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ORIGINAL RESEARCH

Factors influencing reproductive performance of cows from different Nguni ecotypes in southern Mozambique

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Abstract The objective of this study was to assess the reproductive performance of two Nguni ecotypes (Nguni and Landim) raised in a subtropical environment to enhance strategies for livestock development and restocking programmes within the southern African region. Reproduction data collected between 1996 and 2009 from 365 cows of the Landim and Nguni ecotypes were analysed. From the results, ecotype, place of birth, year and season of birth/calving had significant effects on age at first calving (AFC) and calving interval (CI). Overall means for AFC and CI were 1,071±166 days and 432±85 days, respectively, while average calving rate was 88.0±4.7%. Heifers born in the dry season had lower AFC than heifers born in the wet season. Heifers born at Impaputo Breeding Center were the youngest at first calving, followed by the South African born ones. Heifers of the Landim ecotype also calved younger than heifers of the Nguni ecotype. CI was shorter in wet seasons (main breeding seasons) than in dry seasons. Interaction between ecotype and year–season ($p<0.005$) showed that, in wet and dry seasons, Nguni cows had shorter CI than the Landim. This study demonstrates for the first time a possible genotype-by-environment interaction between Nguni ecotypes. This might aid future cattle development and restocking programmes in southern Africa taking into consideration the adaptation of indigenous genotypes and climate change.

Keywords Breeding season · Calving · Landim · Livestock development · Sanga · Subtropical environment

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Introduction

Nguni cattle, within the Sanga group, were derived from the following three main migration routes through southern Africa: the first one from Ethopia southwest to Ovamboland and Botswana; the second route from Ethopia south to Zimbabwe, the northern and eastern parts of South Africa; and the third route from Ethiopia southeast to Mozambique, Zululand and Swaziland (Ramsay 1988). The interaction between the environment and the genotype over a period of 1,200 years resulted in different Sanga cattle ecotypes, which probably led to different Nguni ecotypes found in South Africa, Swaziland, Namibia and Zimbabwe sharing a common genetic background (Ramsay 1988).

In Mozambique, the Nguni, known as the Landim, was numerically the largest indigenous cattle breed (Morgado 1953/1954; Rocha 1985; Maciel 2001) and mainly distributed among the provinces of Maputo, Gaza and Inhambane in the southern region, where the tsetse fly challenge was low (Rocha et al. 1991). Indigenous to southern Africa countries, and despite being highly adapted to the harsh local environments (Rocha 1985, Collins-Lusweti 2000; Muchenje et al. 2008), the different Nguni ecotypes are yet to be fully characterized. Performance of the Landim has only been compared with the Afrikaner (also an indigenous breed to southern Africa) at the Chobela Research Station (Catalão and Syrstad 1990; Carvalheira et al. 1995) in Maputo province. Unfortunately, large numbers of these animals were lost between 1987 and 1992 during the Mozambican civil war.

Following the end of the war, Mozambique undertook a Livestock Restocking Program importing indigenous cattle breeds from neighbouring countries, especially South Africa, as a fast way of reestablishing the national cattle population and industry. The rehabilitated Impaputo Breeding Center (PFI), at the border with Swaziland, was stocked with nuclei herds of Nguni ecotypes from South Africa and Landim ecotypes from the Chobela Station in 1996. The main goals of the PFI were to establish an *ex situ* conservation programme and increase cattle numbers in order to meet the local/national demands for indigenous cattle and their products. The animals in these nuclei herds are the only ones in Mozambique registered with the Nguni Cattle Breeder's Society of South Africa.

The objective of the current study was to assess the reproductive performance of two Nguni cattle ecotypes (Nguni and Landim) under the same local environment, in order to better inform livestock restocking programmes and cattle development strategies in Mozambique. The hypothesis tested was that, under the same local environmental conditions, South African Nguni and Mozambican Landim did not differ in reproductive performance.

Materials and methods

Description of the study area/site

Maputo province is characterized by warm tropical climate with an average temperature of 23.6°C (1994 to 2009), reaching the maximum average of 28.7°C and the minimum average of 18°C (FAO 2007).

This study was conducted at the Impaputo Breeding Center (PFI) located at 25.93° latitude South and 32.16° longitude East, in the transition area between the Cordilleras of the Great and the Small Libombos mountains, and at an altitude of 150 m above sea level. In order to assess the effects of seasonal variation of climatic conditions on reproductive performance of Nguni cows, from Mozambique and South Africa ecotypes, temperatures and rainfall data were extracted from the meteorological station nearest to the PFI since the centre has no weather station. Changalane meteorological station, located 43.2 km from PFI at 26.28° South and 32.18° East and at an altitude of 104 m above sea level, would have been the ideal weather data source. However, there was not sufficient weather data covering the study period at this station. The Maputo–Mavalane village located at 25.92° latitude South and 32.57° longitude East, at an altitude of 44 m above sea level and 45.7 km from PFI, was the alternative site due to the availability of climatic data for the whole study period.

PFI is characterized by a subtropical climate and falls within a semi-arid agroecological region. Figure 1 shows the rainfall and the temperature patterns in wet and dry seasons during the study years in Maputo–Mavalane village, within which PFI is located.

The hottest months, between December and March, and the coldest months, between July and October, coincide within the wet (October to April) and dry (May to September) seasons (Fig. 1), respectively. In 2000, the southern region suffered heavy floods, due to the heavy downpours (i.e. 408.4 mm of rain falling only in March). However, PFI had a slightly different rainfall pattern, due to its location and higher altitute as it normally does not receive rains coming from the East (Indian Ocean), but rather rains from South–East.

