GENETIC PARAMETERS FOR MILK PRODUCTION OF EWES IN FOUR SOUTH AFRICAN WOOLLED SHEEP FLOCKS UNDER DIFFERENT GRAZING CONDITIONS

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INTRODUCTION

Body weight has always been one of the most important traits considered during selection of both replacement ewes and rams in many wool and meat sheep breeding enterprises. Continuous selection for increased body weight under extensive conditions, where nutritional resources could be a limiting factor, is not always feasible. As body weight at all ages are positively genetically correlated (Safari et al., 2005), selection for an increased body weight at any age will lead to an increase in mature body weight, which could have a negative impact on overall profitability.

Maternal breeding values for early growth traits have been estimated for numerous sheep breeds and flocks (El Fadili et al., 2000; Ligda et al., 2000; Al-Shorepy, 2001; Neser et al., 2001; Hanford et al., 2002; Hanford et al., 2003; Maniatis & Pollott, 2003; Van Vleck et al., 2003; Mandal et al., 2006; Miraei-Ashtiani et al., 2007; Van Wyk et al., 2008). Few, if any, of these studies have led to the implementation of breeding plans incorporating maternal breeding values in sheep. In beef cattle breeding, maternal breeding values for birth and weaning weight are routinely used as selection criteria.

Meyer et al. (1994) reported that milk production of the dam is the main determinant of maternal effects on growth of beef calves. Furthermore, it has also been reported that differences in milk production of beef cows affect weaning weight of their calves (Minick et al., 2001). Expected differences in milk production of progeny of sires accurately predict differences in actual milk production of their daughters and weaning weight of the daughters' calves, and can be used in a selection program (Diaz et al., 1992; Minick et al., 2001; Baker et al., 2003).

The use of maternal breeding values for early body weight and expected progeny differences in milk production, hold possibilities for implementation in the sheep breeding industry. This is especially true in flocks where an increase in body weight could not be accompanied by an increased lambing percentage, due to the specific flock already having a high lambing percentage. No literature references on the relationship between maternal breeding values for early growth traits of sires and milk production of their daughters could be found for sheep. This relationship should therefore be investigated in various sheep flocks before recommendations as to its implementation in practice can be made.

The aim of this study was therefore to estimate genetic parameters for milk production in various grazing sheep flocks. Furthermore, the effect that the inclusion of maternal breeding values for early growth traits in the selection objective has on early growth, total weight of lamb weaned and milk production was also investigated.

MATERIALS AND METHODS

Milk production was recorded in four flocks for which estimated direct-maternal correlations for early body weight varied in sign and magnitude. The flocks, direct-maternal correlations for 42-day weight and weaning weight, as well as recording period for each are summarised in Table 1.

Table 1. Flocks used in the study, direct-maternal correlations for 42-day weight and weaning weight, as well as recording period for each flock

Flock	**42-day weight (r_{am})**	**Weaning weight (r_{am})**	**Recording period**
Carnarvon Afrino	+0.46 ± 0.20	+0.32 ± 0.12	2005 to 2014
Elsenburg Merino		+0.67 ± 0.21	2005 to 2014
Cradock fine wool Merino	-0.33 ± 0.12	-0.01 ± 0.16	2006 to 2011
Grootfontein Merino	-0.81 ± 0.05	-0.20 ± 0.12	2007 to 2014

r_{am} = correlation between direct genetic and maternal genetic effects of early body weight

The results of the first phase of the study (Snyman & Cloete, 2008) indicated that milk production at three and twelve weeks of lactation gave the best indication of total milk production over the lactation period. Therefore, milk production of all the above mentioned ewes was recorded at three and twelve weeks of lactation by means of the oxytocin technique (Bencini et al., 1992). On the day of milk recording, the lambs were removed from the ewes at 08:00. Each ewe was injected intramuscularly with 10 IU of oxytocin. The ewes were hand milked immediately after injection, until no more milk could be withdrawn from the udder. This milk was discarded and the time recorded. After a three-hour period, during which the lambs were still kept away from the ewes, the ewes again received a 10 IU oxytocin injection. They were hand milked again until no more milk could be withdrawn from the udders. This volume of milk was recorded. During the second milking, the ewes were milked in the same order as during the first milking, to ensure a three-hour inter-milking period for each ewe.

