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The effect of ecotype and year on the production and reproductive performance of Nguni cows in the Limpopo Province of South Africa

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Abstract

This study investigated the effects of Nguni cattle ecotype and year on the production and reproductive performance of cows in the Limpopo Province of South Africa. Production data for 471 calvings (142 Venda, 65 Shangaan, and 264 Pedi ecotype Nguni cows) at Mara Research Station were analysed to determine the differences between years and ecotypes in birthweight, weaning weight, days-to-reconception, inter-calving period, weight of cow at breeding and at weaning, and weaning efficiency. The effects of ecotype and year on the production and reproduction parameters were analysed using the SAS® mixed models procedure. Cows of the Shangaan ecotype were the smallest in size, while the Venda ecotype was both heavy and short, and gave birth to calves with lower birthweights and higher weaning weights. Ecotype did not affect the inter-calving period and days-to-reconception, but influenced weaning efficiency and weight-related reproduction traits. Year influenced the birth and weaning weights, with years with high precipitation also having high production efficiencies. The smaller-framed Shangaan ecotype had a better weaning efficiency, days-to-reconception, and inter-calving period than the Pedi and Venda ecotypes in the year with the lowest precipitation (2011). No year effects were observed for days-to-reconception, but the inter-calving period, weaning efficiency, and weight-related reproductive traits were affected by year. Ecotype and year thus both influenced the production and reproduction traits of Nguni cattle.

Keywords: cattle ecotype, inter-calving period, Pedi, reconception, Shangaan, Venda

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Introduction

Nguni cattle (*Bos taurus africanus)* have been of interest for researchers, breeders, and farmers alike for several decades (Mkhize *et al.*,2018), and this interest gained momentum following a report by

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Bonsma *et al.* in 1950. Several important studies followed over the years, such as Schoeman (1989), Leppen *et al.* (1993), Scholtz & Ramsey (2007), Mapiye *et al.* (2007), Matjuda (2012), Maiwashe *et al.* (2013), and Sanarana *et al.* (2015). Much of this research was done at the Mara Research Station of the Agricultural Development Institute in the Limpopo Province, but production and reproduction data for the Nguni ecotypes are still scarce. The Limpopo Province is known for high temperatures, low and erratic rainfall, and drought susceptibility. Nguni cattle's potential for adaptation, production efficiency, and reproduction are the main reasons for the continued interest in the breed, and Nguni cattle are popular in the Limpopo Province because of their suitability for harsh conditions. Three Nguni cattle ecotypes are bred at the Mara Research Station to conserve and maintain ecotype purity. These ecotypes are kept in different areas on the farm to ensure that they do not interbreed. The three Nguni cattle ecotypes are the Pedi, Shangaan, and Venda, which are named after the tribes with which they were originally found (that is, the Bapedi, Vachangana, and Vhavenda). Visual appraisal of the Nguni cattle ecotypes indicates that they differ greatly, with about 80 different coat colour patterns (uniform, spotted, or pied) recognised for the Nguni cattle breed (Nguni Cattle Breeders' Society, 2008). These differences also extend to the frame size of the cows, which varies between the ecotypes. Although the Nguni breed is small to medium in size, several variations within the breed depend on the prevailing nutritional conditions (Bester *et al.*, 2003; Mkhize *et al.*, 2018).

According to the Nguni Cattle Breeders' Society (2008), Nguni cattle are kept in a wide variety of extensive environments throughout South Africa, and the specific differences in these environments may have a greater effect on some animals' genotypes than others. These specific environmental differences can alter the order of value of a series of genotypes, as some genotypes may be more sensitive to these environmental differences than others. Sanarana *et al.* (2015) demonstrated that there are genetic distances between the Nguni cattle breed ecotypes. These genetic distances indicate genetic variability within the breed, which may have resulted from the adaptation of Nguni cattle to different bioregions.

