THE EFFECTS OF WEATHER VARIABILITY ON GROWTH POTENTIAL OF AFRIKANER CATTLE IN A SEMI-ARID REGION IN ZIMBABWE

by

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Abbreviation

Age90	Actual age of calf after 90 days
Age11	weaning age
BD	Birth date
MRI	Matopos Research Institute
G1	Average daily weight gain
G2	Preweaning weight gain from 90 days to weaning
G3	Preweaning weight gain from birth to weaning
G4	Early postweaning weight gain
Wt	Weight
WW	weaning weight
g	line
m	environment
s	supplement
Dage	dam age
GLS	general linear square
OLS	ordinary least square regression

ABSTRACT

The abiotic environment plays an important role in cattle production. Key abiotic elements evaluated in this study are rainfall and temperature. This study was carried out to assess the effect and contribution of rainfall and temperature, amid other factors, on pre- and post-weaning growth traits of Afrikaner cattle at Matopos Research Institute from 1958 to 1997.

Historical data generated from a genotype x environment interaction study at Matopos Research Institute was used to identify factors associated with the average daily weight gain of calves of Afrikaner cattle breed. A total of 10 700 records were retrieved comprising of birth weight (BW), 90 day weight, 205 day weight and early post-weaning weight as well as additional corresponding rainfall and temperature data from 1958 to 1997. The rainfall and temperature data was computed asrainfall and temperature variability. The data was corrected for heteroscedasticity using the generalized least squares approach (GLS) before running an ordinary least square regression (OLS) analysis to determine the association between growth rate and potential explanatory factors for average daily weight gain, pre-weaning weight gain and early post-weaning weight gain.

The weight gain between birth and 90 days of calf age was described as average daily weight gain (G1). The predictor variables used to assess G1 were; year of birth, age of dam, previous lactation status, line, environment, sex of calf, date of birth, birth weight, temperature variability from birth to 90 days (TempVar90), cumulative rainfall from birth to 90 days (90dayCumrain) and season. In this study G1 was significantly affected ($p < = 0.01$) by year of birth, dam age, previous lactation status, environment, sex of calf, date of birth, birth weight, cumulative rainfall, temperature variability and season. Independent variables that were not significant are; line and the interaction between sex and environment. The results

from the data analysis revealed that previous lactation status was significantly affecting G1. Afrikaner calves born from first lactating cows were gaining 23.2% more weight than calves from zero lactation status and calves born from cows in second lactation status were gaining 16.6% more weight than calves from no lactation status. The results also revealed that calves born from early mated cows were gaining 13.5% more weight than calves born from late mated cows. Generally female calves were 13.6% lighter than male calves. Season was also shown to have a significant effect ($p<=0.01$) on average daily weight gain, calves gained 5.1% more weight in summer than in winter and 9.8% in transition season than in winter. Supplementing cows had no influence on the average daily weight gain in Afrikaner calves.

The weight gain between 90 days of age and 205 days of age was classified as pre-weaning weight gain (G2). The predictor variables used in this analysis were; year of birth, age of dam, previous lactation status, line, environment, sex of calf, date of birth, age of calf at 90 days recording time (age90), weight of calf at 90 days (wt90), birth weight, date of birth, sex-environment interaction, actual amount of rainfall received between 90 days and 205 days (G2-rain), cumulative rainfall from birth to weaning (wwrain), average temperature variability from birth to weaning (TempVarWW) and season. In this study variables significantly, $p < = 0.01$, affecting G2 were year of birth, environment, first lactation status, sex of calf, sex-environment interaction, date of birth, age90, wt90, G2-rain, wwrain, TempVarWW, season. G2 was not significantly affected by age of dam, second lactation status, line, birth weight. This study revealed that calves born from cows in first lactation were 5% heavier than calves born in zero lactation group. The calves also born from early mated cows were 8.7% lighter than calves born from late mated cows. Seasonal effect were also assessed in this study, the results showed that calves were generally 9% heavier in summer than in winter, and 13% heavier in transition season than in winter.

This study also evaluated pre-weaning weight gain from birth to weaning (G3). The non-genetic factors evaluated for G3 were year of birth, age of dam, previous lactation status, line, environment, sex of calf, date of birth (sdob), age of calf after 90 days (age90), weight of calf after 90 days (wt90), birth weight, G2-rain, wwrain, TempVarWW and season. The predictor variables which were significantly affecting G3 are; year of birth, first lactation, environment, sex of calf, sdob, wt90, age90, birth weight, G2-rain, wwrain, temperature variability and transition season. The non-significant variables were; second lactation, line, age of dam, summer season and the interaction between sex and calf was also not significant. In this study the female calves were gaining 7.6% less weight compared to the male calves, however the interaction between sex and environment was not important. The calves born from early mated cows were 5.4% lighter than the calves born from late mated environment. This study also revealed that calves born from cows in first lactation were 4.4% heavier than calves born from cows which were previous not lactating, however there was no statistical difference in terms of weight gain between calves born from cows in second lactation and no lactation. In terms of seasonal effect, the summer season was not different with the winter season however calves could still gain 1.7% more weight than calves in winter. The transition season was more influential with calves gaining 9.3% more weight than in winter.

In this analysis the weight gain between 205 days of age and and early postweaning weight gain (G4). The non-genetic factors assessed for G4 were year of birth, age of dam, previous lactation status, line, environment, sex of calf, date of birth, birth weight, age of calf at weaning (age11), weaning weight (ww), cumulative rainfall from birth to early postweaning age (Epwwrain), actual amount of rainfall received between weaning age and early postweaning age (G3-rain), and average temperature variability from birth to early postweaning age (TempVarEpww) and season.

The early postweaning weight gain (G4) was significantly ($p< = 0.01$) affected by year of birth, second lactation, line, environment, birth weight age of dam, sex of calf ($p<=0.1$), sdob, age11 ($p<0.05$), ww, temperature variability and season. G4 was not significantly affected by first lactation status, G3-rain, cumulative rainfall (EPWWrain). This study revealed that female calves gained 4% less weight compared to male calves and the interaction between sex and environment showed that female calves in early mated group gained 6.3% less weight compared to either male or female calves in late mated environment. The early mated and supplemented line produced calves which were 7.1% heavier than calves from the late mated and non supplemented line. The results also revealed the importance of different weather seasons on growth potential of Afrikaner cattle, with calves losing 4.9% of its weight in summer and gaining 4.5% more weight in transition season compared to winter season.

This study revealed that from birth to early post-weaning age weather variables assessed in this study, rainfall and temperature variability were consistently influencing weight gains in Afrikaner calves. The non-genetic factors which were important in influencing weight gain in calves were: initial weight, age of calves, the cow’s previous lactation status and the environment as defined in this study.

Declaration

I certify that the work presented in this dissertation is, to the best of my knowledge and belief, original, except as acknowledged in the text, and that the material has not been submitted, either in whole or part, for a degree in this or any other university. I acknowledge that I have read and understood the university's rules, requirement, procedure and policy relating to my higher degree research award and to my dissertation. I certify that I have complied with rules, requirements, procedures and policy of the university (as they maybe from time to time).

Signature

L Chipfupa

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Dedication

I chose to dedicate this dissertation to my mother, Sarah Chipfupa, for the unconditional love she have for me.

CHAPTER 1

Introduction

1 Background

Livestock rearing in most African countries is wholly dependent on natural rangelands. These natural rangelands in Southern Africa contribute to more than 80% of ruminant animal feeds (Smith et al., 1990 and Fynn and O'Connor, 2000)

Kadzere (1995) and Stalker et al. (2006) noted that livestock nutrition in Southern Africa depends directly on the utilization of natural pasture, as this constitutes the main feed base. Depending on the weather conditions influencing the area, the composition of 80% of ruminant feeds from the rangelands could be sour veld, sweet veld or mixed. The sweet veld has a higher nitrogen content which is high enough to support microbial activities in the rumen (McDonald and Greenhalgh, 1993 and Mutanga et al., 2004). The nitrogen content is 2-3 % in winter and dry seasons, 6-7% in wet summer season. The reported percentage nitrogen in summer is high enough for general body maintenance and also sustain a certain level of animal production in the form of milk and meat production and draught power. Rangelands management through controlled grazing regimes and adherence to recommended carrying capacityis synonymous to enhancement and sustenance of animal production (Osoro and Wright, 1992 and Fynn and O'Connor, 2000).

Devendra (1990) and Mutanga et al. (2004) noted that availability and quality of nutrients in ruminant diet are two of the major factors which limit animal production in the tropics, besides water accessibility and tropical animal diseases.

Most of the indigenous livestock animal breeds in Africa (cattle, goats and sheep) have been developed and improved under certain climatic conditions, with natural rangelands as the main feed source. This means the nutrition available for these breeds during development and improvement form part of their permanent environment and any change or shift in climate in terms of weather pattern would result in change of nutritional value of rangelands (Greg and Joel, 2011) and breed potentiality is also affected.

Sweet and sour veld and legume tree forages (leaves, pods and edible twigs of shrubs) form the main diet of indigenous cattle breeds in Southern Africa (Kadzere, 1995 and Snyman, 1998). The nutritive value of these grass and browse feed resources in terms of biomass production, chemical composition, fibre content and palatability are essential for the survival and general animal performance henceforth the need to frequently assesses them in the wake of climate and seasonal changes. Frequency in grazing, fire regimes droughts, floods and the general change in weather patterns may cause changes in rangeland composition and feeding value. Such changes may affect animal production when animals are exposed to poor nutrition and disease occurrence. The state of the grass influences the voluntary feed intake and the quantity of nutrients absorbed by the body (McDonald, 1981 and Mutanga et al., 2004); nutrient intake will in turn affect what the body can store in terms of energy (Wettermann, 1993 and Stalker et al., 2006).

The weather variability in terms of sporadic changes in monthly or annual rainfall, and maximum and minimum temperatures, has a bearing in graze and browse nutritive value which subsequently impact on body weights and conditions (Weladji and Holand, 2003). The nutritive value components that are highly sensitive to weather variability include digestibility and degradability coefficients, grass and browse chemical compositions, like nitrogen levels, acid detergent fibre, neutral detergent fibre and minerals, and also palatability; these components affect feed intake and utilization (Van Soest, 1994).

It is well documented that the annual rainfall and both minimum and maximum temperatures an area receives affect the quality of the vegetation and dry matter production in that region (Afolayan, Pitchford and Weatherly, 2002 and Magadzire, 2002), however the nature, strength and extend of the correlations that exist need to be established, and directly associated to animal performance data.

This research study aims at establishing the correlation between average daily weight gains, pre-weaning gains and post-weaning gains in an indigenous cattle population, Afrikaner cattle breed, and the rainfall and temperature variability in the study area, Matopos Research Institute in Zimbabwe. The established relationships will aid in individual selection with reference to abiotic factors and other non genetic factors influencing average daily weight gains pre and post-weaning weight gains in Afrikaner cattle.

For the purpose of this study, multiple regression analysis was used in defining how rainfall variability and temperature variability are associated with calf weight changes in Afrikaner cattle breed in a semi-arid area in the Southern part of Zimbabwe, Matabeleland South. The results obtained through this study from regression analysis will in retrospective determine the change of the rangelands status and quality in Matabeleland South from 1958 to 1997.

1.1 Problem statement/ Knowledge gap

For animals reared wholly on rangelands, daily weight gains is positively associated with the quality of the rangeland which depends on weather conditions experienced in the area. The quantity and quality of the rangeland influences its carrying capacity and the level of animal performance, in turn the quality of feed is defined by its palatability, chemical composition, digestion or degrading rates and eventually the amount of nutrients absorbed in the animal's gut system. The rate of rumen degradability depends on the nitrogen content in the feed, acid detergent fibre, neutral detergent fibre and other factors such as microbial density in the rumen (Van Soest, 1994). Okigbo (1984) also highlighted that the state of grazing in Southern Africa is predetermined by the prevailing climatic and soil conditions. Such conditions give rise to the vegetation cover, quantity and quality of rangeland and resulting in two distinct grass types sour and sweet veld (Chesworth, 1992). The relationship among weight losses and gains, under such stressful range conditions has received little emphasis (Paula *et al*. 2011).

Much efforts has been made to improve growth traits such as weaning weight, birth weight, average daily weight gain, pre- and post-weaning weight gains through development of lines, selection programmes, sire and maternal breed effects on growth traits as reported by Oxford *et al*. (2009). Animal breeders have also tried to improve the growth traits through crossbreeding projects exploiting the principle of heterosis and complimenting traits. In crossbreeding projects exotic breeds were crossed with indigenous breeds, both exotic and indigenous cattle breeds were used as maternal or paternal breeds.

Not much attention has been directed to the study of the degree of contribution of rainfall and temperature variability to growth traits such as average daily weight gains, pre- and post-weaning weight gains in Afrikaner cattle under semi-arid conditions. Paula *et al*. (2011) noted that weight fluctuations have not been studied because many cattle are supplemented during times of restricted feed supply. According to Paula *et al*. (2011) one of the most important limitations to beef production in Southern Africa is poor performance of cattle on the veld in the dry season. It has been reported that growth and productivity of beef enterprise in Africa is hindered by poor weight gains and high levels of mortality. Weight gains patterns has been positively associated with reduced fertility, delay in reaching market weights, increased finishing costs in commercial beef farms and overall reductions in off-take. Assessment of rangeland conditions in relation to growth patterns is of particular importance in range fed cattle production systems were there is minimum or no interventions. Poor growth rates were mainly referenced to sour and mixed veld areas (Paula *et al*.,2011), but in recent years it has also been reported for most of the livestock production areas in Zimbabwe, due to prolonged droughts.

This research project is inspired by work done by Beffa (2005) of genotype x environment interaction in Afrikaner cattle breed at Matopos Research Institute in Zimbabwe. In his study Beffa (2005) defined the major component of environment as early mated and supplemented (group 1) versus late mated and non supplemented cows (group 2). The early mated group was mated to calve in September whilst the late mated group was mated to calve in December. The two groups give the basis of comparisons of the summer and the winter months, rainfall and temperature variability. The animals in the supplemented group were fed wholly on the natural range, with its quality depending on abiotic factors such as annual rainfall, maximum temperature and relative humidity. In this project, calf weight traits data from two groups of animals, as defined earlier, were recorded and retrieved.

For the current project, data recorded by Beffa were used, various weather and environment variable components, as defined by Beffa (2005), were determined and their contribution to weight changes in calves of Afrikaner cattle breed were quantified. The study is retrospective and based on historical data ranging from 1958 to 1997. Data was analyzed by using a multiple linear regression analysis which is a mathematical approach to establish correlations between variables and calf weight changes and also rank independent variables according to their predictive strength.

The continuous weather variation has an impact on the nutrition aspect of the rangelands as a feed source to ruminant animals and also on the grazing behaviour of animals. The study evaluates the change in climate and its effect on the rangelands at Matopos Research Institute in Matabeleland South through assessing changes in cattle weight in the area.

1.2 Motivation of the study

Indigenous cattle breeding and rearing is of great importance for the beef industry in Southern Africa. Indigenous breeds are used in cross-breeding programmes with exotic breeds. The crossbred progeny would have improved traits in disease tolerance, hardness and good meat quality.

Most communal farmers in Southern Africa keep indigenous cattle breeds and their crosses for milk, meat and trading purposes (generating farm income). Other important uses of indigenous breeds include paying bridal price (lobola) and other cultural events such as ritual ceremonies. The farmers rely mainly on natural rangelands as feed source providing at least 80% of animal feed (Van Soest, 1994). During dry season, as rangelands approaches its nutritional bottleneck, some farmers supplement their animals with veld hay, maize silage and stover whilst resource poor farmers do not supplement at all.

Considering the importance of indigenous cattle breeds for the beef industry and small scale farmers across African states and specifically for resource poor farmers, it is important to continue with research on behavioural trends, nutrition, physiology and genetics revolving around these breeds in the wake of climate change. The application of mathematical theories in animal production systems allow researchers to generate valuable information using history data. In this study the history data of both dependent and independent variables, and the proposed mathematical approaches will contribute to the understanding of dynamic relationships between weather parameters and animal weight changes.

1.3 Research question and objectives

Two questions will be addressed in this proposed study: the first question aims at the way and the extent to which cumulative and actual rainfall and average temperature variability during the period between 1958 and 1997 impacted on calf growth traits in Afrikaner cattle. The second question to be addressed looks at the relationship between weight changes in Afrikaner cattle breed from birth to early post-weaning during the mentioned period at Matopos Research Institute in Matabeleland South, Zimbabwe.

The aim of the study was to gain more information on factors that influence calf growth traits in relation to climate change in an effort to establish some practical solutions for addressing efficiency of beef production.

Therefore the objectives of the study were as listed below:

a) To determine the effect of weather and non-genetic variables on average daily weight gains in Afrikaner cattle breed reared at Matopos Research Institute in Zimbabwe from 1958 to 1997.

b) To assess the extend of contribution of rainfall, temperature and non-genetic variabler on weight change variance in Afrikaner cattle breed reared at Matopos Research Institute in Zimbabwe.

c) To identify important variables influencing calf growth traits during different age stages of its life history, and formulate a predicting model.

1.4 Hypotheses to be tested

a) The average temperature variability, cummulative rainfall amount and actual rainfall experienced from birth to early post weaning age days and other non-genetic factors considered in this study has no significant effect on average daily weight gain of calf of Afrikaner cattle breed at Matopos Research Institute, in Zimbabwe.

b) Temperature variability and cumulative rainfall has the same influence on average daily weight gain as other independent variables considered in this research, at Matopos Research Institute, from 1958 to 1997.

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CHAPTER 2

Literature Review

2.1 Introduction

The sustainability and profitability of cattle rearing in Southern Africa is synonymous to good rangeland management. A well managed rangeland will provide a good feed source to ruminant animals both in terms of quantity and quality of graze and browse. Research in animal production and agribusiness has shown that feed cost threatens the profitability of any animal production enterprise (Gura, 2008 and Chakoma *et al.,* 2010).

For resource poor farmers the rangelands will provide more than 80% of animal feed requirements (Chesworth, 1992). In semi arid regions most of the farmers keep indigenous animals which thrive well even under low input environment. These breeds have been developed and still being improved so that they can survive and being productive under harsh environmental conditions such as low annual rainfall, high temperatures during the day in summer and low rangeland biomass production especially in winter (Magadzire, 2002). Dry season result in the grass having reduced low nutritive value, protein content ranging between 0.8 to 2% (Van Soest, 1994)and the grass accumulates high lignin content or indigestible fibre content (McDonald and Greenhalgh, 1993) in fact most of good quality grass turns into moribund material.

This becomes a crucial time for farmers to intervene with high energy and protein supplements. However, most indigenous cattle breeds under communal farming set up are not supplemented, one of the reason being farmers do believe that the breeds have what it takes to survive under harsh conditions (Beffa, 2005). Some farmers though with strong financial capitals supplement their animals for phosphorus, energy and protein boost so that the animals could maintain and increase their productive state (Mukumbuta and Yamba Yamba, 2010; Chakoma *et al.,* 2010).

In a poorly managed rangeland, which can result in overgrazing or rangeland that has been subjected to droughts and floods, grass biomass becomes inadequate in terms of its nutritional contribution to animal requirements. Changes in vegetation composition, vegetation cover, annual vegetation biomass production and vegetation species composition could be gradual yet significant to animal weight changes, and this could be due to interaction of so many factors (Fynn and O' Connor, 2000).

A number of studies on the effects of both, biotic and abiotic factors modeling their effects on rangelands has been done**,** however, most studies fall short in incorporating changes in animal weights as response variable. In this chapter literature will be reviewed on the effect of climate changes on rangelands, rangeland ecology, and the importance and use of Afrikaner cattle breed.

2.2 Semi arid rangelands ecology

In Southern Africa most of the rangelands are under semi-arid climatic conditions. These semi-arid regions are characterised by relatively low annual rainfall. However the amount of rainfall received is highly variable ranging from 350 mm to 1300 mm (Magadzire, 2002). The semi-arid regions in Zimbabwe are also characterized by relatively high maximum temperatures ranging from 23^0C to 33^0C in summer months and minimum temperatures ranging from -2^0C to 15^0C in winter. Such weather variations translate to very low vegetation biomass production in areas receiving low amounts of rainfall and few pockets of high vegetation production in high rainfall areas (Chakoma *et al.,* 2010).

Most grass species found in semi-arid regions are a mixture of annual and perennial species. Due to relatively dry conditions experienced in the region, sweet veld like *Panicum maximum* is the main grass type, in Matebeleland, South of Zimbabwe (Kadzere ,1995 and Mashoko, *et al.,* 2007). Other grass species found in the region are *Heteropogon*, *Andropogon* and *Hypharrhenia* grass species (Mashoko, *et al.,* 2007). Acacia species are common browsable legume trees found in semi-arid regions (Mashoko, *et al.,* 2007), for example *Acacia nilotica*, *Ziziphus macronata*, *Colophospermum mopane* and *Combretum apiculatum* are common in the Matopos area, Matabeleland South, and according to agro-ecological land classification in Zimbabwe, the area is in natural region IV (NR IV) (Vincent, 1960, Ward *et al.,* 1979, Magadzire, 2002 and Beffa, 2005).

2.2.1 Importance of rangelands in livestock rearing and production

In Southern Africa rangelands provide approximately 80% of animal feeds requirements (Mashoko, *et al.,* 2007). The grass is highly nutritive in summer due to warm and moist conditions, and the nutritive value reduces to critical levels in winter due to cold and dry conditions (Chamaka *et al.,* 2010). The veld grass is a source of fibre and protein, with a protein content of up to 7% in rainy season and 1,5 to 3% in winter dry season (Mashoko, *et al.,* 2007).

The browsable tree species are also good feed sources for ruminant animals. Le Houerou (1980) noted that in Southern Africa trees form a very essential feed source in the form of edible twigs, leaves, seeds and pods. According to Kadzere (1995) livestock depends more on browse as the dry season prolongs. The legume trees are rich in protein content varying from 13 to 27 % (Atta-krah, 1990; Devendra, 1990; Makoboki *et al.*, 2005) especially the tree parts the animal consumes, the leaves, twigs and the fruits.

A survey by Mashoko *et al.* (2007) to promote peri- urban agriculture in Zimbabwe, showed that feed is the most important constrain in cattle production. This means that the level of livestock nutrition is a fundamental determinant of productivity (Kadzere ,1995). Kadzere 1995) also outlined factors influencing animal nutrition which include socio-economic (Barret, 1991) and managerial abilities of the farmer, vegetation and environmental factors of the location.

2.3 Effects of weather variable changes on animal production in Southern African rangelands

Research studies on the state of semi arid rangeland have pointed out factors mainly associated with vegetation changes with some researchers emphasizing more on one over the other. Some researchers have concluded that grazing regimes and stocking rates initiate vegetation change on rangelands (O'Connor *et al.*, 1995 and Mashiri *et al.*, 2008) whilst others have identified and emphasized climatic variability as the primary agent of vegetation change on rangelands (Fuhlendorf *et al.*, 2001). However rainfall and temperature variability are key weather variables contributing to rangelands productivity among other factors.

2.3.1 Effect of rainfall

In terms of climatic variability, weather variables such as annual rainfall and inter-annual precipitation and daily maximum temperatures have profound effects on rangelands (Mashiri *et al.,* 2008).

In a study done in semi-arid areas of South Africa, grass species abundance was found to be more responsive to rainfall variability than to grazing (O'Connor, 1994). In the same study droughts were found to cause mortality of grass species, resulting is reduced productivity of rangelands and impacting on cattle performance. Vegetation changes due to weather variability in most case rainfall variability (Mashiri *et al.*, 2007), is associated with annual or short-lived grass species (O'Connor *et al.,* 1995) or changes in botanical composition (Fynn *et al.,* 2000). Wheeler (1986) highlighted the effect of climatic environment on seasonal pasture production, with pasture quality and quantity being better in rainfall months than in drier months.

2.3.2 Effect of temperature

According to Esler *et al.* (2006), relatively high temperatures coupled with moist conditions result in enhanced vegetation growth, whilst warm weather conditions with little or no moisture damages the plant cells and reduces the quality of grass and shrubs.

When considering how daily temperature variability, i.e. the difference between daily maximum and daily minimum temperatures, influence the animal foraging and or grazing behaviour, most profound effects are due to maximum temperatures. Therefore in relatively humid and hot temperature most animals spend grazing time under shades reducing food intake which may result in weight loss or slow weight gain

Minimum temperatures during winter months result in cattle requiring more nutrients and dry matter for maintenance and try to combat cold stress. The other effect due to low temperatures is the reduced quality of natural rangelands in winter (Wheeler, 1986 and Snyman, 1998). A study revolving around the law of thermodynamics has shown that poor quality feed or dysfunctional rumen microbial ecosystem result in increased heat generation in the animal's body (Leng, 1990). In the case that this is coupled by environmental heat load ruminant production in humid tropics is slowed (Leng, 1990). Pratt and Gwynne (1997) noted that the frequency of cattle moving around is affected at warm to hot weather conditions, and in most cases grazing time is reduced (Magadzire, 2002, Mulliniks et al. 2012).

