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Final Report on the Performance of the Style Instruments

By

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SUMMARY

This report analyses a trial comparing the performance of the CSIRO Style instruments over a range of wool types with a view to determining the commercial potential of the instrument.

No overall significant differences were found amongst the instruments for six of the 10 traits. For the other four traits, one instrument was divergent, possibly due to lighting differences. There were significant level dependencies for nine of the 10 traits, but it is difficult to be conclusive about the significance of these level dependencies given the small number of instruments involved in the trial.

Sensitivity analysis suggests that the instruments measure characteristics that could be used to discriminate between commercial sale lots.

However, considerably more work would be required to ensure the instruments are sufficiently robust for commercial operation, and an initial evaluation of the likely value of the additional information that could be supplied suggests that the commercial viability of the instrument is likely to be dependent on testing charges applied.

INTRODUCTION

Previous reports have described trials of the performance of the CSIRO-developed Style instruments[1]. A further trial was deemed necessary to compare the performance of the CSIRO Style instruments over a broad range of wool types with a view to determining the commercial potential of the instrument for use in AWTA Ltd. A suitable trial was designed incorporating three instruments, **Style A** & **Style C** at AWTA Ltd's Melbourne Laboratory and **Style B** at CSIRO. This paper reports the results of this trial.

The style instrument consists of three major components:

- automated sample feeding and removal
- measurement hardware; and
- processing and controlling software.

The instrument provides quantitative estimates of Staple Length, Tip Length, Crimp Frequency, Crimp Definition, Greasy Wool Yellowness, Wool Area, Dust Area and Dust Colour, all of which have some bearing on subjective assessment of style.

AIM

The aim of this trial was to determine the between-instrument and between-laboratory agreement for the measurement of each of the Style parameters when measuring the same staples.

A secondary objective was to evaluate the robustness of the technology for commercial application.

MATERIALS & METHODS

Wools for the trial were selected from the three major selling centres. A wide range of wools was selected, including Merino and Crossbred, and both Combing and, for the first time, Carding types. Approximately 89 sale lots were sampled and two sets of 60 staples (A & B) were sub-sampled from each sale lot. Since measurement on the Style instrument is non-destructive, the same staples from each lot were measured on each of the 3 instruments.

During transportation of the staples between the two laboratories, some of the staples were dislodged from their trays. The data used in this report only includes the staples that were successfully measured on each instrument. Approximately half of the measured staples were lost.

One-way analysis of Variance was conducted on the mean of the remaining data for each sale lot for 10 style traits:

- Staple Length (SL),
- Tip Length (TL),
- Staple Crimp Frequency (CF),
- Crimp Definition (CD),
- Wool Yellowness (Y-Z)
- Wool Area (WA)
- Dust Area (DA)
- Dust Colour (DX, DY & DZ).

IWTO-0 analysis was also conducted to compare each instrument against the grand mean of the three instruments.

To gain a feel for the usefulness of the measurements an estimate of the variance of the difference between each instrument and the grand mean was calculated for each trait. This variance was used to estimate a confidence interval and a sensitivity measurement. The mathematical expressions for these calculations are summarised in the next section.

Derivation of Confidence Interval and Sensitivity Estimates

The variance of a difference is given by the general formula:

$$Var(A-B) = Var(A) + Var(B) \qquad (1)$$

Let B be the mean of 3 instruments, then;

$$Var(B) = \frac{Var(A)}{3} \qquad (2)$$

Therefore;

$$Var(A-B) = \frac{4Var(A)}{3} \qquad (3)$$

Re-arranging to solve for Var(A)

$$Var(A) = \frac{3Var(A-B)}{4} \qquad (4)$$

And hence,

$$SD(A) = \sqrt{\frac{3Var(A-B)}{4}} \qquad (5)$$

The 95% Confidence Interval is then, simply:

$$95\%CI = \pm 1.96SD(A) \tag{6}$$

And the sensitivity is:

$$Sensitivity = \left(\frac{SD(A)}{Range}\right) * 100 \tag{7}$$

It was not possible to estimate a sampling variance since the data supplied had a significant amount of missing data.

RESULTS & DISCUSSION

Loss of Data

As mentioned in the 'Materials and Methods' section a number of staples were dislodged from their delivery trays during transport and could not be correctly re-allocated. Data from such samples was thus not available. In addition, the Style instruments sometimes reject staples. Table 1 shows the rejection rate for four conditions and the overall acceptance rate (Image OK). The high rejection rate (11.93%) for the "Staple at top/bottom of frame" was due, in part at least, to some large Crossbred staples that were simply out of the acceptable range for imaging.

