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Article

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Abstract

Maternal influence on growth of artificially reared Sahiwal cattle was investigated using data from the National Sahiwal Stud (NSS). Growth records on animals born from 1973 to 2004 were used for the analysis. The traits considered were; birth weight (BW, kg), weaning age at 42kg weight (WA1, days), weaning age at 55 kg weight (WA2, days), weaning age of all animals weaned at 42 kg and 55 kg combined (WA, days), branding age at 130 kg (BA, days), preweaning daily gain to WA1 (DG1, g/day), preweaning daily gain to WA2 (DG2, g/day), preweaning gain from combined data (DG, g/day), post weaning daily gain to BA (PDG, g/day) and average daily gain from birth to BA (ADG, g/day). Maternal effects were important for BW but low to almost absent for pre- and post weaning traits. Ignoring maternal effects substantially increased the direct additive genetic variance and hence direct heritability estimates. Fitting maternal effects reduced direct heritability from 0.34 to 0.15 for BW. Genetic correlations between direct and maternal effects were positive and high for BW (0.66 and 0.72). The low and absence of maternal effects on pre- and post weaning traits shows that improvement in these traits would be more efficiently achieved if selection was based on the animal's direct genetic potential. The influence of maternal effects on BW of artificially reared Sahiwal cattle indicates that inclusion of these effects in analysis of BW will result in accurate parameter estimates which would improve selection efficiency.

Introduction

The Sahiwal breed (a *Bos indicus*) is known to have the greatest potential for growth under tropical environments (Trail and Gregory, 1981). Growth traits are of great economic importance due to their direct influence on profitability. Variation in early growth traits has been attributed to both direct and maternal genetic effects (Meyer, 1992; Campelo *et al*., 2004). In most *Bos indicus* cattle breeds, maternal effects are always ignored in genetic evaluations. Maternal effects if not fitted for, when they are present, normally increases the proportion of variance that is due to additive genetic variance and hence direct heritability (Maniatis and Pollot, 2003). To improve on the efficiency of selection, all components of genetic variance including direct, maternal and permanent maternal effects need to be fully accounted for (Campelo *et al*., 2004).

Sahiwal is a dual purpose cattle breed kept for both milk and meat production. In most production systems utilising dual purpose cattle breeds, calves are usually separated from their dam and reared artificially through bucket feeding. In such case the maternal environmental influence is expected to be minimal. Low maternal influence on preweaning traits of artificially reared calves has been reported for *B. indicus* breeds of cattle (e.g. Khan *et al.,* 1999; Demeke *et al.,* 2003). However, information on the magnitude of maternal influence on growth of artificially reared Sahiwal calves in semi-arid environment is scarce. The objective of this study was to estimate (co) variance components and genetic parameters for growth traits of Sahiwal cattle in semi-arid Kenya.

Material and methods

Data on growth of Sahiwal cattle were obtained from the National Sahiwal Stud (NSS) maintained by National Animal Husbandry Research Centre, Naivasha. Details of climate and herd management have been described by Muhuyi *et al.* (1999). The traits considered were; birth weight (BW, kg), weaning age at 42 kg weight (WA1, days), weaning age at 55 kg weight (WA2, days), weaning age of all animals weaned at 42 kg and 55 kg combined (WA, days), branding age at 130 kg (BA, days), preweaning daily gain to WA1 (DG1, g/day), preweaning daily gain to WA2 (DG2, g/day), preweaning gain from combined data (DG, g/day), post weaning daily gain to BA (PDG, g/day) and average daily gain from birth to BA (ADG, g/day).

Growth records on animals born from 1973 to 2004 were used for the analysis. Preliminary least squares analyses of variance were conducted using GLM procedures of SAS (1998) to determine the most appropriate fixed effect model to describe the data. The model consisted of all main effects and first order interaction of year and season. Fixed effects of sex, year and season of birth or weaning (for BA, PDG and ADG) were fitted in the subsequent animal model analysis in which the error term was assumed to be normally distributed with zero variance. Dam age and weight post *partum* were fitted as linear covariables. Apart from BW, subsequent calf weights were fitted as linear covariables in the analysis of the other traits. Year of birth ranged from 1973 to 2004 while year of weaning ranged from 1973 to 2005. There were four seasons classified as January to March for the primary dry season; April to June for the main wet season; July to September and October to December for the secondary dry and wet seasons, respectively. The mean dam age in years was 6.6 and ranged from 2.2 to 22.3 while the mean post *partum* weight in kg was 380 and ranged from 203 to 560kg. Number of records and summary statistics with means, standard deviation and coefficient of variation are presented in Table 1.