Evidence from the literature indicates that phenotypic and genotypic differences exist among the Nguni cattle breed ecotypes (Sanarana *et al.*, 2015). However, the differences in production and reproductive performance between these ecotypes is not evident in the literature. The supposition of differences in production and reproduction suggests that different management strategies should be applied to these ecotypes for optimal performance, which may have far-reaching consequences in the beef production sector. In an effort to provide answers and management guidelines, this study aimed to investigate the effect of ecotype and year on the production and reproductive performance of Venda, Pedi, and Shangaan ecotypes of the Nguni cattle breed at the Mara Research Station in the Limpopo Province.

Materials and methods

The study used historical data for three Nguni cattle ecotypes at the Mara Research Station, collected over a five-year period (2009 to 2013). The station is located approximately 54 km west of Makhado, in the Limpopo Province (23°08'04" S and 29°33'24" E), at 961 m above sea level. The study location has mean daily maximum temperatures ranging from 22.6 °C in winter to 30.4 °C in summer. The long-term mean annual rainfall recorded at Mara Research Station is 452 mm per annum, 80% of which occurs in the summer months (between November and March). The mean annual rainfall recorded at Mara Research Station for the study period (2009 to 2013) was 521 mm, ranging from 310 mm per annum in 2011 to 620 mm per annum in 2009.

The Mara Research Station is located within the Arid Sweet Bushveld biome (Acocks, 1998). The vegetation in this area is characterised by woody species such as *Acacia tortilis, Boscia albitrunca, Commiphora pyracanthoides,* and *Combretum apiculatum,* as well as *Grewia* species and grass species like *Eragrostis rigidor, Panicum maximum*, *Panicum coloratum, Urochloa mosambicensis*, and *Digitaria eriantha* (Dekker *et al*., 2001).

Data from 2009, 2010, 2011, 2012, and 2013 were included. The observed annual precipitation levels for the years investigated were 590 mm (2008), 620 mm (2009), 470 mm (2010), 310 mm (2011), 600 mm (2012), and 540 mm (2013). Raw data for 702 calvings were edited to remove all calves that were born out of season and cattle that died or were culled within the first few years of the study period. Only cows that were present for all the breeding seasons within the period of the study were included in the data set. The final data set included 471 calvings, with 264, 142, and 65 calvings for the Pedi, Venda, and Shangaan ecotypes, respectively.

The calving data for the Nguni cattle ecotypes were measured to determine the effects of ecotype and year on the morphological growth, production, and reproductive characteristics of the three Nguni cattle breed ecotypes at the Mara Research Station. This data contained records of cow identities, monthly cow weights, cow shoulder heights, calf birth dates, calf birthweights, calf weaning weights (adjusted to a 205-day weaning weight to limit variation), and calf yearling weights. The data were used to derive the following additional parameters: inter-calving period (calculated as the number of days between consecutive calvings for a particular cow), days-to-reconception (calculated as the date of birth minus the gestation period), and the weaning efficiency (calculated as the weaning weight of the calf divided by the weight of the dam at weaning).

The SAS® (2015) mixed models procedure was used to analyse for variance in production and reproduction parameters due to ecotype and year. Least square means were separated using the *pdiff* function by employing the Bonferroni multiple range test method because of the unbalanced nature of the data set. The relationship between live weight and body measurements was explored using the GPLOT procedure in SAS® (2015). A scatter plot for body measurements for all ecotypes was done to demonstrate the size distribution of the three ecotypes.

Results and discussion

Table 1 provides the descriptive statistics for the anthropometric body measurements of the Nguni cattle ecotypes. The average shoulder heights of the Nguni cows ranged from 110 cm to 170 cm, while body length ranged from 118 cm to 167 cm. On average, the Nguni cows weighed 350.61 kg, ranging from 220 kg to 550 kg. The mean body compactness ratios, in terms of weight per body length and weight per shoulder height, were 2.79 kg/cm and 2.53 kg/cm, respectively. The body measurements of the Nguni cattle used in this study were acceptable and complied with the requirements of the Nguni Cattle Breeders' Society, which specifies that the shoulder heights of Nguni cows should range from 110 cm to 120 cm, with an average body length of about 133.7 cm (Nguni Cattle Breeders' Society, 2008). Therefore, the Nguni cows sampled in this study can be regarded as typical and an acceptable cohort representative of Nguni cattle.