Table 1: Reason for non-imaging of staples

Condition	Count	Percentage (%)
Object too Narrow	11	0.02
Object too Small	39	0.06
Unable to detect staple	1143	1.80
Staple at top/bottom of frame	7574	11.93
Image OK	54743	86.19
Total	63510	100.00

Over 86% of all staples were imaged successfully. Unfortunately, the percentage of staples for which data are available for all three instruments fell to approximately 50% of the total. It is unlikely that such staple loss would occur in commercial use as transportation, the major cause of loss, is not required.

Overall Mean Differences between the Three Instruments.

Table 2: Overall Means & Statistical Significance of Differences between the Three Instruments

Trait	Style A	Style B	Style C	Significance
Staple Length (mm)	76.2	76.4	76.0	NS
Tip Length (mm)	3.8	3.8	3.8	NS
Crimp Freq. (cr/cm)	3.9	3.9	3.9	NS
Crimp Definition	1.1	1.1	0.9	***
Wool Yellowness (Y-Z)	4.2	4.1	4.1	NS
Wool Area (%)	74.0	73.8	70.5	NS
Dust Area (%)	26.0	26.2	29.5	NS
Dust Colour (X)	19.1	18.9	19.7	***
Dust Colour (Y)	19.8	19.6	20.5	***
Dust Colour (Z)	15.7	15.9	16.5	**

Note: NS (not significant), * (Significant at 95% Level), ** (Significant at 99% Level) and *** (Significant at 99.9% Level).

The remaining data were used in a One-way analysis of variance that compared the results for the same staples in the three instruments. Table 2 (see previous page) summarises the instrument means and statistical significance of the between-instrument differences for each of the style traits.

In each case of a statistically significant difference, i.e. Crimp Definition and Dust Colour, Instrument 'Style C' appeared to be the divergent instrument, while the remaining two instruments had very similar values. It appears that Style C had a difference in calibration of its lighting when compared to the other two instruments. The commercial value of these statistical significances has not been investigated.

Level Dependent Differences.

The level dependency of the style traits is summarised from the IWTO-0 analysis and is presented in Table 3. Each instrument's results are compared to the pooled grand mean of the three instruments.

Table 3: Significance of Level Dependant Differences for the Three Instruments

Trait	Style A	Style B	Style C
Staple Length (mm)	*	**	*
Tip Length (mm)	NS	*	NS
Crimp Freq. (cr/cm)	***	***	***
Crimp Definition	***	***	***
Wool Yellowness (Y-Z)	NS	**	***
Wool Area (%)	***	**	*
Dust Area (%)	***	**	*
Dust Colour (X)	NS	*	NS
Dust Colour (Y)	NS	*	NS
Dust Colour (Z)	NS	NS	NS

Plots for each style parameter of the individual instrument difference from the Grand Mean (3 instruments) are included as Appendix 1 (Figures 1-10).

The data reported in Table 2 for the overall bias suggested Style C should be removed from the analysis for Crimp Definition and Dust Colour. Plots are included in the Figures showing the difference between Style A and Style B for Crimp Definition (Figures 4) and Dust Colour (Figures 8, 9 & 10).

With only three instruments, it is difficult to be conclusive as to whether or not the level dependence shown in Table 3 is merely an artefact of the small number of instruments and the normal range of variance between instruments. Similar level dependency results are often found when analysing fibre diameter data from a small number instruments.

Confidence Limits of a Single Test

Table 4 summarises the average Confidence Interval for each of the style attributes measured

Table 4: Summary of Instrument Confidence Interval (CI)* of a Single Test.

Trait	Average 95% CI
Staple Length (mm)	±0.5
Tip Length (mm)	±0.3
Crimp Freq. (cr/cm)	±0.1
Crimp Definition	±0.1
Wool Yellowness (Y-Z)	±0.2
Wool Area (%)	±2.6
Dust Area (%)	±2.6
Dust Colour (X)	±0.3
Dust Colour (Y)	±0.3
Dust Colour (Z)	±0.3

* Note: The above Confidence Intervals do not include any sampling variance component, so are likely to under estimate the Confidence Interval for a routine Style test.

Sensitivity of Measurements

Table 5 summarises the average sensitivity estimate for each of the style attributes.

To put the data in perspective it is worthwhile examining a couple of examples. Diameter has an average SD of 0.155 µm and a range from 16 – 36 µm. Therefore, the sensitivity measure is

$$Sensitivity = \left(\frac{0.155}{(36-16)}\right) \times 100 = 0.8\%$$

For ATLAS Staple Length the average SD between instruments is 0.616 mm and ranges from 60 –120 mm. Therefore, the sensitivity measure is

$$Sensitivity = \left(\frac{0.616}{(120-60)}\right) \times 100 = 1\%$$

The larger the reported Sensitivity value the less sensitive the measurement system.

