

1970 50

UNIVERSITY OF THE FREE STATE

HIERDIE EKSEMPLAAR MAG OORSGEEN
OMSTANDIGHEDE UIT DIE
BIBLIOTEK VERWYDER WORD NIE

University Free State



3430000933444

Universiteit Vrystaat

**A GENETIC EVALUATION OF THE MATOPOS SABI SHEEP
FLOCK IN ZIMBABWE**

by

Oswald Matika

Dissertation submitted to the Faculty of Natural and Agricultural Sciences
Department of Animal Science
University of the Free State

In partial fulfilment of the requirements for the degree

PHILOSOPHIAE DOCTOR

Promoter : Prof. J.B. van Wyk
Co-promoters : Prof. G.J. Erasmus
Dr R.L. Baker

Bloemfontein, November 2001

Universiteit van die
Oranje-Vrystaat
BLOEMFONTEIN

2 5 APR 2002

UOVS SASOL BIBLIOTEEK

TABLE OF CONTENTS

PREFACE	iii
1. INTRODUCTION	1
2. A DESCRIPTION OF GROWTH, CARCASS AND REPRODUCTIVE TRAITS	
2.1 Introduction	4
2.2 Material and Methods	5
2.3 Results and Discussion	7
2.4 Conclusions	14
3. GENETIC PARAMETER ESTIMATES FOR REPRODUCTION AND SURVIVAL TRAITS USING A THRESHOLD MODEL	
3.1 Introduction	15
3.2 Material and Methods	16
3.2.1 Animals	16
3.2.2 Statistical analysis	16
3.3 Results and Discussion	18
3.4 Conclusions	24
4. GENETIC PARAMETER ESTIMATES FOR GROWTH, CARCASS AND EWE TRAITS	
4.1 Introduction	26

4.2	Material and Methods	27
4.3	Results and Discussion	31
4.4	Conclusions	40
5.	PHENOTYPIC AND GENETIC RELATIONSHIPS AMONG LAMB AND EWE TRAITS	
5.1	Introduction	41
5.2	Material and Methods	42
5.3	Results and Discussion	43
5.4	Conclusions	48
6.	RESISTANCE OF SABI AND DORPER EWES TO GASTROINTESTINAL NEMATODE INFECTIONS	
6.1	Introduction	51
6.2	Material and Methods	52
6.2.1	Statistical analysis	53
6.3	Results and Discussion	56
6.4	Conclusions	62
7.	GENERAL CONCLUSIONS	63
	ABSTRACT	66
	OPSOMMING	69
	REFERENCES	72

PREFACE

In accordance with the tradition, in the Department of Animal Science, five articles (submitted for publication), introduced and finalised with a general conclusion, have been used in a serious attempt to characterise the Sabi flock at Matopos Research Station. The value and benefits of publishing the work from this dissertation can not be over emphasised. An attempt, to minimise repetition has been made, however, some repetition might be inevitable.

The author wishes to express his sincere appreciation and gratitude to the following persons and institutions:

Prof. Japie van Wyk without whose valuable guidance, assistance and motivation I would not have achieved and accomplished this work.

Prof. Gert Erasmus who was the co-supervisor for all the editing, guidance and may this work be one of his farewell gifts for his impending retirement.

Dr. Leyden Baker, co-supervisor, for all his input in the preparation of the scientific publications.

The Head and Staff of Matopos Research Station for all their inputs.

International Livestock Research Institute for partially funding the work on internal parasite resistance at Matopos Research Station.

Dr. Author Gilmour for the use and valuable advice on ASREML.

All members of the Department of Animal Science who made my stay in Bloemfontein memorable.

My late Mother and Father

Lastly, but not least to my family (Debbie and Aimee Ruvarashe), without whose support I would not have accomplished this thesis.

And to the Almighty for being with me all the time.

1

General Introduction

The Sabi sheep breed of Zimbabwe faces extinction, especially through crossbreeding, if something is not done soon. Being indigenous (endemic) to semi-arid parts of Zimbabwe with its extreme climatic fluctuations, it is in all likelihood better adapted to these conditions than any exotic genotype with a higher production potential. Since it has become very costly, and even prohibitive, to improve environments, interest is growing in the better utilisation of adapted local breeds where these still exist. The sudden scramble by, albeit a handful of scientists, to characterise, popularise and genetically improve such breeds is therefore more than warranted. Reasons for investigating the possibility of artificial selection to improve production are obvious but, ironically, the possibility of genetically improving, and not only maintaining adaptability also exists, since the indisputably short-term environmental changes by man have not necessarily always as yet been countered by natural selection.

Sabi sheep are the only indigenous sheep breed in Zimbabwe. Estimates of genetic parameters for this breed are lacking in literature. The reliability of the estimated genetic merit depends on the judicious choice of the fixed model used to describe the biological processes and the prediction methodology used among others (Johnson & Garrick, 1990). In order to institute constructive genetic change in the Sabi, there is need to know some of the important genetic properties. Genetic parameters will need to be estimated so as to formulate a breeding strategy. Selection is likely to be more effective if the genetics of traits conferring adaptation to harsh environment are better understood, and if the most important of these traits

are included in the breeding goal. Traits conferring better adaptation may include physical attributes such as litter size, coat type and the ability to store body fat, some aspects of behaviour, especially maternal and grazing behaviour, and disease resistance (Simm *et al.*, 1996). A better understanding of the relationships between production traits and these adaptation traits will also be critical for the development of appropriate, sustainable breeding programmes. This reduces the risk of there being detrimental correlated effects of selection.

Objective selection within breeds or strains is intended to increase the average level of genetic merit of the population. Simms *et al.* (1996) proposed the following steps: (i) deciding what to improve (the 'breeding goal') - obviously there needs to be genetic variation in the trait or combination of traits if any improvement is to be made; (ii) deciding what to measure and select (the 'selection criterion') in order to make improvements in the breeding goal (in some cases the selection criterion may be the same as the goal; in others some indirect measurement is needed, for example when the goal trait can only be measured in one sex or after slaughter); (iii) designing the breeding programme (e.g. numbers of the males and females selected annually, ages at mating); (iv) implementing the programme; (v) monitoring progress and redesigning the programme if necessary.

Improvement in the efficiency of production is achieved by exploiting the genetic variation in the traits of interest. In the current characterisation study, traits to be included are amongst others those for growth, carcass, reproductive traits and resistance to internal parasites. To obtain accurate estimates of the genetic parameters, it is imperative that the most suitable models are fitted to the data to account for all 'known' sources of environmental variation. Initially, the 'fixed' effects to be included are to be investigated. In addition appropriate models to determine the random effects are to be established for each trait and later to be used in multivariate restricted maximum likelihood analyses (REML) to determine the relationships among them. However, simultaneous improvement in multiple traits requires that there be no major genetic antagonisms amongst them. In addition, genetic correlations are essential in predicting indirect responses to selection and are needed to determine the optimum weighting and expected response in selecting to improve more than one trait. Methods for parasite control exploiting the host resistance, may not only be cost effective, reducing the risk of drug resistance etc, but may be the only tool available

to control gastrointestinal parasites for the resource poor farmers. Finally further areas of research to improve the Sabi sheep will be discussed.

2

A description of growth, carcass and reproductive traits

2.1 Introduction

The indigenous Sabi sheep of Zimbabwe is a fat-tailed hair breed (Ward, 1959) with similar features to the Red Maasai and Tswana sheep of eastern and southern Africa (Mason & Maule, 1960). Sabi sheep are mainly found in the medium and low rainfall regions (less than 600mm per annum) of Zimbabwe. Sheep production in these areas is suited to hair breeds since they are not affected by sharp, barbed-awned grass seeds (e.g. *Heteropogon contortus*, Spear grass) as are woolled sheep (Le Roux, 1970).

In order to make genetic improvement in growth, carcass and reproductive traits, it is necessary to have accurate estimates of environmental and genetic parameters of these traits. Adjustments for various environmental effects such as year of birth, sex, type of rearing and age of dam are essential in prediction of breeding values and in selection programmes.

Although estimates of genetic and non-genetic parameters abound in the literature, (reviewed by Fogarty, 1995) none are available for Sabi sheep. Traits relevant to the multi-purpose role of the Sabi including their ability to survive and reproduce in a harsh environment need elucidation. Therefore, the purpose of this paper is to describe the effect of environmental factors in order to characterise growth, carcass and

reproductive traits for use in the development of suitable models for the accurate estimation of genetic parameters, prediction of breeding values and formulation of appropriate breeding policies for this rare breed of sheep.

2.2 Materials and Methods

Data were obtained from the Sabi flock maintained on natural rangelands at the Matopos Research Station, at an altitude of 1340 metres above sea level. The wet season is from November to April and the mean annual rainfall is 609mm (range among years 257-1376 mm). The dominant vegetation type is Savannah with various *Acacia* species and grass species. Ward *et al.* (1979) gives a detailed description of the climate and vegetation types.

The origin and description of the foundation flock, is given by Ward (1959). Until 1985 young ewes were exposed to sires of other breeds (e.g. Mutton Merino, Wiltshire Horn, Suffolk and Dorper) for their first and second lamb crop in a crossbreeding experiment. Their retention as replacement ewes in the purebred flock was dependent on their ability to rear and wean heavier crossbred lambs. Data from this crossbreeding experiment were not included in the present analyses. From 1986, all ewes (about 400) were mated to 15 Sabi rams per mating cycle, with each sire mated to between 20 and 30 ewes. Two to three sires were used in more than one year which resulted in creating ties between years from both the male and female side.

All animals were grazed during the day (6 to 7 hours) and penned at night. Hand mating was done once a year over a period of 35 days to lamb from the end of September to the beginning of December. Supplements (200 g per ewe per day of 75% maize and 25% cottonseed meal) were normally given to ewes exposed to the ram a month before lambing for 100 days. Ewes were vaccinated for pulpy kidney four weeks before lambing.

At lambing, both lambs and dams were weighed and the lambs ear-tagged. Tail docking and castration were carried out within 24 hours of birth using rubber rings. Initial ram selection was based on birth weights with male singles of over 3 kg and twins over 2.5 kg birth weight being retained, while the rest of the male lambs were

castrated. The response to selection was assumed to be minimal since no index or breeding values were used in the choice of rams or ewe lambs. Weaning was at 140 days of age up to 1990 and at 100 days of age thereafter. Weaning was always at the end of the rainy season and it was done in one group. This necessitated the use of age as a covariate to account for the different ages within years as this was deemed to be statistically more appropriate than correcting to a constant age. Lambs were vaccinated against pulpy kidney at weaning.

Maiden ewes were exposed to the rams at 18 months of age only if they had attained a minimum live weight of 30 kg and had no apparent deformities. Selection criteria used subsequently were that: all ewes giving birth to twins and rearing them to weaning were retained; ewes giving birth to a single and rearing it to weaning and ewes giving birth to twins and rearing one to weaning were next in line for selection. If more replacements were required, dry ewes and ewes, which gave birth but did not wean a lamb, were retained. Once the ewe flock had stabilised at about 450-500 ewes from 1990 onwards, all ewes which failed to lamb for two consecutive lambings and those not rearing lambs were culled. Animals without complete records of parentage were eliminated. Culling was also on age and dentition status. The harsh semi-arid environment causes extreme teeth wear and loss and ewes were culled heavily on dentition status from 6 years of age and older.

The data set analysed consisted of 4355 lamb and 4299 ewe records collected from 1984 to 1994. Over the 11 years only five ewes gave birth to triplets and these were discarded from the analyses. Also excluded were lambs whose dams were not identified at birth and those that did not have date of birth or birth weight recorded. This reduced the data set from 4399 to 4355 for lamb records.

The growth traits analysed were: birth weight (BW); weaning weight (WW); 12 month weight (12W); 18 months weight (18W); average daily gain from birth to weaning (ADG); total litter weight at weaning (the sum of naturally reared individual lamb weights within a year per ewe lambing and is a trait of the ewe) (LWW). Those for carcass and reproductive traits were: slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight after 24 hours at +4 °C (CCW); ewe mating weight (MW); post partum weight (PPW); ewe weight at weaning of the lamb (EWW); fertility (whether a ewe lamb or not; 0 or 1); reproductive rate (number of lambs born to a ewe exposed; 0, 1 or 2); ewe weaning rate (number of lambs weaned to a ewe

lambing; 0, 1 or 2); flock weaning rate (number of lambs weaned to a ewe exposed; 0, 1 or 2); prolificacy (number of lambs born to a ewe that lambled; 1, or 2) and lamb survival rate (whether a lamb born alive, was dead or alive at weaning; 0 or 1) for ewe reproductive traits. The Kleiber ratio ($KL=ADG \text{ to weaning}/WW^{0.75}$) has been suggested as an indirect selection criteria for efficiency of feed conversion under field conditions (Scholtz & Roux, 1988) and was included as an additional trait.

The least squares model (Harvey, 1990) fitted for the traits included the main effects of year of birth (1984-1994), sex (female, castrate, ram), birth type (single, twin), type of rearing (single raised as single, twin raised as a single, twin raised as a twin) and dam age (2 to 7+ years of age except for ewe trait which had 9 year olds and above). Birth date (measurement of day of birth within each birth year) was included as a linear covariate for birth weight. For the other traits, age at measurement was fitted as a linear covariate and slaughter age (1, 2 or 3 years) for carcass traits. Total litter weight weaned (LWW) was calculated as follows: lamb records were corrected to 120 day weight; followed by least-squares corrections for sex of lamb and then summing the corrected weaning weight of the weaned lambs per ewe lambing in a given season. The numbers of the data used in the analysis and model specification for the different traits are presented in Table 2.1.

2.3 Results and Discussion

All main effects fitted were significant ($P<0.05$) for most growth (except lamb age for 18 months weight), and reproductive traits except for ewe age for carcass traits ($P>0.05$) (Table 2.1).

Significant two-way interactions between year of birth and sex for 12W and 18W were found. Generally rams were heavier than females and castrates except in 1990 when rams had similar performance to castrates and females at weaning and were later outperformed for yearling and 18 month weights by the latter. The most probable explanation for the significant interactions for sex and year of birth may be two-fold: a) that rams were separated from castrates and females at weaning and raised in a separate part of the farm; b) that under favourable grazing conditions (feed availability and management), rams expressed their full growth potential and, under unfavourable

conditions, they seemed to be more affected in terms of performance than females and castrates. The significant interaction between sex and type of birth for lamb survival to weaning could be due to high mortality for castrated male twins (33 per cent for castrates versus 6 per cent for rams) which is constituted by the remainder of males from ram selection.

The least squares means and coefficient of variation (CV%) for all traits are presented in Tables 2.2 and 2.3.

Males were heavier than females at birth. Consistent superiority of male lambs has been widely reported (Burfening & Carpio, 1993; Snyman *et al.*, 1995a; Mousa *et al.*, 1999; Mukasa-Mugerwa *et al.*, 2000). Rams were consistently heavier up to 18 months of age than both castrates and females. Similar trends were reported in literature (Tawonezvi & Ward, 1987; Inyangala *et al.*, 1990; Buvanendran *et al.*, 1992; Burfening & Carpio, 1993). This has been attributed to hormonal differences between sexes and the resultant effects on growth (Bell *et al.*, 1970). The birth weights reported in this study are low and may predispose the lambs to hypothermia, starvation, respiratory diseases and many others (Al-Shorepy & Notter, 1998). Females and castrates had lower KL than rams and singles had the highest KL for birth type similar to that reported by van Wyk *et al.* (1993a). Single born lambs were heavier at birth, grew faster to weaning and had higher weaning weights than twins. After weaning, twins grew faster than singles but the 18 month weight was heavier for the latter. A study on Dorpers in Zimbabwe by Buvanendran *et al.* (1992) reported similar results as those observed in this study. The effect of type of rearing also persisted up to 18 months where the difference between those raised as twins and those raised as singles gradually declined to 6.5 % comparable to 6.9 % found by Snyman *et al.* (1995a) in Afrino sheep. Similar effects of rearing status has been well documented elsewhere (Tawonezi & Ward, 1987; Boujenane & Kerfal, 1990). Total litter weight weaned was highest for twins surviving to weaning. Ercanbrack & Knight (1998) found that selecting for total litter weaned can be effective for both growth and reproductive traits including lamb survival.

Table 2.1 Numbers used and model specification for growth¹, carcass² and reproductive traits³

Trait	N	Year	Sex	Type of birth	Type of rearing	Ewe age	Year x sex	Birth status x sex	Slaughter age	Birth date	Lamb age(L)	Lamb age (Q)	Lamb age (C)
BW	4352	***	***	***		***				***			
WW	3713	***	***		***	***					***	NS	NS
12W	2334	***	***		***	***	***				***	*	NS
18W	2148	***	***		***	***	***				NS	NS	NS
ADG	3307	***	***		***	***	***				***	***	**
LWW	3318	***			***	***							
KL	3713	***	***		***	***					***	***	NS
SLW	1710	***	***	***		**			***				
HCW	1710	***	***	***		NS			***				
CCW	1710	***	***	***		NS			***				
MW	3930	***				***							
PPW	3773	***				***							
EWV	2796	***			***	***							
EL/EE	4299	***				***							
LB/EE	4299	***				***							
LB/EL	3771	***				***							
LW/EE	4299	***				***							
LW/LB	3771	***				**							
SURV	4355	***	***	***		**		**			**		

1= Birth weight (BW); weaning weight (WW); 12 month weight (12W); 18 month weight (18W); average daily gain to weaning (ADG); total litter weight at weaning (LWW); Kleiber ratio (KL), weight at mating (MW); post partum weight (PPW), ewe weight at weaning of lamb (EWV); Covariate fitted as linear (L) or quadratic (Q) or cubic (C).

2= Slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCW)

3= Lambs born (LB); lambs weaned (LW); ewes lambing (EL); ewes exposed (EE); lamb survival to weaning (SURV)

* = P<0.05, ** = P<0.01; *** = P<0.001; NS = Non-significant

Year = Year of birth/mating

Table 2.2 Least squares means and standard errors (SE)[#] of growth¹ and carcass² traits

Traits	Growth						Carcass			
	BW	WW	12W	18W	ADG	LWW	KL	SLW	HCW	CCW
Sex										
Female	2.55	16.6	22.5	32.7	117		14.3	29.6	12.3	11.7
Castrate		16.7	22.6	34.5	118		14.2	29.6	13.9	13.5
Ram	2.71	18.5	24.1	37.6	130		14.5	31.8	15.1	14.6
Birth/ rearing										
Single-single	2.96	19.3	24.6	36.1	136	18.7	14.7	29.9	14.0	13.5
Twin-single		17.2	23.0	35.1	122	16.3	14.5			
Twin-twin	2.29	15.3	21.5	33.6	106	28.9	13.8	28.1	13.1	12.7
Ewe age (years)										
2	2.36	16.3	22.4	34.2	115	20.4	14.2	29.0	13.5	13.0
3	2.64	17.7	23.3	35.2	125	21.8	14.5	29.4	13.5	13.0
4	2.74	17.9	23.3	35.4	126	22.1	14.5	30.3	13.8	13.3
5	2.70	17.6	23.6	35.2	124	21.8	14.4	28.9	13.6	13.2
6	2.65	17.1	23.1	35.1	121	21.1	14.2	27.3	13.5	13.1
7+	2.67	16.8	22.6	34.4	118	20.7	14.1	29.2	13.5	13.0
Slaughter age (years)										
1								17.9	8.3	7.9
2								33.0	15.2	14.8
3								36.1	17.2	16.6
Birth date / Age(L)										
Age (Q)		NS	0.00	NS	0.01		0.00			
Age (C)					0.00		-			
LS mean	2.63	17.2	23.5	35.7	122	21.3	14.3	29.0	13.6	13.1
R²	0.39	0.41	0.56	0.54	0.43	0.57	0.68	0.34	0.51	0.50
CV (%)	15.8	16.6	12.2	10.4	18.8	18.0	8.1	24.2	17.3	17.6

¹ = Birth weight (BW); weaning weight (WW); 12 month weight (12W); 18 month weight (18W); average daily gain to weaning (ADG); total litter weight at weaning (LWW); Kleiber ratio (KL); Covariate fitted as linear (L) or quadratic (Q) or cubic (C).

² = slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCW); (kg for all growth and carcass traits except for ADG = g/day)

[#] The ranges of standard errors were: BW (0.01-0.02); WW (0.01-0.22); 12W (0.01-0.27); 18W (0.01-0.36); ADG (0.05-1.88); LWW (0.07-0.26); KL (0.03-0.04); SLW (0.40-0.98); HCW (0.13-0.31); CCW (0.12-0.31)

Table 2.3 Least squares means and standard errors (SE)[#] of reproductive traits¹

Traits	Reproductive								
	MW	PPW	EWW	EL/EE	LB/EE	LB/EL	LW/EE	LW/LB	SURV
Sex									
Female									0.84
Castrate									0.76
Ram									0.95
Birth/ rearing									
Single-single			35.9						0.90
Twin-single			37.0						
Twin-twin			37.2						0.79
Ewe age (years)									
2	35.3	32.9	34.7	0.89	0.98	1.11	0.79	0.82	0.81
3	36.9	35.7	36.5	0.90	1.04	1.16	0.88	0.88	0.86
4	38.8	37.0	37.2	0.93	1.09	1.18	0.94	0.88	0.87
5	39.0	36.0	37.5	0.91	1.09	1.20	0.93	0.87	0.97
6	39.3	36.1	37.5	0.87	1.05	1.20	0.87	0.85	0.85
7+	38.7	35.8	37.0	0.87	1.08	1.24	0.85	0.81	0.82
8				0.80	0.91	1.13	0.74	0.85	
9+				0.71	0.80	1.13	0.66	0.84	
Birth date/lamb age									0.002
LS mean	38.0	35.6	36.7	0.86	1.01	1.17	0.83	0.85	0.85
R²	0.24	0.30	0.20	0.04	0.07	0.06	0.05	0.02	0.08
CV (%)	10.3	10.9	9.12	36.8	48.4	30.3	63.2	40.0	39.6

1 = Weight at mating (MW); post partum weight (PPW), ewe weight at weaning of lamb (EWW), lambs born (LB); lambs weaned (LW); ewes lambing (EL); ewes exposed (EE); lamb survival to weaning (SURV)

The ranges of standard errors were: MW (0.02-0.03); PPW (0.02-0.03); EWW (0.02-0.03); EL/EE (0.01-0.05); LB/EE (0.02-0.04); LW/EE (0.02-0.08); LB/EL (0.01-0.06); LW/LB (0.01-0.07); SURV (0.0001-0.01)

Year of birth had a significant effect ($P < 0.05$) on all traits studied, some being more profoundly affected than others. No clear trend in lamb performance between years was found. The differences in performance between years reflect variation in the physical environment resulting from changes in the weather conditions (especially rainfall) which directly affect the quantity and quality of herbage available and the incidence of parasitic diseases in different years. Though birth weight was significantly affected, it varied less than the other weights. This may be due to the fact that other weights will fluctuate with environmental factors such as amount of forage and milk, but birth weight is only indirectly affected through the body condition of the ewe. Similar variations in performance between years have been reported in literature (Khombe, 1985; Tawonezvi & Ward, 1987; Inyangala *et al.*, 1990).

Age of dam was a significant source of variation for birth weight to 18-month weight ($P < 0.001$). All growth traits increased with age from 2-year-old ewes and peaked at four years. The fact that young ewes tend to produce smaller lambs has been documented (Wilson, 1987; Tawonezvi & Ward, 1987). Young ewes are still growing (and need to meet energy demands for foetal growth and for their own growth) and mothering ability (especially milk production) increases with age and body weight (Stobart *et al.*, 1986; Wilson, 1987; Boujenane *et al.*, 1991; Van Wyk *et al.*, 1993a). Highest total weight of litter weaned was from four year-old ewes. Total weight of litter weaned was lower than that reported for the Columbia, Suffolk and Targhee breeds (Abdulkhaliq *et al.*, 1989). Snyman *et al.* (1997) reported varied total weight weaned across parity in different environments for three sheep breeds. Kleiber ratio decreased with ewe age from the youngest unlike that reported by van Wyk *et al.* (1993a) which increased with age from two to six year olds then decreased.

Pre-weaning average daily gains reported here are higher than others reported for hair sheep breeds off range (Wildeus, 1997). Differential growth from weaning to 12 months of age for lambs born to the youngest and the oldest ewes, twins, females and castrates was observed. Differential growth persisted after 12 months of age for those disadvantaged by type of rearing but was less so for those lambs born to the young and the oldest ewes (Table 2.2). Similar results have been reported elsewhere in literature (Baker *et al.*, 1974; Olson *et al.*, 1976; Tawonezvi & Ward, 1987).

Rams had higher carcass weights than either castrates or females. Singles were heavier than twins. The heaviest carcass was from lambs born of four year-old ewes. Similar to those reported by Conington *et al.* (1995). The economical carcass weight was from two year-old animals with an extra year adding 3kg on slaughter weight and about 2kg for dressed carcass. Dressing percentage was about 45%. These are similar to those reported for Scottish Blackface sheep (Conington *et al.*, 1998).

Sabi ewes are heaviest at mating with the lowest weight at parturition (Table 2.3). Young ewes had lower live weights at mating, post-partum and at weaning. Ewes were heaviest for mating weight between five and six years of age, and at four years of age for post partum weight. Lamb body weight is positively correlated with ewe weight (Reddy *et al.*, 1984). Selection for growth traits is expected to increase ewe adult weight (Näsholm, 1990; Näsholm & Danell, 1996).

Reproductive performance was at its highest between four and five years of age. Sabi sheep had fertility levels of 0.86, higher than the 0.73-0.74 reported for crosses between Finnish Landrace and Ile de France (van Haandel & Visscher, 1995) and Border Leicester (Brash *et al.*, 1994b) respectively. However, they were lower than the 0.91 reported for Targhee (Iman & Slyter, 1996) and 0.92 in Dorset, Corriedale, Finn-Dorset-Targhee ewes (Brash *et al.*, 1994a; Brash *et al.*, 1994c; Iman & Slyter, 1996) respectively. Sabi sheep in this study were not very prolific (1.17) but were within the range of that reported by Kominakis *et al.* (1998). Prolificacy was highest for ewes at seven years of age but was lower than in other hair breeds (Wildeus, 1997) and other sheep breeds (Brash *et al.*, 1994a; Brash *et al.*, 1994b; Hall *et al.*, 1994; Iman & Slyter, 1996). Number of lambs weaned to those ewes exposed to the ram increased with age and was best between four and five year old ewes. Sabi sheep had fewer lambs weaned over ewes exposed (0.83) to those reported elsewhere in literature (Brash *et al.*, 1994a; Iman & Slyter, 1996).

Average lamb survival was 0.85 with castrates having the lowest survival rate (0.76) and rams having the highest (0.95). Higher survival rates for rams were mainly because the heaviest lambs at birth were retained as future rams. The remainder of the males with inferior birth weights were castrated and docked within 24 hours of birth and this may explain the high losses. Other results in literature found no effects of sex on survival of lambs to weaning (Tawonezvi & Ward, 1987). Twin born lambs had a lower survival (0.79) compared to singles (0.90) with is comparable to published results (Smith, 1977; Khombe, 1985; Tawonezvi & Ward, 1987; Subandriyo & Inounu, 1994; Mukasa-Mugerwa *et al.*, 2000). Physiological starvation, resulting in small and weak offspring at birth and less vigour for early nursing and lower ability to compete for a limited supply of milk was suggested as the major cause of death among twins (Tawonezvi & Ward, 1987; Subandriyo & Inounu, 1994). Lambs born later in the season had higher survival rates and that survival increased with increasing birth weight. Other workers found that birth weight was strongly associated with survival (Atkins, 1980; Dalton *et al.*, 1980; ; Gama *et al.*, 1991; Burfening & Carpio, 1993; Mukasa-Mugerwa *et al.*, 2000). Survival increased with dam age, from 2 years of age and declined after five years of age. Similar results were reported in literature (Warren & Mysterud, 1995; Mukasa-Mugerwa *et al.*, 2000). Lamb survival is a complex trait influenced by the lamb's own ability to survive and by its dam's rearing ability (Burfening, 1993).

2.4 Conclusions

Sabi sheep have low birth, mature and carcass weights. Ewe weight most likely influences the economic outcome of a sheep enterprise. We need to study the interrelationship between ewe weight and other characteristics as maternal ability, growth of lambs, lamb survival and reproductive performance of the ewe. Slaughter age off range was optimum around two years of age. Ewe culling is recommended for ewes over seven years of age. Environmental effects considered in this study are important and will need to be taken into consideration for the accurate estimation of genetic parameters and prediction of breeding values. The significant sex x year of birth interaction for post-weaning growth traits need to be incorporated in the models for estimation of genetic parameters.

3

Genetic parameter estimates for reproduction and survival traits using a threshold model

3.1 Introduction

Reproduction and survival rate are undoubtedly the most important traits in all systems of sheep production and in all environments. The need to incorporate at least one of these in the breeding objective for maternal mutton breeds cannot be overemphasised. Increased reproduction and survival rate should not only lead to higher income but also increased genetic improvement. The most important measure of a flock's overall reproductive performance is the number of lambs weaned per ewe exposed, which is the product of the proportion of ewes lambing (fertility), litter size at birth (prolificacy) and survival rate of lambs born to weaning (Lee & Atkins, 1994).

Though most recent literature estimates tended to be from REML analyses fitting linear models, caution must be exercised, since in breeds where multiple births are the norm, there may be little differences with Threshold models (Matos *et al.*, 1997). However, in less prolific sheep like the Sabi, rapid genetic progress could be obtained fitting the appropriate threshold models. The main theoretical reason put forward for linear models being inappropriate is that breeding values and residuals are not independent of each other and their marginal distributions are difficult to specify (Gianola, 1982). To overcome these problems, Gianola & Foulley (1983) proposed a non-linear approach based on the assumption of ordered observed

categories on an underlying non-observable normal distribution with fixed thresholds. The underlying variate is mapped into the observable phenotypic categories (Gianola, 1982). Procedures and software programmes for predicting breeding values for categorical traits have been developed (Gianola & Foulley, 1983, Foulley *et al.*, 1983; Harville & Mee, 1984; Foulley & Gianola, 1984; Konstantinov, 1995).

The objective of this study was to provide estimates of genetic parameters to characterise Sabi sheep in terms of reproductive performance and lamb survival to weaning for use in the development of appropriate breeding objectives and improvement programs. Another, was to encourage conservation of Sabi sheep by improving profitability which is determined by both reproduction and production traits. Reproductive performance is usually defined as lamb (weight or/and numbers) per ewe per annum.

3.2 Materials and Methods

3.2.1 Animals

Until 1985 young ewes were exposed to sires of other breeds (e.g. Mutton Merino, Wiltshire Horn, Suffolk and Dorper) for their first and second lamb crop in a crossbreeding experiment. Their retention as replacement ewes in the purebred flock was dependent on their ability to rear and wean heavier crossbred lambs. Data from this crossbreeding experiment were not included in the present analysis. The general management is described in Chapter 2.

3.2.2 Statistical analysis

The numbers of records, sires, categories and thresholds for each trait analysed are presented in Table 3.1. The data consisted of 4304 ewe records collected over the eleven-year period from 1984 to 1994. Data were edited to include only sires with more than eight progeny for reproductive traits and five progeny for lamb survival as per the requirements of the the GFCAT set of programmes developed by Konstantinov (1995).. Lambs with known non-genetic causes of death were excluded.

The ewe reproductive traits were defined as follows: fertility (whether a ewe lamb or not; 0 or 1); reproductive rate (number of lambs born to a ewe exposed; 0, 1 or 2); ewe weaning rate (number of lambs weaned to a ewe lambing; 0, 1 or 2); flock weaning rate (number of lambs weaned to a ewe exposed; 0, 1 or 2); prolificacy (number of lambs born to a ewe that lambed; 1 or 2) and lamb survival rate (whether a lamb born alive, was dead or alive at weaning; 0 or 1).

Table 3.1 Description of data set on reproductive traits

TRAIT	No. of records	No. of sires	No. of categories	No. of thresholds
Fertility (EL/EE)	3958	90	2	1
Prolificacy (LB/EL)	3462	85	2	1
Reproductive rate (LB/EE)	3958	90	3	2
Ewe weaning rate (LW/EL)	3462	85	3	2
Flock weaning rate (LW/EE)	3958	90	3	2
Survival (LW/LB)	4041	128	2	1

*EL = ewe lambing; EE = ewe exposed; LB = lambs born; LW = lambs weaned

Least-squares procedures (Harvey, 1990) were used to determine the "fixed" effects to be included in the model. The "fixed" effects fitted were ewe age and year of lambing for all reproductive traits and sex and birth status for lamb survival to weaning. Lambing date was included as a covariate for prolificacy and lamb survival to weaning.

Genetic parameters were estimated using the GFCAT set of programmes, developed by Konstantinov (1995), based on the threshold model, with support for REML-type variance component estimation based on the methods of Gianola &

Foulley (1983). Under this model the categorical traits occur as a result of an underlying unobserved phenotype exceeding a given threshold. The unobserved continuous phenotypes are assumed to follow a normal distribution. For each trait, a vector, μ , of means corresponding to sub-population determined by combinations of levels of 'fixed' β and random s factors is modelled as:

$$\mu = X\beta + Zs$$

where

μ is a vector of underlying means,

β is a vector associated with effects of year of birth and age of dam for ewe traits and birth status for survival,

s is a vector of sire effects and

X and Z are design matrices.

The s effects are assumed to be normally distributed, with $E(s) = 0$ and $\text{Var}(s) = A\sigma_s^2$, where A is a numerator relationship matrix. All traits were analysed separately. The heritability (h^2) was estimated by setting the error variance to unity:

$$h^2 = (4\sigma_s^2) / (1 + \sigma_s^2)$$

Since the underlying scale is unknown, solutions for the thresholds, all the effects and estimated sire breeding values are expressed in units of residual standard deviations of the underlying variable.

3.3 Results and Discussion

Solutions for thresholds, age of dam, birth status and sex are presented in Table 3.2. Estimates of sire variance and heritability are presented in Table 3.3 and published heritability estimates are summarised in Table 3.4.

For all reproductive traits except prolificacy, the solutions increased with increasing age up to five years and declined thereafter. This was similar to those reported elsewhere in literature (Olivier *et al.*, 1998; Snyman *et al.*, 1998c). Twins had lower survival rates

than singles. Entire males had the highest survival rate, followed by females and the least were castrates. This may be ascribed to some management practices which were done within 24 hours of birth ie castration and docking.

The heritability estimate for fertility (EL/EE) of 0.02 is lower than other reported estimates using threshold models, but within the range of estimates obtained using restricted maximum likelihood (REML) procedures (Table 3.4). This low heritability for fertility may be due to the possibility that over time natural selection favoured only fertile animals (86 per cent fertile for the Sabi sheep) under this harsh environment and hence lower additive genetic variance (Tawah *et al.*, 1997). The potential for genetic improvement of fertility by within flock selection appears limited.

In general, high estimates of h^2 of prolificacy (LB/EL) using threshold models have been reported (Table 3.4) similar to the estimate of 0.26 obtained in this study. The REML estimate in the present study of 0.08 ± 0.01 is in accordance to those documented in literature using REML procedures (Table 3.4). In a review, Fogarty (1995) reported an average heritability estimate for litter size of 0.10 and a lower average animal model REML estimate of 0.07. In another review of 30 studies with different sheep breeds, Bradford (1985) had an average estimate of heritability for LB/EL of 0.10 (range -0.15 to 0.35). Therefore, there is the possibility to improve Sabi sheep genetically for multiple births. However, other factors need to be taken into consideration. One of the major constraints to raising large litters is management (De Lange, 1984). Perhaps different objectives need to be specified for different environments, hence the need to examine the correlation of this trait with other reproductive and production traits. Ercanbrack & Knight (1998) found that litter weight was more effective in selection protocols since it is a product of net reproductive rate and average weaning weight per lamb, with weaning weight reflecting milk production, mothering ability and lamb growth rate. They define net reproductive rate as lambs weaned per ewe placed in breeding (product of ewe viability, fertility, prolificacy, fraction born alive and the fraction weaned).

Table 3.2 Solutions for thresholds, age of dam, birth status and sex

	EL/EE	LB/EL	LB/EE	LW/EE	LW/EL	LW/LB
Thresholds						
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2			2.4147	2.1926	2.5096	
Age of dam						
2	0.6192	-2.3158	0.4264	0.1164	0.6603	-0.1625
3	0.6731	-2.0710	0.5698	0.3183	0.9123	0.0000
4	0.8417	-1.9604	0.7036	0.4536	1.0119	0.0681
5	0.7357	-1.8706	0.6951	0.4380	1.0441	0.1628
6	0.6274	-1.8696	0.6426	0.3466	0.9707	-0.0036
7 +	0.3915	-1.8066	0.5192	0.1649	0.8729	-0.1792
Birth status						
1						0.5817
2						0.0000
Sex						
1						-0.5924
2						-0.8737
3						0.0000

*EL = ewe lambing; EE = ewe exposed; LB = lambs born; LW = lambs weaned

Table 3.3 Sire variances and heritability estimates on the underlying scale for reproductive traits

Trait	σ_{sire}^2	h^2
Fertility (EL/EE)	0.00411	0.016
Prolificacy (LB/EL)	0.07033	0.263
Reproductive rate (LB/EE)	0.01575	0.062
Ewe weaning rate (LW/EL)	0.00927	0.037
Flock weaning rate (LW/EE)	0.00486	0.019
Lamb survival (LB/LW)	0.04360	0.043

*EL = ewe lambing; EE = ewe exposed; LB = lambs born; LW = lambs weaned

Table 3.4 Summary of published heritability estimates of fertility (EL/EE) and prolificacy (LB/EL) of various sheep breeds.

Heritability	Method	Breed	Reference
Fertility (EL/EE)			
0.01	PHS	Scottish Blackface	Atkins (1986)
0.08	TSM	Rambouillet, Finnsheep	Matos <i>et al.</i> (1997)
0.10	TAM	Rambouillet	Matos <i>et al.</i> (1997)
0.17	TAM	Finnsheep	Matos <i>et al.</i> (1997)
0.20	TSM	Carnarvon Merino	Olivier <i>et al.</i> (1998)
0.07	TSM	Grootfontein Merino	Olivier <i>et al.</i> (1998)
0.20	TSM	Afrino	Snyman <i>et al.</i> (1998b)
Prolificacy (LB/EL)			
0.07	REML	Romanov	Maria (1995)
0.08	REML	Segurena	Analla <i>et al.</i> (1997)
0.45	TSM	Rambouillet	Matos <i>et al.</i> (1997)
0.13	TAM	Finnsheep	Matos <i>et al.</i> (1997)
0.14	TSM	Finnsheep	Matos <i>et al.</i> (1997)
0.25	TAM	Rambouillet	Matos <i>et al.</i> (1997)
0.08	TAM	Rasa Aragonesa	Altarriba <i>et al.</i> (1998)
0.07-0.14	REML	Romney, Coopworth, Perendale	Davis <i>et al.</i> (1998)
0.06	REML	Boutsico	Kominakis <i>et al.</i> (1998)
0.31	TSM	Carnarvon Merino	Olivier <i>et al.</i> (1998)
0.17	TSM	Grontfontein Merino	Olivier <i>et al.</i> (1998)
0.42	TSM	Afrino	Snyman <i>et al.</i> (1998c)
0.01-0.07	REML	Hungarian Merino	Nagy <i>et al.</i> (1999)
0.01-0.17	REML	Rambouillet	Okut <i>et al.</i> (1999)
0.05	REML	Rambouillet	Lee <i>et al.</i> (2000)
0.11	REML	Brown-headed Meat	Hagger (2000)
0.12	REML	Valais black Nose	Hagger (2000)
0.16	REML	White Alpine Sheep	Hagger (2000)
0.23	REML	Black-Brown Mountain	Hagger (2000)
0.16	REML	Chios	Ligda <i>et al.</i> (2000)
0.09	REML	Suffolk and Polypay	Rao & Notter (2000)
0.11	REML	Targhee	Rao & Notter (2000)
0.07	REML	Columbia	Bromley <i>et al.</i> (2001)
0.09-0.10	REML	Rambouillet, Targhee	Bromley <i>et al.</i> (2001)
0.12	REML	Polypay	Bromley <i>et al.</i> (2001)

* TSM-Threshold sire model; TAM-threshold animal model; REML Restricted Maximum Likelihood procedures; PHS-Paternal half-sib; LB-Lambs born; EL-Ewes lambing; EE-Ewes exposed to the ram

Table 3.4 (cont.) Summary of published heritability estimates of reproductive rate (LB/EE) and flock weaning rate (LB/EE) and lamb survival.