Table 1–Number of records, means, standard deviations (SD) and coefficient of variation (CV) for growth traits

	Trait[a]									
	BW (kg	WA1 (da	WA2 (days)	WA (da	BA (da	DG1 (g/day)	DG2 (g/da	DG (g/d	PDG (g/da	ADG (g/da
No. records	10145	3571	2877	6447	2980	3571	2877	6447	2980	2980
Mean	21.9	79.4	144.0	108.2	376.1	276.6	243.9	262.0	322.0	302.0
SD	2.5	19.3	18.8	19.2	38.9	22.0	12.0	21.5	27.2	15.2
CV (%)	10.2	24.3	13.0	17.7	10.1	7.9	4.9	8.2	9.5	5.0

[a]See text for description of traits

Estimates of (co) variance components and genetic parameters were obtained using the DFREML programme (Meyer, 1998) fitting univariate animal models. The following six models were fitted:

Model 1 $\mathbf{y = Xb + Z_1a + e}$ (1)

Model 2 $\mathbf{y = Xb + Z_1a + Z_3c + e}$ (2)

Model 3 $\mathbf{y = Xb + Z_1a + Z_2m + e}$ (3)

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

Model 4 $\mathbf{y = Xb + Z_1a + Z_2m + Z_3c + e}$ (5)

with $\text{cov}(\mathbf{a, m}) = 0$, $\text{var}(\mathbf{c}) = \mathbf{I}_{NC}\sigma^2_c$ and $\text{var}(\mathbf{e}) = \mathbf{I}_n\sigma^2_e$

Model 5 $\mathbf{y = Xb + Z_1a + Z_2m + e}$ (4)

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

Model 6 $\mathbf{y = Xb + Z_1a + Z_2m + Z_3c + e}$ (6)

with $\text{cov}(\mathbf{a, m}) = \mathbf{A}\sigma_{am}$, $\text{var}(\mathbf{c}) = \mathbf{I}_{NC}\sigma^2_c$ and $\text{var}(\mathbf{e}) = \mathbf{I}_n\sigma^2_e$

where **y** is a vector of observations on the specific trait of the animal, **b, a, m** and **c** are vectors of fixed effects including covariables, direct additive genetic effects, maternal additive effects and maternal permanent environmental effects, respectively, $\mathbf{X}$, $\mathbf{Z_1}$, $\mathbf{Z_2}$ and $\mathbf{Z_3}$ are corresponding incidence matrices relating the effects to **y**, **e** is the vector of residual error, **A** is the numerator relationship matrix, **I** is the identity matrix, NC is the number of dams, n is the number of animals in the analysis including parents without records, σ_{am} is the direct additive genetic by maternal genetic covariance and σ^2_c and σ^2_e are the maternal permanent environmental and residual error variances, respectively. Likelihood ratio tests were carried out to determine the best model to fit the growth data. Likelihood ratio was calculated as deviations from log likelihood of model 1 and the other competing models. The likelihood ratio was compared with the tabulated chi-square statistics with the number of parameters taken as the degrees of freedom.

Results and discussion

The estimates of variance components and genetic parameters for each trait using different models are presented in Table 2. Maternal effects had an influence on BW and ignoring them (Model 1) substantially increased the direct additive genetic variance and hence direct heritability estimates. Log likelihood did not increase when maternal effects were fitted but including permanent maternal effects (c^2) or accounting for direct-maternal covariance in the model substantially reduced the direct heritability estimates but did not improve on the log likelihood. The best model to estimate genetic parameters for BW based on the likelihood ratio test was model 1, a model that included direct genetic effects. Maternal heritability (m^2) estimate for BW from model 3 was (0.10) and higher than estimates reported in separate studies for *B. indicus* breeds (Haile-Mariam and Kassa-Marsha, 1995; Khan *et al*., 1999; Demeke *et al*., 2003). In the Boran breed, maternal effects do not influence BW (Wasike, 2006).

Estimates for permanent maternal effects were low (0.04 to 0.07) and consistent with reports for artificially fed *B. indicus* cattle (Khan *et al*. 1999; Demeke *et al*. 2003). Maternal variance on BW in Sahiwal cattle is due to cytoplasmic effects. However, permanent maternal effects accounted for very little variation suggesting minimal effects of uterine environment provided by the dams to their offspring during embryonic development. Correlation between direct and maternal effects was positive and high (0.66 and 0.72). This is in agreement with Demeke *et al.* (2003). Favourable relationship between genetic effects implies that they can be selected for simultaneously.

