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CORRELATION ANALYSIS OF FIBRE DIAMETER AND COLOUR OF CLEAN WOOL

CRC SII Project 2.2.1

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Background

Using the current IWTO Standard (IWTO 56-07, 2007), the colour of clean wool is tested in $0^o/45^o$ instrument geometry by means of pressing a bulk of wool against glass. Account is taken of texture or appearance of the bulk wool due to the inclusion of specular light in the spectra. Statistically, it has been observed that measured colour (Y & Y-Z) of clean wool is related to fibre diameter (Mahar, 2007). If this is the case, the effect of fibre diameter on the measured wool colour should be eliminated to determine the potential genetic improvement in colour of wool of different fibre diameter. This report examines the correlation relationship between measured wool colour and Mean Fibre Diameter (MFD) from 10 years of AWTA colour testing data.

Colour Characteristics of Merino and Crossbred Fleeces in Database

It has been known that Merino wool fibres are different from crossbred fibres in the fine structure of their cortical and cuticle cells. Their optical properties may be different. Therefore, analyses were conducted separately for the colour data of Merino and crossbred fleeces which were tested by AWTA Ltd in the period of 1997 to 2007.

The numbers of tests and colour characteristics are shown in Table 1 for Merino fleece and Table 2 for crossbred fleece. As the tables show, the colour of cleaned wool had been tested on a great number of Merino and crossbred fleeces before 2000, while there was much less testing post 2000. For analysis, the data from 2000 to 2007 was pooled into one ‘season’ due to the lower test frequency in this period.

In general, it has been observed that:

- The fleeces tested in each season had similar MFD and colour characteristics i.e. X, Y, Z, and (Y-Z).
- Between the fleece types:
    - The crossbred fleece was 8.2 micron higher than the Merino fleece; both fleece types had similar diameter variation.
    - The Merino fleece had higher average values and variation in X, Y, Z than the crossbred fleece.
    - The Merino fleece was 1.1 T units lower in (Y-Z) than the crossbred; both wool types had similar variation.

Table 1. Fibre diameter and colour characteristics of Merino fleece

'Season'	Number	Statistic	Fibre Diameter	Colour X	Colour Y	Colour Z	Colour Y-Z
97-98PI	22,501	Mean	21.0	66.7	70.6	61.7	8.9
		Var	3.0	5.6	6.8	6.2	0.8
		SD	1.7	2.4	2.6	2.5	0.9
97-98PII	20,821	Mean	21.7	66.6	70.5	61.8	8.6
		Var	3.6	4.0	5.0	4.5	0.6
		SD	1.9	2.0	2.2	2.1	0.8
98-99PI	26,509	Mean	21.2	67.4	71.3	62.7	8.6
		Var	3.9	4.6	5.7	5.7	1.3
		SD	2.0	2.1	2.4	2.4	1.1
98-99PII	19,437	Mean	21.4	67.5	71.4	62.9	8.5
		Var	4.6	3.9	4.8	4.9	0.6
		SD	4.6	3.9	4.8	4.9	0.6
99-00	26,143	MEAN	21.6	67.8	71.8	63.2	8.6
		Var	4.6	2.7	3.4	4.0	0.8
		SD	2.1	1.6	1.8	2.0	0.9
00-07	5,619	MEAN	20.8	67.5	71.5	62.5	9.0
		Var	3.6	6.1	7.4	8.5	0.9
		SD	1.9	2.5	2.7	2.9	1.0
Total	121,030	MEAN	21.4	67.2	71.2	62.5	8.7
		Var	3.9	4.2	5.2	5.2	0.8
		SD	2.4	2.3	2.7	2.7	0.9

Note: PI is Part I of the seasonal data; PII is Part II of the seasonal data.

