# Wool Studies.

# I. The Variation and Interdependence of Merino Fleece and Fibre Characteristics.

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## I. Introduction.

THE sheep used at Onderstepoort for experimental purposes are as a rule obtained from other centres, where conditions are more suited to breeding. Soon after their arrival here, marked changes are to be observed in the wool produced by the animals. It is well known that changes in environmental conditions may produce considerable changes in the wool, and the individual contributions of changes in such factors as meteorological and nutritional conditions have been studied to a certain extent.

As an example may be quoted the work done at the Grootfontein School of Agriculture, from where many of the sheep used at Onderstepoort are obtained. It has been demonstrated at that Institution (Maré and Bosman, 1934) that underfeeding produces lighter fleeces and finer fibres. Furthermore, the seasons have no effect on the wool produced, provided the feed is kept constant. (Bosman, 1935.)

It has also been observed that when sheep, which have been grazed, are stall-fed, a reduction in the fibre thickness takes place. This latter effect may, therefore, be expected at Onderstepoort, where the sheep are stall-fed after having been reared under grazing conditions where they were bred.

The degree to which the various fibre characteristics respond, both individually and in relation to one another, calls for a systematic investigation, as it is felt that the result of such an investigation will be important, not only for its own sake, but also for its possible bearing on experimental results, obtained where similar conditions prevail.

In the present investigation no attempt has been made to assign or discuss possible causes of such variations in the wool produced. The object has been a statistical study of the data of the wool produced by a group of merino wethers sent from Grootfontein to Onderstepoort, where they were kept under experimental conditions for two years.

A point which should be borne in mind is that, in accordance with usual experimental procedure, the group of sheep was selected from the flock for uniformity of type, fleece and body weight.

In the study attention was directed mainly towards the following points:—

(1) The change of each characteristic from one year to another.

(2) The correlation between the values of the same characteristic for different years.

(3) The correlation between different characteristics for the same year.

(4) The correlation between the changes in different characteristics for the same sheep.

Such a study indicates to what extent the various fleece attributes are related to their previous values, and also the extent to which one attribute can be described in terms of another.

## II. Material.

### (a) The Sheep.

The sheep were obtained from Grootfontein and were used at Onderstepoort in a study of the effect of supplements of sulphur on growth and wool production. Since a full report of the experiment has been given (du Toit, Malan, Groenewald and Botha, 1935; van Wyk, Botha and Bekker, 1935), a brief summary of the history of the animals will suffice.

A selected group of merino wethers, born at Grootfontein between 10/3/1930 and 9/6/1930, were shorn between 31/3/1931 and 8/4/1931, and sent to Onderstepoort, where they arrived on 8/10/1931. They were shorn again in December, 1931, and placed on a basal ration for a pre-experimental period of eleven months. At the conclusion of this period in November, 1932, they were shorn again, and placed on the same basal ration for twelve months, during which period certain groups were dosed with supplements of sulphur and sulphur compounds. Finally, they were shorn at the end of the experimental period in November, 1933.

At Grootfontein the animals were grazed on typical Karroo veld, while the basal ration at Onderstepoort consisted of half a pound of crushed yellow maize and half a pound of green feed daily, with teff hay *ad lib*. Except in the case of the teff hay, individual feeding was employed.

The data were thus obtained for wool grown under the following conditions:—

1931: Six months grazing at Grootfontein, followed by two months at Onderstepoort, where the animals were stall-fed.

1932: Eleven months on basal ration at Onderstepoort.

1933: Twelve months on basal ration with sulphur supplements at Onderstepoort.

## (b) Experimental Results.

The sheep were weighed monthly from 23/12/31 until the conclusion of the experiment, i.e. during the pre-experimental and experimental periods. The grease weight ($x$), clean weight ($y$), and percentage yield ($z$) of the fleeces obtained from the 1931, 1932 and 1933 clips at Onderstepoort were determined, as also the mean fibre length ($l$), mean fibre thickness ($t$) and mean fibre weight ($w$) of a shoulder sample taken from an area marked on the skin. These samples were taken just before the sheep were shorn on each occasion.

