SECTION A

CHAPTER 1

1.1 GENERAL INTRODUCTION

Beef cattle production in Southern Africa is predominantly an extensive system, being based on the utilisation of mainly natural pastures. Smit (1999) noted that natural pasture remains the cheapest source of forage for cattle production, but that the economic viability of cattle farming is coming under pressure due to ever increasing input costs. Furthermore, cattle production in the subtropics is not only faced with climatic and nutritional stresses, but is also subjected to managerial and disease limitations. Thus, susceptibility to these stressors accounts for large differences in growth rate, fertility and mortalities between and within breeds. Therefore, breeds that are able to adapt to these stressors can be expected to be more profitable (Van Zyl *et al.,* 1993).

During the past thirty years, despite a weaner production system having been proven to be less profitable than the sale of more mature cattle, this is still the system applied most widely in South Africa by beef producers. A report in the Agri Review (1995) noted that beef cattle producers were comparatively worse off in 1994 than in 1988 as a result of increased input costs, while producer prices remained fairly constant. These concerns are as relevant today (Cousins, 2004) as they were 10 years ago. The reason is that beef prices show a recurring long-term cycle with high prices being repeated every five to ten years. Prices then remain fairly constant over the intervening period while input costs escalate. Thus, it is imperative that producers strive to be more efficient. However, this does not seem to be taking place, as the national calving average remains at between 50 and 60% (Harwin *et al.,* 1967, Meaker 1984, MacGregor, 1997, Parkinson, 2003). It is therefore clear that past and current selection and management practices have not been successful in increasing the efficiency of weaner production systems. It seems fair to speculate that in order to make cow-calf operations more efficient and profitable, without drastically increasing input costs, cattle producers will have to improve the reproductive and production efficiencies of their herds. Bellows and Short (1994) observed that the greatest production loss results from cows not being pregnant at the end of the breeding season. The long term, improvement in reproduction can come via selecting animals that are adapted to a particular environment, but improvements in the environment should not be ignored. Simply improving the management system can rapidly improve the reproduction rate of a herd. This is worthy of note since it is generally accepted that reproductive performance is the most important economic trait in a beef cow-calf herd and far exceeds the impact of improved growth rates. It is important therefore, that aspects impacting on fertility receive the major research emphasis. Aspects investigated were non-genetic factors (environmental) influencing production, fertility level and heifer frame size and their subsequent relationship to the production traits of their calves.

Adaptability is the basis for successful and efficient extensive beef cattle production in the sub-tropics. A certain minimum level is required to achieve adequate reproduction and production levels within specific environmental conditions. In this regard the control of ticks in tropical areas is significant. This study investigates factors, which influence reproduction and production performance of beef cattle under extensive management conditions in the arid sub-tropics of Southern Africa. Control of ticks is an important, time consuming and costly aspect of cattle production in tropical areas. An attempt was thus made to identify traits that influence tick burdens on cattle. Animals that have low tick burdens are probably adapted to the environment in which they occur. The motivation was that selection of animals adapted to the stressors of the tropics could lower input costs, decrease body maintenance costs, improve body condition and ultimately improve reproductive performance. This should improve overall herd efficiency.

Furthermore, the impact the bull has on herd fertility is often underestimated and poor conception rates are generally considered to be female orientated. However, certain management decisions could adversely impact on bull fertility and equally contribute to lowered herd fertility. In this context the role played by herd sires should also receive due cognisance and attention not focussed only on increasing growth rates through the ability of such sires to impart their genetic potential to their progeny.

Following this introduction the thesis is structured as follows: In Chapter 2 the non-genetic influences on pre- and post-weaning growth traits of a tropically adapted beef breed in the arid sub-tropical environment of Southern Africa are addressed. The interrelationship among lifetime cow fertility, cow size, pre-weaning and post-weaning calf growth in Santa Gertrudis cattle is discussed in Chapter 3. Chapter 4 deals with the effect of heifer frame size on their subsequent reproductive performance and on the pre-weaning performance of their calves. These three chapters deal with factors affecting the production of the cow herd. Section B, Chapter 5 addresses the tick burdens of tropically adapted beef cattle as influenced by selected physical and production traits. The last section (section C) includes Chapter 6 which introduces this section, is followed by Chapter 7 focussing on the relationship between growth parameters, scrotal circumference and sheath area in tropically adapted beef bulls. Chapter 8 evaluates the association among growth and quantitative testicular traits of tropically adapted yearling bulls fed different dietary energy levels. Followed by Chapter 9, the relationship between scrotal circumference, quantitative testicular traits and growth performance in tropically adapted yearling beef bulls differing in age is addressed. Finally general implications and recommendations addressing beef cattle production in a scientific manner are presented in Chapter 10.