Table 2. Fibre diameter and colour characteristics of crossbred fleece

'Season'	Number	Statistic	Fibre Diameter	Colour X	Colour Y	Colour Z	Colour Y-Z
97-98PI	1,247	Mean	29.1	65.1	69.1	59.3	9.7
		Var	4.2	2.6	3.2	3.3	0.5
		SD	2.0	1.6	1.8	1.8	0.7
97-98PII	1,016	Mean	29.0	65.3	69.2	59.5	9.7
		Var	5.0	3.3	3.9	5.3	1.0
		SD	2.2	1.8	2.0	2.3	1.0
98-99PI	1,046	Mean	30.4	65.7	69.6	60.2	9.4
		Var	4.6	4.0	4.9	5.0	0.8
		SD	2.1	2.0	2.2	2.2	0.9
98-99PII	753	Mean	29.7	66.0	69.9	59.9	10.1
		var	5.7	2.9	3.5	6.2	1.0
		SD	2.4	1.7	1.9	2.5	1.0
99-00	1,588	MEAN	29.7	66.7	70.7	60.7	10.0
		Var	5.7	1.8	2.2	4.3	1.2
		SD	2.4	1.4	1.5	2.1	1.1
00-07	701	MEAN	29.74	66.81	70.86	60.62	10.24
		Var	8.03	2.48	2.98	5.67	1.22
		SD	2.83	1.58	1.73	2.38	1.11
Total	6,351	MEAN	29.6	65.9	69.9	60.0	9.8
		Var	5.4	2.8	3.4	4.8	0.9
		SD	2.3	1.7	1.8	2.2	1.0

Note: PI is Part I of the seasonal data; PII is Part II of the seasonal data.

Correlation between MFD and Measured Colour

Correlation analyses were conducted between MFD and measured colour of clean wool for both Merino and crossbred fleece data. The correlation coefficients are listed in Table 3 for Merino fleece and Table 4 for crossbred fleece.

Tables 3 & 4 show that:

- Measured wool colour parameters, X, Y, Z, and (Y-Z) were all significantly correlated to MFD for both Merino and crossbred data at confidence level of 99%;
- Wool yellowness, (Y-Z), showed a positive and much higher correlation than X, Y and Z values;
- Most interestingly, colour parameters of X and Y were positively correlated to MFD for the Merino fleece data but negatively for the crossbred fleece data; and,
- Colour parameter Z had the same sign (negative) correlation with MFD for both Merino and crossbred data. The value of this correlation for the crossbred fleece data was slightly higher than the correlations for X and Y.

Due to the differences in the number of tests for each 'season', significance tests of difference were carried out to compare the correlation coefficients between the Merino and crossbred data. Based on the numbers of tests and the correlation coefficients in Tables 3 & 4, z values (Hubert, 1972) are listed in Table 5 for each pair of Merino and crossbred data for each 'season'. The significance tests showed that the correlations between MFD and X, Y, Z and (Y-Z) were significantly different between the Merino and crossbred data, except for the correlation pairs of (Y – Z) in the data of 2000 – 2007 data and Z in the data of 1998 – 1999 Part I (Table 5).

Table 3. Correlation coefficients between MFD and measured colour for Merino fleece data

	Correlation coefficient, r, for Merino fleece				
'Season'	**Number**	**Colour X**	**Colour Y**	**Colour Z**	**Colour Y- Z**
97-98PI	22,501	-0.01	0.00	-0.15****	0.41**
97-98PII	20,821	0.25**	0.25**	0.09**	0.49**
98-99PI	26,509	0.08**	0.10**	-0.12**	0.47**
98-99PII	19,437	0.08**	0.09**	-0.10**	0.56**
99-00	26,143	0.02**	0.03**	-0.20**	0.50**
00-07	5,619	0.07**	0.08**	-0.06**	0.41**
Total	121,030				
Weighted Av		0.08	0.09	-0.10	0.48

Note: ** represents that correlation is significant at the α level of 0.01 (two tailed).

PI is Part I of the seasonal data; PII is Part II of the seasonal data.

