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Environmental and genetic components influencing mature cow weight in Tswana cattle selected for early growth traits

M. I. Keoletile[1, 2], S. D. Mulugeta [2], E. Rakwadi [1], P. Kemoreng[1], T. M. Sebolai[1, 2], K. E. Ravhuhali [2], and O. Mojanaga[1]

[1] National Agricultural Research and Development Institute, Private Bag 0033, Sebele, Gaborone, Botswana
[2]Department of Animal Science, Faculty of Agriculture, Science and Technology, North West University, Private Bag X2046, Mmabatho 2735, Mahikeng, South Africa

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The objective of this study was to determine the environmental and genetic factors influencing mature cow weight (MCW) trait in Tswana cattle breed. Analyses of environmental and genetic effects for mature cow weight trait were performed using 19301 records of Tswana cows born between 1996 and 2010 from 610 dams and 137 sires in 54 contemporaries. Mature cow weight trait was analysed using repeatability model. The significant environmental effects for MCW were selection line, cow age and contemporary group. Heritability estimate for mature cow weight traits was 0.26±0.03. Genetic correlations between growth traits and MCW ranged from 0.15±0.17 between BWT and MCW to 0.84±0.19 between YWT and MCW. Phenotypic correlations between growth traits and MCW ranged from 0.15±0.04 between BWT and MCW to 0.31±0.03 between EWT and MCW. The existence of significant genetic variability and moderate repeatability in MCW trait coupled with high genetic correlation between this trait and early growth traits suggest that caution should be exercised when selecting for growth traits to avoid undesirable resultant change in mature cow weight trait.

Key words: Selection, cow weight, genetic correlations, heritability, repeatability model.

INTRODUCTION

Mature body weight and milk production potential are well known essential mechanisms in determining the production competence of beef cows (McMorris et al., 1986; Montaño-Bermudez and Nielsen, 1990; Miller and Wilton, 1999; Zindove et al., 2015) and cows with high mature weight require more energy for maintenance. As a consequent, increasing mature cow weight (MCW) should generally be considered undesirable for the breeding herd as Fiss and Wilton (1989) asserted. In addition, the inclusion of mature cow size in selection programme to improve feed efficiency of the cow herd has been emphasised (Garrick, 2010; Crook et al., 2010). Fiss and Wilton (1989) further added that elevated maintenance cost associated with large mature cows is detrimental in any breeding program. Mature cow weight can therefore be considered in genetic evaluation together with some genetically correlated traits measured earlier in life to account for culling in field data (Kaps et al., 1999). The aim of this study was therefore to investigate the impact of mass selection for weaning

*Corresponding author. E-mail: mikeoletile@gmail.com.

Table 1. Summary statistics of the data used for analysis of mature cow weight.

Observation	No. of observations	Average	SD	Min	Max
Total number of records	19301				
Dams	610				
Sires	137				
Number of generations	4				
Contemporary group	54				
Cow weight (kg)		428.7	69.9	157	670
Cow age (years)		7.2	2.8	2.0	17.6

Table 2. Least square means (± S.E.) for selection lines.

Selection line	Cow weight (kg)
S2	445.98±4.62[a]
S1	441.16±4.62[b]
S3	393.93±4.71[c]

[a,b,c] means with different superscript differ significantly (P<0.05), S.E. = standard error, S1= selection for weaning weight, S2 = selection for 18 months weight and S3 = unselected control population.

weight (S1) and 18-months weight (S2) on mature cow weight compared to the unselected control line (S3) in Tswana cattle.

MATERIALS AND METHODS

Data obtained from Department Of Agricultural Research in Botswana consisting of records as described in the previous study which focused the estimates of covariance components and genetic parameters for growth traits, was extracted for parameters as listed in Table 1 and used for cow weight analysis. Experimental animals were generally grazed on veld as a main source of feed from birth to maturity and occasional supplemented with mineral/nutritional licks during severe draughts and dry winter seasons.

