RELATIONSHIPS AMONG PRODUCTIVE CHARACTERS OF MERINO SHEEP IN NORTH-WESTERN QUEENSLAND

1. ESTIMATES OF PHENOTYPIC PARAMETERS

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SUMMARY

Estimates of repeatability and phenotypic relationships among 10 fleece characters were obtained from a flock of Merino sheep at the Toorak Field Station, Julia Creek. The repeatability of all characters was high, ranging from 0.45 to 0.80.

Phenotypic correlations were generally comparable with published data for similar strains. The principal antagonistic relationship is that between clean wool weight and crimp frequency ($r = -0.45$).

I. INTRODUCTION

A knowledge of the phenotypic relationships among characters of economic importance makes it possible to predict the effect of culling operations on the subsequent performance of the retained portion of the flock. The phenotypic statistics are also required in predicting the genetic consequences of selection when selection is based on more than one character.

Estimates of means, standard deviations, repeatabilities and phenotypic correlations were reported by Morley (1951, 1955) for eight sheep and wool characters measured in the flock of Trangie Agricultural Experiment Station in New South Wales. Young, Turner, and Dolling (1960) presented estimates of repeatability obtained from "Gilruth Plains" Field Station in south-western Queensland. They paid particular attention to the possibility of sex differences, but concluded that at least with respect to the 10 characters considered by them, estimates obtained from ewes were equally applicable to rams.

The aim of this study was to obtain estimates of phenotypic parameters from sheep run in a third type of environment, that of north-western Queensland.

II. MATERIALS AND METHODS

(i) *Environment.*—Toorak Field Station is situated 35 miles south of Julia Creek, Queensland. It comprises 36,000 ac of open Mitchell grass downs country and is typical of much of the north-western pastoral zone of the State. Mitchell grasses (species of *Astrebla*) dominate the perennial pasture. The annual Flinders grasses (species of *Iseilema*) and button grass (*Dactyloctenium radulans*) make a significant contribution in some seasons.

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The rainfall averages under 17 in. and is strongly seasonal. Very little rain falls during the winter months and about half the annual total is typically recorded in January and February. Periodic droughts occur when the summer rains fail. Monthly average maximum screen temperatures exceed 95°F for 4–6 months each summer. Daily maxima commonly exceed 100°F consecutively for periods of 2–3 weeks. In the coldest months of the year, June and July, maxima in the high 70's occur. Winter minima average about 45°F, but may be much lower during periods of strong westerly to south-westerly winds.

(ii) *Sheep*.—The data were obtained from a flock of Merino ewes of Medium Peppin origin locally bred and introduced to the Field Station as yearlings in 1951. Drought conditions delayed their first mating until 1953, since when they have been mated annually in the autumn. Results from the ewe progeny of these foundation animals have also been included.

These sheep are used primarily for investigations into life-time productivity and fertility. Therefore, no culling of ewes has been practised at any time.

(iii) *Characters Measured*.—The characters studied were:

Greasy Wool Weight.—Total fleece weight including bellies but excluding skirtings and locks.

Per cent. Clean Scoured Yield.—The percentage of bone-dry clean wool (free of vegetable matter and scouring residuals) in a midside sample of the fleece.

Clean Wool Weight.—Calculated as the product of greasy wool weight and clean scoured yield.

Fibre Diameter.—The mean diameter of 100 fibre snippets from a subsample of the scouring sample.

Coefficient of Variation of Fibre Diameter.—Calculated from the individual fibre diameter measurements. It is a measure of diameter variation among the fibres of the midside subsample and not through the fleece.

Staple Length.—The mean length of 6 staples.

Crimps per Inch.—The mean number of crimps per inch in 6 measured staples. (The same subsample as used for fibre diameter and staple length measurements).

Body-weight.—Liveweight "off shears", normally in the later part of July.

Neck Score.—Grade score for degree of wrinkledness and folds on the neck.

Side Score.—Grade score for degree of wrinkledness and folds on the side. For side and neck scores, photographic standards are used (Turner *et al.* 1953).