Table 1 Descriptive statistics for anthropometric body measurements of Nguni cattle ecotypes (pooled data) at the Mara Research Station from 2009 to 2013

Variable	N	Mean	SD	Minimum	Maximum
Shoulder height (cm)	180	127.97	7.13	110	170
Body length (cm)	180	141.16	7.79	118	167
Body weight (kg)	180	350.61	50.11	220	550
Weight/shoulder height ratio (kg/cm)	180	2.79	0.34	2.00	3.87
Weight/body length ratio (kg/cm)	180	2.53	0.31	1.69	3.46

N: number of observations, SD: standard deviation

No differences in weight were observed between the Pedi (354.94 kg) and Venda (359.32 kg) ecotypes, but both differed (P <0.05) from the Shangaan ecotype (331.36 kg), which was lighter (Table 2). The shoulder heights of the Pedi (129.68 cm) and Shangaan (127.98 cm) ecotypes did not differ, but both ecotypes were taller (P <0.05) than the Venda ecotype (125.75 cm). There was no significant difference in body length between the Shangaan and Venda ecotypes, which were both relatively long, at 143.43 cm and 141.08 cm, respectively, but both differed (P <0.05) from the shorter Pedi ecotype (139.92 cm). Ecotype had no significant effect on either the mature weight/shoulder height ratio or the mature weight/body length ratio of these Nguni cattle ecotypes, which shows that all three ecotypes have similar body compactness. The close relationship observed between these ecotypes agrees with the observations of Sanarana *et al*. (2015), who reported a closer genetic distance between the Pedi and Shangaan ecotypes and a closer genetic distance between the Venda and Shangaan ecotypes, and therefore more genetic distance between the Venda and Pedi ecotypes.

Table 2 Least square means (± standard error) for the effect of ecotype on the body measurements of the three Nguni ecotypes

Variable	Pedi	Shangaan	Venda
Body weight	$354.94^{a} \pm 5.60$	$331.36^{b} \pm 7.41$	$359.32^{a} \pm 6.40$
Shoulder height	$129.68^{a} \pm 0.79$	$127.98^{a} \pm 1.05$	$125.75^{b} \pm 0.90$
Body length	$139.92^{a} \pm 0.88$	$143.43^{b} \pm 1.16$	$141.08^{b} \pm 1.00$
Weight/shoulder height ratio	2.84 ± 0.04	2.74 ± 0.04	2.82 ± 0.05
Weight/body length ratio	2.54 ± 0.04	2.53 ± 0.04	2.51 ± 0.05

[a,b]Means in the same row with different superscript letters differ (P <0.05)

The Shangaan ecotype was similar to the Pedi ecotype in shoulder height, but was also similar to the Venda ecotype in terms of body length, indicating more variation in the Shangaan ecotype than in the other two ecotypes. The inconsistency of the Shangaan ecotype can be corroborated by the results of Sanarana *et al.* (2015), who reported that the Shangaan ecotype lacks the unique alleles that are required both in conservation and in the measurement of population genetic distinctiveness, as described by Szpiech & Rosenburg (2011). Sanarana *et al.* (2015) indicated that the absence of these unique alleles in the Shangaan ecotype can be observed by the ecotype's tendency to resemble other ecotypes. The Venda ecotype was similar in weight to the Pedi ecotype, even though it has been reported that the Venda and Pedi are more genetically distant, based on the results of principal component analysis. Therefore, the differences observed in the anthropometric body measurements support the previously described phenotypic differences in conformation between the three Nguni ecotypes (Sanarana *et al.*, 2015).