Table 4. Correlation coefficients between MFD and measured colour for crossbred fleece data

	Correlation coefficient, r, for crossbred fleece				
'Season'	**Number**	**Colour X**	**Colour Y**	**Colour Z**	**Colour Y- Z**
97-98PI	1,247	-0.22**	-0.20**	-0.33**	0.33**
97-98PII	1,016	-0.26**	-0.25**	-0.38**	0.38**
98-99PI	1,046	-0.04	-0.02	-0.13**	0.32**
98-99PII	753	-0.24**	-0.22**	-0.31**	0.34**
99-00	1,588	-0.30**	-0.28**	-0.39**	0.36**
00-07	227	-0.36**	-0.34**	-0.47**	0.48**
Total	5,877				
Weighted Av		-0.22	-0.21	-0.32	0.35

Note: ** represents that correlation is significant at the α level of 0.01 (two tailed). PI is Part I of the seasonal data; PII is Part II of the seasonal data.

Table 5. 'z' values and significance tests of differences between correlation coefficients for Merino and crossbred fleece data

	'z' values between correlation coefficients			
'Season'	**Colour X**	**Colour Y**	**Colour Z**	**Colour Y-Z**
97-98PI	7.23**	6.95**	6.69**	3.20**
97-98PII	16.20**	15.99**	15.11**	4.04**
98-99PI	3.86**	3.94**	0.40	5.80**
98-99PII	8.62**	8.41**	5.73**	7.34**
99-00	12.46**	12.21**	8.01**	6.45**
00-07	6.60**	6.38**	6.56**	-1.23

Note: ** represents that the correlations of each 'season' pair of Merino and crossbred fleece data are significantly different at the α level of 0.01. PI is Part I of the seasonal data. Pll is Part II of the seasonal data.

Linear Relationship between Measured Wool Colour and MFD

Linear regression analyses of measured wool colour and MFD are shown in Tables 6 & 7 for Merino and crossbred, respectively. The following observations are made:

- Measured wool colour parameters generally had statistically significant linear regression relationships with MFD:
    - Colour parameters X, Y and (Y-Z) had positive regression coefficients, while Z had negative coefficients for the Merino fleece data;
    - Colour parameters X, Y and Z had negative regression coefficients, while (Y-Z) had positive coefficients for the crossbred fleece data; and,
    - Colour parameters (Y-Z) and Z showed stronger linear relationships with MFD than did X and Y.
- The coefficients of the MFD versus Y-Z relationship were larger for the Merino fleece data than for the crossbred fleece data for the 1997 – 1999 'seasons'. Interestingly, these coefficients became similar for both sets of fleece data for the 2000 – 2007 'season'.

To visualise the regression relationships between MFD and the measured colour parameters, (Y-Z), X, Y, and Z , 300 tests were randomly selected and plotted in Figure 1 for the data of 98-99 Part I (the 'season' with the largest coefficient for MFD versus (Y-Z) in the Merino fleece database) and in Figure 2 for the data of 00-07 (the 'season' with the smallest coefficient for MFD versus (Y-Z) in the Merino fleece database). The differences between these regression relationships for the Merino and crossbred fleece data are consistent with the correlation results shown in Tables 3 & 4.

Table 6. Linear regression analyses for the relationship between wool colour and MFD for Merino fleece data