Statistical analyses

Annually, total milk production over the 70-day lactation period from three to twelve weeks was calculated for each ewe in each of the flocks from the recorded three and twelve week milk productions by employing regression procedures.

Least-squares means for year of recording, age of the ewe and number of lambs suckled were obtained for the different flocks for total milk production over the 70-day lactation period (TMP) with the GLM procedure of SAS (2009). Fixed effects for year, age of the ewe, number of lambs suckled and significant two-factor interactions were included in the model for each flock.

Genetic parameters for milk production

Repeatability models were run with the ASREML program (Gilmour et al., 2009). Splines were fitted to separate ewe ages 2, 3, 4, 5, 6, 7 and 8 years. Direct additive and maternal additive genetic effects, animal permanent environmental effects and maternal permanent environmental effects were tested for total milk production in different combinations to yield four possible models. The four models were:

$$\mathbf{y} = X\mathbf{b} + Z_1\mathbf{a} + W_1\mathbf{anim} + \mathbf{e} \quad (1)$$

$$\mathbf{y} = X\mathbf{b} + Z_1\mathbf{a} + W_1\mathbf{anim} + W_2\mathbf{mpe} + \mathbf{e} \quad (2)$$

$$\mathbf{y} = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + W_1\mathbf{anim} + \mathbf{e}; \text{ with } cov(a,m) = 0 \quad (3)$$

$$\mathbf{y} = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + W_1\mathbf{anim} + W_2\mathbf{mpe} + \mathbf{e}; \text{ with } cov(a,m) = 0 \quad (4)$$

where **y** is a vector of observed traits of animals; **b**, **a**, **m, anim** and **mpe** were vectors of fixed effects, direct additive genetic effects, maternal additive genetic effects, animal permanent environmental effects and maternal permanent environmental effects respectively; X, Z_1, Z_2, W_1 and W_2 were incidence matrices respectively relating fixed effects, direct additive genetic effects, maternal additive genetic effects, animal permanent environmental effects and maternal permanent environmental effects to **y**; **e** is the vector of residuals; A was a numerator relationship matrix, and σ_{am} is the covariance between direct additive genetic and maternal additive genetic effects.

The Likelihood ratio statistic (LogL) was used to determine the most suitable model for each trait. The Likelihood ratio statistic is $\log\sigma = L(b_2) - L(b_1)$, where $L(b)$ is the log likelihood function evaluated at the maximum likelihood estimator (b). The statistic $-2(\log L_2 - \log L_1)$ has a χ^2 distribution with degrees of freedom equal to the difference between the number of parameters for the two models being compared. An effect was considered to have a significant influence when its inclusion caused a significant increase in log likelihood, compared to the model in which it is ignored. For the purpose of this study, a significance level of $P<0.05$ was applied throughout.

Depending on the model, variance ratios were computed as direct heritability ($h^2_a = \sigma_a^2/\sigma_p^2$) and maternal heritability ($h^2_m = \sigma_m^2/\sigma_p^2$), while the maternal and animal environmental variance ratios were estimated as $c_{mpe} = \sigma_{mpe}^2/\sigma_p^2$ and $c_{anim} = \sigma_{anim}^2/\sigma_p^2$ respectively.

Correlations between milk production and early body weight and total weight of lamb weaned

A multivariate repeatability model including total milk production, total weight of lamb weaned and body weight before mating (the latter only in the case of the Afrino ewes), fitting only direct additive effects, was fitted for each data set (ASREML; Gilmour et al., 2009).

