Short Communication

The possible genetic improvement of reproduction and survival rate in Afrino sheep using a threshold model

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The objective of this study was to estimate heritability and breeding values on the underlying scale for different reproductive traits and survival rate in Afrino sheep to ascertain whether they can be improved by selection on estimated breeding values obtained under a threshold model. Data collected on the Carnarvon Afrino flock over the period 1969 to 1994 were analysed by means of a GFCAT set of programmes. The reproductive traits analysed included fertility (whether a ewe lambed or not; 0 or 1), litter size (number of lambs born to a ewe mated; 0, 1, 2 or 3), fecundity (number of lambs born to a ewe that lambed; 1, 2 or 3), number weaned (number of lambs weaned to a ewe mated; 0, 1, 2 or 3) and survival rate from birth to weaning (whether a lamb born alive, was dead or alive at weaning; 0 or 1). Heritabilities on the underlying scale of 0.20, 0.27, 0.42, 0.19 and 0.02 were estimated for the respective traits. The results suggest that reproduction rate, but not survival rate, can be increased in Afrino sheep by selection on breeding values estimated on the underlying scale applying a threshold model.

Die doel van hierdie studie was om oorerflikhede en teelwaardes op die onderliggende skaal vir verskillende reproduksie-eienskappe en lamoorlewingstempo in Afrinoskape met behulp van 'n drumpelwaarde model te beraam. Data wat vanaf 1969 tot 1994 op die Carnarvonse Afrinokudde ingesamel is, is met behulp van 'n GFCAT-program ontleed. Die volgende eienskappe is ontleed, naamlik vrugbaarheid (of 'n ooi gelam het of nie; 0 of 1), aantal lammers gebore (aantal lammers gebore per ooi gepaar; 0, 1, 2 of 3), fekunditeit (aantal lammers gebore per ooi gelam; 1, 2 of 3), aantal lammers gespeen (aantal lammers gespeen per ooi gepaar; 0, 1, 2 of 3) en lamoorlewingstempo (of 'n lam wat lewendig gebore was, dood of lewendig is met speen; 0 of 1). Oorerflikhede op die onderliggende skaal van 0.20, 0.27, 0.42, 0.19 en 0.02 is vir die onderskeie eienskappe beraam. Die resultate dui daarop dat reproduksietempo, maar nie lamoorlewingstempo nie, verhoog kan word in Afrino skape deur seleksie gebaseer op teelwaardes beraam op die onderliggende skaal met behulp van 'n drumpelwaardemodel.

Keywords : Afrino sheep, threshold model, sire evaluation, reproductive traits

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Reproduction and survival rate are traits that are universally important in any environment or livestock production system. Other traits vary in importance and can, in some situations, be of little or no value. Reproductive traits and survival rate are, by definition, threshold traits. Threshold traits are not continuous in their expression, but exhibit categorical phenotypes. In these cases the pheno-

type is expressed in two or more distinct, mutually exclusive and exhaustive categories. If a polygenic mode of inheritance is assumed for these traits, it is evident that the threshold concept (Wright, 1934) as discussed *inter alia* by Dempster & Lerner (1950), Bulmer (1980) and Gianola (1982) should apply.

In this case Best Linear Unbiased Prediction (BLUP) does not yield the maximum likelihood estimate of the best predictor since the data and genetic values to be predicted do not follow joint normal distributions. These variables are not normally distributed and a single heritability for the trait does not exist on the discontinuous scale. Gianola (1982) states that the main theoretical reason for not using BLUP with categorical data is that breeding values and residuals are not independent of each other and their marginal distributions are difficult to specify. Threshold procedures should therefore be more suitable when analysing reproduction data, as threshold model sire breeding values are expressed in units of residual standard deviation of the underlying scale.

The objective of this study was to estimate heritability and breeding values on the underlying scale for different reproductive traits and survival rate in Afrino sheep to ascertain whether they can be improved by selection on estimated breeding values.

Data collected on the Carnarvon Afrino flock over the period 1969 to 1994 were used for this study. A detailed description of the management and selection procedures followed in this flock is given by Snyman *et al.* (1995).

