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Abstract

The objective of this study was to assess the growth performance of six cattle breed groups from birth to 18 month of age at Songa Research Station in Rwanda. Records of animals born between 1998 and 2008 were evaluated using nested ANOVA for effects of non-genetic factors on growth performance of different cattle breed groups; compare growth rate of different cattle breed group; and identify suitable breed group for Songa environment. The animals used in the study were taken from a herd of crossbreds of Ankole dams with Brown Swiss, Friesian, Jersey and Sahiwal sires.

Birth weight was not affected by breed group, sex of the calf or environmental factors, such as year and season of birth. However the calves sired by Brown Swiss and Friesians were heavier than calves sired by Jerseys. At weaning, the effects of breed group, year of birth and season of birth were all highly significant ($P<0.001$), as was the effect of nesting season in breed groups. Weaned calves of Ankole-Friesian crosses (AF) were significantly heavier than those of all other breed groups except Ankole × Brown Swiss (AB) and Ankole × Sahiwal (AS) crossbreds. The heaviest calves were born during season 4 of the year, though weaning weights across seasons did not differ significantly ($P>0.05$). Male weaned calves (179.3±6.0 kg) were heavier than female weaners (164.6±9.9 kg). A wide range of weaning weight for AB and AF breed groups were observed, compared with the range of mean weights for AJ, AJS, AS, and ASJ suggesting that breed groups containing Jersey and Sahiwal blood are more resilient to environment pressure. Mature weights of animals was significantly affected by breed group ($P<0.01$), sex ($P<0.001$), and year of birth ($P<0.001$) while season and its interaction with breed group ($P>0.05$) did not influence it. Generally, breed group AB grew faster than all other breed groups while the lowest growth rate was registered in breed group AS. However, the speed of growth was similar to those in breed groups AJ, AJS, AS and AJS. We observe that AS, AJS and ASJ breed group was the best breed group for the area of study and that the major factors to consider during the breeding of the various breed groups include sex, season of birth and year of birth. It is therefore recommended that to attain the best level of performance for these cattle, artificial insemination should be synchronized with maximum forage availability at parturition.

Key words: Crossbreeding, Jersey, non genetic factors, Sahiwal

Introduction

The cattle population in Rwanda is dominated by the indigenous long horned Ankole cattle which are estimated at 86% of the national herd. This breed is highly adapted to adverse environmental conditions, including tolerance to heat stress and resistance to endemic diseases. Additionally, Ankole cattle can withstand periodic feed shortage better than exotic breeds; can walk long distances in search of pasture and have got an added advantage of producing high quality beef. Generally, the Ankole is a medium sized breed with males maturing at a live weight of 350 to 400 kg and females at 200 to 350 kg. Milk production per animal per day ranges between one to six kg (Petersen et al 2003; Kugonza et al 2011). Newborn calves weigh about 14–23 kg and remain small for several months. Ankole cattle are, thus, characterized by low productivity and low growth rates (Trail et al 1971). Reasons advanced for the low productivity include low genetic potential and low standards of husbandry, including breeding, feeding and housing. On the other hand, *Bos taurus* breeds that are predominantly found in temperate countries have a high production potential but they are not well adapted to tropical conditions because of their low heat and disease tolerance (Tadesse and Dessie 2003). Therefore, crossbreeding of *B. indicus* with *B. taurus* breeds has been widely used to combine the high production potential of exotic breeds with the adaptability of the local ones. Usually, the first crossbred generation between native females and exotic males is very successful (Kiwuwa et al 1983). A crossbreeding program in Rwanda was re-established at Songa Research station in 1999 after the unfortunate interruption of cattle genetic improvement activities by the 1994 genocide. The programme involved using exotic breeds, Friesian, Jersey and Brown Swiss and local Ankole cattle, to develop a dual-purpose breed for milk and meat production, for smallholder farmers. Substantial pre-weaning and post weaning data was generated, and analysed to shed some light on comparative growth potential of different crossbred breed groups at the station. The objectives of this study were to analyse the main non-genetic factors affecting pre-weaning and post-weaning growth traits of different cattle breed groups, compare their growth rate and identify the best crossbreed suitable for the Songa environment.

Materials and Methods

Location and climatic conditions

The study was conducted at Songa Research Station (2^o 24'S, 29^o 46'E). The station is located in the mid-altitude zone (1500–1600 m asl) of Rwanda; with average annual temperature ranging between 22^oC and 29^oC; an average annual rainfall of 1087 mm and relative humidity of 77%. The rainfall pattern is bimodal, with short rains (season A) falling between September and December and long rains (season B) extending from March through May. The dry season extends between June and August. The rain is heavy in April and May, and decreases gradually until October. The natural vegetation consists of natural grass composed of *Brachiaria decumbens* and planted multipurpose trees like *Calliandra calothyrsus* and *Leucaena leucocephala*. The soils are clay sandy on the hills and clay in marshland.