Variation in temperature variability has also physiological implications to animals. Within the thermo-neutral zone, dietary energy is used for growth, maintenance and physical activity. However below thermo-neutrality, additional energy may need to be diverted from productive process in order to maintain homeothermy (Collin *et al.,* 2001). Reduction in voluntary feed intake and the associated thermic effect of feeding is an efficient mechanism to reduce heat production (Quiniou and Dubois, 2000)

2.4 The Afrikaner cattle breed

2.4.1 History of the breed

The Afrikaner cattle breed was originally classified as Bos indicus cattle (Loubser *et al.,*2007), however further research into the breed's anatomy and genotype reclassify the breed as Bos Taurus cattle (*Bos Taurus Afrikanus*).

a)

b)

c)

Figure 2.1 Afrikaner cattle: mature bulls (a and b) and c cows with 5 months old calves at Matopos Research Institute, Zimbabwe (Nengomasha, 2002).

This hardy beef breed is said to have been discovered by the Portuguese explorers in the 14th century in Southern Africa. By the 18th century the Afrikaner cattle was a well defined breed, essential for draught purposes, meat and milk. However the breed was further improved in terms of disease tolerant and resistant and also in terms of efficiency in growth related traits after the Anglo-Boer war when cattle numbers were decimated by the rinderpest (1896-1897) and the war (Loubser *et al.*,2007). Refer to Figure 2.1 showing an improved Afrikaner cattle breed.

2.4.2 Breed description

The Afrikaner cattle breed is well adapted to extensive environmental conditions like arid desert conditions with extreme heat. The breed has high tolerance and resistance to tropical diseases as well as internal and external parasites. As far as adaptation to tropical diseases by Afrikaner cattle is concerned, the breed is highly resistant to tick associated diseases such as redwater, heartwater and gallsickness. The adaptation of the breed to arid desert conditions and extreme heat can be attributed to the thick hide, which has twice as many sweat pores as those of cattle breed in Europe, while the short, strong, shiny hair also discourages tick attacks.

The Afrikaner has a low maintenance requirement which means the breed can survive in relatively low rainfall regions with low annual biomass production. Loubse *et al.*, 2007, recognize the good foraging ability of Afrikaner cattle, which could be attributed to its oval shaped confirmation, slightly sickle hocks enabling it to walk long distances without effort.
Other important characteristics making the breed suitable for communal farming and developing farmers include; good temperament henceforth easy to handle and excellent mothering abilities, easy calving with low mortality rate, weans heavy crossbred calves (Mpofu, 2002; Loubser *et al.*, 2007; Scholtz, 2010). Table 2.1 adapted from Loubser *et al* (2007) shows the consistency of the Afrikaner breed, in South Africa, in terms of the birth weight, weaning weight and 18 months weights recorded from 1999 to 2009, these weight averaged 32 kg, 191 kg and 294 kg respectively. The data used for average figures in Tables 2.1 and 2.2 was retrieved from the South African herd book. Other cow productive parameters such as age at first calf and inter-calving period were also consistency in the 10 year period, with value of 36 months and 448 days respectively (Table 2.2). The cattle breed can be reared wholly on the veld, producing meat of high quality and tender, tasty and succulent.

Table 2.1: Weights at birth, Weaning (205Days) and 18 months (540 Days).

Year	**Birth (male and female)**		**Weaning (male and female)**		**18 months (female)**	
	Animals	**Kg**	**Animals**	**Kg**	**Animals**	**Kg**
1999	510	33	2 213	185	663	292
2000	675	32	2 415	184	545	288
2001	435	33	1 819	190	589	291
2002	582	33	1 971	186	452	287
2003	1 110	33	2 077	194	434	283
2004	935	32	2 079	196	538	292
2005	873	32	2 255	196	562	305
2006	943	33	1 906	195	624	298
2007	1 102	32	1 498	193	499	294
2008	1 016	31	1 213	195	376	314
Average	**818**	**32**	**1 945**	**191**	**528**	**294**

Source: (Loubser *et al.*, 2007)

Table 2.2: Cow productivity

Year	**Age at first calving**		**Inter calving period**		**Cow weight (Kg)**	**Ratio % (cow calf weight)**
	Animals	**Months**	**Animals**	**Days**		
1999	480	36	1 724	438	469	42.1
2000	506	37	1 903	450	463	39.8
2001	442	36	1 775	451	474	40.7
2002	458	36	1 512	439	473	41.3
2003	915	38	3 168	467	473	41.1
2004	745	38	2 896	457	479	41.6
2005	854	38	2 820	445	476	41.4
2006	705	36	2 625	446	487	42.1
2007	656	35	2 538	443	472	42.5
2008	669	35	2 101	433	478	43.2
Average	**643**	**37**	**2 266**	**448**	**476**	**41.7**

Source: (Loubser *et al.*, 2007)

2.5 Summary

This chapter has reviewed several aspects of literature that surrounds the problem identified in this research study. Literature reviewed has shown the importance and adaptability of indigenous cattle breeds in semi-arid climatic conditions. The literature has also shown how weather variability affects the grass species composition, quality and quantity of rangelands.

The literature reviewed indicated that there could be a relationship between the weather variables, rangeland condition and animal weight changes in indigenous cattle breeds.

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CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research site

The study was conducted using secondary data. The data was provided by Matopos Research Institute (MRI) and include the following: calf weight data, age of dam, sex of calves, previous lactation status of the dam, month of weighing for 90, 150, 205 days weights. The principal custodian of this data is Dr Mario Beffa, who generated this data from his doctorate research in genotype x environment interaction study in Afrikaner cattle at Matopos Research Institute, from 1957 to 1999.

MRI is one of the four livestock and pasture research stations in Zimbabwe, and falls under the Ministry of Agriculture in the government of Zimbabwe. MRI is 28.000 hectares in size and is situated 30 km due South west of Bulawayo in Matobo district in Matabeleland South, Zimbabwe (see Figure 3.1 below).

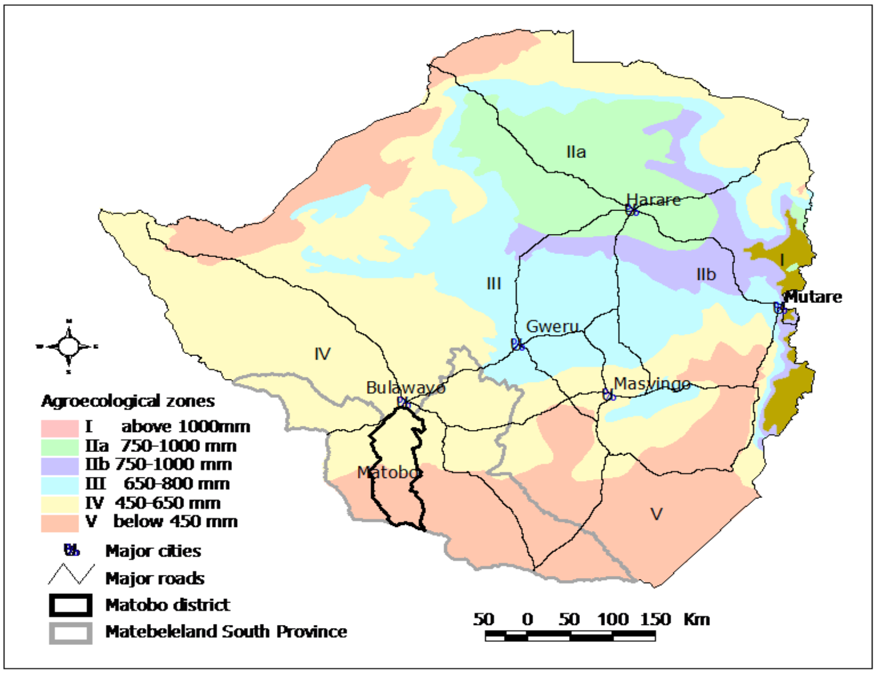

Figure 3.1: Map of Zimbabwe: Location of Matabeleland South Province and Matobo (Matopos) district, indicating where the research site is situated (MATOPOS, ICRISAT, GIS offices).

The MRI is situated in the Natural Region IV (NR IV) according to the Zimbabwean agro-ecological land classification system (Vincent and Thomas, 1960; Magadzire, 2002). This area is characterized by semi arid conditions with average rainfall of 600 mm per year (range 257 – 1376 mm) (Table 4). Exact figures for temperature and rainfall during the time of study were retrieved from Beffa (2005) as shown in figures 3.2 and 3.3 and Table 3.1.

Table 3.1 Mean monthly rainfall, maximum and minimum temperatures recorded at Matopos Research Institute from 1958 to 1997

Month	Rainfall (mm)	Maximum Temperature	Minimum Temperature
January	126	28	16.6
February	89	27.4	16.3
March	54	27.4	15.4
April	26	26.1	13.1
May	8	24.2	9.9
June	2	21.7	7.5
July	2	21.5	7.3
August	2	24.4	9.2
September	8	28.1	12.5
October	35	29.4	15.0
November	95	28.8	16.1
December	119	27.9	16.3

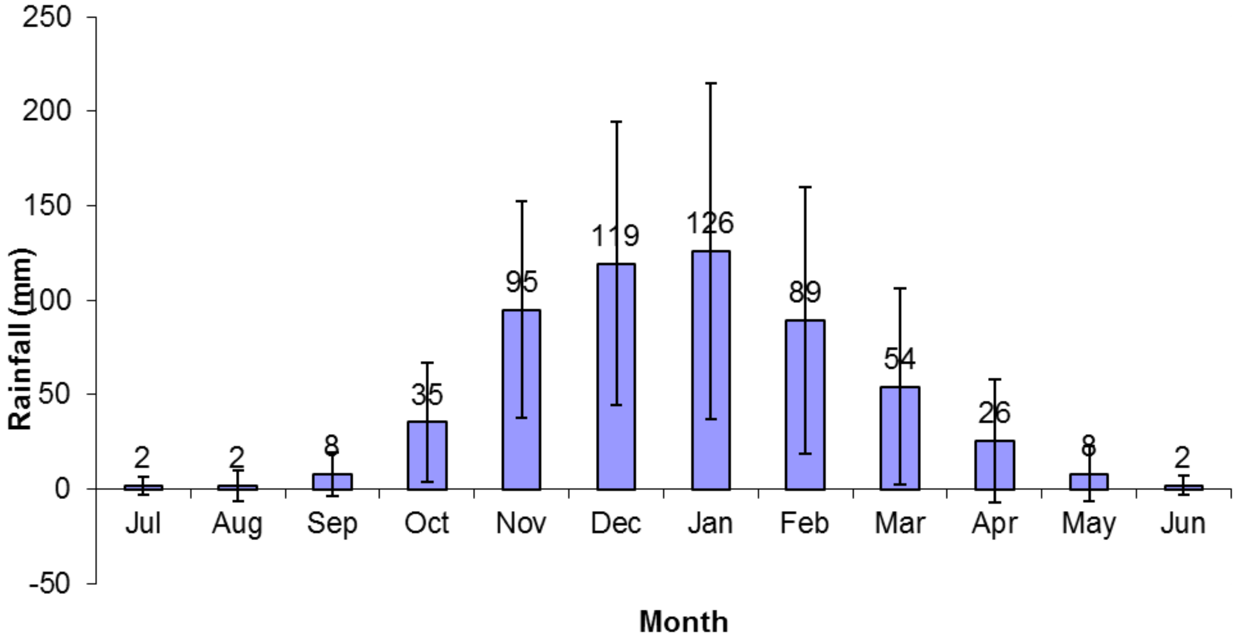

Figure 3.2: Mean monthly rainfall at Matopos Research Institute, in Zimbabwe during the period of the study from 1958 to 1997.

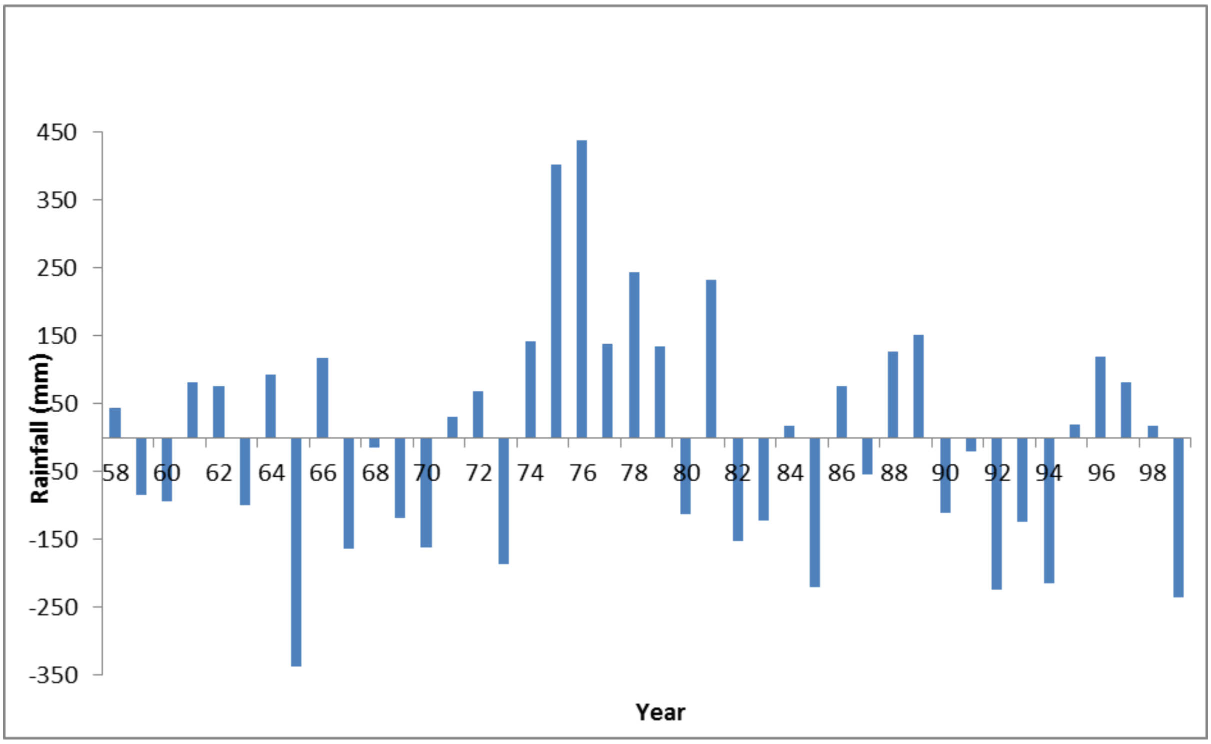

Figure 3.3 Matopos Research Institute annual rainfall (deviated from a mean of 566 mm), 1957/8 to 1998/9 (Beffa, 2005).

A brief note on agro-ecological land classification in Zimbabwe:

Vincent and Thomas (1960) divided Zimbabwe into five main natural regions according to differences in effective rainfall (Figure 3.2, figure 3.3 and Table 3.1 Rainfall patterns and crop production progressively deteriorate from Region I to V.

Table 3.2 Agro-ecological zones of Zimbabwe and the recommended farming systems in each zone (Vincent and Thomas, 1960).

Natural Region	**Area (km^{-2})**	**Rainfall (mm yr^{-1})**	**Farming System**
I	7 000	> 1 000	Specialised and diversified
II	58 600	750 – 1 000	Intensive farming
III	72 900	650 – 800	Semi-intensive farming
IV	147 800	450 – 650	Semi-extensive farming
V	104 400	< 450	Extensive farming

Annual rainfall is highest in Natural region I which covers approximately 2% of the land area. It is a specialized and diversified farming region with plantation forestry, fruit and intensive livestock production. Tea, coffee and macadamia nuts are grown in frost-free areas. Natural region II covering 15% of the land area, receives lower rainfall than region I, nevertheless is suitable for intensive farming based on crops or livestock production.

Natural region III is a semi-intensive farming region covering 19% of Zimbabwe. Although rainfall in this region is moderate in total amount, severe mid season dry spells make it marginal for maize, tobacco and cotton, or for enterprises based on crop production alone. The farming systems are therefore based on both livestock (assisted by the production of fodder crops) and cash crops.

Natural region IV is a semi-extensive farming region covering about 38% of Zimbabwe. Rainfall is low and periodic seasonal droughts and severe dry spells during the rainy season are common. Crop production is therefore risky except in certain very favorable localities, where limited drought resistant crops are grown as a sideline. The farming is based on livestock and drought resistant fodder crops.

Natural region V is an extensive farming region covering about 27% of Zimbabwe. Rainfall in this region is too low and erratic for the reliable production of even drought resistant fodder and grain crops, and farming is based on grazing natural pasture. Extensive cattle or game ranching is the only sound farming system for this region.

3.2 Experimental design

This section details the experimental design used by Beffa (2005) and gives an overview of how the data used in this research study was generated.

Two lines of 100 purebred Afrikaner cows each were established from a common gene pool, and subjected to different nutritional and management regimes, hereafter termed environments. In the supplemented line cows were offered supplements during the dry season (9 kg maize silage and 1 kg cotton seed meal per head per day) and were mated to calve early (October to December) relative to the expected onset of the rains. In the non supplemented line cows were mated to calve 2 months later than those in the supplemented line. In addition, 2 open herds of 25 pedigree cows were maintained in both environments. In addition, routine practices such as castration, weaning, dosing and vaccinations were performed at fixed times in the year where age differed by approximately 2 months.

For the first eight years (1957 to 1964) six foundation sires were rotated among the line (Table 3.3), thereafter the lines have been closed. However, the rotation was not uniform: bulls numbered 4, 5 and 9 were used for 3 to 6 years in the S environment (supplemented), and only one year each in the NS environment (non-supplemented). Similarly bulls 6 and 11 were used for 3 to 4 years in the NS environment but only one year each in the S environment. Only bulls numbered 2 was used for more than one year in both environments. A fixed mating season of 90 days and four single-sired herds of 25 cows each were used within each line. After 1964 three bulls were replaced each year and one was retained as a repeat sire. Selection for weight within line was to establish lines adapted to their respective environments and was based on weight at weaning for bulls and weight prior to mating (three years) for replacement heifers. In the pre-crossover phase, a total of 5 male calves were retained at weaning as potential replacement bulls, with at least one bull being selected from each mating herd in an attempt to maintain four sire families and reduce the effects of inbreeding.

Table 3.3 Rotation across the supplemented and non-supplemented lines of six foundation bulls (in bold italics) during the establishment of line-environment interaction study with grade Afrikaner cattle (identity numbers less than six digits represent foundation animals

Cow herds								
	Non-supplemented lines			Supplemented lines				
Year	1	2	3	4	5	6	7	8
57	1	***2***	***4***	***5***	***6***	7	8	3
58	***9***	***5***	***2***	***4***	10	***6***	7	8
59	***5***	***6***	83	***2***	***9***	10	***4***	***11***
60	***11***	83	***5***	***9***	444	***2***	10	***6***
61	572040	***9***	83	***5***	***2***	444	***11***	10
62	83	572040	***5***	***9***	***11***	10	444	***2***
63	572040	572036	***9***	83	572003	***5***	***2***	444
64	602338	602362	572036	572040	602323	572003	602325	***6***

From 1976 to 1978 the number of breeding females in each line was increased to 150 and two equal sub lines were created (Figure 3.4). One sub line remained within each environment as a control (S/S and NS/NS, leading symbol denotes selection line, trailing symbol environment post-crossover). The remaining sub lines were interchanged between environment (S/NS and NS/S). Significantly, the supplemented regime in the supplemented environment was altered so that animals were offered 0.5 kg of protein rich concentrates per head per day during the dry season. In addition, the mating season was decreased to 65 days for the 1977 to 1982 matings, but subsequently reverted to 90 days.

Bulls were selected within the control sub-lines and were used within line across environments. Bulls selection took place two weeks before weaning and in the post crossover phase, six animals were selected with a proviso that not more than two animals will be selected from a particular cowherd. Candidates were to have reasonably well developed testes and sound animals were selected on weight linearly adjusted for age from 1988 onwards. Selection criteria was based on weight adjusted for other known environmental factors derived from a fixed effects model, which were lines, environment, year of birth and age and previous lactation status of the dam (heifer, suckling or not suckling). Cows were mated in five single sire herds of 15 cows each. Four bulls were replaced each year and one was retained as a repeat sire.

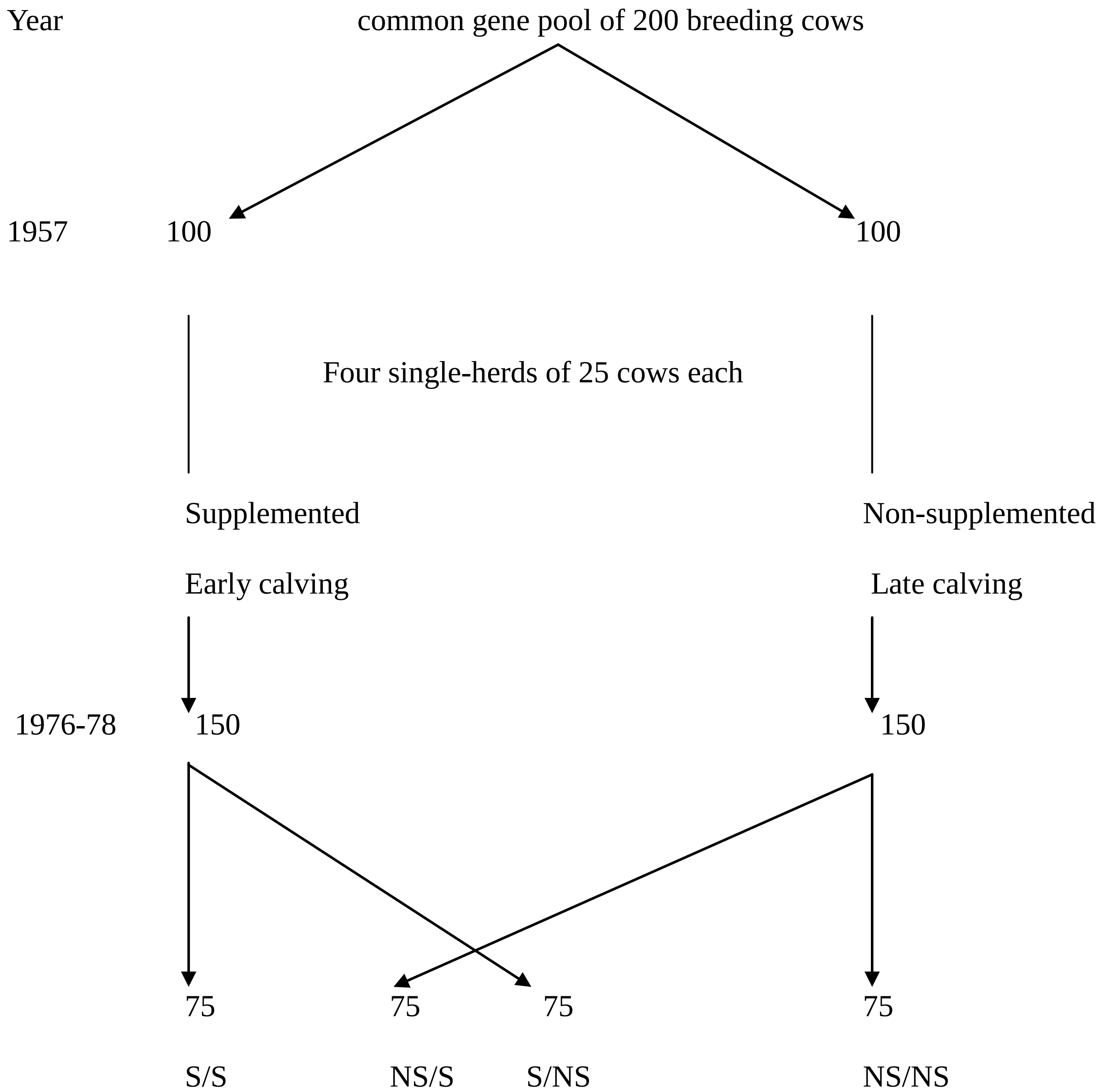

Figure 3.4 Schematic representation of the experimental design of the genotype-environment interaction study with purebred Afrikaner cattle.

Replacement heifers were generated within sublines and entered their respective mating groups at 27 months of age. Replacement rates were kept constant across sublines and were dictated by subline with the least number of suitable replacement heifers. Only sound heifers weighing in excess of 265 kg were deemed suitable and selection was based on weight linearly adjusted for age. This selection and culling intensities differed for the sublines. Cows were culled for poor production (infertility and low calf weaning weight). In the post crossover phase cows in excess of 12 years of age were generally not retained for breeding purposes. The allocation of sires and heifers to the mating herds was based on minimizing relationships as far as possible.

The description of calf weight and weight gain traits used in this study are shown in Tables 3.4 and 3.5.

Table 3.4 Abbreviations and variable description of growth traits considered in this study.

Abbreviation	Variable description
Body weights (Kg)	
BW	Weight within 24 hours of birth and used to calculate average daily weight gain and pre-weaning weight gain
W90 andW205	Weight of calf at 90 days, and 205days of age from birth and was used to calculate average daily weight gain and pre-weaning weight gain.
Weightgain (kg/day)	
G1	Average daily gains between birth and 90 days of age.
G2	Pre-weaning weight gain between 90 days of age and 205 days of age
G3	Pre-weaning weight gain between birth and 205 days age
EPWG	Early post-weaning gains between weaning and early post weaning age

Beffa (2005) noted that the choice of 90 and 205 day weights correspond to standard measures in the industry whilst 150 day weights will be used as an additional, intermediate point in this study. Weight gains will be considered because they are more sensitive indicators of environmental stress compared to assessment of birth, weaning weight and post-weaning weight as noted by Beffa and Wyk, 2009a.