Among the 3 weaning age traits, maternal effects were only evident in WA2 where estimates were 0.01 and 0.03, respectively for $m^2$and c^2, respectively (Table 2). Models with direct-maternal correlation were not fitted where maternal effects were not important. Fitting maternal model for WA2 improved the likelihood but did not change h^2 (0.09). The results of this study are contrary to studies in beef cattle that reported effects of maternal influence on weaning weight (WW) (Meyer, 1992; Gutierrez *et al*. 1997; Ferreira *et al*. 1999). This could be due to the fact that the calves in the present study were artificially fed and maternal environment removed at birth and any presence of maternal effects could only be explained as carryover effects from the residual prenatal care of the dam. Low m^2 estimates (0.04) for WW have been reported in bucket feed Boran cattle (Demeke *et al*. 2003). On the other hand, the likelihood ratio tests did not improve for c^2 effects. Accounting for direct-maternal correlation increased both h^2 and m^2 resulting into a negative correlation (-0.57) but the log likelihood did not improve. Antagonism between direct and maternal effects has been reported for WW for zebu beef cattle (Gutierrez *et a*l., 1997). The implication is that selection for increased maternal effects would result in depressed direct genetic potential of the animals.

Maternal effects were not important for BA, DG1, DG2, DG, PDG and ADG. Permanent maternal effects were minimal (0.01-0.06) and did not improve the log likelihood. Presence of maternal effects on pre-weaning gains was reported in bucket fed Boran cattle (Demeke *et al*., 2003). As explained earlier, since maternal effects are attributed to the dam environment, minimal maternal influence was expected in artificially reared calves and this coupled with the early weaning (42 and 55kg) could explain the absence of maternal effects for most of the pre-weaning growth traits.

Conclusions

This study has demonstrated the importance of maternal effects for BW in the Sahiwal cattle and if ignored will lead to bias in the estimates of direct heritability. Use of models that account for maternal effects in analysis of BW will therefore result in accurate parameter estimates which would improve selection efficiency. On the other hand, there is a high and positive genetic correlation between direct and maternal effects implying that selection to improve direct genetic potential of the animal would result in improved maternal attributes. Given the low and absence of these effects on pre- and post weaning traits, improvement in these traits would be more efficiently achieved if selection was based on the animal's direct genetic potential.

Table 2–Estimates of variance components and genetic parameters for growth in Sahiwal cattle at Naivasha.

Trait	Models	σ^2_a	σ^2_m	σ^2_c	σ_{am}	σ^2_e	σ^2_p	h^2	m^2	r_{am}	c^2	h^2_T	Δ log L[b]
BW	1	1.68				3.30	4.98	0.34				0.34	0
	2	1.05		0.35		3.41	4.81	0.22			0.07	0.22	-1235.66
	3	0.72	0.48			3.63	4.82	0.15	0.10			0.20	-3973.58
	4	0.79	0.22	0.23		3.54	4.78	0.16	0.05		0.05	0.19	-3966.57
	5	0.63	0.27		0.27	3.68	4.85	0.13	0.06	0.66		0.24	5.01
	6	0.67	0.13	0.18	0.21	3.61	4.81	0.14	0.03	0.72	0.04	0.22	3.60
WA1	1	9.94				362.49	372.43	0.03				0.03	0
	2	10.07		0.00		362.38	372.45	0.03			0.00	0.03	-248.17
	3	9.93	0.00			362.50	372.43	0.03	0.00			0.03	-2120.57
WA2	1	36.03				316.97	353.00	0.10				0.10	0
	2	30.49		9.04		312.77	352.29	0.09			0.03	0.09	-49.65
	3	33.16	3.38			316.32	352.86	0.09	0.01			0.10	-1651.12
	4	30.72		8.90		312.70	352.32	0.09	0.00		0.03	0.09	-1542.10
	5	43.31	12.83		-13.42	310.46	353.18	0.12	0.04	-0.57		0.08	0.92
WA	1	20.81				346.27	367.09	0.06				0.06	0.0
	2	20.94		0.00		346.17	367.11	0.06			0.00	0.06	0.07
	3	19.88	1.22			345.95	367.05	0.05	0.00			0.06	-1495.27
DG1	1	17.68				465.70	483.38	0.04				0.04	0.00
	2	17.68		0.00		465.70	483.38	0.04			0.00	0.04	28.46
	3	17.87	0.00			465.54	483.41	0.04	0.00			0.04	-1552.65
DG2	1	4.73				138.24	142.97	0.03				0.03	0
	2	4.36		1.57		137.02	142.95	0.03			0.01	0.03	15.15
	3	4.79	0.00			138.19	142.98	0.03	0.00			0.03	-1575.27
	4	4.37	0.00	1.57		137.01	142.95	0.03	0.00		0.01	0.03	-1533.87
DG	1	19.26				444.30	463.56	0.04				0.04	0
	2	17.29		6.95		439.12	463.37	0.04			0.02	0.04	0.69
	3	19.47	0.00			444.13	463.59	0.04	0.00			0.04	-1495.41
	4	17.49	0.00	7.07		438.84	463.41	0.04	0.00		0.02	0.04	-1494.76
BA	1	236.35				1276.19	1512.54	0.16				0.16	0
	2	221.17		50.92		1239.17	1511.25	0.15			0.03	0.15	42.06
	3	236.51	0.00			1276.07	1512.58	0.14	0.00			0.16	-1588.02
	4	221.18	0.00	50.89		1239.18	1511.25	0.16	0.00		0.03	0.15	-1508.32
PDG	1	144.67				592.25	736.93	0.20				0.20	0
	2	112.98		41.79		576.17	730.94	0.15			0.06	0.15	-37.67
	3	132.66	9.48			593.17	735.31	0.18	0.01			0.19	-1602.95
	4	113.56	0.00	41.53		575.96	731.05	0.16	0.00		0.06	0.16	-1559.59
ADG	1	5.09				226.32	231.41	0.02				0.02	0
	2	5.3		0.00		226.14	231.43	0.02			0.00	0.02	95.81
	3	5.22	0.00			226.21	231.42	0.02	0.00			0.02	-1404.50