Animal and herd management

Heifers were artificially (AI) inseminated at between 18–24 months depending on incidence of first estrus. Subsequent AI services were affected on incidence of estrus after calving. Heat detection was based on observations and reports from trained herdsmen and technicians. Pregnancies were confirmed by rectal palpation; and repeat breeders were inseminated accordingly. Progeny records of individual animals born in the herd were established at birth. The records included identification of dam and sire, date of birth (day, month, year), and monthly weights until 18 months of age. The calves were dehorned by the hot iron method. Male calves were castrated using a burdizzo at the age of 2–3 months. Weaning was done in groups when calves were about 8–11 months of age based on subjective judgment of vigour and ability of the weaners to survive without milk and the weaning weight were later adjusted to 10 months. The cross-breeding program was based on a foundation of dam lines of indigenous Longhorn Ankole cattle and their female progenies when bred with Brown Swiss, Friesian, Jersey and Sahiwal semen. Culling was based on subjective opinion of old age (e.g. loss of teeth) and infertility.

Routine veterinary attention was provided to each animal. The animals (except young calves) were sprayed twice per week to control ecto-parasites using recommended formulations of acaricides on the market. Anti-helminths (mainly Albendazole) were used against endo-parasites especially in the wet season (after the rains). Vaccinations against notifiable diseases (FMD, Anthrax and CBPP and Blackleg) were implemented upon notification of impending threats by competent authority of Rwanda Agricultural Board (RAB).

The Database

The database consisted of progeny records taken monthly, but for this study, only birth weight (338 records), weaning weight (320 records), and weight at 18 months (160 records), recorded over a 10 year period from1998 to 2008 were used. These animals were the progeny of 208 dams and 28 sires. Earlier, the database was cleaned of all animals with unknown pedigree, which were then eliminated from the analysis. Birth weights were recorded within 24 hours of birth while weaning weight was taken on the date of group weaning. Weight at puberty was taken at 18 months of age. Growth rates (g d^{-1}) were computed as the slope of the linear regression model (i) using all the weight data collected monthly from birth to 18 month.

$$Y = a + bx + \varepsilon..............(i);$$

Where, Y = weight of animal (kg); x = age (d); a = intercept when x=0; b = slope of regression; and ε = random error of variations.

Statistical analysis

Differences among breed groups, sexes, years, and seasons of birth were examined using General Linear Models (SAS, 2004).
The model used was: $Y_{ijk} = \mu + B_i + G_j + Y_k + S_l + (SB)_{(i)} + \varepsilon_{ijk;}$
Where:
Y_{ijkl} = Observation in a given growth trait
μ = Overall mean
B_i = Fixed effects of breed group (i=1, 2,...,6)
G_j = Fixed effects of sex levels (j=1,2)
Y_k = Fixed effect of the year (k=1, 2…10)
S_l = Fixed effect of Season (s=1,2,3,4)
S(B) = Fixed effects of breed group nested within Season l
ε_{ijkl} = random error including months of birth

SAS Nested Procedure was used to derive variance components attributed to breed group, sex, seasons and months of birth. Variance components were estimated for random effects as shown in the analytical model.

Results

The mean live weights of the six cattle breed groups at birth, weaning, 18 month and their standard deviations are presented in Table 1. Birth weight was not affected for any of the sources of variation studied, although sex of the calf tended to significance (P=0.076). However the calves sired by Brown Swiss and Friesians were heavier than calves sired by Jerseys, while calves sired by Sahiwal were intermediate in size (Table 2). There was a conspicuous variation in birth weights of calves across the years of birth (Figure 1), with calves born in 2001 being relatively heavier than those of 2005, 2002 and 2000, in that order. The lowest birth weights were registered in 1998, and 2008. The birth weights of male calves were about 4 percent higher than those of female calves; but the weight difference was not statistically significant (P>0.05).

Analysis of variance for weaning weight found significant differences in weaning weights among breed groups (P<0.001), year (P<0.001) and seasons of birth (P<0.05). Nesting season in breed groups also depicted a strongly significant relationship (P<0.01). The mean weaning weight of Ankole-Friesian crossbred calves (AF) was significantly higher than for weaners of other breed groups except AB and AS (Table 2). Calves born during season 4 of the year were the heaviest. But the weaning weights across season 1 to season 3 did not differ significantly (P>0.05) (Table 2). Male weaners (179.3±6.0 kg) were heavier than female weaners (164.6±9.9 kg). The effects of nesting breed groups within season indicated that season 2 was the least preferable season of birth for breed group AB (P<0.01). Season 1 was most preferable for breed group AF (P<0.05) while the AB breed group varied widely across seasons. Figure 2 shows wide variation in weaning weight for AB and AF breed groups across seasons as compared to AJ, AJS, AS, and ASJ suggesting breed groups containing Jersey and Sahiwal blood are more resilient to environment pressure/seasonal variability.

We found that weaning weights differed significantly across years of birth (P<0.001). Calves born in 2008 were significantly heavier at weaning than those born before (2002, 2004, 2005, and 2007) (Figure 3). Weights of weaned calves in the other years were intermediate and not significantly different from each other. Parameter estimates showed that weaners born in 2002, 2004 and 2007 contributed to reduced least square mean by approximately 34% (P<0.01), 60% (P<0.01) and 52% (P<0.05) respectively.

