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RESEARCH ARTICLE

Estimates of phenotypic and genetic parameters and responses to selection in growth traits in three beef cattle breeds raised under ranch conditions in Botswana

Rakwadi E.[ac*], Nsoso S. J.[b], Gondwe T. N.[c] and Banda J. W.[c]
[a]Department of Agricultural Research, P O Box 69, Lobatse, Botswana. [b]Department of Animal Science & Production, Botswana University of Agriculture & Natural Resources, Private Bag 0027, Gaborone, Botswana.
[c]Bunda College of Agriculture, Lilongwe University of Agriculture & Natural Resources, P O Box 219, Lilongwe, Malawi.

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ABSTRACT

The study estimated phenotypic and genetic parameters and responses to selection of growth traits in three beef cattle breeds raised under ranch conditions in Botswana. Weights at birth (BW), weights at weaning (7 months; WW) and weights at 18 month (18MW) were obtained for Brahman (*n* = 841), Bonsmara (*n* = 926) and Tuli (*n* = 403) breeds from 1997 to 2008 inclusive from the Department of Agricultural Research, Botswana. Sex, age of dam, month of birth and year of birth significantly affected (P<0.05) performance of growth traits. Birth weight did not differ (P > 0.05) between breeds, (26.0±0.97kg, 26.5±2.38kg, 32.1±2.29kg for Tuli, Brahman and Bonsmara, respectively). WW was significantly higher (P < 0.05) in Bonsmara (215±10.9kg) than Tuli (144±5.00kg). At 18MW Bonsmara (323±15.0kg) and Brahman (303±18.4kg) had significantly high weights than the Tuli (221±6.62kg). Heritability estimates for BW, WW and 18MW, respectively did not differ (P > 0.05) between breeds, but were highest for Bonsmara (0.36±0.12, 0.69±0.08 and 0.64±0.08) and lowest in Tuli (0.21±0.11, 0.36±0.12 and 0.21±0.12) with Brahman being intermediate 0.57 ± 0.11, 0.53 ± 0.10 and 0.45 ± 0.10). Greater phenotypic and genetic correlations were observed in WW and 18MW for Bonsmara and Brahman. No response to selection was observed for all the traits in the three breeds under study. This may imply that the three breeds population have limited genetic variation for further selection.

Keywords Beef cattle, Botswana, livestock performance, live weights, ranch conditions

*Correspondence E-mails: elrakwadi@gov.bw

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INTRODUCTION

In Botswana, beef cattle production is an important farming activity because it sustains the livelihoods of local farmers by providing food, manure, hide, cash, security, social and cultural identity and provides medium of exchange of goods and services (Oladele and Monkhei, 2009). It is vital in beef production system to evaluate genetic parameters that influence growth performance as they influence profitability (Raphaka and Dzama 2010). These parameters are unique to the population in which they are estimated and they may also change over time due to selection and management decisions (Ndofor-Foleng *et al.,* 2012). Information on heritability estimates is essential for planning effective breeding programmes and for predicting response to selection. Genetic parameter estimates for growth traits exist for some breeds e.g. Tuli in Zimbabwe (Assan, 2012), Bonsmara in South Africa (Corbet *et al*., 2006; Selapa *et al*., 2012) and indigenous Tswana and Musi (composite breed) in Botswana (Raphaka and Dzama 2010). The Brahman breed has traits that are useful for a wide range of production systems, such as adaptability to harsh climatic and environmental conditions found in Botswana. Brahman has good combining ability with other breeds for improved productivity (Pico *et al*., 2004). Genetic parameters for growth traits for Brahman were estimated in several countries. For example, Pico *et al*. (2004) in South Africa found 0.28 (BW), 0.14 (WW) and 0.18 (18MW) and Kriese *et al*. (1991) found 0.37 (BW) and 0.63 (WW) in United States of America. Bonsmara and Tuli are beef breeds of South Africa and Zimbabwe, respectively; hence they are adaptable to the tropical environmental conditions. Genetic parameters for growth traits of local beef cattle under Botswana condition are scarce, which is consistent with the observation of Beffa (2005) for indigenous sanga breeds. Therefore, estimation of genetic parameters in Botswana environmental conditions is paramount. Therefore, the objective of this study was to estimate phenotypic and genetic parameters and responses to selection in birth, weaning and 18 month weights of the Brahman, Bonsmara and Tuli breeds raised under ranch conditions in Botswana.