Heritability	Method*	Breed	Reference
Reproductive rate			
(LB/EE)			
0.24	TSM	Dormer	Konstantinov <i>et al.</i> (1994)
0.13	TSM	Grootfontein Merino	Olivier <i>et al.</i> (1998)
0.20	TSM	Carnarvon Merino	Olivier <i>et al.</i> (1998)
0.23	REML	Afrino	Snyman <i>et al.</i> (1998a)
0.27	TSM	Afrino	Snyman <i>et al.</i> (1998c)
Ewe weaning rate			
(LW/EL)			
0.00-0.10	REML	Columbia, Polypay, Rambouillet, Targhee	Okut <i>et al.</i> (1999)
0.02	REML	Targhee	Bromley <i>et al.</i> (2001)
0.03	REML	Rambouillet	Bromley <i>et al.</i> (2001)
0.04	REML	Polypay	Bromley <i>et al.</i> (2001)
0.05	REML	Columbia	Bromley <i>et al.</i> (2001)
Flock weaning rate			
(LW/EE)			
0.18	TSM	Carnarvon Merino	Olivier <i>et al.</i> (1998)
0.09	TSM	Grootfontein Merino	Olivier <i>et al.</i> (1998)
0.29	REML	Afrino	Snyman <i>et al.</i> (1998a)
0.19	TSM	Afrino	Snyman <i>et al.</i> (1998c)
Lamb survival			
0.12	TSM	Dormer	Konstantinov <i>et al.</i> (1994)
0.00	TSM	Grootfontein Merino	Olivier <i>et al.</i> (1998)
0.00	TSM	Carnarvon Merino	Olivier <i>et al.</i> (1998)
0.02	TSM	Afrino	Snyman <i>et al.</i> (1998c)

* TSM-Threshold sire model; TAM-threshold animal model; REML Restricted Maximum Likelihood procedures; LB-Lambs born; LW-Lambs weaned; EL-Ewes lambing; EE-Ewes exposed to the ram

The heritability estimate for reproduction rate (LB/EE) was 0.06. This estimate was lower than those reported for a threshold model (Table 3.4). However, the estimate of h^2 is comparable to some reported in literature: 26 heritability estimates reviewed by Fogarty (1995) ranged from < 0 to 0.54 with a weighted mean of 0.08.

The estimate for flock weaning rate (LW/EE) of 0.02, was lower than those in literature (Table 3.4). In a review, Fogarty (1995) reported that the mean heritability obtained using paternal half-sib, regression of offspring on dam and maximum likelihood models for lambs weaned (per ewe exposed) was 0.05 whereas the REML animal model estimates were lower (0.04.). The possibility to make rapid progress through selection for this trait would be limited.

Some studies have shown that lamb survival can be genetically improved, either by selecting ewes on their rearing ability (Donnelly, 1982; Haughey, 1983) or by selecting rams based on their progeny survival (Knight *et al.*, 1979). In the present study the heritability estimate of lamb survival was 0.04. This heritability estimate was within the range of those reported elsewhere (Table 3.4) except for the estimate reported by Konstantinov *et al.* (1994), where survival was defined slightly differently. Estimates reported in literature were generally low. In reviews, the average heritability estimate are 0.07 for lamb survival (Cundiff *et al.*, 1982) and lower estimates were reported by Fogarty (1995) for those obtained using REML procedures. The low estimates of heritability may be due to several reasons among which: a) the stringent culling of ewes failing to rear lambs might have reduced the observed genetic variation; b) severe weather conditions which prevail at the time of lambing and c) management factors predisposing lambs to low survival. However, lamb survival is a complex trait influenced by the lamb's own ability to survive and by its dam's rearing ability (Burfening, 1993). Haughey (1983) reported that selection for and against rearing ability resulted in significant differences among lines indicating that lamb survival responded to selection even though the heritability estimate of the trait is low.

3.4 Conclusions

From the results of this study some conclusions and possible recommendations can be made: Results firstly indicate that ewes of six years and older have a lower reproduction than two-year-olds. Therefore, culling of ewes of six years of age and above is recommended.

Prolificacy was the only reproductive trait of the Sabi sheep where reasonable genetic progress is possible through selection. However, this should be carefully considered in view of the low survival rate among twin born lambs. The low

heritability estimate of lamb survival may indicate that higher survival rates could be achieved through a better control of the environmental factors. The role of castration and docking of lambs within 24 hours of birth on stress and lamb survival need further investigation. Selection for higher birth weight may also improve lamb survival especially in the case of multiple births.

Though, most of the reproductive parameters considered in this study including lamb survival had low heritability estimates, sire ranking could be a useful tool to retain animals with the highest genetic merit. Genetic correlations among reproductive traits and between production traits need to be examined. Total litter weight weaned might be a better trait to select for since others have found that it encompasses all the reproductive traits.

4

Genetic parameter estimates for growth, carcass and ewe traits

4.1 Introduction

Genetic characterisation of local breeds is of paramount importance, not only for conservation purposes but also for the definition of breeding objectives and breeding programmes. When records are non-existent and breeds are not well defined in the field, information could be obtained from research station information where pedigree and performance records could well have been kept.

Growth, carcass and ewe traits are not only influenced by the direct genetic composition of the individual and environment under which it is raised, but also by the maternal genetic composition and maternal environment. Maternal ability mainly represents the dam's milk production and mothering ability (see reviews: Baker, 1980; Robison, 1981). The genotype of the dam therefore affects the phenotype of the young through a sample of half her direct additive genes for growth as well as through her genotype for maternal effects (Meyer, 1992). Although maternal effects are expected to be more substantial for sheep than cattle or pigs (Bradford, 1972), studies on maternal effects in sheep especially tropical hair breeds, have been very limited. Genetic and environmental relationships between direct and maternal effects for growth and most other traits have often been found to be negative (Näsholm & Danell, 1994). Several studies have also attributed most variation in lamb weights to maternal

effects (Hanrahan, 1976; Burfening & Kress, 1993; Maria *et al.*, 1993; Van Wyk *et al.*, 1993b; Snyman *et al.*, 1995b). However, there is still much conflicting information about the direct-maternal genetic correlation (Näsholm & Danell, 1996). When maternal genetic effects are of importance, but not accounted for, heritability estimates should be biased upwards and realised selection efficiency reduced (Näsholm & Danell, 1994).

Although estimates of genetic and non-genetic parameters for many livestock breeds are available in the literature (Fogarty, 1995) very little is available for tropical hair breeds and none for the Sabi sheep breed of Zimbabwe. The objective of this study was to estimate genetic parameters on growth, carcass and ewe traits for Sabi sheep in an effort to make the genetic parameter characterisation of one of the unique indigenous breeds in Africa as comprehensive as possible.

4.2 Materials and Methods

Data on Sabi sheep at Matopos Research Station near Bulawayo, Zimbabwe, collected from 1984 to 1994 were used in this study. A detailed description of the management procedures followed is given in Chapter 2. Traits analysed were: birth weight within 24 hours of birth (BW); 30 day weight (30W); 60 day weight (60W); weaning weight (WW) at 120 days; Kleiber ratio (KL); 12 month weight (12W); 18 month weight (18W), total weight of litter weaned (LWW) (the sum of naturally reared individual lamb weights within a year per ewe lambing and is a trait of the ewe); pre-weaning average daily gain (ADG); slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCW); ewe weight at mating (MW), post partum (PPW) and at weaning of lamb (EWW). Lamb age was fitted as a linear or quadratic effect for all growth traits to 18 months of age. The Kleiber ratio ($KL = ADG \text{ to weaning} / WW^{0.75}$) has been suggested as an indirect selection criteria for efficiency of feed conversion under field conditions (Scholtz & Roux, 1988) and was included as an additional trait.

The fixed effects included in the model were year of birth (1984-1994), sex (males, castrates, females), type of birth (singles and twins) or type of rearing, age of dam (2 to 7 years and older) and birth date (measurement on day of birth nested within birth year) or lamb age as a covariate (Linear or quadratic). Year of birth and sex were

combine into a class to account for the interaction after weaning due to animals of different sexes being raised on separate farms. The model specification for each trait is presented in Table 4.1.

Table 4.1 Model specification for fixed effects of growth, carcass and ewe traits[#]

Fixed effects	Traits														
	BW	30W	60W	WW	KL	ADG	12W	18W	SLW	HCW	CCW	LWW	MW	PPW	EWW
Year of birth	X	X	X	X	X	X			X	X	X	X	X	X	X
Sex	X	X	X	X	X	X			X	X	X				
Type of birth	X								X	X	X				
Type of rearing		X	X	X	X	X	X	X				X			X
Age of dam	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Age of slaughter									X	X	X				
Year of birth x sex class							X	X							
Day of birth nested within year	X														
Lamb age (L)		X	X	X	X	X	X	X							
Lamb age (Q)		X	X		X	X	X								

[#] Traits: birth weight (BW); 30 day weight (30W); 60 day weight (60W); weaning weight (WW); Kleiber ratio (KL); average daily gain from birth to weaning (ADG); 12 month weight (12W); 18 month weight (18W); slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCM); total litter weight weaned (LWW); ewe weight at mating (MW); postpartum weight (PPW); ewe weight at weaning of lamb (EWW).

Estimates of (co)variance components were obtained using the ASREML programme (Gilmour *et al.*, 1999) fitting univariate animal models. The following six models were fitted:

$$y = Xb + Z_1a + e \quad (1)$$

$$y = Xb + Z_1a + Z_3pe + e \quad (2)$$

$$y = Xb + Z_1a + Z_2m + e \quad (3)$$

$$\text{with cov}(a,m) = 0$$

$$y = Xb + Z_1a + Z_2m + e \quad (4)$$

$$\text{with cov}(a,m) = A\sigma_{am}$$

$$y = Xb + Z_1a + Z_2m + Z_3pe + e \quad (5)$$

$$\text{with cov}(a,m) = 0$$

$$y = Xb + Z_1a + Z_2m + Z_3pe + e \quad (6)$$

$$\text{with cov}(a,m) = A\sigma_{am}$$

Where: y is a vector of observations on the specific trait of the animal; b , a , m and pe are vectors of fixed effects including covariables, direct additive genetic effects, maternal additive effects and permanent environmental effects due to the dam, respectively; and X , Z_1 , Z_2 , and Z_3 are corresponding incidence matrices relating to the effect of y ; e is the vector of residuals and A is the numerator relationship matrix.

A detailed discussion of factors utilised in the fixed part of the model is given in Chapter 2. Log likelihood ratio tests were conducted to determine the most suitable model for each growth and carcass trait in univariate analyses. For ewe traits log likelihood ratio tests were only possible fitting Models 2 and 3 due to limitations of the data. Analysing mature weights, no differences in parameter estimates were reported using repeated measures or non-linear growth functions (Kaps *et al.*, 1999). All the ewe traits were therefore fitted as repeated measures.

4.3 Results and Discussion

The log likelihood obtained for each trait under six different models of analysis and the most appropriate model (in bold) from log likelihood ratio tests are given in Table 4.2.

The most appropriate model for birth weight, 60 day weight, Kleiber ratio and average daily gain to weaning included a maternal genetic as well as permanent environmental effect (Model 5). The appropriate model for 30 day weight, weaning weight and 12 months weight had permanent environment effect (Model 2) whilst the rest (18W, SLW, HCM, CCW) had only the direct additive effect (Model 1). The model with the permanent environmental effect (Model 2) was the most appropriate for ewe adult weights and total litter weaned.

Parameter estimates fitting most appropriate models for growth, carcass and ewe traits are presented in Table 4.4. Published heritability estimates for the different growth traits are summarised in Tables 4.4 - 4.6.

The direct additive contribution to birth weight, 30 day weight, 60 day weight, weaning weight, 12 months weight, 18 months weight, total litter weight weaned, Kleiber ratio and pre-weaning average daily gain was 0.25, 0.13, 0.13, 0.16, 0.26, 0.39, 0.12, 0.08 and 0.17 respectively (Table 4.3). Direct heritability was 0.27, 0.18, 0.53, 0.58 0.67 for slaughter, hot and cold carcass, post partum, mating and ewe weaning weights respectively (Table 4. 3).

The estimate of direct heritability for BW was higher than most of those reported in literature (Table 4.4). Similar estimates of heritability for birth weight of 0.16 to 0.33 were reported by Lewer *et al.* (1994). Al-Shorepy & Notter (1998) noted that birth weight had received limited consideration in sheep industry breeding programmes but is a trait of potential economic importance. Other researchers (Smith, 1977; Notter & Copenhaver, 1980) found lamb survival (Finnish Landrace crosses) was maximised at birth weights of between 5.2 and 5.5 kg respectively. An intermediate optimum exist, with excessively large lambs liable to dystocia and extremely small lambs at risk of death from hypothermia (Al-Shorepy & Notter, 1998). Though birth weight can be improved through selection in Sabi sheep, this must be carefully considered as the optimum birth weight may not be as high as those in literature. With an average birth

weight of 2.8 kg at present, Sabi sheep may benefit from an increase in this trait since underweight lambs may be a more serious problem than overweight lambs.

Table 4.2 Log likelihoods obtained for growth and carcass traits under six different models with the 'best' model[#] in bold.

Random effects	Trait [†]											
	M	BW	30W	60W	WW	KL	ADG	12MW	18W	SLW	HCW	CCW
h_a^2	1	1464.2	-2755.0	-4590.2	-5626.8	-2535.1	10585.2	-3447.3	-3559.1	-3515.8	-2545.4	-2528.0
$h_a^2 + PE$	2	1517.7	-2729.4	-4569.5	-5603.1	-2518.1	10608.3	-3439.6	-3557.6	-3515.9	-2545.5	-2528.1
$h_a^2 + h_m^2$	3	1520.0	-2737.6	-4568.0	-5604.1	-2519.9	10603.5	-3444.6	-3558.9	-3515.9	-2545.5	-2528.1
$h_a^2 + h_m^2 + r_{am}$	4	1521.0	-2736.9	-4567.9	-5603.3	-2519.2	10603.5	-3444.1	-3558.8	-3513.8 [‡]	-2543.3 [‡]	-2526.4 [‡]
$h_a^2 + h_m^2 + PE$	5	1524.2	-2728.6	-4565.1	-5599.6	-2515.8	10610.3	-3439.6	-3557.6	-3517.3	-2545.5	-2528.1
$h_a^2 + h_m^2 + r_{am} + PE$	6	1524.3	-2728.21	-4564.9	-5598.9	-2515.4	10610.3	-3439.6	-3557.2	-3513.8	NC	NC

h_a^2 direct heritability; h_m^2 maternal heritability; r_{am} genetic correlation between animal effects; PE maternal environmental variance as proportion of (σ_p^2) phenotypic variance.

[†] Traits: birth weight (BW); 30 day weight (30W); 60 day weight (60W); weaning weight (WW); Kleiber ratio (KL); average daily gain from birth to weaning (ADG); 12 month weight (12W); 18 month weight (18W); slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCM).

NC No convergence; M model number; [‡]Poor convergence; [#] 'Best' model was defined as that model with the largest log likelihood value using the log likelihood tests. An effect was considered to have a significant effect when minus 2-times the difference between the log likelihoods was greater than the values of the chi-square distribution with one degree of freedom (3.84).

Table 4.3 Parameter estimates from 'best' models with appropriate sampling errors or growth* carcass† and ewe‡ traits.

	h^2_a	h^2_m	PE	σ^2_p
BW	0.25 ± 0.04	0.12 ± 0.03	0.08 ± 0.03	0.200 ± 0.00
30W	0.11 ± 0.03	0.03 ± 0.03	0.11 ± 0.03	2.127 ± 0.06
60W	0.13 ± 0.03	0.06 ± 0.02	0.06 ± 0.02	4.297 ± 0.11
WW	0.13 ± 0.04	0.06 ± 0.03	0.07 ± 0.02	9.11 ± 0.24
KL	0.07 ± 0.03	0.04 ± 0.02	0.06 ± 0.02	1.426 ± 0.04
ADG	0.17 ± 0.04	0.04 ± 0.03	0.09 ± 0.03	0.5983 ± 0.02
12W	0.27 ± 0.05	0.00 ± 0.00	0.09 ± 0.02	8.607 ± 0.30
18W	0.39 ± 0.05			13.230 ± 0.49
SLW	0.27 ± 0.06			27.730 ± 1.02
HCW	0.18 ± 0.06			7.158 ± 0.25
CCW	0.18 ± 0.06			7.012 ± 0.25
LWW	0.09 ± 0.02		0.04 ± 0.02	12.14 ± 0.32
MW	0.58 ± 0.03		0.13 ± 0.03	16.65 ± 0.64
PPW	0.53 ± 0.03		0.11 ± 0.02	16.47 ± 0.61
EWW	0.67 ± 0.03		0.15 ± 0.03	12.60 ± 0.57

h^2_a direct heritability; h^2_m maternal heritability; PE maternal environmental variance as proportion of (σ^2_p) phenotypic variance.

* **Growth traits:** BW birth weight; 30W 30 day weight; 60W 60 day weight; WW weaning weight; KL Kleiber Ratio (ADG to weaning^{0.75});

ADG average daily gain to weaning ; 12W 12month weight; 18W 18 month weight

† **Carcass traits:** SLW slaughter weight; HCW hot carcass weight; CCW cold carcass weight

‡ **Ewe traits:** LWW total litter weight weaned; MW ewe weight at mating; PPW post partum weight; EWW ewe weight at weaning of lambs

Table 4.4 Summary of published heritability estimates for birth weight (BW), 30 day weight (30W) and 60 day weight (60W).

BREED	Age (Days)	h_a^2	h_m^2	r_{am}	PE	h_T^2	REFERENCE
BW							
Afrino	BW	0.22	0.09		0.12	0.27	Snyman <i>et al.</i> (1995b)
Swedish finewool	BW	0.07	0.30	0.13-0.19		0.24	Näsholm & Danell (1996)
Baluchi	BW	0.17	0.10	0.17	0.08	0.24	Yazdi <i>et al.</i> (1997)
Composite	BW	0.23	0.07		0.25		Al-Shorepy & Notter (1998)
Composite	BW	0.09	0.17	0.01	0.09		Mousa <i>et al.</i> (1999)
Belgian Texel	BW	0.09	0.15	0.00			Janssens <i>et al.</i> (2000)
Dorper	BW	0.11	0.10	0.35	0.12	0.21	Neser <i>et al.</i> (2001)
30W							
Composite	45	0.24	0.03		0.13		Fossceco & Notter (1995)
Swedish finewool	21	0.07	0.17	0.37		0.22	Näsholm & Danell (1996)
Suffolk	30	0.16	0.04		0.19		Notter (1998b)
Polypay	30	0.07	0.17		0.15		Notter (1998b)
Belgian Texel	30	0.06- 0.08	0.16- 0.22	-0.02 0.06	to- 0.15		Janssens <i>et al.</i> (2000)
S.A Mutton	36	0.12	0.49	-1.00	0.09		Neser <i>et al.</i> (2000)
Merino	42	0.28	0.10	-0.63	-0.58	0.17	Neser <i>et al.</i> (2001)
Composite	60	0.23	0.00		0.11		Fossceco & Notter (1995)
Dorset composite	65	0.04- 0.05	0.10- 0.18		0.11	0.10	Al-Shorepy & Notter (1996)
Welsh Mountain	77	0.17	0.09	0.24		0.26	Aslaminejad & Roden (1997)
Targhee	60	0.0- 0.07	0.10- 0.11		0.08- 0.09		Notter & Hough (1997)
Welsh Mountain	50	0.03- 0.49	0.01- 0.32	0.99 1.00	to -	0.03 - 0.10	Saatci <i>et al.</i> (1997)
Targhee	60	0.06	0.10	0.00	0.10		Notter (1998a)
Suffolk	60	0.14	0.05		0.11		Notter (1998b)
Polypay	60	0.08	0.07		0.15		Notter (1998b)
Composite	50	0.09	0.09	-0.39	0.12		Mousa <i>et al.</i> (1999)
Belgian Texel	70	0.10- 0.11	0.13- 0.19	-0.02to- 0.06	0.10		Janssens <i>et al.</i> (2000)
S.A. Mutton Merino	50	0.28	0.13	-0.77	0.14		Neser <i>et al.</i> (2000)

Table 4.5 Summary of published heritability estimates for weaning weight (WW), 12 months weight (12W), 18 month weight (18W) and daily gain from birth to weaning (ADG).