(iv) *Sheep Records and Method of Analysis*.—For the seven fleece characters repeatabilities were estimated from data on 1095 ewes with 1, 2 or 3 records in the years 1955 to 1959, but only 690 of these were used in calculating correlations among the characters. Repeatabilities and correlations involving the two fold scores and body-weight were estimated from data on 775 ewes with 1 or 2 records in the years 1958 and 1959.

Ewes were grouped according to year of birth, so the final pooled analyses of dispersion were of the form shown in Table 1.

TABLE 1

ANALYSIS OF DISPERSION FOR ESTIMATING PHENOTYPIC PARAMATERS

Source of Variation	Degrees of Freedom	Expectation of Mean Square or Product
Between sheep, eliminating years, within ages	m	$s_{ij} + \frac{m+n}{m} S_{ij}$
Sheep × years, within ages	n	s_{ij}

The phenotypic correlation between two characters, x_i and x_j, measured in the same year was estimated as:

$$\frac{s_{ij} + S_{ij}}{\sqrt{(s_{ii} + S_{ii})(s_{jj} + S_{jj})}}$$

This is computationally equivalent to using the pooled sums of squares and products for sheep and sheep × years.

Repeatability, by definition, is the proportion of the variance among individual records due to permanent differences among animals, i.e.

$$\frac{S_{ii}}{s_{ii} + S_{ii}}$$

It can also be thought of as the correlation between records in different years.

By analogy with repeatability, the correlation between two characters x_i and x_j measured in different years was estimated as:—

$$\frac{S_{ij}}{\sqrt{(s_{ii} + S_{ii})(s_{jj} + S_{jj})}}$$

III. RESULTS AND DISCUSSION

(a) Means and Coefficients of Variation

To permit comparison with other localities, means and coefficients of variation are listed in Table 2. They were obtained by weighting the means and mean squares for each age group by degrees of freedom. The overall greasy wool weight (8.25 lb), although low by comparison with more favoured sheep areas, is slightly above the district average. The Commonwealth Bureau of Census and Statistics quotes 8·14 lb as the average cut per head over the period 1955–1960 for adult sheep (including rams and wethers) in the Shire in which the Field Station is situated.

TABLE 2

PHENOTYPIC MEANS AND COEFFICIENT OF VARIATION

Character	Mean	Coefficient of Variation (%)
Greasy wool weight (lb)	8·25	14·0
Per cent. clean scoured yield	54·4	9·3
Clean wool weight (lb)	4·50	17·3
Fibre diameter (microns)	21·0	9·8
Coefficient of variation of fibre diameter (%)	16·9	18·0
Staple length (in.)	3·07	13·3
Crimps per inch	12·2	18·5
Body-weight (lb)	85·0	11·1
Neck score	3·9	23·9
Side score	2·0	41·5

The between-fibres coefficient of variation of diameter (C) is sufficiently low (16·9 per cent.) in relation to mean fibre diameter (21·0 microns) to justify the use of the mean fibre diameter alone in estimating mean fibre cross-sectional area (A). In fact, variations in C would be expected to account for less than 0·5 per cent. of the variance of $\sqrt{A}$.

Turner (1956) reviewed the ranges in published coefficients of variation for seven of the characters studied. The present data fall within or very slightly outside those ranges. They are also comparable with estimates reported by Young, Turner, and Dolling (1960).

(b) Phenotypic Correlations

For testing the significance of the phenotypic correlations in Table 3 the degrees of freedom for sheep only were considered. On this basis the significance of correlations of 0·07 or less is doubtful, while correlations greater than 0·13 can be regarded as well established. In interpreting the correlations it is convenient to group the characters in various ways, as follows:

(i) *Greasy Wool Weight, Yield, and Clean Wool Weight.*—By definition, greasy wool weight (G) is the sum of clean wool weight (C) and other parts not wool (N). From the means and coefficients of variation for G and C in

