SYSTEMATIC ENVIRONMENTAL INFLUENCES AND VARIANCES DUE TO DIRECT AND MATERNAL EFFECTS AND TRENDS FOR YEARLING WEIGHT IN CATTLE

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ABSTRACT

Pedigree yearling records from 1021 local Tuli calves born at Matopos Research Station were analyzed for non genetic factors, genetic parameters and trends on the yearling weight. It was found that sire, year of birth, sex of calf, age of dam had significant effect ($p < 0.01$) on all growth trait. The inconsistency of literature estimates indicated the importance of estimation of environmental factors that affect yearling weight within specific experimental herds and environment. Model incorporating both direct and maternal additive genetic effect, covariance and correlations of direct-maternal and permanent environmental maternal effects was adopted for the study. Direct and maternal heritability estimates of 0.18 ± 0.001 and 0.04 ± 0.001 were observed, respectively. Direct-maternal genetic correlation was low and positive, 0.07± 0.012. The regression of average direct breeding values on year was almost zero and the regression of average maternal breeding values on year 0.03 kg/yr. Correction of environmental effects was necessary to increase accuracy for selection of yearling weight in local Tuli cattle. Maternal genetic effects should be included in a model of covariance components estimation at 12 months of age.

Keywords: Non genetic, Direct, Maternal trends, Yearling weight, Growth traits, Tuli cattle

INTRODUCTION

Yearling weight is the second most important trait after fertility and is of value in selecting both heifer and bull for replacement of the breeding herd (Sibanda, 1999) and its importance is also derived from its positive genetic correlation with mature weight which is the common interest of the farmers (Norris *et al.,* 2004). Definition and quantification of systematic environmental influences in domestic animals is a prerequisite to successful conduct of performance recording schemes (Bosso *et al.,* 2009). Adjustment of growth records for such factors provides a basis for the objective selection of animals and the design of breeding programs (Holland and Odde, 1992; Fields and Sand, 1994) and the knowledge of the extent of their effects on weight traits enable development of effective management systems for increased beef production.

Plans to implement genetic improvement programmes which utilize adapted genotypes of indigenous cattle in Sub Saharan Africa is the only way to secure sustainable beef production meant for the local population. Indigenous livestock breeds have always played an important role in the lives of people of Sub Saharan Africa (Bosso *et al.,* 2009), however information on genetic parameters which are population specific are scanty for Sanga cattle herds indigenous to East, Central and Southern Africa (Beffa, 2005). Such information on the nature and magnitude of population parameters(i.e. variance components and heritabilities) for these cattle herds are needed for effective designing of breeding programmes and to estimate breeding values for traits of relevance to beef producers (Intaratham *et al.,* 2008).

Evaluation of genetic and environmental trends is crucial in the tropics, where environmental differences in climatic conditions, particularly rainfall, are high (Haile-Mariam and Philipson, 1995). Genetic trends are very useful tool to evaluate the results of the genetic improvement programme (Bosso *et al.,* 2009). Annual trends for weight traits should be monitored over time to check the validity of the predictions made and to investigate direction of genetic change and whether the selection strategies implemented could reach a selection limit or have unexpected other effects. The objectives of this study were: (1) to establish the effects of non-genetic factors on yearling weight in local Tuli cattle (2) to estimate direct and maternal effects for yearling weight in the local Tuli cattle (3) to evaluate genetic trends for yearling weight in the local Tuli cattle of Zimbabwe.

MATERIALS AND METHODS

Environment: Matopos Research Station (20 0 23′ S, 310 30′ E) is situated 30 km South West of Bulawayo in Zimbabwe. The stations altitude is low (800m) and it experiences low erratic rainfall (<450) per annum (Homann *et al.*, 2007). Very high summer temperatures, maximum and minimum mean temperatures of hottest months are 21.6 ^{o}C and 11.4 ^{o}C respectively. Possibility of severe droughts (Hagreveas *et al.,* 2004). The most common type of vegetation is sweet veld with comparatively high nutritional value as browsing crop (Ncube, 2005) and annual grass species (Hlatswayo, 2008). If managed well the range lands should be able to meet the nutritional requirements of goats and other livestock (van Rooyen *et al.,* 2007). However, significant proportion of the rangeland are now degraded, resulting in low biomass (Hlatswayo, 2008) and thus limited feed resource of poor quality particularly during the dry season (Day *et al.,* 2003). Gambiza and Nyama (2000) gave detailed description of the climate and vegetation type. The development and management of the herd has been described by Ward *et al.* (1978).