PFI consists of 1,700 ha, of which 630 ha are suitable for natural and cultivated pasture production, 570 ha suitable for improved natural pastures (after shrub cleaning) and 500 ha suitable for browsing. The vegetation is mainly composed of mixed grass species such as *Hyparrheania* sp., *Panicum maximum*, *Eragrostis superba*, *Echinochloa* spp., *Urochloa mozambicensis*, *Cynodon* spp., *Rynchelitrum repens* and *Themeda triandra* associated with *Acacia* sp. Underground water is irregular and difficult to find, while the surface water is in excess during wet seasons and almost nonexistent in dry seasons. Access to good quality feed is also a challenge, especially during dry seasons.

Animal management

Reproduction data, collected between January 1996 and December 2009, from 365 cows of the Landim and Nguni ecotypes reared at PFI were analysed. Animals were commercially managed on natural grasslands with feed supplementation during dry seasons. Dry season feed supplementation consisted of hay from *Sorghum sudanensis* and *P. maximum* mixture, grounded with some molasses and chicken manure. Calves were weaned at approximately 8 months of age, weighing on average 140–150 kg. Branding of animals was also undertaken at weaning. Females were selected for early age at first calving and based on longevity of their dams. Females which did not calve at 4 years of age were culled. During the last 2 years, cows born in 1994 and 1995 were kraaled to maintain their body condition until their calves were weaned.

Two breeding seasons, from January 1 to March 30 and from July 1 to August 30, were practiced to ensure that cows calve during a restricted period. All cows that were exposed to a bull (25 cows for one bull) but did not

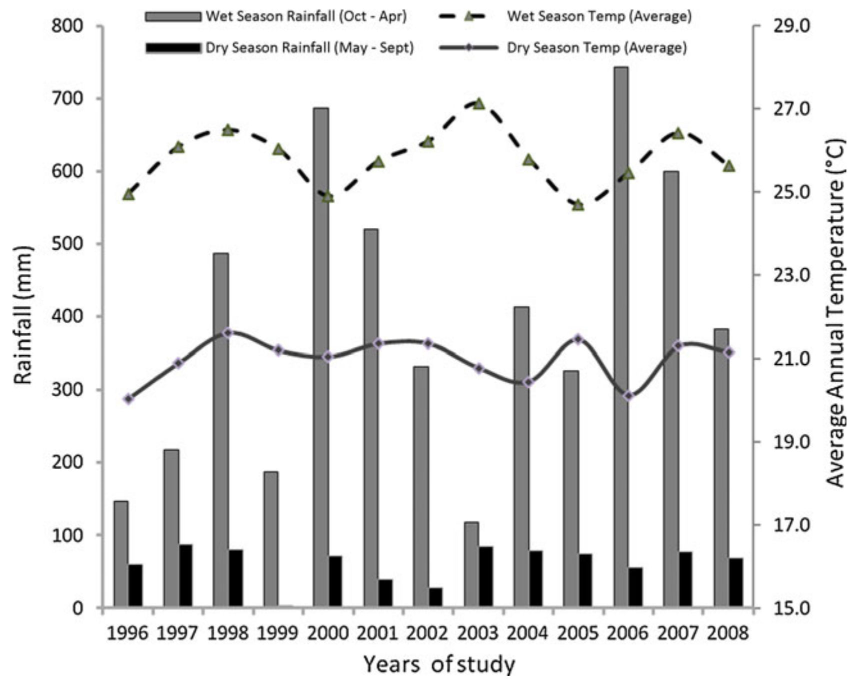

Fig. 1 Rainfall and temperature patterns during the wet (October to April) and dry (May to September) seasons over a 12-year period (1996–2008) at Mavalane district in Maputo province. *Grey bar* rainfall in wet season, *black bar* rainfall in dry season, *dashed line* temperature in wet season, *solid line* temperature in dry season

conceive for two consecutive breeding seasons were culled. Nguni and Landim were bred in separate herds to ensure purity within the two ecotypes. Dipping in acaricide solution against ticks was routinely done, once every 2 to 3 weeks, depending on the degree of tick infestation. Deworming was also carried out at the end of the wet and dry seasons, while vaccination against brucellosis was carried out at 4–8 months of age in heifers, and annual screening for the disease was performed on breeding females and males. An annual TB surveillance was also undertaken.

Derivation of traits

Reproductive performance data were collected on 365 cows of Landim and Nguni ecotypes between 1996 and 2009. These cows were born at the Chobela Research Station (Landim), at PFI (Landim and Nguni) and in South Africa (Nguni). Age at first calving (AFC) was calculated as the period, in days, between the heifer's birth date and its first calving date. To conform with the management practice on the farm, only cows with AFC greater than 540 days and less than 1,460 days were included in the analysis. The few animals that did not meet these criteria were excluded as outliers.

Calving intervals (CI) were calculated as the period, in days, between a given calving date and the most previous one. CI shorter than 300 days and longer than 730 days were excluded from the analysis as they were considered abnormal calvings. All parities were numbered, and births were classified as normal, abortions, stillbirth or premature. Based on preliminary analysis, parities beyond seventh were pooled into parity seventh, and their respective calving intervals into the seventh calving interval. Records for which the cow parity was uncertain were also excluded. Calving rate (CR) was computed as the number of cows calving in each season divided by the number of cows submitted to the breeding season, multiplied by hundred.