The following analyses were done, using the ASREML program (Gilmour et al., 2009):

Bivariate analyses between total milk production (fitting a repeatability model) and 42-day body weight (fitting a univariate model) for all flocks, including direct additive genetic effects, maternal additive genetic effects and maternal permanent environmental effects for 42-day body weight and direct genetic and animal permanent environmental effects for milk production. Covariances between direct and maternal effects for 42-day body weight, as well as between direct effects for milk production and maternal effects for 42-day body weight, were included. The same analyses were done for weaning weight in all flocks.

Breeding values for milk production

Estimated breeding values and accuracies of milk production of individual animals were obtained as solutions from the ASREML program (Gilmour et al., 2009). Accuracy of EBVs were calculated as $\sqrt{\{1 - [(\text{predicted error variance reported with each BLUP value})^2 / \text{additive genetic variance of the specific trait}]\}}$.

Additionally, different sets of breeding values were calculated for the Afrino sires used in 2008 and 2009. These include breeding values as predictions of milk production of their daughters before they had any lactating daughters, then after their daughters had one or two lactation records respectively.

Predictors of early body weight and total weight of lamb weaned

Estimated breeding values, as indicated in Table 2, were obtained from the data set of project AP10/1/4 for Afrino sheep.

Table 2. Estimated breeding values used for analyses for Afrino sheep in this study

Trait (EBV = estimated breeding value)	**Abbreviation**
Direct EBV for 42-day weight of the lamb	EBV-W42
Direct EBV for 42-day weight of the dam	EBV-W42-D
Direct EBV for 42-day weight of the sire	EBV-W42-S
Direct EBV for 42-day weight of the sire of the dam	EBV-W42-SD
Maternal EBV for 42-day weight of the lamb	MBV-W42
Maternal EBV for 42-day weight of the dam	MBV-W42-D
Maternal EBV for 42-day weight of the sire	MBV-W42-S
Maternal EBV for 42-day weight of the sire of the dam	MBV-W42-SD
Direct EBV for weaning weight of the lamb	EBV-WW
Direct EBV for weaning weight of the dam	EBV-WW-D
Direct EBV for weaning weight of the sire	EBV-WW-S
Direct EBV for weaning weight of the sire of the dam	EBV-WW-SD
Maternal EBV for weaning weight of the lamb	MBV-WW
Maternal EBV for weaning weight of the dam	MBV-WW-D
Maternal EBV for weaning weight of the sire	MBV-WW-S
Maternal EBV for weaning weight of the sire of the dam	MBV-WW-SD
Direct EBV for total weight of lamb weaned of the lamb	EBV-TWW
Direct EBV for total weight of lamb weaned of the dam	EBV-TWW-D
Direct EBV for total weight of lamb weaned of the sire of the dam	EBV-TWW-SD

Trait (EBV = estimated breeding value)	Abbreviation
Obtained from current study:	
Direct EBV for total milk production of the lamb	EBV-TMP
Direct EBV for total milk production of the dam	EBV-TMP-D
Direct EBV for total milk production of the sire of the dam	EBV-TMP-SD

Stepwise regression procedures (SAS, 2009) were done to determine those effects contributing the most to variation in 42-day body weight, weaning weight and total weight of lamb weaned respectively. Effects included were total milk production and all the breeding values in Table 2. Additional fixed effects included for 42-day body weight and weaning weight were year-sex, year-rearing status, age of dam and age at recording of the specific body weight. For total weight of lamb weaned, year, age of the ewe and number of lambs weaned were also included.

RESULTS AND DISCUSSION

The effects of year, age of ewe and number of lambs weaned on total milk production per 70-day lactation period (TMP) during the project are given in Table 3. The Cradock fine wool Merino ewes had the highest milk production per ewe, followed by the Afrino, the Grootfontein Merino and then the Elsenburg Merino ewes. These differences could be ascribed to breed and environmental influences. Differences in milk production of non-dairy sheep breeds and flocks were also reported by Torres-Hernandez & Hohenboken (1979), Aboul-Naga et al. (1981), Peralta-Lailson et al. (2005), Morgan et al. (2006) and Abd Allah et al. (2011).