Weight of animals at 18 months were significantly affected by breed group (P=0.0029), sex (P=0.0001), and year of birth (P=0.0001) (Table 2), while season (P=0.959) and its interaction with breed group (P=0.1004) did not have influence on mature weight. Parameter estimates indicated that apart from breed groups AF and ASJ which had positive but non-significant (P=0.06) contribution to mean weight at 18 months of age, each additional one animal of the breed group AB (P<0.01), AJ and AJS (P<0.05) contributed to reductions in weights at 18 months of age by approximately 78, 45 and 30 kg respectively. The heaviest weights were registered by breed groups AF and ASJ, but breed group ASJ was not significantly different in mature weights than breed group AJS and AJ. The lowest mature weights were registered in breed group AB which was significantly lower than in all other breed groups (P<0.05) (Table 2). At the same time, no differences were observed across seasons of the year. Contrary to common perception, the adjusted mean mature weights of females (233.0±3.7 kg) were higher than the mature weight of male animals (192.2±6.0 kg). Parameter estimates suggested that each additional female to the herd increased least square means of mature weight by approximately 41 kg.

Table 1 Mean Weight of six cattle breed groups at birth, weaning and at maturity (18 months**).**

Category	Factor		Birth Weight (kg)				Weaning Weight (kg)				Weight at 18 months (k		
		n	Mean	s.e	Min	Max	Mean	s.e	Min	Max	Mean	s.e	Min
Breed Groups	A×B	64	28.8	0.78	20	50	162.8	4.63	110	233	228.2	4.40	246
	A×F	75	28.9	0.45	25	36	167.4	5.59	102	223	219.4	5.70	260
	A×J	128	28.9	3.27	18	24.5	146.0	3.47	104	205	223.4	3.97	224
	A×J×S	125	34.2	6.23	20	29.5	152.7	4.45	108	200	226.2	5.09	221

	A×S	205	27.6	0.37	18	38	154.3	4.06	102	240	228.6	2.00	254
	A×S×J	112	26.9	0.46	18	36	149.1	4.39	101	218	212.5	4.93	241
Sex	Male	204	28.22	0.38	18	50	153.9	2.38	101	210	203.7	3.43	243
	Female	505	29.65	1.96	18	29.5	154.5	2.58	104	240	231.8	1.78	240
Overall		709	29.06	1.17	18	50	154.1	1.80	101	240	223.7	1.67	221

Table 2 Least Square means (± s.e) of birth, weaning and 18 months weight of calf breed groups across seasons at RAB Songa Research Station (1998-2008)

Age	Breed groups	Season of Year 1	2	3	4	Mean[1]
Birth	AB	27.7± 1.9	29.5 ± 1.8	33.2 ± 2.1	29.2 ± 4.0	29.9^{a} ± 1.4
	AF	26.2 ± 4.2	31.3 ± 1.6	29.9 ± 1.7	26.6 ± 2.9	28.6^{ab} ± 1.5
	AJ	24.8 ± 1.4	26.2 ± 1.9	26.2 ± 1.0	27.8 ± 2.1	26.2^{bc} ± 1.0
	AJS	27.3 ± 1.6	27.1 ± 1.7	26.1 ± 1.5	28.9 ± 1.6	27.3^{bc} ± 0.9
	AS	27.5 ± 1.5	27.6 ± 1.8	28.1 ± 2.1	26.8 ± 1.4	27.5^{ab} ± 1.1
	ASJ	26.3 ± 1.3	26.6 ± 1.1	27.5 ± 1.4	30.2 ± 4.1	27.6^{ab} ± 1.2
	Season Mean[2]	26.6 ± 1.0	28.0 ± 0.9	28.5 ± 0.8	28.3 ± 1.3	
Weaning	AB	159.5 ± 14.3	126.0 ± 24.8	181 ± 9.4	226.1 ± 24.4	173.3^{a} ± 10.1
	AF	238.1 ± 24.4	181.2 ± 12.0	169.3 ± 10.0	205.9 ± 18.5	198.6^{b} ± 9.2
	AJ	126.8 ± 12.1	170.2 ± 15.3	180.4 ± 6.9	147.4 ± 13.0	156.2^{c} ± 6.6
	AJS	153.0 ± 10.6	151.4 ± 14.7	175.8 ± 9.1	157.8 ± 10.0	159.5^{ac} ± 6.1
	AS	171.0 ± 10.1	152.8 ± 15.5	168.3 ± 9.4	177.2 ± 10.7	167.3^{ac} ± 7.1
	ASJ	138.5 ± 12.6	153.8 ± 7.9	163.0 ± 7.5	179.6 ± 12.3	158.7^{ac} ±5.9
	Season Mean[2]	164.5^{a} ± 6.5	155.9^{a} ± 7.0	173.1^{ab} ± 5.3	182.3^{c} ± 8.1	
18 Months	AB	196.5 ± 14.8	220.3 ± 28.8	165.7 ± 13.8	164.8 ± 25.6	186.8^{a} ± 11.7
	AF	223.6 ± 11.9	220.8 ± 11.4	247.5 ± 18.8	251.5 ± 14.8	235.9^{b} ± 8.4
	AJ	222.4 ± 12.0	230.9 ± 8.0	213.3 ± 9.4	197.8 ± 20.9	216.1^{c} ± 7.7
	AJS	211.4 ± 12.0	209.6 ± 7.3	222.5 ± 10.5	204.3 ± 28.8	211.9^{c} ± 11.1
	AS	215.8 ± 8.8	201.4 ± 7.8	196.1 ± 8.1	212.9 ± 11.1	206.6^{c} ± 6.1
	ASJ	216.8 ± 6.3	198.2 ± 12.3	219.7 ± 12.2	242.7 ± 9.5	219.8^{c} ± 5.9
	Season Mean[2]	214.4 ± 5.1	213.5 ± 6.0	210.8 ± 5.5	212.3 ± 8.4	

