AN INTEGRATED SYSTEM OF GROWTH TRAIT IMPROVEMENT IN BEEF CATTLE UNDER COMMUNAL MANAGEMENT CONDITIONS

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BLOEMFONTEIN
December 2000

DECLARATION

*I, **JAMES MULAUDZI**, do hereby declare that this research project submitted for the degree **Master of Technology: Agriculture** is my own independent work that has not been submitted before to any institution by me or anyone else as part of any qualification.*

.... 18/04/2001

Signature of Student *Date*

DEDICATED TO MY FAMILY

- Mother, for your love, support and continuous guidance and confidence in me throughout my life.
- Harry, for your brotherly advice, love and support over the years.
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ABBREVIATIONS

BW	Body weight
WTS	weights
LW	live weight
HG	heart girth
WH	wither height
cm	centimetre
Kg	kilogram
Kg/d	kilograms per day
g	gram
%	percentage
SD	standard deviation
Mo	months
D	days

PREFACE

The objective of this study was to characterise live body measurements in communal beef cattle, and to derive prediction equations for live weight using body measurements. The reasons were to determine growth of cattle in relation to the corresponding environment and to improve marketing of cattle. Growth can be improved by improving the environment under which they live and by crossing genetically superior animals. Designing a cheap method to determining live body weight rather than the unaffordable weighing scales can effect marketing under communal conditions. It was therefore favourable in this study to derive prediction equations using heart girth and wither height. Although the results of this study did not finally make the designation of measuring tapes, they laid the foundation for future intervention.

This dissertation is presented in the form of scientific publications and was compiled using the instructions of the Journal of *Tropical Science*. In this thesis chapter one is a general introduction, while chapter two and chapter four contain literature reviews focusing on the environmental factors affecting pre- and post-weaning growth traits, and the relationship between body weight and body measurements. Chapters three and five focus on linear body measurements of beef cattle under communal management conditions, and give an estimation of live body weights from body measurements. Chapter six constitutes a general conclusions. Chapters three and five are the extensions of two short papers published in the proceedings of the South African Society of Animal Science. The modifications and additions represent the accumulated wisdom obtained from an additional two months of data collection. Although every effect is made to limit repetition, the inclusion of two articles made it impossible especially with regards to references, and materials and methods.

CHAPTER 1

GENERAL INTRODUCTION

In the past, indigenous cattle in South Africa (SA) were mainly used as foundation stock for upgrading with *Bos taurus* cattle, which were thought to be superior. These attempts failed in the tropics and subtropics and attention was focused on the development of various indigenous cattle breeds (Kars, Erasmus & Van der Westhuizen, 1994). The introduction of new breeds, in an attempt to improve the indigenous breeds has become a common practice. This has resulted in a dramatic decrease in the number of pure indigenous cattle. The Nguni and Afrikaner represent the two indigenous Sanga cattle breeds of South Africa, with Pedi described as a relative or variant of Nguni. Presently, commercial beef producers are showing renewed interest in the indigenous breeds, especially Nguni, owing to growth and favourable reproduction characteristics under adverse conditions such as drought and parasite burdens.

Indigenous cattle play an important roe in the traditional subsistence style of farming. Milk production for sale and household consumption is of overriding importance. Draft power and manure is of major importance to farmers. Meat production may have to be considered as a by-product until such time as marketing and price infrastructure have been developed to increase the economic motivation to produce meat for increased income. In the recent past, lobola was a system used to move cattle from one herd to another, thus preventing inbreeding. Cattle are also used as some form of savings and as an insurance against unforeseen events.

Although genetic improvement of traditional livestock may not necessarily be the top priority for improving their productivity, the introduction of new breeds may provide the trigger and focal point for other developmental changes that could contribute more to overall productivity than the new breed <u>per se</u>. The breed to be introduced should lead to a medium-term improvement in productivity and should have similar or better resistance to environmental stress than indigenous breeds. The possible advantage of crossing local African breeds is that there would be little or no loss of resistance to environmental stress.