The reproductive traits analysed included fertility (whether a ewe lambed or not; 0 or 1), litter size (number of lambs born to a ewe mated; 0, 1, 2 or 3), fecundity (number of lambs born to a ewe that lambed; 1, 2 or 3), number weaned (number of lambs weaned to a ewe mated; 0, 1, 2 or 3) and survival rate from birth to weaning (whether a lamb born alive, was dead or alive at weaning; 0 or 1).

Data were edited to include only sires with more than 10 progeny. The number of data records, number of sires, categories and thresholds for each of the traits analysed, are summarized in Table 1.

Table 1 Description of the data set

Trait	No. of records	No. of sires	No. of categories	No. of thresholds
Fertility	3580	113	2	1
Litter size	3580	113	4	3
Fecundity	3186	108	3	2
Number weaned	3580	113	4	3
Survival rate	4816	148	2	1

Data were analysed by means of the GFCAT set of programmes, developed by Konstantinov (1992). GFCAT is a set of programmes for the analysis of mixed threshold models with support for REML-type variance components estimation based on the methods of Gianola & Foulley (1983). Under these models, the respective traits occur as a result of an underlying unobserved phenotype exceeding a given threshold (Konstantinov *et al.*, 1994). The unobserved continuous phenotypes are assumed to be normally distributed. For each trait a vector, μ, of means corresponding to subpopulations determined by combinations of levels of fixed **b** and random **s** factors, is modelled as :

$$\mu = \mathbf{Xb} + \mathbf{Zs}$$

where
μ is a vector of underlying means,

b is a vector associated with the effects of year-season (26), age of dam in years (6) and birth status (3; for survival rate only),

s is a vector of sire effects and

X and Z are design matrices.

The **s** effects are assumed to be normally distributed, with $E(\mathbf{s}) = 0$ and $Var(\mathbf{s}) = A\sigma^2_s$, where A is a numerator relationship matrix.

Solutions for thresholds, **b** and **s** were computed as described by (Konstantinov *et al.*, 1994). All traits were analysed separately.

Solutions for thresholds, age of dam and birth status are presented in Table 2. As the underlying scale is unknown, these solutions are expressed in units of residual standard deviations of the underlying variable.

Table 2 Thresholds and solutions for age of dam and birth status

	Fertility	Litter size	Fecundity	Number weaned	Survival rate
Thresholds					
1	0.0000	0.0000	0.0000	0.0000	0.0000
2		1.6258	2.2994	1.4742	
3		3.7969		3.5387	
Age of dam					
2	1.5079	0.9872	–0.4011	0.7357	0.0552
3	1.7746	1.4092	0.0686	1.1960	0.2264
4	1.8913	1.6067	0.3210	1.3769	0.1997
5	1.9096	1.6379	0.3327	1.3565	0.1313
6	1.7220	1.5268	0.2726	1.2606	0.0000
Birth status					
1					1.4450
2					1.1137
3					0.8872

Fertility, litter size, fecundity and number weaned increased with an increase in age of dam from two to four years, after which it showed a slight decline. The effect of age of dam on survival rate showed no distinct pattern. As expected, survival rate decreased with increasing birth status of the lambs.

Estimates of sire variances and heritabilities for the different traits are supplied in Table 3.

Very little threshold heritability estimates for reproduction traits are available in the literature. Jorgensen (1994) reported heritability estimates for litter size at birth and litter size at weaning ranging from 0.14 to 0.19 and 0.09 to 0.27 respectively, while Konstantinov *et al.* (1994) obtained an estimate of 0.24 for litter size at birth in Dormer sheep. Threshold model heritabilities obtained with the GFCAT-programme by Olivier *et al.* (1998) for a Merino flock at the Carnarvon experimental station accords well with those estimated for Afrino sheep in this study. These results, indicating that reproduction rate in Afrino sheep can be improved genetically by selection for multiple births, are in accordance with previous findings in the literature (Fogarty, 1995).