Age of dam had a variable influence on total milk production in the different flocks. In the Cradock fine wool Merino flock, where the ewes are run on irrigated pastures during lactation, no differences in TMP due to age of dam were observed. The 5-year old Afrino ewes produced significantly more milk than their respective 2-, 3-, 4- and 6-year old breed contemporaries.

The 2- and 8-year old Grootfontein Merino ewes respectively produced less and more milk than most of the other age groups. In the Elsenburg Merino flock, the 2-year old ewes produced less milk than the older ewes. Varying results were also reported regarding the effect of ewe age on milk yield. Boujenane & Lairini (1992) and Abd Allah et al. (2011)

found that milk production was influenced by ewe age, while other researchers reported no effect of ewe age (Torres-Hernandez & Hohenboken, 1979; Aboul-Naga et al., 1981).

The number of lambs suckled had a significant influence on milk production in all flocks, with ewes nursing twins producing more milk than ewes nursing single lambs. The same trend was observed by Torres-Hernandez & Hohenboken (1979), Boujenane & Lairini (1992), Morgan et al. (2006), Morgan et al. (2007) and Abd Allah et al. (2011). Afrino ewes nursing triplets produced the most milk in the current study. The latter ewes and their lambs were usually kept separate on an irrigated pasture.

Table 3. Effects of year, age of ewe and number of lambs weaned on total milk production (± s.e.) per 70-day lactation period (TMP) during the project for ewes in the four flocks

Effect	Afrino ewes (litre)	Grootfontein Merino ewes (litre)	Cradock fine wool Merino ewes (litre)	Elsenburg Merino ewes (litre)
Year				
2005	132.55^{abcde} ± 8.43			
2006	173.31^{afgh} ± 3.57		154.64^{e} ± 3.63	82.79^{ab} ± 5.84
2007	126.63^{fiklm} ± 4.85	145.31^{a} ± 6.31	159.22^{b} ± 3.70	88.63^{cdef} ± 5.85
2008	166.98^{bij} ± 7.36	104.26^{abcde} ± 6.00	142.86^{ab} ± 3.45	89.74^{ghij} ± 5.85
2009	144.51^{finop} ± 4.10	134.64^{bd} ± 6.05	127.95^{ab}± 3.55	74.72^{acgk} ± 5.94
2010	130.49^{gjqrs} ± 5.52	153.13^{b} ± 6.16		92.87^{almno} ± 5.93
2011	169.83^{cknq} ± 7.37	170.76^{abfe} ± 6.39	108.58^{ab} ± 4.49	74.20^{bdhl} ± 5.71
2012	163.72^{dlor} ± 5.14	143.96^{cf} ± 6.08		77.31^{eim} ± 5.85
2013	183.53^{empst} ± 7.11	155.34^{d} ± 6.43		77.93^{fjn} ± 5.69
2014	135.53^{ht} ± 13.29	139.79^{e} ± 6.37		84.05^{ko} ± 5.80
Age of dam				
2	154.79^{a} ± 4.76	124.66^{abc} ± 5.10	141.01 ± 3.61	73.09^{abcde} ± 5.69
3	153.46^{b} ± 3.98	141.26^{a} ± 5.03	141.29 ± 3.62	81.62^{a} ± 5.67
4	144.93^{c} ± 3.92	143.16^{bd} ± 4.91	141.22 ± 3.87	86.01^{b} ± 5.72
5	170.07^{abcd} ± 3.83	142.93^{c} ± 5.48	137.33 ± 4.02	83.04^{c} ± 5.68
6	145.91^{d} ± 4.86	136.91^{e} ± 6.32	136.84 ± 4.74	87.31^{d} ± 5.89
7	146.44 ± 10.08	119.03^{d} ± 9.39	134.21 ± 5.15	83.74^{e} ± 5.96
8		195.84^{abcde} ± 16.09		
Number of lambs weaned				
1	115.99^{a} ± 1.78	122.07^{ab} ± 3.01	117.29^{ab}± 2.32	75.32^{a}± 0.93
2	142.64^{a} ± 1.50	141.03^{a} ± 3.38	148.54^{a} ± 2.06	91.28^{a} ± 1.49
3	199.50^{a} ± 7.33	167.10^{b} ± 12.89	150.13^{b} ± 6.61	80.80 ± 16.38
Average (CV%)				
TMP	135.00 (27.84)	119.12 (36.57)	137.92 (34.66)	77.54 (29.71)