The objective of this study is to develop an integrated system of growth trait improvement under communal management conditions. Matters of great concern include body measurements to improve markets for cattle and to develop baseline data for future intervention programmes.

CHAPTER 2

ENVIRONMENTAL FACTORS AFFECTING PRE- AND POST-WEANING GROWTH TRAITS

2.1 INTRODUCTION

Growth is defined as a maturation of the reproductive system, as well as an increase in body size and weight, and is affected by many factors such as genetics, nutrition and management, and is accelerated or delayed by environmental factors (Heinrichs & Hargrove, 1987; 1994). Heinrichs, Rogers and Cooper (1992) define growth as a natural expansion process whereby an animal increases in external size in all directions at a rather uniform and constant rate. It is understood that growth is facilitated by the use of body measurements and other treatments (Heinrichs *et al.*, 1992).

2.2 BREED TYPE

2.2.1 Pre-weaning growth traits

Differences between breeds of calves were found at birth and at weaning (Reynolds, DeRouen & Koonce, 1982; Baker, Long, Posada, McElhenney & Cartwright, 1989). At birth Nguni calves were 1.83kg lighter than Pedi calves, but at weaning, Nguni calves were 22.14kg heavier than Pedi calves (Lubout, Lepen & Venter, 1986). Brahman-sired calves were heavier at birth than Hereford-sired calves, but calves from Brahman dams were lighter than Hereford-dam calves (Roberson, Sanders & Cartwright, 1986) at birth. At weaning, Brown Swiss weighed 200.9kg and Shorthorn 191.7kg, while Ayrshire calves were the lightest at 184.2kg (Heinrichs & Hargrove, 1994). Among straightbreds, Angus calves were the oldest at weaning and Brahman calves were the youngest (Reynolds *et al.*, 1982). Afrikaner X Brahman and Brahman X Afrikaner were similar at weaning: 194.6kg compared to 194.2kg (Roberson *et al.*, 1986). In conclusion, Baker *et* *al. (1989)* stated that Holsteins are the heaviest followed by Brahmans and Angus. Herefords are then heavier than Jerseys at all ages.

2.2.2 Post-weaning growth traits

Nguni calves were 21.9kg and 30.5kg heavier than Pedi at 365 and 540 days respectively (Lubout *et al.*, 1986). At 540d and 25mo, Shorthorn were 9.4kg and 2.8kg lighter than Brown Swiss, and 40.1kg and 49.9kg heavier than Ayrshire at the same age. Ayrshires were the lightest at 388.7kg and 492.3kg for 540d and 25mo (Heinrichs & Hargrove, 1994). Holsteins gained less at 360d, but from the period of 360 to 450d, Holsteins and Brahmans were the fastest gaining among straightbreds. Brahman X Holstein crosses had the fastest gain during the period 360 to 450d. Holsteins were the heaviest among straightbreds followed by Brahmans and Angus, with Hereford then Jerseys being the lightest (Baker *et al.,* 1989).

2.3 PARITY

2.3.1 Pre-weaning growth traits

Parity influences both weight of animals and weight of their offspring. Body weight increases with increasing number of parity at all ages. Body weight increased from parity one up to parity five and six and then started to decline at parity seven. During week seven and during the postparturition period, body weight increased respectively by 11.8% and 12.1% for second-parity cows, and by 21.0% and 21.6% for third-parity cows. It increased by 23.2% and 22.3% for fourth-parity cows, by 25.5% and 25.1% for fifth- and sixth-parity cows, and 26.5% and 30.0% for seventh-parity cows compared with the first-parity heifers (Kertz, Reutzel, Barton & Ely, 1997). However Negash (1999) found a fluctuating pattern. Body weight increased from parity one to three, declined by 20kg at parity six and increased by 24kg at parity seven, with a peak body weight of 542kg at parity seven. Enevoldsen and Kristensen (1997) found a difference of 53kg between first and fifth or greater lactations for body weight, while Negash (1999) found more than 68kg difference from the same parities.