[1] *Means with the same superscripts in the column are not significantly different (P>0.05).*
[2] *Means seasons with the same letters in the row are not significantly different (P>0.05)*

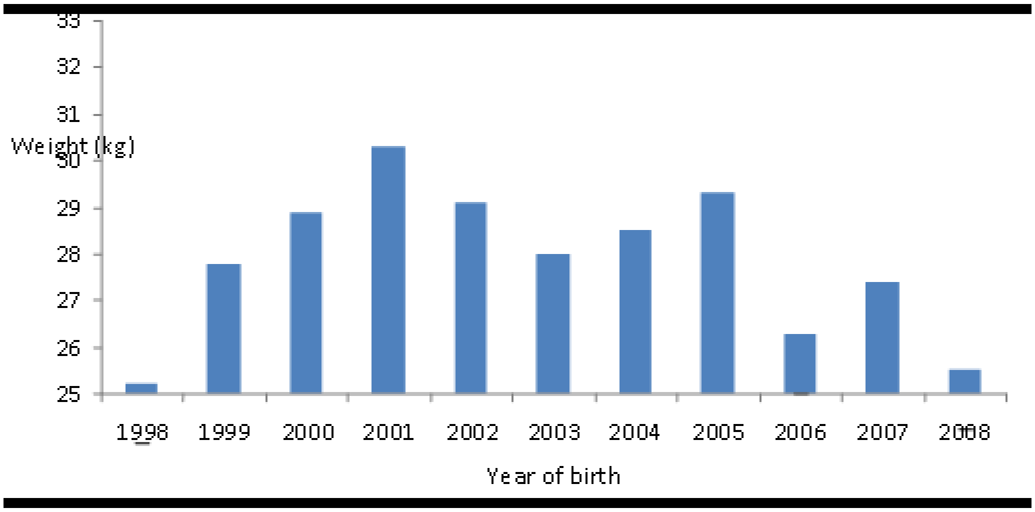

Figure1. Birth weights of calves born across years of birth at RAB Songa Research Station.