Table 3.5 Description and computation of variables used in this study

Variable	Detailed description and computation
Dependent variables	
G1	Average daily weight gain of calf between birth and 90 days (kgs/day)
G2	Pre-weaning weaninig weight gain of calf (kgs/day)
G3	Pre-weaning weight gain of calf from birth to weaning (kgs/day)
G4	Early post-weaningpost-weaning weight gain (kgs/day)
Independent variables	
Year weights were recorded (Yr)	Year of birth
Dam age in years (Dage)	Age of lactating cows ranged from 3 to 15 years
Lactation status (ls)	0= no lactation; 1=first lactation; 2= second lactation
Line of Afrikaner cattle (g)	1supplemented; 2= non-supplemented
Environment (m)	1= early mated; 2 = late mated
Supplement (s)	1= supplemented; 2= non-supplemented
sex of calf (sex)	0= male 1= female
Standardized date of birth (sdob)	Standardized birth date relative to 1st September
Age of calf at 90 day weighing time (Age90)	Actual age of calf in days at 90 day target weighing time
Age of calf at weaning (Age11)	Actual age of calf in days at weaning time
Early post-weaningpost-weaning age (Age14)	Actual age of calf in days at early post-weaningpost-weaning weighing time
Calf birth weight (BW)	Weight of calf taken within 24 hours of birth
Actual amount of rain received from birth to 90 days (G1-Rain)	Cumulative rainfall recorded from birth to 90 day (mm)
Actual amount of rain received from 90 day to weaning (G2-Rain)	The difference between cumulative rainfall recorded from birth to weaning and cumulative rainfall recorded from birth to 90 days (mm)
Actual amount of rain received from weaning to early post-weaningpost-weaning (G3Rain)	The difference between cumulative rain recorded from birth to early post weaning and cumulative rainfall recorded from birth to weaning (mm)
Cumulative rain from birth to weaning (WWrain)	Amount of rainfall recorded from birth to weaning (mm)
Season	Summer, winter and transition
Cumulative rain from birth to early post weaning (EPWrain)	Amount of rain received from birth to early post-weaningpost-weaning (mm)
Average daily temperature variability from birth to 90 days (TempVar90)	The difference between daily maximum temperatures and daily minimum temperatures (averaged by the age of the calf at 90 day weighing time.
Average daily temperature variability from birth to weaning (TempVarWW)	The difference between daily maximum temperatures and daily minimum temperatures (averaged by the age of the calf at weaning weighing time)
Average daily temperature variability from birth to earlypost weaning (TempVarEPW)	The difference between daily maximum temperatures and daily minimum temperatures (averaged by the age of the calf at early post-weaningpost-weaning weighing time)

3.3 General Management of Afrikaner cattle breed at Matopos Research Institute

Matopos Research Institute houses Tuli, Nguni and Afrikaner cattle breeds indigenous to Zimbabwe (Moyo, 1990). For the purpose of this study, the management of Afrikaner cattle breed was dealt with in details.

3.3.1 Grazing

The experimental site was sub-divided into 35 paddocks and as far as possible lines were offered similar grazing. This was not always possible during the mating season (December to May) that necessitated 10 non-adjacent paddocks and was subjected to water reticulation limitations particularly during droughts and borehole and water failures.

3.3.2 Calving

As cows displayed signs of approaching parturition they were moved from the large dry season management herds and placed in a calving paddock close to the homestead. All cows in this camp were checked daily and cow-calf pairs were rounded up and taken to the handling facilities within 24 hours of birth. Calves were identified by means of ear notching and particulars, including weights, of the cow and calf were recorded.

3.3.3 Prophylaxis and tick control

All cattle were rounded up and dipped in acaricide plunge dip once a week in the wet season and once every fortnight at the height of the dry season, normally June through to August. All animals were annually vaccinated against rabies, anthrax, botulism. Young animals were vaccinated against quarter-evil and contagious abortion (heifers). It was recommended that the animals be treated for round worms and fluke at the beginning and end of the wet season (in October and in May).

3.3.4 Weighing, castration and weaning

As standard procedure cattle were individually weighed on monthly basis. Up and until 1974 all weights were measured on a pounds scale and in the remaining experimental years weights were weighed and recorded in kilograms (kgs) with fitted balancing scales. All male calves not retained for breeding purposes were castrated approximately two weeks before physical weaning in mid- August where calf ages ranged from four to seven months for the NS environment and for seven to ten months for the S environment.

3.4 Data preparation

In this study secondary data on calf weight traits, from 1958 to 1997, was retrieved at Matopos Research Institute (MRI). A total of 10 800 calf records which were collected between 1958 and 1997 were used in this study. The records comprised of birth weight, calf date of birth, dam age, and weight at 90 days of age, weaning weight, early post-weaning weight, age at weaning, age at 90 days and age at early post-weaning. The data were retrieved from Matopos Research Institute where a genotype – environment interaction study in Afrikaner cattle was carried out.

The data was stored as hard copies in standard recording weighing books. The data was then entered in Microsoft excel spread sheet and processed to suit the objectives of the current study before running the analysis using SPSS version 20. SPSS was also used to come up with rainfall graphs and charts as presented in Chapter 4. During data processing some records were deleted.

The records which were deleted included;

1. Calf entries with missing records on birth weight, weaning and early post-weaning weight.

2. Calf entries which were recorded as out of season
3. Negative values of average daily weight gain (G1)

3.4.1 Weather variables

Rainfall, maximum and minimum temperatures data from 1958 - 1997 were retrieved from the Matopos Research Institute meteorological unit. The daily rainfall and temperature data was processed and clustered into cumulative rainfall and average temperature variability in time frame categories according to calf life history. The monthly data was clustered into seasons: winter, summer and transition. The months considered in the transition season were August, September and October. The time frames studied are from birth to 90 days, 90 days to 205 days, birth to 205 days and 205 days to early post weaning age (350 days). Therefore the effects of the cumulative rainfall and average temperature variability within these time categories on animal weight changes were studied. Other influential factors such as year of birth, dam age, line, previous lactation status, birth of date, supplement, mating time (environment), age of calf at 90 days weighing time, age of calf at weaning, age of calf at early post-weaning, weaning weight and early post-weaning weight as presented in Table 3.6 above were also included in the research.

3.5 Statistical methodology

3.5.1 Descriptive statistics

3.5.1.1 Definitions, descriptions and calculations of important variables

G1, G2, G3 and G4 represent the average daily weight gains of the calf between birth weight and 90 days, 205 days and 90 days, birth day and 205 days and 205 day and early post weaning age respectively (see Table 3.4 page 34),

$$G1 = \frac{90\ day\ weight - Birth\ weight}{age\ at\ 90}$$

$$G2 = \frac{205\, day\, weight\ - 90\ day\ weight}{age\ at\ 205}$$

$$G3 = \frac{205\ day\ weight - Birht\ weight}{age\ at\ 205}$$

$$G4 = \frac{early\ postweaning\ weight - Weaning\ weight}{early\ post - weaning\ age}\}$$

Average temperature variability (range) = (maximum temperature – minimum temperature)/age of calf

Cumulative rainfall = the amount of rainfall experienced by a calf from day of its birth to the calf age in question

Actual rainfall at early post weaning age = is the difference between cumulative rainfall from birth to early post weaning age and cumulative rainfall from birth to weaning age.

3.5.2 Data interpretation

Multiple regression model was used in establishing relationships between average daily weight gain in Afrikaner calves as dependent variable and the independent variables that includes weather parameters. From the SPSS regression output the regression model was validated by assessing the adjusted R-squared value. Multicollinearity among dependent variables was assessed by running a correlation matrix using SPSS. The model validation technique and multicollinearity are detailed below.

3.5.2.1 Model validation procedure/technique

Adjusted R-squared value will be used to assess the fit of the model.

Adjusted R-squared is calculated as; $R^{-2} = 1 - \frac{n-1}{n-p-1}(1-R^2)$

n = number of observations, p = number of explanatory variables fitted in the model

As a rule of thumb when adjusted R-squared value is close to 1 indicates a great fit.

Adjusted R-squared value was preferred over R-square because of unstable nature of the latter when there is addition of explanatory variables (Gujaratti and Porter, 2005).

3.5.2.2 Multicollinearity

Multicollinearity prevents proper parameter estimation and it may preclude computation of the parameter estimates completely if it is serious enough. It was therefore considered necessary to run a bivarate Pearson correlation matrix due to the nature of the independent factors evaluated in this study. The predictors could be correlated due to time factor, for example, date of birth, year of birth, age of calf, and also due to the way the experimental treatment are defined in this study, for example, supplemented vs non supplemented line, supplemented vs non supplemented group, age of dam vs previous lactation status.

Therefore Pearson correlation matrix was used as a diagnostic test for multicollinearity and the results are presented in appendices 3, 4, 5 and 6.

3.6 Multiple linear regression analysis (MRA): ordinary least square regression

Application of multiple regression analysis (MRA) extends to wide range of academic fields such as medical sciences (Broyles, 2006), social sciences, agriculture, wildlife and ecology and economics (Gujaratti and Porter, 2003). Barker *et al.,* (1998) used MRA and principal component analysis (PCA) to establish relationships among pubertal and growth characters in different cattle breeds.

Weight changes were expressed as regressions on independent variables as given in Table 3.4 above. The general ordinary least square regression model used in this study was stated as,

$$Y_i = \beta_0 + \beta_i X_i + \mu_i \qquad \text{[equation 1]}$$

where :

Y_i – is the vector of observations of calf weight traits (G1, G2, G3 and G4)

μ – error term (the error term in weighted least square regression is equal to one of the predictor variable.

β_0 - intercept

$\sum \beta_i X_i$ – partial regression coefficients

X_i = independent variable

β_i = regression coefficient

It is however very important to note that in this study several independent factors could have been used to weight the data, factors such as date of birth, age of calf and year of birth. Gujarati and Porter (2003) stated that the factor which causes a large variance in the dependent variable should be used as a weighting scale, with this in mind date of birth was selected to weight the data in all the four analysis.

The constants in the multiple regression model were estimated using the method of Ordinary Least Squares with correction of heteroscedasticity (OLS). Gujarati and Porter (2003) preferred OLS to other techniques because it is easy to use and OLS estimators have minimum variance in the class of linear estimators, that is, they are BLUE (best linear unbiased estimators). The other important reason for the choice of ordinary least square regression in this study was its applicability to continuous variables such as weight gains used as dependent variables in this study.

3.6.1 Multiple linear regression model assumptions

To run a successful multiple linear regression model several critical model assumptions have to be satisfied;

i. Each value of X and of Y is observed without measurement error
ii. The relationship between Y and each of the independent variables X are linear in the parameters of the specific functional form chosen
iii. Each conditional distribution of a mean of zero
iv. The variance of conditional distribution of μ is constant for all such distributions
v. The value of μ are serially independent
vi. The independent variables X, are linearly independent of each other
vii. The fixed X model requires that the conditional distributionof the disturbance term must be normal in form.

3.6.1.1 Test for Normality

The normality of residual can be visually inspected from the histogram with the superimposed curve. With this method the skewness for symmetry and kurtosis for peakedness of the data was examined.

As stated in section 3.4 above for data preparation that the analysis was run using SPSS, a normal probability plot of residuals was requested as another form of normality diagnosis.

Diagonal alignment of the data indicates normality and deviation in the center is observed suggesting kurtotic deviation

3.6.1.2 Test for Autocorrelation

The Durbin – Watson test will be used to detect significant autocorrelation. The Durbin-Watson test statistics is computed as follows;

$$d = \frac{\sum_{t=2}^{n}\left(e_t - e_t^2\right)}{\sum_{t=1}^{n} e_t^2}$$

The null hypothesis to be tested is given as;

$$H_0 : \rho = 0$$

The alternative hypothesis to be tested for positive autocorrelation is

$$H_a : \rho > 0$$

The alternative hypothesis to be tested for positive autocorrelation is

$$H_a : \rho < 0$$

A two-sided test is also possible. In this case the alternative hypothesis is

$$H_a : \rho \neq 0$$

3.6.1.3 Test for Homoscedasticity

The Levene statistic test was used to test for homoscedasticity.

The null hypothesis for the test of homogeneity of variance states that the variance of the dependent variable is equal across groups defined by the independent variable, that is, the variance is homogenous.

If the probability associated with the Levene statistic is less than or equal to the level of significance, conclude that the variance is no homogenous.

Preliminary data processing revealed that the dependent variables G1, G2, G3 and G4 had unequal variance, and to correct for heteroscedasticity generalized least square approach also known as weighted least squares was used.

3.7 Data analysis

A multiple linear regression analysis involving the use of ordinary least square (OLS) with correction of heteroscedasticity using weighted least square estimation technique was used to determine the effect of weather variables and other factors on average daily weight gain traits, G1, G2, G3 and G4 in Afrikaner cattle. The data was analyzed using statistical package for social scientist (SPSS) software IBM STATISTICS version 20.

In all four analyses independent variables such as sex, environment, supplement, line and previous lactation status were used as dummy variables

The general multiple regression linear model with dummy variables can be presented as

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 D_i + \beta_7 D_j + D_k \beta_8 + D_l \beta_9 + D_j D_i \beta_{10} + D_j D_k \beta_{11}$$

Where Y is the dependent variable average daily weight gains in Afrikaner calves (G1, G2, G3 or G4)

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ *and* β_7 represent the standardized beta coefficients

$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9$ *and* X_{10} denotes the independent variables

D_i dummy variable denoting environment (i = 1 early mated cows, 0 late mated cows)

D_j dummy variable denoting sex of calf (j = 0 male, 1 female)

D_k dummy variable denoting supplement (k = 0 non supplement, 1 supplement)

D_l dummy variable denoting line (l = 0 non supplemented, 1 supplemented)

$D_i D_j$ dummy variable denoting interaction of sex of calf and environment

$D_j D_l$ dummy variable denoting interaction of sex of calf and line

Initial data analysis was done using the ordinary least squares (ols) model of the form:

$$Y_i = b_0 + b_1 X_{i1} + ...b_p X_{ip} + e_i$$

Where e_i- is the error term which follows a normal distribution with mean zero and variance δ^2.

3.7.1 Diagnosis of heteroscedasticity

The scatter plot of standardized residuals versus standardized predicted values shows heteroscedasticity meaning values of residuals is not constant across values of the predicted values hence one of the OLS assumptions was violated (see appendix 1 and 2).

3.7.2 Correction of heteroscedasticity

The WLS model was computed to obtain valid estimates

$$Y_i = b_0 + b_1 X_{i1} + ...b_p X_{ip} + e_i$$

Where e_i- is the error term which follows a normal distribution with mean zero and variance $\delta^2 X_i^w$.

The correction of heteroscedasticity using the weighted least square approach (WLS) was adapted from Gujarati and Porter (2003).

3.8 Bibliography

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter result of all the four growth traits, average daily weight gain, pre-weaning weight gain and early post-weaning weight gain, are presented in form of tables and figures and also interpreted and discussed. The results and discussion points are relevant to Afrikaner cattle breed housed at Matopos Research Institute, under semi-arid region in Zimbabwe.

The number of observations means and standard deviations of all dependent and independent variables used in this study are presented in Table 4.1. The correlation coefficients between all the dependent variables and their respective independent variables are presented in appendices 1, 2, 3 and 4. The output for ordinary least square regression corrected for heteroscedasticity for all four analyses are presented in Tables 4.2, 4.3, 4.4 and 4.5 respectively.

It is however important to note that the interpretation and discussion of these results may lack referencing due to the nature of the study; for example, how the average daily weight gain was split into 3 categories i.e. 1) between birth and 90 days 2) 90 days and weaning age 3) and birth and weaning age. The other reason for lack of referencing could be the nature of the independent variables assessed in this study.

Table 4.1 Descriptive statistics of variables used for average daily weight gain (G1), pre-weaning weight gain (G2), pre-weaning weight gain (G3) and early post-weaning weight again (G4) analyses

Variable	Mean	Standard Deviation	Number of observations
G1	0.78	± 0.15	6596
G2	0.31	± 0.10	6561
G3	0.63	± 0.11	6596
G4	0.01	± 0.04	6543
Year of birth	79.50	± 11.53	10803
Dam age (years)	6.91	± 2.88	10803
Lactation status			10803
Line of Afrikaner cattle			10803
Environment			10803
sex of calf			7288
Standardized date of birth	98.65	± 35.55	7279
Weight of calf at 90 days of age (kg)	102.81	± 16.33	6650
Actual age of calf at 90 day weighing time (days)	90.39	± 9.07	6828
Birth Weight (kg)	32.09	± 4.91	7103
Age11(days)	224.93	± 35.66	6783
Weaning weight (kg)	173.73	± 34.94	6638
Average daily temperature variability from birth to 90 days (degrees celsius)	11.91	± 1.76	6827
TempVarWW (degrees celsius)	12.88	± 0.72	6779
TempVarEPWW (degrees celsius)	13.54	± 0.53	6715
90 day cum Rain (mm)	289.48	± 160.74	6826
G2-rain (mm)	105.95	± 119.82	6770
WWrain (mm)	395.45	± 221.28	6775
G3-rain (mm)	30.36	± 28.70	6705
EPWWrain (mm)	426.39	± 225.43	6713

4.2 Average daily weight gain from birth to 90 days of age (G1)

The average daily weight gain (G1) obtained in the current study was 0.78 kg per day (Table 4.1), this value is slightly higher than 0.716kg per day as reported by du Plessis, Hoffman and Calitz (2006). The standard deviations and the number of observations of G1 are presented in Table 4.1. G1 was assessed from birth to 90 days and was calculated by subtracting birth weight from 90 day weight and dividing by age of calf at 90 days of weighing. The adjusted R-squared value of the fitted model was 0.147, accounting for 14.7% of the variation on G1 (Table 4.2). The factors influencing G1 evaluated in this study were; year of birth, age of dam, previous lactation status, line, environment, sex of calf, date of birth (BD), birth weight, 90 days cumulative rainfall, temperature variability from birth to 90 days of age (Temp90) and season. The correlation matrix run for all the variables, in this analysis, indicated that there was no multicollinearity within the variables (see appendix 3 page 113).

Table 4.2 The relationship between independent variable and G1 estimated by beta coefficients

Variable	Coefficient	S.E	t-value	p-value
Constant	0.628^{***}	0.046	13.701	0.000
Year of birth	0.138^{***}	0.014	10.144	0.000
Dam age	0.066^{***}	0.014	4.597	0.000
Dummy A	0.232^{***}	0.019	12.256	0.000
Dummy B	0.166^{***}	0.020	8.275	0.000
Dummy line	0.017^{ns}	0.013	1.314	0.189
Dummy environment	0.135^{***}	0.021	6.325	0.000
Dummy sex	0.136^{***}	0.017	-8.047	0.000
Sdob	0.082^{***}	0.022	-3.704	0.000
Summer	0.051^{***}	0.018	2.825	0.005
Transition	0.098^{***}	0.020	4.834	0.000
Birth weight	0.095^{***}	0.013	7.487	0.000
90daycumrain	-0.061^{***}	0.019	-3.310	0.001
TempVar90	-0.086^{***}	0.018	-4.790	0.000
DsexDm	-0.016^{ns}	0.020	-0.814	0.415
R	0.383			
R^2	0.147			
R^{-2}	0.145			
Durbin-Watson	1.794			

a) $^{*}p < 0.1$, $^{**}p < 0.05$ and $^{***}p < 0.01$, ns-non significant

b) Dummy A denotes first lactation and dummy B denotes second lactation

4.2.1 Effect of year of birth

Year of birth in this study represents the period when the genotype x environment interaction studies were carried out and also defines experimental years when the calves were born and when experimental treatments were implemented. Therefore, this study has evaluated the effects of selected non-genetic factors on average daily weight gains (G1) in Afrikaner cattle from 1958 to 1997 at Matopos Research Institute in Zimbabwe. In this study the year of birth was significant on G1 at all selected levels of significance ($p=0.000$, $p < 0.1$) (Table 4.2). Year of birth had a beta value of 0.138 ± 0.014. The beta value indicates that year of birth contributes 13.8% of the variation in G1. The mean of G1 in this study was 0.78 kg per day (Table 4.1). Therefore, the calves in this study were exposed to both rainy and wet period and dry warm and cold months. The outcome of this study seems to suggest that the weather variations experienced yearly were important in influencing the average daily weight gains of calves. The average daily weight gain (G1) is shown to have lower points in the following years: 1963, 1978 and 1991 with G1 means of 0.6820, 0.7109 and 0.7309 kg per day respectively (figure 4.1). However peak points were recorded in 1966, 1970, 1988 and 1994 with G1 means of 0.8418, 0.8263, 0.8366 and 0.8635 respectively (Figure 4.2.1) in relation to weather conditions during these years. MacGregor and Casey (2000) also reported the weather variation as determining the yearly variability on average daily weight gains in calves.

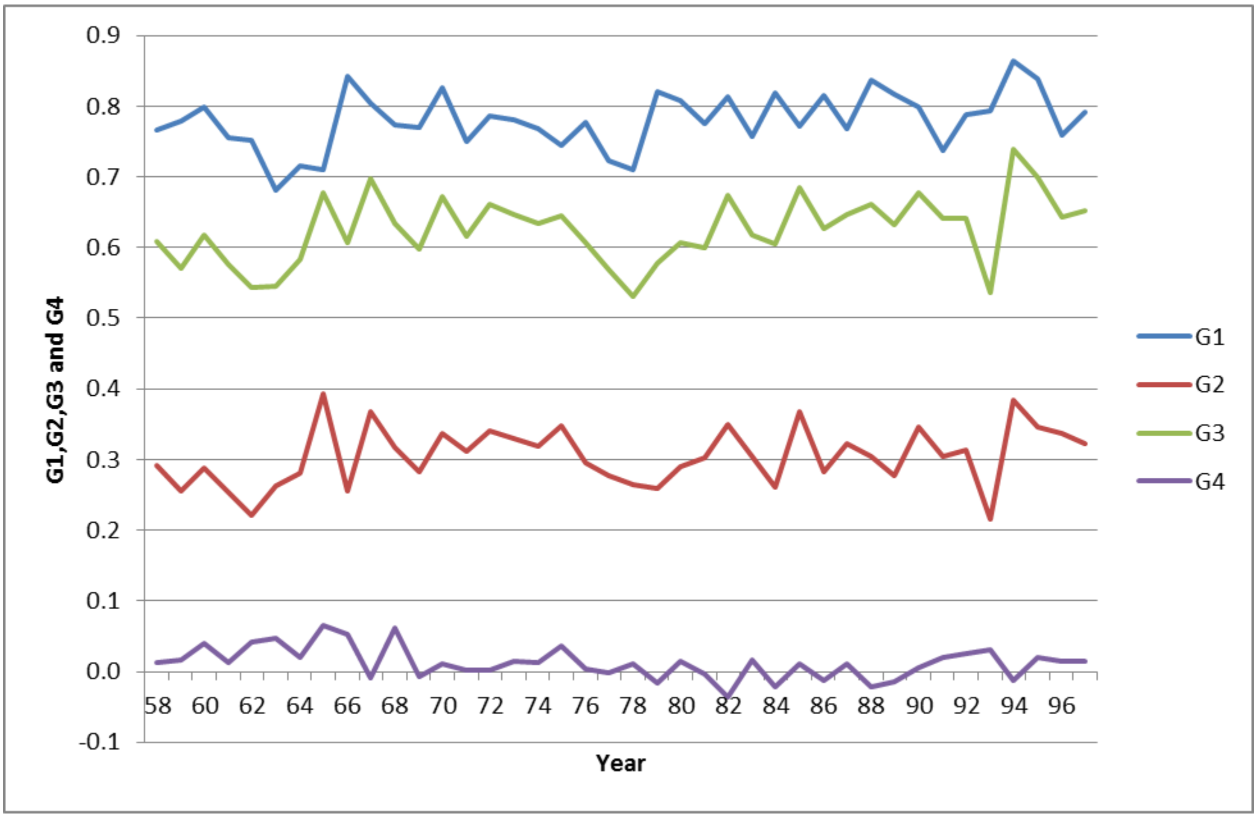

Figure 4.2.1 Average daily weight gain (G1), pre-weaning weight gain from 90 days to weaning (G2), pre-weaning weight gain from birth to weaning (G3) and post-weaning weight gain (G4) from 1958 to 1997 in Afrikaner cattle at Matopos Research Institute in Zimbabwe.

