Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

A STUDY OF GENETIC AND ENVIRONMENTAL VARIATION AND COVARIATION IN PRODUCTIVE TRAITS OF A FLOCK OF PERENDALE SHEEP

A thesis presented in partial fulfilment
of the requirements for the degree
of Doctor of Philosophy in
Animal Science at
Massey University

ROGER PAUL LEWER

1978

A B S T R A C T

Performance records on 1724 two-year, 1160 three-year, 726 four-year and 449 five-year Perendale sheep from the Massey University flock were analysed. These records were collected between birth-years 1961 and 1974 inclusive, and therefore different numbers of years were involved at each age. The data comprised 97, 82, 65 and 56 sire groups for the respective ages. There were 403 ewes in 56 sire groups which had four consecutive records between two- and five-years of age. There were 922 two-year, 584 three-year, 296 four-year and 125 five-year dam-daughter pairs, but the last age group of records was considered too few to justify analysis.

The dependent variables examined were quality number (QN), wool character (WC), staple length (SL), greasy fleece weight (GFW), fibre diameter (FD), and number of lambs weaned per ewe joined and present at lambing (NLW). Fibre diameter had been recorded in fewer years than the other traits and there were consequently less observations available.

The effects of the environmental factors of year, age of the dam of the ewe, rearing rank, NLW (wool traits only), and all interactions among them were assessed by computing the percentage of the total variance contributed by each factor for each variable. Quadratic components for these fixed effects were temporarily considered to be variance components for this purpose. Year effects were the most important source of enviromental variation in wool characteristics, but were less important for NLW. None of the other main effects were consistently important (i.e. contributed greater than two percent of the total variation) in explaining the observed variability. Year x NLW was the only interaction

which contributed more than two percent of the total variance in any wool trait. The affected characteristics were two- and three-year QN, three-year FD and five-year SL. NLW (five-year-old ewes only) was affected by dam age x rearing rank and year x rearing rank interaction.

Heritability estimates calculated by paternal half-sib method (daughter-dam regression estimates in brackets) were in the range of 0.22 - 0.28 (0.39 - 0.66), 0.16 - 0.39 (0.12 - 0.25), 0.32 - 0.71 (0.25 - 0.36), 0.24 - 0.53 (0.43 - 0.62), 0.38 - 0.68 (0.45 - 0.50) and 0.02 - 0.24 (-0.02 - 0.03) for QN, WC, SL, GFW, FD and NLW respectively. Differences between ages were seldom significant and the relevance of such a comparison was discussed. Paternal half-sib heritability estimates for the average of four mature (two- to five-years) production records were 0.50, 0.61, 0.84, 0.44, 0.49 and -0.01 for the same respective characteristics. Binomial analysis methods resulted in heritability estimates for fertility (twinning in brackets) of 0.06 (0.12), 0.02 (0.15), -0.01 (0.13), and -0.15 (0.01 for two-, three-, four- and five-year-old ewes respectively.

Repeatability was estimated by averaging the regression of later on earlier record for all pairs of ages for wool traits and mature ages for reproductive characteristics and resulted in values of 0.46 (QN), 0.18 (WC), 0.50 (SL), 0.62 (GFW), 0.71 (FD), and 0.09 (NLW). Similar methods gave computed values for the repeatability of the difference between zero and one lamb weaned of 0.01, and between one and two lambs weaned of 0.13.

Genetic and phenotypic correlations between all variables were calculated separately at each age by paternal half-sib and daughter-dam methods. The correlations were positive for GFW - FD, GFW - SL, GFW -

WC, QN - WC and FD - SL, negative for GFW - QN, QN - FD and QN - SL, and mixed for FD - WC and SL - WC although the last of these were mostly positive. The phenotypic correlations between wool traits and reproduction were negative for NLW - GFW and NLW - SL and approximately zero for the remainder. Genetic correlations were negative for NLW - GFW, NLW - FD and NLW - SL, positive for NLW - QN and mainly positive for NLW - WC. Many of the genetic correlations involving NLW had large standard errors.

Application of the results was discussed in terms of the selection indices which were constructed.

ACKNOWLEDGEMENTS

It is with great pleasure that I acknowledge the many people who have assisted me to complete this thesis. Foremost are my supervisors Professor A.L. Rae and Dr. G.A. Wickham, to whom I owe my deepest gratitude and appreciation for their continuous help and suggestions throughout the course of this study.