Statistical analysis

Reproductive performance data were analysed using the PROC GLM procedure of SAS Institute (2003). Sources of variation or factors that were fitted in the model included breed type (ecotype), place of birth of foundation animal, parity, year and season of calving and year–season by ecotype interactions. Least square means (LSmeans±standard errors) for the groups are presented as LS means±SE.

AFC, as a dependent variable, was analysed, and the fixed effects for this were herd (South Africa, Chobela and PFI), year–season of birth and ecotype (Nguni and Landim). The following statistical model was used:

$$Y_{jklm} = \mu + h_j + ys_k + t_l + e_{ijklm}(\mathrm{AFC})$$

where

Y_{jklm}	The observations on age at first calving in days
μ	The underlying constant common to all observations
h_j	The fixed effect of the jth herd (j=1, 2, 3)
y_{sk}	The fixed effect of the kth year–season of birth (k= 1994, 1995,…….. 2006)

t_l The fixed effect of the lth ecotype (l=Nguni, Landim) and

e_{ikllm} The random residual NID (0, σ_e^2).

For the analyses of the dependent variables, CI and CR, the fixed effects were parity (1 to 8), herd (South Africa, Chobela and PFI), year–season of calving and ecotype, as well as the interactions between year–season-by-ecotype and parity-by-ecotype. For these variables, the following statistical model was used:

$$Y_{ijklm} = \mu + p_i + h_j + ys_k + t_l + e_{ijklm}(\text{CI and CR})$$

where Y_{ijklm}=the observations on calving interval in days, μ, h_j, ys_k, t_l and e_{ikllm}=as described in AFC model, while p_i=the fixed effect of the ith parity (i=1,2,…8). The differences were considered to be significant at $P<0.05$.

The abortion rate and other calving abnormalities were calculated as year by season frequencies for each ecotype.

Results

Average reproductive performance of different ecotypes

The LS means±SE for AFC, CI and CR for the two ecotypes are presented in Table 1. AFC for the Landim ecotype was significantly lower ($p<0.005$) than for the Nguni. Origin of the herd had a significant effect on AFC ($p<0.05$), with heifers born at PFI being younger than the ones born at Chobela. Both CI and CR were also significantly influenced by herd origin ($p<0.0001$), with the South African-derived cows having longer CI and lower CR than the PFI (Table 1).

Seasonal variation in age at first calving

The AFC for the heifers born in dry and wet seasons during the study period is presented in Fig. 2. Year–season of birth significantly affected AFC ($p<0.0001$). Except for heifers born in 2004 and after, heifers born in dry seasons (May to September) were generally younger at first calving than those born in wet seasons (October–April) as illustrated in Fig. 3. Heifers born in the dry season of 2004 (1,288.37±67.53 days) were the oldest at first calving, while those born in dry and wet seasons of 2007 were the youngest at first calving.

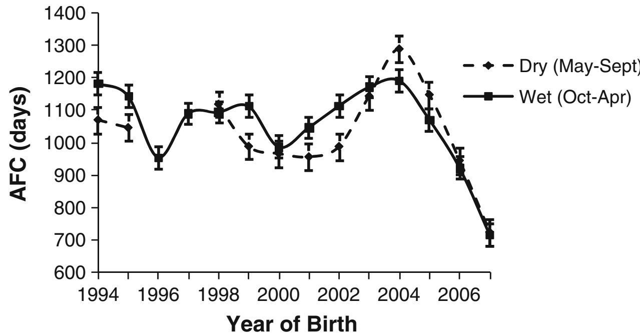

Fig. 2 Effects of wet (October to April) and dry (May to September) seasons on age at first calving (AFC) in days of heifers of the Landim and Nguni ecotypes born during 1994 to 2006 period in Impaputo Breeding Center (PFI). *Dashed line* dry season, *solid line* wet season. *Vertical lines within the dashed and solid lines* indicate the standard errors of the least square means

Calving intervals

Parity had a significant effect ($p<0.0001$) on CI and on CR. An interaction between ecotype by parity significantly affected CI ($p<0.05$). Figure 3 shows the trends of calving intervals by cow parity for the Nguni and Landim ecotypes.

To maintain congruence between parities and CI, parities corresponded to the CI, with parity 1 being associated with the cow's second calving. Across ecotypes, CI associated with parity 1 and 2 were significantly higher than CI in all the other subsequent parities ($p<0.0001$ to $p<0.05$), at parity 3, CI was significantly higher than the CI for parities fourth through sixth ($p<0.005$), and at parity 5, CI was only

Table 1 Comparative reproductive performance of Landim and Nguni ecotypes in Impaputo Breeding Center (PFI) in Mozambique during 1994 to 2009 period

Traits	Overall mean	Ecotypes		Origin of the herd		
		Nguni	Landim	Mozambique		South Africa
				Chobela	PFI	South Africa
AFC (days)	1,071±166	1,085±40**	1,003±39**	1,129±69***	965±22***	1,039±22***
CI (days)	432±85	422±9	446±11	428±12	415±9*	458±10*
CR (%)	88.1±14.7	90.0±1.5	85.7±1.9	88.9±2.0	91.5±1.5*	83.4±1.7*

AFC age at first calving, *CI* calving intervals, *CR* calving rates

*$p<0.0001$; **$p<0.005$; ***$p<0.05$, least square means (LSM) differ significantly