Table 5: Summary of Instrument Sensitivity Estimates.

Trait	Average Sensitivity
Staple Length (mm)	0.5
Tip Length (mm)	2.4
Crimp Freq. (cr/cm)	2.3
Crimp Definition	5.6
Wool Area (%)	2.1
Wool Yellowness (Y-Z)	1.7
Dust Area (%)	2.1
Dust Colour (X)	2.5
Dust Colour (Y)	2.3
Dust Colour (Z)	2.1

The data summarised in Table 5 suggests that the instruments are measuring characteristics that could be used to discriminate between sale lots with a reasonable level of sensitivity. Only Crimp Definition has an average sensitivity over 2.5%. The other Style traits have values that indicate that they can be used to discriminate between sale lots. A resolution of the ability of the Style instruments to discriminate between sale lots requires a further trial that incorporates the sampling variance into the design.

Robustness of Operation

From a mechanical point of view this iteration of the instrument performed much more reliably and with significantly less intervention by the operators than previous iterations. CSIRO has substantially re-engineered the hardware and improved the software.

Despite the improvements in the software, software problems required reasonably frequent intervention by operators, which, from a commercial operations perspective, is most undesirable.

Economic Viability

For any objective measurements to be commercially viable, they must deliver information that is much more reliable than subjective assessment, or at a lower cost than can be achieved by subjective assessment. The Style Instruments produce objective data on 8 additional parameters, which cannot yet be directly converted to provide an assessment of Style.

Style is recognised as being a relatively minor component of the value of greasy wool. Currently, it is technically possible to provide subjective assessments of style for a relatively small cost per lot – less than $1,000,000 for the Australian woolclip sold at auction. Therefore, to compete with this the Style instrument would need to deliver a commercial service at around $2.00 per lot. It is unlikely that this could be achieved with current economies of scale in the Australian testing environment.

CONCLUSION

The CSIRO Style instruments are considered not commercially suitable for measurements in their current form under the existing economies of scale in the current Australian testing environment.

One of the three instruments in these trials showed significant differences in four of the ten traits, possibly because of a difference in the calibration of its lighting system.

However, the sensitivity analysis indicates that the data could be used to discriminate between sale lots. It is not known whether the measurements provide data that is sensitive enough for commercial companies to use in their trading operations, and a considerable amount of additional cost would be incurred to determine this.

Considerable capital has already been expended on this development and considerable additional capital will be required to develop the technology to a stage where it could be commercially viable, and where the measurements it provides would be accepted by the industry as a whole. Given the relatively low importance of style in determining wool value, continuation of this development is unlikely to attract the necessary funding to commercialise this technology and thus further work will be suspended indefinitely.

REFERENCES

1. Hansford et al (1998) The Variation in and Relationships between the Objectively Measured Components of Greasy Wool Style. IWTO T&S Committee, Dresden, Report 23.

ACKNOWLEDGEMENTS

The completion of this trial has involved a co-ordinated effort by a number of staff from AWTA Ltd and CSIRO.

On behalf of AWTA Ltd Rick Stadler organised the testing operations at the Melbourne Laboratory. David Crowe conducted the analysis and drafted the text of this paper. Jim Marler also provided input to the analysis.

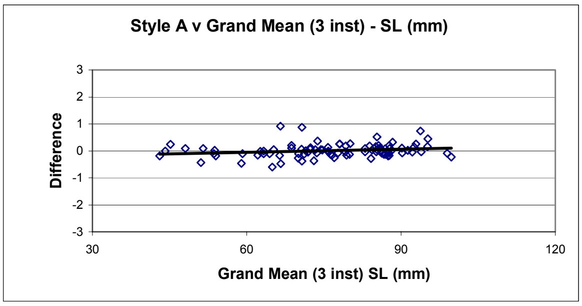
The contributions of Tseviet Tchen, Craig Tischler and Graham Higgerson, all from CSIRO, to the development of this version of the style instrument are also acknowledged.