Using the records from data collected on selected Tswana cattle obtained from DAR as described above, analysis of mature cow weight was undertaken using a mixed model. The analyses were performed in such a way that they utilized the entire observations recorded for each cow. The fixed effects fitted for mature cow weight were selection line, contemporary group, cow age in years fitted as covariate (linear and quadratic) and the interaction between cow age and selection line. Contemporary group was derived by concatenating season and year of weighing. Variance and covariance components were estimated by fitting repeatability animal models to the data using the ASREML program (Gilmour et al., 2015). Genetic parameters were then derived from the variance components. Correlations between mature cow weight and early growth traits were estimated by fitting bivariate animal models. Mature cow weight for each cow was taken as the average of all the individual cow weight observations recorded at different parturition and weaning dates. Only animals with all the records for early growth traits (birth, weaning, yearling, and eighteen months weights) and mature cow weight traits were extracted and used for the estimation of correlations. The general form of the model for the estimation of variance components with their expected variance-covariance structure were outlined as follows:

$$Y = X\beta + Z_d u_d + Z_c u_c + \varepsilon$$

Where, Y = the observed mature cow weight trait; X = the incidence matrix relating fixed effects to the observations; β = vector of fixed effects; Z_d = incidence matrix relating direct additive genetic effects to the observations; Z_c = incidence matrix relating permanent environmental effects to the observations; u_d = a vector of random direct additive genetic effects; u_c = a vector of random permanent environmental effects and ε = a vector of random residual effects.

The random effects in the mixed models were assumed to have the following distributions:

$$[\mu_d', \mu_c', e']' \sim N[(0', 0', 0')', \Sigma]$$

$$\Sigma = \begin{bmatrix} A\sigma_d^2 & 0 & 0 \\ 0 & I_q\sigma_c^2 & 0 \\ 0 & 0 & I_n\sigma_e^2 \end{bmatrix}$$

Where; A is a numerator relationship matrix among all animals, σ^2_d is the direct genetic variance; I_q and I_n are identity matrices equal to the number of dams and number of animals with observation respectively; σ^2_c and σ^2_ε are permanent environment variance and error (temporary environmental) variance, respectively.

RESULTS AND DISCUSSION

Mature cow weight varied significantly with selection line. Mature cow weight among the selection lines ranged from 393.93±4.71 to 445.98±4.6 kg (Table 2). The lightest cow weight was observed in the unselected control line (S3) while the heaviest cow weight was detected in the eighteen months weight selection line (S2).

The results revealed that selection for weaning weight and eighteen months weight significantly increased mature cow weight. However, selection for eighteen months weight increased mature cow weight more than as selection for weaning weight did. The current results are consistent with the report by Nephawe (2004) that an

