THE IMPROVEMENT OF LAMB SURVIVAL OF MERINO SHEEP AS A CORRELATED RESPONSE TO DIRECT SELECTION FOR REARING ABILITY

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SUMMARY

Data were available for peri-natal lamb survival (PNS), lamb survival from 4 days to weaning (S4DTW), birth weight (BW) and birth coat score (BCS) in South African Merino sheep that were selected divergently from the same base population for their ability to rear multiples. These data spanned the period 1986-2008, and were subjected to genetic analyses involving two three-trait linear-threshold analyses, entailing PNS and S4DTW analysed along with the other traits. The lamb survival trait considered was treated as a categorical trait in both instances. The line selected in the upward direction was denoted the high line (H line) and the line selected downward as the low line (L line). Heritability was estimated at 0.15 for PNS, 0.20 for S4DTW, 0.16 for BW and 0.60 for BCS. Corresponding estimates for maternal heritability amounted to 0.16, 0.10, 0.25 and 0.06 and to 0.11, 0.05, 0.08 and 0.03 for the dam permanent environment. Expressed relative to the overall mean, direct and maternal breeding values for PNS improved at respectively 0.61% p.a. and 0.46% p.a. in the H line. Corresponding genetic trends in the L line amounted to respectively 0.26% p.a. and -0.96% p.a. Direct and maternal genetic trends for S4DTW amounted to respectively 0.70% p.a. and 0.16% p.a. in the H line and to respectively -0.26% p.a. and -0.26% p.a. in the L line. It was concluded that genetic change in lamb survival would accrue when selection is based on a trait like maternal multiple rearing ability.

INTRODUCTION

Ovine lamb survival has long been considered a trait of economic importance (Haughey 1991). Apart from the obvious loss of monetary income incurred by lamb deaths, there is also an important animal welfare component associated with it. Various analysts considered the prospect of improving lamb survival genetically as being relatively poor (Morris *et al*. 2000; Everett-Hincks *et al*. 2005). The binomial distribution of survival traits and generally low levels of genetic variation in these traits have contributed to this assessment. However, recent analyses involving threshold models have reported noteworthy genetic variation in survival (Welsh *et al*. 2006; Riggio *et al*. 2008), while divergence were reported in age-specific lamb survival (survival of birth, survival from birth to docking and survival from docking to weaning) of Merino sheep selected divergently for ewe multiple rearing ability (Cloete *et al*. 2009).

Peri-natal lamb survival is defined as survival of the peri-parturient period, up to an age of three days (Haughey 1991). Survival of this phase is often seen as critical to ensure good survival to weaning. This study therefore reports genetic variation in peri-natal lamb survival, as well as lamb survival from four days to weaning. These traits were analysed along with lamb birth weight and birth coat score, enabling the estimation of (co)variance components for all traits.

MATERIALS AND METHODS

The resource population involved Merino sheep that were divergently selected for their ability to rear multiples since 1986. Selection was based on maternal ranking values for number of lambs weaned per parity (Cloete *et al*. 2004; 2009). The origin, environment, management and selection

practices in the resource population are described in the literature cited, and will not be elaborated further.

Age-specific lamb survival of 5,686 lambs born from 1986 to 2008 was available in the resource population, as described by Cloete *et al*. (2009). These data were used to construct individual records for peri-natal survival (PNS – defined as the survival prior to, during and up to 3 days after birth), and survival from 4 days of age up to weaning (S4DTW). Birth weight (BW) was recorded within 24 hours of birth in all these lambs, with the exception of a small number that were mutilated by vermin. Birth coat score (BCS) was recorded for lambs that were born from 1995. Scores ranged from 1 (hairy) to 5 (woolly), as detailed by Cloete et al. (2003).