Materials and Methods

Source of data

The data used in the study was collected from 1997 to 2008 in various ranches of the Department of Agricultural Research in Botswana. Data on BW, WW and at 18MW were retrieved for Bonsmara, Brahman and Tuli beef cattle breeds from records at ranches. The Bonsmara was kept at Lesego ranch (latitude 21º 92′S and longitude 27º 32′E), Tsetseku (latitude 19º 33′S and longitude 23º 12′E) and Dikgatlhong ranch (latitude 25º 44′S and longitude 25º 06′E), Brahman at Dikgatlhong, Xanagas ranch (latitude 22º 24′S and longitude 20º 24′E) and Nata ranch (latitude 20º 12′S and longitude 26º 09′E). The Tuli was kept at Lesego ranch only. All the animals with missing weights and no pedigree information were discarded. The final data after verification comprised of Brahmans (n=841 animals), Bonsmara (n=926 animals) and Tuli (n=403 animals). A total number of 39, 22 and 10 sires were used in Brahman, Bonsmara and Tuli herds, respectively. A mating ratio of 1 bull: 25-30 cows was used *per* year giving an average number of progeny of 20-25 *per* sire *per* year. Sires were repeatedly used each year to provide common genetic links between generations in each breed.

Management

Cattle from the five ranches were raised on natural pastures and supplemented with Dicalcium Phosphate and salt at a ratio of 1:2. Water was provided *ad libitum* and animals were subjected to routine veterinary care. At all the five ranches, a three month breeding season was practised, starting from the 1st January and ending on 31st March using single sire mating. Artificial insemination was started at the same time on some of the herds. Calving season started in October and ended in January. At birth, calves were weighed and identified by ear tags within 24 hours. Dams were also weighed within 24 hours after calving.

Calves remained on natural pasture with their dams until weaning (7 months). Thereafter calves were separated according to sex and run on different paddocks until they were ready for selection. Selection of breeding animals, both males and females was done at 18 months of age based on an index, physical appraisal and conformation. Indices are a generalized linear model for simulating beef cattle production under a wide range of management schemes and environments hence differing widely in their genotypes, size, growth rate and milk production (Dzama *et al.,* 2001). The indices were calculated for contemporary group after correcting for age of the animal as a covariate.

All animals performing below the mean of the group were culled while those above were selected as replacements. Depending on the number of replacement stock required, some of the animals performing averagely were also selected especially in situations where the number of replacement stock was inadequate. Heifers and young bulls not selected were sold through auction. Cows were culled for poor reproduction efficiency and old age.

Statistical analysis

The Mixed Model Procedure of Statistical Analysis System package (SAS 2008) was used to identify fixed effect for each trait and significance were declared at $P < 0.05$. The fixed effects included in the final model used for the analysis of growth traits were sex (males and females), month of birth, year of birth, station and age of dam. The model did not compare the breeds, each breed was analysed separately. Classification of age of dam was done following the system of Beffa (2005) and Gottschall *et al.* (2007), where there were three classes: young cows aged 3-4 years, mature cows aged 5-10 years and old cows aged >10 years, respectively. The ages of dams ranged from 3 years to 16 years. Sex was fitted in the model because animals were kept in separate paddocks from weaning at 7 months onwards and managed as different herds. WW and 18MW were corrected to 210 and 540 days of age for each animal, respectively.

Genetic and phenotypic parameters for BW, WW and 18MW were estimated using the ASReml Programme of Gilmour *et al*. (2006) by fitting a multi-trait individual animal model with animal being a random effect and sex, year of birth, station and age of dam as fixed effects for each breed. Full pedigrees were fitted for each breed. Maternal and permanent environmental effects were also fitted as random effects for each trait in each breed. Best linear unbiased prediction (BLUP) breeding value estimates for each trait were derived as by-products of ASReml analyses.

$Y = Xb + Z_1a + Z_2m + Z_3c + \varepsilon$

Where;

Y = the vector of observations BW, WW and 18MW,

b = the vector of fixed effects sex, month of birth, year of birth, station, age of dam, station,

a = the vector of random additive genetic effects,

c = the unknown vector of permanent environmental effects contributed by dams to records of their progeny,

m = the vector of random maternal genetic effects,

X = incidence matrix of calf records to fixed effects,

Z_1 = incidence matrix relating to the calf records for additive genetic effects,

Z_2 = incidence matrix relating to the calf records for maternal genetic effects,

Z_3 = incidence matrix relating to the dams records for permanent environmental effects,

ε = the random error associated with observation, assumed to be normally and independently distributed with mean zero.