From a statistical analysis of the results of the experiment (du Toit et alia, 1935; van Wyk et alia, 1935) it was concluded that, in the case of the wethers under consideration, the sulphur supplements had no influence on any of the fleece characteristics studied, hence for the purpose of this paper no differentiation between the groups will be made, and the data for the final period (1933) will be treated as if all the sheep received the same ration.

In the discussion the data for the separate years, 1931, 1932 and 1933 will be indicated by the suffixes 1, 2 and 3 respectively to the symbols for the attributes.

For the sake of direct comparison between the different years, the fleece weights are given as the average increase per day, while for fibre length and fibre weight the values given have been calculated so as to correspond to 300 days' growth. The fibre weights and fibre lengths for the 1931 samples were not available, and are, therefore, not included. The data for only 46 sheep were available for all three periods, hence this number was used in the analysis, except where otherwise stated.

In Table I are given the mean values of the fleece and fibre characteristics studied, together with the body weights and ages of the animals.

The figures for body weight and greasy fleece weight show that the sheep are a type which is mostly used at Onderstepoort in sheep experiments, the mature body weight being approximately 74 lb. and the fleece weight $9\frac{1}{2}$ lb. for 12 months' growth.

Table I.

| Period. | Age. | Mean Body Weight (shorn). $(g)$ | Mean Fleece Weight (per day). $(x)$ | Mean Scoured Fleece Weight (per day). $(y)$ | Mean Fibre Length (Shoulder), (300 days). $(l)$ | Mean Fibre Thickness (Shoulder). $(t)$ | Mean Fibre Weight (Shoulder), (300 days). $(w)$ |
|---|---|---|---|---|---|---|---|
| 1931.......... | Tooth. 2 | | 11·567±0·1567 gm. | 6·065±0·1802 gm. | | 16·76±0·1638 $\mu$ | |
| 1932.......... | 4 | 31·56±0·2913 kg. | 10·496±0·1850 gm. | 4·824±0·0918 gm. | 8·142±0·0793 cm. | 15·48±0·1512 $\mu$ | 19·99±0·4289 $10^{-6}$ gm. |
| 1933.......... | 6 | 35·67±0·3401 kg. | 13·924±0·2435 gm. | 6·564±0·1177 gm. | 9·531±0·1082 cm. | 17·49±0·1626 $\mu$ | 29·79±0·5753 $10^{-6}$ gm. |

Table III.

| Characteristic. | $x_3-x_2$. | $y_3-y_2$. | $l_3-l_2$. | $t_3-t_2$. | $w_3-w_2$. | $g_3-g_2$. |
|---|---|---|---|---|---|---|
| Mean Difference......... | 3·428±0·1390 gm. | 1·740±0·0803 gm. | 1·389±0·0658 cm. | 2·015±0·0908 $\mu$. | 9·806±0·4149 gm. | 4·239±0·4341 kg. |
| Percentage Change *..... | 28·3 | 30·6 | 15·7 | 12·2 | 39·6 | 12·6 |

* The change expressed as a percentage of the average for the two years.

The scoured fleece weight, representing the total amount of wool keratin produced by a sheep, is of primary importance, and depends on the total number of fibres and on the weights of the fibres. The weight of a fibre again depends on its thickness and length since the specific gravity is constant or very nearly so (King, 1926). The thickness and length of fibres can only be estimated from samples, and the values obtained vary with the area of the skin from which the sample was obtained. In merino sheep experiments it is usual to analyse a shoulder sample since this portion of the fleece represents the bulk of the fleece (Duerden and Bell, 1928).

Table I includes the fibre lengths and fibre weights calculated for 300 days' growth, together with the mean fibre thickness, in microns, of the shoulder samples. The average fibre thickness represents that of the dry fibre and has an average value of $16 \cdot 6\mu$. The mean value for scoured fleece weight represents approximately five pounds of clean wool grown per year.