Two three-trait animal models were fitted with either PNS or S4DTW together with BW and BCS. Lamb survival was defined as a binary trait with two categories (1 for lambs dying in the particular category and 2 for those surviving), whereas BW and BCS data were treated as continuous. The fixed effects included year of birth (1986 – 2008), sex (male and female), dam age (2 to 7+ years) and birth type (single and multiple). Animal, maternal genetic and dam permanent environment terms were included as random effects. The genetic correlation between direct and maternal genetic effects was included initially. It was not significant for either trait, and was excluded from the final runs. The software used was THRGIBBSF90 (Misztal *et al*. 2002). This software is suitable for the estimation of variance components and genetic parameters in threshold animal mixed models for any combination of categorical and continuous traits. The programme POSTGIBBSF90 was used for Post Gibbs analysis (Misztal *et al*. 2002). In all cases, a single chain of 200,000 cycles were run, with the first 40,000 cycles used as the burn-in period.

RESULTS AND DISCUSSION

Data description: The proportion of lamb surviving amounted to 0.88 for PNS and 0.86 for S4DTW (1 is subtracted from the mean value in Table 1 to account for the coding). Sawalha *et al*. (2007) reported a proportion of 0.95 lambs surviving the period during or shortly after birth. Riggio *et al*. (2008) accordingly found a proportion of 0.92 lambs surviving birth. Postnatal survival was high in the study of Sawalha *et al*. (2007), namely a proportion of 0.98 surviving from 1 to 14 days and 0.96 surviving from 15 days to 120 days of age. Cumulative survival in the study of Riggio *et al*. (2008) amounted to 0.87 after four weeks and to 0.85 after 12 weeks. Survival was thus generally somewhat poorer in the present study.

BW and BCS were normally distributed and averaged respectively 3.8 kg and a score of 3.2 (Table 1). The overall mean for BW was within the range of 3.6 to 4.9 kg reported for seven Australian Merino resource flocks (Safari *et al*. 2007a). At 3.85 kg for BW and 3.22 for BCS, the previous means reported for a smaller data set of the same resource population (Cloete *et al*. 2003) also accorded with the present study. The variability of the BW data used in the present study compared well with coefficients of variation ranging from 17 to 22% in the study of Safari *et al*. (2007a).

Table 1. Descriptive statistics for the raw data analysed

Trait	Number of observations	Mean ± s.d.	Skewness	Kurtosis	Range
PNS	5,686	1.88 ± 0.32	n.a	n.a.	1 – 2
S4DTW	5,024	1.86 ± 0.35	n.a.	n.a.	1 – 2
BW	5,665	3.79 ± 0.86	0.02	0.10	1 – 7
BCS	3,521	3.19 ± 0.92	-0.95	1.68	1 – 5

n.a. – as means for survival are incidence dependent, statistical information is not supplied

Genetic parameters: Lamb survival on the underlying scale was moderately heritable, at 0.15 (PNS) and 0.20 (S4DTW) (Table 2). Corresponding estimates for the maternal genetic variance ratio (m^2) were respectively 0.16 and 0.10. Sawalha *et al*. (2007) analysed lamb viability (defined as survival at birth and up to 24 hours and thus corresponding with PNS), and obtained estimates of 0.05 for h^2, 0.10 for m^2 with a litter effect of 0.19. Riggio *et al*. (2008) estimated h^2 of survival at birth and up to 24 hours at 0.33, using a sire model and the probit link function. Literature estimates comparable to S4DTW were 0.13 for h^2 and 0.14 for m^2 with 0.25 for the litter effect for lamb survival from 1 to 14 days of age in the study of Sawalha *et al*. (2006). These estimates generally corresponded with the present study.

(Co)variance ratios for BW and BCS were within 0.01 when jointly estimated with either PNS or S4DTW (Table 2). Estimates for BW were 0.16 for h^2, 0.25 for m^2 and 0.08 for c^2. Genetic parameters for BW are relatively scarce for Merino lambs. Previous estimates of h^2 ranged from 0.12 to 0.19 (Duguma *et al*. 2002; Cloete *et al*. 2003; Safari *et al*. 2007b). Corresponding estimates for m^2 ranged from 0.19 to 0.25, and those for the dam permanent environment (c^2) from 0.07 to 0.10. Variance ration estimates for BCS were 0.60 for h^2, 0.06 for m^2 and 0.03 for c^2. An earlier study on a smaller data set of the same resource population yielded estimates of 0.70 for h^2 and 0.04 for c^2 (Cloete *et al*. 2003). Part of the maternal variation was partitioned towards m^2 when using the larger database of the present study. Kemper *et al*. (2003) accordingly reported the h^2 of BCS to be 0.65, while Ponzoni *et al*. (1996) reported an estimate of 0.66.