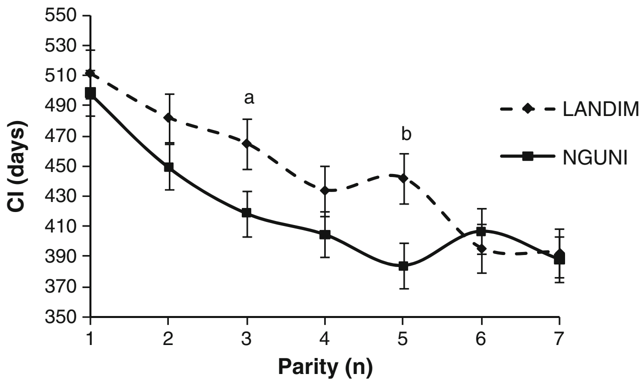

Fig. 3 Effects of number of parities on calving intervals (CI) in days of cows of the Nguni and Landim ecotypes during 1998 to 2009 period in Impaputo Breeding Center (PFI). *Dashed line* Landim ecotype, *solid line* Nguni ecotype. *Vertical lines within the dashed and solid lines* indicate the standard errors of the least square means. *Different letters* indicate statistical differences between ecotypes within parity ($p<0.05$)

significantly higher than parity seventh ($p<0.05$). In the Landim, CI from parities 3, 4 and 5 were significantly different from CI at parities 6 and 7 ($p<0.05$), while in the Nguni, only CI at parity 3 was significantly different from CI at parities fifth and seventh ($p<0.05$). No significant differences in CI between seventh parity and beyond, which were also associated with lower calving intervals, justified the grouping of data from the eighth calving onwards into the seventh parity (eighth calving interval).

Only the CI estimates associated with the third ($p=0.017$) and fifth ($p=0.028$) parities were significantly different between the two ecotypes. As observed in Fig. 4, calving intervals decreased as parities increased. However, an increase in CI was observed on the fifth and on the sixth parities for the Landim and the Nguni, respectively, followed by a decrease until the seventh parity, when both ecotypes registered similar CI.

Seasonal variation of calving interval

Year–seasons ($p<0.005$) as well as ecotype-by-year–season interaction ($p<0.0001$) had a significant effect on CI. Figure 4a, b shows the seasonal variation in CI between the two Nguni ecotypes (Landim and Nguni).

In general, there were ecotype-by-calving season interactions for both dry and wet seasons; in the dry seasons, Landim and Nguni cows had similar CI estimates, while in the wet seasons, Nguni cows had lower CI than the Landim.Within the same year, interaction of ecotypes-by-year–season was observed in 1998 dry season ($p<0.005$) and in 2004 and 2005 wet seasons ($p<0.05$).

As observed in Fig. 4a, calving intervals in dry seasons were generally longer for the Landim than for the Nguni, with exceptions for CI between 1998 and 1999 and

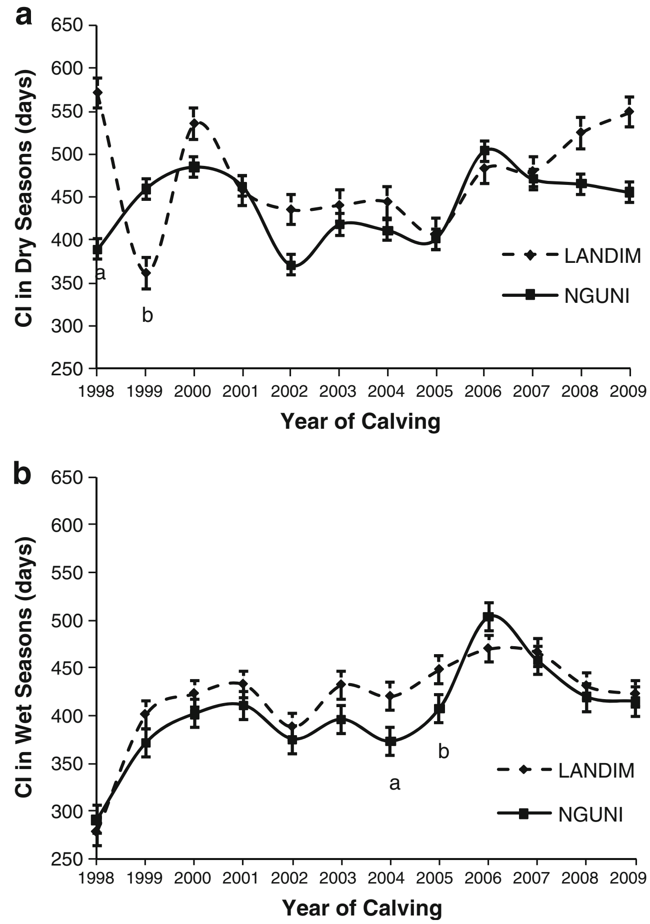

Fig. 4 **a** Effect of dry season (May to September) on calving intervals (CI) in days of cows of the Nguni and Landim ecotypes during 1998 to 2009 period in Impaputo Breeding Center (PFI). *Dashed line* Landim ecotype, *solid line* Nguni ecotype. *Vertical lines within the dashed and solid lines* indicate the standard errors of the least square means. *Different letters* indicate statistical differences between ecotypes within the year–season ($p=0.0009$ for **a** and $p=0.02$for **b**). **b** Effect of wet season (October to April) on calving intervals (CI) in days of cows of the Nguni and Landim ecotypes during 1998 to 2009 period in Impaputo Breeding Center (PFI). *Dashed line* Landim ecotype, *solid line* Nguni ecotype. *Vertical lines within the dashed and solid lines* indicate the standard errors of the least square means. *Different letters* indicate statistical differences between ecotypes within the year–season ($p<0.05$)

between 2005 and 2006, which were shorter in the Landim. In the dry seasons, the Nguni had the shortest calving interval between 2001 and 2002. As observed in Fig. 4b, wet seasons between 2005 and 2006 had the longest CI for both Landim and Nguni ecotypes, which was significantly different from all other wet seasons ($p<0.05$), while the shortest CI was observed between 1997 and 1998.