Table II gives the coefficients of variability (i.e. the standard deviation expressed as a percentage of the mean) of the various characteristics of the 46 sheep studied.

TABLE II.

*Coefficients of Variability.*

| Period. | Grease Weight ($x$). | Clean Weight ($y$). | Percentage Yield ($z$). | Fibre Length ($l$). | Fibre Thickness ($t$). | Fibre Weight ($w$). | Body Weight ($g$). |
|---|---|---|---|---|---|---|---|
| 1931.. | % 9·2 | % 12·1 | % | % | % 6·6 | % | % |
| 1932.. | 11·9 | 12·9 | 8·8 | 6·6 | 6·6 | 14·6 | 6·3 |
| 1933.. | 11·9 | 12·2 | 8·4 | 7·3 | 6·3 | 13·1 | 6·5 |

The table shows that there is a very close agreement between the coefficients of variability of the same characteristic for different years. Since the mean values vary considerably from year to year this would seem to indicate that the variation in each characteristic, as measured by the standard deviation, is proportional to the mean, so that the higher values are also more variable, and vice versa.

### III. COMPARISON OF THE DIFFERENT YEARS.

In Table I a considerable change is shown in the values of the fleece characteristics from one year to another. There was a decrease in all the values from 1931 to 1932 and then an increase in 1933 to values exceeding those of 1931. These changes took place throughout the group and are frequently observed in merino sheep that are similarly treated. Taking differences between the 1932 and 1933 values in order to eliminate correlational effects, the results summarised in Table III are obtained.

The percentage increases, therefore, varied from about 12 per cent. to 40 per cent. for the different characteristics, all these values being highly significantly different from zero. In the present paper the test for significance has been taken to indicate that the probability of obtaining a certain value or a greater one, on the assumption that the population value is zero, is less than 5 per cent, whereas '' highly significant '' is used to denote that the above probability is less than one per cent.

In the above case, therefore, all the differences may be considered as real and not merely accidental. These values, however, give no indication of how and when the changes occurred. It was, therefore, decided to obtain thickness measurements of a single staple taken from a sample at equal intervals of length. Although the results obtained in this way are only approximate, they show the general trend of the changes during the whole period of 3 years. A typical curve giving the values obtained for one sheep is given (Fig. 1). Several others were investigated and these showed remarkably close agreement with the one represented here.
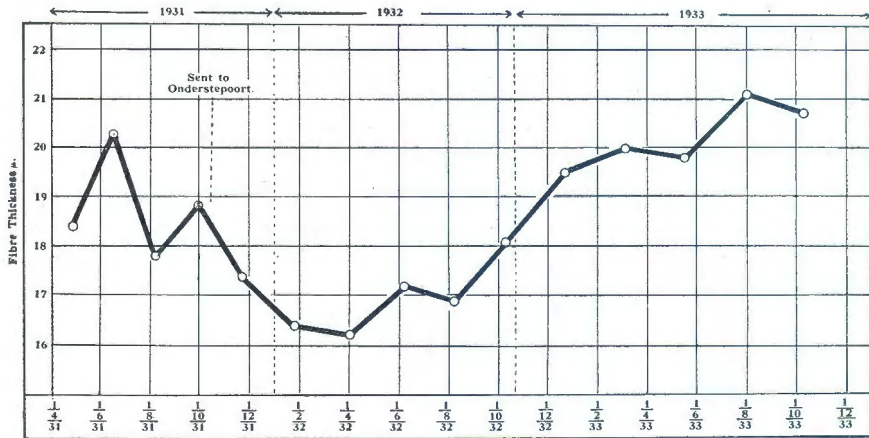


Fig. I.

It will be noted that the fibre thickness decreased to a minimum in April, 1932, followed by a continuous rise until July, 1933, when it seemed to have reached a more or less constant value, though no data are available after December, 1933. In other words, during the pre-experimental, or 1932 period, the fibre thickness at first diminished and then increased, while during the greater part of the experimental, or 1933 period, the thickness was increasing.

