

The Impact of Test Result Precision on Genetic, Culling and Classing Decisions Taken on Farm

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Summary

The increasing use by wool producers of diameter measurement On-Farm has highlighted the lack of information on the impact of the precision of the test result for a single sheep for sound on-farm decision-making. This paper provides a mathematical study which highlights the key issues that wool producers using either, the laboratory testing of mid-side samples, the FLEECESCAN or the OFDA2000 in-shed, in-store or in-race need to consider. The factors that have an impact on “On-Farm” decisions related to Mean Fibre Diameter are the precision (i.e. the 95% Confidence Limit) of the test result and the diameter uniformity of the mob of sheep. The higher the Confidence Limit the greater the adverse effect. Improving the diameter uniformity of the mob of sheep will require sampling and testing procedures of high precision (i.e. lower Confidence Limits) if economic gains are to be maintained and continued.

Introduction

The number of wool producers using On-Farm testing of Mean Fibre Diameter (MFD) has been increasing. Wool producers need to ask themselves the question as to why they are prepared to have tests performed on individual fleeces. The most common applications are to gather information:

- for use in genetic improvement through a specific breeding program;
- for culling inferior animals;
- for use in classing the flock into lines of different Mean Fibre Diameters for sale; or
- for all of the above.

Each will have different outcomes in the interpretation of test data taken On-Farm or in-shed.

In the first two cases, it is the ranking of an individual sheep with respect to the other sheep in the mob that is the important parameter, whereas in the third case, it is important that fleeces are assigned to the correct line based on the measured MFD.

The precision, or more simply the repeatability, of the measurement will have an impact on all of the applications. For example, the more precise (i.e. a lower Confidence Limit) is the measured MFD the smaller the number of incorrect decisions that will be made. It is also important to appreciate that it is the precision of the estimate of the fleece that is important not the precision of the estimate at a single site such as the hipbone or the mid-side (Marler and Couchman (2001)).

The impact of the precision of measurement on both sheep selection and fleece classing can be evaluated from a simple mathematical approach.

Method

Using Microsoft EXCEL it is possible to generate a mob of sheep with a known average Mean Fibre Diameter and known Between-Sheep Standard Deviation (SD) of Diameter. For the purpose of this exercise a mob of 2000 sheep was created having a mob average of 19.0 μ m with a between sheep Standard Deviation of 1.5 μ m using the EXCEL function “ROUND(NORMINV(RAND(),19.0,1.5),1)”. This function calculates a random value from a population that is normally distributed with a Mean of 19.0 μ m and a Standard Deviation of 1.5 μ m. By copying this function to 2000 cells in a single column we now have our 2000 sheep. These diameters can now be defined as the “True” diameters for each sheep.

The same function in EXCEL can be used to simulate testing of these sheep. This is achieved by assuming an overall Confidence Limit for the sampling and test procedures and converting this back to a Standard Deviation representing the total variation (SD_{Total}). The expected measured result for each of the 2000 sheep can be calculated by the “True Diameter + “ROUND(NORMINV(RAND(),0, SD_{Total}),1)”.

Using the above processes two different mobs of 2000 sheep each were generated with the same mob average MFD (19.0 μ m) but differing in uniformity of MFD (i.e. Between-Sheep SDs in the mobs of 1.0 μ m and 2.0 μ m). Having generated the data for a range of different Measurement Confidence Limits it is possible to simulate the effects of ranking the sheep from finest to coarsest based on the measured values and comparing these to the True Ranking based on the rank for the True Diameter of each sheep.

A sheep classing exercise has also been performed. Using the measured values for each of the different Confidence Limits, the wool was classed into four lines based on the measured MFD. The cut-off limits for the four lines were derived using the “CLASSER” software (Vizard and Williams(1993)). The MFD for each line was calculated as the arithmetic average of the MFD for each sheep in the classed line. The “True MFD of the Classed Line” was also calculated and compared to the expected values based on the measured data.