The effect of dam parity on birth weight of offspring follows a different pattern. The birth weight of female calves was seven to eight percent higher for calves born from second- and third-parity cows than calves born from heifers. In subsequent parities, female calves had a lower birth weight and were approximately one kilogram heavier than those born from heifers. Bull calves followed a similar pattern of increased birth weight for those born from second- and third-parity cows, but only calves born from cows in seventh and greater parities experienced a considerable decrease (9.5%) in birth weight (Kertz, Barton & Reutzel, 1998). Negash (1999) found that birth weight increased from 39.5kg at parity one to 41.1kg at parity six and seven. According to Van Zyl, Schoeman and Coertze (1992) milk production of the dam is the most important factor that influences pre-weaning growth traits. Milk production of dams increases significantly from the first to the third lactation, but not thereafter (Clutter & Nielsen, 1987).

2.3.2 Post-weaning growth traits

Consumption of milk may have a slightly negative effect on post-weaning gains, but still results in a greater weight per day of age to slaughter (Neville *et al.* as cited by Clutter & Nielsen, 1987). The pre-weaning maternal environment appears to have a major effect on the subsequent post-weaning gains of replacement heifers. Estimates of maternal influence on pre-weaning growth show a definite advantage for calves from high-milking females. Of the 16.9kg difference in weaning weight between high and low milking groups, 10.6kg were maintained through the 280d feedlot period to slaughter (Clutter & Nielsen, 1987). Therefore it cannot be ruled out that post-weaning growth also increases from parity one to three and declines thereafter.

2.4 AGE

2.4.1 Pre-weaning growth traits

Generally, body weight of cattle increases with age. The pre-weaning daily body weight gain was linear at 0.82 to 0.92. However, the relative daily gain was much greater at an earlier age, presumably because of the lower maintenance requirement at a smaller BW. For instance, 0.92kg of daily gain at 90kg has a much greater relative BW increase than the 0.92kg of daily gain at 450kg of BW (Kertz *et al.*,1998).

Age of dam influences birth and weaning weight of calves (Fordyce, James, Holroyd, Beaman, Mayer & O'Rourke, 1993). Heifers mated at 13-15 months of age had lower birth weights and weaning weights than those from heifers mated at 25-27 months. The main reasons for these differences seem to be the higher stress experienced by heifers (birth weight) and lower milk production owing to reduced udder development (weaning weight) (Rust & Van der Westhuizen, 1994). Birth and weaning weight increased with dam age up to seven years and nine years respectively and then declined gradually for older dams (Roberson *et al.*, 1986).

2.4.2 Post-weaning growth traits

The effect of dam age on post-weaning growth is not clear. Dam age is more significant for pre-weaning than for post-weaning growth traits. Since birth weight is positively correlated to yearling and mature weights, selection for birth weight may improve these post-weaning growth traits (Kars *et al.*, 1994). Although post-weaning growth is not directly dependent on the milk status of the dam, Clutter and Nielsen (1987) indicated that progeny of high-milking dams (and/or of older dams) maintained 63% of the advantage in weaning weight through the post-weaning feeding period to slaughter.

2.5 SEX

2.5.1 Pre-weaning growth traits

Male calves were heavier than females at birth and weaning (Fordyce *et al.*, 1993; Reynolds *et al.*, 1982; Kars *et al.*, 1994; Roberson *et al.*, 1986; Kertz *et al.*, 1997; Dinkel, Tucker & Marshall, 1990). Nguni bulls were 7.3% and 8.8% heavier than heifers at birth and weaning respectively (Kars *et al.*, 1994), while Kertz *et al.* (1997) reported an 8.5% greater mean birth weight in bulls than heifers. Nguni bull calves were two kilograms heavier than heifers, while Pedi were one kilogram heavier at birth. At 205 days, Nguni bulls were 18kg heavier while Pedi bulls were 20kg heavier (Lubout *et al.*, 1986). Kassa-Mersha and Arnason (1986) and Reynolds *et al.* (1982) found that bulls were respectively 13.1kg and 16.6kg heavier than heifers at weaning. Dinkel *et al.* (1990) found that bulls were heavier and more efficient at weaning than heifers, apparently because of higher milking breed-groups of dams, which were able to provide additional energy to meet bulls' demands without increased energy consumption.