The bearing of the above changes on experimental results and their interpretation is of importance. Treatment effects which would normally have been reflected as small differences in fleece characteristics, may have remained obscure during the period when the fleece was undergoing wide changes, due to environmental factors. On the other hand, when a difference in treatment also affects the rate of adaptation to the new environment, the interpretation will greatly depend on the duration of the experimental period, and may lead to erroneous conclusions.

In the present case it took nearly two years for the fleece characteristics to attain values which appear to have reached a constant level under the changed environmental conditions. The rate and nature of the above changes need further investigation. For this purpose it seems advisable to send sheep from and to different centres under strictly controlled conditions, simultaneously eliminating other influencing factors, such as age, etc.

## IV. ANALYSIS OF THE FLEECE.

### (a) The relation between the values for different years of the same attribute.

The simple correlation coefficients, $r_{12}$, $r_{23}$ and $r_{31}$ between the values of the fleece characteristics for the years 1931, 1932 and 1933 are summarised below:—

TABLE IV.

| Correlation Coefficient. | Grease Weight $(x)$. | Clean Weight $(y)$. | Fibre Length $(l)$. | Fibre Thickness $(t)$. | Fibre Weight $(w)$. | Body Weight $(g)$. |
|---|---|---|---|---|---|---|
| 1932 & 1933 : $r_{23}$.. | **0·8235** | **0·7340** | *0·7682* | **0·8347** | **0·7436** | *0·4824* |
| 1931 & 1932 : $r_{12}$.. | **0·5108** | **0·7174** | | **0·7811** | | |
| 1931 & 1933 : $r_{13}$.. | **0·5286** | **0·5931** | | **0·7891** | | |

(In some cases more animals than 46 were available and were used in calculating the above coefficients.)

*N.B.*—Significant values are given in italics and those highly significant are given in black type. This system is followed throughout in subsequent tables.

All the above correlation coefficients are highly significant, and practically of the same order, except perhaps in the case of body weights $(g)$, where the correlation is somewhat lower. None of the values differ significantly, either amongst themselves, or between different years. The order of the correlation coefficients indicates that 50 to 60 per cent. $(r^2 \times 100)$ of the variation of a characteristic can be expressed in terms of the variation of the same characteristic for either of the two previous years. The high correlation coefficients, even when the change from one year to another is so exceptionally high, therefore demonstrate the necessity of a pre-experimental period in merino experiments where the fleece characteristics are being considered.

## (b) Simple correlation coefficients between different characteristics for the same year.

It is evident from the agreement in the differences between the values from one year to another, as shown in §III, that the fleece weights at least are to some extent associated with fibre characteristics. The degree of interdependence, as expressed by the simple correlation coefficient, is shown in the table given below. The correlation coefficients between different characteristics have been calculated separately for each year.

TABLE V.

| Characteristic. | Year. | Grease Fleece Weight $(x)$. | Scoured Fleece Weight $(y)$. | Fibre Length $(l)$. | Fibre Thickness $(t)$. |
|---|---|---|---|---|---|
| Scoured Fleece Weight (y).... | 1931 | 0·6707 | | | |
| | 1932 | 0·8015 | | | |
| | 1933 | 0·7864 | | | |
| Yield Percent (z)............ | 1932 | −0·2623 | 0·4495 | | |
| | 1933 | | 0·4198 | | |
| Fibre Length (l)............. | 1932 | | 0·3525 | | |
| | 1933 | 0·3408 | 0·4471 | | |
| Fibre Thickness (t)........... | 1931 | 0·0088 | −0·0591 | | |
| | 1932 | 0·1647 | 0·2694 | −0·0823 | |
| | 1933 | −0·0601 | −0·0729 | −0·2214 | |
| Fibre Weight (w)............ | 1932 | | 0·4321 | 0·3889 | 0·8833 |
| | 1933 | | 0·1821 | 0·3333 | 0·8431 |