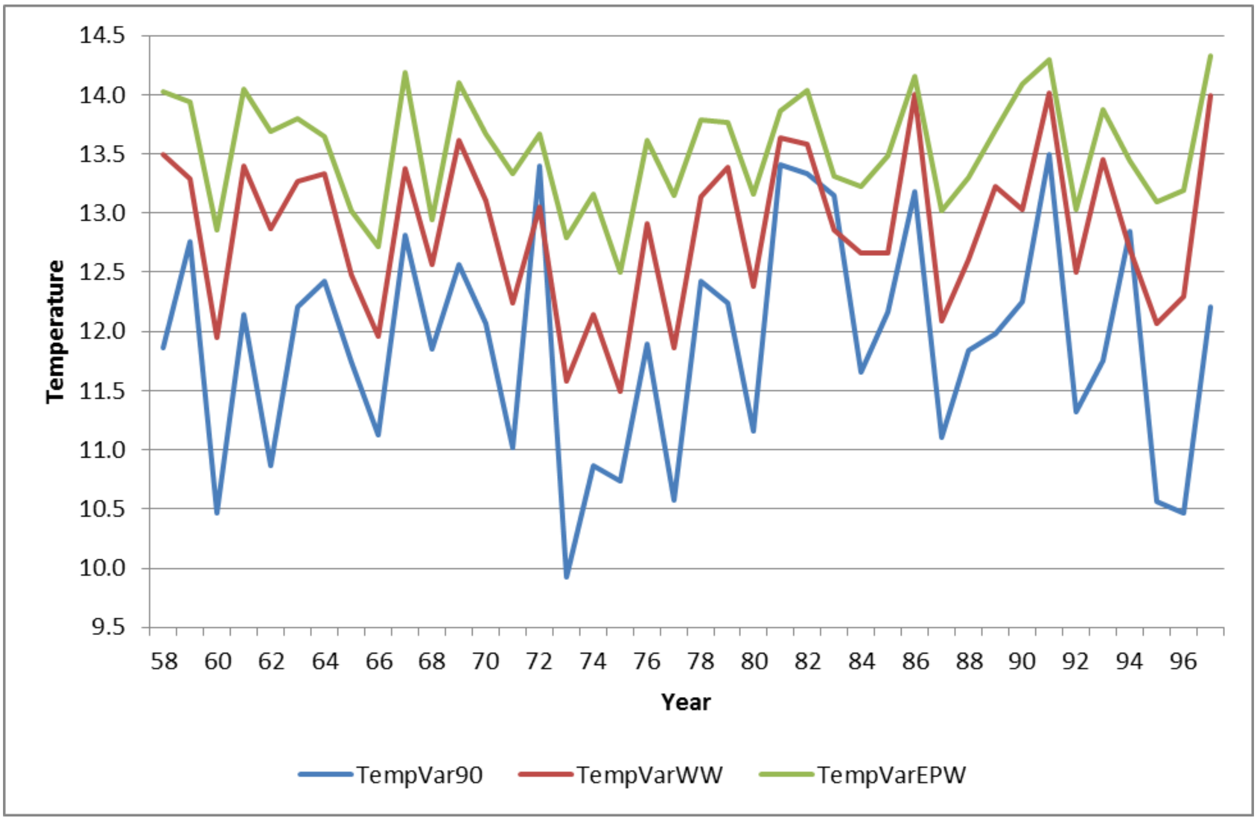

Figure 4.2.2: Temperature variability, from birth to 90 days of age (TempVar90), from birth to weaning age (TempVarWW) and from birth to early post-weaning age (TempEPW) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

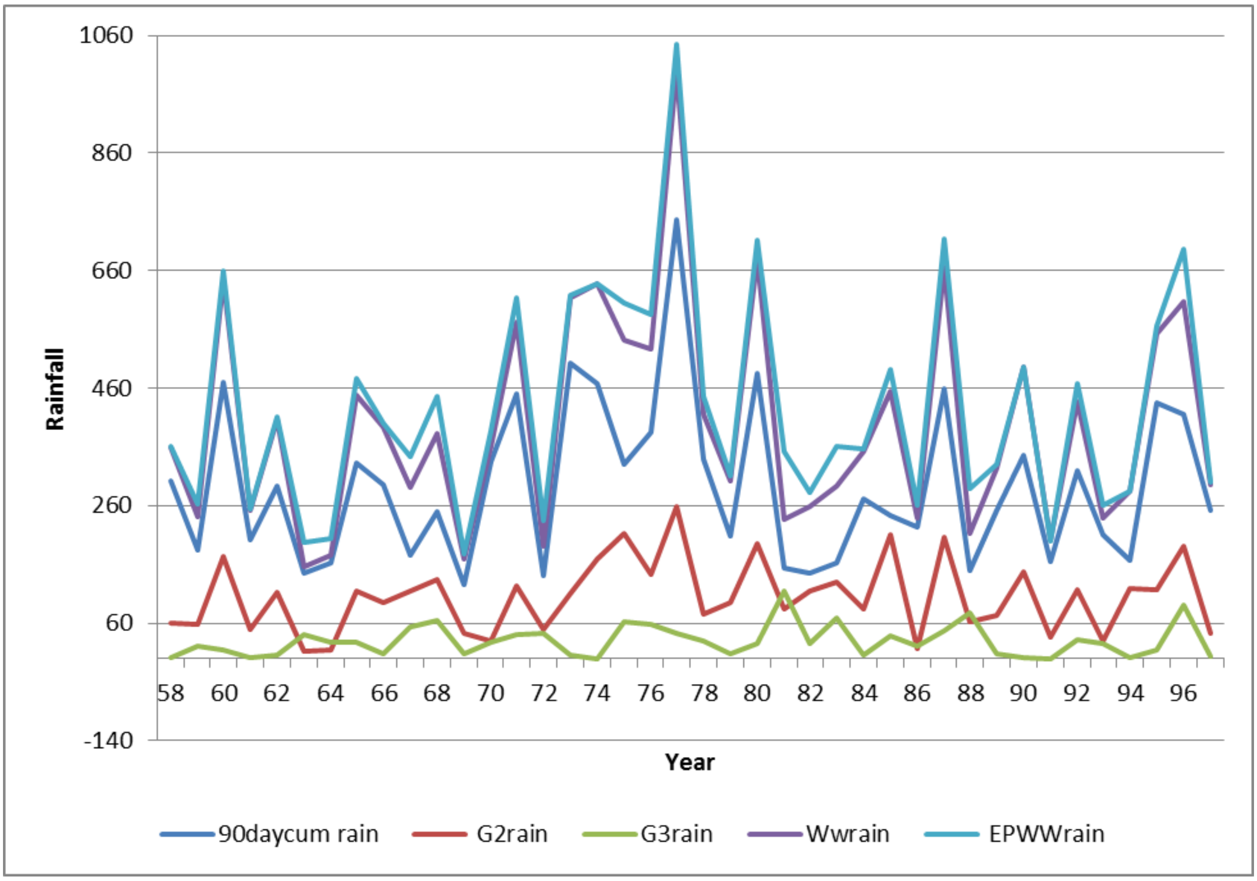

Figure 4.2.3: Rainfall variability; from birth to 90 days of age (90daycum rain), from 90 days to weaning age (G2 rain), from weaning age to early post-weaning (G3rain), from birth to weaning age (Wwrain) and from birth to early post-weaning age (EPWWrain) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

4.2.2 Age of dam

The age of dam was significant (p=0.000, $p < 0.01$) (Table 4.3) on G1. The age of dam had a beta value of 0.066 ± 0.014 (Table 4.2). The age of dams used in this study from 1958 to 1997 ranged from 3 to 15 years with an average age of 6.91 years (Table 4.1). The results from the data analysis agrees with trend shown in Figure 4.5, G1 increased from younger cows, 3 - 7 years, with a decline in G1 in older cows, from 7 - 14 years of age, before an unusual rise at age of 15. The findings in this research are consistent with what was reported in earlier research (Befa, 2005). Younger cows seems to have more influence on G1 (Figure 4.2.4) than older cows. Loy et al. (2002) reported that maximum milk production and superior growth rate of calves, was obtained from 6-10 year old cows. However Goyache et al. (2003) reported consistency in motherly abilities for older cow from 7 to 14 years of dam age. Henceforth the research result cement the idea of culling and selection, removing the less producing cows thereby increasing the efficiency of the herd (Loy et al. 2002).

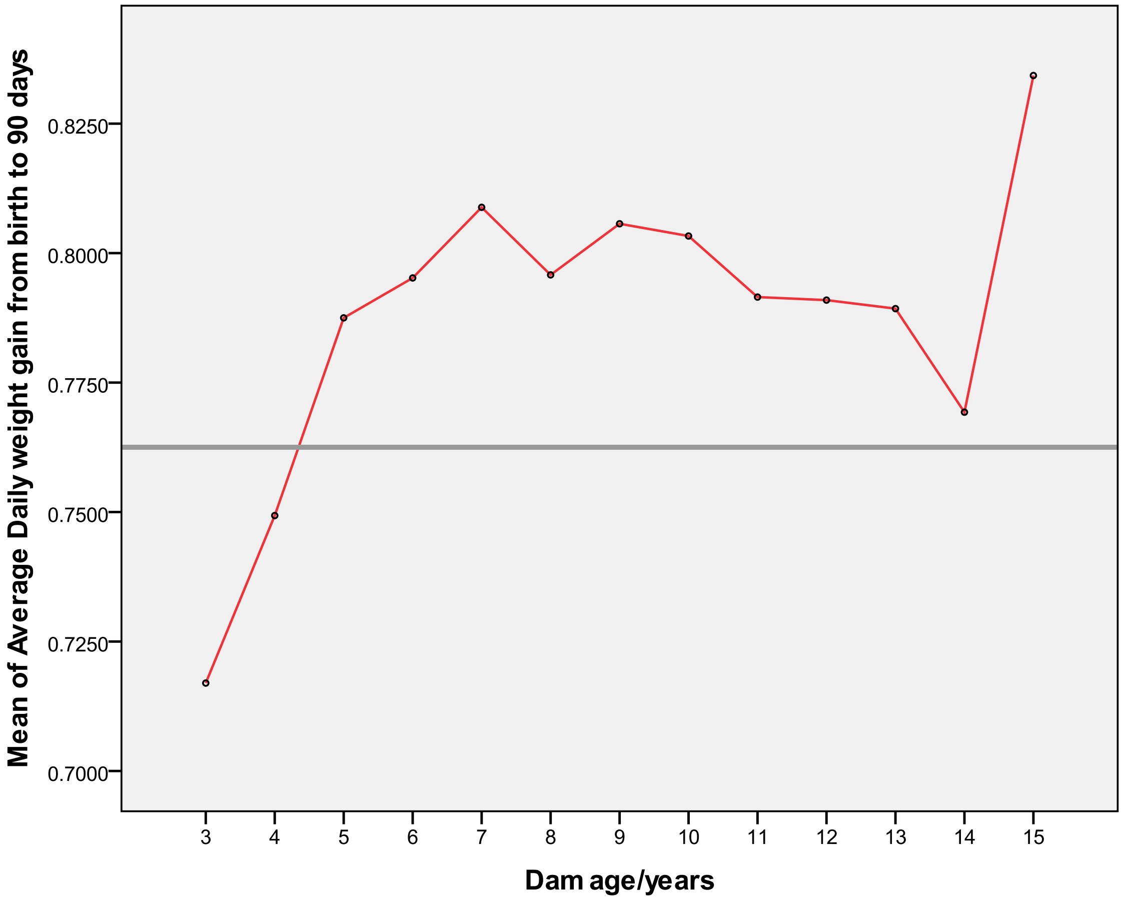

Figure 4.2.4 Average daily weight gain from birth to 90 days (G1) at different age of dams at Matopos Research Institute in Zimbabwe from 1958 to 1997.

4.2.3 Previous lactation status

Previous lactation status was assessed as dummy variables. Lactation status was expressed in three levels as follows: 1) 3 year old heifers no lactation 2) suckling first lactation and 3) not suckling second lactation. The results revealed that both dummy variables for first and second lactation status were significantly affecting ($p < 0.01$) G1. The dummy variable for first lactation had beta value of 0.233 ± 0.019, indicating that calves born from first lactation status were gaining 23.3% (0.18 kg/day) more weight compared to calves born from no lactation cows. The dummy variable for second lactation status had a beta value of 0.166 ± 0.020 (Table 4.2), indicating that calves born from second lactation were gaining 16.6% (0.13kg/day) more weight compared to calves born from no lactation status cows. According to Goyache (2003) young cows in the age category of 2-3 years produces less quantities of milk than their older contemporaries. The young cows are still in the fast growing phase hence the consumed nutrients are partly directed to the cow's muscle and tissue developments rather than to milk production. Pilarczyk (2007) reported that milk yield remains one of the most important factors of calf body weight at weaning which has a consequence for the farm profitability. In general according to Pilarczyk (2007), milk production of cows was responsible for 60% of the calf daily gains and that the high yielding cows nursed calves that are heavier at weaning.

4.2.4 Effect of line

The effect of line was analysed as a dummy variable. The late mated and non supplemented line was selected as reference. The results revealed that the early mated and supplemented line was not statistically different ($p = 0.189$) to the non supplemented line. The beta value of line was 0.017 ± 0.013 (Table 4.2), indicating that calves from the early mated and supplemented line gained 1.7% (0.01kg/day) more weight compared to the calves from the non supplemented line. The results have shown that the underlining principle or composition of line could not account for major changes in average daily weight gain in Afrikaner calves. This means that the timing of mating interacting with the supplement treatment was not important in influencing G1. Cows in the early mated group were supplemented with 1kg cotton seed plus 9kg maize per day per head in the dry season versus late mated cows which relied on rangeland throughout the year. This could mean that the rangelands at Matopos Research Institute were in good condition both during the wet and dry months. However MacGregor and Casey (2000) reported that cows calving earlier than the rest of the herd produced heavier weaners, meaning the calves had a superior growth rate.

4.2.5 Effect of environment

G1 was found to be significantly affected by the environment ($p=0.000$, $p < 0.01$) (Table 4.2). Environment had a beta value of 0.135 ± 0.021 (Table 4.2) indicating that calves born from the early mated group were gaining 13.5% (0.11kg/day) more weight compared to calves born from the late mated group. The early mated group calved from October to December, prior to the onset of the rains, whereas the late mated group calved with the onset of the rains, December to February. Therefore the calves born from the early mated group had their G1 assessed in summer which is relatively a higher input season compared to a dwindled rangeland value for the December – February calves. This finding is in agreement with what was reported by MacGregor and Casey (2000).

4.2.6 Effect of sex

Average daily weight gain (G1) was computed for both male and female calves henceforth the effect of sex on G1 was assessed. Sex was found to be significant on G1 ($p=0.000$, $p \leq 0.01$) (Table 4.2). Sex of calf had a beta value of -0.136 ± 0.017 (Table 4.2) indicating the female calves were 13.6% lighter in weight compared to the male calves. The overall G1 mean was 0.78kg per day (Table 4.1); the male calves generally gained 0.11kg per day more compared to female calves. Loy et al (2002) reported that bull calves grew approximately 5% faster than steer calves, and steer calves grew approximately 8% faster than heifer calves at 210 days of age. Other workers have also reported differences in sex of calf in average daily weight gains (Karimi, *et al*. 2005 and Taylor, 2007), with male calves consistently being heavier than the female calves.

4.2.7 Effect of date of birth (BD)

Standardized date of birth denotes birth dates (BD) of calves and was found to have no significant effect ($p=0.000$, $p < 0.01$) (Table 4.2) on G1. BD had a beta value of -0.082 ± 0.022 (Table 4.2). BD determines the time when 90 day age, weaning and early post-weaning ages are attained. In this study these ages was certainly attained in different months and seasons because one line was early mated the other line was late mated. BD had a significant effect on average daily weight gain from birth to 90 days of age (G1) due to the body score condition of the dam at the time of calving. The different dates of birth these Afrikaner calves experienced could also mean the dams were exposed to different plane of nutrition during the pregnancy time. This might have subsequently influenced birth weights, quantity and quality of milk in general and colostrum in particular produced by the dam, hence the influence of BD on G1. Neibergs and Johnson (2012) reported that generally nutrient restriction did not influence birth weight or average daily weight gain of calves but dams restricted from specific nutrients such as protein, produced steers that were lighter at slaughter.

4.2.8 Effect of birth weight (BW)

Birth weight (BW) was significant ($p < 0.01$) on G1 (Table 4.3). In this study birth weight had a mean value of 32.5 kg (Table 4.1). BW had beta value of -0.095 ±0.013 (Table 4.2). Several studies have highlighted the effect of initial weight on average daily weight gains in beef production. The negative beta value indicates the suppressing effect BW had on G1 and having other independent factors fixed, the average daily weight gain will decrease by 9.5% due to the effect of birth weight. Greenwood et al (2006) reported that cattle grown slowly from birth to weaning exhibited incomplete compensation and remained smaller during growth to 30 months of age.

4.2.9 Effect of temperature variability (TempVar90)

Temperature variability from birth to 90 days of age (TempVar90) was significant, at 10% level of significance, on G1 ($p=0.000$, $p < 0.01$) (Table 4.2). TempVar90 had a beta value of -0.086 ± 0.018 (Table 4.3). Temperature influences the rangeland dynamics which involves soil properties, plant growth and production and also cattle foraging behaviour. Henceforth during the period of G1 the movement and feeding behaviour of the calf is mainly controlled by the dam. The less significance of TempVar90 seems to suggest that indirectly temperature affects calves at their early stages of growth. Temperature variability could be linked to milk production by dams or cows, the quantity and quality directly affecting G1. The lowest values of temperature variability were noted in 1960, 1974, 1977, 1980, 1988, 1995 and 1996 with highest values recorded in 1959, 1964, 1967, 1972, 1981, 1983, 1986, 1991 and 1994 (Figure 4.2.2) in relation to G1 for these years. Hennesy and Morris (2003) reported that lighter birth weight and slow growth rate was associated by higher temperature variabilities.

4.2.10 Effects of rainfall variability (90dayCumrain)

90 day cumulative rainfall (90dayCumrain) was highly significant at 1% level of significance ($p=0.001$, $p <= 0.01$) (Table 4.2). 90dayCumrain had a beta value of -0.061 ± 0.019 (Table 4.2). G1. Earlier research has shown strong relationship existing between quality and quantity of rainfall and vegetation biomass production. Therefore the quality and quantity of graze also affects the body conditions of a lactating cow, the quantity and quality of milk produced and also stress and all these are transferable to the calf, henceforth the variation in G1 due to rainfall. Figure 4.2.3 above shows the variability of 90dayCumrain from 1958 to 1997. These views being articulated on the effects of rainfall variability are also shared by Hennesy and Morris (2003), who reported that precipitation varied among years thereby altering forage quantity and quality along the years with winter feeds needs.

4.2.11 Season

The seasonal effect was assessed on G1. Three seasons were considered in this study winter, summer and transition seasons. Two dummy variables were used with winter selected as reference season to summer and transition. Both dummy variables were significant at 1% level of significance. Dummy variable for summer had beta value of 0.051 ± 0.018 (Table 4.2) indicating that calves gained 5.1% (0.04kg/day) more weight in summer than in winter. Dummy variable for transition season had a beta value of 0.098 ± 0.020 (Table 4.2) indicating that calves gained 9.8% (0.08kg/day) more weight than in winter.

4.2.12 Conclusion

Average daily weight gain from birth to 90 days of age (G1) is assessed in a critical time of the calf life history. The feeding behaviour, abiotic factors, diseases and management are some of the factors that can assure survival and normal growth of the calf. Stunted growth can be avoided when the calf have access to colostrums and adequate milk from the dam.

The most important factors influencing G1 were year of birth, previous lactation status, sex of calf, birth weight and date of birth. Other factors which were significant are temperature variability, season, rainfall variability and dam age. Interaction between sex and environment was not important and line was not also significant.

4.3 Pre-weaning weight gain from 90 days to weaning age (G2)

The average pre-weaning weight gain from 90 day of age to weaning age (G2) obtained in the current study was 0.3062 kg per day (Table 4.1). The standard deviations and the number of observations of G2 are presented in Table 4.1. G2 was assessed from age at 90 days to weaning and was calculated by subtracting weight at 90 days of age from weaning weight and dividing by weaning age. The ordinary least square regression model coupled by the weighted least squares approach used had an adjusted R-squared value of 0.437 which means the model accounted for 43.7% of the variation in G2. The factors influencing G2 evaluated in this study were; year of birth, age of dam, previous lactation status, line, environment, sex of calf, standardized date of birth, age of calf at 90 day weighing time, weight of calf at 90 days of age, birth weight, actual amount of rainfall received from 90 days to weaning age (G2-rain), cumulative rainfall amount from birth to weaning (wwrain), average temperature variability from birth to weaning age (TempVarWW) and season (summer, winter and transition).

Table 4.3 The relationship between independent variable and G2 estimated by beta coefficients

Variable	Coefficient	S.E	t-value	p-value
Constant	0.825^{***}	0.034	24.552	0.000
Year of birth	0.113^{***}	0.011	9.942	0.000
Dam age	0.019^{ns}	0.012	1.620	0.105
Dummy A	0.050^{***}	0.016	3.193	0.001
Dummy B	-0.015^{ns}	0.017	-0.922	0.356
Dummy line	0.011^{ns}	0.011	1.044	0.297
Dummy environment	-0.087^{***}	0.030	-4.915	0.000
Dummy sex	-0.073^{***}	0.014	-5.260	0.000
Dsex x Dm	-0.023^{ns}	0.016	-1.426	0.154
Sdob	-0.456^{***}	0.020	-22.665	0.000
wt90	0.172^{***}	0.012	13.990	0.000
age90	-0.375^{***}	0.011	-33.326	0.000
Birth weight	-0.016^{ns}	0.011	-1.366	0.172
G2-rain	0.093^{***}	0.016	5.924	0.000
WWrain	-0.082^{***}	0.018	-4.455	0.000
TempVarWW	-0.122	0.014	-8.714	0.000
Summer	0.090^{***}	0.016	5.693	0.000
Transition	0.131^{***}	0.018	7.122	0.000
R^{-2}	0.437			
R^2	0.662			
Durbin-Watson	1.446			

a) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ and ns-not significant

b) where dummy A denotes first lactation and dummy B denotes second lactation

4.3.1 Effect of year of birth

Year of birth had highly significant ($p<0.01$) influence on G2. Year of birth had a beta value of 0.113 ± 0.011 (Table 4.3). The beta value showed that if other factors are hold constant the value of G2 will be influenced by 11.3%. Work done in arid sub tropical environment on different beef breed types also found year to be highly significant ($p < 0.01$) on weaning weight and average daily weight gains (du Plessis, Hoffman and Calitz, 2006). (Thiruvenkadan, Murugan and Karunanithi, 2009) also reported the significant effect of year in Tellichery goats. The mean of G2 in this study was 0.3062 kg per day (Table 4.1). Figure 4.3.1 shows that all the yearly G2 means do not lay on the reference line in fact yearly peaks and deeps are shown. Highest G2 means were recorded in 1965, 1967, 1985 and 1994 with values of 0.3924, 0.3687, 0.3676 and 0.3832 kg per day respectively (figure 4.3.1). Figure 4.3.1 also shows that lowest G2 means were recorded in 1962, 1966, 1979 and 1993 with values of 0.2204, 0.2592 and 0.2149 kg per day respectively. During the period from 90 days of age to 205 days of age critical months to consider for supplemented line were June, July and August whereas for the non-supplemented line were March, April and May. The mean G2 for the S line was 0.3339 kg per day and NS line was 0.2761 kg per day. Therefore the management aspects, the grazing behaviour of these calves during this period, and the quality and quantity of browse and graze are some of the factors that can be attributed to variations in pre-weaning weight gain (G2).

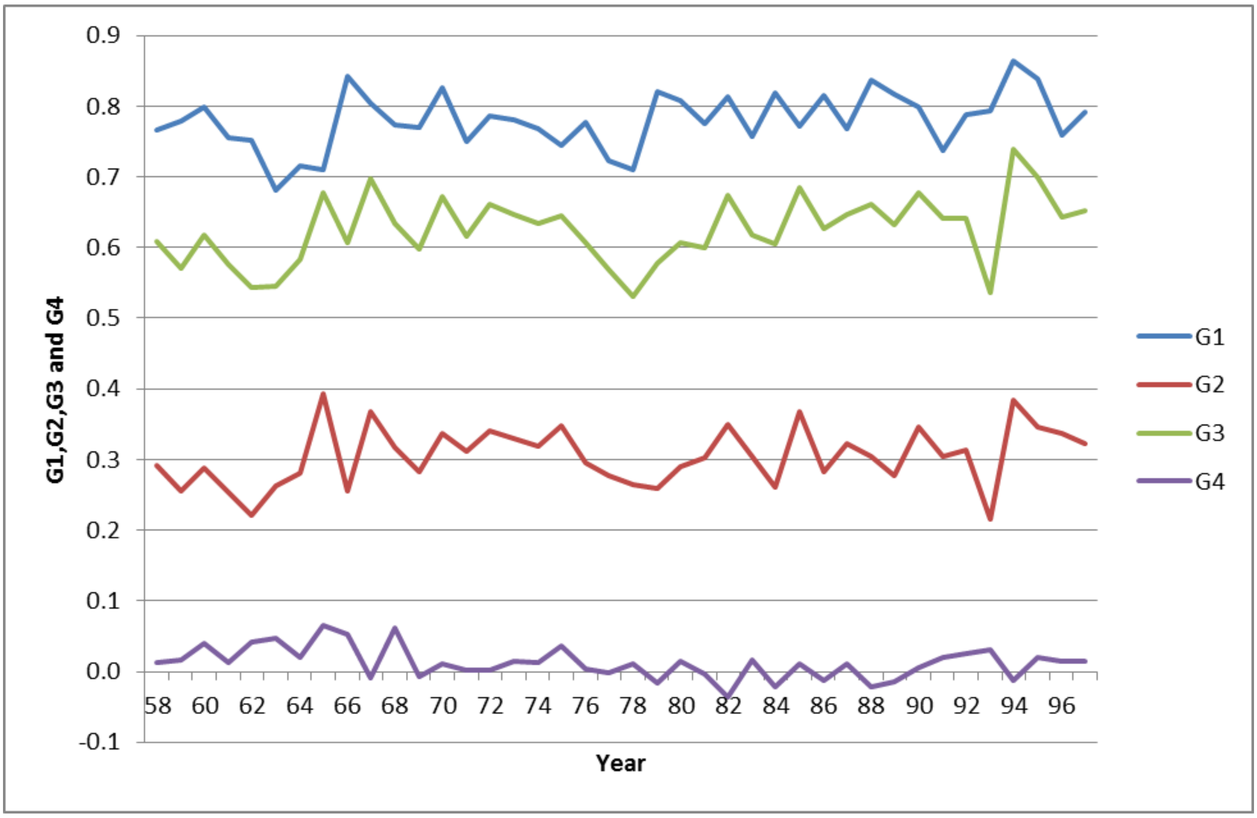

Figure 4.3.1 Average daily weight gain (G1), pre-weaning weight gain from 90 days to weaning (G2), pre-weaning weight gain from birth to weaning (G3) and early post-weaning weight gain (G4) from 1958 to 1997 in Afrikaner cattle at Matopos Research Institute in Zimbabwe.