The relationship between body weight and body length measurements for the Nguni ecotypes was explored using the GPLOT procedure of SAS® (Figure 1). A linear relationship was observed for all three ecotypes between body length and body weight, with body length increasing with an increase in body weight.

Figure 2 illustrates the relationship between body weight and shoulder height for the three Nguni ecotypes. A linear relationship was observed, with shoulder height increasing with an increase in body weight. The tallest animals were of the Shangaan ecotype, which was also the lightest of the three ecotypes, followed by the Venda ecotype. The Venda was the only ecotype that was more compact (short and heavy) than the other ecotypes, making it more desirable, according to Vargas *et al.* (1998) and Riley *et al.* (2007). These studies indicated that heavier, smaller-framed animals are preferable, since they have higher reproductive efficiencies and overall efficiencies than larger-framed, heavier animals.

Figure 3 shows the relationship between the body weight/shoulder height ratio and the body weight/body length ratio, which also reflects a linear relationship. A positive correlation was observed between the weight/shoulder height ratio and the weight/body length ratio, with an increase in one variable correlating with an increase in the other. Klosterman *et al.* (1968) indicated a strong positive correlation between the body weight/hip height ratio and body condition score. Riley *et al.* (2007) also observed positive correlations between the body weight/hip height ratio and body weight.

The least square means and standard errors for the effects of ecotype on birthweight and weaning weight are presented in Table 3. Ecotype significantly affected the birthweights of Nguni calves across all the years measured. The Pedi and Shangaan ecotypes had comparable birthweights, which were higher (P <0.05) than those of the Venda ecotype. Larger-framed cows were expected to give birth to bigger calves than those born from medium- and smaller-framed cows, and this statement was true for the Pedi ecotype, which is a larger-framed animal than the other two ecotypes. However, unexpectedly, Shangaan calves were statistically as big as the Pedi calves, and even bigger than the Venda calves. The Shangaan was the smallest of the three ecotypes in terms of weight, and similar to the Pedi ecotype in terms of shoulder height.

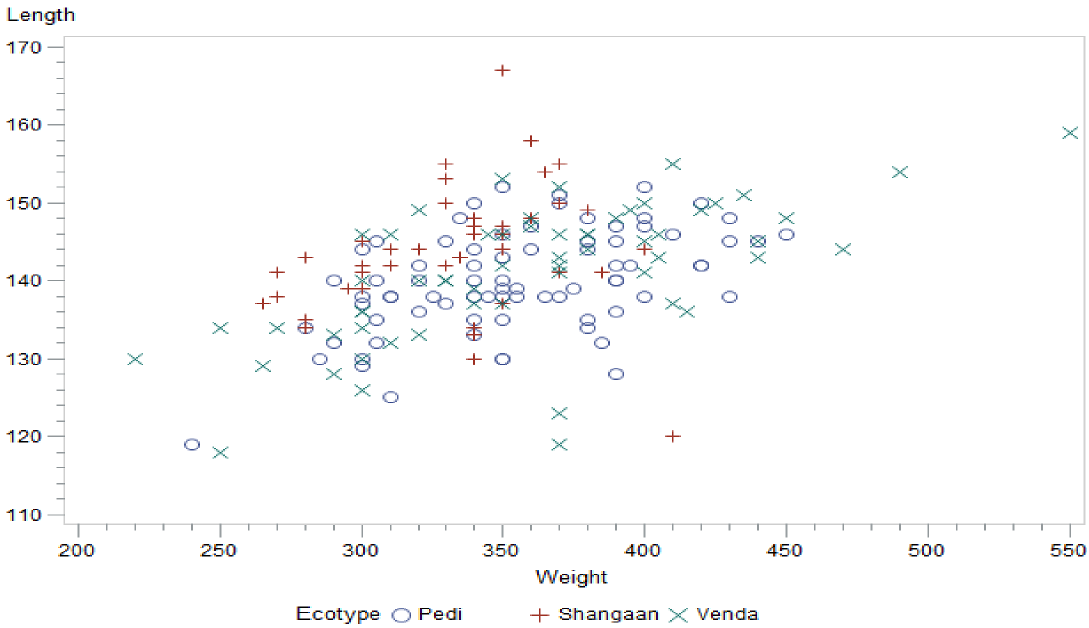

Figure 1 Relationship between the body weight and body length of different ecotypes of Nguni cattle.