BREED	Age	h_a^2	h_m^2	r_{am}	PE	h_T^2	REFERENCE
WW							
Dorset composite	90	0.23	0.00		0.07		Fossceco & Notter (1995)
Afrino	120	0.33	0.17			0.41	Snyman <i>et al.</i> (1995b)
Swedish finewool	105	0.12	0.13	0.47		0.28	Näsholm & Danell (1996)
Swedish finewool	120	0.15- 0.16	0.11	0.44 -0.47		0.28- 0.31	Näsholm & Danell (1996)
Targhee	120	0.10	0.05		0.08		Notter & Hough (1997)
Baluchi	98	0.16	0.03	0.52	0.06	0.22	Yazdi <i>et al.</i> (1997)
Targhee	120	0.10	0.06	0.00	0.06		Notter (1998a)
Suffolk	90	0.21	0.00		0.19		Notter (1998b)
Polypay	90	0.07	0.00		0.23		Notter (1998b)
S.A. Mutton Merino	100	0.19	0.09	-0.55	0.10		Neser <i>et al.</i> (2000)
Dorper	100	0.20	0.10	-0.55	-0.58	0.13	Neser <i>et al.</i> (2001)
12W							
Afrino		0.58	0.05			0.61	Snyman <i>et al.</i> (1995b)
Targhee		0.26	0.05		0.05		Notter & Hough (1997)
Baluchi		0.29	0.02	0.12	0.02	0.31	Yazdi <i>et al.</i> (1997)
Belgian Texel		0.25	0.04	-0.04			Janssens <i>et al.</i> (2000)
18WT							
Hyfer		0.44					Fogarty <i>et al.</i> (1994)
Australian Merino		0.27- 0.50					Lewer <i>et al.</i> (1994)
Grootfontein Merino		0.38	0.01				Olivier <i>et al.</i> (1994)
Afrino		0.56	0.06			0.60	Snyman <i>et al.</i> (1995b)
Composite		0.26	0.01	1.00	0.02		Mousa <i>et al.</i> (1999)
ADG (birth to)							
Black-Brown	30	0.10-	0.02-	-0.08-(-	0.06-.10		Hagger (1998)
Mountain		0.16	0.06	0.45)			
White Alpine	30	0.08-	0.04-	-0.17-(-	0.04-		Hagger (1998)
		0.14	0.06	0.44)	0.06		
Composite	51	0.21	0.01		0.03		Mousa <i>et al.</i> (1999)
Baluchi	98	0.12-	0.03	0.23-0.28	0.04-	0.16-	Yazdi <i>et al.</i> (1997)
		0.19			0.06	0.24	

Table 4.6 Summary of published heritability for litter weight weaned (LWW) and Kleiber ratio (KL)

BREED	h_a^2	h_m^2	r_{am}	PE	h_T^2	REFERENCE
LWW						
Various	0.08-0.19					Fogarty (1995)-a review
Afrino	0.06-0.17					Snyman <i>et al.</i> (1997)
Carnarvon Merino	0.09-0.26					Snyman <i>et al.</i> (1997)
Grootfontein Merino	0.05-0.08					Snyman <i>et al.</i> (1997)
Columbia	0.07					Okut <i>et al.</i> (1999)
Polypay	0.06					Okut <i>et al.</i> (1999)
Rambouillet	0.14					Okut <i>et al.</i> (1999)
Targhee	0.17					Okut <i>et al.</i> (1999)
Columbia	0.02			0.10		Bromley <i>et al.</i> (2001)
Polypay	0.10			0.00		Bromley <i>et al.</i> (2001)
Rambouillet	0.11			0.05		Bromley <i>et al.</i> (2001)
Targhee	0.08			0.07		Bromley <i>et al.</i> (2001)
KL						
Dorner	0.14	0.13	-0.25		0.15	Van Wyk <i>et al.</i> (1993b)

Total weight of litter weaned (LWW) as the sum of naturally reared individual lamb weights within a year per ewe lambing ; Kleiber ratio (KL=ADG to weaning/WW^{0.75})

Direct heritability for 30 and 60 day weights were intermediate to those published in literature (Table 4.5) except for the 0.00 found in Western flocks reported by Notter & Hough (1997) and 0.03 by Saatci *et al.* (1997) for 60 day weights. However, the contribution of direct additive effect increased to 18 months of age. Though similar to those in literature, the direct heritability estimates tended to be more on the lower scale of those reported (Table 4.4 - 4.6). Genetic direct additive estimates for body weights increased in importance with increasing age as in other studies (Mavrogenis *et al.*, 1980; Snyman *et al.*, 1995b; Fossceco & Notter, 1995; Näsholm & Danell, 1996; Al-Shorepy & Notter, 1996; Notter & Hough, 1997; Mousa *et al.*, 1999). The lower direct additive estimates in early body weights (30 and 60 day weights) may be due to the fact that lambs were not creep fed and raised in a generally poor nutritional environment resulting in lambs not expressing their genetic potential. Notter & Hough (1997) found similar results in a none creep fed environment.

Direct effects for total litter weight weaned were within the range of those reported in literature (Table 4.6) with Kleiber ratio lower than the 0.14 reported by Van Wyk *et al.* (1993b). Total litter weight weaned per ewe lambing is a trait often used as an overall measure of range lamb production (Bromley *et al.*, 2001) and has had favourable genetic and economic responses (Ercanbrack & Knight, 1998). In a review, Fogarty (1995) reported an average heritability estimate of 0.14 from six studies and Bromley *et al.* (2001) an average of less than 0.08 for four breeds which all compare favourably with 0.12 in the current study. Genetic improvement for litter weight weaned has been attributed to also affect fertility, prolificacy, lamb growth, lamb survival to weaning, and ewe viability from mating to weaning (Ercanbrack & Knight, 1998). In an experiment with mice, direct selection for litter weaned was three times as effective as selection for litter size at birth for increasing litter weight weaned (Luxford & Beilharz, 1990).

The direct heritability estimate of 0.27 for slaughter weight was less than the 0.36 reported for Scottish Blackface lambs (Conington *et al.*, 1998) and 0.31 for Swedish lambs (Henningsson & Malmfors, 1995) but higher than the 0.22 for Japanese Black cattle (Kitamura *et al.*, 1999). Heritability estimates for hot and cold carcass weights were the same. This was similar to 0.17 reported for Swedish lambs (Henningsson & Malmfors, 1995) and 0.23 for Japanese Black cattle (Kitamura *et al.*, 1999) but smaller than the 0.39 reported in Scottish Blackface ewes (Conington *et al.*, 1998) and 0.28-0.35 for Brahman cattle (Crews & Franke, 1998).

Direct heritability estimates for adult ewe weights were high and similar to 0.29-0.63 reported by Näsholm & Danell (1996) in Swedish finewool sheep, 0.17 to 0.61 for Mehraban sheep (Saeid Bathaei & Le Roy, 1998), 0.29-0.73 for Herefords and Wokalups (Meyer, 1998) and 0.44-0.53 for Angus cattle (Kaps *et al.*, 1999). There is need to understand the influence of ewe weights on the efficiency of sheep breeding. The interrelationships between ewe weights, lamb growth, reproduction and maternal capacity need better understanding in order to correctly consider these traits in an efficient breeding programme. Michels *et al.* (2000) concluded that since ewe weight can influence the litter weight components, a clear cut relationship between the litter weight components and ewe weight can probably not be considered as general but vary among differentially selected breeds and lines within them.

Maternal heritability estimates at birth were on the lower scale of those in literature (Table 4.4). In some studies (Maria *et al.*, 1993; van Wyk *et al.* 1993b; Tosh & Kemp, 1994; Näsholm & Danell, 1996), maternal heritability was higher than the direct additive component whilst in others it was the reverse (Tosh & Kemp, 1994; Snyman *et al.*, 1995b; Al-Shorepy & Notter, 1998; Naser *et al.*, 2001). Maternal heritability estimates in the current study declined from birth to weaning, being negligible at 12 months and thereafter (Table 4.3). Estimates of maternal heritability for 60-day weights are in the middle of those reported in literature (Table 4.4). The most appropriate model from log likelihood ratios for weaning weight included maternal effects. The low productivity and the poor environment could partially explain low maternal effects in the Sabi sheep. Contrary to some carry-over effects exhibited in other breeds, maternal effects were non-existent after weaning (Table 4.5). Other studies have found evidence of post-weaning body weights with significant carry over maternal effects for sheep (Swan & Hickson, 1994; Mortimer & Atkins, 1994) and in beef cattle (Meyer, 1992). The decrease with age for maternal heritability is in agreement with other studies (Robison, 1981; Tosh & Kemp; 1994, Snyman *et al.*, 1995b; Näsholm & Danell, 1996). The maternal heritability for Kleiber ratio was much lower than reported by Van Wyk *et al.* (1993b). The pre-weaning maternal effects for average daily gain between birth and 120 days were lower than those reported by Van Wyk *et al.* (1993b) but higher than those reported by Yazdi *et al.* (1997).

Fitting the most appropriate models for all the traits under consideration indicated that no genetic correlations exist between the direct and maternal effects. Sabi sheep have relatively low maternal effects to weaning unlike in breeds with high potential. Other studies found negative genetic correlation between direct and maternal effects for growth traits in sheep (Khaldi and Boichard, 1991; Burfening and Kress, 1993; Van Wyk *et al.*, 1993b). Maria *et al.* (1993) found that they varied between -0.99 and 0.99 for Romanov sheep. Näsholm & Danell (1994) reported direct-maternal additive correlations, which were positive and increased with age (to 90 days). Some authors concluded that negative direct-maternal additive correlations might be environmentally induced (Robison, 1972) or amplified by management system (Meyer, 1992; Swalwe, 1993). Others have discussed the possibility that the negative environmental covariance between dam and offspring that is not accounted for, biases the additive genetic direct-maternal genetic correlation downward (Baker, 1980; Meyer, 1992).

The maternal permanent environmental component due to the dam contributed six and 13 per cent of the total phenotypic variances at birth and weaning (Table 4.3). These results are similar to those reported elsewhere (Clarke & Johnson, 1993; Maria *et al.*, 1993; Snyman *et al.*, 1995b). The permanent environmental effect due to the dam can be ascribed to uterine environment, the effects of multiple birth and on milk yield. These decreased in importance as lambs became increasingly independent of the ewe (Tosh & Kemp, 1994).

4.4 Conclusions

Genetic progress is possible for all growth traits analysed for the Sabi sheep. However, their inclusion in any selection programme would need to take into account the maternal and genetic correlations among the growth traits especially for early (pre-weaning) growth traits and other fitness traits such as reproduction, internal and external (tick) parasite resistance where possible. Perhaps here could be a need to have two breeding objectives, one selecting for a dam line adapted to harsh semi-arid environment and the other concentrating on growth and efficiency of lamb production.

Since litter weaned is a composite trait, its interrelationship with other traits needs to be examined for Sabi sheep before it can be used for ewe selection.

An increase in ewe live weights as a correlated response to selection for other growth and carcass traits may be undesirable for harsh environment and needs further investigation.

There seems to be an absence of reliable estimates of genetic parameters on the Sabi on other carcass traits such as muscle depth and fat cover which may be used in selection criteria and the interrelationships between carcass and fitness traits in these hardy animals.

5

Phenotypic and genetic relationships among lamb and ewe traits

5.1 Introduction

Sabi sheep have hairy coats and fat tails making them uniquely qualified to be productive under hot and semi-arid conditions similar to other hair breeds (Mason, 1980; Fitzhugh & Bradford, 1983). Sabi sheep under an extensive production system have low birth and body weights as reported in Chapter 2. Unlike most breeds, where improvement in birth weight and body weights may cause rather than solve problems of lamb survival, it has been postulated that selection for birth weight may be more beneficial for the Sabi sheep on condition that the genetic and phenotypic correlations are not antagonistic to other traits (Chapter 4).

Breeding programmes designed to improve production efficiency require knowledge of the genetic parameters for characters of economic importance such as those of growth (Stobart *et al.*, 1986), total weight of lamb weaned and prolificacy (Bromley *et al.*, 2001) and reproduction (Al-Shorepy & Notter, 1996, Lee *et al.*, 2000). Butcher *et al.* (1964), postulated that although weaning weight is a major factor in determining the income from farm flocks, with birth weight having no economic value *per se*, large positive genetic correlations between them would permit early selection and culling. This would, in pure flocks allow early selection of rams for replacement or for sale. Dickerson (1970) concluded that improvements in reproduction were

particularly likely to increase efficiency of production, after pointing out that the efficiency of livestock production is controlled by reproduction, female production and growth of offspring. Therefore, genetic correlations are essential in predicting indirect responses to selection and are needed to determine the optimum weighting and expected response in selection to improve more than one trait.

Although estimates of genetic correlations for sheep production traits abound in literature (Fogarty, 1995; Michels *et al.*, 2000), few are available for hair breeds and none for the Sabi sheep of Zimbabwe. Simultaneous improvement in growth, reproduction, carcass and lamb survival requires information on both heritabilities and genetic correlations. If there are major genetic antagonisms among these traits then selection indexes need to be developed to accommodate this. Therefore, the knowledge of the magnitude and the sign of the genetic correlation between traits under consideration are a prerequisite if any meaningful genetic progress is to be attained through any selection programme. The aim of the current study was to estimate heritabilities and genetic and phenotypic correlations for growth, lamb survival and ewe traits for Sabi sheep reared in a semi-arid environment.

5.2 Materials and Methods

Data on Sabi sheep at Matopos Research Station near Bulawayo, Zimbabwe, collected from 1984 to 1994 were used in this study. A detailed description of the management procedures followed is given in Chapter 2. Traits analysed were: birth weight within 24 hours of birth (BW); pre-weaning lamb survival (SURV); weaning weight (WW) at 120 days; 12 month weight (12W); 18 month weight (18W), total weight of lamb weaned (LWW) (the sum of naturally reared individual lamb weights within a year per ewe lambing and is a trait of the ewe); slaughter weight (SLW); hot carcass weight (HCW); cold carcass weight (CCW); ewe weight at mating (MW), post partum (PPW) and at weaning of lamb (EWW). Reproductive traits considered were fertility (FERT) (whether a ewe lamb or not, 1 or 0) and prolificacy (PROL) (number of lambs born to ewes lambing, 1 or 2). A detailed description of the data used for reproductive parameters is reported in Chapter 3.

The fixed effects included in the model were year of birth (1984-1994), sex (males, castrates, females), type of birth (singles or twins) or type of rearing, age of dam (2 to

7 years and older) and birth date (measurement on day of birth nested within birth year) or lamb age as a covariate. Year of birth and sex were combined into a single class to account for the interaction after weaning due to animals of different sexes being raised on separate farms.

Estimates of (co)variance components were obtained using the ASREML programme (Gilmour *et al.*, 1999) fitting bivariate animal models except for fertility, prolificacy and lamb survival. Models fitted for these were those determined from univariate analysis described in Chapter 4. Reproductive traits and lamb survival were analysed using logit and probit link functions to link the binomially distributed data to the normal distribution. A model (Model 2) including direct and permanent environment due to the animal was fitted for fertility and prolificacy while for lamb survival only direct additive effects were fitted. The results from logit and probit analyses were similar as has been reported previously (Lopez-Villalobos & Garrick, 1999; Morris *et al.*, 2000), and therefore only the results from the logit analysis are presented. Genetic correlations between reproductive traits and lamb survival were done using Spearman's correlation of breeding values with the other traits. This should be considered an approximation. Although a genetic correlation is by definition a correlation between breeding values, the values used are a prediction.

5.3 Results and Discussion

Heritability, phenotypic, environmental and genetic correlation estimates from bivariate analyses of growth, carcass, reproduction and lamb survival are presented in Table 5.1. Heritability estimates were in close agreement to those of univariate analyses reported in Chapter 4, although in some cases slightly higher. This may be due to the fact that animals with both records were a selected sample and reproductive traits are measured in the female only. The subset of ewes that did not lamb is not a random sample of ewes, but a sample that has a lower than average ovulation rate (Waldron & Thomas, 1992). Direct heritability estimates were: 0.28, 0.17, 0.25, 0.39, 0.59, 0.50, 0.68, 0.12, 0.25, 0.11, 0.12, for birth weight, weaning weight (120 days), 12 month weight, 18 month weight, ewe mating weight, post partum weight, total weight of lamb weaned, slaughter weight, hot and cold carcass weights respectively.

Genetic correlations among birth weight and other weights to 18 months were high (0.75 to 0.85) whilst the relationship among weaning, 12 month and 18 month weight was close to unity. Fogarty (1995) reviewed lower genetic (0.07-0.32) and phenotypic correlations between birth weight and later weights. The largest relationships were found between chronologically adjacent weights similar to other studies (Fogarty, 1995; Yazdi *et al.*, 1997; El Fadili *et al.*, 2000). This suggests that the genes responsible for live weight recorded between birth and 18 months of age may be the same and weights in early life (birth weight, weaning weight) are a suitable criterion in selecting for growth.

The genetic correlation between birth weight and ewe weights were moderate (mating, post-partum and dam weight at weaning of lamb: 0.51, 0.40, 0.49 respectively) and were close to unity between 18 month weight and ewe weights (0.96, 0.92, and 0.84 respectively). The absence of genetic antagonisms among the various lamb and ewe weights indicates that none of the traits should be affected adversely through selection. Selecting for either birth weight or weaning weight without changing ewe weights would be difficult. This is in agreement with findings from other workers (Näsholm & Danell, 1996; Yazdi *et al.*, 1997; Mousa *et al.*, 1999).

Total weight of lamb weaned was moderately correlated to birth weight ($r_g=0.46$) but tended to be highly correlated with 18 month weight (0.92) and ewe weights (0.75-0.91). In the literature genetic and phenotypic correlations between live weights and total weight of lamb weaned are scarce and varied. Bromley *et al.* (2001) reported genetic correlations between birth weight and total weight of lamb weaned ranging from -0.22 to 0.28 and residual correlations of -0.02 to 0.00 (Table 5.2). Although the definition of total weight of lamb weaned was slightly different from that used in the current study, Snyman *et al.* (1998a,b) reported high (0.69-0.89) genetic and moderate (0.13-0.32) phenotypic correlations between total weight of lamb weaned and various lamb weights (Table 5.2 & 5.3). In his review, Fogarty (1995) only cited one reference for a genetic correlation between total weight of lamb weaned and hogget weight of 0.58 and a phenotypic correlation of 0.15. In the same review, the correlation of total weight of lamb weaned and fertility was 0.82 for genetic and 0.69-0.77 for phenotypic correlations. Improvement of either 18-month weight or ewe weights would increase the total weight of lamb weaned. The genetic correlations between total weight of lamb weaned and fertility, prolificacy and lamb survival were 0.01, -0.05 and 0.13, respectively (with large standard errors) and these estimates

were lower than those reviewed by Fogarty (1995) and those in other literature (Table 5.3). Ewes with a high total weight of lamb weaned may not be in good condition in the subsequent mating season especially where feed availability is limiting and this may affect ovulation which is highly (0.91) correlated to prolificacy (Davis *et al.*, 1998).

The genetic correlation between birth weight and slaughter and carcass weight was moderate and was high at 18 months. This is due to the fact that most of the males are slaughtered between 18 and 24 months of age. Any selection on other live weights will improve the weight of carcasses.

Table 5.1 Heritability (on diagonal with SE in parenthesis), phenotypic (above diagonal and environmental correlations in parenthesis) and genetic correlation[†] (below diagonal with standard errors are in parenthesis) estimates for growth, carcass and ewe traits.

Trait [#]	BW	WW	W12	W18	MW	PPW	EWV	LWW	SLW	HCW	CCW	FERT	PROL	SURV
BW	0.28 (0.04)	0.34 (0.25)	0.34 (0.03)	0.40 (0.05)	0.25 (0.01)	0.13 (-0.11)	0.28 (0.07)	0.09(0. 02)	0.26 (0.14)	0.21 (0.14)	0.21 (0.14)			
WW	0.81 (0.07)	0.17 (0.00)	0.80 (0.78)	0.66 (0.61)	0.55 (0.32)	0.48 (0.19)	0.50 (0.13)	NC	0.44 (0.46)	0.40 (0.42)	0.38 (0.41)			
W12	0.75 (0.07)	0.97 (0.02)	0.25 (0.01)	0.80 (0.77)	0.78 (0.66)	0.67 (0.44)	0.59 (0.19)	NC	0.59 (0.44)	0.54 (0.45)	0.53 (0.45)			
W18	0.85 (0.05)	0.94 (0.033)	0.94 (0.022)	0.39 (0.01)	0.90 (0.74)	0.81 (0.45)	0.71 (0.36)	0.38 (0.07)	0.77 (0.70)	0.71 (0.62)	0.70 (0.61)			
MW	0.51 (0.07)	0.86 (0.05)	0.88 (0.03)	0.96 (0.02)	0.59 (0.01)	0.76 (0.44)	0.77 (0.20)	0.27(0. 13)						
PPW	0.40 (0.08)	0.86 (0.05)	0.88 (0.03)	0.92 (0.03)	0.96 (0.01)	0.50 (0.01)	0.74 (0.30)	0.28 (0.10)						
EWV	0.49 (0.07)	0.86 (0.051)	0.78 (0.040)	0.84 (0.034)	0.99 (0.005)	0.96 (0.010)	0.68 (0.03)	0.20 (- 0.00)						
LWW	0.43 (0.16)	NC	NC	0.85 (0.12)	0.84 (0.08)	0.94 (0.07)	0.79 (0.09)	0.09 (0.00)						
SLW	0.78 (0.15)	0.65 (0.18)	0.94 (0.08)	0.96 (0.05)					0.25 (0.01)					
HCW	0.76 (0.21)	0.48 (0.27)	0.90 (0.11)	0.93 (0.07)						0.11 (0.00)				
CCW	0.75 (0.21)	0.44 (0.27)	0.84 (0.13)	0.92 (0.07)							0.12 (0.00)			
FERT	0.06 (0.02)	0.03 (0.06)	0.02 (0.44)	0.04 (0.18)	-0.08 (0.00)	0.01 (0.62)	-0.04 (0.18)	0.01 (0.74)				0.08 (0.04)		
PROL	-0.02 (0.60)	0.07 (0.02)	0.12 (0.00)	0.07 (0.02)	0.22 (0.00)	0.13 (0.00)	0.24 (0.000)	-0.05 (0.07)				-0.17 (0.055)	0.22 (0.03)	
SURV	0.18 (0.00)	0.26 (0.00)	0.15 (0.00)	0.15 (0.00)	0.05 (0.06)	0.06 (0.05)	0.03 (0.25)	0.13 (0.00)				0.06 (0.033)	0.14 (0.000)	0.01 (0.02)

† Genetic correlation between reproductive traits (fertility and prolificacy), survival and the rest of the traits was through a Spearman's correlation of breeding values obtained in univariate analyses

BW birth weight; WW weaning weight; W12 12month weight; W18 18 month weight; SLW slaughter weight; HCW hot carcass weight; CCW cold carcass weight; LWW total weight of lamb weaned; MW ewe weight at mating; PPW post partum weight; EWV ewe weight at weaning of lambs; FERT fertility (0 or 1); PROL prolificacy (1 or 2); SURV lamb survival to weaning (0 or 1); NC no convergence

The heritability estimates for fertility (0.08), prolificacy (0.22) and lamb survival (0.01) were from univariate, logit transformed analyses compared to estimates of 0.02, 0.26 and 0.04, respectively reported for the same traits in Chapter 3 using threshold models. The estimate of heritability for fertility was higher than that from the threshold model, but still within the reported values (Matos *et al.*, 1997, Olivier *et al.*, 1998) but lower than 0.20 reported by Olivier *et al.* (1998) and Snyman *et al.* (1998a). The estimate for prolificacy was almost the same as that reported in Chapter 3 for the threshold model using the same data set. However, the estimate of heritability for survival (using logit transformation) was lower than that reported for the threshold model (Matos *et al.*, 2000;) but was in close agreement to that reported elsewhere (Olivier *et al.*, 1998; Snyman *et al.*, 1998a; Lopez-Villalobos & Garrick, 1999).