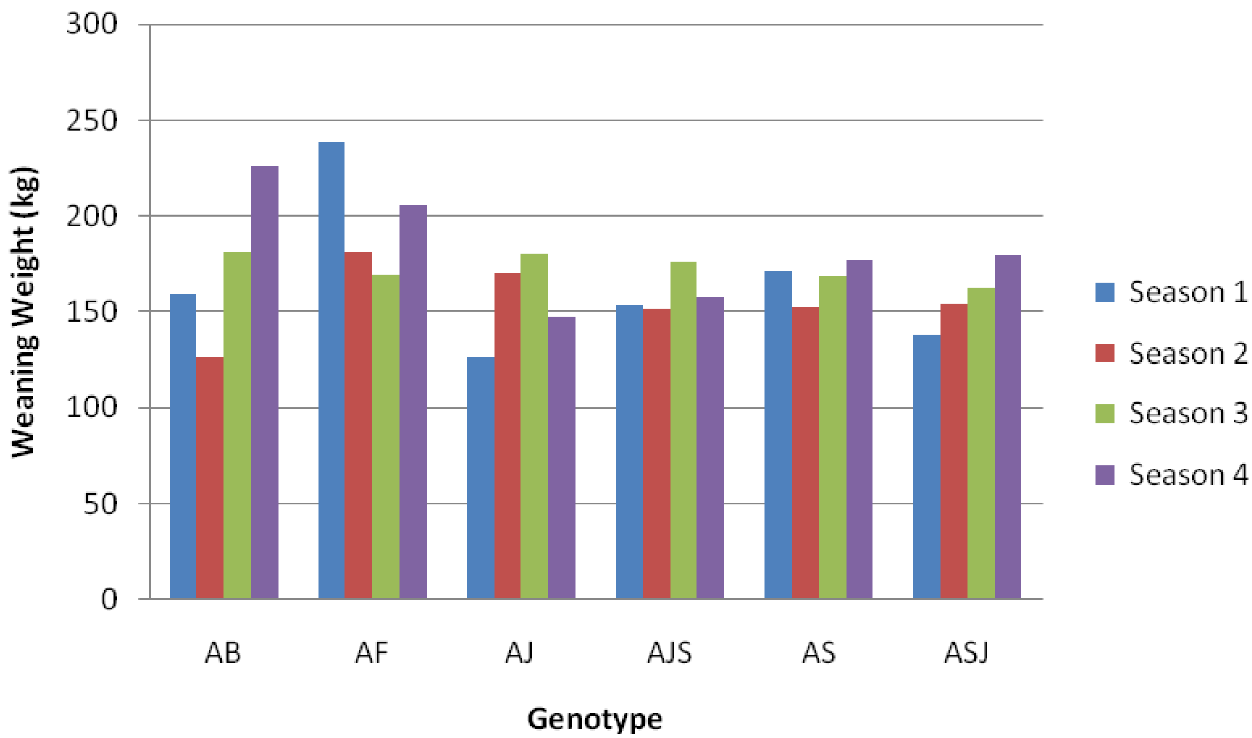

Figure 2. Weaning weights of calves born at RAB Songa Research Station: Breed group season interactions

Animals that were calved in 1998 were significantly heavier than those born in 1999, 2000, 2001, 2003, 2006 and 2007. Calving of 1999, 2003 and 2004 registered higher mature weights than those of 2001 and 2007. The mature weights of calving from 2000 were higher than those from 2003, 2006 and 2007. Animals born in 2002 also weighed more than those calved in 2003, 2004, 2006 and 2007 (Figure 4).

Due to limited data, partitioning between pre weaning and post weaning growth rates could not be done. Therefore, growth rates from birth to 18 months of age were computed as one data set. Growth rates of calves from birth to maturity differed by breed group (P=0.002), and year of birth (P=0.02). Season and its interaction with breed group did not significantly influence as well as sex did not affect growth rates.

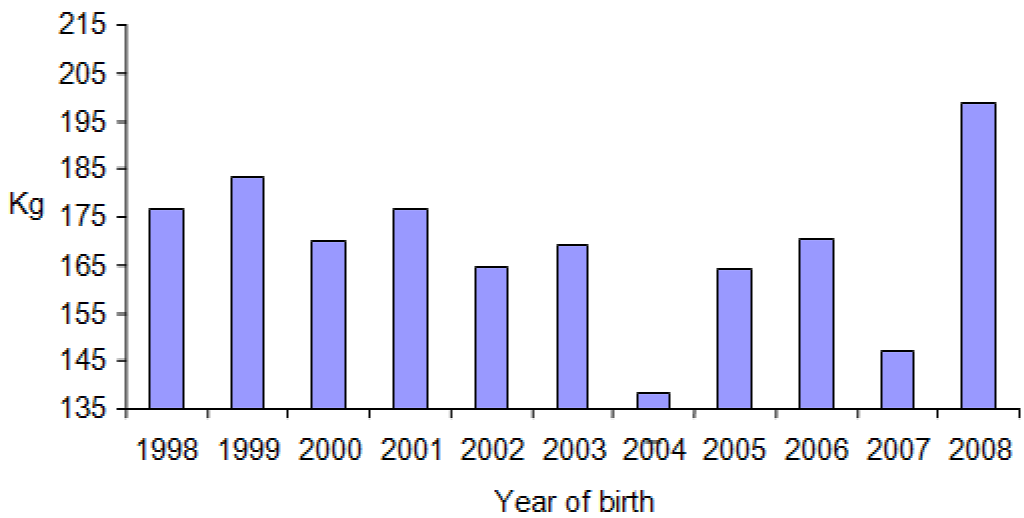

Figure 3. Variations in weaning weight of calves across years of birth at Songa Research Station

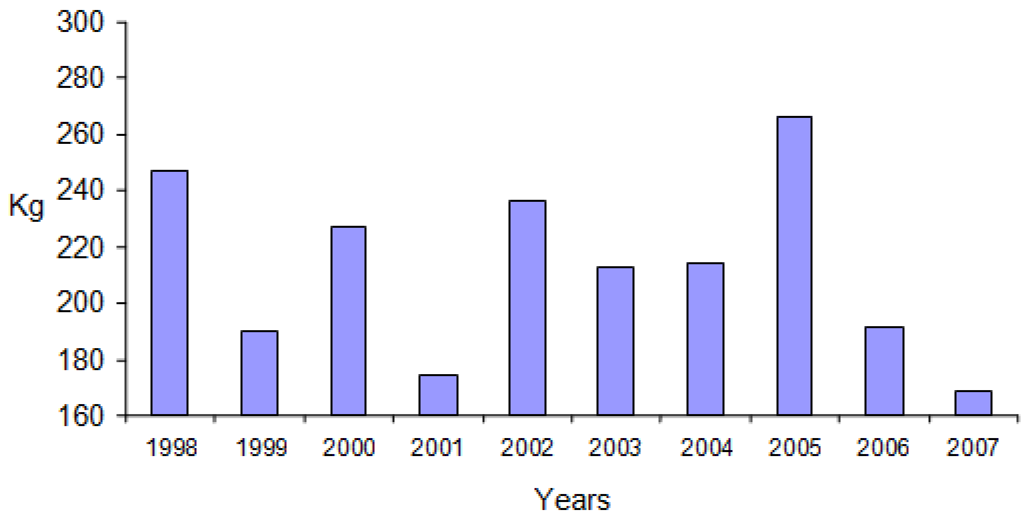

Figure 4. Variation of weight at 18 months age of cattle breed groups by year of birth at Songa Research Station.