Repeatability estimates were calculated following the method described by Shehu *et al*. (2008) and Wilson *et al.* (2009) using Mixed model procedure of SAS (SAS Institute 2002-2008) in a single trait animal model. Repeatability was analysed considering the calf weights as the trait of the dam.

RESULTS

Sex, age of the dam, month and year of birth significantly affected performance in all traits in the three breeds (Table 1). The correction factors for male calves were higher than their female counterparts for all the traits of the three breeds. High heritability estimates were obtained for BW, WW and 18MW in the three traits for the three breeds and are shown in Table 3. Furthermore, although, the heritability estimates did not differ significantly (P>0.05) for the same trait between breed, they were higher in Bonsmara, followed by Brahman and least in Tuli. Moderate to high repeatability estimates were obtained for growth traits for the three breeds (Table 4). The responses to selection for birth, weaning and 18month weights for the three breeds were either around zero or negative (Figure 1).

DISCUSSION

Correction factors in sex, age of dam, month of birth and year of birth in this study were used to reduce variation due to certain classifiable environmental factors (Cundiff *et al.,* 1966). These factors have to be made within trait and breed to produce parameter estimates that are not biased (Raphaka and Dzama, 2009) hence maximise responses to selection. Correction factor for male calves in the current study was higher (P < 0.05) than their female counterparts for all the breeds as expected. Calves born to dams of ages 5 to 10 years had the heaviest BW and thereafter decreased from 11 years and older. The correction factor for WW (Table 1) in all the breeds for age group 3 to 4 years was comparable to that of Tswana (10.36±1.32) reported by Raphaka and Dzama (2009.

Birth weight, WW and 18MW obtained in this study for Brahman were similar to the mean weights reported by Plasse *et al*. (2004) in a *Bos indicus* herd upgraded to Brahman. Moyo *et al*. (1996) also reported significantly higher WW for Brahman and Tuli breed (207 and 187 kg, respectively) in Zimbabwe than found in this study. Such differences between countries reflects genotype by environmental interaction that is evident in beef production (Raphaka and Dzama, 2009), which has to be taken into cognisance for efficient beef production. The trends in heritability estimates reported in the present study were consistent with similar reports from elsewhere (Nephawe *et al.,* 1999; Bradfield *et al*., 2000; Ferraz *et al*., 2000; Norris et al., 2004; El-Saied et al., 2006; Pereira et al., 2008; Cucco et al., 2009; Raphaka and Dzama 2010; Afroz *et al*., 2011; Ndofor-Foleng *et al*., 2012). The high heritability estimates are due to high genetic variation relative to total phenotypic variation, thus presenting a wide scope of genetic selection for improved productivity (Wasike *et al*., 2006 and Raphaka and Dzama 2010).

High heritability values for BW in Bonsmara and Brahman breeds suggest that selection on the basis of individual performance will be effective in achieving increased gain in this trait (Rabeya *et al*., 2009). However, breeders should select for average birth weight than higher birth weight to avoid losses due to dystocia (Raphaka and Dzama 2010). Heritability estimates tended to increase from BW to 18MW, an observation similar to the one made by Cucco *et al*. (2010) on post weaning growth traits. The estimates reveal that variations due to additive gene action increase with subsequent growth traits taken within the same individual.

The lower heritability estimates in the Tuli than Bonsmara and Brahman breeds in this study could be due to small sample size and variable management systems the breeds were raised under. According to Lasley (1978), when the repeatability estimate for a trait is high, culling on the basis of the first record should be effective in improving the overall record of the herd in the following year. Therefore, offspring from the superior individuals in the herd should be given preference when selection is made for the replacement stock. The high phenotypic correlation estimates between WW and 18MW among the three breeds in this study suggests that WW is a good indicator of subsequent weights of the calf. Therefore, selection for improved productivity at weaning is possible in these breeds. Similarly the high genetic correlations between WW and 18MW for Bonsmara and Brahman in this study (Table 3) indicate that WW is a good indicator of 18MW. Similar results are reported by Van Niekerk *et al*. (2004) and Rabeya *et al*. (2009). This means that calves heavier at weaning will have heavy 18 month weights if all factors do not change. Therefore, these traits are controlled by the same genes and thus selection for any one of these traits would lead to positive changes in the other. Selection using an index that combines all important traits is essential to maximise profitability and prevent undesirable responses (Raphaka and Dzama 2010). Bosso *et al*. (2009) found that body weight in N'Dama cattle exhibited positive, although smaller, genetic trends of 0.06 kg/year for BW and 0.17 kg/year for weight at 12 months. Estimates of maternal and permanent environmental effects were negligible (>$1x10^{-6}$) for all traits in the three breeds. These results are consistent with the findings of Montaldo and Kinghorn (2003) who reported maternal effects for WW to be close to zero (0.02). Low response to selection in the current breed is unexplainable particularly for the Bonsmara and Brahman breeds. The negligible genetic improvement for all traits indicates that selection was not effective or non-systematic (Figure 1).