Although every effort were made to limit repetition, the structure and layout of the thesis having being prepared in a publication format has made this unavoidable.

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CHAPTER 2

NON-GENETIC INFLUENCES ON PRE- AND POST-WEANING GROWTH TRAITS OF A TROPICALLY ADAPTED BEEF BREED IN THE ARID SUB-TROPICAL ENVIRONMENT OF SOUTHERN AFRICA

2.1 ABSTRACT

Production data of Santa Gertrudis cattle for a ten-year period were analyzed. The herds were managed extensively under harsh arid environmental conditions in the northern thornveld region of Namibia. The cattle were divided into summer and winter breeding seasons, which were limited to 90 days for each group. The effect of sex, herd, season, calf birth year and cow parity group on birth weight, pre-weaning average daily gain, weaning weight, yearling weight, eighteen month weight and post-weaning growth rate were analyzed. Sex was a highly significant ($p < 0.001$) source of variation for birth weight, weaning weight, 12 month weight, 18 month weight and significantly influenced ($p < 0.05$) pre- and post-weaning weight gain. Male calves were 3.05, 13.75, 123.37 and 238.99 kg heavier than the female calves at birth, weaning, yearling and eighteen months respectively and grew faster by 0.07 kg/day from birth to weaning and 0.65 kg/day from weaning to 12 months of age. The effect of season on birth weight, weaning weight, 18-month weight and pre-weaning growth rate was highly significant ($p < 0.001$). Calves born in the summer season had a lower birth weight compared to calves born in the winter season. However, the summer season calves were heavier by 17.67 kg at weaning but only by 1.7 kg at 12 months. They grew faster by 0.16

kg/day from birth to weaning. Calf birth year significantly influenced ($p < 0.001$) all traits measured with no fixed trend over time for the traits. Herd effects were highly significant ($p < 0.001$) for birth weight and 12-month weights and significantly influenced ($p < 0.05$) weaning weight, 18-month weight and growth rate from weaning to 12 months. The effect of cow parity was not significant on birth weight, 12-month weights, 18-month weights and post-weaning growth rates, but was significant ($p < 0.05$) for weaning weight and pre-weaning growth rates. Sex, herd, season of calving, calf birth year and herd x season x calf birth year significantly influenced growth traits and should be taken into consideration when selecting cattle.

2.2 INTRODUCTION

It is generally recognised that poor reproductive and reduced growth performance are the major factors limiting cattle production in the tropics (Jones and Hennessy, 2000). The constraints placed on production traits are predominately environmentally imposed (Duarte-Ortuno *et al.,* 1988, Howden *et al.,* 1999). Under reasonable management conditions in the subtropics, crossbreeding Zebu cattle with *Bos taurus* breeds can increase production by improving reproductive performance, together with pre- and post-weaning growth (Koger 1973, Koger 1980, Gregory *et al.,* 1999). However, with cross-breeding comes the dilution of genetic resistance to tropical diseases and the need for improved feeding and management is increased. Moreover, cross-breeding may pose a threat to long-term genetic conservation of local genetic resources (Kurwijila 2005).

The importation of Santa Gertrudis cattle by the South African government in 1956 from King Ranch, Texas, offered the seed stock producers an attractive alternative to the British breeds less adapted to tropical climates. Seed stock producers were afforded the opportunity to capitalise on a cattle breed with favourable characteristics in terms of production and adaptability in hot climates. Furthermore, it is generally acknowledged that beef cattle operations in Southern Africa are practised mainly on natural pasture (Meaker, 1984). However, information on the production efficiency norms for cow herds under arid environmental conditions in Southern Africa is limited. Published information on the performance of the Santa Gertrudis cattle in the Southern African sub-tropics is also decidedly scarce. The objective of this study was to provide information on the production characteristics of Santa Gertrudis cattle under extensive grazing and management conditions in the arid sub-tropical environment of Southern Africa.