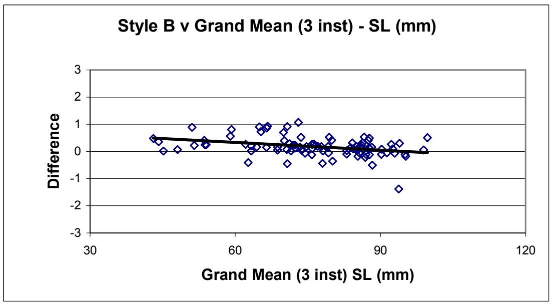
APPENDIX 1

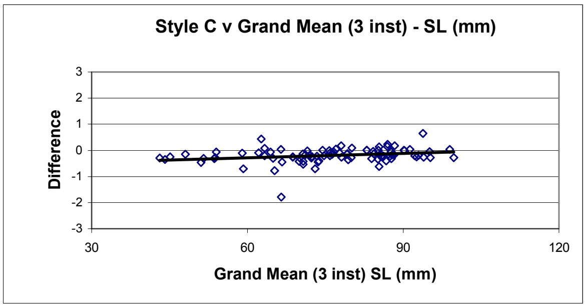
Figure 1: Staple Length (mm)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	76.2	76.4	76.0	76.2	NS
Diff from GM	0.0	0.2	-0.2	0.0	
SD Diff	0.2501	0.3586	0.2813	0.3	
Sensitivity	0.4	0.5	0.4	0.5	
95%CI	0.4	0.6	0.5	0.5	

Difference Plots







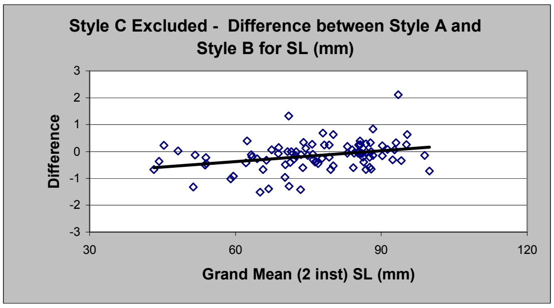
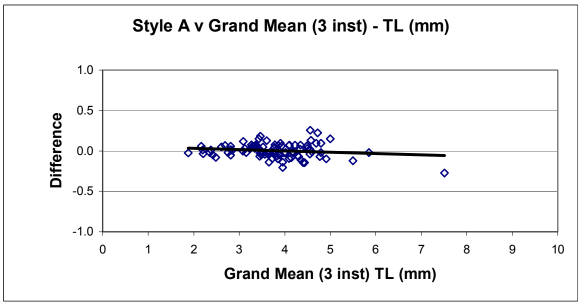
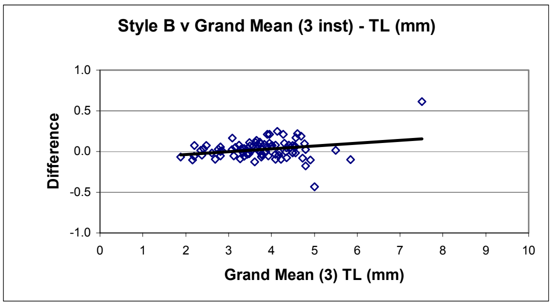


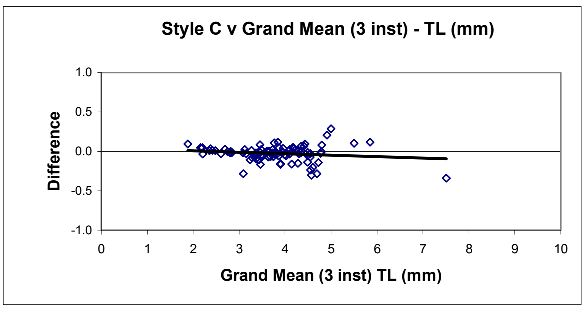
Figure 2: Tip Length (mm)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	3.78	3.81	3.75	3.78	NS
Diff from GM	0.00	0.03	-0.03	0.0	
SD Diff	0.1488	0.1996	0.1008	0.2	
%SD of Range	2.4	2.7	1.7	2.4	
95%CI	0.3	0.3	0.2	0.3	

Difference Plots







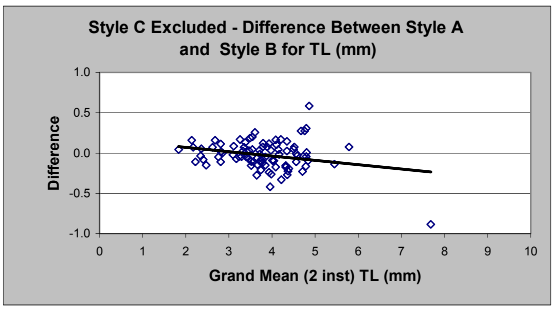
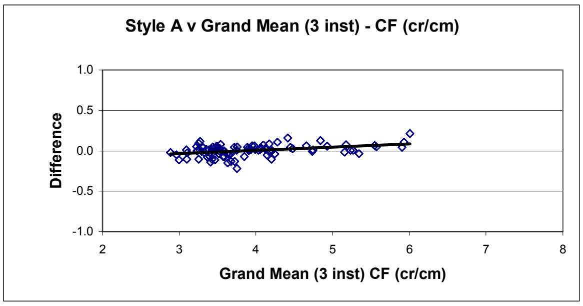
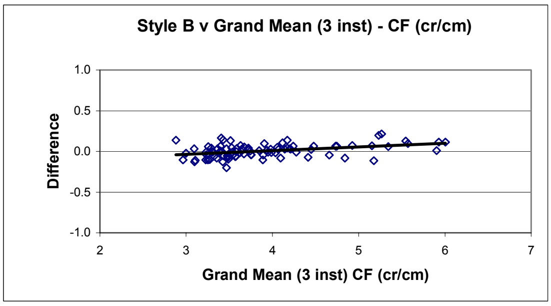