[a] See text for descriptions of trait

[b] Δ log L, the deviations in log likelihood of competing models

σ^2_a -direct additive genetic, σ^2_m, - maternal genetic, σ^2_c, - permanent maternal, σ^2_p, - phenotypic, and σ^2_e, - Error variances, σ_{am}, - direct-maternal, h^2 - covariance direct heritability, m^2 -maternal heritability, r_{am} -direct-maternal

Correlation, c^2 - permanent maternal effects, h^2_T - and total heritability

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References

Campelo J.E.G., Lopes P.S., Torres R.A., Silver L.O.C., Euclydes R.F., Araujo C.V. and Pereira C.S. (2004). Maternal effects on the genetic evaluation of Tabapua beef cattle. Genetics and Molecular Biology. 27, 517-512.

Demeke S., Neser F.W.C. and Schoeman S.J. (2003). Variance components and genetic parameters for early growth traits in a mixed population of purebred Bos indicus and crossbred cattle. Livestock Production Science. 84 11-21.

Ferreira G.B., MacNeil M.D. and Van Vleck L.D. (1999). Variance components and breeding values for growth traits from different statistical models. Journal of Animal Science. 77, 2641-2650.

Gutierrez J.P., Canon J. and Goyache F. (1997). Estimation of direct and maternal genetic parameters for preweaning traits in the Austriana de los valles beef cattle breed through animal and sire models. Journal of Animal Breeding and Genetics. 114, 261-266.

Haile-Mariam M. and Kassa-Marsha H. (1995). Estimates of direct and maternal (co)variance components of growth traits in Boran cattle. Journal of Animal Breeding and Genetics. 112, 43-52.

Khan U.N., Dahlin A., Zafar A.H., Saleem M., Chaudhry M.A. and Philipsson J. (1999). Sahiwal cattle in Pakistan: genetic and environmental causes of variation in body weight and reproduction and relationship to milk production. Animal Science. 68, 97-108.

Maniatis N. and Pollott G.E. (2003). The impact of data structure on genetic (co)variance components of early growth in sheep, estimated using animal model with maternal effects. Journal of Animal Science. 81, 101-108.

Meyer K. (1992). Variance components due to direct and maternal effects for growth traits of Australian beef cattle. Livestock Production Science. 31, 179-204.

Meyer K. (1998). DFREML. Version 3.0β. User Notes, pp 6-22.

Muhuyi W.B., Lokwaleput I. and Sinkeet S.N. (1999). Conservation and utilisation of the Sahiwal cattle in Kenya. FAO Animal Genetics Research Information. 26, 35-44.

Trail J.C.M. and Gregory K.E. (1981). Sahiwal cattle: an evaluation of their potential contribution to milk and beef production in Africa. ILCA, Monogram No. 3, ILCA, Addis Ababa, Ethiopia.

Wasike C.B. (2006). Genetic evaluation of growth and reproductive performance of Kenya Boran Cattle. Msc thesis, Egerton University, Njoro, Kenya.