Table 3 shows that breed group AB grew significantly faster than all other breed groups ($P<0.01$). The lowest growth rate was registered in breed group AS ($P<0.01$). However, the rate of growth of AJ, AJS, ASJ were similar ($P>0.05$).

Table 3 Least square means of growth rates of cattle breed groups at Songa Research Station across seasons.

	Growth rates ($g\ d^{-1} \pm$ s.e)				
	Season of Year				
Breed group	1	2	3	4	Breed group Mean[1]
AB	381.8 $\pm$23.5	394.9 $\pm$ 25.0	424.5 $\pm$ 26.4	398.9 $\pm$ 25.6	400.0^{a} $\pm$ 16.4

AF	358.5 ± 21.8	381.5 ± 21.8	373.4 ± 22.5	350.7 ± 27.0	366.0^{b} ± 16.0
AJ	313.4 ± 16.7	368.4 ± 17.5	364.5 ± 18.1	356.7 ± 21.1	350.7^{bc} ± 12.7
AJS	320.4 ± 24.1	358.9 ± 22.2	348.9 ± 22.4	347.7 ± 22.9	344.0^{bc} ± 14.0
AS	316.8 ± 24.9	355.1 ± 21.5	319.7 ± 21.2	319.8 ± 21.5	327.9^{c} ± 14.9
ASJ	326.6 ± 17.9	332.6 ± 15.5	348.1 ± 19.0	358.6 ± 24.6	342.0^{bc} ± 13.1

[1]*Breed group means with same letters do not differ significantly.*

On the contribution of the environment to variance components, this study adopted year and season of birth as proxy indicators for environmental influence on progeny performance (birth weight, weaning, weight at 18 months, and growth rates). Nested random effect analysis of variance was executed to assess the contribution of genetic and environmental source to total variance. The random effects associated with error variance increased with age; while the aggregate proportional contribution of environment (YoB and SoB) declined (Table 4). The most consistent environmental factor has been the year of birth on all performance indicators.

Table 4 Percent contributions to variance components of birth weight, weaning weight, mature weight and growth rate of cattle at Songa Research Station

	Percent Contributions to Variance Component			
Factor	Birth weight	Weaning weight	Weight at 18 months	Growth rate
Breed group	-	4.1	-	0.3
Sex	7.8	-	3.4	-
YoB	44.4	37.7	22.8	28.7
SoB	5.9	-	-	-
MoB	23.5	13.6	25.1	-
Error	18.5	44.6	48.7	71.0
% Environment	73.8	51.3	47.9	28.7
Total	100.0	100.0	100.0	100.0

Discussion

Causes of variation in birth weight

The influence of breed group on birth weight was not significant despite the observed difference in mean birth weights (Table 2). No previous studies on the breed group effects on birth weight under Rwanda conditions have been documented. However, from work done with other comparable breed groups, the results of this study are in agreement with those from crossbreeding experiments carried out at Naivasha NAHRS (Annual report 1974); but contradicts those of Trail et al (1971) who reported that the progeny of Boran and Ankole dams were significantly heavier (14.0%) than those of zebu dams (P>0.05). Several researchers have reported comparable, lighter or heavier birth weight values obtained from different crossbreeding programs. Trail et al (1985) reported 30, 30, 28.2, 32.6, 31.9, 27.8 kg weights of Angus x Ankole, Angus x Boran, Red Poll x Ankole, Red Poll x Boran, Red Poll x Zebu calves respectively raised in Uganda. Later on, Rege et al (1994b) reported birth weights of 20.4 kg for Jersey x Ghana Short horn while Danbaro (1990) reported 21.2 kg for the same breed. Higher estimate of birth weight (39.1 kg) for Friesian calves have been reported by Shin et al (1986). Some workers reported lower mean Friesian birth ranging from 25.8 to 33.5 kg (Frietas et al 1987; Bilal 1996; Singh et al 1997, Vassilev 1998, probably working in more difficult environments.

Even though not statistically significant, the birth weight of male calves was approximately 4% higher than that of female calves. The non-significant effect of sex on birth weight in this study is in agreement with observations by Diack et al (2004) and Bosso (2006). On the contrary, Tadesse and Dessie (2003) reported higher birth weight in male calves (30.8 kg) than in female calves (29.9 kg) of Holstein calves kept in Ethiopia. Nevertheless, many researchers have reported significant effect of sex on birth weight, including Freitas et al (1987) and Guaragna et al (1990) who reported that birth weight was significantly affected by sex of calves in Holstein Friesian. The difference in birth weight between sexes was lower than most values reported in literature. This is attributed to longer gestation period of male calves or higher androgen concentration in foetuses. The heaviest calves were born in 2001, followed by 2005, 2002, 2000 respectively, while the lightest birth weights were registered in 1998, and 2008. Despite the observed variation (Figure 1), the effect of the year on birth weight was not significant; yet, a significant effect of year on birth weight has been reported by various researchers (e.g. Sang et al 1986, Kayigisiz et al 1995). Year effect doubtlessly reflects climatic, feeding, sanitary, and management conditions of the dam during gestation; and because of changes that occur in these conditions from year to year, differences in calf birth weights among years are expected. Therefore, the years 2001, followed by 2005, 2002, 2000 were respectively more favourable than 1998 and 2008.