2.3 MATERIAL AND METHODS

Data were collected from 1979 to 1998 from Santa Gertrudis herds on a ranch in the north-eastern part of Namibia where single sire mating was practised. The calving and progeny data recorded were also checked with the records kept by the South African Santa Gertrudis Cattle Breeder Society. Information from record cards on cattle then present and those no longer in the herd was extracted for sex, date of birth and weaning, weights at birth, weaning, 12 and 18 months. Data were edited for errors and outliers (weights of animals differing greatly from the norm that were either excessively light or heavy for a specific age group). Calf weights at weaning, 12 and 18 months were computed from the weighing dates closest to the actual dates. All records where the calf or dam identification number was missing were deleted.

The ranch is situated 17° east, 20.5° south and 1 500 m above sea level, comprising an area of 55 000 ha, of which 42 000 ha was available for commercial cattle ranching. The herd was kept under extensive management, with a limited salt-phosphate lick. Cattle were grazed on natural pastures, which can be classified as "thorn bush savannah". The vegetation in the area includes woody species such as *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and the major grass species, were *Eragrostis rigidior, Panicum maximum* and *Digitaria eriantha*. A short duration (less than 3 weeks) and long rest (5 – 8 month) rotational grazing system was practised.

Average monthly temperatures ranged from a maximum of 32℃ in January to a maximum of 14.5℃ in July. The soils are predominantly sand and loam, with scattered areas comprising acid granite. The rain falls predominantly between October and March, with 80% of the yearly rainfall occurring in this period. The rainfall averaged 485 mm per year, but from 1979 – 1998, the area experienced drought conditions and received less than 403 mm per year.

A 90-day breeding season was used with the summer breeding season starting mid-January and ending mid-April and mid July to mid August for the winter breeding season. All bulls allocated cows for breeding within each herd were sheath washed for vibriosis *(Compylobacter foetus)* and trichomoniases *(Trichomonas foetus)* infection using a 0.9% physiological phosphate buffered saline solution before being fertility tested. Three weeks before the breeding season commenced, semen was collected by means of electro-ejaculation. The breeding soundness examination endorsed by the society of Theriogenology (Ball *et al.,* 1983) served as the guideline for the evaluation of spermatozoa. Cows were selected on age (based on number of permanent incisors and on the state of teeth wear), and fertility. A policy of culling females that did not calve for two consecutive breeding seasons was consistently followed. Weaning weights, weaning rates and herd retention of calves, were also used in the selection process. Occasional culling for poor temperament and uterine prolapses also took place. Cow fertility was coded as high for cows with an average calving interval of less than 400 days (HFG), medium for cows with a calving interval of between 401 and 467 days (MFG) and low for cows with a calving interval of more than 467 days (LFG). Weighing of calves took place at weaning, which was done between 7 – 9 months depending on the season (Calves were weaned at approximately 7 months of age in years receiving lower rainfalls and closer to 9 months in years with higher rainfall).

For each of the summer and winter breeding seasons the weaned heifer calves were combined into one herd and culling was for low weight-for-age, lack of sexual development and structural faults (e.g.: devils grip, lack of femininity, lack of sexual development in the form of vulva and udder development, feet and leg faults, over or undershot jaws). Once a second selection process was completed at approximately 20 months of age heifers were allocated to a breeding herd. Although both herds were managed extensively on natural pastures, heifers which performed above average for growth and development were selected for herd A, as this was considered to be the "first cut" single sire herd. Heifers that were below the herd average for growth and development were considered "second cut" heifers and allocated to herd B. The number of heifers allocated to herds A and B varied from year to year depending on the size of the calf crop and culling intensity of the different herds before bulling commenced at this time. Culling was once again on the basis of low weight-for-age, lack of sexual development and structural faults. The average culling rate was approximately 10% for heifers selected at 20 months of age prior to bulling. The different herds were kept in separate, but adjacent camps and to reduce possible camp effects, camps were not allocated in blocks but were randomly and evenly dispersed over the whole study area. Cow-herds were kept in close proximity to each other as far as was practically possible and care was taken not to allow the stocking rate to exceed 15 ha/LSU.