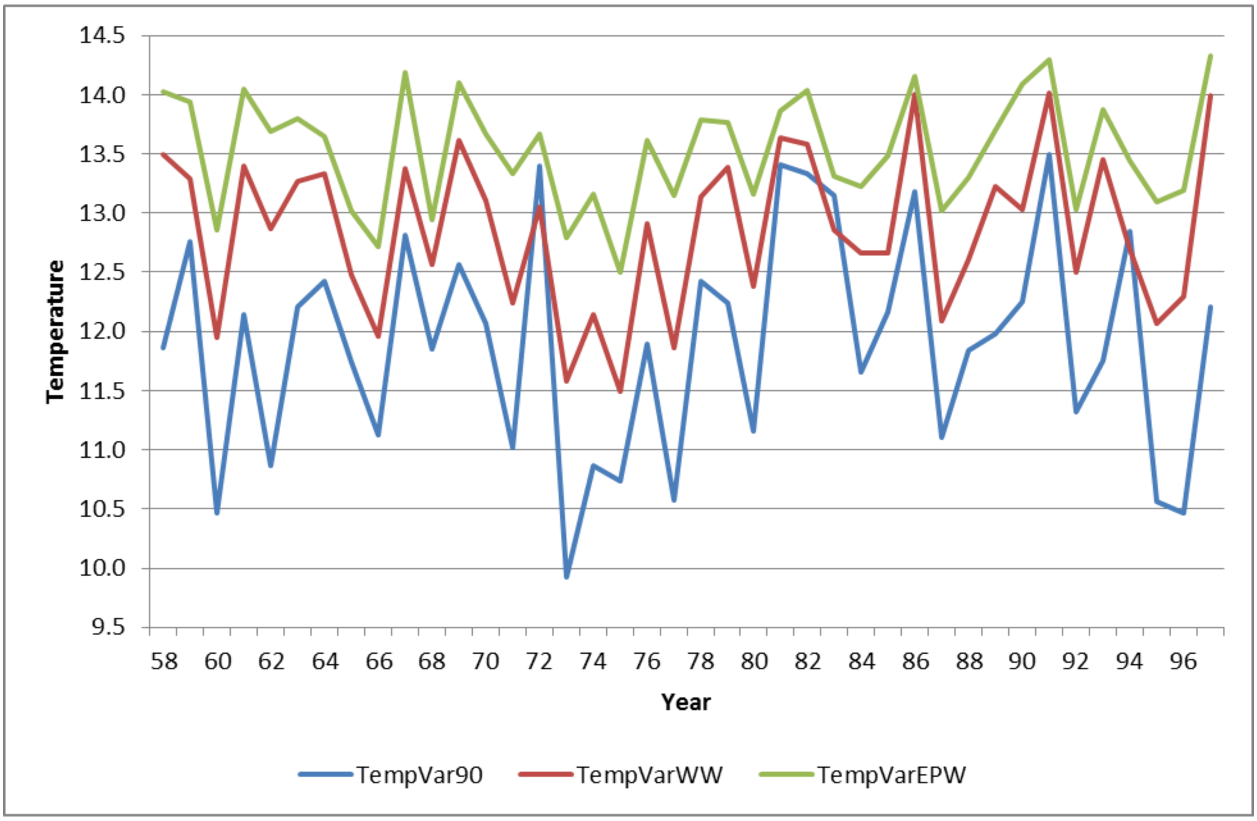

Figure 4.3.2: Temperature variability, from birth to 90 days of age (TempVar90), from birth to weaning age (TempVarWW) and from birth to early post-weaning age (TempEPW) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

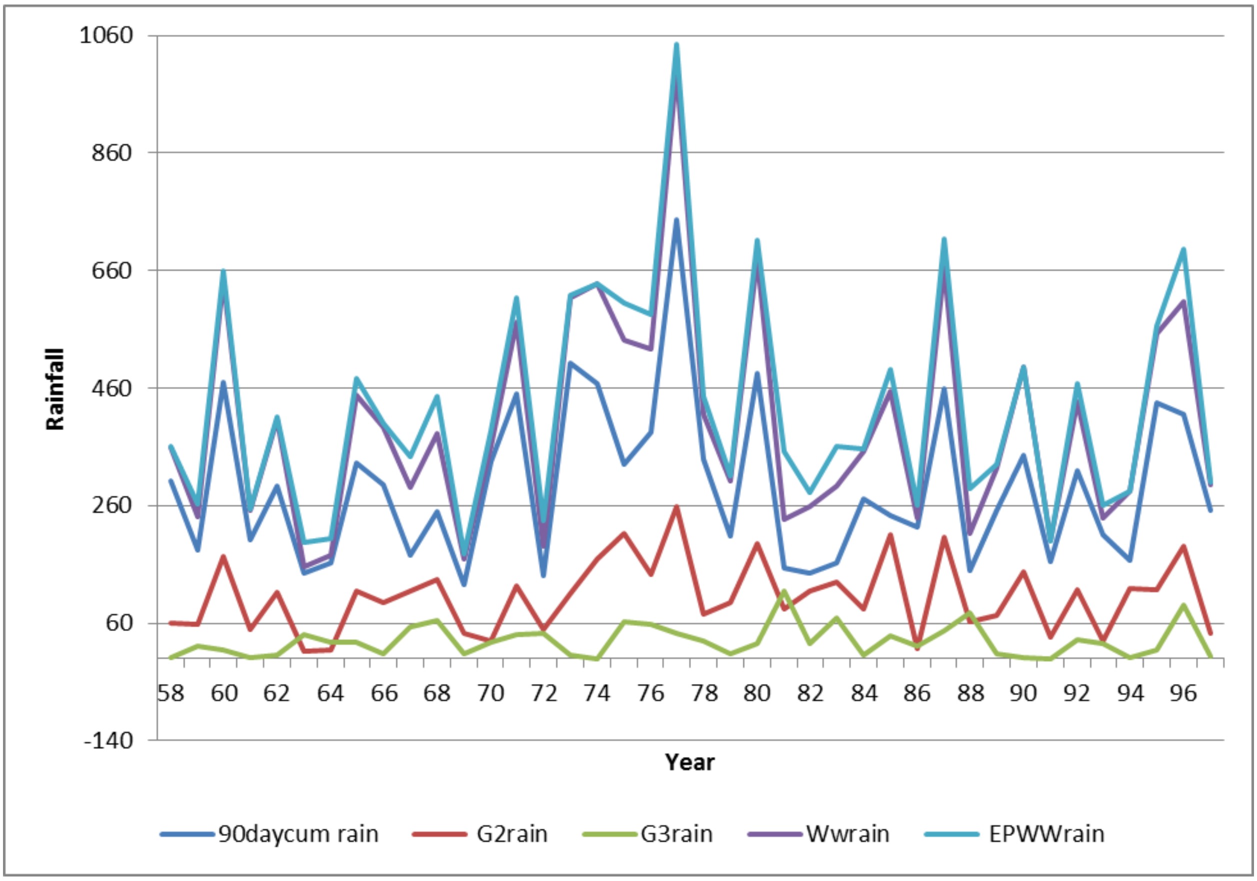

Figure 4.3.3: Rainfall variability; from birth to 90 days of age (90daycum rain), from 90 days to weaning age (G2 rain), from weaning age to early post-weaning age (G3rain), from birth to weaning age (Wwrain) and from birth to early post-weaning age (EPWWrain) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

4.3.2 Age of dam (Dage)

Age of dam assessed in this study ranged from 3 to 15 years from 1958 to 1997. In study age of dam (Dage) was found not to have any significant effect (p=0.105, p>0.01) (Table 4.3) on G2. Figure 4.3.4 also shows similar G2 means across all ages (Dage) except for a sharp decline on older cows of 14 and 15 years of age. The number of observations on ages 14 and 15 were 18 and 2 respectively in this case there are no enough observations to derive a credible mean for comparison. In trying to assessing the potential of Dage in predicting G2 this research has found out that beta value of Dage (0.019 ± 0.019, Table 4.3) was very small henceforth age of dam cannot be used in semi-arid regions of Zimbabwe to predict the pre-weaning weight gain (G2). The results also showed that holding other factors constant dam age would contribute 1.9% variation in G2. The weaker association of Dage and G2 (r = 0.001, appendix 2) could be as a result of calves gaining more independence, foraging on their own and spending less time on suckling. During this period from 90 days to 205 days the calves to direct influences of abiotic factors such as temperatures and rainfall variability. Pilarczyk (2007) stated the importance of milk yield on calf body weight at weaning which has the consequences for the farm profitability. Research has also shown that milk production of cows was responsible for 60% of the calf daily gains and that the daily yielding cows nursed calves that are heavier at weaning.

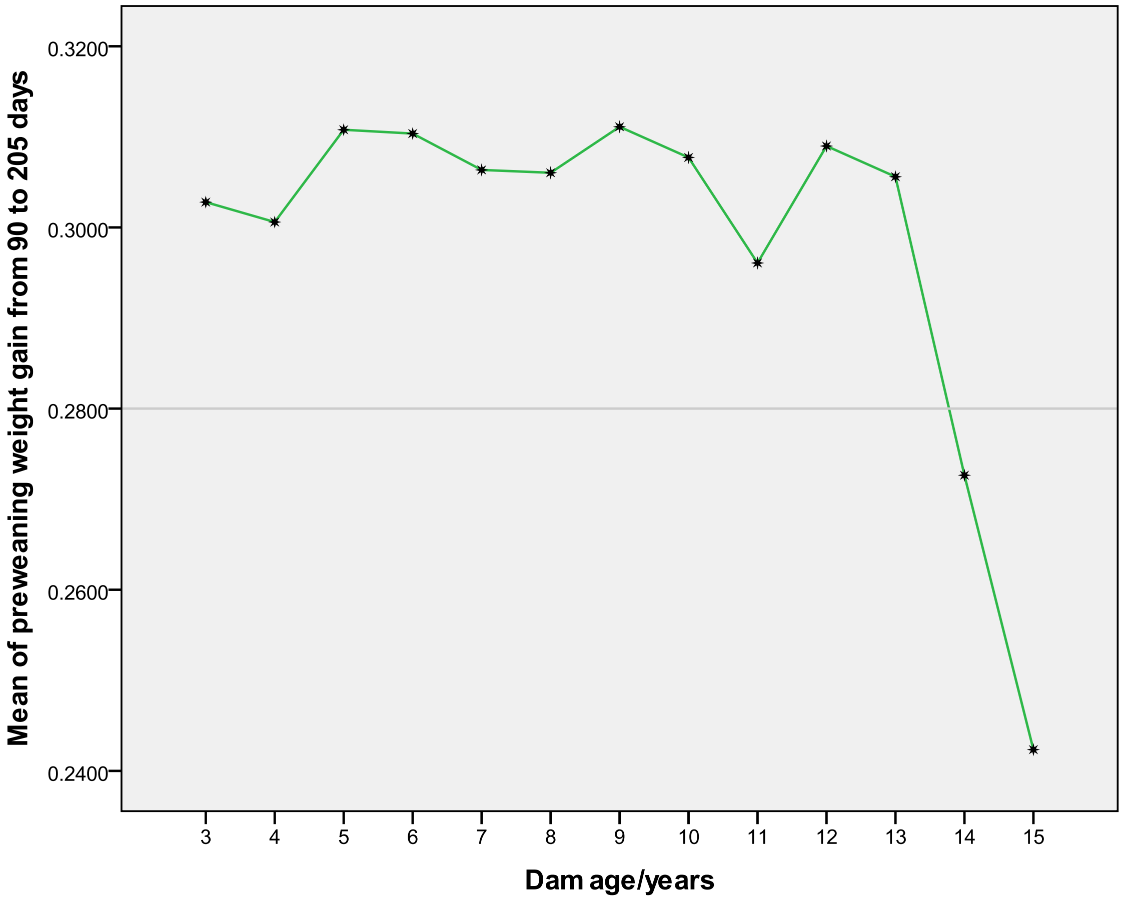

Figure 4.3.4 Pre-weaning weight gain from 90 to 205 days age at different age of dams at Matopos Research Institute from 1958 to 1997.

4.3.3 Previous lactation status

Previous lactation status of dams was treated the same as described in G1, grouped into three categories which were; 1) no lactation level 2) first lactation level and 3) second lactation level. Previous lactation status was analysed as dummy variables, two dummy variables were used. The no lactation dummy variable was used as a reference variable. The results from data analysis revealed that dummy variable for first lactation status was significant on G2 ($p=0.001$, $p <= 0.1$) (Table 4.3), the pre-weaning weight gain between 90 days of age and 205 days of age. However the dummy variable for second lactation was not significant ($p = 0.356$, $p > 0.1$) as shown in Table 4.3. Dummy variable for first lactation had a beta value of 0.05 indicating that calves born from first lactating cows were gaining 5% (0.02kg/day) more weight than cows born from no lactating cows. Dummy variable for second lactation had a beta value of -0.015 suggesting that calves born from second lactating cows were gaining 1.5% (0.005) more weight compared to calves born from no lactating calves however the value was not statistically different. The cows in the no lactation level are young cows of at least 3 years of age; 4 to 6 years of age are mainly in the first lactation level and older cows makes up the second lactation level.

4.3.4 Effect of line

Two variables in this study line and supplement were highly correlated with a correlation coefficient of 0.935. The dummy for line was not significant ($p=0297$, $p > 0.1$) (Table 4.3) on G2. The cows in the supplement line were offered rich proteins, 9kg maize silage and 1kg cotton seed per head per day during the dry season while the non supplemented line relied on the range throughout the year. The beta value for line was 0.011 which suggest that calves from the supplemented line gained 1.1% (0.003kg/day) more weight than the calves from the non supplemented line. However the rich protein supplement could probably have improved reproductive traits such as cow fertility and such investigation was not done in this study. Literature has also shown that supplementing animals during the dry season helps the animals to utilize the graze more effective (Martin et al 2007). Stalker et al (2006) reported that weaning weight and average daily gains from birth to weaning were greater from calves born to cows fed supplement.

4.3.5 Effect of environment

There were two environments in this study the first one was a group of cows early mated and expected to calve in December and the second one are cows which were late mated and expected to calve in September. Environment was found to be highly significant ($p<=0.01$) (Table 4.3) on the pre-weaning weight gain from 90 days of age to weaning age. This result is consistent from the work reported by Thiruvenkadan et al (2009) in Tellichery goats. The most important months for the assessment of G2 were April, May and June for December calves and January, February and March for September calves. The December calves had their G2 assessed in winter season when the range had reached its nutritional bottleneck, whereas the September calves had their pre-weaning time in a high input environment. Environment had a suppressing effect on G2 as indicated by the negative beta value (-0.087). The beta value also showed that calves born from the late mated cows were gaining 8.7% (0.03kg/day) more weight compared to calves born from the early mated cows.

4.3.6 Effect of sex

The effects of sex was highly significant ($p=0.000$, $p<=0.01$) (Table 4.3) on G2. Sex had a beta value of -0.073 (Table 4.3). Two classes of sex were used in this study; males and females. The beta value indicates that the female calves were 7.3% (0.02kg/day) lighter as compared to the male calves and this result is in agreement with Beffa (2005). However

Melaku *et al*. (2011) reported no significant influence due to sex of calf, significance influence was reported by Adissu (1999). In this study the interaction between sex and environment was not important ($p = 0.154$, $p > 0.1$).

4.3.7 Effect of date of birth (BD)

The effect of standardized date of birth (BD) was highly influential on G2 variability ($p<=0.01$) (Table 4.3). Sdob had a beta value of -0.456 (Table 4.3) Figure 4.3.5 shows that there is an inverse relationship between BD and G2, the calves born early had a higher G2 compared to the late born calves relative to the first of September. This is also supported by the negative coefficients of beta value, which indicates that when other factors are hold constant G2 would slow down by 45.6% due to date of birth. The date of birth of calf also determines the season in which the pre-weaning weight gains of individual or a group of calves will be assessed, December calves will be assessed in winter and the September calves was assessed in summer. Winter months considered for G2 analysis were April, May and June and the summer months were December, January and February. Conditions of the wet season which influence pasture availability had a positive influence on daily weight gain of calves. The positive effects of the season were also reported by de Leeuw, Bekure and Grandin, (1984) who found that calves that entered the long dry season (July – November) at early age were exposed to poor pastures for long resulting in growth retardation. However it is also important to note that winter months have a very low parasite load, hence Taylor (2007) reported higher pre-weaning weight gain in winter compare to summer season.

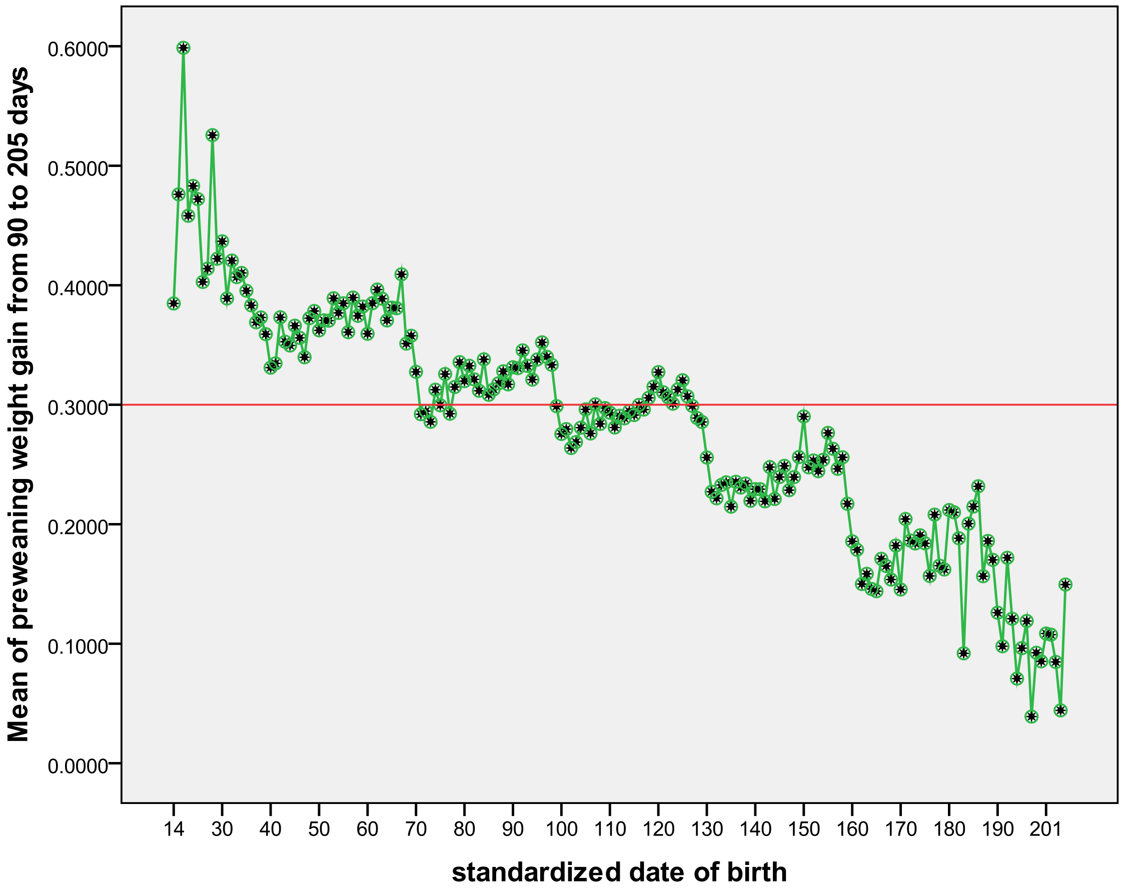

Figure 4.3.5 Pre-weaning weight gain from 90 to 205 days at different standardized date of birth in Afrikaner cattle at Matopos Research Institute from 1958 to 1997.

4.3.8 Effect of age between birth and 90 day of age (age90)

The effect of age90 on G2 was found to be highly significant ($p<0.01$) (Table 4.3). Age90 represent the actual age of the calf when recording weight at 90 days. Age90 ranged from 70 days to 108 day. As age90 increases it result in a decrease in feed conversion efficiency of calves. At low feed conversion efficiency there is slow pre-weaning weight gain. The beta value of age90 was -0.375 ± 0.011 (Table 4.3) which indicates that age90 had a suppressing effect on G2. The negative beta value of Age90 could be used to explain the state of the environment the calves were experiencing from birth to 90 days. For calves born in September the mothers experiences a low input environment in-terms of the quantity of vegetative biomass. This could impact on the overall milk production by the dams hence the

Afrikaner calves at Matopos Research Institute generally experienced a 37.5% suppressing effect on potential pre-weaning weight gain..

4.3.9 Effect of 90 day weights

Calf weight after 90 days of birth was used as initial weight for pre-weaning weight gain between 90 days and 205 days. It then helps to assess notion of heavier calves versus lighter calves in response to pre-weaning weight gain.

The actual weight of calf at 90 days (wt90) had a significant effect ($p<0.01$) (Table 4.3) on G2. For pre-weaning weight gain between 90 days of age and 205 days, the initial weight is wt90. Earlier research had shown that the higher the initial weight the slower it is for calves to gain weight. The beta value of wt90 was -0.172 ± 0.012 (Table 4.3), the negative sign means that wt90 has a suppressing effect on G2 with calves generally losing 17.2% of weight due weight recorded at 90 days of age.

4.3.10 Effect of birth weight

In this study birth weight had no significant effect ($p=0.172$, $p > 0.1$, Table 4.3) on the pre-weaning weight gain between 90 days of age and 205 days of age. The beta value, -0.016 ± 0.011, and t-value, -1.366, indicates the weaker influence of birth weight on G2. However Odhiambo et al (2009) reported a positive correlation between birth weight and weaning weight, reduced birth weight was positively correlated to lighter weaning weight.

4.3.11 Effect of rainfall variability (WWrain and G2 - rain)

Two important rainfall components were analysed in this study, cumulative and actual rainfall. The cumulative rainfall from birth to weaning (WWrain) had a significant effect (p<0.01) on G2 (Table 4.3). WWrain had a beta value of -0.082 ± 0.018 (Table 4.3). The negative beta value suggests that calves lost 8.2% weight due WWrain variability. The G2-rain was also significant on G2 with a beta value of 0.093 ± 0.016 (Table 4.3). The calves gained 9.3% more weight due to G2-rain. The mean value of WWrain in this study was 395 mm. Figure 4.3.3 shows wwrain over the experimental years, 1958 to 1997. The Cumulative rainfall is important in assessing annual or periodic biomass production in semi arid areas and it is directly linked to surface biomass production.

4.3.12 Effect of temperature variability (TempVarWW)

The effects of average temperature variability from birth to weaning (TempVarWW) was found to be significant (p<=0.01) (Table 4.3) on G2. The mean TempVarWW at Matopos Research Institute during the time of study was 12.87^{0}C (Table 4.1). From 1958 to 1997 TempVaWW ranged from 11.5^{0}C to 14.3^{0}C higher with TempVarWW values recording in 1958, 1959, 1961, 1965, 1967, 1969, 1979, 1981, 1982, 1987 and 1997and lower values recorded in 1960, 1966, 1971, 1973, 1976, 1977, 1987, 1992, 1995 and 1996 (Figure 4.3.2). High TempVarWW means the difference between maximum and minimum temperatures is wide, animals could experience very hot weather conditions during the day and extremely cold conditions during the night. In both cases animal appetite is depressed, the basal metabolic rate is affected and general animal movement is also affected. In a semi-arid condition high temperature variability is expected in summer and low variability in winter. TempVarWW had beta value of -0.122 (Table 4.3), the negative beta value suggest temperature variability during the period in question had a suppressing effect on G2 and also the magnitude suggest that temperature variability is a comparably weaker predictor of G2 when considering other independent variables assessed in this study (Table 4.3). Holding other factors constant TempVarWW was responsible for calves gaining 12.2% less weight than expected.

4.3.13 Effect of season

The overall effect of season was analyzed as dummy variable two dummy variables were created. Winter season was used as a reference variable to summer and transition season. In this study both summer and transition were significant ($p < 0.01$), the Afrikaner calves gained 9% (0.03kg/day) more weight in summer season compared to winter season. The results also showed that Afrikaner calves were gaining 13% (0.04kg/day) more weight in transition season than in winter. Over all the transition season influenced pre-weaning weight gain more indicated by the t-value (7.122) and the beta value 0.131 ± 0.018 (Table 4.3).

4.3.14 Conclusion

The pre-weaning weight gain was assessed between 90 days of calf age and 205 days (G2). The results showed that the most important factors influencing G2 were year of birth, date of birth, wt90, age90, temperature variability and season. Other significant factors were; first lactation status, environment, sex of calf and rainfall variability. The non significant factors were; second lactation, line, sex-environment interaction and birth weight.