Non-Genetic Factors Analysis: Data on yearling weight were obtained from Matopos Research Station, Bulawayo, Zimbabwe, between 1988 to 1997. The data included a total of 1021 pedigree progeny records from 42 sires and 420 dams of the local Tuli cattle (Table 1). The General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) (1999 - 2000) was used to establish the significance of the non-genetic factors. The linear statistical model fitted was: Yijklm =u + Gi + Pj + Sk + Al + Eijklm, where: Yijklm is the lth observation of ith sire, jth year and kth sex; u is the overall population mean; Gi is the random effect of ith sire NID (0, σ2 s); Pj is the fixed effect of jth year of birth (j = 1988, 1989,……, 1997); Sk is the fixed effect of kth sex of calf (k = male, female); Al is the fixed effect of lth age of dam (l = 1, 2… 15); eijklm is the random error associated with each observation assumed to be NID (0,σ2e).

Animal Model: An animal model was applied to estimate variance components and genetic parameters using ASREML methodology (Gilmour *et al.,* 2000). In matrix notation the univariate mixed linear model used was of the maternal form: Y = Xb + Zu + Wm + Spe + e, where Y =vector of yearling weight; b = vector of year of birth, sex and age of dam; u = vector of random animal effects; m = vector of random maternal (indirect) genetic effects; pe = vector of random permanent environmental maternal effects of dam; e = vector of random residual effects; X, Z, W and S are incidence matrices relating records to fixed, animal, maternal genetic and permanent environmental maternal effects respectively.

Genetic trends were estimated as the regression of the mean predicted direct and maternal breeding values on year of birth. Environmental trends were directly obtained from the estimates of the fixed effects solutions of year of birth and phenotypic trends from the annual least squares means.

Table 1: Summary statistics of the data sets for yearling weight in local Tuli cattle of Zimbabwe

Component	Recorded values
Records	1021
Animals	1553
Base parents	462
Sires	42
Dams	420
Mean	172.25
SD	28.46

SD=standard deviation

RESULTS AND DISCUSSION

Differences between sire, year of birth, sex and age of dam were highly significant ($p < 0.001$) for yearling weight (Tables 2 and 3) and conform to reports in literature (Bosso *et al.,* 2009). The significance for sire effect for yearling weight did not declined even this could be probable sire influence carry over effects unlike the maternal influence which tend to decline with progressed age of the animal. Post-natal influence that has been estimated is the sum of the effects of the 'true' post natal maternal environment and probably also the carried over effect of the prenatal maternal which would have declined by age of 1 year. Much of the sire estimated effects were much of genetic potential than environmental for yearling weight. Bull calves were 11 % heavier than heifers at 1 year weight. Covariance component and genetic parameters for yearling weight are presented in Tables 3 and 4. The sum of total additive genetic variance for yearling weight in local Tuli cattle was 192.77 and variance component for maternal permanent environmental maternal genetic variance for yearling weight were less than 1% in local Tuli.

Table 2: Analysis of variance for yearling weight in local Tuli cattle of Zimbabwe

Factor	df	SS
Sire	1	498.90**
Sex	1	72357.26***
Year of birth	8	4381.71***
Age	12	2116.65***
Error		541.29

**p< (0.05), **p< (0.01), ***p< (0.001)*

Table 3: Least squares means for yearling weight in local Tuli cattle of Zimbabwe

Effects	Least squares mean
	Sex
Male	180.89±1.73
Female	161.29±1.59
	Age of dam
3	169.83± 2.40
4	174.37± 2.54
5	181.42± 2.27
6	180.16± 2.37
7	180.84 ±2.79
8	185.10 ±2.58
9	176.93 ±2.75
10	175.96± 3.47
11	173.48 ±3.58
12	165.85 ±3.83
13	160.51 ±4.27
14	146.89± 4.49
15	152.82 ±8.07
	Year of birth
1988	170.77± 2.55
1989	163.95 ±2.60
1990	158.01 ±3.33
1991	170.02± 3.13
1992	172.27± 5.07
1993	161.46 ±4.99
1994	166.26 ±5.24
1995	189.16 ±6.20
1996	176.69 ±5.99
1997	162.67± 5.78