Bull calves were not castrated at weaning and were all weaned into one herd, where they remained on natural pasture until they were about 2 years old. Such two-year old bulls were then selected each year on high weight-for-age and large scrotal circumference (>32 cm). Bulls with large pendulous sheaths were also culled and selection was also for good temperament and sleek hair coat. Less than 10% of the annual bull crop was kept for own use or sold to other breeders. Bulls not selected were slaughtered.

The data were analysed using a mixed linear model, with sire fitted as a random effect and sex, herd (H), season (S), calf birth year (C), calving status based on the number of calves produced (parity group) and the C x S x H interaction fitted as fixed effects. Fertility level represented as inter-calving period was fitted as a co-variant and ages at weaning, 12 months and 18 months fitted as linear co-variants on weaning, yearling, and eighteen month weight, respectively. The model used for each trait was presented by:

$Y_{hijklmno} = \mu + P_h + G_i + S_j + H_k + D_l + C_m + R_n + (C \times S \times H)_{jkm} + b(x_{hijklmno} - \bar{X}) + e_{hijklmno}$,

where $Y_{hijklmno}$ = growth trait (birth weight, weaning weight, average daily gain from birth to weaning, twelve month weight, average daily gain from weaning to twelve month weight, eighteen month weight and average daily gain from twelve months to eighteen months) for the oth calf of sex i in the nth fertility level from the hth sire, born by cow of the lth parity group in the jth season and within the mth year and reared in the kth herd,

μ = overall mean,

P_h = random effect of hth sire,

G_i = fixed effect of the ith sex (i = 1, 2),

S_j = fixed effect of the jth season of calving (j = 1, 2),

H_k = fixed effect of the kth herd (k = 1, 2)

D_l = fixed effect of the lth calving status or parity group (l = 1, …10+),

C_m = fixed effect of the mth calf birth year (m = 86, … 99),

R_n = fixed effect of the nth fertility (n = 1 (HFG), 2 (MFG), 3 (LFG)),

$(C \times S \times H)_{jkm}$ = herd x season x calf birth year interaction, b = linear regression of calf weight (weaning weight, yearling weight or eighteen month weight) on age at weaning, at yearling and at eighteen months respectively,

$x_{hijklmno}$ = exact age of oth calf (days) at weaning, yearling or eighteen months,

X = mean age at weaning, yearling or eighteen months and

$e_{hijklmno}$ = random error, assumed to be normally and independently distributed with a zero mean and a variance of σ^2.

The data were analysed using the General Linear Models Procedures of the statistical analysis system (SAS, 1995). Previous lactation status of the dam had no significant effect on growth traits pre-weaning or post-weaning and was not included. Effects included in the final analysis were those found to be significant from a preliminary analysis. The program adjusted for significant fixed effects and the least square means and standard errors (SE) for each growth trait are presented.

2.4 RESULTS AND DISCUSSION

The least squares means (LSM) and standard errors (SE) for the fixed effects and co-variables used to determine pre-weaning and post-weaning growth traits in Santa Gertrudis cattle are presented in Tables 2.1 and 2.2 respectively. The overall least squares means for live weight from birth to 18-month weight are in agreement with those reported by Cartwright *et al.* (1964) for Brahman x Hereford cattle, Hailu and Thorvaldur (1986) for Boran cattle and Koch *et al.* (1994) and Newman *et al.* (2002) for Santa Gertrudis cattle.

Sex was a highly significant ($p < 0.001$) source of variation for weights at birth, weaning, 12 months and 18 months and significantly influenced pre- and post-weaning weight gain. The males were 8.7% heavier than their female counterparts at birth. They further outperformed the females for all traits measured pre-weaning, with a similar trend reported for post-weaning traits. Interpretation of post weaning results for male and female contemporary groups is complicated by the fact that male and female calves were managed as separate groups post-weaning. They were however, grazed in close proximity to each other and subjected to similar management practises. On average, male calves were 6.1%, 39.8% and 68.2% heavier than females at weaning, 12 months and 18 months of age and grew faster by 0.07 kg and 0.60 kg pre- and post weaning respectively. The significant effect of sex reported in this study is in agreement with similar results obtained for pre-weaning growth traits by Lesmeister *et al.* (1973), Reynolds *et al.* (1982), Rege and Moyo (1993), MacGregor (1997) and Tomo *et al.* (1999) who found male calves were usually heavier than female calves at birth and at weaning. Objective post-weaning comparisons are limited, but Ebangi (2000) reported post-weaning growth traits in favour of male animals and Eriksson *et al.* (2002) observed that male animals grew faster than female animals post weaning. Ebangi (2000) ascribed the difference reported between male and female animals to mainly differences in their endocrinological functions. In the present study a combination of endocrinological functions and the increased selection pressure on males than female calves may account for the findings.