The genetic correlation between fertility and lamb and ewe weights is low (-0.08 to 0.06) with some having large standard errors. The implication is that the genes controlling fertility and live weights are probably different. A larger data set is needed to validate this result.

The genetic correlation between prolificacy and birth weight was negative and low. Bromley *et al.* (2000) concluded that birth weight and prolificacy were only slightly genetically correlated, with mostly different genes involved in the expression of these two traits. The genetic correlation between prolificacy and weaning weight, 12 month weight, 18 month weight, ewe mating, post-partum and ewe weight at weaning were 0.07; 0.12; 0.07; 0.22; 0.13; 0.24 respectively. The weighted average genetic correlation between ewe weight and prolificacy at various ages was 0.41 (-0.46 to 0.78) (Fogarty, 1995). The relationships among and within breeds between prolificacy and ewe weights varied and are well reviewed by Michels *et al.* (2000). It appears that any genetic improvements especially for ewe weights at mating or weaning will have a low to moderate response in improving prolificacy. It is of interest to note that the genetic correlation between fertility and prolificacy is negative (-0.17). Animals bearing twins may fail to conceive in the subsequent year because they may still be in poor body condition.

There is evidence of a small degree of genetic variation for lamb survival to weaning (Cundiff *et al.*, 1982, Piper *et al.*, 1982; Lopez-Villalobos & Garrick, 1999). Genetic correlations between lamb survival and birth weight, weaning weight, 12 month weight, 18 month weight and total weight of lamb weaned were 0.18, 0.26, 0.15, 0.15, 0.13 respectively. However, the genetic correlations between ewe weights were low (0.03 to 0.06). Fogarty (1995) reviewed lamb survival as a ewe trait and its genetic correlation ranged from 0.16, 0.11, 0.51 to -0.30 for birth weight, weaning, hogget weight and total weight of lamb weaned, respectively. There were also low phenotypic correlations varying from -0.18 to 0.04. Selection for live weight in the Sabi flock, will not drastically improve survival but will have some beneficial effects. Better control of environmental effects will yield more rapid response to higher lamb survival.

5.4 Conclusions

Live weights are generally low in the Sabi Sheep. From the results of this study it is evident that no important antagonistic relationships exist among traits. Birth weight is generally considered as a trait having an intermediate optimum with both too low and too high values causing survival problems. The positive genetic correlation found between birth weight and survival suggests that the flock studied is below the optimum. Although speculatively, this could be due to a gradual, long-term deterioration in the environment. Contrary to what is normally the case in improved livestock where guarding against high birth weights is generally recommended, a genetic improvement in birth weight, also because of its high genetic correlation with later weights, should be considered a priority in the Sabi sheep until an optimum is reached.

Total weight of lamb weaned will also need to be considered in the selection strategy since it is a composite trait incorporating elements of not only lamb growth and survival to weaning, but also ewe reproductive performance.

Table 5.2 Heritability (h^2), phenotypic (r_p), environmental (r_e) and genetic correlation (r_g) estimates published in literature for birth weight (bw), weaning weight (ww) and other parameters[#]

Breed	Trait ²	h^2_{a1}	h^2_{a2}	r_p or r_e	r_g	Reference
Birth weight						
Swedish finewool	WW	0.06	0.15	-	0.44	Näsholm & Danell, 1996
Swedish finewool	SLW	0.06	0.15	-	0.44	Näsholm & Danell, 1996
Swedish finewool	MATURE	0.07	0.63	-	0.36	Näsholm & Danell, 1996
Baluchi	WW	0.14- 0.20	0.13- 0.19	0.39-0.41	0.40-0.81	Yazdi <i>et al.</i> , 1997
Segurena	WW	0.43	0.31	0.51	0.59	Analla <i>et al.</i> , 1997
Segurena	PROL	0.43	0.07	0.00	0.18	Analla <i>et al.</i> , 1997
Segurena	W3	0.43	0.26	0.33	0.56	Analla <i>et al.</i> , 1997
Composite	WW	0.09	0.09	0.43	0.45	Mousa <i>et al.</i> , 1999
Composite	W19	0.09	0.35	0.27	0.35	Mousa <i>et al.</i> , 1999
Composite	W31	0.09	0.44	0.39	-0.01	Mousa <i>et al.</i> , 1999
Moroccan Timahdit	W3	0.18	0.50	0.40	0.49	El Fadili <i>et al.</i> , 2000
Columbia	PROL	0.24	0.07	0.04	-0.01	Bromley <i>et al.</i> , 2000
Polypay	PROL	0.16	0.13	0.04	0.03	Bromley <i>et al.</i> , 2000
Rambouillet	PROL	0.21	0.09	0.00	0.26	Bromley <i>et al.</i> , 2000
Targhee	PROL	0.19	0.14	0.02	0.11	Bromley <i>et al.</i> , 2000
Columbia	LWW	0.25	0.03	-0.02	-0.22	Bromley <i>et al.</i> , 2001
Polypay	LWW	0.16	0.09	0.00	0.28	Bromley <i>et al.</i> , 2001
Rambouillet	LWW	0.20	0.14	-0.03	0.23	Bromley <i>et al.</i> , 2001
Targhee	LWW	0.25	0.11	-0.02	0.11	Bromley <i>et al.</i> , 2001
Dorper	WW	0.11	0.20	-	0.27	Neser <i>et al.</i> , 2001
Weaning weight						
Composite	W3	0.07	0.08	0.86	1.00	Al-Shorepy & Notter, 1996
Composite	W4	0.07	0.19	0.62	0.86	Al-Shorepy & Notter, 1996
Swedish finewool	SLW	0.14	0.18	-	0.95	Näsholm & Danell, 1996
Segurena	PROL	0.31	0.07	0.01	0.48	Analla <i>et al.</i> , 1997
Segurena	W3	0.31	0.26	0.69	0.76	Analla <i>et al.</i> , 1997
Baluchi	W12	0.19	0.32	0.59-0.60	0.93-0.94	Yazdi <i>et al.</i> , 1997
Afrino	W9	0.41	0.63	0.80	0.98	Snyman <i>et al.</i> , 1998a
Afrino	W18	0.41	0.60	0.64	0.92	Snyman <i>et al.</i> , 1998a
Afrino	LWW	0.41	0.17	0.13	0.75	Snyman <i>et al.</i> , 1998a
Afrino	NLB	0.41	0.23	0.04	-0.01	Snyman <i>et al.</i> , 1998a
Composite	W19	0.09	0.35	0.34	0.43	Mousa <i>et al.</i> , 1999
Composite	W31	0.09	0.44	0.30	0.32	Mousa <i>et al.</i> , 1999
Hungarian Merino	W12	0.21	0.13	-	0.54	Nagy <i>et al.</i> , 1999
Hungarian Merino	W24	0.21	0.11	-	0.41	Nagy <i>et al.</i> , 1999
Targhee	PROL	0.16	0.11	0.05	0.48	Rao & Notter, 2000
Suffolk	PROL	0.13	0.09	0.08	0.43	Rao & Notter, 2000
Polypay	PROL	0.10	0.10	0.02	0.09	Rao & Notter, 2000

[#] other parameters: W3=90 day weight; W4=120 day weight; W12= 12 months weight;

W14=14 month weight; W18= 18 month weight; W19= 19 month weight; W24= 24 month

weight; W30=30 month weight; W31=31 month weight, LWW=total weight of lamb weaned;

SLW=slaughter weight; PROL = prolificacy; NLB= number of lambs born over ewes exposed to the ram at mating.

Table 5.3 Heritability (h^2), phenotypic (r_p), environmental (r_e) and genetic correlation (r_g) estimates published in literature for post weaning weights and other parameters[#]

Breed	Trait1	Trait2	h^2_{a1}	h^2_{a2}	r_p or r_e	r_g	Reference
Prolificacy							
Rambouillet	PROL	W6	0.19	0.35	0.03*	0.22	Waldron & Thomas, 1992
Composite	PROL	W3	0.05	0.14	0.11	0.33	Al-Shorepy & Notter, 1996
Composite	PROL	FERT	0.05	0.09	-	0.56	Al-Shorepy & Notter, 1996
Segurena	PROL	W3	0.07	0.26	0.01*	0.36	Analla <i>et al.</i> , 1997
Rambouillet	PROL	W18	0.06	0.48	0.00*	0.35	Lee <i>et al.</i> , 2000
Columbia	PROL	LWW	0.07	0.02	0.41*	0.65	Bromley <i>et al.</i> , 2001
Polypay	PROL	LWW	0.12	0.07	0.33*	0.42	Bromley <i>et al.</i> , 2001
Rambouillet	PROL	LWW	0.09	0.10	0.33*	0.62	Bromley <i>et al.</i> , 2001
Targhee	PROL	LWW	0.10	0.10	0.33*	0.55	Bromley <i>et al.</i> , 2001
Total weight of lamb weaned							
Afrino	LWW	W18	0.17	0.60	0.26	0.89	Snyman <i>et al.</i> , 1998a
Tygerhoek Merino	LWW	W14-16	0.13	0.55	0.15	0.80	Snyman <i>et al.</i> , 1998b
Grootfontein Merino	LWW	W14-16	0.13	0.38	0.20	0.67	Snyman <i>et al.</i> , 1998b
Klerfontein Merino	LWW	W14-16	0.22	0.43	0.32	0.72	Snyman <i>et al.</i> , 1998b
Fertility							
Composite	FERT	W3	0.09	0.14	-0.04	-0.31	Al-Shorepy & Notter, 1996
Others							
Swedish Finewool	MATURE	SLW	0.39	0.24	-	0.44	Näsholm & Danell, 1996
Various	W12	W18	0.26	0.36	0.71	0.62	Stobart <i>et al.</i> , 1986
Various	W12	W30	0.26	0.25	0.55	0.24	Stobart <i>et al.</i> , 1986
Various	W18	W30	0.36	0.25	0.75	0.73	Stobart <i>et al.</i> , 1986
Afrino	W18	NLB	0.60	0.23	0.16	0.31	Snyman <i>et al.</i> , 1998a
Composite	W19	W31	0.35	0.44	0.65	0.97	Mousa <i>et al.</i> , 1999
Hungarian Merino	W12	W24	0.13	0.11		0.57	Nagy <i>et al.</i> , 1999

[#] Other parameters: W3=90 day weight; W6=180 day weight; W12= 12 month weight; W14=14 month weight; W16= 16 month weight; W18= 18 month weight; W19= 19 month weight; W24= 24 month weight; W30=30 month weight; W31=31 month weight, LWW=total weight of lamb weaned; SLW=slaughter weight; FERT=fertility; PROL=prolificacy; NLB=number of lambs born.

6

Resistance of Sabi and Dorper ewes to gastrointestinal nematode infections in a semi-arid environment

6.1 Introduction

Gastrointestinal nematode parasitism imposes severe economic constraints on sheep and goat production on rangelands. *Haemonchus contortus* is regarded as the most economically important nematode parasite in Zimbabwe (Vassilev, 1995). The critical periods for dosing small ruminants is not well documented in a semi-arid environment. Recommendations vary from three dosings a year to more frequent dosing favoured by some sheep producers e.g. at three week intervals in lambs (Vassilev, 1995). Past intensive dosing programmes, the threat of drug resistant strains emerging (Van Wyk *et al.*, 1997) and the ever-increasing cost of drugs has necessitated that alternative methods to contain and control gastro-intestinal parasitism is explored. Methods of internal parasite control, which rely on rotational grazing, are limited in communal grazing systems. An attractive solution is to utilise the animal's genetic resistance to internal parasites (Baker, 1998). The indigenous Sabi sheep of Zimbabwe (Ward, 1959) with similar features to the *Red Maasai* and *Tswana* sheep of eastern and southern Africa (Mason & Maule, 1960) have been shown under controlled artificial challenge to be resistant to internal parasites (McKenzie, 1987).

Research on resistance to internal parasites with indigenous sheep in Sub-Saharan Africa under natural pasture worm challenge has been carried out on the Red Maasai in Kenya (Baker *et al.*, 1999) and the Menz and Horro in Ethiopia (Tembely *et al.*,

in Kenya (Baker *et al.*, 1999) and the Menz and Horro in Ethiopia (Tembely *et al.*, 1998), but Sabi sheep have not been evaluated for resistance under natural pasture challenge. Studies in sheep showing resistance to internal parasites have also indicated that they had reduced peri-parturient rise as compared to the unselected or susceptible sheep (Zajac *et al.*, 1988; Woolaston, 1992, Morris *et al.*, 1998). The peri-parturient rise in faecal egg output in ewes is a well documented phenomenon and is normally attributed to depressed immunity of the lactating ewe (Connan, 1968; O'Sullivan & Donald, 1970; Brunsdon & Vlassoff, 1971). The current study is part of a Pan-African research project (ILCA, 1991) initiated in 1996 to evaluate resistance to internal parasites of Sabi and Dorper sheep. The present study also investigates the occurrence of the peri-parturient rise in nematode egg output during lactation in breeding Sabi and Dorper ewes.

6.2 Materials and Methods

Data were obtained from the Sabi flock on natural rangelands at Matopos Research Station. The average rainfall during the study period was 624 mm (313-851mm). Distribution was erratic with 1998 having the last rains in January instead of the normal end of rainy season in April-May. Sabi rams (17) were purchased from communal areas in North Gokwe along the Zambezi River and in Gwanda South along the Botswana border and 17 rams were from the Matopos bred Sabi flock. Dorper rams (23) and ewes (526) were purchased from the commercial farming sector all over Zimbabwe.

A study of internal parasite resistance in Sabi and Dorper sheep was started in 1996. Six Dorper rams, four Sabi rams bred at Matopos and four purchased Sabi rams were mated for 35 days each year in June to Sabi and Dorper ewes in a diallel design. All breeding ewes were always grazed together in one group throughout the year. Most of the rams were used once with two Dorper rams, one Sabi bred at Matopos and one bred in communal areas used as repeat rams across mating years.

All rams and ewes had blood and faecal samples taken and weighed at the following periods: at mating; one month pre lambing; one month post lambing, two months post lambing; weaning of lambs at 3 months post lambing. At weaning faecal samples were sent to the Veterinary laboratory in Harare for cultures. Dosing was

February to March) when all ewes were dosed to prepare them for the next mating. At the other sampling times ewes with egg counts higher than 1500 (initially 2000) and /or PCV less than 20 per cent were treated. The percentage of sheep with high faecal egg counts (FEC>1500) was determined. The protocol was similar to that described by Baker (1998). All ewes were treated with an acaricide weekly during the wet season and fortnightly during the dry season to control ticks.

Faecal egg counts were analysed using the modified McMaster method (MAFF, 1977), with a lower limit of detection of 50epg (eggs per gram) of faeces. PCV was measured by the microhaematocrit method.

6.2.1 Statistical analysis

The data set analysed consisted of 1888 ewe records collected from 1996 to 2000. Some ewe records were missing at various sampling periods over the years (Table1). Data were analysed using least squares analysis of variance (Harvey, 1990). The fixed effects included in the model were year (1996-2000), age of ewe (2 to 5 years and older), breed (Sabi or Dorper) and physiological status (dry, pregnant or lactating) and, in preliminary analyses, all first order interactions. Faecal egg counts were logarithm transformed (LFEC, $\log_{10}(\text{FEC}+25)$) to normalise the variance and the results back-transformed by taking anti-logarithms and presented as geometric means (GFEC). All statistical tests for FEC were applied to the transformed data.

Table 6.1 Numbers used in the analyses from mating to weaning of lambs for Sabi and Dorper ewes evaluated from 1996 to 2000

	Mating	1 Month pre lambing	1 Month post lambing	2 Months post lambing	Weaning of lambs
Total	1888	1620	1558	1572	1650
Age of ewe					
2	604	530	475	448	543
3	496	421	404	447	435
4	369	310	304	311	313
5 +	419	359	375	366	359
Year					
1996	425	342	261	281	345
1997	420	332	338	334	358
1998	381	302	302	307	302
1999	333	329	336	332	329
2000	329	315	321	318	316
Breed					
Sabi	1281	1210	1169	1154	1237
Dorper	607	410	389	418	413
Physiological status					
Dry	1888	503	446	501	518
Preg/Lact [#]	-	1117	1112	1071	1132

[#] Pregnant pre and lactating post lambing

Table 6.2 Model specification for ewe weights (LWT), logarithm transformed faecal egg counts (LFEC) and packed cell volume (PCV) for Sabi and Dorper ewes from mating to weaning of lambs

Fixed effects	Mating			1 Month pre lambing			1 Month post lambing			2 Months post lambing			Weaning of lambs		
	LWT	PCV	LFEC	LWT	PCV	LFEC	LWT	PCV	LFEC	LWT	PCV	LFEC	LWT	PCV	LFEC
Age	***	***	NS	***	**	***	***	NS	NS	***	*	NS	***	***	NS
Year	***	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Breed	***	***	***	***	***	***	***	**	***	***	***	NS	***	NS	NS
PSTAT [#]	-	-	-	***	NS	*	***	***	***	***	***	***	***	***	***
Year*Breed	***	***	***	***	***	***	***	**	-	***	-	***	***	*	*
Age*Breed	***	***	*	***	***	*	***	-	-	***	**	-	***	-	**
Breed*PSTAT [#]	-	-	-	*	NS	NS	NS	*	*	NS	NS	NS	NS	NS	NS
R ²	0.43	0.31	0.31	0.44	0.36	0.65	0.37	0.43	0.20	0.39	0.15	0.26	0.51	0.21	0.30
CV (%)	13.7	11.74	22.32	12.6	10.31	17.79	12.90	11.92	18.75	11.7	13.06	19.53	12.6	11.59	17.36

[#]PSTAT Physiological status (dry, pregnant or lactating)

= P < 0.05; ** = P < 0.01; *** = P < 0.001; NS = Non significant

6.3 Results and Discussion

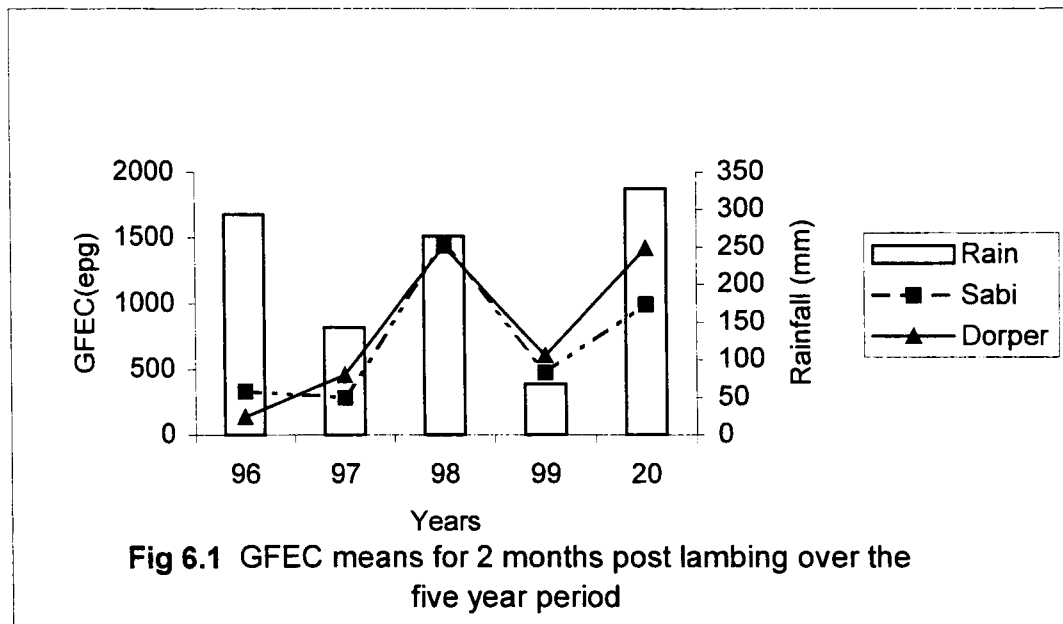
Faecal cultures from lamb and ewes consists mainly of *Haemonchus* (71-90 %) with other genera of parasites identified being *Cooperia*, *Trichostrongylus*, *Strongyloides*, *Oesophagostomum* and *Trichuris* spp.. Worm counts at necropsy identified *Haemonchus contortus*, *Trichostrongylus colubriformis* and *Oesophagostomum columbianum*.