Results and Discussion

1. The Impact of Test Result Precision on Sheep Selection

In order to select the finest sheep in a mob the sheep are listed in order from the finest to the coarsest. The finest is allocated a number (rank) one and the rest numbered in order up to 2000 for the coarsest. The impact of the precision of the test results can be shown by comparing the rank of each sheep based on its measured value compared to the true rank. The Confidence Limit for Fleece Testing has been typically reported as $\pm 0.6\mu\text{m}$ to $\pm 1.6\mu\text{m}$ (Morgan (1990), Cottle et al (1996), Baxter (2000) and Baxter (2001)). These reported Confidence Limits generally underestimate the real Confidence Limits as the values typically refer to a single site rather than the entire fleece. For the purpose of illustration different Confidence Limits ($\pm 0.4\mu\text{m}$ and $\pm 1.6\mu\text{m}$) have been compared for each of the two different mobs.

From an examination of the graphs (Figures 1 and 2) a number of conclusions can be drawn:

- The greatest error in ranking occurs at the average MFD for the mob. This is evidenced by the ballooning effect in all the figures around the middle. This occurs as a consequence of the normal distribution. Small differences in the measured MFD can move the rank of a given sheep over a large number of other sheep compared to both extremes, where the same difference in measurement will have a smaller impact as there are less sheep numbers to move over. The consequences to sheep selection are minor, as it is normally at the extremes that “On-Farm” decisions are being made (eg the coarsest to cull or the finest, in the case of rams, to keep).
- The lower the Confidence Limit of the test result (i.e. the more precise) the less the errors in the ranking of the sheep.

For any given test-result precision, the more uniform the between sheep MFD in the mob the greater the errors in the ranking of the sheep.

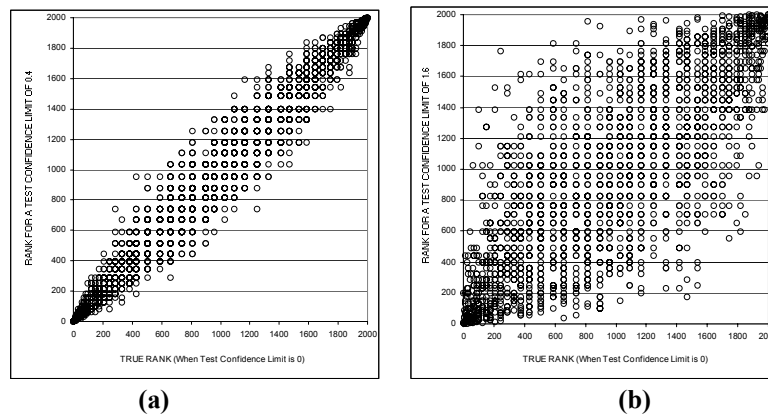


Figure 1. Comparison of Individual Sheep Ranks for a mob with a between sheep SDD of $1.0\mu\text{m}$ and two test result precisions, (a) $\pm 0.4\mu\text{m}$ and (b) $\pm 1.6\mu\text{m}$.

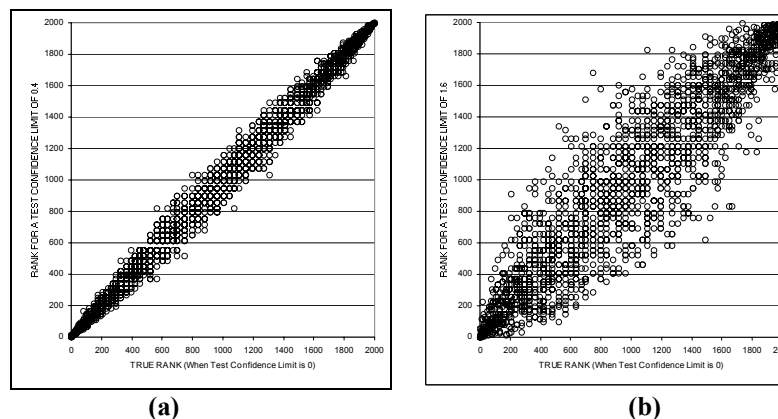


Figure 2. Comparison of Individual Sheep Ranks for a mob with a between sheep SDD of $2.0\mu\text{m}$ and two test result precisions, (a) $\pm 0.4\mu\text{m}$ and (b) $\pm 1.6\mu\text{m}$.