Nguni ecotype influenced the weaning weights of the Nguni calves over all the years measured. The Pedi ecotype had the highest weaning weight (156.87 kg) of the three ecotypes (P <0.05; Table 3), and significantly differed from both the Shangaan (136.36 kg) and Venda (144.04 kg) ecotypes. There were no differences in birth or weaning weights between the Venda and Shangaan ecotypes. The inconsistencies of the Shangaan ecotype described by Sanarana *et al.* (2015) were also observed in this study, in that its birthweight was similar to that of the Pedi ecotype, while its weaning weight corresponded with that of the Venda ecotype. The Venda ecotype had a lower birthweight and a higher weaning weight, which makes it a preferable ecotype in a breeding herd, according to the Nguni Cattle Breeders' Society (2008) and Skrypzeck *et al.* (2000), because of its preferred birthweight and higher growth rate. The Pedi ecotype had a higher birthweight and weaning weight and can be recommended above the Venda and Shangaan ecotypes for producing heavier weaners. The Shangaan ecotype had a higher birthweight and a lower weaning weight, which is an undesirable trait in a breeding herd.

Table 3 Least square means (± standard error) for the effects of ecotype on the birth and weaning weights of Nguni cattle over a five-year period (pooled data, n = 415)

Variable	Pedi	Shangaan	Venda	Pooled
Birthweight (kg)	$25.46^{a} \pm 0.26$	$25.01^{a} \pm 0.70$	$24.08^{b} \pm 0.38$	24.98 ± 4.48
Adjusted weaning weight (kg)	$156.87^{a} \pm 1.84$	$136.36^{b} \pm 4.56$	$144.04^{b} \pm 2.78$	152.00 ± 29.39

^{a,b}Means in the same row with different superscript letters differ (P <0.05)

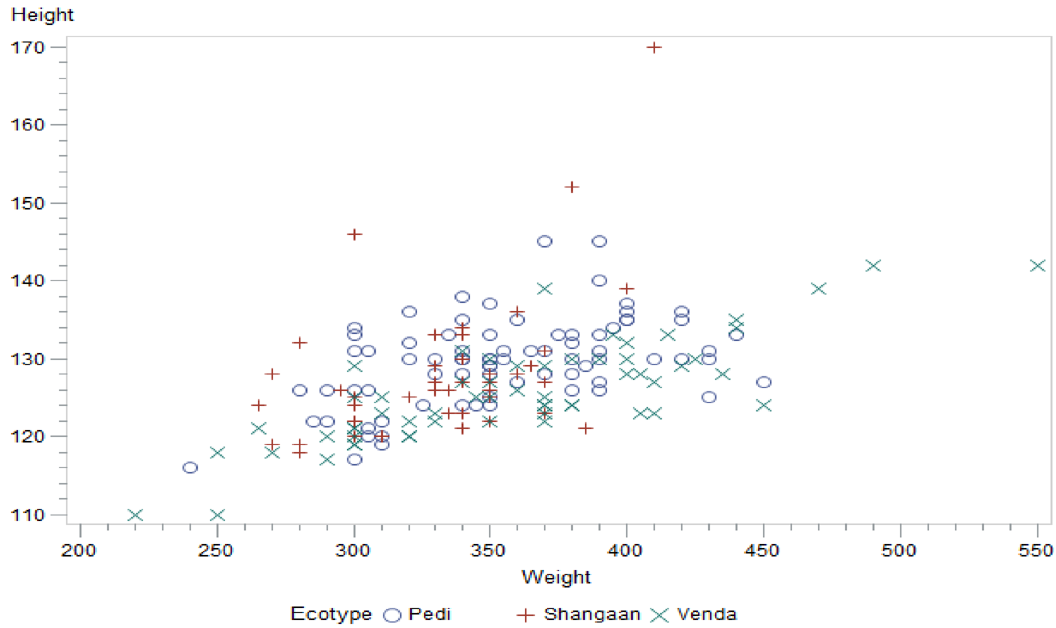

Figure 2 Relationship between the body weight and shoulder height of different ecotypes of Nguni cattle.