Calving rate and abortion rate

Calving rates (CR) were significantly affected by interactions between ecotype and parity ($p<0.005$), as well as year–season ($p<0.001$), with wet seasons having significantly higher CR than dry seasons. Table 2 presents the CR observed among both ecotypes with respect to parity.

As observed in Table 2, while calving rates among the Landim increased between the fourth and seventh parity, among the Nguni, the highest CR (97%) was observed in the fifth parity. During the study period, there was an outbreak of abortions from 2005 to 2008, with the highest abortion rate being observed in 2006. Figure 5 presents abortion rates by ecotype and season.

As presented in Fig. 5, the highest (51.2%) contagious abortion rate was observed in 2006 for both Landim and Nguni. Surprisingly, Landim had higher abortion rates than the Nguni ecotype. Higher rate of abortions was observed in wet seasons than dry seasons, with 42.1% of Landim cows aborting compared to 25% of the Nguni cows during the 2006 wet season. Thereafter, abortion rates steadily decreased, with the lowest rates (2.3%) being observed in 2009.

Discussion

In this study, the overall AFC mean for both Landim and Nguni was 35±5 months, which is similar to the results obtained by Grossi et al. (2008) for the Nelore cattle (36.00 ±4.00 months) in the State of São Paulo, Brazil. The large standard errors were most probably due to large differences in age of the foundation herds that were brought in from Chobela Station and South Africa. Under PFI environment, Landim cows were younger than Nguni at first calving. Cows that were born at PFI were not only the youngest at first calving but also had the shortest CI and the highest CR. This might be related to the management that the PFI animals are submitted to, like exposure to the bull after weaning, good quality dry season feed supplementation, as well as the subtropical climate of the region. These results are in agreement with those reported by Scholtz and Lombard (1992) for the Nguni ecotype in South Africa.

Table 2 Effect of parities on calving rates of the Nguni and Landim ecotypes in Impaputo Breeding Center (PFI) during 1996 to 2009 period

Parity	Calving rates (LSM±SE, %)	
	Landim	Nguni
1	74.0±1.9	76.6±1.7
2	77.9±2.2	84.4±1.7*
3	83.2±2.5	90.6±1.9*
4	88.1±2.8	92.7±2.1
5	87.2±3.1	97.0±2.3*
6	94.5±3.6	92.7±2.5
7	95.5±3.8	96.3±2.5

*$P< 0.05$

Although cows that were born at Chobela, the original Landim herd, were the oldest at AFC under PFI environment, they were still about 5.5 months younger than the 41 months reported by Catalão and Syrstad (1990) and Carvalheira et al. (1995) for Chobela's Landim herd. At Chobela, a dry tropical climate, cows were submitted to the bull only at 18 months age and received only some straw supplementation and molasses during very dry years (Catalão and Syrstad 1990; Carvalheira et al. 1995), while at PFI, cows received good quality hay mixed with molasses and chicken manure in all dry seasons.

The highest AFC value, 42±2 months, similar to the results obtained by the authors referenced above for Mozambican conditions, was obtainded for cows which were born in the dry season of 2004. This performance compared well to heifers born in the dry seasons of other years. The high AFC values associated with the births in the 2004 dry season are understandable given that there was a severe drought in that year. In 2000, floods affected all the south region as well as the study site, which made the year's dry season less drier, having benefitted from the residual soil moisture from the flooding. Heifers that were born in that dry season were therefore signifcantly younger at first calving than the ones born in 2002 through 2004, as a result of the relatively better pasture and nursing conditions during their early calfhood. Over the years, heifers born at PFI became younger at first calving. For example, in 2007, an average AFC of 23±5 months and 24±6 months in the wet and dry seasons, respectively, was obtained and the lowest recorded. This low AFC in 2007 compared to previous years might be mainly associated with selection for precocity carried out at PFI.

Despite stressful conditions in dry seasons, specifically the unavailability of green pastures, heifers at PFI had generally lower AFC compared to wet seasons. This result seems to contradict with observations made by Carvalheira et al. (1995). The standard management practices at PFI, which included good quality feed supplementation during dry seasons in parallel with low temperatures, are probably the reasons for the lower AFC observed among heifers born during the dry seasons compared to wet seasons. Apparently, dry seasons' temperatures in southern Africa are also more favourable for animals to reproduce and have more regular oestrous cycles than wet and summer seasons (Kanuya et al. 2006 and Villa-Mancera et al. 2010). Previous studies reported that stressful conditions inhibit the immune (Sapolsky et al. 2000) and endocrine (Vighio and Liptrap 1990) systems through inhibition of HMG-CoA reductase enzyme for steroidogenesis, which then inhibits cholesterol, insulin-like

