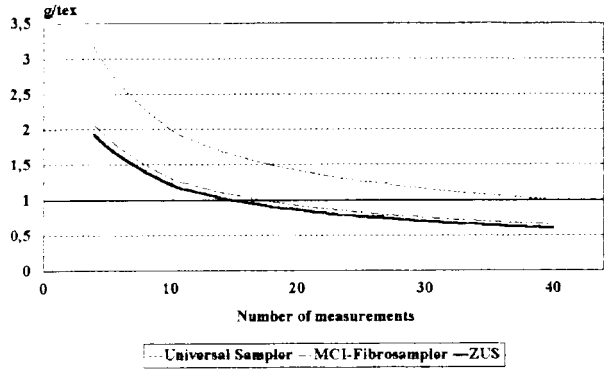

Figure 11. Confidence intervals for Strength, as measured by different HVI systems; roller ginned *Gossypium hirsutum* samples.