The non-significant effect of season on birth weight observed in this study is in agreement with results from other studies. Oddoye et al (1999) found a non-significant effect of season on birth weight and pre-weaning average daily gain of Sanga cattle. Similarly Orneas (1982), Shin et al (1986) and Guaragna et al (1990) reported non-significant effect of season of calving on birth weight of calves in Holstein Friesian calves. In contrast, other workers have reported significant effect of season on birth weight Okantah (1990) in Sanga calves and Chaudhri et al (1995) in Jersey calves. Seasonal fluctuations in temperature, precipitation, relative humidity and other climatic factors are the most important causes of the influence of season of birth since these variables determine the abundance or scarcity of forage available, which is directly related to the general physical condition of the dam during gestation, and thus perhaps reflect on birth weights of the calves. Thus the non-significance on influence of season on birth weight suggests that the variation in temperature, precipitation and other environment factors among seasons had little effect on dams during gestation period.

Weaning weight

The significant effect of breed group on weaning weights observed in this study is in agreement with those of Trail et al (1971) on crossbreeding Ankole, Boran and Zebu in Western Uganda; and Sottie et al (2009) who found significant breed group effect on weaning weight of Sanga and Friesian-Sanga crossbred calves in Ghana. The effect of season on calf body weight and growth is related to the availability of feed (Okantah and Curran 1982). Season of birth as expected had significant influence on weaning (Table 2), supporting earlier studies (e.g. Okantah and Curran 1982). The significant effect of breed group by season interaction on weaning traits in this study indicates breed groups are responding in different ways to effects of season within the same ecological zone and breed groups cannot be discussed in isolation without reference to the respective seasons of birth. The results from analysis indicate that some seasons of birth had greater effect on some breed groups than others. The effects of season of birth and breed group have also been found to be significant under tropical conditions elsewhere (Magaña and Segura-Correa, 2006). In our study, there was a change of merit when animals were compared across seasons. For instance, the weaners of Ankole × Friesian crosses were significantly heavier than weaners of other breed groups in season 1 and 2, while Ankole × Brown Swiss crosses were the heaviest in season 3 and 4. This suggests that the variation in temperature, precipitation and other environmental factors among seasons had significant effect on the calves or on their dams at weaning.

The best season of birth for nearly all breed groups was season 4 (February to Mid- June). On this basis, it appears that there is advantage in mating cows at a certain time of the year, so that the birth – weaning intervals includes the largest number of days with the highest availability of forage, which in turn would determine plentiful feeding for dams and thus more efficient nursing conditions. The results suggest that the best breeding season for Songa is that of May to the end of August. The mean values of weight at weaning reported in this study are lower than mean values reported by Joao et al (1982) of 217±1 kg for Canchim cattle when similarity in weaning age is considered, but are higher than those reported by Danbaro (1990) for Jersey x Sokoto Gudali, Ngere (1971) for Friesian x Ghana short horn and Ahunu et al (1997) for Red Poll x Ndama. However, the apparent variations in weaning weight in the present study when compared to data reported elsewhere should be interpreted with caution in view of the great variability in weaning age. In addition, the different conditions prevailing at experimental stations or farms and management with or without supplementation could be among the probable sources of error when herds of different breeds and in different environments are compared. The wide range of weaning weight for AB and AF breed groups (Figure 2) compared with the range of mean weights for AJ, AJS, AS, and ASJ suggests breed groups containing Jersey and Sahiwal blood were more resilient to environment pressure and therefore these breed groups are considered the best for Songa environment.

The effect of sex was not significant, however, the least square constants showed a 15 kg difference in favour of males. The sexual dimorphism observed in weaning weight could be partially explained by the action of sex hormones on secondary sex characteristics (e.g. skeletal conformation and muscle size). In addition different figures mostly found in literature are due to difference in breed groups used, management practice of supplementation or time of castration (Pahnish et al 1961; Sacker et al 1971b). Also owing to the longer gestational period, males are heavier at birth and carry this advantage throughout the nursing period, with higher weaning weights.