The model specification for each trait is presented in Table 6.2. Least squares means for ewe live weight, LFEC, GFEC and PCV at each sampling are presented in Table 6.3. Dorper ewes were consistently and significantly heavier than Sabi across all sampling periods from mating to weaning of lambs ($P < 0.001$). The Dorpers had heavier weights across the years with the interactions reflecting the magnitude of the differences. The same explanation is true for the interactions for PCV and LFEC with the Sabi being superior except at weaning probably because of the higher proportion of Dorpers already treated throughout the year.

The variations in LFEC and PCV over the years were mainly due to the fluctuations in rainfall. A plot of GFEC for the Sabi and Dorper sheep at two months post sampling for each year closely resembled the plot of rainfall at the period of sampling (Fig 6.1). In years of high rainfall, with a high parasite challenge, the two breeds had similar LFECs. This may be due to the immune system being overwhelmed by the parasite challenge. The rainfall quantity and distribution also affect other factors such as nutrition and predominance of different nematode species. The other factor, which applied to all the years, is that the management of the flock was sub-optimal, especially from 1996 to 1998, due to several changes of personnel and managers.

Table 6.3 Least squares means by breed and physiological status from mating to weaning of lamb for ewe live weight (LWT, kg), packed cell volume (PCV,%) logarithm transformed faecal egg counts (LFEC, epg) and the geometric mean of faecal egg count (GFEC,epg).

Sampling time	Trait	Breed		Physiological status	
		Sabi	Dorper	Dry	Pregnant / lactating
Mating	LWT	34.3	42.2		
	PCV	29.7	28.0		
	LFEC	2.07	2.20		
	GFEC	118	158		
1 Month pre-lambing	LWT	33.5	40.0	36.0	37.5
	PCV	28.0	26.6	27.2	27.3
	LFEC	2.27	2.50	2.35	2.42
	GFEC	187	317	227	261
1 Month post lambing	LWT	31.7	38.2	36.0	34.0
	PCV	26.4	25.8	26.7	25.6
	LFEC	2.73	2.89	2.73	2.89
	GFEC	537	779	542	771
2 Month post lambing	LWT	32.8	39.0	37.1	34.7
	PCV	27.6	26.5	27.5	26.7
	LFEC	2.76	2.77	2.71	2.83
	GFEC	579	583	512	676
Weaning	LWT	33.7	41.5	39.3	35.9
	PCV	28.1	27.9	28.4	27.6
	LFEC	2.67	2.72	2.63	2.76
	GFEC	473	520	423	581



ewes were more resistant to endoparasites than Dorper ewes as evidenced by significantly (at least $P < 0.05$) lower FEC and higher PCV at most sampling times except at 2 month post lambing and at weaning for FEC (Table 6.3). These results are similar to those of McKenzie (1987) which were obtained using artificial (experimental) infections under controlled conditions in crates. In the Sabi ewes there was a peri-parturient rise in FEC one month post lambing which persisted to two months post lambing whilst in the Dorper the peri-parturient rise peaked at one month post lambing (Fig 6.2 & 6.3). Since a higher proportion of Dorper ewes were treated with an anthelmintic than the Sabi ewes post lambing (Table 6.4) the differences between the two breeds in FEC are underestimates. These results are consistent with those in the literature (Tembely *et al.*, 1998; Baker *et al.*, 1999). The peri-parturient rise has been attributed to depressed immunity amongst other factors and some workers have demonstrated that there is a genetic basis to the peri-parturient rise (Courtney *et al.*, 1984; Zajac *et al.*, 1988). The peri-parturient rise in worm egg counts has been extensively studied in temperate regions where it has considerable epidemiological importance (Barger, 1993).

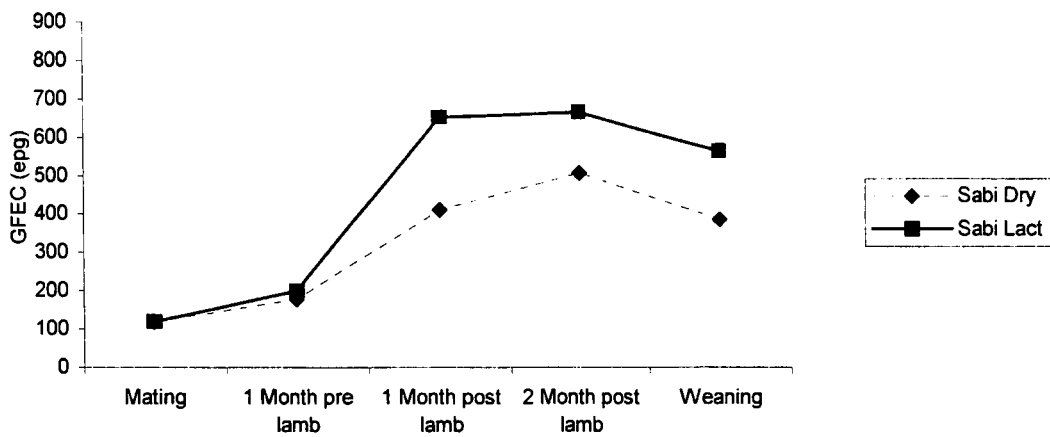


Fig 6.2 Peri parturient rise in Sabi sheep for different physiological periods

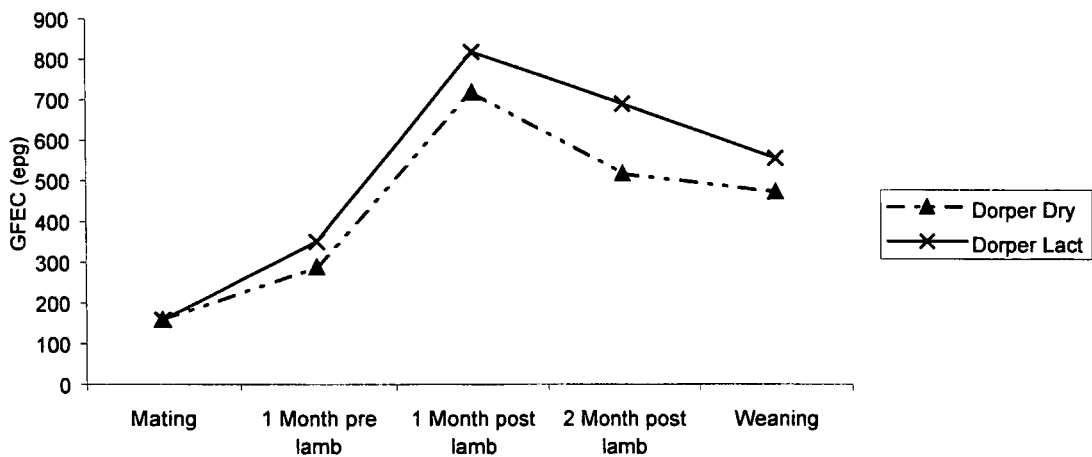


Fig 6.3 Peri parturient rise in Dorper sheep for different physiological periods

The high LFEC observed in the dry animals may be due to several reasons. More lactating ewes were treated than the dry ewes between parturition and weaning of lambs. There was also drug resistance in the flock (ascertained from drug reduction tests, unpublished) and continuous pasture re-infestations of the dry ewes from the pregnant ewes since all ewes were grazed together. Another possible reason is that lambing period coincides with the beginning of the rainy season and a general increase in parasite incidence. A higher proportion of Dorper ewes were treated than Sabi ewes (Tables 6.4 & 6.5). Three percent of the ewes (2% of Sabi and 4% of Dorper) had egg counts greater than 1500epg and these were dosed at mating. The percentage of ewes dosed rose to 12 % one month before lambing when 18 % of the Dorper ewes and five per cent of the Sabi ewes were dosed. The proportion of dosed ewes more than doubled to 31 % a month after lambing and 28 % at 2 months post lambing (Table 6.4). Other workers (Baker *et al.*, 1999) reported a higher proportion of Dorper ewes treated with anthelmintic than the Red Maasai. More Dorper ewes were treated twice and thrice during the year than the Sabi ewes (Table 6.5). This serves to reinforce the greater susceptibility of the Dorper to internal parasites as opposed to the Sabi.

The effect of ewes with twins versus those with singles was not significant for any trait at any measurement time post weaning. This may have been because twins were 6.27% of all the lambings and 91% of the twins were Sabi. Other studies have shown a significant litter effect on the peri-parturient rise with higher FEC in multiple births (Woolaston, 1992; Romjali *et al.*, 1997; Tembely *et al.*, 1998).

TABLE 6.4 Least squares means by year, breed and physiological status for the percentage of ewes treated with an anthelmintic at each sampling time and the total number of treatments per annum

	Mating	1 month pre lambing	1 month post lambing	2 month post lambing	Weaning of lambs	Treatments per annum
Total	0.03	0.12	0.31	0.28	0.19	0.92
Breed						
Sabi	0.02	0.05	0.23	0.25	0.16	0.70
Dorper	0.04	0.18	0.39	0.31	0.22	1.13
PSTAT[#]						
Dry	-	0.13	0.28	0.21	0.16	0.77
Preg/Lact.		0.10	0.35	0.34	0.22	1.07
Model						
Age	NS	NS	*	NS	NS	NS
Year	***	***	***	***	***	***
Breed	*	**	***	*	**	***
PSTAT [#]	-	NS	**	***	**	***
Breed*PSTAT [#]	-	NS	NS	NS	NS	NS

[#]PSTAT Physiological status (dry 0, pregnant or lactating 1); Breed 1=Sabi, 2=Dorper

* = P < 0.05; ** = P < 0.01; *** = P < 0.001; NS = Non significant

Standard error range for percentage treatment 0.004-0.034

Table 6.5 Percentage of ewes dosed per annum within breed and physiological status

Freq of dosing (not dosing) per year	Breed		Physiological status				Whole flock			
	Sabi		Dorper		Dry		Preg/Lact		N	%
	N	%	N	%	N	%	N	%		
0	508	52.0	140	39.8	189	50.8	459	48.1	648	48.9
1	212	21.8	92	26.1	96	25.8	208	21.8	308	22.9
2	201	20.6	76	21.6	47	12.6	230	24.1	277	20.9
3	52	5.3	43	12.2	38	10.2	57	6.0	95	7.2
4	1	0.0	1	0.00	2	0.0	0	0.0	0	0.0
Total	974		352		372		954		1326	

6.4 Conclusions

Sabi ewes were shown to be significantly more resistant to internal parasites (predominantly *Haemonchus contortus*) than Dorper ewes. There is also a peri-parturient rise in FEC in ewes lambing in both Sabi and Dorper. It is recommended that dosing is minimised (to both save cost and slow down the development of drench resistant worms). The only ewes that should be drenched are individual ewes (ie avoid blanket drenching of the whole flock as much as possible) showing strong symptoms of infection (eg ewes with very high FEC or very low PCV). Ascertaining which ewes to be drenched would be assisted by a test such as the FAMACHA chart when the challenge is predominantly *Haemonchus*.

7

General Conclusions and Recommendations

Sabi sheep are common in communal areas (small holder farmers) in flocks where parentage is uncertain and breeding is uncontrolled. Situations like this will always pose a challenge to both the animal scientist and the policy makers as to the most cost-effective way to obtain sustainable improvement in a low input low output farming system. The flocks in the research station are therefore crucial for determining a way forward but also act as nucleus flocks for conservation. Any meaningful genetic improvement in flocks in communal Zimbabwe is non-existent since no records what so ever are kept. Results from this study will be more applicable or useful in flocks where both pedigree and production records are kept. A stratified meat production system with room for both pure breeders and cross breeding is proposed. The most desirable quality about the Sabi is that they thrive under marginal environment (physical and management). Work on adaptive traits will therefore play a crucial role in overall breeding objectives and selection criteria for this breed. This current study has attempted to summarise research findings, which are directly applicable to the improvement to the Sabi flock under consideration.

From the analysis of the environmental effects, the following points are apparent:

- a) Sabi sheep have relatively low birth, mature and carcass weights.
- b) Slaughter age off range is optimum at two years of age
- c) Ewes of six years and older have a lower reproduction than two-year-olds and culling of ewes of six years of age and above is therefore recommended.

d) Lamb survival can be enhanced by better management of lambs at birth to reduce unnecessary stress. The role of castration and docking of lambs within 24 hours of birth on stress and lamb survival needs further investigation.

The number of lambs born per ewe lambing was the only reproductive ewe trait in which moderate genetic progress can be made. However, this should be carefully considered in view of the low survival rate among twin born lambs. The low heritability estimates of lamb survival may indicate that higher survival rates could be achieved through better control of the environmental factors.

Although, genetic progress is possible for all growth traits analysed, both maternal and permanent environmental factors did not seem to play a major role in most of the traits studied, unlike in most 'improved' breeds.

An increase in ewe live weights as a correlated response to selection for other growth and carcass traits may be undesirable for harsh environment and needs further investigation.

From the results of this study it is evident that no important antagonistic relationships exist among growth, carcass and reproductive traits. Birth weight is generally considered as a trait having an intermediate optimum with both too low and too high values causing survival problems. The positive genetic correlation found between birth weight and survival suggests that the flock studied is below the optimum. Although speculatively, this could be due to a gradual, long-term deterioration in the environment. Contrary to what is normally the case in improved livestock where guarding against high birth weights is generally recommended due to a possible increase in dystocia, a genetic improvement in birth weight, also because of its high genetic correlation with later weights, should be considered a priority in the Sabi sheep until an optimum is reached.

Total weight of lamb weaned is a composite trait that encompasses both direct lamb traits (survival, growth rate and weaning weight) and ewe trait (fertility, prolificacy) also need to be considered in the selection strategy.

Research on internal parasites is still at infancy at Matopos. There is more work on genetic parameter estimates for both ewes and lambs yet to be done. The relationships of internal parasite resistance with other production traits form part of the future work. Current work has demonstrated that opportunities exist for within breed to select for gastro-internal parasites. Immediate benefits are reduced pasture contamination, less anthelmintic use reducing both cost and risk of the drug resistance. More research on the genetic estimates and correlations are needed so that internal parasite resistance can be incorporated in the breeding objectives of Sabi sheep. This is to be the subject of a future study. It is hoped that this study will form the foundation of work for the conservation of the Sabi sheep. More consolidation is needed on adaptive traits which render apparent benefits to the farmer. In addition internal parasite resistance and tick resistance needs to be strengthened with more rams from communal systems evaluated.

ABSTRACT

A total of 4355 lamb and 4299 ewe records, obtained from Sabi sheep at Matopos Research Station from 1984 to 1994, were analysed to describe growth, carcass and reproductive traits and to investigate non-genetic factors influencing their expression. Year of birth, sex, birth/rearing status of lamb, dam age, age of lamb and slaughter age were significant sources of variation for body weights, average daily gain, carcass and reproductive traits except for exact age of lamb at 18 months, ewe age for hot and cold carcass weight. Significant ($P < 0.001$) two-way interactions were found between year of birth and sex for pre-weaning average daily gain, 12 and 18 month weight and for birth status and sex for lamb survival. Least-squares means: 2.63 kg for birth weight; 17.2 kg for weaning weight (recorded at 120 days of age); 23.5 kg for 12 months weight; 35.7 kg for 18 months weight; 124 g/day for average daily gain between birth and weaning; 21.7 kg for total weight of litter weaned and 14.6 for Kleiber ratio. Slaughter weights were low (29 kg) yielding 13.6 and 13.1 kg hot and cold carcass weights respectively. Average weight of ewe at mating in May/June were 38 kg, and 35.6 kg for post-partum in October/November and 26.2 kg at weaning of lambs in February. The least squares means for reproductive traits were: 0.86, 1.01, 1.17, 0.83, 0.85 for ewes lambing to those exposed; lambs born to ewes exposed; lambs born to ewes lambing; lambs weaned to ewes exposed to the ram and lamb survival to weaning respectively. The model best describing the data were constructed and used in the subsequent analyses of (co)variances and heritability estimates in univariate models.

Variance components of reproductive traits and lamb survival to weaning were estimated using a threshold model. The heritability estimates were low with 0.02, 0.06,

0.04, 0.02 and 0.04 for fertility (whether a ewe lamb or not; 0 or 1); reproductive rate (number of lambs born to a ewe exposed; 0, 1 or 2); ewe weaning rate (number of lambs weaned to a ewe lambing; 0, 1 or 2); flock weaning rate (number of lambs weaned to a ewe exposed; 0, 1 or 2); and lamb survival rate (whether a lamb born alive, was dead or alive at weaning except for prolificacy (number of lambs born to a ewe that lambled; 1, or 2). Though slow genetic progress is possible with all reproductive and survival traits, it could be faster to select for prolificacy while guarding against a higher lamb mortality.

Genetic parameters for growth traits were estimated using ASREML from data consisting of 4123 lamb records from 130 sires and 1131 dams. The direct additive contribution to birth weight, 30 day weight, 60 day weight, weaning weight, pre-weaning average daily gain, 12 months weight, 18 months weight and Kleiber ratio was 0.25, 0.13, 0.13, 0.16, 0.17, 0.26, 0.39, and 0.08 respectively. The direct heritability was 0.27, 0.18, 0.18, 0.12, 0.58, 0.53 and 0.67 respectively for slaughter, hot carcass, cold carcass, total weight of lamb weaned, mating, post partum and ewe weight at weaning. Maternal heritability declined from 0.12 at birth to 0.06 at 60 days of age and was negligible thereafter. The maternal permanent environmental component due to the dam contributed three to fifteen per cent of the total phenotypic variances for all the traits under consideration. Genetic progress is possible for all the growth, carcass and ewe traits considered in this study.

Genetic and phenotypic correlations were estimated among lamb and ewe traits. Direct additive estimates of heritability were: 0.28; 0.17; 0.25; 0.39; 0.59; 0.50; 0.68; 0.12; 0.25; 0.11; 0.12; for birth weight, weaning weight (120 days), 12 month weight, 18 month weight, ewe mating weight, post partum weight, total weight of lamb weaned, slaughter weight, hot and cold carcass weights respectively. Genetic correlations among birth weight and other weights to 18 months were high (0.75 to 0.85) whilst the relationship among weaning, 12 month and 18 month weight was close to unity. The genetic correlation between birth weight and ewe weights (mating, post-partum and dam weight at weaning of lamb) were moderate *viz* 0.51, 0.40, 0.49 respectively and were close to unity at 18 months of age *viz* 0.96, 0.92 and 0.84 respectively. Total weight of lamb weaned was moderately correlated to birth weight ($r_g=0.46$) but tended to be highly

correlated with 18 month weight (0.92) and ewe weights (0.75-0.91). The genetic correlation between birth weight and slaughter and carcass weight was moderate and was high at 18 months. The heritability estimates from a univariate logit transformed analyses for fertility, prolificacy and lamb survival were 0.08, 0.22 and 0.01 respectively. The genetic correlation between fertility and lamb weight and ewe weights was low (-0.08 to 0.06) and some with large standard errors. The genetic correlation between prolificacy and birth weight was negative and low. The genetic correlation between prolificacy and weaning weight, 12 month weight, 18 month weight, ewe mating, post-partum and ewe weight at weaning were 0.07; 0.12; 0.07; 0.22; 0.13; 0.24 respectively, with that between fertility and prolificacy being negative (-0.17). Genetic correlations between lamb survival and birth weight, weaning weight, 12 month weight, 18 month weight and total weight of lamb weaned were 0.18, 0.26, 0.15, 0.15, 0.13 respectively. Birth weight and total weight of lamb weaned can fruitfully be included in a selection index for the Sabi flock.