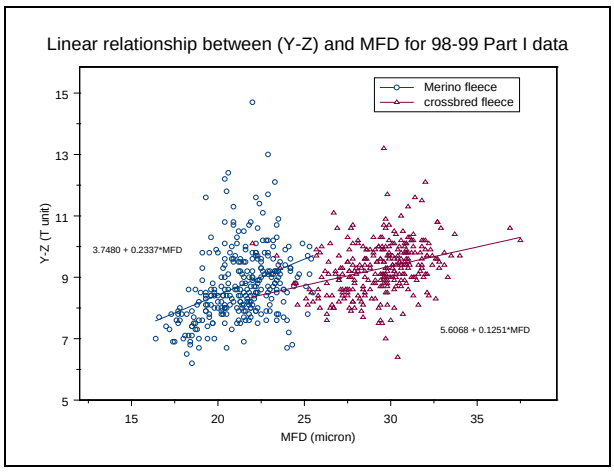
'Season'	Colour	Parameter	Value	Std. Error	t value	Pr(>|t|)
Colour 97-98 PI	X	Intercept	67.06	0.2	349.4	0.00
		Slope	-0.02	0.0	-1.7	0.10
	Y	Intercept	70.75	0.2	334.9	0.00
		Slope	0.00	0.0	-0.5	0.64
	Z	Intercept	66.31	0.2	331.2	0.00
		Slope	-0.22	0.0	-23.1	0.00
	Y-Z	Intercept	4.44	0.1	66.6	0.00
		Slope	0.21	0.0	68.0	0.00
Colour 97-98 PII	X	Intercept	60.97	0.2	397.6	0.00
		Slope	0.26	0.0	36.8	0.00
	Y	Intercept	63.97	0.2	372.9	0.00
		Slope	0.30	0.0	38.0	0.00
	Z	Intercept	59.77	0.2	357.1	0.00
		Slope	0.10	0.0	12.4	0.00
	Y-Z	Intercept	4.19	0.1	76.3	0.00
		Slope	0.20	0.0	80.7	0.00
Colour 98-99 PI	X	Intercept	65.44	0.1	466.6	0.00
		Slope	0.09	0.0	13.8	0.00
	Y	Intercept	68.78	0.2	439.4	0.00
		Slope	0.12	0.0	16.2	0.00
	Z	Intercept	65.79	0.2	422.1	0.00
		Slope	-0.15	0.0	-20.1	0.00
	Y-Z	Intercept	2.98	0.1	45.9	0.00
		Slope	0.27	0.0	87.4	0.00
Colour 98-99 PII	X	Intercept	65.95	0.1	468.6	0.00
		Slope	0.07	0.0	10.9	0.00
	Y	Intercept	69.51	0.2	441.4	0.00
		Slope	0.09	0.0	12.3	0.00
	Z	Intercept	65.24	0.2	410.5	0.00
		Slope	-0.11	0.0	-14.6	0.00
	Y-Z	Intercept	4.27	0.0	94.3	0.00
		Slope	0.20	0.0	94.0	0.00
Colour 99-00	X	Intercept	67.52	0.1	658.3	0.00
		Slope	0.01	0.0	2.5	0.01
	Y	Intercept	71.14	0.1	620.0	0.00
		Slope	0.03	0.0	5.3	0.00
	Z	Intercept	67.11	0.1	548.6	0.00
		Slope	-0.18	0.0	-32.5	0.00
	Y-Z	Intercept	4.04	0.0	81.6	0.00
		Slope	0.21	0.0	92.6	0.00
Colour 00-07	X	Intercept	67.58	0.6	108.6	0.00
		Slope	0.01	0.0	0.3	0.75
	Y	Intercept	71.43	0.7	108.5	0.00
		Slope	0.02	0.0	0.6	0.56
	Z	Intercept	65.99	0.8	81.8	0.00
		Slope	-0.16	0.0	-4.1	0.00
	Y-Z	Intercept	5.06	0.2	27.7	0.00
		Slope	0.19	0.0	21.3	0.00
Mean	X	Intercept	65.75	0.23	408.18	0.00
		Slope	0.07	0.01	10.47	0.14
	Y	Intercept	69.26	0.24	386.19	0.00
		Slope	0.09	0.01	11.99	0.20
	Z	Intercept	65.04	0.27	358.55	0.00
		Slope	-0.12	0.01	-13.66	0.00
	Y-Z	Intercept	4.16	0.08	65.40	0.00
		Slope	0.21	0.00	74.00	0.00

Note: PI is Part I of the seasonal data; PII is Part II of the seasonal data.