The influence of the incorrect selection of sheep to remain on the property as a percentage is shown to be dependent on the uniformity of the MFD in the mob and the precision of the test is summarised in Table 1.

Table 1: Percentage of Incorrect Selections

Standard Deviation of MFD of the Mob	95% Confidence Limit of Test Result	35% Cull Rate (i.e. 700 out of 2000)	95% Cull Rate (i.e. 1900 out of 2000)
1.0 μm	$\pm 0.4\mu\text{m}$	4	12
	$\pm 1.0\mu\text{m}$	11	27
	$\pm 1.6\mu\text{m}$	15	47
2.0 μm	$\pm 0.4\mu\text{m}$	2	8
	$\pm 1.0\mu\text{m}$	5	17
	$\pm 1.6\mu\text{m}$	9	31

Peterson and Gherardi (2001) found the same effects, which they presented in graphical form, but did not indicate the trends they found were influenced by the diameter uniformity of the mob. The following series of figures show the relationships for each of the two mobs in the same format that they used.

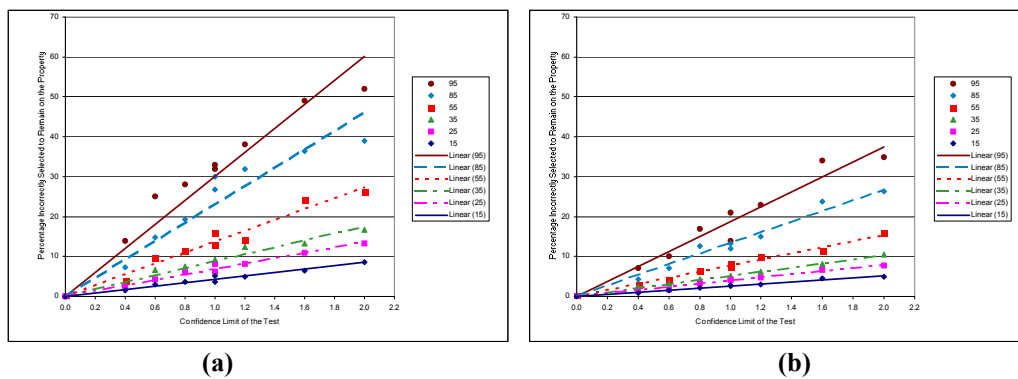


Figure 3. The Impact of the Precision of the Test Result on the Percentage of Animals Incorrectly Selected to remain on the Property for Different Culling Rates ((a) between sheep SDD of 1.0 μm and (b) between sheep SDD of 2.0 μm).

Midside sampling was developed to aid genetic improvement in breeding programs. The heritability of Mean Fibre Diameter was reported by Taylor and Atkins (1992) to be 0.48 and so a moderate precision was all that was needed to input into the genetic models. The data generated for this report provides an opportunity to examine the impact of the Confidence Limit of a test result on the calculated “Genetic Gain per Annum”. For the purpose of this exercise the 35% cull level was considered to represent the ewes and the 95% cull level represents the rams. The average MFD of the mob was assumed to be 19.0 μm and the time taken to turnover one generation was considered to be 5 years. Table 2 shows the impact of Test Result Confidence Limit on the Genetic Gain. The data in the table is reported to two decimal places as the figures relate to the averages for populations of sheep and not a single animal.