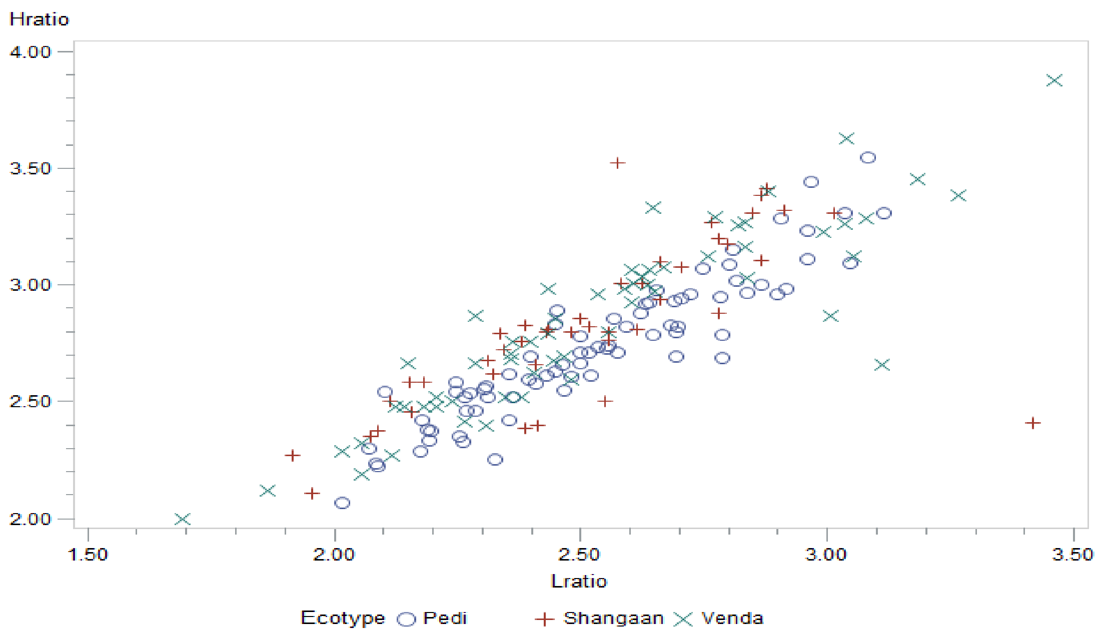

Figure 3 Relationship between the body weight/shoulder height ratio (Hratio) and the body weight/body length ratio (Lratio) of different ecotypes of Nguni cattle.

The effects of year of birth on birth and weaning weights are presented in Table 4. Year of birth influenced the birthweights of calves from all ecotypes (P <0.05), with the highest birthweight recorded in 2012, followed by 2011. Birthweights recorded in 2011 and 2012 were higher (P <0.05) than those recorded in 2009, 2010, and 2013. These results differ from those of Tawonezvi *et al.* (1988), who reported no significant effects of year on the birthweights of Nguni calves. The year of birth also influenced the weaning weights for all the ecotypes, with calves born in 2012 having the highest average weaning weight (P <0.05) of the years studied. The lowest weaning weight (P <0.05) was recorded in 2011, while 2009, 2010, and 2013 were similar (Table 4).

The higher birth and weaning weights observed in 2012 coincided with higher levels of precipitation, which affected the available nutrition. Previous research corroborates these findings of year effects on weaning weight (Lubout, 1987; Kars *et al.*, 1994). Similarly, Lombard (1971) indicated that changes in environmental conditions such as climate, management, and nutrition contribute to variations in growth traits.