The year of birth effect significantly influenced weaning weight with increased weights occurring in 2008 (Figure 3). The significant effect of year on weaning weight has been reported by several other studies on different breeds of cattle (Badran and El-Barbary 1986; Kabuga and Agyemang 1984; Oudah and Mehrez, 2000; and Lengyel et al 2002). This significant effect seems to depend largely on favourable climatic conditions with increased weaning weights being observed during the years with good rainfall and consequently abundant forage. Favourable environments also ensure low incidence of diseases. The variation in weaning weights caused by year effect in this study agrees with those reported by Kennedy and Chirchir (1971), Tonn (1974) and Mortojo (1973). In a situation where calves and their dams are not supplemented as is the case for Songa farm, the weaning weights of calves seems to vary with rainfall amounts and distribution in each year. This determines the amount and quality of forage available to the animals.

Weight at 18 month of age

The significant effect of breed group on weight at 18 month of age is confirmed in this study and agrees with Trail et al (1971) who worked with crossbred beef cattle in Western Uganda. The results of this study were highly significant ($P<0.001$) (Table 5), however what is surprising is that the weight difference of 41 kg between means of the female and male cattle obtained in this study was significant, and is contrary to several investigations where the male performance is superior, because the poorer performance of females compared to males is expected from their sexual hormonal imbalance. The possible reason could be due to sale of fast growing male animals right after weaning. This is the cattle management practice at the station, hence possibility of missing the records of fast growing animals. The performance of breed groups varied from year to year. For instance animals born in 1998 were significantly heavier than those born in 1999-2003 and 2006-2007 (Figure 4); while animals born in 2006 and 2007 registered lightest weight. In situations where cattle are not supplemented as is the case for Songa farm, the body weight of animals seem to vary with amount and distribution of rainfall in each year, which directly determines the quantity and quality of pastures in each particular year and this is also different from place to place. On the other hand, season of birth had no significant influence on weight at 18 month of age. This suggests that the variation in temperature, precipitation and other environmental factors among seasons had little effect on heifers at 18 month of age.

Growth rates

The breed group effect was significant for growth rates. It should be noted however, that breed effect was partially confounded with period as some breed group data was missing in some periods. Therefore, only general trends can be inferred from the results for breed group effect. Breed group AB grew faster than all other breed groups; but its growth rate was not significantly higher than breed group AF. The lowest growth rate was registered in breed group AS. However, the speed of growth was similar to those in breed groups AJ, AJS, AS and AJS ($P>0.05$) (Table 8). This is perhaps due the higher growth potential of Holstein Friesian and Brown Swiss, thus the crossbreds with Ankole excelled due heterotic effect. Effect of season was significant ($P<0.001$) for weaning weight, however, what was surprising was that season of birth did not significantly influence weaning to 18 month growth rate and had no contribution to variation of growth rate after weaning period. This could be due to the post weaning stress which may have obscured the effect of season of birth. It was clear that no particular season of birth was significantly associated with superior performance of any breed group studied.

Variance components

From Table 4, only the year of birth contributed consistently to the variance components. The breed group had no contribution for birth weight, while the variance ratios for effect of sex (7.8%), Year of birth (44.4%), Season of birth (5.9%), and the composite (Yob x Sob x Mob) effect accounted for 73.8% of the variability. The present composite effect reported agrees with Pribyl et al (2003) who reported that the composite (herd × year × month) effect accounted for 73% of variability. However, when herd, year and month effect were separately included in the analysis, reported proportions of variability were 48% herd, 20% year, and 5% month. Krupa *et al*. (2005) reported the variance ratios for effect of sex (6%) breed (2.2%) and dams age (2.2%) as well as herd-year-season effect (72%) and these findings were similar to those reported by Jakubec et al (2003). When compared to the findings of the present study, those earlier reports show that environmental factors contributed a higher proportion to the total variance. The higher contribution of the environmental effect may be due to high herd variability in both management practices and climatic conditions. The random effects associated with error variance increased with age; while the aggregate proportional contribution of environment declined (Table 4). Except the year of birth that consistently contributed to all age groups, only breed group contributed to the growth rate.

Conclusion

- In this study, aimed at assessing the non-genetic (environmental factors) influencing growth and performance of cattle at Songa Research Station, Rwanda, results show that environmental factors had a significant influence on weaning weight, and weight at 18 month of age, but not earlier, on birth weight.
- The interaction of Breed group × Season had a significant effect on the weaning weight, hence emphasizing the importance of matching cattle breed groups with particular environments.
- No phenotypic parameter estimates were found in literature for the cattle breed groups studied, whether in different or similar production system/conditions to Rwanda. However, the results obtained in the current study for birth, weaning and mature weights are comparable with those reported for other pure and crossbred populations.
- The breed groups, Ankole × Brown Swiss (AB), and Ankole × Friesian (AF) grew faster than those containing Sahiwal and Jersey blood; however, they showed wide variation in growth indicating their susceptibility/sensitivity to tropical environmental stress.
- Breed groups: AS, ASJ, AJ and AJS proved to be less sensitive to seasonal variation and hence, are the best breed groups for the Songa and related environments.
- It can be concluded that Ankole × Jersey and Ankole × Sahiwal crossbred cattle have the potential of surviving and producing under minimal management, typical under resource poor farmer's conditions. However, the development of Friesian × Ankole and Brown Swiss × Ankole crosses under a management system of improved nutrition can hold a promise for the cattle industry in Rwanda.

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