Table 2.1 : Least squares means (±SEM) for weight (kg) and average daily weight gain (kg) from birth to weaning of Santa Gertrudis Cattle.

Fixed effects	No.	Birth (kg)	No.	Weaning (kg)	No.	Birth – weaning (kg)
Overall Herd	1057	**	2506	*	888	*NS*
A	373	34.1 (0.04)	1233	247.7 (0.68)	297	1.0 (0.01)
B	684	38.2 (0.17)	1273	254.7 (0.68)	591	1.0 (0.01)
Sex		**		**		*
Males	574	38.2 (0.15)	1271	237.2 (0.91)	468	1.06 (0.01)
Females	483	35.1 (0.14)	1235	223.4 (0.81)	420	0.99 (0.01)
Birth Year		**		**		**
1986	3	34.0 (0.01)	62	231.0 (0.89)	1	0.96 (0.01)
1987	12	36.9 (0.15)	96	238.3 (0.74)	1	1.21 (0.01)
1988	53	37.5 (0.15)	151	247.0 (0.72)	51	1.12 (0.01)
1989	85	37.6 (0.13)	169	239.3 (0.73)	78	1.04 (0.01)
1990	164	36.5 (0.13)	160	247.1 (0.59)	131	1.04 (0.01)
1991	155	35.8 (0.15)	255	226.2 (0.74)	133	0.99 (0.01)
1992	105	36.0 (0.11)	258	223.1 (1.04)	94	0.98 (0.01)
1993	118	37.3 (0.17)	169	247.1 (0.54)	109	1.10 (0.01)
1994	138	36.1 (0.15)	392	214.5 (0.87)	126	1.05 (0.01)
1995	106	36.6 (0.15)	239	226.6 (0.97)	95	0.97 (0.01)
1996	55	38.1 (0.20)	266	226.4 (0.93)	45	1.06 (0.01)
1997	37	40.1 (0.17)	226	229.0 (0.73)	24	0.97 (0.01)
1998	22	37.9 (0.14)	55	247.3 (0.56)	1	0.92 (0.01)

Fertility Level		*NS*		*NS*		*NS*
High	469	36.7 (0.16)	914	239.1 (0.87)	391	1.01 (0.01)
Medium	418	36.8 (0.14)	1032	227.6 (0.89)	352	1.03 (0.01)
Low	170	37.0 (0.15)	560	221.4 (0.80)	145	1.04 (0.01)
Calving Status		*NS*		*		*
1			4	225.0 (0.001)		
2	269	36.2 (0.14)	689	230.8 (0.91)	220	1.05 (0.01)
3	223	37.0 (0.17)	530	228.4 (0.87)	185	1.02 (0.01)
4	189	36.8 (0.14)	423	229.3 (0.79)	155	1.02 (0.01)
5	136	37.2 (0.15)	322	232.4 (0.86)	120	1.03 (0.01)
6	93	36.7 (0.14)	211	230.2 (0.92)	83	1.01 (0.01)
7	57	37.5 (0.16)	142	232.0 (0.81)	50	1.03 (0.01)
8	33	36.7 (0.18)	82	233.1 (0.98)	29	1.04 (0.01)
9	27	37.6 (0.20)	43	242.8 (0.84)	22	1.05 (0.01)
10+	30	36.8 (0.12)	38	220.2 (0.78)	24	0.92 (0.01)
Season		**		**		**
Summer	825	35.1 (0.12)	1904	239.4 (0.84)	692	1.04 (0.01)
Winter	232	37.1 (0.10)	602	221.7 (0.83)	196	0.88 (0.01)

*Means with a different superscript letter within a column and item differ ($p < 0.05$).

**Means with a different superscript letter within a column and item differ ($p < 0.001$).

Table 2.2 : Least squares means (±SEM) for weight (kg) and average daily weight gain (kg) from 12 – 18 month of age of Santa Gertrudis cattle.