Various of my friends, in particular Mr. C.J. Dodd and Mr A.B. Pleasants were of immense assistance during the period of computer familiarization. They and other colleagues and fellow students have provided a source of stimulating discussion on many occasions. Mr. L. Pearson of the Computer Science Department of the University gave invaluable help in problem-solving and the creation of files. The Computer Unit staff led by Mr. C. Read were always helpful.

Thanks are also due to the Massey University farm and technical staff who collected the records and to the Library staff for their continuous assistance.

Mrs. D. Steffert deciphered much of my early writing and typed the draft of the thesis. All credit must go to Miss J. McKegg for skilfully executing the final typing.

My wife Raewyn and daughters Kathryn and Juliet have suffered my frequent depressions and frustrations without complaint throughout this and earlier studies, and provided inspiration for their continuation. Without their support and encouragement the task may never have been completed.

The very generous leave conditions extended by the Ministry of Agriculture and Fisheries are gratefully acknowledged.

TABLE OF CONTENTS

Chapter		Page
	ABSTRACT	ii
	ACKNOWLEDGEMENTS	v
	LIST OF TABLES	x
ONE	INTRODUCTION	1
TWO	REVIEW OF LITERATURE	3
	I. Introduction	3
	II. Heritability	4
	A. Introduction.	4
	B. Wool Characteristics.	6
	C. Number of Lambs Weaned.	16
	III. Genetic Correlations	19
	A. Introduction.	19
	B. Between Wool Characteristics.	21
	C. Wool Characteristics and Number of Lambs Weaned.	25
	IV. Repeatability	29
	A. Introduction.	29
	B. Wool Characteristics.	30
	C. Number of Lambs Weaned.	39
	V. Phenotypic Correlations	42
	A. Introduction.	42
	B. Wool Characteristics.	42
	C. Wool Characteristics and Number of Lambs Weaned.	45
THREE	MATERIALS	48
	I. The Sheep and Environment	48
	A. The Farm.	48
	B. The Perendale.	48
	C. Management.	48
	II. The Data.	50

Chapter			Page
FOUR	METHODS		56
	I.	Analysis of Variance.	56
		A. Least Squares and Computing Methods	56
		B. Fitting Models to the Data.	59
		C. Significance Testing.	64
	II.	Accounting for Observed Variance.	65
		A. Variance Component Estimation.	65
		B. Proportion -of-variance Calculations.	67
	III.	Environmental Effects.	68
	IV.	Genetic and Phenotypic Parameters.	69
		A. Paternal Half-sib Analysis.	69
		1. Wool Traits and Number of Lambs Weaned.	69
		2. Fertility and Twinning.	72
		B. Daughter-dam Regression Analysis.	77
		C. Repeatability.	80
		1. Wool Characteristics.	80
		2. Number of Lambs Weaned.	81
	V.	Selection.	83
FIVE	RESULTS AND DISCUSSION.		84
	I.	Analysis of Variance and Environmental Effects.	84
		A. Quality Number.	84
		B. Wool Character.	95
		C. Staple Length.	97
		D. Fleece Weight.	99
		E. Fibre Diameter.	103
		G. Number of Lambs Weaned.	104
	II.	Selection.	108
	III.	Within-age Study.	110
		A. Heritabilities.	110
		1. Quality Number.	111
		2. Wool Character.	114
		3. Staple Length.	114

Chapter		Page
	4. Fleece Weight.	115
	5. Fibre Diameter.	116
	6. Number of Lambs Weaned.	117
	7. Fertility and Twinning.	119
	8. Conclusions.	120
	B. Genetic Correlations.	122
	1. Between Wool Characteristics.	122
	(a) Greasy Fleece Weight with other Wool Characteristics.	122 122
	(b) Quality Number with Other Wool Characteristics.	125
	(c) Fibre Diameter with Other Wool Characteristics.	126
	(d) Staple Length with Wool Character.	127
	2. Between Number of Lambs Weaned and Wool Characteristics.	128
	3. Conclusions,	131
	C. Phenotypic Correlations.	132
	1. Between Wool Characteristics.	132
	(a) Greasy Fleece Weight with Other Wool Characteristics.	132
	(b) Quality Number with Other Wool Characteristics.	135
	(c) Fibre Diameter with Other Wool Characteristics.	135
	(d) Staple Length with Wool Character.	136
	2. Between Number of Lambs Weaned and Wool Charateristics.	136
	3. Conclusions.	138
IV	Between-age and Lifetime Study.	139
	A. Repeatability.	139
	1. Bartlett's Test of Homogeneity of Variance.	139