TABLE 3

PHENOTYPIC CORRELATIONS AMONG CHARACTERS MEASURED IN THE SAME YEAR

Character	Greasy Wool Weight	Per cent. Clean Scoured Yield	Clean Wool Weight	Fibre Diameter	C. of V. of Fibre Diameter	Staple Length	Crimps per Inch	Body-weight	Neck Score	Side Score
Greasy wool weight	..	+ 0·11	+ 0·84	+ 0·06	+ 0·08	+ 0·39	− 0·33	+ 0·15	+ 0·33	+ 0·28
Per cent. clean scoured yield ..	+ 0·11	..	+ 0·56	− 0·02	+ 0·05	+ 0·32	− 0·36	+ 0·02	− 0·03	−0·00
Clean wool weight	+ 0·84	+ 0·56	..	+ 0·05	+ 0·09	+ 0·49	− 0·45	+ 0·13	+ 0·22	+ 0·20
Fibre diameter	+ 0·06	− 0·02	+ 0·05	..	− 0·04	− 0·10	− 0·21	+ 0·11	+ 0·12	+ 0·08
Coefficient of variation of fibre diameter	+ 0·08	+ 0·05	+ 0·09	− 0·04	..	− 0·01	− 0·21	− 0·09	+ 0·00	− 0·03
Staple length	+ 0·39	+ 0·32	+ 0·49	− 0·10	− 0·01	..	− 0·36	+ 0·05	− 0·25	− 0·21
Crimps per inch	− 0·33	− 0·36	− 0·45	− 0·21	− 0·21	− 0·36	..	+ 0·00	+ 0·05	+ 0·09
Body-weight	+ 0·15	+ 0·02	+ 0·13	+ 0·11	− 0·09	+ 0·05	+ 0·00	..	− 0·09	− 0·14
Neck score	+ 0·33	− 0·03	+ 0·22	+ 0·12	+ 0·00	− 0·25	+ 0·05	− 0·09	..	+ 0·65
Side score	+ 0·28	− 0·00	+ 0·20	+ 0·08	− 0·03	− 0·21	+ 0·09	− 0·14	+ 0·65	..

—	Correlations Among First 7 Characters	Correlations Involving Last 3 Characters
Degrees of freedom (sheep)	684	768
Degrees of freedom (sheep × years)	545	420

Table 2 and their correlation (+0·84) it can be inferred that N has a coefficient of variation of the same order as C, and that C and N are positively correlated ($r = +0\cdot29$).

Since per cent. clean scoured yield (Y) is 100 times the ratio C/G, the relationships between Y and G and between Y and C can also be predicted. If it is assumed that the correlations among the logarithms of Y, C, and G are of the same order as those among the original variates, it follows that r_{YG} is approximately +0·07 and r_{YC} approximately +0·60. These values are quite close to those actually calculated from the data (+0·11 and +0·56 respectively). It also follows that the mean clean scoured yield is close to the ratio of the means of C and G.

(ii) *Relationships Among the Components of Clean Wool Weight.*—Turner (1951) defined the components of clean wool weight as:

Smooth body surface area (a function of body weight).

Wrinkling factor (a function of fold score).

Mean fibre cross-sectional area (a function of fibre diameter).

Mean fibre length (a function of staple length).

Mean number of fibres per unit area of smooth skin.

This study provides estimates of the relationships among the first four of these components. However, since no data on the fifth component (density) were collected, it is not possible to apportion the variance of clean wool weight along the lines suggested by Turner (1956). It is still profitable to examine the gross linear correlations. The strongest relationship is that between staple length and clean wool weight ($r = +0\cdot49$). The longer staple is associated with slightly finer wool, somewhat less fold development, and negligible body-weight difference. In contrast, the developed (higher fold score) sheep appear less favourably as shown by the slight, but probably significant, tendency to smaller body size and greater fibre diameter. On the other hand, they do produce somewhat more clean wool. This agrees with the finding of Morley (1955), but is contrary to the observations of other authors reviewed by Turner (1956), who found a sufficiently strong negative relationship with per cent. clean scoured yield to counter an initial advantage in greasy wool weight.

(iii) *Relationship Between Neck and Body Fold Scores.*—If the correlation between the two fold scores is calculated from the sheep components (S_{ij}), r is found to be +0·98. This suggests that the two scores are measures of substantially the same attribute.

This point, and the significance of other relationships among the variates, will be discussed more fully in the second paper of this series when estimates of genetic parameters are presented.