2.5.2 Post-weaning growth traits

Bulls were also heavier than heifers at 365 and 540d (Kars *et al.*, 1994; Kassa-Mersha & Arnason, 1986). Nguni bulls were 7.9% and 4.8% heavier than heifers at 365 and 540d of age respectively (Kars *et al.*, 1994). Nguni bull cattle were 16kg heavier than heifers, while Pedi bull cattle were 14kg heavier at 365d of age (Lubout *et al.*, 1986). At 540d, Nguni were 13kg heavier and Pedi were two kilograms heavier than heifers. At 24mo of age, Kassa-Mersha and Arnason (1986) revealed that gains in corresponding differences were estimated at 17.6kg and 4.5kg respectively in favour of the male sex.

2.6 SEASON

2.6.1 Pre-weaning growth traits

Change in seasons and the season of birth influence the growth of cattle. Kassa-Mersha and Arnason (1986) found that growth during the rainy seasons was approximately 10kg less from birth to weaning. Calves born later in the rainy season reached the eight-month weaning age in winter, and drought during the suckling period caused a natural stagnation in their normal growth. Month of birth also affects growth. December-born calves weighed one kilogram heavier at birth than November-born calves and weighed three kilograms and six kilograms less at weaning in Nguni and Pedi respectively (Lubout *et al.*, 1986). Negash (1999) found that winter-born calves had the highest birth weight, the reason being that calves were given supplements (semi-intensive management). Weaning weight of calves decreased by 2.86kg/week for calves born after 1st October, suggesting that the calving season for beef cattle should commence as early as possible in spring. Cattle should be mated so that birth coincided with the emergence of pastural spring growth (De Waal,1990).

2.6.2 Post-weaning growth traits

There is an inverse relationship between weaning weight and post-weaning growth traits for seasonal effect. Calves born in summer reach the yearling weight in summer and vice versa. Therefore, summer-born calves are heavier at 365d than winter-born calves (Kassa-Mersha & Arnason, 1986). During early summer, the post-weaning body weight of heifers started to respond to the increase in nutritive value of the veld and reached maximum body weight in autumn. During the following winter, heifers maintained their body condition or, at worst, experienced a slight drop in body condition, which after pasture growth recommenced in early summer (De Waal, 1990). December-born cattle were slightly heavier than November-born cattle at 365 and 540d of age (Lubout *et al.*, 1986).

2.7 CONCLUSION

Body weight is influenced by various environmental factors such as sex, parity, age, breed type and season. Body weight increases with increasing number of years and dam parity. Male cattle are heavier than females at all age groups within the same breed. Cattle improve their weights in summer and therefore supplementary feeding in winter can further improve weight.

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CHAPTER 3

LINEAR BODY MEASUREMENTS OF BEEF CATTLE UNDER COMMUNAL MANAGEMENT CONDITIONS

3.1 INTRODUCTION

In beef cattle, growth rate and efficiency of converting feed into body weight gains are an important economic traits (Park, Bishop & Davis, 1993). Yerex, Young, Donker and Marx (1988) found a very negative relationship between feed efficiency and body measurements. Wither height has been studied because it reflects skeletal growth while heart girth is important in estimation of body weight (Heinrichs, Rogers & Cooper, 1992). Body dimensions at any given age are the result of all the factors, including various genetic and environmental effects, that determine development of the individual (Heinrichs & Hargrove, 1994; Park *et al.*, 1993).