The residual variance components accounted for over 70 % of the phenotypic variance and were the largest component of the phenotypic variance of the trait. The magnitude of total genetic variance probably reflects large sampling covariances among estimates in the local cattle breeds. Direct and maternal genetic effects and their covariances have not been previously established as important for yearling weight in local Tuli in Zimbabwe. Direct heritability estimates observed was 0.18 ± 0.001, and were comparable with those reported elsewhere (Abassa *et al.,* 1989; Swalve, 1993; Mac Neil *et al.,* 1998; Mercadante *et al.,* 2003). Higher estimates of direct heritability of 0.25 and 0.30 have been reported in cattle (Mc Neil, 2003; Norris *et al.,* 2004). Direct heritability estimates on the upper range have also been reported worldwide for yearling weights; 0.38 (Splan *et al.,* 1998), 0.27 (Meyer, 1994), 0.48 (Groeneveld *et al.,* 1998) and 3.6 (Ferreira *et al.,* 1999). In a study on the difference in yearling weights of cattle due to sexes, Van Vleck and Cundiff (1998) reported direct heritability of 0.55 and 0.49 for females and males respectively, while in another study Khan and Akhtar (1995) reported 0.26 and 0.71 as direct heritabilities for females and males respectively. Mohiudin (1993) in a comprehensive review found a wide variety of estimates of heritability for female yearling weight. Range of 0.16 to 0.71 with an average estimate of 0.48 was much higher than the estimate found in this study. However, the 0.18 heritability for female yearling weight was within the reported range (Mohiudin, 1993). Lower estimates of direct heritability for yearling weight than in the present study have been reported in cattle e.g. 0.14 (Lee *et al.,* 2000) and 0.09 (Lubout *et al.,* 1990). The methods used in most of the studies which reported higher estimates of direct heritability in literature ignored maternal effects, which could have inflated the additive genetic variance and not always the residual variance (Meyer, 1992), increasing the estimates of heritability. Bosso *et al.* (2009) found an increasing trend in direct heritability birth weight (0.40) > weaning weight (0.47) > weight at 15 months (0.48) without accounting for maternal genetic effects. The presence of a maternal genetic effect in our model might have contributed to the low estimates of yearling weight.

The relatively high maternal components that explains 14 % of the total variation indicates that this effect should be kept in the model of analysis even at the age of one year. The maternal heritability estimates for yearling weight were lower than direct heritability (0.18 vs. 0.14). The maternal heritability estimates were low as compared to those observed in earlier reports in beef cattle (Swalve, 1993; Mercadante, *et al*., 1997; Mac Neil *et al.,* 1998). The maternal heritability in this study is within the reported range (Meyer, 1992; Lee *et al.,* 2000) in Australian beef cattle and Ferreira *et al.* (1999) using different statistical models. The magnitude of maternal effects indicates that maternal effects were important for yearling weight in this herd. Maternal effects on post weaning growth traits of beef cattle have been found in some breeds as for the local Tuli cattle (Koch *et al.,* 1973; Alenda and Martin, 1987).

The maternal permanent environmental effects contributed less than 1 % in the present study; elsewhere Wasike *et al.* (2000) observed a higher contribution of 4 % in Boran cattle in Kenya, while Pico (2004) reported 3 % maternal permanent environmental effects for yearling weight which was slightly higher than the 0.02 reported for Nelore cattle (Eler *et al.,* 1992). Within the same range Meyer (1992) estimated for both the Australian Angus and Zebu crosses maternal permanent environmental effects of 0.03. Five percents were reported for Hereford cattle (Meyer, 1992), Boran cattle (Haile-mariam and Kassa-Mersh, 1995) and Gobra cattle of Senegal (Diop and Van Vleck, 1998).

The results in literature dealing with the genetic correlations between direct and maternal effects for yearling weight are mostly negative: for example, -0.50 for Gobra cattle of Senegal (Diop, 1997) and -0.48 for Herefords (Meyer, 1993). Direct-maternal genetic correlations in the present study were low and positive, 0.07 ± 0.01. Positive genetic correlation of direct-maternal genetic correlation for yearling weight of 0.40 ± 0.31, 0.05 ± 0.31 and 0.64 ± 0.37 in Pinzgauer, Gelbvieh and Red Poll cattle, respectively, and of 0.01 for Zebu crosses and 0.49 for Angus in Australia for yearling weight have been reported (Mackinnon *et al., 1*991; Meyer, 1992). The positive genetic correlation of direct-maternal genetic effect for yearling weight is an indication that there is no antagonistic tendency which could retard selection progress (Meyer, 1993). However, we can not rule out that the positive direct-maternal genetic correlation could probably be the result of smaller data sets used in this study. The estimates of direct and maternal genetic correlation could not be ignored taking into account the proportion of maternal to direct genetic variance for yearling weight.