4.4 Pre-weaning weight gain from birth to weaning age (G3)

The average pre-weaning weight gain from birth to weaning obtained in the current study was 0.642 kg per day (Table 4.1). The standard deviations and the number of observations of G3 are presented in Table 4.1. The pre-weaning weight gain (G3) was assessed from birth to weaning and was calculated by subtracting birth weight from weaning weight and dividing by weaning age. The ordinary least square regression was coupled with generalized least squares model to correct for heteroscedasticity diagnosed in the dependent variable. However the overall analysis accounted for 54.4% of the variation in G3 as indicated by the adjusted R-squared value in Table 4.4.

The factors influencing G3 evaluated in this study were; year of birth, age of dam, previous lactation status, line, environment, supplement, sex of calf, date of birth (sdob), age of calf at 90 days weighing time (age90), weight at 90 days of age (wt90), birth weight (BW), actual rainfall from 90 days to weaning age (G2-rain), cumulative rainfall from birth to weaning(wwrain), average temperature variability from birth to weaning (TempVarWW) and season. Supplement was not included in the regression analysis because of a very strong positive relationship with environment (r = 0.935, Appendix 3).

Table 4.4 The relationship between independent variable and G3 estimated by beta coefficients

Variable	Coefficient	S.E	t-value	p-value
Constant	0.642^{***}	0.034	18.769	0.000
Year of birth	0.147^{***}	0.010	14.345	0.000
Dam age	0.016^{ns}	0.011	1.485	0.137
Dummy A	0.044^{***}	0.014	3.104	0.002
Dummy B	-0.019^{ns}	0.015	-1.252	0.210
Dummy line	0.002^{ns}	0.010	0.186	0.853
Dummy environment	-0.054^{***}	0.016	-3.418	0.001
Dummy sex	-0.076^{***}	0.012	-6.119	0.000
Dsex x Dm	-0.002^{ns}	0.015	-0.128	0.898
Sdob	0.104^{***}	0.018	5.728	0.000
wt90	0.833^{***}	0.011	75.323	0.000
age90	-0.326^{***}	0.010	-32.139	0.000
Birth weight	-0.220^{***}	0.010	-21.597	0.000
G2-rain	0.135^{***}	0.014	9.646	0.000
WWrain	-0.103^{***}	0.017	-6.217	0.000
TempVarWW	-0.102^{***}	0.013	-8.058	0.000
Summer	0.017^{ns}	0.014	1.188	0.235
Transition	0.093^{***}	0.016	5.632	0.000
R	0.739			
R^2	0.546			
R^{-2}	0.544			
Durbin-Watson	1.409			

a) $p < 0.1$, $p < 0.05$, $p < 0.01$ and ns-not significant

b) where dummy A denotes first lactation and dummy B second lactation

4.4.1 Year of birth

The effect of year was found to be highly significant (p=0.000, p<0.01) (Table 4.3) on pre-weaning weight gain (G3) of Afrikaner cattle at Matopos Research Institute. Year of birth had a beta value of 0.147 (Table 4.4) and Figure 4.4.1 seems to confirm the weaker beta value of year of birth. However Figure 4.1 shows that there some important variation within G3 due to year of birth, with the higher G3 mean recorded in 1965 (0.6772), 1967 (0.6996), 1982 (0.6738), 1985 (0.6850) and 1994 (0.7398) whereas the lower G3 means were recorded in 1962 (0.5437), 1963 (0.5437), 1978 (0.5305) and 1993 (0.5357). The results seems to suggest that holding all other independent variables constant 14.7 % of the variation in G3.

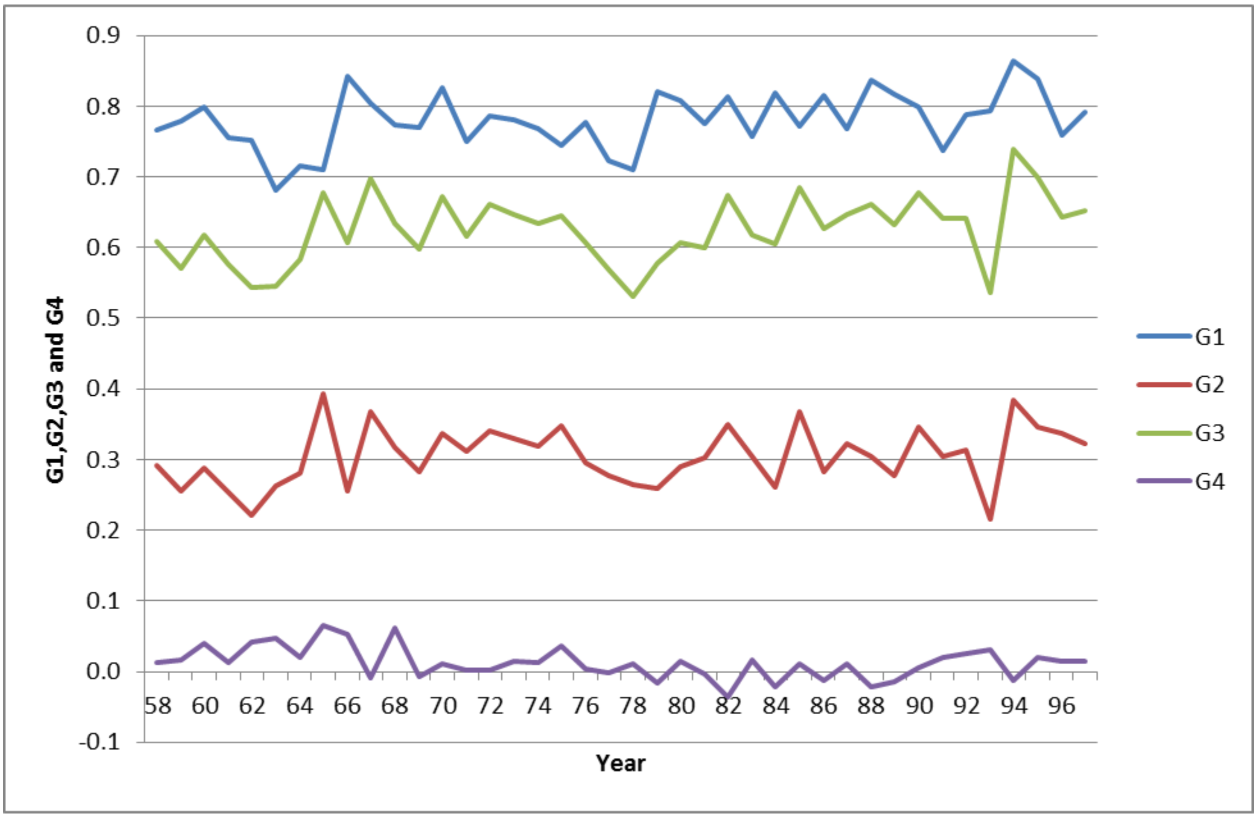

Figure 4.4.1 Average daily weight gain (G1), pre-weaning weight gain from 90 days to weaning (G2), pre-weaning weight gain from birth to weaning (G3) and post-weaning weaning weight gain (G4) from 1958 to 1997 in Afrikaner cattle at Matopos Research Institute in Zimbabwe.

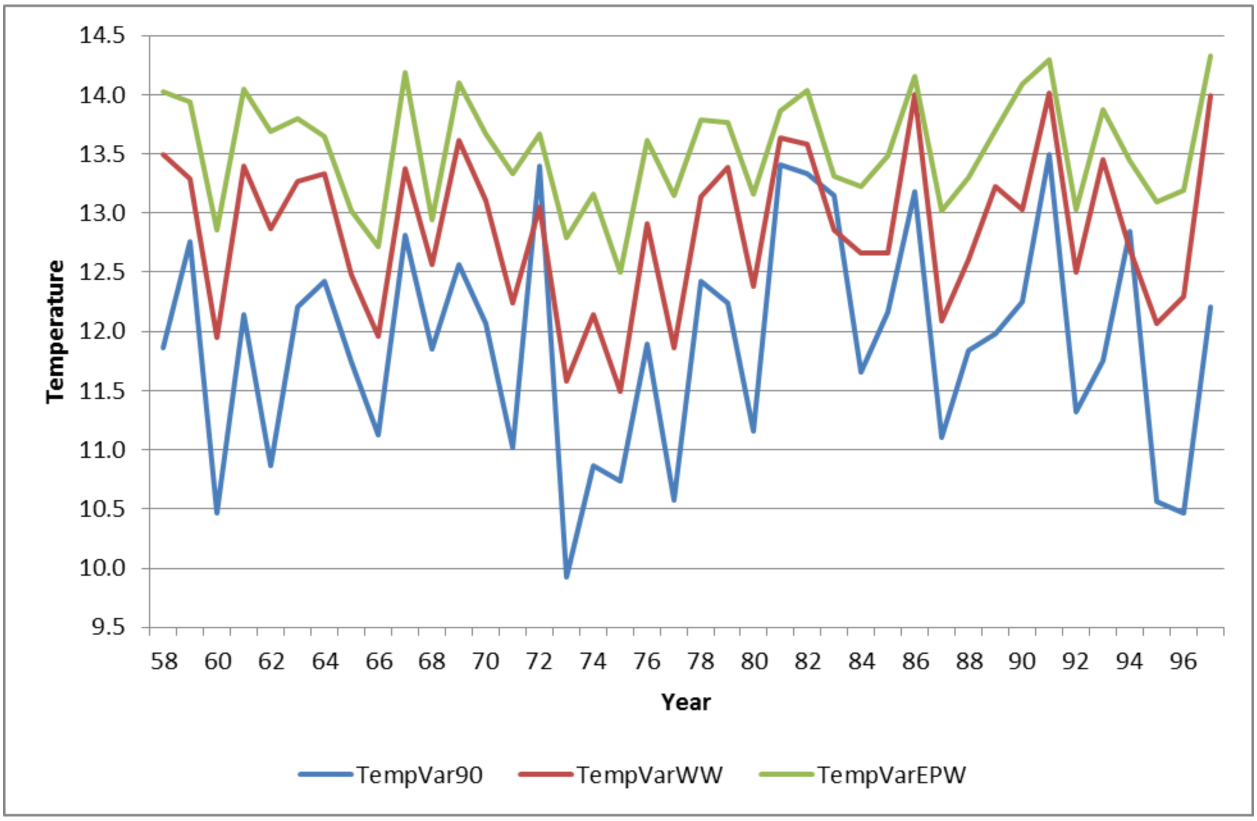

Figure 4.4.2: Temperature variability, from birth to 90 days of age (TempVar90), from birth to weaning age (TempVarWW) and from birth to early post-weaning age (TempEPW) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

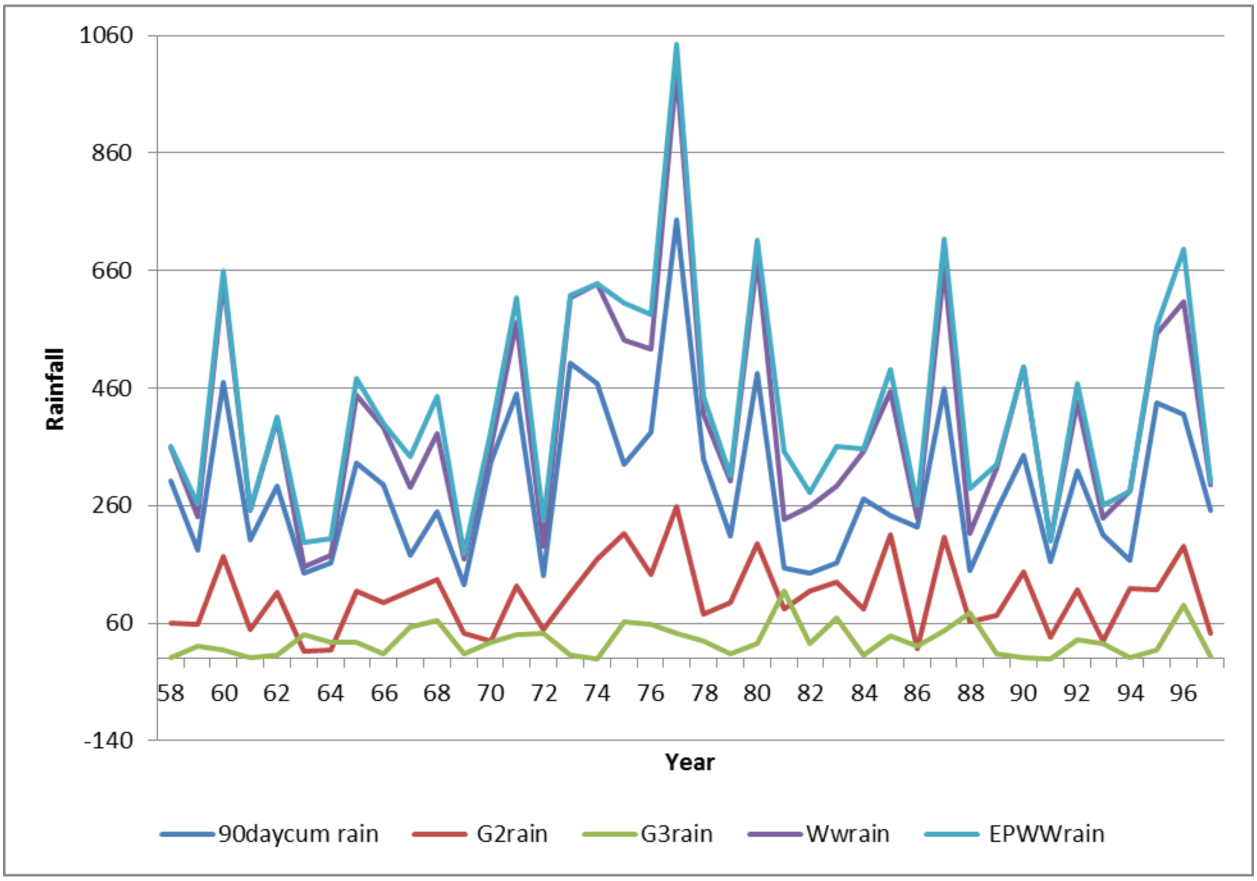

Figure 4.4.3: Rainfall variability; from birth to 90 days of age (90daycum rain), from 90 days to weaning age (G2 rain), from weaning age to early post-weaning age (G3rain), from birth to weaning age (Wwrain) and from birth to early post-weaning age (EPWWrain) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

4.4.2 Age of dam

Average pre-weaning weight gain (G3) was found not to be influenced by the age of dam at all level of significance (p=0.137, p > 0.1) (Table 4.4). In this study the age of dams ranged from 3 years to 15 years the beta value of age of dam was 0.016 (Table 4.4) and seem to suggest that in semi-arid regions of Zimbabwe age of dam cannot be used in predicting G3. Dams at different age groups experiences highly variable milk production, energy, protein and maintenance requirement. This could influence the quality and quantity of milk production henceforth they should be some degree of notable variation on G3 due to age of dam. Even though age of dam was found to have no effect on average daily weight gain of calves from birth to weaning, Greenwood et al (2006) reported that preweaning growth was in most cases influenced by the nutritional status of the cows during pregnancy.

4.4.3 Previous lactation status (ls)

The effect of previous lactation status (ls) was considered in three categories 1) no lactation 2) first lactation and 3) second lactation, and two dummy variables were derived from the stated classes. The no lactation status was used as a reference dummy, reference to first and second lactation status. The results showed that the dummy for the first lactation was highly significant ($p=0.000$, $p<=0.01$) on G3 whereas second lactation had no significant influence ($p=0.210$) on G3. The calves born from the first lactation group were 4.4 % (0.03kg/day) heavier than the calves born from the no lactation group. Though the results showed that dummy for second lactation was not significant, the calves from the second lactation group were 1.9% (0.01kg/day) lighter in weight as compared to calves in no lactation group.

During the pre-weaning weight gain (G3) calves suckle for 2-3 months solely dependent on dam quality and quantity of milk which could be influenced by previous lactation status. Jenkins et al. (2000) reported that improving the nutritional environment of lactating beef cows will result in a nonlinear increase in milk yields of cows. This also translates to weight gains variables in calves and reduced weaning weights.

4.4.4 Effects of line

The influence of line was assessed as a dummy variable. The analysis showed that there was no significant difference in weight changes between the calves from the non supplemented line and the supplemented line in Afrikaner cattle. The results showed that the calves the supplemented line were gaining 0.2% (0.01kg/day) more weight than the calves from the non supplemented line and this difference was not statistically difference as indicated by the p-value ($p=0.853$, $p>0.1$) (Table 4.4). The selection done within the lines for birth weight and weaning weight and other reproductive traits did not influence the pre-weaning weight gains from birth to weaning. The genotype defined by the line was not important in influencing the pre-weaning weight gain (G3).

4.4.5 Effects of environment

The environment as explained in this study, was found to have a highly significant ($p=0.001$, $p<=0.01$) (Table 4.4) influence on G3. The environment was designed to have 1) a group of cows which were supplemented and expected to calve early and 2) the second group of cows were non supplemented and expected to calve late. The calves from the early mated group were gaining 5.4 % (0.03kg/day) less weight than the calves from the late mated group.

4.4.6 Effects of sex

This study also tried to establish the effects of sex of calf on weight gain, pre-weaning weight gain. Sex of calf was found to influence G3 significantly ($p<0.01$). The results showed that the male calves gained 7.6% (0.05kg/day) more weight the female calves and this result was similar to what was reported by Taylor (2007). Taylor (2007) reported the influence of sex on pre-weaning weight gain ($p<0.05$), with male calves gaining 0.07kg/day from birth to weaning. The study also revealed that the interaction between sex of calf and environment was not significant ($p=0.898$).

4.4.7 Effects of date of birth (BD)

The date of birth was assessed as standardized date of birth (BD) and was predetermined by the environment as defined in this study. The early mated cows calved down from October to December whereas late mated cows calve from December to February. The BD was found to be significantly influencing G3 ($p<=0.01$) (Table 4.3). BD had a beta value of 0.104 (Table 4.4). The results suggest that when other independent factors are held constant the calves generally contribute 10.4% to the total variation in G3. It can be deduced that calves born from October to December had their G3 assessed from October to March whereas calves born from December to February were assessed from December to May. The period from birth to weaning it's a period of two halves in the life history of the calves. The first 2-3 months after birth the weight gains are mainly influenced by the dam and its nursing ability on the calf whereas from 3-8 months (weaning time) the calf will be both suckling and grazing. Given such analysis the level of input in each season or month or any abiotic factors would influence the growth of the calf both directly and indirectly. According to Story et al. (2000) the date of birth influences the weaning time of calves, and could be during high vegetative biomass input or during the time when the rangeland reaches its nutritional bottleneck (Magadzire, 2002).

4.4.8 Effects of age between birth and 90 days of age (age90)

The age90 was found to be highly significant ($p<=0.01$) (Table 4.4) on G3. The beta value of -0.326 ± 0.010 (Table 4.4) seem to point out that the calves loses 32.6% of pre-weaning weight due to age90. Figure 4.4.4 also shows that there is no linear relationship between G3 and age90. Higher values of G3 were found at ages 80 days and 106 days, and lower values were recorded at 103, 105 and 108 days of age. Gasser (2006) reported that preweaning average daily weight gain had more consistent influence on age at puberty than post-weaning average daily gains in heifers that were weaned 200 days of age.

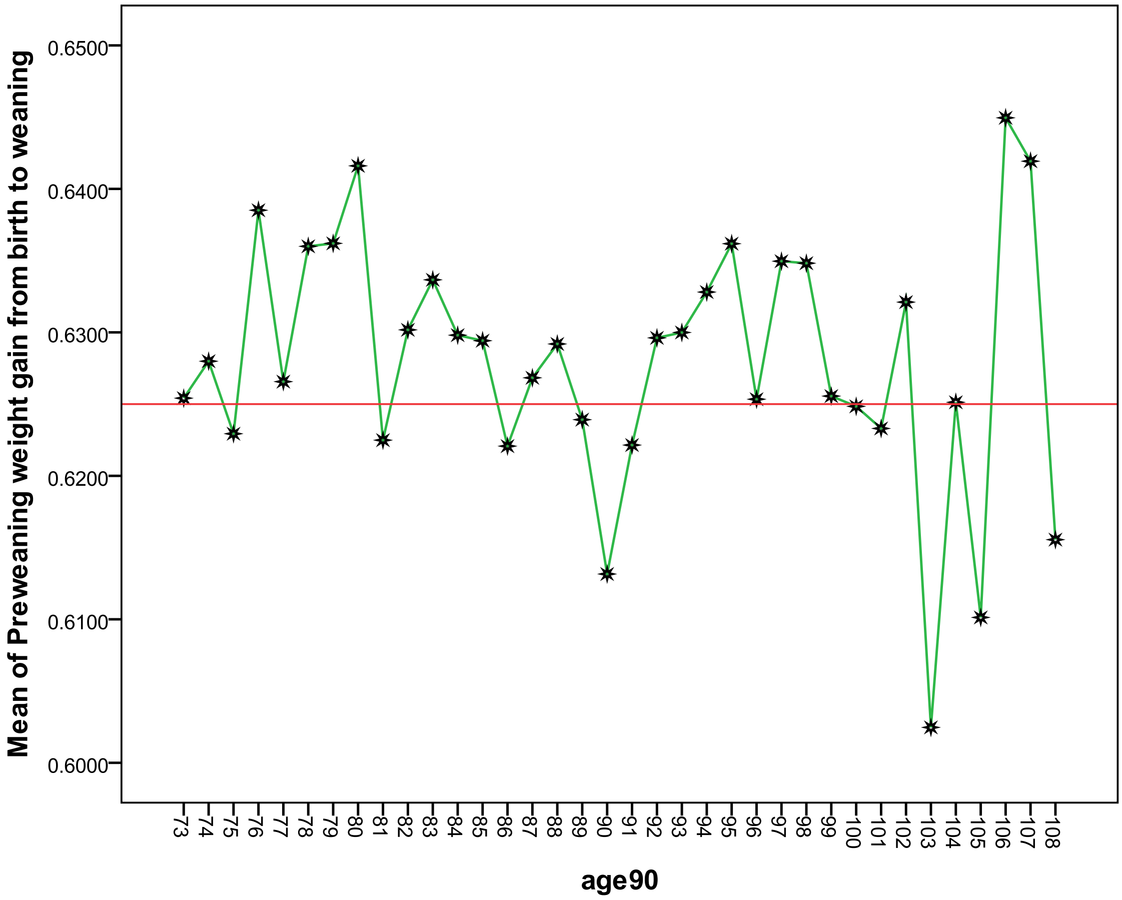

Figure 4.4.4 Pre-weaning weight gain from birth to weaning at different ages of calf at 90 days (age90) at Matopos Research Institute from 1958 to 1997.

4.4.9 Effect of 90 day weight

Weight after 90 days of calf's birth was assessed to establish its contribution to variations in pre-weaning weight gain from birth to weaning. In this study wt90 was found be highly significant, $p<0.01$ and this is evident from the beta value (0.833) and the t-value (75.323) as shown in Table 4.3. The results also suggest that wt90 had a positive effect on G3, holding other variables constant, wt90 accounts for 83.3% of the variation in G3.

4.4.10 Effect of birth weight

The pre-weaning weight gain from birth to weaning (G3) was found to be affected by birth weight ($p<=0.01$). However birth weight seems to a suppressing effect on G3 as indicated by the negative beta value (-0.220 ± 0.010). This seems to suggest that under the influence of birth weight alone calves gain 22 % less weight than average. Odhiambo et al (2009) stated that the calves which were born with reduced birth weights had lighter weaning weights.

4.4.11 Effects of temperature variability (TempVarWW)

Temperature variability from birth to weaning (TempVarWW) was significantly affecting G3 ($p<=0.01$) (Table 4.3). TempVarWW had beta value of -0.102 (Table 4.4). From birth to weaning the important months to consider in the two defined environments are 1) December to July and 2) October to April. During this period from birth to weaning time the lowest temperature variability were recorded in 1960, 1966, 1971, 1973, 1976, 1977, 1987, 1992, 1995 and 1996 with highest values recorded in 1958, 1959, 1961, 1965, 1967, 1969, 1979, 1981, 1982, 1987, 1992 and 1993 as reflected in Figure 4.4.2. The negative beta value suggest that temperature variability caused calves lose 10.2% of weight.

4.4.12 Effect of rainfall variability (WWrain and G2-rain)

Rainfall is an important determinant parameter to beef production. Pre-weaning weight gain was found to be affected by both cumulative rainfall calculated from birth to weaning (WWrain) ($p=0.000$, $p < 0.01$) and actual rainfall received from 90 days of age to weaning ($p=0.000$, $p < 0.01$) (Table 4.4). WWrain had a beta value of -0.103 ± 0.017 (Table 4.4) and this suggest that with the nature of rainfall variability (Figure 4.4.3) experienced at Matopos Research Institute causes calves to lose 10.3% from its average pre-weaning weight gain. On the other hand G2-rain had a positive effect on G3 indicated by its beta value, 0.135 ± 0.014.

The beta value of G2-rain seems to suggest that calves had a positive gain in weight approximately 13.5% above average. Recent work by Starkey et al (2013) showed that the poor grass results in poor average daily weight gains of calves and also the state of the grass was positively correlated to the fat content in calves.