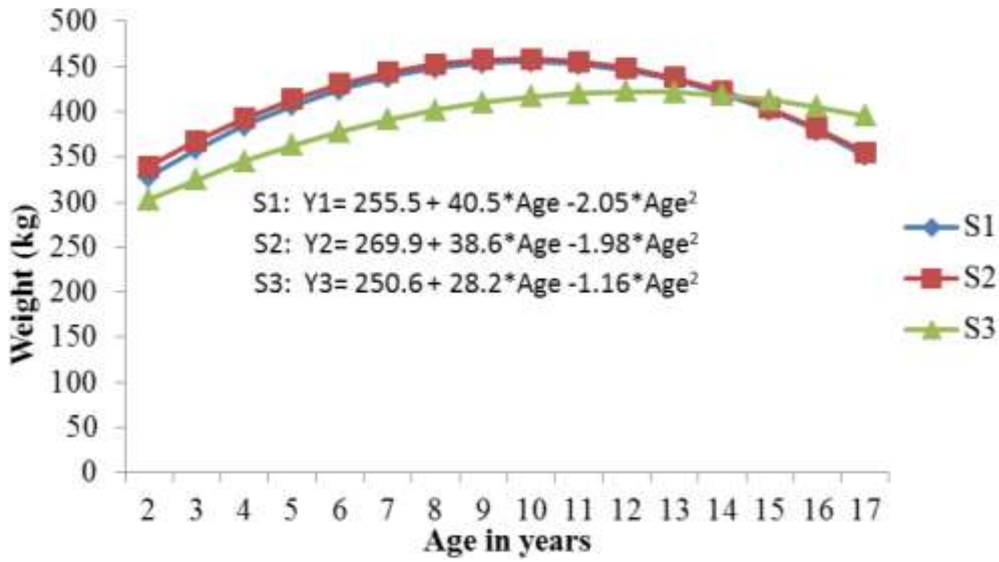

Figure 1. Predicted cow weight with age for the three selection lines (S1= selection for weaning weight, S2 = selection for 18 months weight and S3 = unselected control population).

increase in overall growth at saleable age of calves (weaning and slaughter weight) may increase mature cow size, which the author further stated is of concern in the beef production system due to the cost of energy required to maintain mature cow weight. Boligon et al. (2013) also reported positive and medium correlation between mature cow weight and both weaning and yearling growth traits in selected Nellore cattle. Furthermore, Boligon et al. (2010) and Forni et al. (2007) revealed that selection of young animals for greater weight may result in heavier animals at adult age owing to indirect correlated response.

Both linear and quadratic dam age significantly influenced mature cow weight and their effects varied with selection line. Cow weight increased linearly with the age of the cows at rates of 28.16±1.64, 38.65±0.48 and 40.46±0.5 kg per annum in S3, S1 and S2 lines, respectively. In the three lines, the cow weight reached a maximum value between 8 and 10 years of age and declined thereafter at rate of 1.16±0.10, 1.98±0.07 and 2.05±0.07 kg per annum in S3, S1 and S2 lines, respectively (Figure 1). In general, both the rates of increase and decrease in cow weight with age were significantly slower in control population than in the two selected lines.

The results agreed with the findings by Nephawe (2004) who reported that cow weights demonstrated an increasing trend at early ages, a flush pattern at intermediate ages, and a declining trend at latter ages. Crook *et al*. (2010) also revealed a quadratic relationship between age of cow (in years) and cow weight at calving and at weaning. The same authors further stated that cow weights at calving and at weaning amplified rapidly with age up to around six years, after which the rate of change with age diminished. Variation of cow age effect with selection line may be due to the fact that the magnitude of the influence of the two selection criteria differs, with eighteen months weight selection displaying more change. Therefore, the cow's loss of efficiency to mobilize nutrients towards production and maintenance as it ages coupled with deterioration on the grazing pasture mostly affected the animals from the selection lines with greater mature cow weight than those unselected control cows with less mature weight.

The results indicate that direct genetic, permanent and temporary environmental variances constituted significant proportions of the phenotypic variance of mature cow weight (Table 3). Direct genetic effect constituted 26% of the phenotypic variance while temporary environmental effect constituted 54%. Permanent environmental effect was accountable for 20% of the phenotypic variance, indicating that mature cow weight is moderately repeatable.

Direct heritability estimate of 0.26±0.03 currently obtained for mature cow weight of Tswana cattle is comparable with the range of values: 20.9±10.3, 19.3±9.3, 38.5±15.8 and 39.9±13.7 reported for Aberdeen Angus, South Devon, Limousin and Simmental, respectively by Roughsedge et al. (2005) and 0.29±0.04 and 0.37±0.04 reported for the South African Simmental by Crook et al. (2010). The significant heritability estimate indicates that the trait can be included in the selection indices for growth traits to control its unfavourable increase due to indirect response to selection for early growth traits in Tswana cattle. The ratio of the total phenotypic variance of cow weight due to permanent environmental effects associated with the cow accounted for approximately 20%. Mature cow weight in

Table 3. Variance components and heritability estimates (± S.E.) for cow mature weight.