Table 3 Estimates of sire variances and heritabilities on the underlying scale

Trait	Sire variance	Heritability
Fertility	0.05342	0.20
Litter size	0.07366	0.27
Fecundity	0.11832	0.42
Number weaned	0.04919	0.19
Survival rate	0.00515	0.02

Virtually no sire direct (genetic) influence was exhibited for survival rate. This is also in accordance with the results obtained by Olivier *et al.* (1998) for Merino sheep.

These results indicate that selection for improved reproduction performance should be based on fecundity or litter size at birth (combination of fertility and fecundity). These traits have a higher heritability than fertility, and an increased selection intensity with these traits is possible, as they have more than one threshold. Selection intensity is usually lower in traits with only one threshold, compared to those with two or three thresholds or continuous traits (Bourdon, 1997). This is especially true when a larger or smaller proportion need to be selected than the number of animals available of the favourable phenotype. Selection response would be greater if animals closer to the threshold on the underlying liability scale could be identified and selected. This is, however, not possible as there are, in the case of fertility, only two distinct phenotypes. This problem could to a large extent be eliminated by selection based on threshold estimated sire breeding values for the trait in question. Using estimated sire breeding values would not only increase selection intensity, but also accuracy of selection.

Table 4 shows features of the sire genetic evaluation for the different traits. It is interesting to note that the sires with the worst breeding values for litter size, fecundity and number weaned had

Table 4 Breeding value estimates[a] for the best and the worst sire for each trait

Trait	Best sire	Worst sire
	(n)[b]	(n)
Fertility	0.7097	–0.2943
	(79)	(28)
Litter size	0.5564	–0.2947
	(32)	(55)
Fecundity	0.5383	–0.5933
	(15)	(28)
Number weaned	0.4025	–0.2216
	(7)	(55)
Survival rate	0.0310	–0.0440
	(48)	(39)

[a] Expressed in units of residual standard deviations of the underlying scale; [b] No. of records

more records than the sires with the best breeding values for the respective traits, which can easily happen in practice if the breeding values are unknown.

The main disadvantage of selection based on estimated sire breeding values is that these EBVs for reproductive traits are only available after the first parity of a sire's first daughters. In normal sheep enterprises, this would be when the sire is already four years of age. At that stage, the rams have already been used for two years in the flock. The most important application of sire EBVs in practice would be in the identification of merit rams for use as national AI-sires.

The results suggest that reproduction rate, but not survival rate, can be increased in Afrino sheep by selection on breeding values estimated on the underlying scale applying a threshold model.

References

BOURDON, R.M., 1997. Understanding Animal Breeding. Prentice-Hall.

BULMER, M.G., 1980. The mathematical theory of quantitative genetics. Claredon Press, Oxford.

DEMPSTER, E.R. & LERNER, I.M., 1950. Heritability of threshold characters. *Genetics* 35, 212.

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(3), 101.

GIANOLA, D., 1982. Theory and analysis of threshold characters. *J. Anim. Sci.* 54, 1079.

GIANOLA, D. & FOULLEY, J.L., 1983. Sire evaluation for ordered data with a threshold model. *Genet. Sel. Evol.* 15, 201.

JORGENSEN, J.N., 1994. Estimation of genetic parameters for litter size in sheep using a non- linear method. *Acta Agric. Scand. Seet. A. Animal Sci.* 44, 8.

KONSTANTINOV, K.V., 1992. GFCAT: User's guide. University of the Orange Free State, Bloemfontein.

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(4), 119.

OLIVIER, W.J., SNYMAN, M.A., ERASMUS, G.J. & VAN WYK, J.B., 1998. Genetic parameters for fitness traits in South African Merino sheep. *Livest. Prod. Sci.* (In press)

SNYMAN, M.A., ERASMUS, G.J. & VAN WYK, J.B., 1995. Non-genetic factors influencing growth and fleece traits in Afrino sheep. *S. Afr. J. Anim. Sci.* 25(3), 70.

WRIGHT, S., 1934. An analysis of variability in number of digits in an inbred strain of guinea pigs. *Genetics* 19, 506.