Fixed effects	No.	12 Months	No.	Wean – 12 Month	No.	18 Months	No.	Wean – 18 Month
Overall Herd	1055	**	991	*	366	*	319	*NS*
A	589	374.5 (2.62)	536	0.79 (0.01)	141	418.3 (5.19)	118	0.53 (0.02)
B	466	327.0 (1.76)	455	0.50 (0.01)	225	427.3 (3.64)	201	0.51 (0.01)
Sex		**		*		**		*
Males	379	432.6 (1.79)	354	1.08 (0.01)	29	589.1 (3.42)	29	0.95 (0.01)
Females	676	309.2 (1.25)	637	0.42 (0.01)	337	350.1 (3.72)	290	0.41 (0.01)
Birth Year		**		**		**		**
1985	17	433.6 (2.79)	4	1.42 (0.01)	2	429.0 (0.96)		
1986	47	412.8 (2.88)	32	0.98 (0.01)	1	343.0 (0.01)	1	0.42 (0.01)
1987	40	383.8 (2.43)	39	0.85 (0.02)	21	331.7 (1.52)	20	0.33 (0.01)
1988	72	374.0 (2.25)	72	0.76 (0.01)	57	385.5 (4.33)	53	0.44 (0.01)
1989	99	351.4 (2.03)	97	0.65 (0.01)	49	425.8 (3.40)	49	0.51 (0.01)
1990	112	365.1 (2.13)	112	0.73 (0.01)	28	454.7 (5.31)	28	0.61 (0.02)
1991	97	360.1 (2.50)	94	0.78 (0.02)	13	467.3 (2.30)	13	0.67 (0.01)
1992	71	342.2 (2.17)	71	0.70 (0.01)	26	309.5 (4.36)	26	0.37 (0.01)
1993	84	360.5 (1.83)	83	0.61 (0.01)	45	339.7 (7.66)	15	0.73 (0.01)
1994	99	327.3 (2.26)	96	0.49 (0.01)	31	361.6 (2.18)	31	0.36 (0.01)
1995	127	327.1 (2.13)	120	0.50 (0.01)	36	302.8 (3.00)	27	0.35 (0.01)
1996	98	325.6 (1.92)	88	0.49 (0.01)	40	342.2 (4.55)	39	0.45 (0.01)
1997	91	358.2 (2.43)	82	0.70 (0.01)	17	361.2 (1.82)	17	0.34 (0.01)
1998	1	286.0 (0.01)	1	0.28 (0.01)				
Fertility Level		*NS*		*		*NS*		*NS*
High	451	348.9 (2.39)	429	0.62 (0.01)	110	384.5 (4.46)	103	0.46 (0.01)
Medium	425	349.9 (2.32)	396	0.64 (0.01)	156	367.7 (5.52)	134	0.48 (0.01)
Low	179	359.9 (2.23)	166	0.70 (0.01)	100	354.2 (4.64)	82	0.42 (0.01)

Calving Status		*NS*		*NS*		*NS*		*NS*
1	4	404.0 (0.01)	4	1.11 (0.01)				
2	274	362.6 (2.40)	255	0.67 (0.01)	101	362.3 (5.67)	83	0.47 (0.01)
3	224	346.4 (2.22)	203	0.61 (0.01)	90	366.0 (4.60)	81	0.43 (0.01)
4	174	363.6 (2.41)	165	0.71 (0.01)	58	376.8 (4.59)	50	0.45 (0.01)
5	134	356.9 (2.26)	132	0.67 (0.01)	41	360.2 (4.36)	34	0.43 (0.01)
6	85	340.2 (2.19)	84	0.62 (0.01)	30	375.2 (4.76)	27	0.51 (0.01)
7	70	336.3 (2.10)	64	0.57 (0.01)	23	376.9 (4.97)	23	0.47 (0.01)
8	47	350.5 (2.65)	44	0.68 (0.01)	11	396.0 (6.96)	11	0.44 (0.01)
9	20	346.5 (2.55)	17	0.67 (0.01)	6	327.0 (4.99)	4	0.41 (0.01)
10	15	337.2 (2.03)	15	0.68 (0.01)	5	466.8 (3.83)	5	0.67 (0.01)
11	5	324.4 (3.35)	5	0.46 (0.01)	1	353.0 (0.01)	1	0.42 (0.01)
12	2	280.0 (1.22)	2	0.39 (0.01)				
13	1	215.0 (0.01)	1	0.45 (0.01)				
Season		*NS*		**		*NS*		*NS*
Summer	792	368.1 (1.24)	745	0.60 (0.01)	275	414.3 (2.52)	235	0.29 (0.01)
Winter	263	366.4 (1.58)	246	1.15 (0.01)	91	416.2 (2.38)	84	0.34 (0.01)

*Means with a different superscript letter within a column and item differ ($p < 0.05$).