The correlation coefficients between any two characteristics for the different years are in fair agreement, and indicate that the association between the different attributes, as measured by the simple correlation coefficients, is a constant feature in the wool of these wethers. This conclusion is on the whole strengthened by the values of simple correlation coefficients, calculated from the wool of 33 ewes, used in an iodine nutrition experiment (du Toit, Malan and Groenewald, 1935). These ewes were selected at Grootfontein from the same flock as the wethers in the present study, and were obtained at the same time. In the case of the ewes the following values for the correlation coefficients were obtained: —

## TABLE VI.

|  | Clean Weight ($y$). | Fibre Length ($l$). | Fibre Thickness ($t$). |
|---|---|---|---|
| $l$, Fibre Length | 0·1302 |  |  |
| $t$, Fibre Thickness | **0·4631** | 0·0150 |  |
| $w$, Fibre Weight | **0·4678** |  | **0·7065** |

The only exception as regards the agreement with the values in the previous table, Table VI, is that the correlation between scoured fleece weight ($y$) and the fibre characteristics, length ($l$) and thickness ($t$), is just the other way round. However, the real values of $r_{yt}$ and $r_{yl}$ are perhaps the same in both cases and intermediate between those obtained for the two groups of sheep. The discrepancy between the correlation coefficients given could also have been caused by the method of selection. Corresponding correlation coefficients calculated from 26 wethers (Bosman*) agree well with those given in Table VI.

## V. VARIATION IN THE ATTRIBUTES FOR 1932 AND 1933.

It was shown in paragraph III that· a considerable and highly significant change in the mean value of all the fleece characteristics studied took place from one year to the other. The order and nature of these changes have been discussed. It is also important to know to what extent the differences in individual values between consecutive years of associated attributes are correlated. The simple correlation coefficients are given below:—

## TABLE VII.

|  | $y_3-y_2$. | $l_3-l_2$. | $t_3-t_2$. | $w_3-w_2$. | $g_3-g_2$. |
|---|---|---|---|---|---|
| $x_2-x_3$ | **0·8034** |  |  |  | 0·3590 |
| $y_3-y_2$ |  | **0·6435** | 0·3337 | 0·3013 | 0·3306 |
| $l_3-l_2$ |  |  | 0·2378 | 0·3405 | 0·0064 |
| $t_3-t_2$ |  |  |  | **0·6511** | −0·1784 |

* Report in the course of preparation.

As may be expected a high correlation exists between the differences in grease weight ($x$) and clean weight ($y$). Two other high values are those between the differences in scoured fleece weight ($y$) and fibre length ($l$) and also fibre thickness ($t$) and fibre weight ($w$). Nearly all the other correlation coefficients are significant and practically the same with an approximate value of $0 \cdot 33$. The association between body weight differences and those of the fibre attributes is negligible. It follows, therefore, that in general a sheep that changes considerably in one attribute also changes likewise in another attribute.

The variability in fibre length and fibre thickness for each shoulder sample measured was calculated for 51 different sheep. The simple correlation coefficient between corresponding coefficients of variability for the same sheep was found to be $0 \cdot 6226$, which is a highly significant value. The simple correlation coefficient between the coefficients of variability of fibre length (shoulder sample) for the two years 1932 and 1933 was also calculated, and the value obtained for 45 sheep was $0 \cdot 6402$. This value is of the same order as the previous one and shows that sheep which are more variable in one characteristic are also more variable in another and remain so from one year to the other.

## VI. CONCLUSIONS.

From the preceding analysis, one is able to draw certain conclusions regarding the association of merino fleece and fibre characteristics.

It is evident that environmental conditions can produce considerable changes in the merino fleece. In the case under discussion, the fleeces at first became lighter and the fibres of a shoulder sample finer and shorter, after which the changes were reversed, and the initial values of the fleece and fibre characteristics exceeded. An increase from the second to the third period amounting to about 30 per cent. for the fleece and fibre weights was observed, and about half this value, approximately 15 per cent., for fibre length and fibre thickness, the difference between the mean values for the two periods, being highly significant.