4.4.13 Effects of season

Three seasons were assessed in this study, winter, summer and transition season. In this study winter was made reference season. The results showed that summer season had no significant ($p=0.235$) effect on G3 with calves gaining 1.7% (0.01kg/day) more weight in summer than in winter. On other had the transition season was highly significant ($p=0.000$) on G3 and calves gained 9.3% (0.06kg/day) more weight than in winter season. Taylor (2007) also reported that season had a significant influence on pre-weaning weight gain with calves growing faster by 0.16kg/day from birth to weaning in summer and this figure was higher than what is reported in this study.

4.4.14 Conclusion

Pre-weaning weight gain from birth to weaning is very important in assessing weaning time and also as a determinant in time for attaining predefined weaning mass. Pre-weaning weight gains from calves can also help farmers in assessing their grazing camps and the strategies surrounding rotational grazing. Henceforth selected abiotic factors and other non genetic factors were assessed their potential to influence pre-weaning weight gain. After assessing the t-values and beta values of the factors evaluated in this study, weight at 90 days (wt90), age of calves at 90 days and birth weight were the most influential independent factors, other influential factors include date of birth (BD), cumulative rainfall and temperature variability.

4.5 Early post-weaning weight gain (G4)

The average early post-weaning weight gain (G4) obtained in the current study was 0.010856 kg per day (Table 4.1). The standard deviations and the number of observations of G4 are presented in Table 4.1. The early post-weaning post-weaning weight gain (G4) was assessed from weaning age (205 days) to early post-weaning age (270 days) and was calculated by subtracting weaning weight from early post-weaning weight and dividing by early post-weaning age. The factors influencing G4 evaluated in this study were; year of birth, age of dam, previous lactation status, line, environment, supplement, sex of calf, standardized date of birth (sdob), birth weight, age of calf at weaning (age11), weaning weight (ww), actual rainfall received from weaning to early post-weaning age (G3-rain), early post-weaning rainfall (EPWrain), average temperature variability from birth to early post-weaning age (TempVarEPW) and season. The independent variable supplement was not included in the regression analysis because it was highly correlated to environment (r = 0.935, Appendix 4). The ordinary least square regression model was modified by generalized least squares procedure (GLS) to correct for unequal variance in the dependent variable. The model had an adjusted R – squared value of 0.177 (Table 4.5) meaning the model accounted for 17 % of the variation in G4.

Table 4.5 The relationship between independent variable and G4 estimated by beta coefficients

Variable	Coefficient	S.E	t-value	p-value
Constant	0.501^{***}	0.050	9.926	0.000
Year of birth	-0.144^{***}	0.018	-8.242	0.000
Dam age	0.042^{***}	0.014	2.886	0.004
Dummy A	-0.025^{ns}	0.019	-1.296	0.195
Dummy B	-0.095^{***}	0.020	-4.687	0.000
Dummy line	0.071^{***}	0.013	5.629	0.000
Dummy environment	0.289^{***}	0.022	13.323	0.000
Dummy sex	-0.040^{**}	0.017	-2.355	0.019
Dsex x Dm	-0.063^{***}	0.020	-3.120	0.002
Sdob	-0.477^{***}	0.124	-3.852	0.000
WW	-0.149^{***}	0.018	-8.342	0.000
age11	-0.856^{***}	0.119	-7.177	0.000
Birth weight	0.035^{***}	0.013	2.609	0.009
G3-rain	-0.008^{ns}	0.012	-0.699	0.484
EPwwrain	0.023^{ns}	0.018	1.309	0.191
TempVarEPWW	-0.171^{***}	0.016	-10.904	0.000
Summer	-0.049^{***}	0.018	-2.746	0.006
Transition	0.045^{**}	0.020	2.207	0.027
R	0.423			
R^2	0.179			
R^{-2}	0.177			
Durbin-Watson	1.410			

a) $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ and ns-not significant

b) Dummy A represent first lactation and dummy B represent second lactation

4.5.1 Effect of year of birth

Early post-weaning weight gain (G4) was found to be affected ($p<=0.01$) by year of birth. Year of birth had beta value of -0.144 (Table 4.5), with the negative value indicating the suppressing effect year of birth has on G4. Holding other factors constant year of birth would account for 14.4% loss of weight in Afrikaner calves at Matopos Research Institute. The yearly trend of G4 from 1958 to 1997 is shown in figure 4.5.1 above. The highest G4 means were recorded in 1965, 1968 and 1993 with values of 0.0651, 0.0618 and 0.0314 kg per day respectively, whereas the lowest values were recorded in 1967, 1982 and 1994 with values of -0.0088, -0.0335 and -0.0133 kg per day respectively. For the non-genetic factors studied in Tellicherry goats, year was defined by period and was found to be influencing ($p < 0.01$) post-weaning growth in goats (Thiruvenkadan, Murugan and Karunanithi, 2009). This could have been due to the kidding behaviour of goats, twice in year and in different seasons and also twin kidding could also play a role in influencing post-weaning growth.

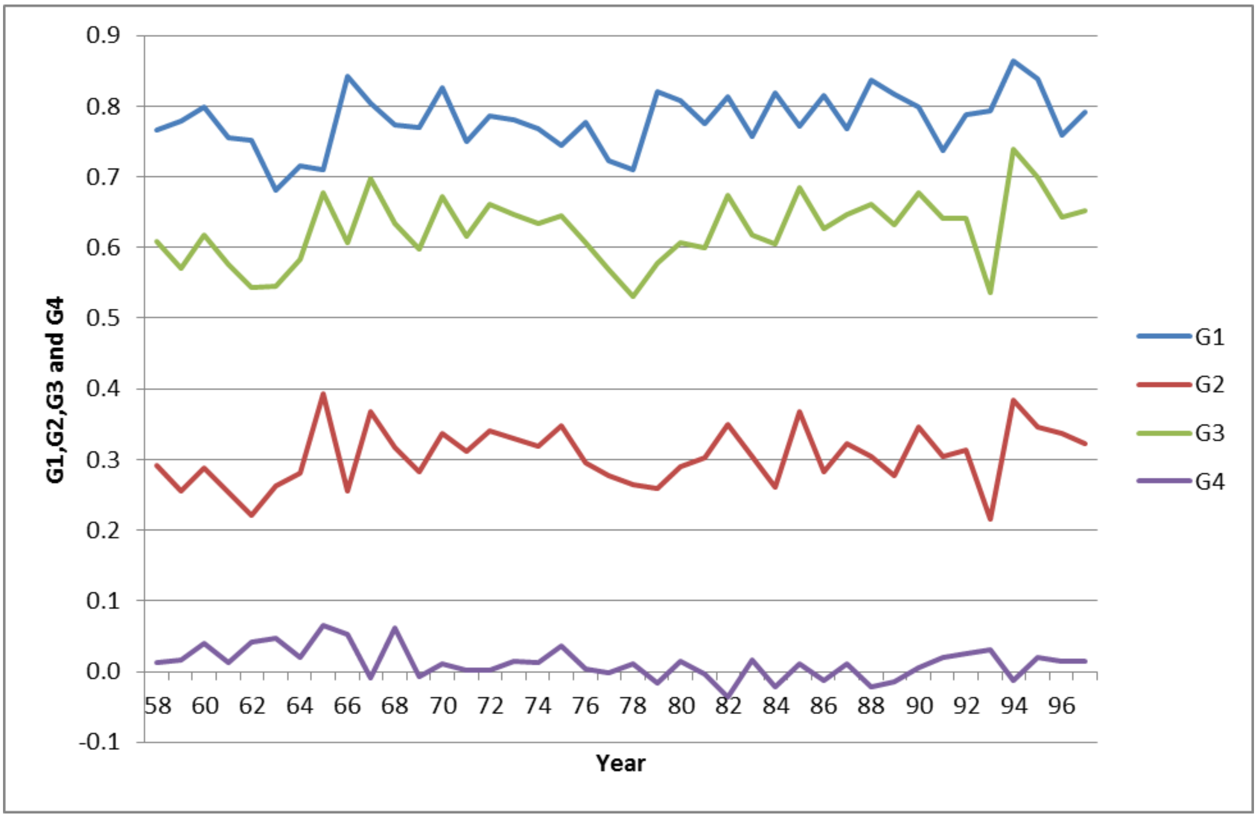

Figure 4.5.1 Average daily weight gain (G1), pre-weaning weight gain from 90 days to weaning (G2), pre-weaning weight gain from birth to weaning (G3) and early post-weaning weaning weight gain (G4) from 1958 to 1997 in Afrikaner cattle at Matopos Research Institute in Zimbabwe.

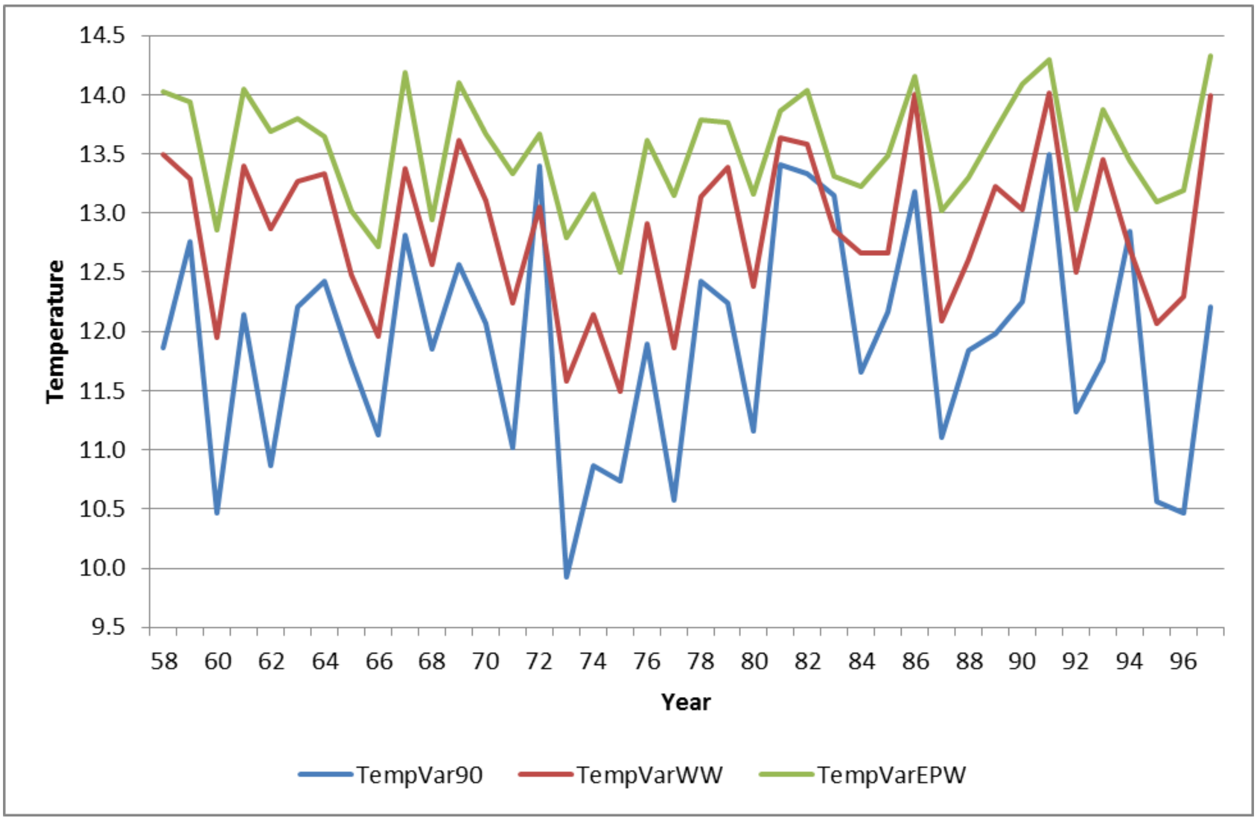

Figure 4.5.2: Temperature variability, from birth to 90 days of age (TempVar90), from birth to weaning age (TempVarWW) and from birth to early post-weaning age (TempEPW) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

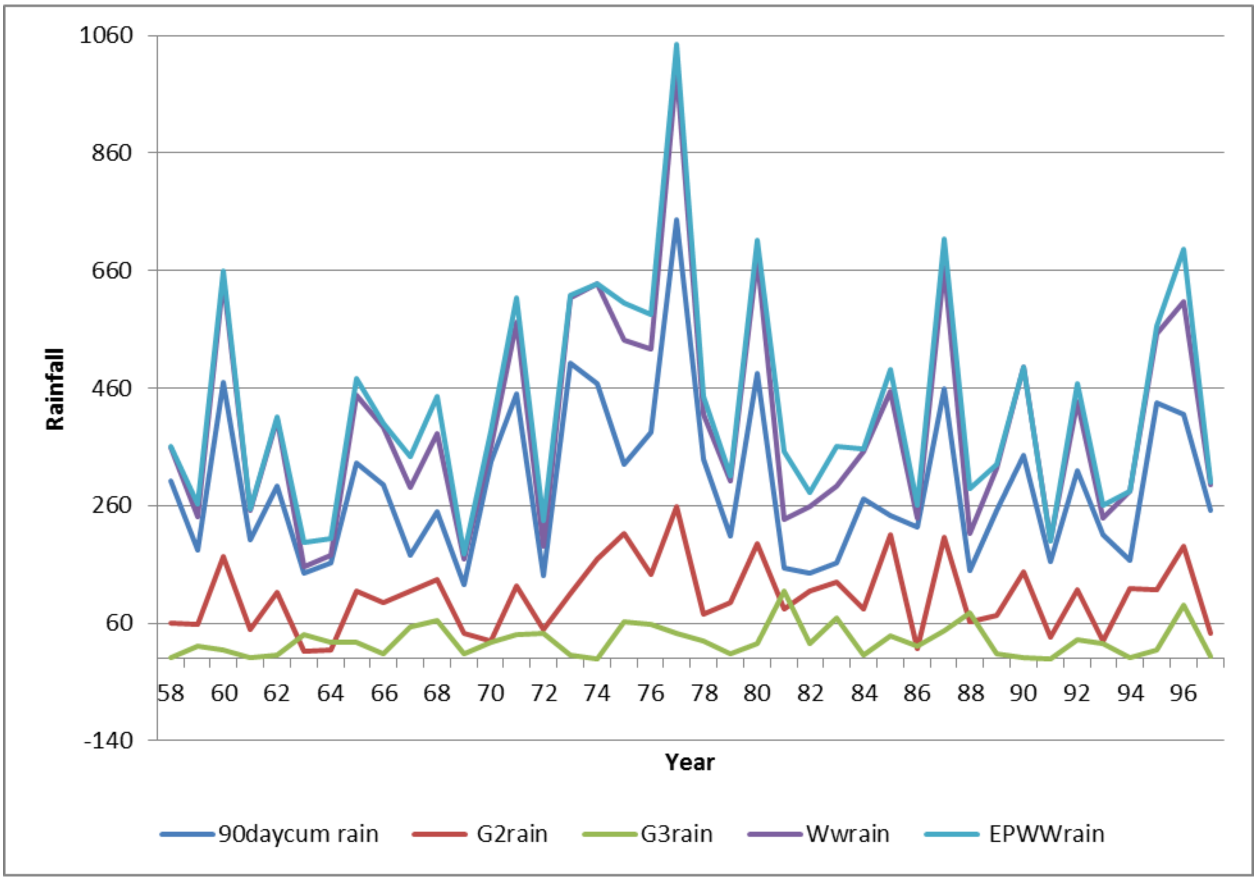

Figure 4.5.3: Rainfall variability; from birth to 90 days of age (90daycum rain), from 90 days to weaning age (G2 rain), from weaning age to early post-weaning age (G3rain), from birth to weaning age (Wwrain) and from birth to early post-weaning age (EPWWrain) from 1958 to 1997 at Matopos Research Institute, Zimbabwe

4.5.2 Effect of line

In this study line was included as a dummy variable, 0 assigned to late mated and non supplemented cows and 1 to early mated and supplemented cows. The effect of line was found to be significantly influencing ($p=0.000$, $p<=0.01$) (Table 4.5) G4. The results showed that calves from the early mated and supplemented line were gaining 7.1 % more weight compared to calves from the late mated and non supplemented line. The difference in early post-weaning weight gain could be as a result of supplement offered to the early mated group. The mating time (early vs late) could also contribute to the variation in G4 due to difference in input levels whether its monthly or seasonal.

4.5.3 Effect of environment

The environment had significant effect ($p=0.000$, $p<=0.01$) on G4. Calves born from the early mated group had gained 28.9% (0.003kg/day) more weight early post-weaning weight gain compared to calves from late mated group. April, May and June were the important months for early mated calves during the assessment of G4, as for the late mated calves June, July and August months were important. Thiruvenkadan et al (2009) also reported effects of season on post-weaning growth in goats. These months had a different abiotic environment which expectedly would affect the early post-weaning weight gain. The environment had a beta value of 0.289 ± 0.022 (Table 4.5). The loss of weight of calves during early post-weaning time could be attributed to calves undergoing stress from the separation from their dams. Loss of weight could also be attributed to the timing of weaning exposing the weaners to less vegetative biomass in winter months. In this study the growth period extended further into the period of poorer grazing conditions. However winter months are also known to have less tick infestations and fewer problems with internal parasites. This contributes positively to growth potential of calves.

4.5.4 Age of dam (dage)

Early post-weaning weight gain in Afrikaner cattle was found to be affected significantly ($p=0.000$) by age of dam (Table 4.5). Dage had a positive beta value of 0.042 (Table 4.5), and this means that holding other factors constant a unit increase in dage result in a 4.2% increase in G4. The small influence of age of dam on G4 was expected due to the reduced contact times between the calves and the dams. Loy et al. (2002) reported that the less influence of dam age on early post-weaned calves could be attributed to the cows approaching the end of the lactation period. During the early post-weaning period the calves are independent from their mothers and completely relying on range as the feed source rather than suckling. It is also important to note that during the pre-weaning period the foraging behaviour of calves is mainly controlled by the dams hence such maternal influence is lost in the post-weaning period. This result is not consistent to what was reported by (MacGregor and Casey, 2000).

4.5.5 Effects of previous lactation status

The influence of previous lactation status was assessed as dummy variables with the no lactation status as reference level to first and second lactation. The calves born from the cows in first lactation were 2.5 % lighter compared to calves born from no lactation cows, however this was not statistically different ($p = 0.195$, $p > 0.1$). The analysis also showed that the dummy for second lactation was significantly ($p = 0.000$) affecting G4. The calves born from the cows in second lactation were 9.5% lighter compared to calves born from no lactation group.

4.5.6 Effect of rainfall variability (EPWWrain and G3-rain)

Cumulative rainfall from birth to early post-weaning age (EPWWrain) and actual rainfall received from weaning age to early post-weaning age (G3-rainfall) were both not significantly affecting G4. EPWWrain had a beta value of 0.023 ± 0.018 (p=0.191) and G3-rain had a beta value of -0.008 ± 0.012 (p = 0.484). The beta values show that Epwwrain contributed 2.3% to G4 increase whilst G3-rain resulted in 0.8% decrease in G4.

The beta value clearly defines EPWWrain as a very weak predictor of G4 and this is also supported by the correlation coefficient henceforth cumulative rain from birth to early post weaning age cannot be used accurately predicting the early post-weaning weight gain at Matopos Research Institute in Zimbabwe. However at early post-weaning period G4 could be highly sensitive to abiotic environmental factors such as rainfall variability. Vegetative biomass production varies with the quantity of rainfall received yearly and this impact on G4. Figure 4.5.3 shows the trend of cumulative rain from birth to weaning. Gasser et al (2006) emphasized on the importance of nutritional plane during the period preceding 7 months of age.

4.5.7 Effects of temperature variability (TempVarEPW)

TempVarEPW denotes the average temperature variability from birth to early post weaning age and TempVarEPWW was found to have a significant effect ($p=0.000$, $p < 0.01$) on G4 (Table 4.5). TempVarEPWW had a beta value of -0.171 ± 0.016 (Table 4.5). The negative beta value shows that TempVarEPW had a suppressing effect on G4, holding all the other factors constant, weaned calves gain 17 % less weight than average due to TempVarEPW. Figure 4.5.2 shows that the lowest temperature variability from weaning age to early post-weaning age were recorded in the following years, 1960, 1966, 1968, 1973, 1975, 1984, 1987, 1992, 1995 and 1996 whereas the highest temperature variability recorded in 1958, 1959, 1961, 1967, 1969, 1982, 1986, 1991 and 1997.

4.5.8 Effect of sex

Sex of calf was analysed as a dummy variable and male calves were considered as a reference point. Sex of calf was found to be highly significant ($p<=0.01$) on G4 (Table 4.5) and this finding was in contrast to what was reported in Tellichery goats by Thiruvenkadan et al (2009). Studies in pigs by Wolter and Ellis (2001) also showed that sex did not affect ($p > 0.05$) pig performance during the nursery and grower periods. Sex had a beta value of -0.040 (Table 4.5) indicating that during early post-weaning female calves were gaining 4% less weight compared to male calves. The interaction between sex and calf was very important for G4, with a beta value of $- 0.063 \pm 0.020$ which means female calves in from the early mated cows were gaining 6.3% less weight compared to calves in late mated environment. Taylor (2007) reported a much higher value of 0.65kg/day in Santa Gertrudis cattle in Namibia from weaning to 12 months of age. However Gasser et al (2006) reported that in female calves, increased growth rates and large weaning body weight were associated with earlier onset of puberty in heifers.

4.5.9 Effect of birth weight

The effect of birth weight on G4 was evaluated from 1958 to 1997 in Afrikaner calves at Matopos Research Institute in Zimbabwe. In this study birth weight was found to have a significant effect ($p = 0.009$) on G4. When other independent variables are hold constant birth weight contributes 3.5% of the variation in G4. Greenwood et al (2006) reported that cattle born small grew more slowly after weaning than their larger counterpart. Greenwood et al (2006) also concluded that, the cattle grown slowly from birth to weaning exhibited incomplete compensation and remained smaller during growth to 30 months os age.

4.5.10 Effect of date of birth (BD)

Standardized date of birth (BD) was found to be affecting G4 ($p<=0.01$) (Table 4.5). BD had a beta value of -0.477 ± 0.124 (Table 4.5), the negative value suggest that when other factors are hold constant the calves gain 47.7% less weight during early post-weaning period. In this study calves born from the early mated group reached their early post-weaning age in the following months April, May and June whereas calves born from the late mated group had their early post-weaning age in June, July and August months. Therefore the variation due to BD on G4 could be attributed to different in monthly dry matter production, temperature and rainfall variability. At Matopos Research Institute the months April, May and June are characterized by lower temperatures ranging from -2^0C – 16^0C and maximum temperatures ranging from 25^0C – 35^0C, with an average rainfall of 450mm (Magadzire, 2002). Such weather conditions result in the rangeland losing both the quantity and quality of rangelands. The rangelands approach its nutritional bottleneck in June, July and August. Other researchers has found that heifers with higher post-weaning average daily gains were significantly ($p<=0.01$) influenced by date of birth (MacGregor and Casey, 2000) and a delay in calving date was associated in reduction in yearling weight and average daily gain from weaning to 12 months of age (Rege and Famula, 1993). Story et al (2000) reported that date of birth of calves was responsible for early weaned calves steers to gain more weight than either the normal weaned or late weaned, as reported in this research study the difference was due to the nutrient content of the diet being consumed.

4.5.11 Effect of weaning age (age11)

Age of calves at weaning (age11) was found to be affecting G4 ($p=0.000$, $p<=0.01$) (Table 4.5). Age11 had a beta value of -0.856 ± 0.119 (Table 4.5), the negative sign of the beta value indicates that age11 had a suppressing effect on G4. This study seems to suggest that age11 was responsible for 85.6% loss of weight in Afrikaner calves at Matopos Research Institute from 1958 to 1997. Figure 4.5.4 also shows the inverse relationship that exists between early post-weaning weight gain (G4) and age of calves at weaning (age11). However (Yanah and Aydin, 2000) found that different ages of weaning had no significant ($p > 0.05$) effect on the average daily weight gains between 6 to 9, 9 to 12 or 12 to 15 months of age in the Brown Swiss cattle in Turkey. The inconsistency in results could be due to breed and geographical region effect.