**Means with a different superscript letter within a column and item differ ($p < 0.001$).

The effect of season on birth, weaning weight, weight gain from birth to weaning and weight gain from weaning to 12 months, was highly significant ($p < 0.001$), but did not affect 12 month and 18 month weights. At birth calves born in winter were 5.5% heavier than those born in summer. This weight difference could possibly be attributed to seasonal variations due to differences in rainfall which in turn affected feed availability. By implication, cows calving down early in the summer season had to endure a period where the pastures are usually mature and of little nutritional value. The last trimester of prenatal calf growth for the summer calving cows occurred during the dry season, usually resulting in weight loss and poor body condition of pregnant cows due to nutritional stress. It is possible that this nutritional stress is inherently passed to the calf through the prenatal developmental environment. The results of the nutritional stress are reflected in calves with lower birth weights in the summer born calves. The winter born calves consequently have experienced a nutritional stress in the early stages of foetal development. However, in the last trimester of foetal growth when 70% of foetal growth occurs, the pregnant cows have benefited from the more nutritional pastures of the rainy season. These winter calving cows subsequently attained higher body condition scores at weaning compared to those calving in summer. The improved nutritional environment is conducive to foetal development giving the winter-born calves a comparative advantage, which is reflected in a higher ($p < 0.001$) birth weight of the calves. Although the winter calves were heavier at birth, the summer born calves grew significantly ($p < 0.001$) more rapidly and were weaned at a higher weight. Summer calves were almost 8% heavier at weaning compared to winter born calves. It is likely that the summer calves were heavier at weaning because the abundant nutritional grazing during the wet season improved the quality and quantity of milk supplied by the cows. According to Letholu (1983), Dionisio (1989), Bothma (1993) and Erat and Buchanan (2005), 50 to 70% of the variation in weaning weight can be attributed to differences in milk production between cows. The effect of season of birth on live weight and growth of Santa Gertrudis cattle agreed with the findings of De Souza and De Ramos (1995), Nesamvuni (1995) and Plasse *et al.* (1995).

Year of birth significantly influenced birth weight, pre-weaning weight gain, weaning weight, yearling weight, 18-month weight and post-weaning growth. From the results it is evident that no consistent trend over time for maximum average weights and weight gains were observed. The heaviest average birth weight of 40.1 kg was recorded in 1997 while the heaviest average weaning weight and 12 month weights of 276.8 kg and 433.6 kg were recorded in 1985 respectively. The inconsistency in performance from year to year is most probably the result of the erratic environmental conditions experienced in the sub-tropical region of the Southern African continent. The environmental conditions for a specific year are seldom, if ever, repeated. These erratic environmental conditions have a substantial effect on the availability and quality of forage produced in a particular year (Tawonezvi, 1989, Smit *et al.,* 1996). Due to a reduction in herd size during the observation period, the 10 years of drought conditions did not impact negatively on the performance of the Santa Gertrudis cattle. Apparently, sufficient forage on the ranch to sustain the herd during the drought period was allowed for. Hence factors other than rainfall may be responsible for the annual variation in growth of the animals. The drought and fluctuation in environmental conditions necessitated certain management decisions to be made in order to maintain the size of the herds and this could possibly explain the highly significant ($p < 0.001$) herd x calf birth year x season interaction and inconsistency in results obtained in this study. Similar inconsistent results were reported by Anunu and Makarechian (1987) in various crossbred cattle, Rust and Van der Westhuizen (1994) in Simmentaller cattle, and Tomo *et al.* (1999) in Angoni cattle in Mozambique. Improved herd management over the years could also have attributed to the significant year effect. Changes in the genetic make-up of the animals in the herd may have been a contributing factor responsible for the differences in production of the animals from 1979 to 1998.