The total heritability and maternal across-year repeatability for dam performance were moderate and low. Use of total genetic effects on selection (h^2t) (Table 5) for yearling weight would optimize genetic progress in local Tuli cattle due to the positive covariance between direct and maternal effects.

Table 4: Estimates of genetic and environmental variances and covariances for yearling weight in local Tuli cattle of Zimbabwe

σ^2A	σ^2M	σ^2AM	σ^2E	σ^2P
111.00	86.77	6.55	412.80	617.47

σ^2A= direct additive genetic; σ^2M= maternal additive genetic variance; σ^2AM= direct and additive variance; σ^2E =error variance; σ^2P=phenotypic variance = sum of variance and covariance components

The direct and maternal trends yearling weights are depicted in Figures 1 and 2 respectively. The differences in average estimated breeding values for direct genetic effects showed that there was very little in terms of genetic gain was realized despite the moderate heritability of yearling weight. The regression of average direct breeding values on year of birth for YWT was almost zero and the regression of average maternal breeding values on year was 0.03 kg/yr. Yearling weight had a maximum average maternal breeding value in year 1993 of 0.29 kg/yr and direct genetic gain remained constant around zero.

Table 5: Direct additive (h^2A), maternal (h^2M) and total (h^2T) heritability estimates, standard errors (SE) and correlation between direct and maternal effects (rAM) for yearling weight in local Tuli cattle of Zimbabwe

h^2A SE	h^2M SE	h^2T	rAM
0.18 ± 0.001	0.14 ± 0.01	0.27	0.07

This was an indication that there was less or not much of correlated response in post weaning growth traits in the selection program. The trends in breeding values for both direct and maternal effects for yearling weight (0.00 vs. 0.03 kg per year) were modest when compared with an average of 2.65 kg per year reported by Mrode (1988) for yearling weight, when reviewing the results of selection experiments. The majority of the estimates of genetic trends reported by Mrode (1988) are from cattle breeds in temperate environments. Few studies have been reported on the improvement of genetic gain in N'Dama in Gambia by 0.17 kg/yr (Boss *et al.,* 2009) and Santa Getrudis in Brazil by 0.291 kg/yr (Ferraz *et al.,* 2000).

The present study is amongst other studies that report positive rate of improvement of yearling weight from harsh semi-arid tropical environment. In this herd, selection for yearling weight theoretically, considering a total heritability of 0.27 and phenotypic standard deviation of 31.69 kg, and assuming an estimated average selection intensity of (i=1.08) where 10% males (Im = 1.755) and 75 % females (If= 0.424) were retained for breeding, the generation interval calculated 5.3 years for males and 7.2 years for females, would give a genetic gain of more than 1.0 kg per year, if single trait individual selection was practiced. The genetic gain observed is less than 50 percent of what seems possible, even if regression of breeding values on year of birth is considered. There was no reason to expect low genetic gains in the study due to the low positive correlation of -0.07 between direct and maternal effects for yearling weight which showed an un-antagonistic tendency which makes it possible to improve both effects simultaneously. Presume the low gains are a result of bulls in particular were not selected at all among those of born in some years, and those selected were not necessarily superior to their contemporaries because selection was based on their own performance and their parents unadjusted weaning weights.

Environmental conditions were improving during the study period as indicated by the significant positive trend (Figure 2). This partially suggests that selection on yearling weight may result into selection for genetic stability in cattle in harsh tropical environments, however the R^2 (0.47) from environmental values, as observed, was less likely to be expected under fluctuating climatic conditions and the effect that they have on availability and quality of grazing.

Conclusion: The inconsistency of published results on non genetic factors in cattle indicates the importance of quantifying the effects of environmental factors on yearling weight within specific herd and environment and failure to adjust for age of dam will result in selection biased against the progeny of younger dams with a resulting increase in generation interval and reduced selection intensity. Maternal genetic effects should be included in a model of covariance components estimation in local Tuli cattle raised in Zimbabwe even for traits measured at 12 months of age. Estimates of direct and maternal heritability for 12 months of age indicate that selection can be effective on population studied. Maternal genetic trends were significant and positive but very low for 12 months, inclusion of sire evaluation program may increase genetic progress in the herd. The results suggest that individual selection or mass selection based on 12 months weight should be effective due to a slight positive covariance component

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