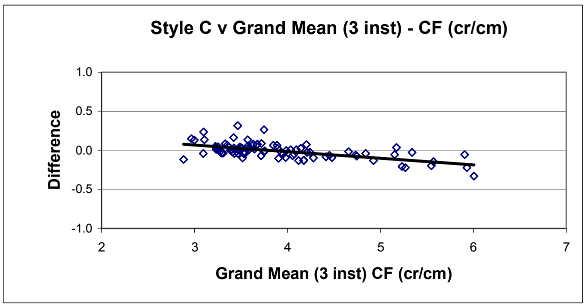
Figure 3: Crimp Frequency (cr/cm)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	3.91	3.92	3.90	3.91	NS
Diff from GM	0.00	0.01	-0.01	0.0	
SD Diff	0.0714	0.0793	0.1004	0.1	
%SD of Range	1.8	2.1	2.8	2.3	
95%CI	0.1	0.1	0.2	0.1	

Difference Plots







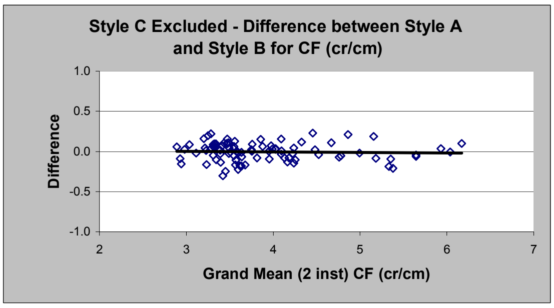
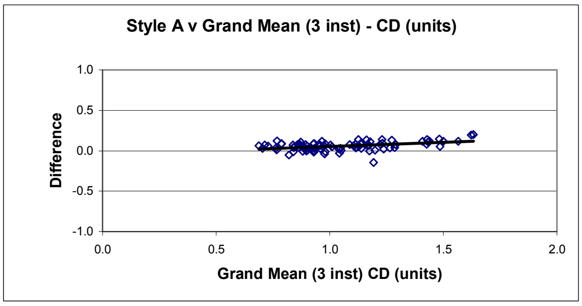
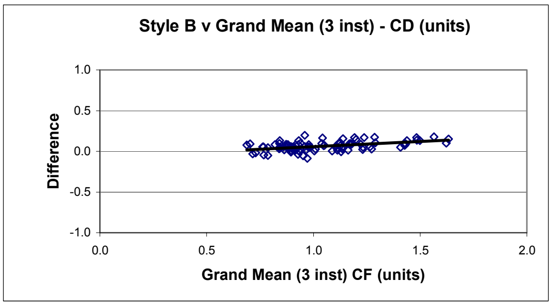


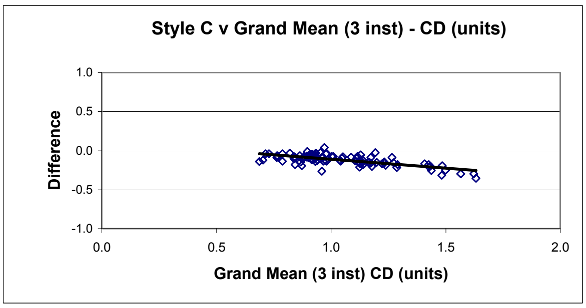
Figure 4: Crimp Definition (units)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	1.11	1.12	0.93	1.05	***
Diff from GM	0.06	0.07	-0.12	0.0	
SD Diff	0.0528	0.0574	0.0725	0.1	
%SD of Range	4.2	4.5	8.0	5.6	
95%CI	0.1	0.1	0.1	0.1	