^{a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t} Values with the same superscripts differed significantly ($P<0.05$) within flocks and effects

Genetic parameters for milk production

The data sets for each flock were used to estimate genetic parameters for milk production. The description of the data sets can be found in Table 4.

Table 4. Description of data sets used for estimation of genetic parameters for milk production

Number of:	Afrino	Grootfontein Merino	Cradock fine wool Merino	Elsenburg Merino
Individual ewe milk records	1613	966	1154	1122
Ewes	655	500	530	491
Sires of ewes	102	87	79	72
Lactations	**Number of ewes (% in brackets)**			
1	192 (29.3)	220 (44.0)	215 (40.6)	172 (35.0)
2	175 (26.7)	149 (29.8)	109 (20.6)	146 (29.7)
3	140 (21.3)	92 (18.4)	114 (21.5)	84 (17.1)
4	98 (15.0)	26 (5.2)	85 (16.0)	52 (10.7)
5	42 (6.4)	10 (2.0)	7 (1.3)	24 (4.9)
6	7 (1.1)	3 (0.6)		13 (2.6)
7	1 (0.2)			

Genetic parameters for total milk production in the four flocks estimated with the most suitable repeatability model are summarised in Table 5. From these results it is evident that milk production was only influenced by direct genetic effects. The data structure could have had an influence on the fact that no maternal or permanent animal variance was partitioned. From the number of repeated records per ewe summarised in Table 4 it can be seen that only about 15% of the ewes in the Afrino and Cradock fine wool Merino data sets had four milk recordings. There were even fewer ewes in the Grootfontein Merino flock with four recordings. In all flocks, Model 1 fitted without splines had the highest log likelihood values. Direct heritabilities for TMP of 0.21 ± 0.03, 0.02 ± 0.03, 0.10 ± 0.04 and 0.29 ± 0.07 were estimated for the Afrino, Grootfontein Merino, Cradock fine wool Merino and Elsenburg Merino flocks respectively. The low heritability estimated for the Grootfontein Merino flock cannot be explained.

There is a dearth of published heritability estimates for milk production of non-dairy sheep breeds (Afolayan et al., 2009a). Published heritabilities are as follow: 0.10 ± 0.05 for Merino sheep (Cloete et al., 2011), 0.10 (3 to 4 weeks lactation) and 0.24 (12 weeks lactation) for crossbred ewes (Afolayan et al., 2009b).

Table 5. Genetic parameters for total milk production in the four flocks estimated with a repeatability model

Parameter	Afrino ewes	Grootfontein Merino	Cradock fine wool Merino	Elsenburg Merino
h^2_a	0.21 ± 0.03	0.02 ± 0.03	0.10 ± 0.04	0.29 ± 0.07
c^2_{anim}	0.00 ± 0.00	0.00 ± 0.00	0.02 ± 0.04	0.10 ± 0.06
t	0.21 ± 0.03	0.02 ± 0.03	0.12 ± 0.03	0.39 ± 0.04

h^2_a = Direct additive heritability; c^2_{anim} = animal permanent environmental effect; t = repeatability

These values are within the range of several estimates published for dairy sheep breeds using both research station and industry field data. In a review, Hamann et al. (2004) cited heritability estimates for milk yield ranging from 0.10 to 0.54. Other subsequent reports of heritability for milk yield in various dairy sheep breeds included 0.25 ± 0.04 (El-Saied et al., 2005), 0.44 ± 0.09 (Marie-Etancelin et al., 2006) and 0.10 ± 0.02 (Gutierrez et al., 2007).