Data from 1996 to 2000 of Sabi and Dorper ewes were used to evaluate within and between breed differences to internal parasite resistance as measured by packed cell volume (PCV) and faecal egg count (FEC). Dorper ewes were consistently heavier than Sabi ewes. Sabi ewes had lower FEC and higher PCV at all sampling times (mating to weaning of lambs) than the Dorper ewes. Furthermore, the proportion of Dorper ewes that was treated with anthelmintic was higher than that of Sabi ewes. There was a periparturient rise in FEC from lambing up to two months post lambing for both breeds. Non genetic factors influencing internal parasite resistance in both breeds were identified. Future research need to focus on the interrelationships between 'adaptive traits' such as internal parasite resistance and both growth and reproductive traits.

OPSOMMING

Altesaam 4355 lam- en 4299 ooirekords verkry vanaf 1984 tot 1994 van Sabiskape by die Matopos Navorsingstasie is ontleed om groei-, karkas- en reproduksie-eienskappe te beskryf en om die nie-genetiese faktore wat hul uitdrukking beïnvloed te ondersoek. Geboortjaar, geslag, geboorte/grootmaakstatus van lam, moeder-, lam- en slagouderdom was betekenisvolle bronne van variasie vir liggaamsgewigte, gemiddelde daaglikse toename, karkas- en reproduksie-eienskappe, behalwe vir lamouderdom op 18 maande en moederouderdom vir warm en koue karkasgewig. Betekenisvolle ($P < 0.001$) tweerigting-interaksies is gevind tussen geboortjaar en geslag vir voor-speense gemiddelde daaglikse toename, 12 en 18 maande gewig en vir geboortestatus en geslag vir lamoorlewing. Kleinste kwadraatgemiddeldes was: 2.63 kg vir geboortegewig, 17.2 kg vir speengewig (geneem op 120 dae ouderdom) 23.5 kg vir 12 maande gewig, 35.7 kg vir 18 maande gewig, 124 g/dag vir gemiddelde daaglikse toename tussen geboorte en speen, 21.7 kg vir totale gewig lammers gespeen en 14.6 vir Kleiberverhouding. Slaggewigte was laag (29 kg) met 'n opbrengs van gemiddeld 13.6 kg en 13.1 kg warm en koue karkasgewigte onderskeidelik. Gemiddelde oigewig met paring in Mei/Junie was 38 kg en 35.6 kg vir na-geboorte in Oktober/November en 26.2 kg by speen van lammers in Februarie. Die kleinste kwadraatgemiddeldes vir reproduksie-eienskappe was: 0.86, 1.01, 1.17, 0.83, 0.85 vir ooie gelam teenoor ooie by ram, lammers gebore teenoor ooie by ram, lammers gebore teenoor ooie gelam, lammers gespeen teenoor ooie by ram en lamoorlewing tot speen onderskeidelik. Die model wat die data ten beste beskryf het is opgestel en gebruik in daaropvolgende ontledings van (ko) variansies en oorerflikheidsberamings in enkel-eienskap modelle.

Variansie-komponente van reproduksie-eienskappe en lamoorlewing tot speen is bepaal deur 'n drumpelmodel te gebruik. Die oorerflikheidsberamings was laag, met 0.02, 0.06, 0.04, 0.02 en 0.04 vir vrugbaarheid (of 'n ooi gelam het of nie : 0 of 1); reproduksie-tempo (aantal lammers gebore van 'n ooi gepaar : 0, 1 of 2); ooi-speentempo (aantal lammers gespeen van 'n ooi wat gelam het : 0, 1 of 2); kudde-speentempo (aantal lammers gespeen van 'n ooi wat gepaar is : 0, 1 of 2) en lamoorlewingtempo (of 'n lewendgebore lam dood of lewendig was met speen, fekunditeit uitgesluit : (aantal lammers gebore van 'n ooi wat gelam het : 1 of 2). Alhoewel stadige genetiese vordering moontlik is met alle reproduksie- en oorlewingseienskappe, kan dit vinniger geskied deur te selekteer vir fekunditeit maar terselfdertyd te waak teen hoër lammortaliteit.

Genetiese parameters vir groei-eienskappe is beraam deur ASREML te gebruik met data bestaande uit 4123 lamrekords van 130 vaars en 1131 moeders. Die direkte additiewe bydrae tot geboortegewig, 30 dae gewig, 60 dae gewig, speengewig, voorspeense gemiddelde daaglikse toename, 12 maande gewig, 18 maande gewig en Kleiber-verhouding was 0.25, 0.13, 0.13, 0.16, 0.17, 0.26, 0.39 and 0.08 onderskeidelik. Die direkte oorerflikheid was 0.27, 0.18, 0.18, 0.12, 0.58, 0.53 en 0.67 onderskeidelik vir slaggewig, warm karkasgewig, koue karkasgewig, totale gewig lammers gespeen, gewig met paring, na-geboortegewig en ooigewig met speen. Maternale oorerflikheid het afgeneem van 0.12 met geboorte tot 0.06 op 60 dae ouderdom en was onbeduidend daarna. Die maternale permanente omgewingskomponent wat betrekking het op die moeder het drie tot vyftien persent bygedra tot die totale fenotipiese variasie vir al die eienskappe oorweeg. Genetiese vordering is moontlik vir al die groei-, karkas- en ooi-eienskappe wat in hierdie studie ondersoek is.

Genetiese en fenotipiese korrelasies is beraam tussen lam- en ooi-eienskappe. Direkte additiewe beramings van oorerflikheid was 0.28, 0.17, 0.25, 0.39, 0.59, 0.50, 0.68, 0.12, 0.25, 0.11, 0.12 vir geboortegewig, speengewig (120 dae), 12 maande gewig, 18 maande gewig, paringgewig, na-geboortegewig, totale gewig lammers gespeen, slaggewig, warm- en koue karkasgewigte onderskeidelik. Genetiese korrelasies tussen geboortegewig en ander gewigte tot 18 maande was hoog (0.75 – 0.85), terwyl die

verhouding tussen speen, 12 maande - en 18 maande gewig naby een was. Die genetiese korrelasie tussen geboortegewig en ooigewigte (paar-, na-geboorte- en moedergewig met speen) was matig, nl. 0.51, 0.40 0.49 onderskeidelik en was naby een op 18 maande ouderdom, nl. 0.96, 0.92 en 0.84 onderskeidelik. Totale gewig lammers gespeen was matig gekorreleerd met geboortegewig ($r = 0.46$), maar het geneig om hoogs gekorreleerd te wees met 18 maande gewig (0.92) en ooigewigte (0.75 – 0.91). Die genetiese korrelasie tussen geboortegewig en slag- en karkasgewig was matig en was hoog op 18 maande. Die oorerflikheidsberamings van enkeleienskap logit getransformeerde ontledings vir vrugbaarheid, fekunditeit en lamoorlewing was 0.08, 0.22 en 0.01 onderskeidelik. Die genetiese korrelasie tussen vrugbaarheid en lamgewig en ooigewig was laag (-0.08 tot 0.06) – sommige met hoë standaardfoute. Die genetiese korrelasie tussen fekunditeit en geboortegewig was negatief en laag. Die genetiese korrelasie tussen fekunditeit en speengewig, 12 maande gewig, 18 maande gewig, paringsgewig, na-geboortegewig en ooigewig met speen was 0.07, 0.12, 0.07, 0.22, 0.13, 0.24 onderskeidelik, met dié tussen vrugbaarheid en fekunditeit negatief (-0.17). Genetiese korrelasies tussen lamoorlewing en geboortegewig, speengewig, 12 maande gewig, 18 maande gewig en totale gewig lammers gespeen was 0.18, 0.26, 0.15, 0.15, 0.13 onderskeidelik. Geboortegewig en totale gewig lammers gespeen kan met vrug in 'n seleksie-indeks vir die Sabi-kudde ingesluit word.

Data vanaf 1996 tot 2000 van Dorper- en Sabi-ooie is gebruik om binne- en tussen-ras verskille t.o.v. inwendige parasietweerstand te evalueer soos gemeet aan 'packed cell volume' (PCV) en miseiertelling (FEC). Dorperooie was konsekwent swaarder as Sabi-ooie. Sabi-ooie het deurgaans laer FEC en hoër PCV getoon as die Dorperooie tydens monsterring (paring tot speen van lammers). Dorperooie het proporsioneel ook meer anti-wurmbehandeling ontvang as die Sabi-ooie. 'n Verhoging in PCV en FEC is tot twee maande na lam waargeneem by beide rasse, maar dit was meer opvallend by die Dorperooie. Nie-genetiese faktore wat inwendige parasietweerstand in albei rasse beïnvloed is geïdentifiseer. Toekomstige navorsing behoort te fokus op die interverhoudings tussen aanpassingseienskappe soos inwendige parasietweerstand, en groei - sowel as reproduisie-eienskappe.

REFERENCES

- Abdulkhaliq, A. M., Harvey, W. R. & Parker, C. F., 1989. Genetic parameters for ewe productivity traits in the Columbia, Suffolk and Targhee breeds. *J. Anim. Sci.* 67, 3250-3257.
- Al-Shorepy, S. A. & Notter, D. R., 1996. Genetic variation and covariation for ewe reproduction, lamb growth and lamb scrotal circumference in a fall-lambing sheep flock. *J. Anim. Sci.* 74, 1490-1498.
- Al-Shorepy, S. A. & Notter, D. R., 1998. Genetic parameters for lamb birth weight in spring and autumn lambing. *Anim. Sci.* 67, 327-332.
- Altarriba, J. L., Varona, L. A., Garcia -Cortes & Moreno, C., 1998. Bayesian inference of variance components for litter size in Rasa Aragonesa sheep. *J. Anim. Sci.* 76, 23-28.
- Analla, M., Munoz-Serrano, A. & Serradilla, J. M., 1997. Analysis of the genetic relationship between litter size and weight traits in Segurena sheep. *Can. J. Anim. Sci.* 77, 17-21.
- Aslaminejad, A. A. & Roden, J. A. 1997. Estimation of direct and maternal genetic parameters for 12 week weight for Welsh Mountain sheep. *Proc. British Soc. Anim. Sci.* 1997 pp 177.
- Atkins, K.D., 1980. The comparative productivity of five ewe breeds. I. Lamb growth and survival. *Aust. J. Exp. Agric. Anim. Husb.* 20, 272-287.
- Atkins, K.D., 1986. A genetic analysis of components of lifetime productivity in Scottish Blackface sheep. *Anim. Prod.* 43, 405-419.
- Baker, R. L., 1980. The role of maternal effects on the efficiency of selection in beef cattle- a review. *Proc. N.Z. Soc. Anim. Prod.* 40, 285-311.
- Baker, R. L., 1998. Genetic resistance to endoparasites in sheep and goats. A review of genetic resistance to gastrointestinal nematode parasites in sheep and goats in the tropics and evidence for resistance in some sheep and goat breeds in sub-humid

- coastal Kenya. *Animal Genetic Resources Information*, 24, 13-30.
- Baker, R. L., Clarke, J. N. & Carter, A. H., 1974. Sources of variation for wool, body weight, and oestrus characters in Romney hoggets. *Proc. N Z. Soc Anim. Prod.* 34, 19-22.
- Baker, R. L., Mwamachi, D. M., Audho, J. O. Aduda, E. O. & Thorpe, W., 1999. Genetic resistance to gastro-intestinal nematode parasites in Red Maasai, Dorper and Red Maasai x Dorper ewes in the sub-humid tropics. *Anim. Sci.* 69; 335-344.
- Barger, I. A., 1993. Influence of sex and reproduction status on susceptibility of ruminants to nematode parasitism. *Int. J. Parasitol.*, 23:463-469.
- Bell, G. H., Davison, J. N. & Scarborough, H., 1970. Textbook of physiology and Biochemistry. Longman Ltd. , Edinburgh, Scotland.
- Boujenane, I., Bradford, G. E. Berger, Y. M. & Chikhi, A., 1991. Genetic and environmental effects on growth to 1 year and viability of lambs from a crossbreeding of D'man and Sardi breeds. *J. Anim. Sci.* 69, 3989-3998.
- Boujenane, I. & Kerfal, M., 1990. Estimates of genetic and phenotypic parameters for growth traits of D'man lambs. *Anim. Prod.* 51, 173-178.
- Bradford, G.E., 1972. The role of maternal effects in animal breeding. VII. Maternal effects in sheep. *J. Anim. Sci.* 35,1324-1334.
- Bradford, G.E., 1985. Selection for litter size. *Genetics of Reproduction in sheep*. Edited by R.B. Land and D.W. Robinson. Butterworths, London. pp 3-18.
- Brash, L. D., Fogarty, N. M. & Gilmour, A. R., 1994a. Reproductive performance and genetic parameters for Australian Dorset Sheep. *Aust. J. Agric. Res.* 45, 427-441.
- Brash, L. D., Fogarty, N. M., Barwick, S. A. & Gilmour, A. R., 1994b. Genetic parameter for Australian maternal and dual-purpose meat sheep breeds. I. Liveweight, wool production and reproduction in Border Leicester and related types. *Aust. J. Agric. Res.* 45, 459-469.
- Brash, L. D., Fogarty, N. M. & Gilmour, A. R., 1994c. Genetic parameter for Australian maternal and dual-purpose meatsheep breeds. I. Liveweight, wool production and reproduction in Corriedale sheep. *Aust. J. Agric. Res.* 45, 469-480.
- Bromley, C. M., Snowden, G. D. & Van Vleck, L. D., 2000. Genetic parameters among weight, prolificacy and wool traits of Columbia, Polypay, Rambouillet and Targhee sheep. *J. Anim. Sci.* 78, 846-858.

- Bromley, C. M., Van Vleck, L. D. & Snowden, G. D., 2001. Genetic correlations for litter weight weaned with growth, prolificacy and wool traits in Columbia, Polypay, Rambouillet and Targhee sheep. *J. Anim. Sci.* 79, 339-346.
- Brunsdon, R. V. & Vlassoff, A., 1971. The post-parturient rise: a comparison of the pattern and relative generic composition of stronglyyle egg output from lactating and non-lactating ewes. *N.Z. J. Agric. Res* 19, 19-25.
- Burfening, P.J., 1993. Direct and maternal genetic effects on lamb survival. *Small Rum. Res.* 11, 267-274.
- Burfening, P. J. & Carpio P., M., 1993. Genetic and environmental factors affecting growth rate and survival of Junin sheep in the central highlands of Peru. *Small Rum.Res.* 11, 275-287.
- Burfening, P. J. & Kress, D. D., 1993. Direct and maternal effects on birth and weaning weight in sheep. *Small Rum. Res.* 10, 153-163.
- Butcher, R. L., Dunbar, R. S. Jr. & Welch, J. A., 1964. Heritabilities of and correlations between lamb birth weight and 140-day weight. *J. Anim. Sci.* 23, 12-15.
- Buvanendran, V., Makuza, S. M. & Chironga, P., 1992. Phenotypic and genetic parameters of weaning traits in Dorper sheep in Zimbabwe. *Small Rum. Res.* 7, 369-374.
- Clarke, J.N. & Johnson, D.L., 1993. Lessons from New Zealand sheep selection experiments. *Proc. Symp. Anim. Breed. Gen.* Palmerston North. N.Z. pp 52-68.
- Conington, J., Bishop, S. C., Waterhouse, A. & Simm, G., 1995. A genetic analysis of early growth and ultrasonic measurements in hill sheep. *Anim. Sci.* 61, 85-93.
- Conington, J., Bishop, S. C., Waterhouse, A. & Simm, G., 1998. A comparison of growth and carcass traits in Scottish Blackface lambs sired by genetically lean or fat rams. *Anim. Sci.*, 67, 299-309.
- Connan, R. M., 1968. Studies on the worm populations in the alimentary tract of breeding ewes. *J. Helminthol.* 42, 9-28.
- Courtney, C.H., Parker, C.F., McClure, K E. & Herd, R. P., 1984. A comparison of the periparturient rise in fecal egg counts of exotic and domestic ewes. *Int. J. Parasit.* 14, 377-381.
- Crews, D. H. & Jr, Franke, D. E., 1998. Heterogeneity of variances for carcass traits by percentage Brahman Inheritance. *J. Anim. Sci.* 76, 1803-1809.

- Cundiff, L. V., Gregory, K. E. & Koch, R. M., 1982. Selection for increased survival from birth to weaning. *Proc. 2nd World Congr. Gen. Appl. Livest. Prod.* V, 310-337.
- Dalton, D. C., Knight, T. W. & Johnson, D. L., 1980. Lamb survival in sheep breeds of New Zealand hill country. *NZ J. Agric. Res.* 23, 167-173.
- Davis, G. H., Morris, C. A. & Dodds, K. G., 1998. Genetic studies of prolificacy in New Zealand sheep. *Anim. Sci.* 67, 289-297.
- De Lange, A.O., 1984. Changing views on the genetic improvement of reproduction in sheep and beef cattle breeds. *Proc. 2nd World Congr. Sheep Beef Breed.*, Pretoria. S.A. 494.
- Dickerson, G. E., 1970. Efficiency of animal production - molding the biological components. *J. Anim. Sci.* 30, 849-859.
- Donnelly, F.B., 1982. A practical attempt to breed for better lamb survival. *Proc. Aust. Soc. Anim. Prod.* 14, 30.
- El Fadili, M., Michaux, C., Detilleux, J. & Leroy, P. L., 2000. Genetic parameters for growth traits of the Moroccan Timahdit breed of sheep. *Small Rum. Res.* 37, 203-208.
- Ercanbrack, S. K. & Knight, A. D., 1998. Responses to various selection protocols for lamb production in Rambouillet, Targhee, Columbia, and Polypay sheep. *J. Anim. Sci.* 76, 1311-1325.
- Fitzhugh, H. A. & Brandford, G. E., 1983. Hair sheep of western Africa and the Americas: A genetic resource for the tropics. Westview Press, Boulder, Co.
- Fogarty, N. M., 1995. Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: a review. *Anim. Breed. Abstr.* 63, 101-143.
- Fogarty, N. M.; Brash, L. D. & Gilmour, A. R., 1994. Genetic parameters for reproduction and lamb production and their components and liveweight, fat depth and wool production in Hyfer sheep. *Aust. J. Agric. Res.* 45, 443-459.
- Fogarty, N.M., 1995. Genetic parameters for live weight, fat and muscle measurements, wool production and reproduction in sheep: a review. *Anim. Breed. Abstr.* 63, 101-143.
- Fossceco, S. L. & Notter, D. R., 1995. Heritabilities and genetic correlations of body weight, testis growth and ewe lamb reproductive traits in crossbred sheep. *Anim. Sci.* 60, 185-195.