As for the Tuli the possible reason for low response to selection may have been contributed by the smaller herd size. However, similar results were reported by Waheed *et al*., 2003. On the contrary the Pereira *et al,* 2008, reported higher annual genetic trends estimates for BW (0.08±0.02 kg/year) and WW (0.48±0.11 kg/year) in a herd of Caracu (1 698 animals). The trends in breeding values for the three breeds were around zero for the three traits of the Brahman, Bonsmara and Tuli breeds throughout the years.

CONCLUSIONS

Fixed effects significantly affected performance in all the three traits across the three breeds, indicating that these have to be corrected for to produce unbiased phenotypic and genetic parameters to be used for selection and general management. The low to moderate phenotypic correlations, moderate to high genetic parameter estimates and negligible maternal and permanent environmental effects indicate that selection for the three

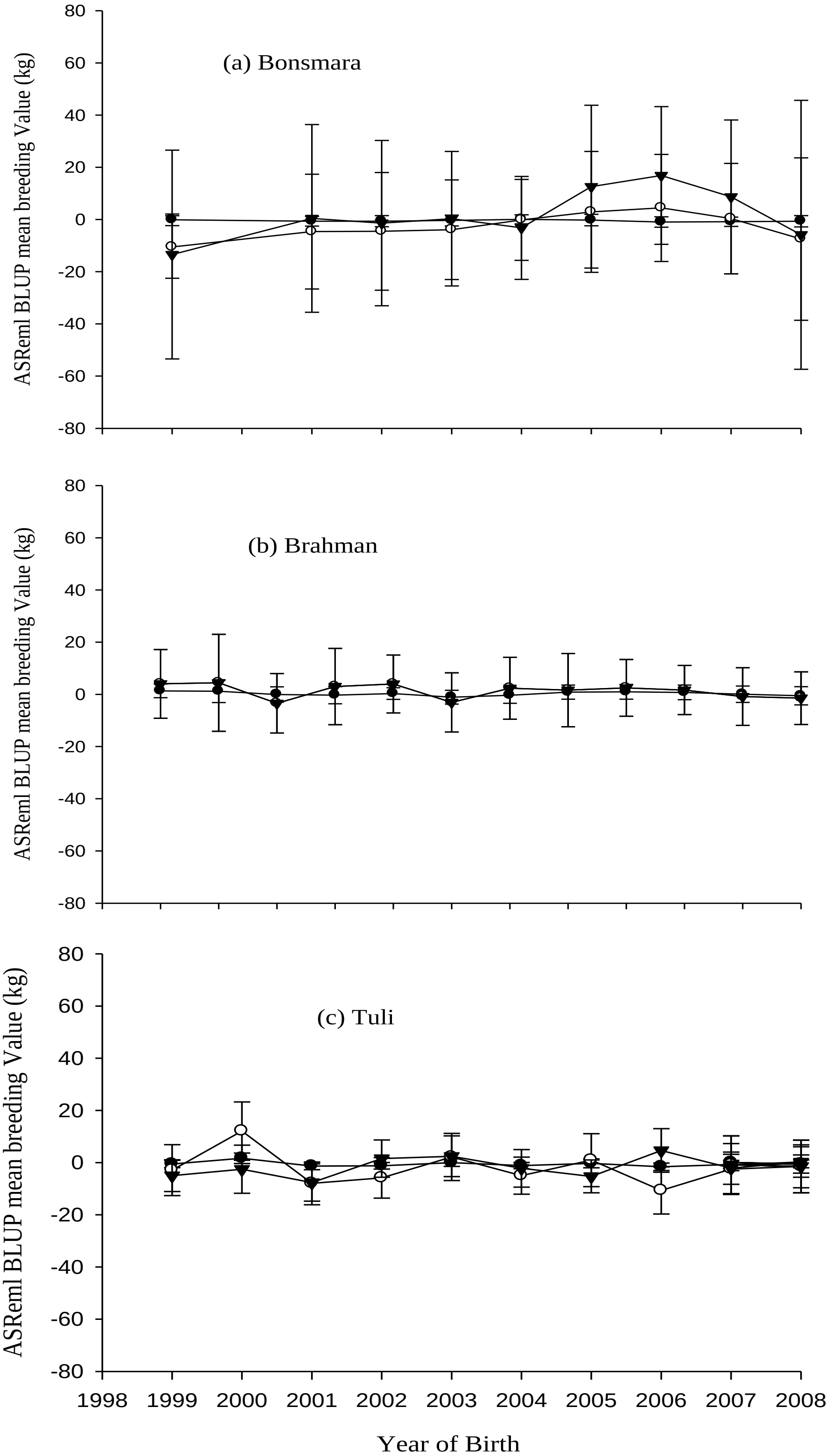

Figure 1: Responses to selection for birth (•), weaning (ₒ) and 18 month weights (▼) for Bonsmara, Brahman and Tuli breeds raised under ranch conditions in Botswana. Error bar = ±SEM

Table 1: Correction factor estimates (± standard error) for significant (P<0.05) fixed effects for Bonsmara, Brahman and Tuli breeds raised under ranch conditions in Botswana[ab]

	Breed								
Effect	**Bonsmara**			**Brahman**			**Tuli**		
Sex (kg)	BW	WW	18MW	BW	WW	18MW	BW	WW	18MW
Male	0	0	0	0	0	0	0	0	0
Female	-1.76 ± 0.35	-12.1 ± 1.92	-18.0 ± 2.92	-2.28 ± 0.33	-15.4 ± 1.69	-41.0± 2.80	-0.90 ± 0.56	-14.4 ± 2.48	-31.5± 3.84
Age of dam (kg)									