Table 2: The Impact of Different Test Result Confidence Limits on Genetic Gain per Annum

Between-Sheep SD (μm)	Confidence Limit (μm)	MFD for Selected Ewes (μm)	MFD Selection Differential (μm)	MFD for Selected Rams (μm)	MFD Selection Differential (μm)	Genetic Gain per Annum (μm)
1.0	0.4	18.46	0.54	16.94	2.06	0.12
	1.0	18.54	0.46	17.09	1.91	0.11
	1.6	18.59	0.41	17.40	1.60	0.10
	2.0	18.62	0.38	17.50	1.50	0.09
1.5	0.4	18.21	0.79	15.89	3.11	0.19
	1.0	18.20	0.80	15.97	3.03	0.18
	1.6	18.29	0.71	16.36	2.64	0.16
	2.0	18.34	0.66	16.44	2.56	0.15
2.0	0.4	17.98	1.02	15.02	3.98	0.24
	1.0	18.00	1.00	15.18	3.82	0.23
	1.6	18.09	0.91	15.30	3.70	0.22
	2.0	18.13	0.87	15.46	3.54	0.21

From Table 2 one can conclude the Confidence Limit of the Test Result has a small impact on the calculated “Genetic Gain per Annum” in absolute terms. This is possibly a consequence of the heritability of only 0.48.

2. The Impact of Test Result Precision on Fleece Classing

The impact of the test precision on classing the fleeces into different diameter classes in preparation for sale was examined by using the program “Classer” to set the diameter cut-offs for the preparation of four lines (Vizard and Williams, 1993). These were determined for a Mob with an overall average Mean Fibre Diameter of 19.0 μ m and a Standard Deviation of Mean Fibre Diameter between sheep of 1.5 μ m. A test precision of $\pm 1.0\mu$ m was used for the purpose of setting the limits

The sheep were then classed based on their “True Value” and their measured values based on two different Confidence Limits ($\pm 0.4\mu$ m and $\pm 1.6\mu$ m). Tables 2 and 3 show the comparisons of the expected Mean Fibre Diameters of the classed lines based on the average of the measured values for each fleece classed into a particular line and the average of the true values for the same fleece.

Table 2: Expected Diameters of Classed Lines Based on a Measurement Confidence Limit of $\pm 0.4\mu$ m

	Expected Value	True Value	Difference
Line 1	17.27	17.30	0.03
Line 2	19.06	19.06	0.00
Line 3	20.35	20.32	-0.03
Line 4	21.52	21.48	-0.04

Table 3: Expected Diameters of Classed Lines Based on a Measurement Confidence Limit of $\pm 1.6\mu$ m

	Expected Value	True Value	Difference
Line 1	17.13	17.60	0.47
Line 2	19.12	19.08	-0.04
Line 3	20.37	20.06	-0.31
Line 4	21.70	21.08	-0.62

The difference between the “Expected Value” and the “True Value” was greatest for the finest and coarsest lines. As the Confidence Limit increased the magnitude of these differences also increased up to approximately 0.5 μ m for a Measurement Confidence Limit of $\pm 1.6\mu$ m. The above differences have been derived from a random testing model and consequently they would themselves have some uncertainty associated with them.

The lines prepared which were closer to the Mob average exhibited much smaller differences in MFD (eg Line 2) whereas the finest (Line 1) and coarsest (Line 4) prepared lines exhibited the largest differences. The finest prepared line had a true value coarser than what was expected and the coarsest prepared line had a true value finer than what was expected.

Conclusions

The factors that have an impact on “On-Farm” decisions related to Mean Fibre Diameter are the precision (i.e. the 95% Confidence Limit) of the test result and the diameter uniformity of the mob of sheep. The higher the Confidence Limit the greater the adverse effect. Improving the diameter uniformity of the mob of sheep will require sampling and testing procedures of high precision (i.e. lower Confidence Limits) if economic gains are to be maintained and continued. There is likely to be little improvement in mobs with a small range in MFD. The Confidence Limit is likely to have only a small effect on the Genetic Gain per Annum for a commercial flock.

Research is needed to quantify the precision limits (i.e. the 95% Confidence Limits) of test procedures currently used by wool producers to make “On-Farm” decisions. It is important that the precision estimate is relevant to the entire fleece and not simply relevant to a single site on a fleece or sheep, which has been the usually reported parameter in the scientific literature.

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