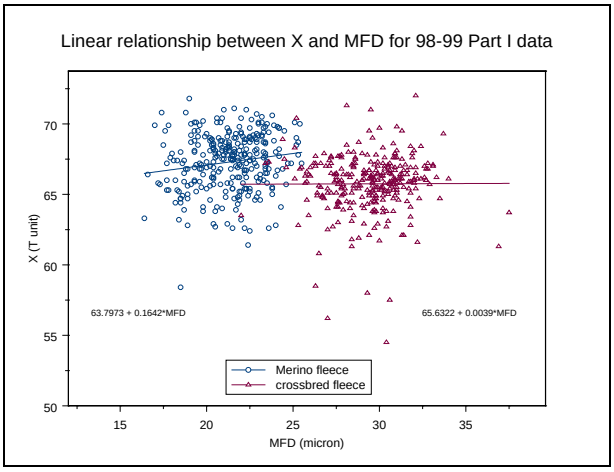
Table 7. Linear regression analyses for the relationship between wool colour and SLOPE for crossbred fleece data

'Season'	Colour	Parameter	Value	Std. Error	t value	Pr(>|t|)
Colour 97-98 PI	X	Intercept	70.17	0.6	109.8	0.00
		Slope	-0.17	0.0	-7.9	0.00
	Y	Intercept	74.21	0.7	104.7	0.00
		Slope	-0.18	0.0	-7.3	0.00
	Z	Intercept	67.99	0.7	98.4	0.00
		Slope	-0.30	0.0	-12.5	0.00
	Y-Z	Intercept	6.23	0.3	22.2	0.00
		Slope	0.12	0.0	12.4	0.00
Colour 97-98 PII	X	Intercept	71.52	0.7	99.8	0.00
		Slope	-0.21	0.0	-8.7	0.00
	Y	Intercept	75.64	0.8	96.4	0.00
		Slope	-0.22	0.0	-8.2	0.00
	Z	Intercept	70.85	0.9	81.7	0.00
		Slope	-0.39	0.0	-13.1	0.00
	Y-Z	Intercept	4.79	0.4	12.8	0.00
		Slope	0.17	0.0	13.2	0.00
Colour 98-99 PI	X	Intercept	66.83	0.9	78.2	0.00
		Slope	-0.03	0.0	-1.2	0.23
	Y	Intercept	70.49	0.9	74.9	0.00
		Slope	-0.03	0.0	-0.8	0.42
	Z	Intercept	64.63	1.0	68.0	0.00
		Slope	-0.14	0.0	-4.4	0.00
	Y-Z	Intercept	5.86	0.3	18.6	0.00
		Slope	0.12	0.0	10.9	0.00
Colour 98-99 PII	X	Intercept	71.02	0.8	93.6	0.00
		Slope	-0.17	0.0	-6.7	0.00
	Y	Intercept	75.12	0.8	89.7	0.00
		Slope	-0.17	0.0	-6.2	0.00
	Z	Intercept	69.39	1.1	64.2	0.00
		Slope	-0.32	0.0	-8.9	0.00
	Y-Z	Intercept	5.73	0.4	13.2	0.00
		Slope	0.15	0.0	10.0	0.00
Colour 99-00	X	Intercept	71.73	0.4	176.6	0.00
		Slope	-0.17	0.0	-12.4	0.00
	Y	Intercept	75.85	0.4	168.7	0.00
		Slope	-0.17	0.0	-11.4	0.00
	Z	Intercept	70.66	0.6	117.6	0.00
		Slope	-0.34	0.0	-16.6	0.00
	Y-Z	Intercept	5.19	0.3	16.5	0.00
		Slope	0.16	0.0	15.4	0.00
Colour 00-07	X	Intercept	72.77	1.0	72.0	0.00
		Slope	-0.20	0.0	-5.9	0.00
	Y	Intercept	77.06	1.1	69.1	0.00
		Slope	-0.21	0.0	-5.6	0.00
	Z	Intercept	72.39	1.4	50.1	0.00
		Slope	-0.40	0.0	-8.2	0.00
	Y-Z	Intercept	4.67	0.7	7.0	0.00
		Slope	0.19	0.0	8.4	0.00
Mean	X	Intercept	70.67	0.73	104.99	0.00
		Slope	-0.16	0.02	-7.13	0.04
	Y	Intercept	74.73	0.81	100.57	0.00
		Slope	-0.16	0.03	-6.58	0.07
	Z	Intercept	69.32	0.94	80.00	0.00
		Slope	-0.31	0.03	-10.62	0.00
	Y-Z	Intercept	5.41	0.40	15.04	0.00
		Slope	0.15	0.01	11.73	0.00