Fertility level did not significantly affect birth weight, weaning weight, pre-weaning growth, 12-month weight, and 18-month weight and wean to 18-month weight gain. However, it did have a significant effect on gain from weaning to 12-month. The non-significant effect of fertility group on corrected weaning weight is supported by the findings of Rege and Moyo (1993) and MacGregor (1997). Lishman *et al.* (1984) reported that early calvers produced heavier weaners in two different climatic regions irrespective of feed supplementation of the cows and / or calves. Morris and Cullen (1988) and Garcia Palomo *et al.* (1992) support the results that heavier weaning weights are simply due to the age difference between cows calving early and those calving later in the season. The results from this study are further supported by Marshall *et al.* (1990), who recorded similar results for the different calving groups, finding no significant differences for calf-birth weight or pre-weaning calf ADG and weaning weights. However, weaning weights were 11.51 kg and 17.65 kg heavier for the high fertility group (HFG) over the medium fertility group (MFG) and low fertility group (LFG) in this study respectively (Table 2.1). This is contrary to the findings of Nesamvuni (1995) and Tomo *et al.* (1999). They noted that calves from the least fertile cows were generally the heaviest at weaning since they were mostly those that missed at least one calving season, and were able to recover more rapidly from the stress of reproduction and nursing a calf. Thus, more time to build up body reserves for subsequent calvings was possible. Fertility level was not a significant source of variation on post weaning growth performance. The HFG calves weighed 10.05 kg and 10.98 kg heavier than the MFG and LFG calves at 12 months (Table 2.2). Rege and Famula (1993) noted a delay in calving date was associated with reduction in yearling weight and average daily gain from weaning to 12 months of age. Meaker *et al.* (1980), Lishman *et al.* (1984) and MacGregor and Swanepoel (1992) reported a favourable relationship between body weight and fertility, while Arije and Wiltbank (1971) and Plasse *et al.* (1995) recorded a positive correlation between age of first oestrus and growth rate. The results from this study are in accordance with MacGregor (1997) and Rege and Moyo (1993), who concluded that earlier calving was associated with higher fertility and would have beneficial effects on growth performance of a herd. Their results are particularly important as their studies were conducted under environmental conditions similar to those found in Southern Africa. The calves of the HFG were 16.8 kg and 30.4 kg lighter than the MFG and LFG at 18 months of age, respectively. Taylor and Swanepoel (2000) found that early and regular calving restricted mature size and could possibly explain the lighter 18-month weight for the HFG as compared to the MFG and LFG categories.

The significant effect of cow reproductive status (parity group) on weight and growth traits observed in this study is similar to the findings by Mabesa (1994) and Tomo *et al.* (1999). Cow reproductive status did not affect birth weight, 12 month, 18 month and post-weaning calf growth. Weaning weight and pre-weaning growth was significantly ($p < 0.05$) reduced by low reproductive status. Mabesa (1994) and Plasse *et al.* (1995) ascribe the variation in weaning weight and pre-weaning calf growth to variation in milk production. Older cows reaching the end of their productive life tend to show more variation in calf growth, since they produce less milk than younger cows, which tends to retard growth of the sibling progeny.

Herd effect was highly significant ($p < 0.001$) for birth weight and 12-month weight and significantly ($p < 0.05$) affected weaning, 18 month and weaning to 12 month ADG. Heifers allocated to herd A were better adapted to the stresses imposed by the environment, as they were the animals that generally weighing more at 12 and 18 months of age.

2.5 CONCLUSIONS

Sex, herd, calving season, calf birth year and herd x calf birth year x calving season were found to be significant sources of variation for pre and post-weaning growth traits in Santa Gertrudis cattle in Southern Africa. Cow parity group (calving status) influenced weaning weight and pre-weaning growth rates, but had no effect on post weaning growth traits.

Male calves were generally heavier at birth by 8.7% and out grew female calves in production traits measured pre and post-weaning.

Calves born in the summer season were significantly lighter at birth, however they out performed the winter calves in all subsequent growth traits. A summer calving season should be maintained as the main breeding season as calves born in the summer are lighter, reducing the incidence of dystocia and out perform winter born calves in pre- and post-weaning growth traits.

Calves born to fertile cows (HFG) are born earlier in the calving season, tend to be lighter at birth and grow faster than calves born to less fertile cows.

Production (growth and fertility) results comparable to those obtained for extensive beef production under temperate climatic conditions are achievable in the Southern Africa arid subtropics from cattle breeds that have both the genetic composition for both adaptability and production.

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