Table 4 Least square means (± standard error) for the effects of year on the birth and weaning weights of Nguni calves

Variable	Birthweight (kg)	Weaning weight (kg)
2009	23.08^{a} ± 0.75	149.26^{a} ± 4.87
2010	23.72^{a} ± 0.86	144.91^{a} ± 6.43
2011	25.80^{b} ± 0.40	126.22^{b} ± 3.01
2012	27.67^{c} ± 0.47	159.78^{c} ± 3.23
2013	23.97^{a} ± 0.42	148.62^{a} ± 3.39

^{a,b}Means in the same column with different superscript letters differ (P <0.05)

Descriptive statistics for the reproductive traits of the Nguni cattle ecotypes are presented in Table 5. A varying number of observations were recorded for each trait because inter-calving period and days-to-reconception records require animals to be present in the breeding cycle for two consecutive years and several animals skipped a year and some animals were culled.

Table 5 Least square means (± standard error) for the effects of ecotype on the reproduction of Nguni cows over a five-year period (2009–2013)

Variable	n	Pedi	Shangaan	Venda	Pooled data
Days-to-reconception	157	87.5 ± 3.23	88.0 ± 5.87	81.9 ± 3.73	85.6 ± 25.76
Cow weight at breeding (kg)	337	355.5^{a} ± 3.55	328.3^{b} ± 7.09	349.7^{a} ± 4.47	351.6 ± 55.9
Cow weight at weaning (kg)	342	385.4^{a} ± 7.38	341.4^{b} ± 8.06	377.8^{a} ± 4.89	380.9 ± 60.74
Inter-calving period (days)	214	454.7 ± 22.96	465.2 ± 43.63	451.5 ± 2.86	458.5 ± 158.47
Weaning efficiency	316	0.407^{a} ± 0.01	0.439^{a} ± 0.01	0.381^{b} ± 0.01	0.402 ± 0.11

^{a,b}Means in the same row with different superscript letters differ (P <0.05)

According to Du Plessis *et al.* (2006), smaller-framed cows perform better than larger-framed cows in terms of reproduction. The expectation was therefore that the Shangaan ecotype, which was lighter than the other ecotypes, would outperform the Venda and Pedi ecotypes. Ecotype influenced the weaning efficiency (P <0.05) of Nguni cows across all the years included in the analysis. Shangaan cows had the highest weaning efficiency of all three ecotypes, which is consistent with the findings of Du Plessis *et al.* (2006). There was no difference in weaning efficiency between the Pedi and Shangaan ecotypes, but both differed (P <0.05) from the Venda ecotype. These results agree with those presented in Table 3 for the effect of ecotype on birthweight, where the Shangaan and Pedi ecotypes had similar birthweights, but both had higher birthweights than the Venda ecotype.

Ecotype did not influence days-to-reconception, and, on average, all three ecotypes reconceived within the required three-month breeding season. These results agree with those of Peters (1984), who recommended that the postpartum anoestrous period should not exceed 80–85 days to produce one calf each year and maximise profitability.

The weight of a beef cow at breeding indicates the cow's body condition score and determines whether the animal is at an optimum weight for conception. Wiltbank *et al.* (1964), Wiltbank *et al.* (1977), and Haresign (1984) highlighted that it is also indicative of the likelihood of subsequent reproductive performance. Emaciated cows and over-conditioned cows do not conceive well. The weights of Pedi and Venda cows at breeding did not differ, but both differed (P <0.05) from the Shangaan ecotype.

Cow weight at weaning gives a good indication of a cow's reproductive efficiency, and a similar trend was observed as for the weight of the cow at breeding. Cows of the Pedi and Venda ecotypes had similar weights at weaning, which were higher (P <0.05) than those of the Shangaan cows. These results were expected, considering the smaller frame of the Shangaan ecotype compared to the larger frames of both the Pedi and Venda ecotypes. Generally, Nguni cows did not lose condition at weaning, even though they had been suckling calves for six months and even if it was a dry year. This is further evidence of the adaptability and tenacity of the Nguni cattle breed. No significant differences were observed among the ecotypes for inter-calving period.