Difference Plots







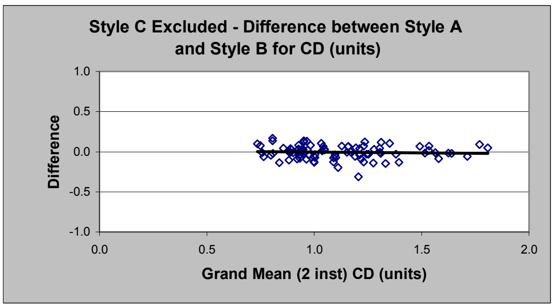


Figure 5: Greasy Wool Yellowness (Y-Z)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	4.20	4.12	4.11	4.14	NS
Diff from GM	0.06	-0.02	-0.03	0.0	
SD Diff	0.0968	0.1092	0.1252	0.1	
%SD of Range	1.4	1.7	1.9	1.7	
95%CI	0.2	0.2	0.2	0.2	

Difference Plots

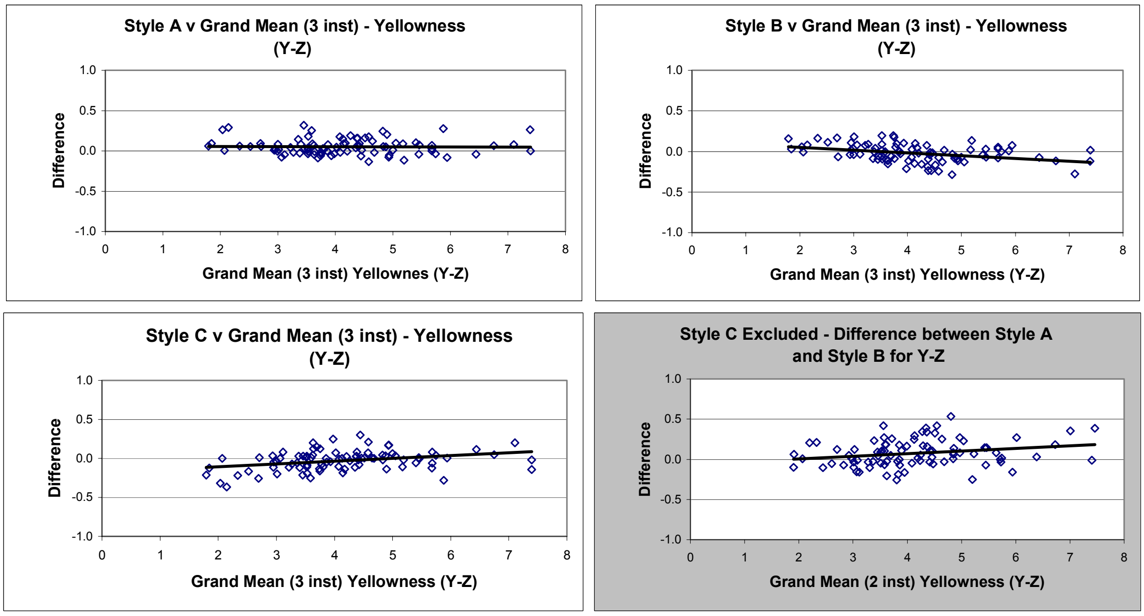


Figure 6: Wool Area (%)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	74.01	73.82	70.45	72.76	NS
Diff from GM	1.25	1.06	-2.31	0.0	
SD Diff	1.3314	1.8440	1.3803	1.5	
%SD of Range	1.9	2.4	1.8	2.1	
95%CI	2.3	3.1	2.3	2.6	