Table 2. Phenotypic variances (σ^2_P) and genetic, maternal and dam permanent environmental (co)variance ratios (± s.e.) for PNS and S4DTW with BW and BCS

Trait / Trait	PNS			S4DTW		
	Survival	BW	BCS	Survival	BW	BCS
σ^2_P	1.708	0.508	0.683	1.525	0.506	0.684
Genetic correlations (h^2 in bold on diagonal)						
Survival	**0.15±0.07**	-0.28±0.19	0.07±0.20	**0.20±0.08**	-0.09±0.19	-0.22±0.18
BW		**0.16±0.03**	0.06±0.11		**0.16±0.03**	0.05±0.11
BCS			**0.61±0.06**			**0.60±0.06**
Maternal genetic correlations (m^2 in bold on diagonal)						
Survival	**0.16±0.05**	0.27±0.17	0.24±0.23	**0.10±0.03**	0.22±0.17	0.22±0.21
BW		**0.25±0.04**	0.02±0.17		**0.25±0.04**	0.02±0.16
BCS			**0.06±0.02**			**0.06±0.02**
Dam PE correlations (c^2 in bold on diagonal)						
Survival	**0.11±0.04**	0.14±0.27	0.17±0.35	**0.05±0.02**	0.21±0.25	-0.82±0.28
BW		**0.08±0.03**	-0.72±0.25		**0.08±0.02**	-0.71±0.22
BCS			**0.03±0.01**			**0.03±0.01**

Ranging between -0.28 and 0.22, direct and maternal genetic correlations were consistently smaller than twice their standard errors (Table 2). Lamb viability to 1 day of age (0 for survivors and 1 for mortalities) was related to BW by Sawalha *et al*. (2007). The derived genetic correlation was unfavourable at 0.21. The sign and magnitude of this correlation were consistent with those reported in the present study (-0.26, remembering that the sign of the correlation has to be reversed because of different coding). No conclusive genetic relationship was found between S4DTW and BCS. Ponzoni *et al*. (1996) accordingly reported a limited impact of BCS on lamb survival. The corresponding dam permanent environmental correlation was high and significant at -0.82.

Genetic trends. Expressed relative to the overall phenotypic mean, the direct genetic trend for PNS amounted to 0.61% per annum in the H line and to 0.26% per annum in the L line.

Corresponding maternal genetic trends amounted to 0.46% and -0.96% per annum for the respective lines. Direct genetic trends for S4DTW amounted to 0.70% of the overall phenotypic mean per annum in the H line and to -0.26% per annum in the L line. Maternal genetic trends in the respective lines accordingly amounted to respectively 0.16% and -0.26 per annum. Previous research indicated divergence in genetic trends for survival of birth (maternal) and in survival from birth to docking (direct) (Cloete *et al*. 2009). A substantial direct improvement was observed in the survival of H line lambs in the period from docking to weaning while maternal breeding values in the L line declined during this period.

Table 3. Regressions (b ± s.e.) of individual predicted breeding values on year of birth for PNS and S4DTW of 3,548 H line lambs and 1,664 L line lambs. Regressions were forced through the origin in all instances.

Trait	PNS		S4DTW	
Line	H line	L line	H line	L line
Direct	0.0114±0.0005	0.0049±0.0011	0.0131±0.0006	-0.0049±0.0011
Maternal	0.0087±0.0006	-0.0281±0.0012	0.0031±0.0005	-0.0048±0.0009

CONCLUSIONS

Results from the present study suggest that genetic improvement in lamb survival is feasible when selection is based on a related trait like maternal rearing ability. Sheep production is seen to benefit from such selection, since ewes capable of rearing their lambs with minimal external efforts would be desirable from an economic as well as from an animal welfare perspective.

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