Parameter	Mature cow weight
σ^2_a	799.55±105.95
σ^2_c	599.79±86.77
σ^2_e	1641.5±17.51
σ_P^2	3062.6±62.90
h^2_a	0.26±0.03
h^2_c	0.20±0.03
h^2_e	0.54±0.01
R	0.46±0.01

S.E. = standard error; σ^2_a= direct variance; σ^2_c= permanent environmental variance; σ^2_p= phenotypic variance; σ^2_e= error variance; h^2_a= direct heritability; h^2_c= permanent environmental proportion; r = repeatability (calculated as $\frac{\sigma_a^2+\sigma_c^2}{\sigma_P^2}$, Falconer and Mackay, 1996) h^2_e= temporary environmental proportion.

Table 4. Estimates (± S.E.) of genetic and phenotypic correlations between mature cow weight and early growth traits obtained from bivariate analysis.

Trait	Genetic correlation	Phenotypic correlation
BWT	0.15±0.17	0.15±0.04
WWT	0.56±0.13	0.27±0.03
YWT	0.84±0.19	0.19±0.03
EWT	0.58±0.13	0.31±0.03

S.E. = standard error, BWT = birth weight, WWT = weaning weight, YWT = yearling weight and EWT= eighteen months weight.

Tswana cattle appear to be a moderately repeatable trait as signified by the magnitude of total animal variance as a fraction of the phenotypic variance (46%). The results are slightly lower but comparable with those obtained by Nephawe (2004) for the Bonsmara cattle in South Africa, and Nephawe et al. (2004) using data of multi-bred beef cattle from the Germplasm Evaluation Project at the United States Meat Animal Research Centre. The results showed that temporary environmental variance which is attributable to random unaccountable effects accounted for a significant proportion of total phenotypic variance.

Phenotypic and genetic correlations between early growth traits (weaning, yearling and eighteen months weights) and mature cow weight were significantly different from zero. The genetic correlation amongst BWT and MWT was not substantially different from zero. Both genetic and phenotypic correlations between early growth traits and mature cow weight increased substantially from birth weight to eighteen months weight. All the estimates for genetic correlations were positive and higher than the corresponding phenotypic correlations except only for birth weight where the estimated values were practically similar (Table 4).

The current results are comparable to the findings by Roughsedge et al. (2005) who reported genetic correlations between mature cow weight and weaning weight and post weaning weight ranging between 0.66 and 0.98 for mixed beef cattle. Costa et al. (2011) reported genetic correlations ranging from 0.66±0.06 to 0.85±0.07 between mature cow weight and early growth weight traits (weaning and yearling weights) of Angus cattle. The stronger genetic correlations witnessed in the current results may indicate that more or less identical set of genes influence both mature cow weight and early growth traits. Similar to the values obtained in the current study, Rigatieri et al. (2012) reported low and positive phenotypic correlations ranging from 0.26±0.02 to 0.49±0.02 between mature cow weight and early growth traits (weaning and yearling weights) and weight gains (pre-weaning gain and yearling gain). The low phenotypic correlations between mature cow weight and early growth traits currently obtained reveals weaker environmental correlations among these traits which may be attributed to the variation in the influence of effects such as random environmental effects, dominance and epistasis genetic effects on these traits. The high genetic correlation between mature cow weight and early growth traits suggest that selection for increased early growth weights may lead to increased mature cow weight hence the trait should also be included in the selection program to avoid adverse indirect response.

Conclusion

Both selection line and cow age significantly influenced the mature cow weight trait in Tswana cattle. The two selection approaches resulted in heavier cows at maturity. The pattern of cow weight changes with age was higher and similar for the two selection lines as compared to the unselected control line. Mature cow weight exhibited significant genetic variability with moderate repeatability. Cow weight exhibited high genetic correlations with early growth traits (weaning, yearling and eighteen months weights). The current results suggest that in practicing mass selection for early growth traits, caution must be taken to avoid undesirable change in mature cow weight by considering mature cow weight trait as part of the selection index.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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