Difference Plots

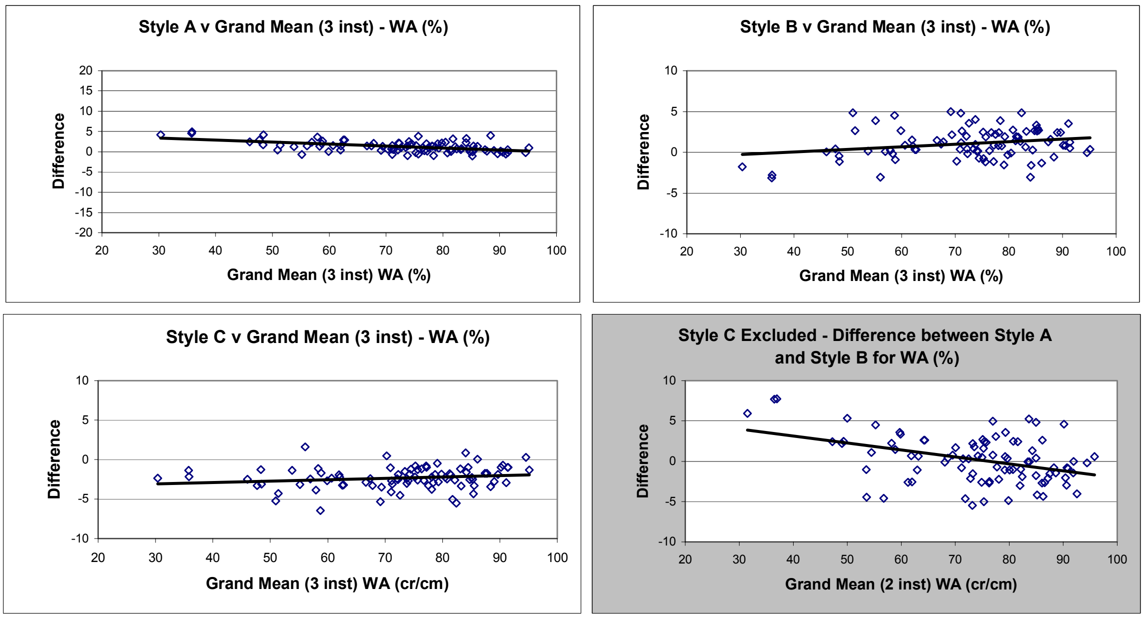
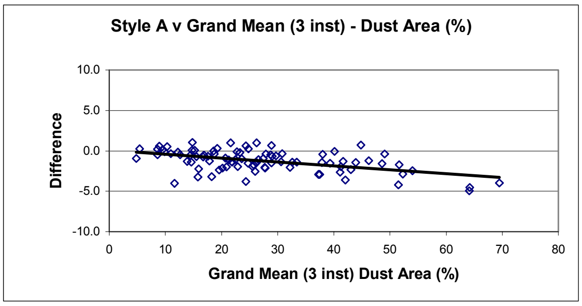
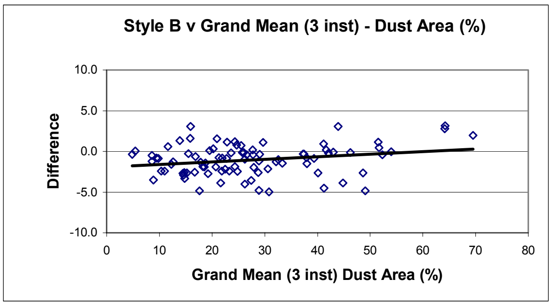


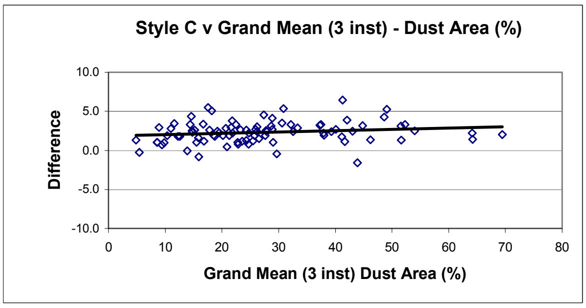
Figure 7: Dust Area (%)

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	25.99	26.18	29.54	27.24	NS
Diff from GM	-1.25	-1.06	2.30	0.0	
SD Diff	1.3277	1.8472	1.3807	1.5	
%SD of Range	1.9	2.4	1.8	2.1	
95%CI	2.3	3.1	2.3	2.6	

Difference Plots







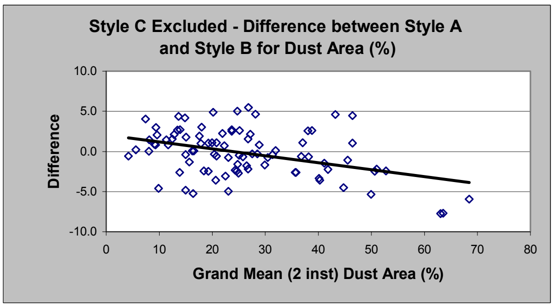
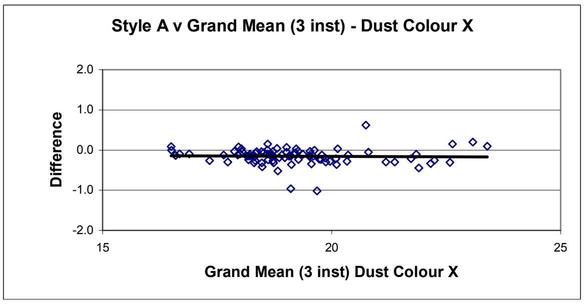
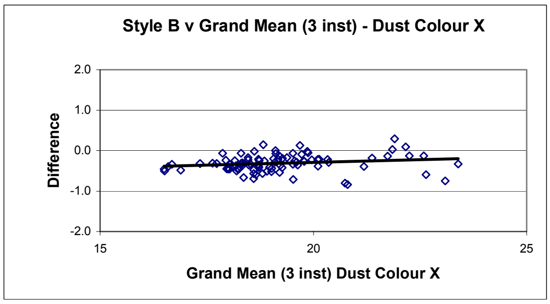