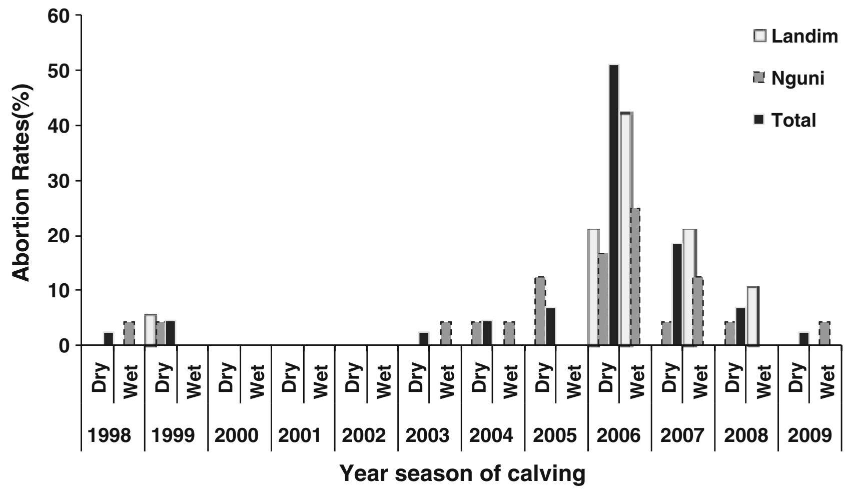

Fig. 5 Abortion rates (in percentages) of cows of the Nguni and Landim ecotypes in wet (October to April) and dry (May to September) seasons during 1998 to 2009 period in Impaputo Breeding Center (PFI)

growth factor (IGF)-I and IGF-II secretions (Maciel 2000 and Maciel et al. 2001), leading to slower development of the reproductive system (Yilmaz et al. 2006). It is likely that selection for precocity, at PFI, indirectly favoured heifers with higher levels of IGF-I, regardless of season of birth.

Calving intervals obtained for the Nguni and Landim ecotypes (14±3 months) in this study were a bit larger than previously reported for the Landim cows in Chobela (13 months) by Catalão and Syrstad (1990). With the exception of parity 5 being significantly different from parity 7 ($p<0.5$), no significant differences were found from parity 4 onwards with other subsequent parities. Beyond parity 7, there were no differences in CI between parities, such that all higher parities were grouped into parity 7. These overall results, greatly influenced by the first three parities, might be associated with the various challenges in the adaptation process that both ecotypes had to undergo when newly arrived at PFI, besides their additional nutritional requirements for growth.

For both ecotypes, CI following the first parity (i.e. between parity 1 and 2) differed significantly from all the remaining parities. The first CI obtained for the Nguni (16 months) and the Landim (17 months) was longer than the ones obtained by Scholtz and Lombard (1992) (15 months) for the Nguni, in South Africa, and Carvalheira et al. (1995) (14 months) for the Landim in Chobela, but similar to the ones reported by Collins-Lusweti (2000) for the first (16 months) and second CI (15 months) in Nguni cows. The relatively long CI in the first and second parities, compared with the results obtained by Scholtz and Lombard (1992) and Carvalheira et al. (1995), might be related to the challenges in adaptation to the PFI environment as already stated above.

From the second to the seventh parity, cows decreased their calving intervals from 16 months and 15 months to 13 months, with an overall average of 15 months and 14 months, for the Landim and Nguni, respectively. Matiko et al. (2008), analysing three management systems, reported that Tanzanian Zebu cows had prolonged intervals between first and second parities due to an 8-month delay in the onset of ovarian activity after calving compared to cows in their third or later parity (6 months). In our study, the overall average CI results are similar to those obtained by Catalão and Syrstad (1990), Scholtz and Lombard (1992) and Carvalheira et al. (1995) for the Nguni and Landim ecotypes. Besides challenges in adaptation, one has to consider that heifers in the first and second parities are still growing, thus, probably resulting in competition and partial diversion of nutritional requirements for growth versus reconception, which explains the longer calving intervals at the first and second parities that influenced overall CI between parities.

Comparing the two ecotypes, CI in the third ($p=0.017$) and fifth ($p=0.0208$) parities were significantly longer in the Landim (15 months each, respectively) than in the Nguni (14 months and 13 months, respectively). Looking at the perspectives of their reproductive lives, these differences might mean that the Nguni cow produces on average, at least, one extra calf in its lifetime compared to the Landim cow, thus, is more reproductively efficient than the Landim ecotype. Between the Landim and the Nguni, similar calving intervals from the sixth to the seventh parity might be related to high selection pressure on these cows for longevity at PFI, as only good cows remain in the herd after the fifth parity, while bad performing ones are culled.

The average CI within the study period (1998–2009) was generally lower in wet seasons (14 months) than in dry seasons (15 months). These results are within the annual averages reported by Scholtz and Lombard (1992) and Carvalheira et al. (1995) (15 months), however, lower than those reported by Collins-Lusweti (2000) (16 months) for the Nguni breed. Cows calving during wet seasons had lower subsequent CI compared to those having previously calved during the dry seasons, with Nguni cows having generally lower CI than Landim in both wet and dry seasons ($p<0.05$).

Within the same year–season, this study found interactions of year–season by ecotypes in the dry seasons of 1998 and 1999 ($p<0.001$) and in the wet seasons of 2004 and 2005 ($p<0.05$), when Nguni cows had significantly higher and lower CI than the Landim, respectively, which disagrees with observations made by Carvalheira et al. (1995). Within ecotypes and dry and wet years–seasons, Nguni had significantly different CI than the Landim, particularly in 2006 ($p<0.0001$) and 2007 ($p<0.05$) wet seasons, which were larger than all the previous wet years–seasons. Considering that Nguni cows were derived from different localities and farms in South Africa, these differences might be related to a possible larger genetic variability and lower selection pressure on this ecotype compared to the Landim, which were derived only from Chobela Station.