Fibre thickness diminished rapidly after the sheep arrived at Onderstepoort, a minimum value being attained after about six months. A gradual increase then occurred to a probably constant value after a further period of fifteen months.

When, therefore, sheep are transferred from one centre to another, the change in environment may influence the fleece considerably, and a distinction should be made between this influence and that of any treatment to which the sheep are then subjected, and it must be recognised that the results obtained will depend on the nature of the possible interaction of the two influences. Otherwise it will be necessary to keep the sheep under the changed conditions, until the fleeces have attained what may be considered as normal characteristics, before commencing the experiment which is designed to ascertain the influence of some treatment or other on the wool.

As shown in Table V there exists a high correlation between the total fleece weight and the scoured fleece weight, the latter representing about 50 per cent. of the total fleece weight, whereas about 60 per cent. of the variation in the total fleece weight is due to the variation in the scoured fleece weight.

As regards the fibres of the shoulder sample, it is seen that the variation in the weight of a fibre depends mainly on the variation in its thickness, the variation in length having a relatively small influence on the variation in fibre weight. The correlation coefficients are constant from year to year, notwithstanding considerable changes in the actual values of the characteristics.

It is also demonstrated that the fibre attributes of a shoulder sample is a poor indication or no indication of the total amount of wool produced by a merino sheep.

The high correlation between the values of any of the fleece and fibre characteristics obtained for the different years is of importance. Approximately 60 per cent. of the variation in the values of one year can be expressed in terms of that for the previous year. This fact illustrates the importance of a pre-experimental period, which enables this proportion to be eliminated from the total variance, whereby a considerably greater accuracy is attained and smaller differences between mean values may be detected. In other words, a difference between treatment groups which would be obscured by the total variance, may become evident after an adjustment for the pre-experimental values has been made. For the same accuracy the number of sheep in any group of an experiment, without a pre-experimental period, must be approximately five times greater than when pre-experimental values are available.

The differences between the 1932 and 1933 values for all the fleece attributes were correlated. A difference in scoured fleece weight was closely reflected by a corresponding difference in the fibre length of the shoulder sample, whereas a difference in fibre weight was accompanied by a corresponding difference in fibre thickness. It is, therefore, possible to study a change in scoured fleece weight by means of the corresponding change in the fibre length of a shoulder sample.

Taking the group as a whole, the distribution of values, as expressed by the coefficient of variability, remained constant from year to year. In other words, the " spread " changed in proportion to the mean value.

A high correlation exists between the coefficients of variability of the fibre length of the shoulder samples taken from the same sheep in successive years. The variability, or spread, in fibre length is, therefore, a constant characteristic of individual sheep. For any one year, the correlation between the coefficients of variability of fibre thickness and fibre length is of the same high order, showing that a sample which is more variable as regards fibre length is also more variable as regards fibre thickness.

529

## VII. Summary.

1. A statistical analysis is given of the fleece and certain fibre attributes of a shoulder sample of a group of wethers sent from Grootfontein to Onderstepoort for experimental purposes. The data comprise values obtained for three successive years.

2. It is shown that a considerable decrease occurred in the mean values from the first to the second year, and then again an increase to mean values exceeding those existing in the first year. The nature of the change in fibre thickness is given in more detail.

3. The values obtained for each characteristic in the different years are highly correlated, from which fact is deduced the importance of a pre-experimental period.

4. The correlation coefficients between the fleece weight and the fibre attributes are, though significant, not very high, and the shoulder sample is, therefore, a poor indication of the total amount of wool produced.

5. The ratios of the standard deviations to the corresponding mean values of the group were constant for the three years.

6. Within a shoulder sample a high correlation exists between the coefficients of variability of fibre length for two years, and also between the coefficients of variability of fibre length and fibre thickness for the same year.

7. The interrelationships of the changes in the various attributes are given.

8. The bearing of the above results on experiments, in which wool is being inbevstigated, is discussed.

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