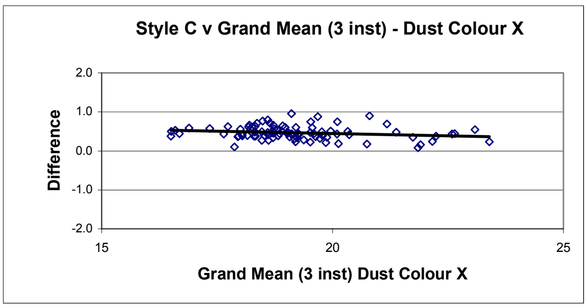
Figure 8: Dust Colour X

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	19.06	18.90	19.68	19.22	***
Diff from GM	-0.16	-0.32	0.46	0.0	
SD Diff	0.2040	0.2101	0.1724	0.2	
%SD of Range	2.5	2.6	2.2	2.5	
95%CI	0.3	0.4	0.3	0.3	

Difference Plots







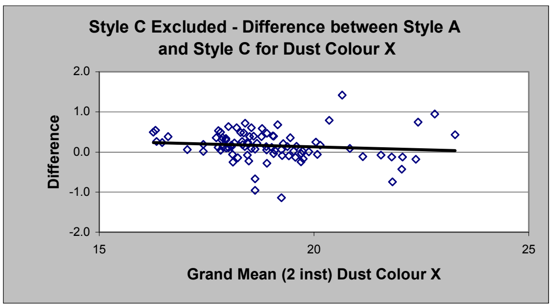
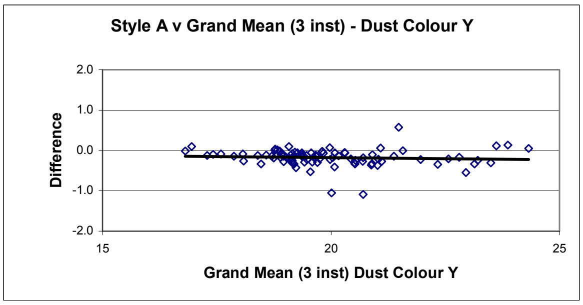
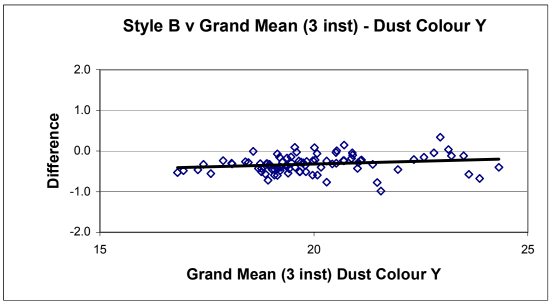


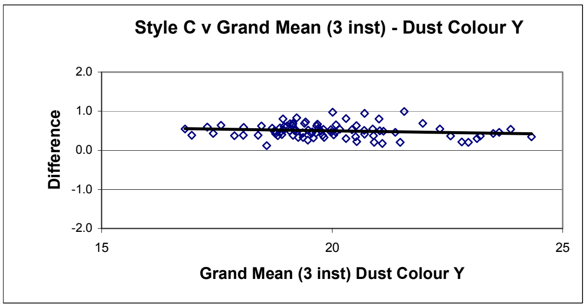
Figure 9: Dust Colour Y

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	19.78	19.63	20.45	19.95	***
Diff from GM	-0.17	-0.32	0.50	0.0	
SD Diff	0.2096	0.2196	0.1742	0.2	
%SD of Range	2.4	2.5	2.1	2.3	
95%CI	0.4	0.4	0.3	0.3	

Difference Plots







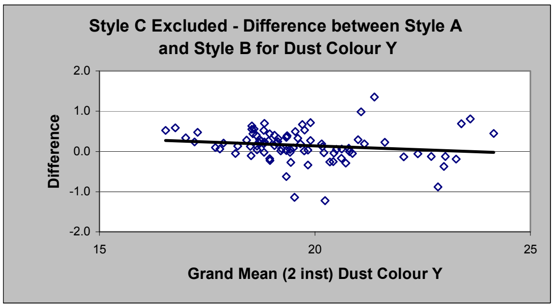


Figure 10: Dust Colour Z

	Style A	Style B	Style C	Average	Significance of Instrument Difference
Mean	15.72	15.86	16.47	16.02	**
Diff from GM	-0.30	-0.16	0.45	0.0	
SD Diff	0.2191	0.2014	0.1809	0.2	
%SD of Range	2.3	2.1	1.8	2.1	
95%CI	0.4	0.3	0.3	0.3	

Difference Plots