Higher calving rates for cows mated in wet seasons (92.1±3.3%) versus lower calving rates for the ones mated in dry seasons (83.7±6.1%) are most probably associated to the main breeding season (wet season) and lower fertility of the dry season mated cows, as already stated above. Although these lower calving rates in dry seasons seem to be linked to lower fertility cows, our results seem to agree with Kanuya et al. (2006) who found that in a semi-arid area of Tanzania, Tanzanian Shorthorn Zebu cows calved all year round, but had a calving peak between April and July (dry season), with conceptions being mostly between July and October of the previous year, when temperatures were still cool and some grass available from the previous wet season. It is important to remember that cows in communal areas are all year round with the bull, while cows at breeding stations have been selected to breed and calve during the "best" seasons which, according to our conditions, seem to be the wet seasons due to availability of grass and feed resources, although it is the hottest and humid season. This contradicts with the desirable cool conditions of the dry seasons necessary for the normal reproduction cycle in the animal.

Our results indicate that heifers born in dry seasons were younger at first calving than heifers born in wet seasons, which seem to agree with Kanuya et al. (2006), as this is the cool season, and heifers at weaning might still have some grass available from the previous wet season, while heifers born in wet seasons are subjected to high environmental temperatures and humidity, although grass and dry season feed supplementation were still available during the weaning period. This seems to also agree with Villa-Mancera et al. (2010), who referred higher conception rates in winter than in summer seasons, greatly influenced by temperatures, relative humidity, temperature–humidity index, wind speed and rainfall for dairy cows in Mexico.

In the main breeding season, January to March, cows had a following dry season feed supplementation during gestation and therefore likely maintained good body condition just before/at calving. Consequently, they suffered less stress during early stages of lactation due to better energy balance. For conceptions happening between July and August, cows were being supplemented, and environmental temperatures were still low with some erratic rains, helping grass to grow and helping cows maintain body condition until calving. Dry season feed supplementation in both breeding/calving seasons, associated with low environmental temperatures, supported the restart of the oestrous cycle on the right times due to low stress of lactation and low negative energy balance.

The differences in CI, between wet and dry seasons, are most probably associated with breeding management where the first main breeding season (January to March) coincides with the wet season, whereas the second breeding season (July to August) coincides with the dry season. Only cows that do not conceive in the first breeding season or calve late in the main calving season (October to December) end up going into the second breeding season (July–August) and calving at the beginning of the next dry season (April to June). This makes calvings that follow immediately after one that occurred in dry season to be much later (i.e. as long as 16 months to 20 months; Fig. 4a, b). Therefore, with more exposures to the bulls, these dry season breeding cows might be less fertile than the ones getting pregnant in the first breeding season. This seems to agree with Bishop and Pfeiffer (2008), who referred that poor reproductive indices by Ankole and Crossbred cattle in Rwanda are more associated with environmental conditions and husbandry practices than genetics.

The lower contagious abortion rate in the Nguni than in the Landim (Fig. 5) might be explained by the fact that the environment in which Nguni cows were raised in their original South Africa sites was probably more open free range than the Landim, making them more exposed to diseases and its vectors and, thus, more tolerant/resistant to diseases than the Landim, and is associated with a better ability to cope with the local brucellosis strain than its Landim counterpart. Both Landim and Nguni heifers in South Africa and Mozambique (Chobela Station and PFI) were vaccinated against brucellosis between 4 and 7 months old.

According to Seifert (1996), typical clinical symptoms of brucellosis depend on the level of host defence, specific for each breed and individual, and result from the sum of genetically determined resistance, level of immunity, age of the animal, productivity, condition, environmental influences and virulence of the pathogen. Higher contagious abortion rates in wet than in dry seasons are in agreement with Segura-Correa and Segura-Correa (2009) who found a prevalence of 2% in wet seasons vs. 0.66% in dry seasons in the southeastern Mexico region. A "self-cleaning" process of the herds occurs due to development of immunity, in which females become fertile again, after recovering from abortion and becoming protected from new infections (Seifert, 1996). This justifies the lower rate of abortion that was observed during the following years.

Looking into the lower AFC for the Landim ecotype versus the lower CI in the Nguni (ecotype-by-year–season interaction), one should think about the economic viability of this management in the whole herd. Is it feasible to have lower AFC which eventually results in higher CI or is it better to have heifers calving at a later age, but every year? When comparing younger and older ages at first calving, Evans et al. (2006) suggest 25–26 months as the optimal AFC to reduce subsequent CI and guarantee superior survival rates, but this will depend on the farm's economic situation such as cull cow price, costs of feed and other inputs (Berry and Cromie 2009). A deeper analysis looking into the economic feasibility of the different scenarios should be carried out.

Conclusions

In conclusion, both ecotypes showed good adaptation to the PFI environment, with heifers that were born at PFI performing better than their mothers which originated from Chobela or South Africa. Nguni and Landim cows, which originated from South Africa and Chobela, had better reproductive results under PFI than what was previously reported in their original environments. This study demonstrated for the first time the existence of significant genotype-by-environment interaction effects regarding reproductive traits for the different Nguni ecotypes in Mozambique, thus providing information which could better aid the planning of future cattle development and restocking programmes in southern Africa.

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References

Berry, D.P. and Cromie, A.R., 2009. Associations between age at first calving ns subsequent performance in Irish spring calving Holstein-Friesian dairy cows. Livestock Science, 123, 44 – 54.

Bishop, H. and Pfeiffer, D. 2008. Factors effecting reproductive performance in Rwandan cattle. Tropical Animal Health and Production, 40, 181–184.