Genetic, phenotypic and environmental correlations between total milk production, total weight of lamb weaned and body weight before mating (only for Afrino ewes), are summarised in Table 6. High genetic correlations were obtained between total milk production and total weight of lamb weaned in all three flocks.

Table 6. Genetic (r_g), phenotypic (r_p) and environmental (r_e) correlations between total milk production (TMP), total weight of lamb weaned and body weight before mating (only for Afrino ewes)

Flock	Parameter	Total weight of lamb weaned	Body weight before mating
Afrino	TMP r_p	0.58 ± 0.02	0.12 ± 0.03
	TMP r_g	0.68 ± 0.10	0.33 ± 0.10
	TMP r_e	0.57 ± 0.02	
Grootfontein Merino	TMP r_p	0.33 ± 0.04	
	TMP r_g	0.66 ± 1.00	
	TMP r_e	0.33 ± 0.04	
Cradock fine wool Merino	TMP r_p	0.41 ± 0.03	
	TMP r_g	0.92 ± 0.11	
	TMP r_e	0.34 ± 0.03	

The results of the analyses between total milk production (fitting a repeatability model) and 42-day body weight and weaning weight (fitting univariate models) are summarised in Table 7 for the four flocks. Significantly high genetic correlations between the direct effect of total milk production and the maternal effect of 42-day body weight have been estimated for the Afrino and Cradock fine wool Merino flocks. A similar significantly high correlation was obtained for weaning weight for the Afrino flock. This indicates that including maternal breeding values for early weights in the latter flock would have a positive effect on milk production.

Table 7. Genetic parameter estimates for and relationships between total milk production (TMP) and early body weights in the four flocks

Flock	Parameter	42-day body weight	Weaning weight
Afrino	TMP r_p	0.16 ± 0.03	0.16 ± 0.03
	TMP r_g	0.36 ± 0.18	0.29 ± 0.25
	r_{a1m2}	0.76 ± 0.12	0.77 ± 0.11
Elsenburg Merino	TMP r_p		0.21 ± 0.03
	TMP r_g		0.64 ± 0.19
	r_{a1m2}		0.99 ± 0.17
Cradock fine wool Merino	TMP r_p	0.11 ± 0.02	0.13 ± 0.03
	TMP r_g	-0.02 ± 0.20	0.28 ± 0.16
	r_{a1m2}	0.83 ± 0.14	0.37 ± 0.12
Grootfontein Merino	TMP r_p	0.05 ± 0.02	0.02 ± 0.02
	TMP r_g	0.16 ± 0.46	0.23 ± 1.02
	r_{a1m2}	0.62 ± 0.46	0.55 ± 1.38

r_g = genetic correlation; r_p = phenotypic correlation; r_{a1m2} = genetic correlation between direct effect of total milk production and maternal effect of early body weight

Very little published information could be found on correlations of milk production with body weight and reproductive traits. Afolayan et al. (2009a) reported genetic correlations between milk yield and pre-weaning growth rate of the ewes of 0.38 ± 0.32 and between milk yield and post-weaning growth rate of 0.49 ± 0.31. Divergent selection for weaning weight in Merino sheep has been shown to result in correlated responses in milk production of ewes (Pattie, 1965).

Afolayan et al. (2009a) reported genetic correlations between milk yield and litter size, lambs weaned per lambs born alive, lambs weaned per ewe lambing and weight weaned of 0.44 ± 0.42, 0.12 ± 0.63, 0.53 ± 0.37 and 0.47 ± 0.34 respectively.

Predictors of early body weights and total weight of lamb weaned

Results for the stepwise regression analyses in the Afrino flock are presented in Tables 8 to 10 for 42-day body weight, weaning weight and total weight of lamb weaned, respectively.