The least square means and standard errors for the effect of year on the reproduction of Nguni cows are presented in Table 6. Many of the statistical differences in the reproduction of Nguni cows between years can be attributed to variations in climatic conditions from 2009 to 2013. Weaning efficiency was affected by year, with the highest (P <0.05) weaning efficiency (0.47) in 2012 (the year with the highest annual precipitation) and the lowest (P <0.05) weaning efficiency (0.33) in 2011 (the year with the lowest annual precipitation). Weaning efficiency did not differ significantly between 2009, 2010, and 2013. Maciel *et al.* (2016) reported year effects on the inter-calving period, and this was also observed in the present study, with the inter-calving period being the longest (P <0.05) in 2011. Cow weight at breeding was highest in 2013, and this differed from other years investigated, while cow weight at weaning was the lowest (P <0.05) in 2012. The low cow weights at breeding in 2011 were likely linked to the low precipitation observed in this year. The results of this study agree with those of Montiel & Ahuja (2005), who found that inadequate protein and energy intake during pregnancy or early lactation results in low body condition scores at calving and a longer inter-calving period in beef cows. No year effects were observed (P <0.05) for the time it took for cows to reconceive.

Table 6 Least square means (± standard error) for the effects of year on the reproduction of Nguni cows of different ecotypes

Year	Weaning efficiency	Days-to-reconception	Cow weight at breeding (kg)	Cow weight at weaning (kg)	Inter-calving period (days)
2009	0.43^{a} ± 10.01	-	331.37^{a} ± 8.45	374.14^{a} ± 6.92	-
2010	0.41^{a} ± 0.02	87.77 ± 7.27	332.95^{a} ± 12.08	377.29^{a} ± 13.53	419.38^{a} ± 47.89
2011	0.33^{b} ± 0.01	82.29 ± 5.33	350.70^{a} ± 5.56	387.03^{a} ± 5.85	545.08^{b} ± 26.30
2012	0.47^{c} ± 0.01	88.94 ± 3.74	335.50^{a} ± 6.68	344.19^{b} ± 6.19	415.85^{a} ± 25.10
2013	0.40^{a} ± 0.01	84.29 ± 3.45	356.58^{b} ± 6.12	376.24^{a} ± 6.19	477.72^{a} ± 20.65

^{a,b,c}Means in the same column with different superscript letters differ (P <0.05)

Conclusions

Ecotype and year significantly affected the production and reproduction efficiency of the three ecotypes of Nguni cattle at Mara Research Station. The Shangaan ecotype was the smallest in size. The Venda ecotype was heavy and short and gave birth to calves with lower birthweights and higher weaning weights, which are desirable traits that rank it higher in terms of production and reproduction than the Shangaan and Pedi ecotypes in the region where the study was conducted. Ecotype did not influence the inter-calving period and days-to-reconception, but it influenced weaning efficiency and weight-related reproduction traits. Year influenced birth and weaning weights, especially in years with high or low precipitation. The smaller-framed Shangaan cows performed better than Pedi and Venda cows in the dry years. Year did not affect days-to-reception, but influenced the inter-calving period, weaning efficiency, and weight-related reproductive traits. It is therefore recommended that cows of the Venda and Pedi ecotypes be managed differently than those of the Shangaan ecotype during periods of scarcity or low precipitation.

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Authors' contributions

This research was conducted to fulfil the requirements of an MSc (Agric) Animal Science degree for MM, under the supervision of ECW and in collaboration with MLM. ECW conceptualised the research project. MM was responsible for designing, preparing, and executing the project, as well as formulating and refining the research article. ECW and MLM revised, corrected, and edited the manuscript and article for submission.

Conflict of interest declaration

None of the authors have any conflicts of interest to declare.

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