Catalão, D. and Syrstad, O., 1990. Productivity of the Nguni and Afrikander cattle in Mozambique. Livestock Production Science, 24, 29 – 36.

Carvalheira, J.G.V., Blake, R.W., Pollak, E.J. and Van Soest, P.J., 1995. Comparison of Landim and Africander cattle in southern Mozambique: II. Female fertility, reproduction and beef offtake. Journal of Animal Science, 73, 3527 – 3533.

Collins-Lusweti, E., 2000. Performance of the Nguni, Afrikander and Bonsmara cattle under drought conditions in North West province of Southern Africa. South Africa Journal of Animal Science, 30, 33 – 41.

Evans, R.D., Wallace, M., Garrick, D.J., Dillon, P., Berry, D.P. and Olori, V., 2006. Effects of calving age, breed fraction and month of calving on calving interval and survival across parities in Irish spring- calving cows. Livestock Science, 100, 216–230.

FAO, 2007. Climate Impact on Agriculture, Climpag. Environment, Climate change and Bioenergy division. FAO Clim- NET. (www.fao.org/nr/climpag/agroclimdb_en.php).

Grossi, D.A., Frizzas, O.G., Paz, C.C.P, Bezerra, L.A.F., Lôbo, R.B., Oliveira, J.A. and Munari, D.P. 2008. Genetic Associations between accumulated productivity, and reproductive and growth traits in Nelore cattle. Livestock Science, 117, 139 – 146.

Kanuya, N.L., Matiko, M.K., Nkya, R., Bittegeko, S.B.P., Mgasa, M. N., Reksen, O. and Ropstad, E. 2006. Seasonal changes in nutritional status and reproductive performance of Zebu cows kept under traditional agro-pastoral system in Tanzania. Tropical Animal Health and Production, 38, 511 – 519.

Maciel, S., 2000. Effects of dexamethasone on endocrine and ovarian function in dairy cows. MSc Thesis. Oklahoma State University, USA.

Maciel, S., 2001. National Strategies for the conservation, improvement and utilization of animal genetic resources in smallholder systems. Proceedings of the Planning and Priority Setting Workshop on Animal Genetic Resources in the SAD region. SACCAR, CTA, ILRI. Gaborone, Botswana.

Maciel, S.M., Chamberlain, C.S., Wettemann, R.P. and Spicer, L.J., 2001. Dexamethasone influences endocrine and ovarian function in dairy cows. Journal of Dairy Science, 84, 1998–2009.

Matiko, M.K., Kanuya, N.L., Waldman, A., Ropstad, E. and Reksen, O. 2008. Environmental constrains on post-partum ovarian activity in Tanzanian zebu cows. Theriogenology, 69, 896 – 904.

Morgado, F.P., 1953/1954. Bovinos de talhoda Estação Zootécnica da Central (Chobela) – Mortalidade, fecunidade e influência de alguns factores no desenvolvimento. Anuais dos Serviços de Veterinária e Indústria Animal, 6, 453 – 467.

Muchenje, V., Dzama, K., Chimonyo, M., Raats, J.G. and Strydom, P.E. 2008. Tick susceptibility and its effects on growth performance and carcass characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture. Animal, 2, 298 – 304.

Ramsay, K. A. 1988. Phenotypic selection of the Nguni cattle in different environments in Southern Africa. Department of Development Aid. South Africa.

Rocha, A., 1985. Revisão da investigação sobre a avaliação de raças e melhoramento animal em Moçambique. Seminário de Produção Animal. Ministério da Agricultura, 2–7 Dezembro, pp. 86–103.

Rocha, A., Starkey, P. and Dionisio, A.C., 1991. Cattle production and utilisation in smallholder farming systems in Southern Mozambique. Agricultural Systems, 37, 55 – 75.

Sapolsky, R.M., Romero, L.M. and munck, A.U., 2000. How glucocorticoids influence stress responses – Integrating permissive, suppressive, stimulatory and preparative actions. Endocrinology Review, 21, 55–89.

SAS Institute, 2003. SAS/STAT User's Guide. Version 9.2. Edition. SAS Institute Inc., Cary, NC, USA.

Segura-Correa, J.C. and Segura-Correa, V.M., 2009. Prevalence of abortion and stillbirth in a beef cattle system in Southeastern Mexico. Tropical Animal Health and Production, 4, 1773–1778.

Seifert, H.S.H. 1996. Tropical Animal Diseases. (Kluwer Academic Publishers, Dordrecht, The Netherlands). Pp. 356–361.

Scholtz, M.M. and Lombard, P.E. (1992).Prospects of Southern African cattle breeds: the Nguni example. Proceedings of the Australian Association for Animal Breeding and Genetics 10, 47–50.

Yilmaz, A., Davis, M.E. and Simmen, R.C. M., 2006. Analysis of female reproductive traits in Angus beef cattle divergently selected for blood serum insulin-like growth factor I concentration. Theriogenology, 65, 1180 – 1190.

Vighio, G.H. and Liptrap, R.M., 1990. Plasma hormone concentrations after administration of dexamethasone during middle of the luteal phase in cows. American Journal of Veterniary Research 51: 1711 – 1714.

Villa-Mancera, A., Méndez-Mendoza, M., Huerta-Crispin, R., Vásquez-Flores, F. and Córodova-Izquierdo, A. 2010. Effect of climate factors on conception rate of lactating dairy cows in Mexico. Tropical Animal Health and Production. Published online 18 November 2010.