Apart from age at recording, which contributed the most to variation, maternal breeding value of the dam for the specific weight had the second highest contribution to variation in 42-day body weight and weaning weight. The maternal breeding value for weaning weight of the dam was the third highest contributor to total weight of lamb weaned.

Table 8. Effects contributing significantly (P<0.05) to 42-day body weight

Trait	Partial R^2	Model R^2	P
MBV-W42-D	0.036	0.036	0.000
EBV-TWW-D	0.013	0.049	0.000
EBV-W42-S	0.013	0.062	0.000
Total milk production	0.007	0.069	0.000
EBV-TMP-D	0.003	0.072	0.010
EBV-TWW-SD	0.002	0.074	0.043
EBV-WW-SD	0.001	0.075	0.054
EBV-TMP-SD	0.001	0.076	0.068

Table 9. Effects contributing significantly (P<0.05) to weaning weight

Trait	Partial R^2	Model R^2	P
MBV-WW-D	0.039	0.039	0.000
EBV-WW-S	0.023	0.062	0.000
EBV-TWW-D	0.007	0.069	0.000
EBV-TWW-SD	0.004	0.073	0.001
MBV-W42-S	0.004	0.077	0.001
EBV-WW-D	0.004	0.081	0.001
EBV-TMP-SD	0.003	0.084	0.006
MBV-W42-SD	0.003	0.087	0.009
EBV-TMP-D	0.002	0.089	0.020
EBV-W42-S	0.001	0.090	0.099

Table 10. Effects contributing significantly (P<0.05) to total weight of lamb weaned

Trait	Partial R^2	Model R^2	P
Total milk production	0.080	0.080	0.000
EBV-TWW-D	0.059	0.139	0.000
EBV-TMP-D	0.012	0.151	0.000
EBV-WW-D	0.011	0.162	0.000
MBV-W42-D	0.008	0.170	0.000
EBV-TWW-SD	0.003	0.173	0.003
MBV-W42-SD	0.003	0.176	0.003
EBV-W42-D	0.002	0.178	0.012
EBV-WW-SD	0.001	0.179	0.090

From Tables 8 to 10 it follows that including maternal breeding value for 42-day weight of the sire of the dam (MBV-W42-SD), breeding value for total weight of lamb weaned of the sire of the dam (EBV-TWW-SD), maternal breeding value for 42-day weight of the dam (MBV-W42-D), maternal breeding value for weaning weight of the dam (MBV-WW-D), as well as breeding value for total weight of lamb weaned of the dam (EBV-TWW-D), should increase early body weights and consequently total weight of lamb weaned. Breeding value for either of the early body weights of the sire (EBV-W42-S or EBV-WW-S) could be included to address direct genetic aspects of early growth if required. An improvement in milk production could be expected due to the high positive correlation estimated between maternal effects for early body weights and direct effects for milk production.

The effect on body weight at an older age when including these parameters instead of body weight *per se*, are currently under investigation. Preliminary results indicated that including maternal breeding values for early body weights in the breeding plan in a flock where there is a positive covariance between direct and maternal effects for body weight, should result in a correlated increase in the older body weight. Genetic correlations of 0.53 ± 0.10 and 0.53 ± 0.08 respectively were estimated for the Carnarvon Afrino flock between maternal effects for 42-day weight or weaning weight on the one hand and direct genetic effects for 14-month weight on the other hand (Snyman, 2013).

CONCLUSIONS

Milk production was only influenced by direct genetic effects in the flocks used in this study. High genetic correlations were obtained between total milk production and total weight of lamb weaned in three flocks and early body weights in all four flocks.

Including maternal breeding values for early body weights of the dam and maternal grandsire in the selection objective would have a positive effect on early growth, total weight of lamb weaned and milk production.

ACKNOWLEDGEMENTS

The authors wish to convey their sincere appreciation to the personnel at Grootfontein Agricultural Development Institute, Carnarvon Experimental Station, Cradock Experimental Station and Elsenburg Institute for Animal Sciences for their valuable contribution in the execution of the project.

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