Chapter		Page
	2. Repeatability Estimates.	139
	(a) Quality Number.	142
	(b) Wool Character.	142
	(c) Staple Length.	143
	(d) Fleece Weight.	143
	(e) Fibre Diameter.	143
	(f) Number of Lambs Weaned.	144
	(g) Number of Lambs Weaned at Different Production Levels.	144
	(h) Conclusions.	147
	B. Heritability of Annual Average Performance.	148
	C. Genetic Correlations Between Ages.	150
V.	Applications and Concluding Comments.	155
	A. Some Aspects of Selection.	155
	B. Selection Indices.	158
BIBLIOGRAPHY		167

LIST OF TABLES

Table		Page
2.1	Estimates of heritability of greasy fleece weight.	8
2.2	Estimates of heritability of quality number.	11
2.3	Estimates of heritability of wool character.	11
2.4	Estimates of heritability of staple length.	12
2.5	Estimates of heritability of fibre diameter.	12
2.6	Estimates of heritability of greasy fleece weight at different ages.	14
2.7	Estimates of heritability of staple length at different ages.	14
2.8	Estimates of heritability of fibre diameter at different ages.	15
2.9	Estimates of heritability of quality number at different ages.	15
2.10	Estimates of heritability of wool character at different ages.	15
2.11	Estimates of heritability of number of lambs weaned.	17
2.12	Estimates of genetic correlations. Wool traits.	22
2.13	Estimates of genetic correlations. Number of lambs weaned with wool traits.	26
2.14	Estimates of repeatability of greasy fleece weight.	32
2.15	Estimates of repeatability of wool character.	36
2.16	Estimates of repeatability of quality number.	36
2.17	Estimates of repeatability of staple length.	37
2.18	Estimates of repeatability of fibre diameter.	38
2.19	Estimates of repeatability of number of lambs weaned.	40
2.20	Estimates of phenotypic correlations. Wool traits.	43
2.21	Estimates of phenotypic correlations. Number of lambs weaned with wool traits.	47

Table		Page
3.1	Distribution of Ages within years.	51
3.2	Number of sire groups analysed.	52
3.3	Daughter-dam pairs.	52
3.4	Number of ewes with records at both age 1 and age 2.	53
3.5	Quality number codes.	53
4.1	Main effects and nested factor. Calculation of reductions in sums of squares and expectations of mean squares.	62
5.1	Two-year-old ewes. Least squares estimates and standard errors of environmental effects.	85
5.2	Three-year-old ewes. Least squares estimates and standard errors of environmental effects.	86
5.3	Four-year-old ewes. Least squares estimates and standard errors of environmental effects.	87
5.4	Five-year-old ewes. Least squares estimates and standard errors of environmental effects.	88
5.5	Two-year-old ewes. Percentage of variance accounted for by each factor for each variable.	89
5.6	Three-year-old ewes. Percentage of variance accounted for by each factor for each variable.	90
5.7	Four-year-old ewes. Percentage of variance accounted for by each factor for each variable.	91
5.8	Five-year-old ewes. Percentage of variance accounted for by each factor for each variable.	92
5.9	Two-year-old ewes. Least squares estimates of environmental effects. Year x NLW interaction on quality number.	96

Table		Page
5.10	Five-year-old ewes. Least squares estimates of environmental effects. Year x rearing rank interaction effect on NLW.	107
5.11	Five-year-old ewes. Least squares estimates of environmental effects. Dam-age x rearing rank interaction effect on NLW.	107
5.12	Difference in standard deviation units between the performance of all animals of age i, and the age i performance of animals which succeed to age j.	109
5.13	Heritability estimates, standard errors and approximate biasses.	112
5.14	Comparative heritability estimates from models including and excluding important interactions.	121
5.15	Estimates of genetic correlations and standard errors. Wool traits.	123
5.16	Estimates of genetic correlations and standard errors. Number of lambs weaned with wool traits.	129
5.17	Estimates of phenotypic correlations. Wool traits.	133
5.18	Estimates of phenotypic correlations. Number of lambs weaned with wool characteristics.	137
5.19	Bartlett's test of homogeneity of variance	140
5.20	Regression of later on earlier record.	141
5.21	Regression of later on earlier record. NLW at different production levels.	145
5.22	Heritability estimates, standard errors and approximate biasses. Average annual performance	149
5.23	Genetic correlations between ages and between each age and average annual performance.	152

Table		Page
5.24	Selection index parameters	160
5.25	Selection index solutions. Hogget.	162
5.26	Selection index solutions. Two-year-old ewes.	164