3-4 years	0	0	0	0					
5-10 years	1.26 ± 0.43	9.55 ± 2.22	8.53 ± 3.15	2.51 ± 0.40	12.3 ± 2.01	9.10 ± 2.79	1.99 ± 0.65	9.43 ± 3.02	13.4 ± 4.54
11+ years	0.57 ± 1.18	-0.09 ± 6.43	-5.33 ± 9.31	2.77 ± 1.20	-9.54± 6.99	1.09 ± 9.78	-0.03 ± 1.65	15.6 ± 7.46	18.6 ± 11.1
Month of Birth (kg)									
January	0	0	0	0	0	0	0	0	0
October	1.45 ± 0.43	3.42 ± 2.17	10.1 ± 3.04	0.70 ± 0.40	-2.98 ± 2.00	5.33 ± 2.81	0.54 ± 0.69	-7.95 ± 3.03	7.02 ± 4.67
November	1.93 ± 0.53	-3.67± 2.67	7.85 ± 3.81	1.56 ± 0.51	-13.02 ± 2.62	-1.38 ± 3.61	-0.20 ± 0.84	-3.05 ± 3.68	5.41 ± 5.64
December	3.48 ± 0.96	-10.9 ± 5.27	-7.06 ± 7.73	1.06 ± 0.84	-35.3 ± 4.4	-9.03 ± 6.11	0.14 ± 1.57	-24.7 ± 6.65	-2.14 ± 11.8
Year of birth (kg)									
1997	0	0	0	0	0	0	-	-	-
1998	0	0	0	-1.76 ± 3.79	-19.0 ± 18.27	-169 ± 33.7	-	-	-
1999	-1.53 ± 2.16	-1.26 ± 1.31	-30.7 ± 16.7	-1.21 ± 1.84	-7.01 ± 9.21	-138 ± 15.1	-	-	-
2000	-1.01 ± 2.16	-1.86 ± 11.4	-75.6 ± 16.8	1.68 ± 1.87	-5.42 ± 9.37	-120 ± 15.3	-	-	-
2001	1.45 ± 2.15	-28.1 ± 11.3	-89.1 ± 16.6	1.15 ± 1.85	-14.4 ± 9.20	-180 ± 15.1	-	-	-
2002	-0.83 ± 2.14	-35.3 ± 11.2	-67.5 ± 16.5	2.91 ± 1.92	-6.85 ± 9.57	-174 ± 15.6	-	-	-
2003	-0.85 ± 2.19	-17.5 ± 11.6	-95.8 ± 17.1	0.61 ± 1.90	-22.5 ± 9.49	-194 ± 15.4	-	-	-
2004	-0.55 ± 2.19	-28.3 ± 11.5	-106 ± 17.2	-1.14 ± 1.99	-10.4 ± 9.83	-185 ± 15.9	-	-	-
2005	0.16 ± 2.19	-29.8 ± 11.7	-103 ± 17.1	2.01 ± 1.98	-26.7 ± 9.81	-180 ± 16.1	-	-	-
2006	0.15 ± 2.21	-29.0 ± 11.7	-84.2 ± 17.3	1.08 ± 1.99	-18.0 ± 9.92	-180 ± 16.0	-	-	-
2007	-3.90 ± 2.30	-16.1 ± 12.9	-106 ± 19.1	2.65 ± 1.96	-23.8 ± 9.80	-194 ± 16.8	-	-	-
2008	N/A	N/A	N/A	3.28 ± 2.58	-10.2 ± 14.3	-206 ± 25.1	-	-	-