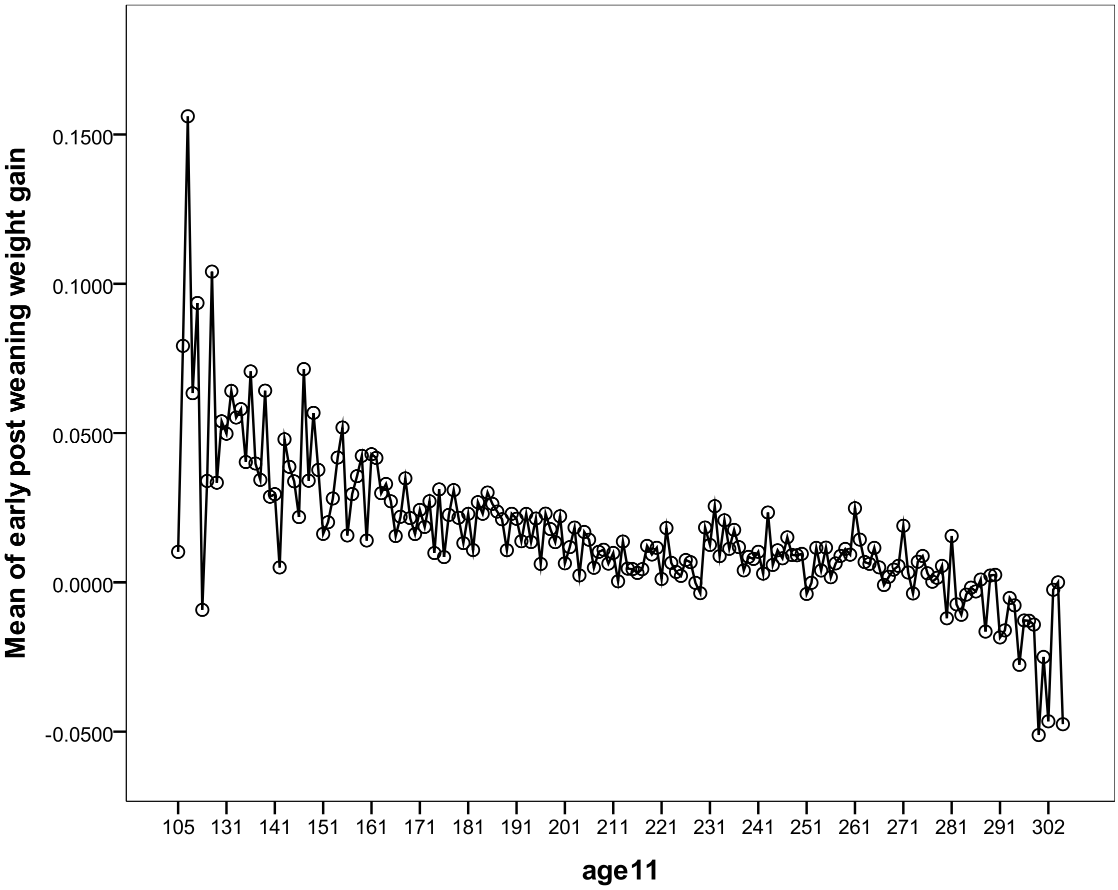

Figure 4.5.4 Mean values of early post-weaning weight gain at different weaning age (ageII) at Matopos Research Institute from 1958 to 1997.

4.5.12 Effect of weaning weight (ww)

In this study weaning weight (ww) was found to have a significant effect ($p<=0.01$) on G4 (Table 4.5). The beta value of ww was -0.149 ± 0.018 (Table 4.5). WW accounted 14.9% loss of weight in G4. Similar work done in pigs in a temperate region revealed that lighter weight pigs have lower feed intakes and reduced weight gains during the immediate period after weaning than those of heavier weight (Himmelberg *et al.,* 1985, Mahan *et al.*, 1998). The relatively higher percentage of variation accounted by weaning weight (15%) in this study is also consistent with revelation by Mahan (1995) who reported that large variation in weight in groups of pigs normally occurs at weaning.

4.5.13 Effects of season

The contribution of season to variation in early post-weaning weight gains (G4) in Afrikaner calves was assessed in three categories. Two dummy variables representing season were analysed with winter as a reference point to dummy for summer and dummy for transition. The results showed that summer season was significantly affecting ($p = 0.006$) early post-weaning weight gains in Afrikaner cattle in semi-arid region of Zimbabwe. During summer season Afrikaner calves seem to be losing 4.9% of its weight compared to winter period as shown by the beta value (-0.049 ± 0.018) in Table 4.5. The results also revealed that the transition season was significant ($p=0.027$) at 5% level of significance. During the transition season the calves gained 4.5% more weight compared during the winter season.

4.5.14 Conclusion

Most cattle farmers wean their calves after six months. From weaning age to early post-weaning weight gain is a critical growth trait that could influence yearling age, bullying time for heifers and also survival of weaners. Of the independent variables assessed the results showed that the most important factors affecting early post-weaning weight gain were; mating time (environment), age at weaning, date of birth, temperature variability and season (summer and transition). Cumulative rain and first lactation status and sex of calf were less important factors.

Ferrell (1982) highlighted the effects of post-weaning feeding on the productive performance of heifers. Under nutrition may result in increased age at puberty, subnormal conception rate and under developed udders. Overfeeding, however, may result in weak estrous symptoms, subnormal conception rate, high embryonic mortality, decreased mammary gland development and decreased milk production. Thus, improper nutrition during the developmental period may have both short-and long-term effects on heifer productivity.

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Chapter 5

Conclusion and Recommendations

5.1 Conclusion

The results of this study suggest that a wide range of non- genetic factors influences the growth of Afrikaner calves from birth to early post-weaning age in semi arid region. However each factor is specific and more important at a different age of a calf in its life history. The time frames considered in this study were average daily weight gain from birth to 90 days of age (G1), pre-weaning gain from 90 days of age to weaning age (G2), pre-weaning gain from birth to weaning age (G3) and early post-weaning weight gain from weaning to early post-weaning age (G4).

The weather variables and other non-genetic factors evaluated in this study are important in assessing performance traits such as average daily weight gains, pre-weaning and post-weaning weight gains in Afrikaner cattle in a semi-arid region of Zimbabwe. The analysis of the performance data was challenging on the correction of unequal variance due to two or more independent variables appearing to be the source of heteroscedasticity.

It is important to appreciate the dramatic differences in production environment both within and across seasons in the sub-tropics. This is determined by the quantity and distribution of rainfall and the effect is well illustrated by the extremely large seasonal (early versus late calving) and yearly variation in calf growth (Figure 4.1).

Age plays a role in the fertility or reproductive performance of cows in cattle production. In notable cases the quantity and quality of milk and the general nursing ability of cows is influenced by age. This study revealed two critical areas were age of dams was more influential; on average daily weight gain from birth to 90 days of age and on early post-weaning weight gain. In both cases age of dam had a positive influence contributing to 4.5% increase in weight gains. Goyache *et al.* (2003) reported the highest weaning weights for calves descending from 7 – 11 years old cows.

The effects of previous lactation status of the cow on calf growth concur with findings from sub-tropical and tropical production environments. Routine evaluation needs to consider this factor to avoid penalizing calves from more productive cows, particularly where the proportion of previous dry cows is high due to poor reproductive performance.

This study has revealed the necessity of supplementing or not supplementing cows in order to influence the growth of Afrikaner calves. From birth to weaning the effect of supplemented line was not significant; the difference between the two lines was 1.7%. However, early post-weaning weight gain was influenced by line, with the supplemented line being 7.1% heavier than the non supplemented line.

The performance of calf growth from birth to 18 months in this study has emphasized the importance of matching animal physiological status with seasonal changes in the sub-tropics. Late born (February) calves showed markedly poorer growth compared with their early (October) born contemporaries and were 33% lighter at the end of their second growing season (at 18 months). The effect of late calving has been reported to be detrimental to subsequent reproductive performance. Generally calving dates can result in improved herd performance. An increase in profit potential may be realized by greater herd reproductive performance and possibly through calf marketing options when either the calving or weaning date is changed.

This study has indicated that initial weight is very influential on weight gains in Afrikaner calves. Research has shown that lighter calves gain weight faster compared to heavier calves. Calves of different weight respond differently in different weather conditions or seasons.

Throughout the life history of Afrikaner calves at Matopos Research Institute, from birth to early post-weaning, the effect of sex was consistent, and female calves were consistently lighter than their male contemporaries. Female calves were on averagely 7.5% lighter than male calves.

Though date of birth denoted by BD was found to be significant for G1, G2, G3 and G4, it however appeared as if BD was more influential during those periods when a calf is less dependent on its mother, from 90 days of age to early post-weaning age.

The effect of season on growth can not only be explained in terms of biomass production which rely on the quantity of rainfall, soil type and temperature range among other factors, but also the level of farm management. The seasonal effects on weight gains was summarized by Kersey and Ray (19987), they noted that, weight loss of about 10% from weaning to 12 months then compensatory weight gain over the summer to almost double the 12 months weight and finally, again 10% weight loss from the fall weight to the next spring weight at 2 years of age.

The influence of birth weight was noticed from birth to early post-weaning age. Sound breeding programmes that positively influence birth weight should be employed for this is beneficial for survival and growth of calves in general.

The abiotic factors studied were cumulative rainfall and temperature variability. The cumulative rainfall had more influence on average daily weight gain from birth to weaning and less so between weaning and early post-weaning. Positive beta values for rainfall were recorded for only G4 with negative value for G1, G2 and G3. Temperature variability was found to be significant from birth to early post-weaning.

The higher pre-weaning average daily gains of early born calves are significant, as it has been reported that heifers experiencing faster pre-weaning growth rates, reach puberty at younger age and achieve heavier weights than slower growing contemporaries. The study also showed that, earlier calving associated with higher fertility would have beneficial effects on growth performance in the herd. It can also be concluded that reasonable growth rates during preweaning period are important for cattle entering the feedlot.

In general, the factors in the linear models for growth traits affect growth traits significantly, which is in agreement with the findings reported in literature. Based on the data available for analyses, the obtained results will serve as a relevant set-up in developing model for genetic evaluation of growth traits in beef breeds in a semi-arid region of Zimbabwe. If these sources of variations can be accurately evaluated such knowledge will enable the breeder to measure the genetic difference between calves with a higher degree.

5.2 Recommendation

Other weather variable factors such as humidity and wind speed should also be in-cooperated in both the regression models and fixed models and account their contribution in the extent to which they influence growth traits under scrutiny in this study.

Heritability traits studied in the genotype x interaction studies in Afrikaner cattle should be assessed for their sensitivity to weather parameters to fill up the knowledge gap that exist.

Timing of mating determines the month or season for calving which in turn influences pre-weaning and early-post-weaning weight gains mainly due to abiotic factors such as rainfall and temperature variability. This study revealed that for calves born in September are likely to have higher weaning weight and can also be weaned earlier due to higher pre-weaning weight gains. As such farmers farming with Afrikaner cattle and relying on rangeland as feed source, should not compromise on mating time since this is a key managerial component that will turn the cattle farming enterprise efficient and profitable.

Supplement was an important factor for early post weaning period, for calves born in September had their post-weaning gains in March, April and May months. In this case supplement helped in utilization of the graze. Whilst for calves born in December had their post-weaning experience in July, August and September months and these are dry months in Zimbabwe, therefore supplement could enhance the feed base and also help in other limiting nutrients

This study also seems to suggest that the first 3 months of the calf history is dependent on the dam for feed and movement behaviour, henceforth abiotic factors could not be directly associated to average daily weight gain. This could mean proper management of the lactating cows will impact on the growth of the calf.

This study has also shown that the survival of calves and growth progress of calves is related to the timing of mating however it is recommended that this hypothesis be tested under experimental conditions.

In conclusion, the challenges of the data analysis shown by a low adjusted R-squared value, leaves the door open for other methods or statistical model be tried and assess the outcome in terms of the parameter weights, standard errors and level of significance.

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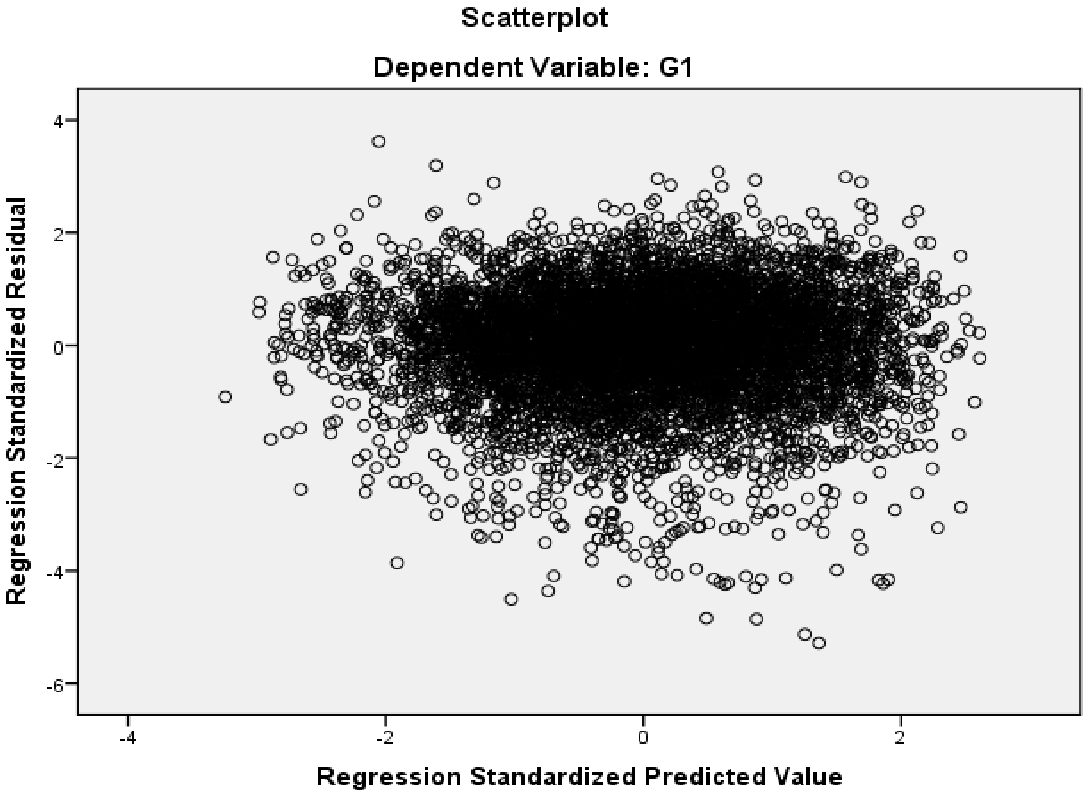
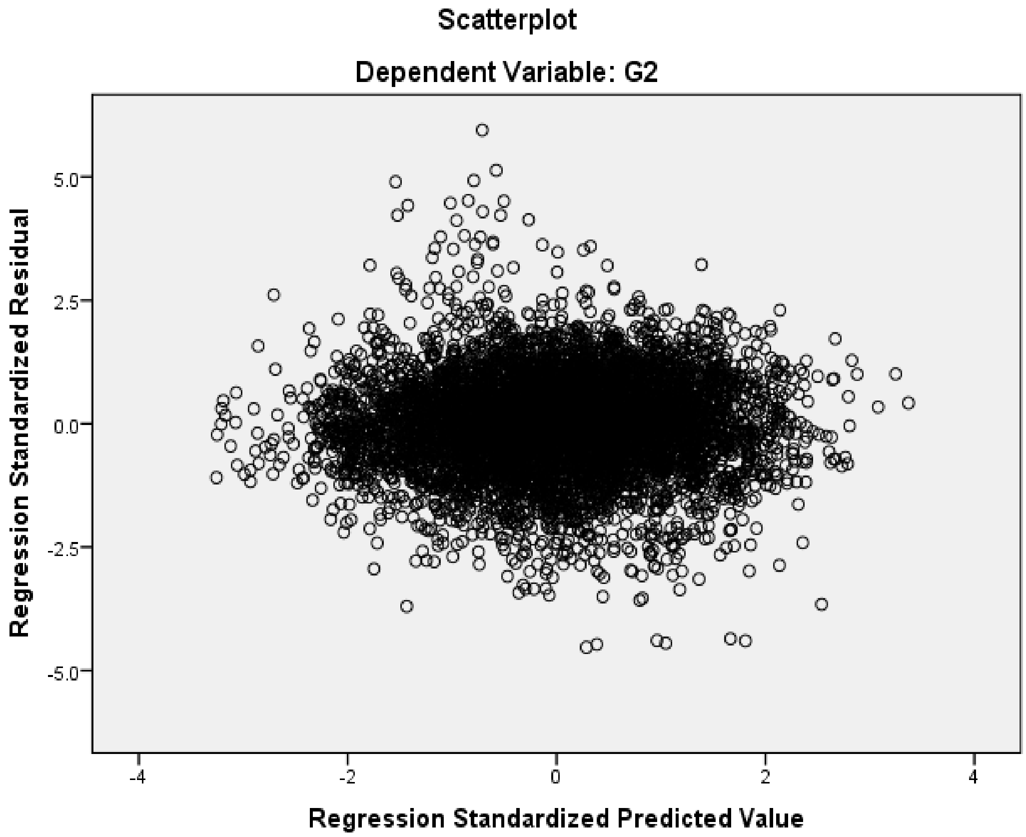
Appendix 1 Average daily weight gain (G1) scatterplot showing unequal variance.



Appendix 2 Pre-weaning weight gain (G2) scatterplot showing unequal variances.



Appendix 3 Correlation matrix for average daily weight gain (G1)

	G1	Year	Dage	Dummy A	Dummy B	line	m	s	sex	BD	Summer	Transition	BW	90dayCumrain	TempVar90
G1	1														
Year	0.094**	1													
Dage	0.131**	-0.214**	1												
Dummy A	0.124**	0.020*	0.093**	1											
Dummy B	0.014	-0.064**	0.314**	-0.704**	1										
line	0.129**	0	-0.004	-0.019*	0.008	1									
m	0.212**	0.006	0.01	-0.062**	0.050**	0.399**	1								
s	0.215**	-0.002	0.018	-0.059**	0.051**	0.388	0.935**	1							
sex	-0.157**	0.004	-0.007	0.004	-0.002	0.007	0.01	0.011	1						
BD	-0.195**	-0.059	0.058**	-0.134**	0.194**	-0.276**	-0.698**	-0.653**	-0.043**	1					
Summer	-0.007	0.004	0	0.084**	-0.072**	-0.194**	0.036**	0.007	0.036	-0.078**	1				
Transition	0.096**	-0.305**	0.039**	-0.050**	0.016	0.32	0.305**	0.307**	-0.01	-0.395**	-0.644**	1			
BW	0.162**	-0.094**	0.146**	0.064**	0.080**	0.188**	0.086**	0.097**	-0.271**	0.100**	-0.074**	0.029**	1		
90dayCumrain	0.048**	0.022	-0.044	-0.002	-0.022	0.070**	0.154**	0.141**	0.018	-0.265**	0.066**	0.056**	-0.046**	1	
TempVar90	-0.030*	0.016	-0.006	0.052**	-0.046**	0.009	0.055**	0.051**	-0.001	-0.053**	-0.063**	0.031	-0.001	-0.724**	1

**$p<0.05$;
*$p<0.1$

Appendix 4 Correlation matrix for pre-weaning weight gain (G2)

	G2	Year	Dage	Dummy A	Dummy B	g	m	s	sex	BD	wt90	age90	BW	G2-rain	WW rain	TempVar WW	Summer	Transition
G2	1																	
Year	0.115**	1																
Dage	0.001	-0.214**	1															
Dummy A	0.149**	-0.020*	0.093**	1														
Dummy B	-0.147**	-0.064**	0.314	-0.704**	1													
g	0.152**	0	-0.004	-0.019	0.008	1												
m	0.320**	0.006	0.01	-0.062**	0.050**	0.399**	1											
s	0.301**	-0.002	0.018	-0.059**	0.051**	0.388**	0.935**	1										
sex	-0.086**	0.004	-0.007	0.004	-0.002	0.007	0.01	0.011	1									
BD	-0.500**	-0.059**	0.058**	-0.134**	0.194**	-0.276**	-0.698**	-0.653**	-0.043	1								
wt90	0.104**	0.049**	0.143**	0.138**	0.014	0.162**	0.202**	0.207**	-0.217**	-0.157**	1							
age90	-0.303**	-0.008	-0.012	0.041**	-0.044**	0.007	0.011	0.011	-0.013	-0.065**	0.399**	1						
BW	0.011	-0.094**	0.146**	0.064**	0.080**	0.188**	0.086	0.097**	-0.271	0.100**	0.419**	-0.019	1					
G2-rain	0.435**	0.065**	-0.076**	0.075**	-0.133**	0.195	0.469**	0.444**	0.021	-0.653	-0.002	-0.125**	-0.081**	1				
wwrain	0.317**	0.053**	-0.072**	0.041	-0.089**	0.157**	0.366**	0.343**	0.023	-0.546**	0.07	0.049**	-0.077**	0.702**	1			
TempVar WW	-0.189**	0.056**	-0.007	0.034**	-0.012	-0.056**	-0.108**	-0.101**	-0.003	0.184**	-0.038**	-0.016	0.063**	-0.389**	-0.696**	1		
Summer	0.068**	0.004	0	0.084**	-0.072**	-0.194**	0.036**	0.007	0.036**	-0.078**	-0.051**	-0.065**	-0.074**	0.006	0.051**	-0.012	1	
Transition	0.244**	-0.305**	0.039**	-0.050**	0.016	0.320**	0.305**	0.307**	-0.01	-0.395**	0.053	-0.059**	0.029*	0.280**	0.191**	-0.131**	-0.644**	1

**p<0.05; *p<0.1

Appendix 5 **Correlation matrix for pre-weaning weight gain (G3)**

	G3	Year	Dage	Dummy A	Dummy B	g	m	s	sex	BD	wt90	age90	BW	G2-rain	WW rain	TempVar WW	Summer	Transition
G3	1																	
Year	0.168**	1																
Dage	0.094**	-0.214**	1															
Dummy A	0.152**	0.020*	0.093**	1														
Dummy B	-0.046**	-0.064**	0.314**	-0.704**	1													
g	0.083**	0	-0.004	-0.019	0.008	1												
m	0.088**	0.006	0.01	-0.062**	0.050**	0.399**	1											
s	0.091**	-0.002	0.018	-0.059**	0.051**	0.388**	0.935**	1										
sex	-0.196**	0.004	-0.007	0.004	-0.002	0.007	0.01	0.011	1									
BD	-0.100**	-0.059**	0.058	-0.134	0.194	-0.276	-0.694	-0.653	-0.043	1								
wt90	0.614**	0.049	0.143**	0.138**	0.014*	0.162**	0.202**	0.207**	-0.217**	-0.157**	1							
age90	-0.020*	-0.008	-0.012	0.041*	-0.044**	0.007	0.011	0.011	-0.013	-0.065**	0.399**	1						
BW	0.145**	-0.094**	0.146**	0.064**	0.080**	0.188**	0.086**	0.097**	-0.271**	0.100**	0.419**	-0.019**	1					
G2-rain	0.104**	0.065**	-0.076**	0.075**	-0.133**	0.195**	0.469**	0.444**	0.021	-0.653**	-0.002	-0.125**	-0.081**	1				
wwrain	0.071**	0.053**	-0.072**	0.041*	-0.089**	0.157**	0.366**	0.343**	0.023**	-0.546**	0.070**	0.049**	-0.077**	0.702**	1			
TempVar WW	-0.098**	0.056	-0.007	0.034*	-0.012	-0.056**	-0.108**	-0.101**	-0.003	0.184**	-0.038	-0.016*	0.063**	-0.0.389**	-0.696**	1		
Summer	-0.068**	0.004	0	0.084**	-0.072**	-0.194**	0.036*	0.007	0.036*	-0.078**	-0.051**	-0.065	-0.014*	0.006	0.051	-0.012	1	
Transition	8.00E+02	-0.305**	0.039*	-0.050**	0.016*	0.320**	0.305**	0.307**	-0.01	-0.395**	0.053**	-0.059**	0.029*	0.280**	0.191**	-0.131	-0.644	1

**p<0.05; *p<0.1

Appendix 6 **Correlation matrix for early post-weaning weight gain (G4)**

	G4	Year	Dage	Dummy A	Dummy B	g	m	s	sex	BD	ww	age11	BW	G3-rain	EPWWrain	TempVarEPW	Summer	Transition
G4	1																	
Year	-0.169**	1																
Dage	0.048**	-0.214**	1															
Dummy A	-0.083**	0.020*	0.093**	1														
Dummy B	0.076**	-0.064**	0.314**	-0.704	1													
g	0.103**	0	-0.004	-0.019	0.008	1												
m	0.026*	0.006	0.01	-0.062	0.05	0.399	1											
s	0.044**	-0.002	0.018*	-0.059**	0.051	0.388	0.935**	1										
sex	-0.091**	0.004	-0.007	0.004	-0.002	0.007	0.01	0.011	1									
BD	0.195**	-0.059**	0.058**	-0.134**	0.194	-0.276	-0.698**	-0.653**	-0.043**	1								
ww	-0.139**	0.079	0.055**	0.198**	-0.145	0.268	0.515**	0.493**	-0.154**	-0.692**	1							
age11	-0.189**	-0.04	-0.053**	0.127**	-0.193	0.29	0.684**	0.645**	0.038**	-0.992**	0.680**	1						
BW	0.110**	-0.094**	0.146**	0.064**	0.08	0.188	0.086**	0.097**	-0.271	0.1	0.185**	-0.090**	1					
G3-rain	0.008**	0.092**	0.011	0.052**	-0.016	-0.021	0.002	-0.002	0.002	-0.067**	0.031*	0.059**	-0.004	1				
EPwwrain	-0.029**	0.066**	-0.073	0.045**	-0.089	0.152	0.339**	0.023	-0.546	0.387**	0.549**	-0.549**	-0.076**	0.197**	1			
TempVarEPW	-0.126**	0.045**	-0.008	0.004	0.024	-0.094**	-0.196**	-0.183	-0.006	0.306**	-0.252	-0.315**	0.065**	-0.219**	-0.652**	1		
Summer	-0.106**	0.004	0	0.084**	-0.072	-0.194**	0.036*	0.007	0.036	-0.078	-0.001	0.082**	-0.074**	0.029	0.052**	-0.021*	1	
Transition	-0.056**	-0.305**	0.037*	0.050**	0.016	0.320**	0.305**	0.307	-0.01	-0.395	0.335	0.416**	0.029*	-0.036*	0.184**	-0.176**	-0.644**	1

$^{**}p<0.05$; $^{*}p<0.1$