(c) Repeatability and Inter-Year Correlation Coefficients

Estimates of repeatability are shown in Table 4. They agree well with other published estimates. For several of the characters values are intermediate between those of Morley (1951) and Young, Turner, and Dolling (1960).

TABLE 4

ESTIMATES OF REPEATABILITY

Character	Repeatability	95% Fiducial Interval
Greasy wool weight	0·68	0·64 – 0·71
Per cent. clean scoured yield	0·65	0·61 – 0·69
Clean wool weight	0·65	0·60 – 0·68
Fibre diameter	0·53	0·48 – 0·58
Coefficient of variation of fibre diameter	0·45	0·39 – 0·50
Staple length	0·57	0·52 – 0·61
Crimps per inch	0·71	0·67 – 0·74
Body-weight	0·80	0·77 – 0·83
Neck score	0·62	0·57 – 0·68
Side score	0·50	0·43 – 0·57
—	First 7 Characters	Last 3 Characters
Degrees of freedom (sheep)	1087	768
Degrees of freedom (sheep × years)	735	420

The between-year correlations of Table 5 are similar to the phenotypic correlations of Table 3, but generally lower in absolute magnitude. This reflects the fact that within years the correlations among the "steady parts" of the 10 characters are in most cases of the same sign as the correlations between their residuals.

These estimates complete the information required to predict the subsequent productivity of sheep selected on their measured past performance. It is clear that culling for low wool weight (greasy or clean) will raise the flock average cut per head, but at the cost of selecting some of the stronger woolled and more wrinkly animals.

Some degree of selection against these two sources of increased wool weight will usually be warranted, but unless kept to a minimum will drastically curtail the improvement in wool weight. For example, a decision to hold crimp frequency constant would reduce the effective selection differential for clean wool weight to less than half its unrestricted value. Since the price differential corresponding to an increase in crimp frequency is small compared with the coefficient of variation of wool weight, the resulting slight increase in value per pound would be inadequate compensation for the decrease in quantity of wool produced.

TABLE 5

Correlations Among Characters Measured in Different Years

Character	Greasy Wool Weight	Per cent. Clean Scoured Yield	Clean Wool Weight	Fibre Diameter	C. of V. of Fibre Diameter	Staple Length	Crimps per Inch	Body-weight	Neck Score	Side Score
Greasy wool weight	..	+ 0·07	+ 0·56	+ 0·04	− 0·09	+ 0·26	− 0·30	+ 0·09	+ 0·33	+ 0·33
Per cent. clean scoured yield ..	+ 0·07	..	+ 0·37	− 0·00	+ 0·06	+ 0·27	− 0·33	− 0·01	+ 0·04	− 0·01
Clean wool weight	+ 0·56	+ 0·37	..	+ 0·04	+ 0·08	+ 0·35	− 0·42	+ 0·06	+ 0·24	+ 0·27
Fibre diameter	+ 0·04	− 0·00	+ 0·04	..	+ 0·01	− 0·08	− 0·17	+ 0·06	+ 0·13	+ 0·07
Coefficient of variation of fibre diameter	− 0·09	+ 0·06	+ 0·08	+ 0·01	..	− 0·01	− 0·19	− 0·07	+ 0·06	− 0·02
Staple length	+ 0·26	+ 0·27	+ 0·35	− 0·08	− 0·01	..	− 0·35	+ 0·02	− 0·24	− 0·17
Crimps per inch	− 0·30	− 0·33	− 0·42	− 0·17	− 0·19	− 0·35	..	+ 0·01	+ 0·03	+ 0·09
Body-weight	+ 0·09	− 0·01	+ 0·06	+ 0·06	− 0·07	+ 0·02	+ 0·01	..	− 0·08	− 0·09
Neck score	+ 0·33	+ 0·04	+ 0·24	+ 0·13	+ 0·06	− 0·24	+ 0·03	− 0·08	..	+ 0·55
Side score	+ 0·33	− 0·01	+ 0·27	+ 0·07	− 0·02	− 0·17	+ 0·09	− 0·09	+ 0·55	..

—	Correlations Among First 7 Characters	Correlations Involving Last 3 Characters
Degrees of freedom (sheep)	684	768
Degrees of freedom (sheep × years)	545	420

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