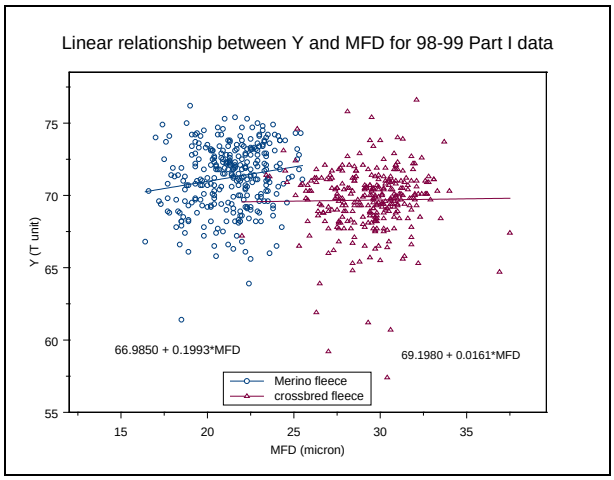
Note: PI is Part I of the seasonal data; PII is Part II of the seasonal data.



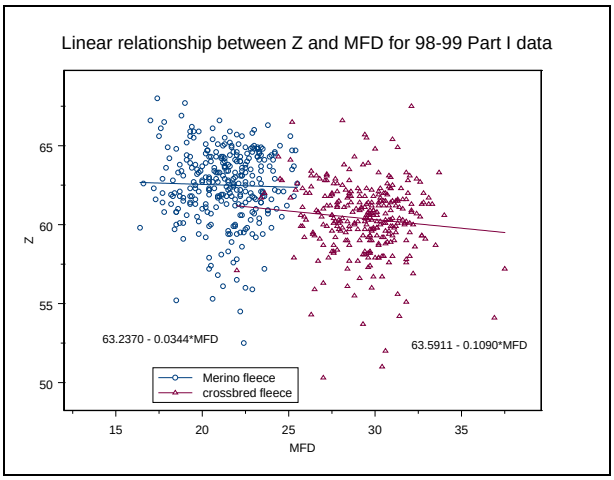
(a) (Y-Z) v SLOPE



(b) X v SLOPE

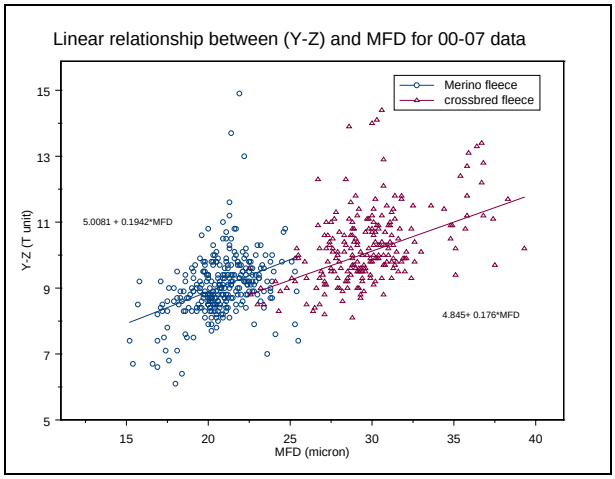


(c) Y v SLOPE

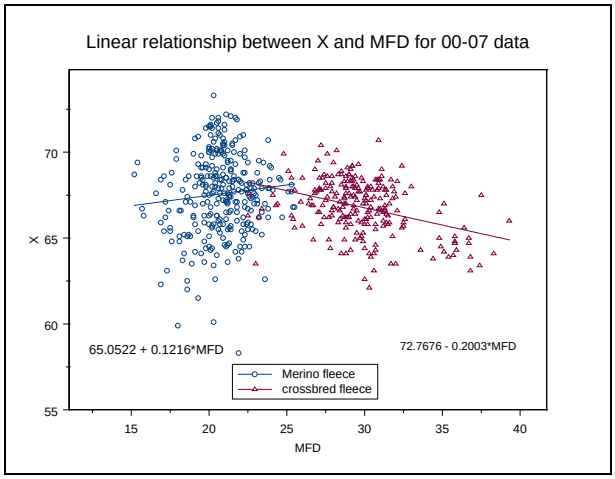


(d) Z v SLOPE

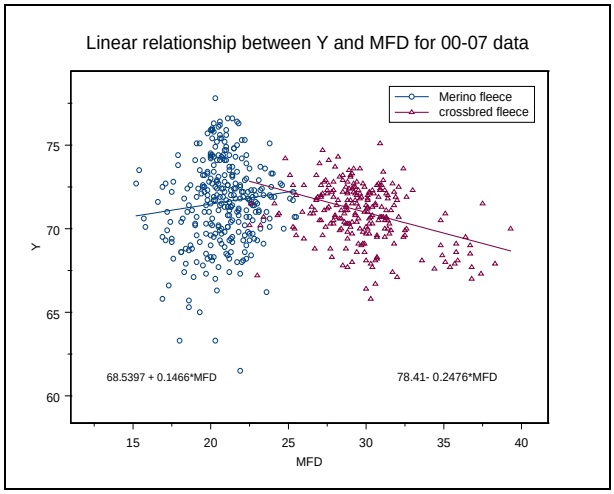
Figure1. Relationships between colour parameters and SLOPE for 300 random tests from the 98-99 Part I ‘season’.



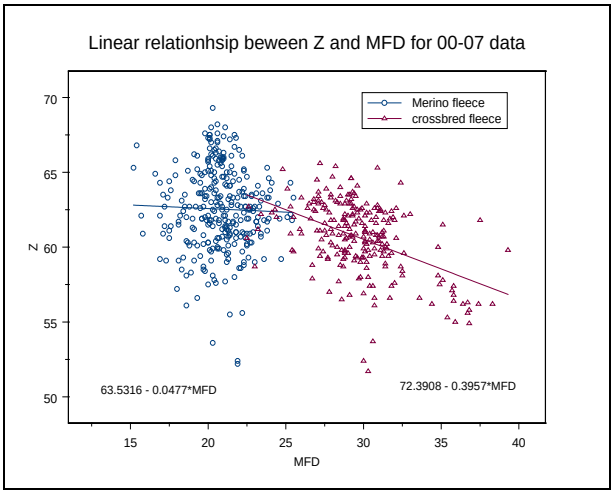
(a) (Y-Z) v SLOPE



(b) Z v SLOPE



(c) Y v SLOPE



(d) Z v SLOPE

Figure2. Relationships between colour parameters and SLOPE for 300 random tests from the 00-07 ‘season’.

Conclusion

In conclusion:

- Measured wool colour parameters, X, Y, Z, and (Y-Z) were all significantly correlated to MFD at the 99% confidence level for both Merino and crossbred data.
    - Wool yellowness, (Y-Z), showed a positive and much higher correlation than X, Y and Z values.
    - Most interestingly, colour parameters of X and Y were negatively correlated to MFD for the crossbred fleece data but positively correlated for the Merino fleece data.
    - Colour parameter Z was negatively correlated to MFD and had a slightly stronger correlation relationship than did X and Y for the crossbred fleece data
- The correlation relationships were significantly different between Merino and crossbred data for colour parameters, X, Y, Z and (Y-Z).
- Measured wool colour parameters had linear regression relationships with MFD:
    - Colour parameters X, Y and (Y-Z) had positive regression coefficients, while Z had a negative coefficient for the Merino fleece data.
    - Colour parameters X, Y and Z had negative regression coefficients, while (Y-Z) had a positive coefficient for the crossbred fleece data.
    - Colour parameters (Y-Z) and Z showed stronger relationships with MFD than did X and Y for both Merino and crossbred fleece data.
- The coefficient of MFD versus Y-Z relationship was larger for Merino fleeces than for crossbred fleeces for the 1997 – 1999 ‘seasons’. However, these coefficients became similar for the fleece data for the 2000 – 2007 ‘season’.

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