[a] BW, WW and 18MW are abbreviations for birth, weaning and 18 month weights.
[b] A dash (-) on its own indicates that an effect was not significant

The birth weight of calves did not differ (P>0.05) significantly between the three breeds, although it was higher in Bonsmara than Brahman and Tuli (Table 2).

Table 2. Least squares means (± standard error) for birth, weaning and 18 month weights for Bonsmara, Brahman and Tuli breeds raised under ranch conditions in Botswana

Traits	Breeds		
	Bonsmara	Brahman	Tuli
Birth weight (kg)	32.1± 2.29	26.5 ± 2.38	26.0 ± 0.97
Weaning weight (kg)	215± 10.9a	175 ± 12.4b	144 ± 5.00b
18 month weight (kg)	323 ± 15.0a	303 ± 18.4a	221 ± 6.62b

[ab] *Means with different superscripts within rows differ significantly (p<0.05).*

Table 3: Genetic and phenotypic parameter estimates (±standard error) of birth, weaning and 18 month weights for Bonsmara, Brahman and Tuli breeds raised under ranch conditions in Botswana[ab]

	Bonsmara			Brahman			Tuli		
Part I	BW	WW	18MW	BW	WW	18MW	BW	WW	18MW
BW	**0.36± 0.08**	0.21±0.04	0.19±0.04	**0.57±0.11**	0.34±0.04	0.25±0.05	**0.21±0.11**	0.11±0.06	0.05± 0.06
WW	0.25± 0.14	**0.69±0.08**	0.66±0.03	0.47±0.31	**0.53±0.10**	0.65±0.03	0.90±0.19	**0.36±0.12**	0.44± 0.05
18MW	0.16± 0.15	0.82±0.06	**0.64±0.08**	0.26±0.16	0.75±0.09	**0.45±0.10**	0.48±0.32	0.38±0.28	**0.21± 0.12**
Part II	29.8± 1.67	958±63.8	2005±134	27.4±1.73	586± 38.7	1302±88.0	31.9±2.46	656± 58.1	1279± 108

[a] *BW, WW and 18MW are abbreviations for birth, weaning and 18 month weights.*
[b] *Heritabilities – in bold along diagonal, phenotypic correlations above diagonal and genetic correlations below diagonal. Part II – total; variance for traits as genetic variance plus residual variance (i.e. total variance less effects of fixed effects)*

Table 4: Covariance components parameters and repeatability (R) estimate for BW, WW and 18MW in Brahman, Bonsmara and Tuli breeds raised under ranch conditions in Botswana.

Breed	Trait [a]	Dam Variance	Residual Variance	R
Brahman	BW	4.68	16.5	0.88±0.23
	WW	100	443	0.74±0.20
	18MW	114	688	0.57±0.23
Bonsmara	BW	3.48	21.2	0.56±0.15
	WW	129	529	0.79±0.18
	18MW	194	914	0.70±0.20
Tuli	BW	1.03	25	0.16±0.21
	WW	150	302	1.33±0.34
	18MW	107	664	0.55±0.29

[a] *BW, WW and 18MW are abbreviations for birth, weaning and 18 month weights.*

growth traits would bring genetic improvements and yield desirable responses to selection in all the three breeds. The moderate to high genetic correlations among traits in the three breeds indicate that selection can be done earlier to reduce cost of production hence increase profitability. Lack of genetic responses indicated that selection should be based on best linear unbiased prediction breeding values. Different phenotypic and genetic parameter estimates among breeds indicate that breed specific parameters are essential for selection to maximise responses.

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Conflict of interest

None

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