- Foulley, J.L. & Gianola, D., 1984. Estimation of genetic merit from bivariate 'all-or-non' responses. *Genet Sel. Evol.* 16, 285-
- Foulley, J.L., Gianola, D. & Thompson, R., 1983. Prediction of genetic merit from data on binary and quantitative variate with an application to calving difficulty. *Genet Sel. Evol.* 15, 401-424 .
- Gama, L. T., Dickerson, G. E., Young, L. D. & Leymaster, K. A., 1991. Effects of breed, heterosis, age of dam, litter size, and birth weight on lamb mortality. *J. Anim. Sci.* 69, 2727-2743.
- Gianola, D., 1982. Theory and analysis of threshold characters. *J. Anim. Sci.* 54, 1079-1096.
- Gianola, D. & Foulley, J.L., 1983. Sire evaluation for ordered categorical data with a threshold model. *Genet Sel. Evol.* 15, 201-224.
- Gilmour, A. R., Cullis, B. R., Welham, S. J. & Thompson, R., 1999. ASREML- Reference manual. NSW Agriculture Biometric Bulletin No. 3. NSW Agriculture, Orange Agricultural Institute, Forest Road, Orange 2800, NSW, Australia.
- Hagger, C., 1998. Litter, permanent environmental, ram-flock, and genetic effects on early weight gain of lambs. *J. Anim. Sci.* 76, 452-457.
- Hagger, C., 2000. Genetic and environmental influences on size of first litter in sheep, estimated by the REML method. *J. Anim. Breed. Genet.* 117, 57-64.
- Hall, D. G., Gilmour, A. R. & Fogarty, N. M., 1994. Variation in reproduction and production of Poll Dorset ewes. *Aust. J. Agric. Res.* 45, 415-426.
- Hanrahan, J.P., 1976. Maternal effects and selection response with an application to sheep data. *Anim. Prod.* 22, 359-369.
- Harvey, W.R., 1990. Mixed Model Least-Squares and Maximum Likelihood Computer Program. Walter R. Harvey.
- Harville, D.A. & Mee, R.W., 1984. A mixed-model procedure for analysing ordered categorical data. *Biometrics* 40, 393-408.
- Haughey, K.G., 1983. Selective breeding for rearing ability as an aid to improving lamb survival. *Aust. Vet J.* 60, 361-363.
- Henningsson, T. & Malmfors, G., 1995. The relationship between live weight of Swedish lambs at 120 days of age and carcass traits. In *Production of lamb meat in accordance with market demand*. Proceedings of the Scandinavian Association of

- Agricultural Scientists seminar no. 256. Hvammeyri Agricultural College, Iceland, June 1995.
- ILCA (International Livestock Centre for Africa), 1991. Proceedings of the Research Planning Workshop on Resistance to Endoparasites in Small Ruminants. 5-7 February 1991. ILCA. Addis Ababa, Ethiopia, pp 78.
- Iman, N. Y. & Slyter, A. L., 1996. Lifetime lamb and wool production of Targhee or Finn-Dorset-Targhee ewes managed as farm or range flock: I. Average annual ewe performance. *J. Anim. Sci.* 74, 1757-1764.
- Inyangala, B. A. O., Rege, J. E. O. & Itulya, S., 1990. Growth traits of the Dorper sheep. I. Factors influencing growth traits. In: Small ruminant research and development in Africa. B. Rey, S.H.B. Lebbie and L. Reynolds (Eds). African Small Ruminant network, ILCA, Nairobi, pp 505-515.
- Janssens, S., Geysen, D. & Vandepitte, W., 2000. Genetic parameters for live weight in Belgian Texel sheep. *Proc. 51st Ann. Meeting European Assoc. Anim. Prod.*, August 21-24 2000, Den Haag, Nederland
- Johnson, D. L. & Garrick, D. L., 1990. Data collection, processing and prediction of breeding values. *Proc. 4th World Cong. Gen. Appl. Livest. Prod.* Edinburgh. Vol XV, 337-346.
- Kaps, M., Herring, W. O. & Lamberson, W. R., 1999. Genetic and environmental parameters for mature weights in Angus Cattle. *J. Anim. Sci.* 77, 569-574.
- Khalidi, G. & Boichard, D., 1991. Direct and maternal effects of growth traits in Barbary sheep. *Anim. Breed. Abstr.* 59 (3), 237 (Abstr. 1785).
- Khombe, C. T., 1985. Environmental factors affecting the growth and viability of crossbred sheep and goats on range grazing in Zimbabwe. In: Small Ruminants in African Agriculture. R.T. Wilson and Bourzat (Eds.). International Livestock Centre for Africa (ILCA), Addis Ababa, pp. 46-52.
- Kitamura, C., Yasuda, Y., Kobayashi, T., Nomura, T. & Shimada, K., 1999. Genetic analysis of direct and maternal effects for calf market and carcass weights in Japanese Black cattle. *Asian- Aus. J. Anim. Sci.* 12, 843-845.
- Knight, T.W., Hight, G.K. & Winn, G.W., 1979. The influence of sires on lamb survival. *Proc. N.Z. Soc. Anim. Prod.* 39, 87.
- Kominakis, A., Rogdakis, E. & Koutsotolis, K. 1998. Genetic parameter for milk yield and litter size in Boutsico dairy sheep. *Can. J. Anim. Sci.* 78, 525-532.

- Konstantinov, K.V., 1995. GFCAT: User's guide. University of the Orange Free State, Bloemfontein, S.A.
- Konstantinov, K.V., Erasmus, G.J. & van Wyk, J.B., 1994. Evaluation of Dormer sires for litter size and lamb mortality using a threshold model. *S. Afr. J. Anim. Sci* 24, 119-121.
- Kumar, N. & Raheja, K. L., 1993. Genetic and phenotypic parameters of growth and reproduction traits in UAS strain of sheep estimated by multitrait animal model. *Indian J. Anim. Sci.* 63, 978-983.
- Le Roux, P., 1970. The influence of plane of nutrition and season of lambing in the production of mutton and lamb production in Matabeleland. *Rhod. Agric. J.* 67, 3-8.
- Lee, G.J. & Atkins, K.D., 1994. The use of reproductive performance in early life to predict lifetime reproductive rate in Australian Merinos. *Proc. 5th World Cong. Gen. Appl. Livest. Prod.* 18, 87-90.
- Lee, J. W., Waldron, D. F. & Van Vleck, L. D., 2000. Parameter estimates for number of lambs born at different ages and for 18-month body weight of Rambouillet sheep. *J. Anim. Sci.* 78, 2086-2090.
- Lewer, R. P., Woolaston, R. R. & Howe, R. R., 1994. Studies on western Australian Merino sheep. II. Genetic and phenotypic parameter estimates for objectively measured traits on ram and ewe hoggets using different model types. *Aust. J. Agric. Res.* 45, 829-840.
- Ligda, Ch., Gabriilidis, G., Papadopoulos, Th. & Georgoudis, A., 2000. Estimation of genetic parameters for production traits of Chios sheep using a multitrait animal model. *Livest. Prod. Sci.* 66, 217-221.
- Lopez-Villalobos, N. & Garrick, D. J., 1999. Genetic parameter estimates for lamb survival in Romney sheep. *Proc. N. Z. Soc. Anim. Prod.* 59, 121-124.
- Luxford, B. G. & Beilharz, R. G., 1990. Selection response for litter size at birth and litter weight at weaning in the first parity mice. *Theor. App. Genet.* 80, 625-630.
- MAFF, 1977. Ministry of agriculture, Fisheries and Food. Manual of veterinary Parasitology laboratory Technique. Technical Bulletin No. 18, Her Majesty's Stationary Office, London, 160pp.

- Maria, G. A., Boldman, K. G. & Van Vleck, L. D., 1993. Estimates of variances due to direct and maternal effects for growth traits of Romanov sheep. *J. Anim. Sci.* 71, 845-849.
- Maria, G.A., 1995. Estimates of variances due to direct and maternal effects for reproductive traits of Romanov sheep. *Small. Rum. Res.* 18, 69-73.
- Mason, I. L. 1980. Prolific tropical sheep. FAO Animal Production and health paper 17, 1.
- Mason, I. L. & Maule, J. P., 1960. The indigenous livestock of Eastern and Southern Africa. Technical Communication No 14, CAB, Bucks, England.
- Matos, C. A. P., Thomas, D. L. Young, L. D. & Gianola, D., 2000. Genetic analysis of lamb survival in Rambouillet and Finnsheep flocks by linear and threshold models. *Anim. Sci.* 71, 227-234.
- Matos, C.A.P, Thomas, D.L., Gianola, D., Tempelman, R.J. & Young, L.D., 1997. Genetic analysis of discrete reproductive traits in sheep using linear and non-linear models: I. Estimation of genetic parameters. *J. Anim. Sci.* 75, 76-87.
- Mavrogenis, A. P., Louca, A. & Robison, O.W., 1980. Estimates of genetic parameters for pre-weaning and post-weaning growth traits of Chios lambs. *Anim. Prod.* 30, 271-276.
- McKenzie, R. L., 1987. The tolerance of indigenous sheep in Zimbabwe to *Haemonchus Contortus*. *Zimb. Vet. J.* 17, 20-23.
- Meyer, K., 1992. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. *Livest. Prod. Sci.* 31, 179-204.
- Meyer, K., 1998. Estimation of genetic parameters for mature weight of Australian beef cows and its relationship to early growth and skeletal measures. *Livest. Prod. Sci.* 44, 125-137.
- Michels, H., Decuyper, E. & Onagbesan, O., 2000. Litter size, ovulation rate and prenatal survival in relation to ewe body weight: genetics review. *Small Rum. Res.* 38, 199-209.
- Morris, C. A., Bisset, S. A., Vlassoff, A., West, C. J. & Wheeler, M., 1998. Faecal nematode egg counts in lactating ewes from Romney flocks selectively bred for divergence in lamb faecal egg count. *Anim. Sci.* 67, 283-288.
- Morris, C. A., Hickey, S. M. & Clarke, J. N., 2000. Genetic and environmental factors affecting lamb at birth and through to weaning. *N. Z. J. Agric. Res.* 43, 515-524.

- Mortimer, S.I. & Atkins, K.D., 1994. Direct additive and maternal genetic effects on wool production of Merino sheep. *Proc. 5th World Congr. Gen. Appl. Livest. Prod.* 18, 103-106.
- Mousa, E., Van Vleck, L.D. & Leymaster, K.A., 1999. Genetic parameters for growth traits for a composite terminal sire breed of sheep. *J. Anim. Sci.* 77, 1659-1665.
- Mukasa-Mugerwa, E., Lahlou-Kassi, A., Anindo, D., Rege, J. E. O., Tembely, S., Tibbo, M. & Baker, R. L. 2000. Between and within breed variation in lamb survival and the risk factors associated with major causes of mortality in indigenous Horro and Menz sheep in Ethiopia. *Small Rum. Res.* 37, 1-12.
- Nagy, I., Solkner, J., Komlosi, I. & Safar, L., 1999. Genetic parameters of production and fertility traits in Hungarian Merino sheep. *J. Anim. Breed. Genet.* 116, 399-413.
- Näsholm, A., 1990. Mature weight of ewe as a trait in sheep breeding. *Proc. 4th World Congr. Gen. Appl. Livest. Prod* Edinburgh. Vol. XV, 89-91.
- Näsholm, A. & Danell, O., 1994. Maternal effects on lamb weights. *Proc. 5th World Congr. Gen. Appl. Livest. Prod.* 18, 163-166.
- Näsholm, A. & Danell, O., 1996. Genetic relationships of lamb weight, maternal ability and mature ewe weight in Swedish finewool sheep. *J. Anim. Sci.* 74, 329-339.
- Neser, F.W.C., Erasmus, G.J. & van Wyk, J.B., 2000. Genetic studies on the South African Mutton Merino: growth traits. *S. Afr. J. Anim. Sci* 30, 172-177.
- Neser, F.W.C., Erasmus, G.J. & van Wyk, J.B., 2001. Genetic parameter estimates for pre-weaning weight traits in Dorper sheep. *Small Rum. Res.* 40, 197-202.
- Notter, D. R., 1998a. The U.S. National sheep improvement program: Across-flock genetic evaluation and new trait development. *J. Anim. Sci.* 76, 2324-2330.
- Notter, D. R., 1998b. Genetic parameters for growth traits in Suffolk and Polypay sheep. *Livest. Prod. Sci.*, 55, 205-213.
- Notter, D. R. & Copenhaver, J. S., 1980. Performance of Finnish Landrace crossbred ewes under accelerated lambing. II. Lamb growth and survival. *J. Anim. Sci.* 51, 1043-1050.
- Notter, D. R. & Hough, J.D., 1997. Genetic parameter estimates for growth and fleece characteristics in Targhee sheep. *J. Anim. Sci.* 75, 1729-1737.
- Okut, H., Bromley, C. M., van Vleck, L. D. & Snowden G. D., 1999. Genotypic expression at different ages: 1. Prolificacy traits of sheep. *J. Anim. Sci.* 77, 2357-2365.

- Olivier, J.J., Erasmus, G.J., Van Wyk, J.B. & Konstantinov, K.V., 1994. Direct and maternal variance component estimates for clean fleece weight, body weight and mean fibre diameter in the Grootfontein Merino Stud. *S. Afr. J. Anim. Sci.* 24, 122-124.
- Olivier, W.J., Snyman, M. A., Van Wyk, J.B. & Erasmus, G.J., 1998. Genetic parameter estimates for fitness traits in South African Merino. *Livest. Prod. Sci.* 56, 71-77.
- Olson, L.W., Dickerson, G. E. & Glimp, H. A., 1976. Selection criteria for intensive market lamb production: growth traits. *J. Anim. Sci.* 43, 78-89.
- O'Sullivan, B. M. & Donald, A. D., 1970. A field study of nematode parasite populations in the lactating ewes. *Parasitology* 61, 175-179.
- Piper, L. R., Hanrahan, J. P., Evans, R. & Bindon, B. M., 1982. Genetic variation in individual and maternal components of lamb survival in Merinos. *Proc. Aust. Soc. Anim. Prod.* 14, 29-30.
- Rao, S. & Notter, D. R., 2000. Genetic analysis of litter size in Targhee, Suffolk, and Polypay sheep. *J. Anim. Sci.* 78, 2113-2120.
- Reddy, K. K. Krishnamacharyulu, E. & Munirathnam, D., 1984. A note the relationship between ewes' weight at service, birth weight and gestation period in Mandya sheep. *Ind. Vet. J.* 61, 501-504.
- Robison, O.W., 1972. The role of maternal effects in breeding: V. Maternal effects in swine. *J. Anim. Sci.* 35, 1303-1315.
- Robison, O. W., 1981. The influence of maternal effects on the efficiency of selection; a review. *Livest. Prod. Sci.* 8, 121-137.
- Romjali, E., Dorny, P. Batubara, A., Pandey, V. S. & Gatenby, R. M., 1997. Peri-parturient rise in faecal strongyle egg counts of different genotypes of sheep in North Sumatra, Indonesia. *Vet. Parasitol.* 68; 191-196.
- Saatci, M. Dewi Ap & Ulutas, Z., 1997. Variance due to direct and maternal effects for weight of Welsh Mountain lambs based on embryo transfer data. *Proc. British Soc. Anim. Sci.* pp 176.
- Saeid Bathaei, S. & Leroy, L. P., 1998. Genetic and phenotypic aspects of the growth curve characteristics in Mehraban Iranian fat-tailed sheep. *Small Rum. Res.* 29, 261-269.

- Scholtz, M. M. & Roux, C. Z., 1988. The Kleiber ratio (growth rate/ metabolic mass) as possible selection criteria in the selection of beef cattle. *Proc. 3rd World Congr. Sheep Beef Breed.* Paris, France. Vol. 2, pp 373-375.
- Shorepy, S. A. & Notter, D. R., 1996. Genetic variation and covariation for ewe reproduction, lamb growth, and lamb scrotal circumference in fall-lambing sheep flock. *J. Anim. Sci.* 74, 1490-1498.
- Simm, G., Conington, J., Bishop, S.C., Dwyer, C.M. & Pattison, S., 1996. Genetic selection for extensive conditions. *Appl. Anim. Behav. Sci.* 49, 47-59.
- Smith, G. M., 1977. Factors affecting birth weight, dystocia and preweaning survival in sheep. *J. Anim. Sci.* 44: 745-753.
- Snyman, M. A., Erasmus, G. J. & Van Wyk, J. B., 1995a. Non-genetic factors influencing growth and fleece traits in Afrino sheep. *S. Afr. J. Anim. Sci.* 25, 70-74.
- Snyman, M.A., Erasmus, G.J., van Wyk, J.B. & Olivier, J.J., 1995b. Direct and maternal (co)variance components and heritability estimates for body weight at different ages and fleece traits in Afrino sheep. *Livest. Prod. Sci.* 44, 229-235.
- Snyman, M. A., Olivier, J. J., Erasmus, G. J. & Van Wyk, J. B., 1997. Genetic parameter estimates for total weight of lamb weaned in Afrino and Merino sheep. *Livest. Prod. Sci.* 48, 111-116.
- Snyman, M. A., Erasmus, G. J., Van Wyk, J. B. & Olivier, J. J., 1998a. Genetic and phenotypic correlations among production and reproduction traits in Afrino sheep. *S. Afr. J. Anim. Sci.* 28, 74-81.
- Snyman, M. A., Cloete, S. W. P. & Olivier, J. J., 1998b. Genetic and phenotypic correlations of total weight of lamb weaned with body weight, clean fleece weight and mean fibre diameter in three South African Merino flocks. *Livest. Prod. Sci.* 55, 157-162.
- Snyman, M.A., Erasmus, G. J. & Van Wyk, J. B., 1998c. The possible genetic improvement of reproduction and survival rate in Afrino sheep using a threshold model. *S. Afr. J. Anim. Sci.* 28, 120-124.
- Stobart, R. H., Bassett, J W., Cartwright, T. C. & Blackwell, R.L., 1986. An analysis of body weights and maturing patterns in Western Range ewes. *J. Anim. Sci.* 63, 727-740.

- Subandriyo, Inounu, I., 1994. Genetic and environmental factors affecting birth weight, weaning weight and preweaning survival rates of prolific Javanese sheep. *Proc. 5th World Congr. Gen. Appl. Livest. Prod.* Vol. 18, 127-130.
- Swalwe, H.H., 1993. Estimation of direct and maternal (co)variance components for growth traits in Australian Simmental beef cattle. *J. Anim. Breed. Gen.* 110, 241-252
- Swan, A.A. & Hickson, J.D., 1994. Maternal effects in Australian Merinos. *Proc. 5th World Congr. Gen. Appl. Livest. Prod.* 18, 143-146.
- Tawah, C.L., Erasmus, G.J., Van Wyk, J.B. & Neser, F.W.C., 1997. A review of the application of threshold models in Animal Breeding. *Proc. 35th S.A. Soc. Anim. Sci. Cong.* Nelspruit, SA. 107-109.
- Tawonezvi, H. P. R. & Ward H. K., 1987. Productivity of indigenous sheep and goats. 1. Environmental influences on performance of sheep. *Zimb. J. Agric. Res.* 25, 41-49.
- Tembely, S., Lahlou-Kassi, A., Rege, J. E. O., Mukasa-Mugerwa, E., Anindo, D. Sovani, S. & Baker, R. L., 1998. Breed and season effects on the peri-parturient rise in nematode egg output in indigenous ewes in a cool tropical environment. *Vet. Parasit.* 77; 123-132.
- Tosh, J.M. & Kemp, R.A., 1994. Estimation of variance components for lamb weights in three sheep populations. *J. Anim. Sci.* 72, 1184-1190.
- Van Haandel, E. B. P. G. & Visscher, A. H., 1995. Genetic parameters for reproduction traits in crosses between Finnish Landrace and Ile de France sheep. *Livest. Prod. Sci.* 43, 129-136.
- Van Wyk, J. A., Malan, F. S. & Bath, G. F., 1997. Rampant anthelmintic resistance in sheep in South Africa- What are the options? Workshop on managing anthelmintic resistance in endoparasites: 16th Int. WAAVP, South Africa.
- Van Wyk, J. B., Erasmus, G. J. & Konstantinov, K. V., 1993a. Non-genetic factors influencing early growth traits in the Elsenburg Dormer sheep stud. *S. Afr. J. Anim. Sci.* 23, 67-71.
- Van Wyk, J.B., Erasmus, G.J. & Konstantinov, K.V., 1993b. Variance component and heritability estimates of early growth traits in the Elsenburg Dormer sheep stud. *S. Afr. J. Anim. Sci.* 23, 72-76.
- Vassilev, G. D., 1995. Control of haemonchosis in sheep by strategic treat with closantel. *Zimb. Vet. J.* 26, 33-60.

- Waldron, D. F. & Thomas, D. L., 1992. Increased litter size in Rambouillet sheep: 1. Estimation of genetic parameters. *J. Anim. Sci.* 70, 3333-3344.
- Ward, H. K. Richardson, F. D., Denney, R. P. & Dye, P. J., 1979. Matopos Research Station: A perspective. *Rhod. Agric. J.* 76, 5-18.
- Ward, H. K., 1959. Some observations on the indigenous ewe. *Rhod. Agric. J.* 56, 218-223.
- Warren, J. T. & Mysterud, I., 1995. Mortality of domestic sheep in free-ranging flocks in south eastern Norway. *J. Anim. Sci.* 73, 1012-1018.
- Wildeus, S., 1997. Hair sheep genetic resources and their contribution to diversified small ruminant production in the United States. *J. Anim. Sci.* 75, 630-640.
- Willham, R.L., 1963. The covariance between relatives for characters composed of components contributed by related individuals. *Biometrics* 19, 18-27.
- Wilson, R.T., 1987. Livestock production in central Mali: Environmental factors affecting weight in traditionally managed goats and sheep. *Anim. Prod.* 45, 223-232.
- Woolaston, R. R., 1992. Selection of Merino sheep for increased and decreased resistance to *haemonchus contortus*: peri-parturient effects on faecal egg counts. *Int. J. Parasitol.* 22; 947-953.
- Yamaki, K., 1994. Growth of lambs and genetic parameters in four breeds. *Proc. 5th World Congr. Gen. Appl. Livest. Prod.* 18, 135-138.
- Yazdi, M. H., Engstrom, G, Näsholm, A., Johansson, K., Jorjani, H. & Liljedahl, L. -L., 1997. Genetic parameter for lamb weight at different ages and wool production in Baluchi sheep. *Anim. Sci.* 65, 247-255.
- Zajac, A. M., Herd, R. P. & McClure, K. E., 1988. Trichostrongylid parasite populations in pregnant or lactating and unmated Florida Native and Dorset/Rambouillet ewes. *Int. J. Parasit.* 18, 981-985.