The majority of linear measurements are found in the areas that measure growth and carcass traits. Height and other measures of long-bone growth are reported to be absolute because of change in breed genotype (Gosey, 1984; Heinrichs *et al.*, 1992). Linear body measurements have been used to contrast shape and developmental pattern, find relationships of certain objective measurements with weight, and examine the relationship between cow size and performance of progeny (Park *et al.*, 1993). However, Bonczek, Richardson, Moore, Miller, Owen, Dowlen and Bell (1992) found live weight and body dimensions of heifers to have little value for the prediction of future yield. Therefore the objective of this study was to characterise live weight and linear body measurements under communal management conditions.

3.2 MATERIALS AND METHODS

3.2.1 Study site

The study was conducted at Muledzhi Communal Dip Tank, situated 50km north of Thohoyandou in the Northern Province of South Africa. The area is located at 22, 41°S latitude and 30, 16°E longitude. Muledzhi consists of four villages, namely Tshithuthuni, Vuvha, Muledzhi and Mapate. Veld type is classified as savannah-mixed-bushveld. The climate is dry tropical, characterised by a hot, wet summer period (wet season) followed by a cold, dry winter period (dry season).

3.2.2 Animals and management

Cattle were Nguni type with 5.29% other breeds including Brahman, Bonsmara, Simmentaler, Jersey, Friesian and Afrikaner. Management practices included dipping cattle every week in summer and fortnightly in winter, but due to the current financial limitations, the system seems to be changing to fortnightly dipping throughout the year. Traditional medications are still used to control diseases. Diseases such as anthrax, blackquarter and contagious abortion are controlled by the state. Cattle graze in the natural communal land with no supplements except during drought, and are bred by natural mating to calve every season of the year. Branding has been the main method of identifying cattle until recently when eartagging was also introduced by this study and were also used to fight against theft.

3.2.3 Measurements

All cattle were eartagged at the beginning of the study. Cattle were weighed using a mobile weighing scale (KD1A DATA COLLETA) with its platform placed inside the crushpen. At the same time heart girth (HG) was measured using a Glassfiber (a plastic-coated fibre tape) just posterior to the shoulder. Wither height (WH) was measured using a wooden tape that was attached to a horizontal sliding bar of a restraining chute above the animal, and which is equipped with a level. One person was responsible for measuring HG and WH. All measurements were taken during September, October and December (1999) and May and July (2000). No data were recorded from January to April 2000 due to the heavy rainfall in the Northern Province

3.2.4 Data analysis

Data were analysed using the General Linear Models procedure of SAS (SAS, 1989). The following models (Model I for weight, II for HG and III for WH) were used to analyse sources of variation.

Model I: $Y_{ijklm} = \mu + R_i + S_j + A_k + M_l + RA_{ik} + RB_{im} + BA_{km} + SA_{jk} + E_{ijklm}$, where

μ = overall mean

R_i = effect of village

S_i = effect of sex

A_k = effect age

M_l = effect of month

RA_{ik} = interaction between villages and age

RB_{im} = interaction between breed and villages

BA_{km} = interaction between breed and age

SA_{jk} = interaction between sex and age

E_{ijklm} = random error effect, E's assumed NID $(0, \sigma^2)$.

Model II: $Y_{ijklm} = \mu + B_i + S_j + A_k + M_l + SM_{jl} + BA_{ik} + SA_{jk} + E_{ijklm}$, where all terms are defined as in Model I except for the interaction between sex and month (SM_{jl}).

Model III: $Y_{ijklm} = \mu + R_i + S_j + A_k + M_l + SA_{jk} + AM_{kl} + E_{ijklm}$, where all terms are also defined as in Model I except for the interaction between age and month (AM_{kl}).

3.3 RESULTS AND DISCUSSION

3.3.1 Environmental factors affecting live body weight

Villages: The analysis of variance and least-squares means ± standard errors for WTS are indicated in Table 3.1 and Table 3.2. The villages influenced (P<0.001) WTS of cattle. Tshithuthuni village had the highest WTS (322.39kg) compared to other villages, while Vuvha had the lowest (211.76kg). Better pasture conditions at Tshithuthuni village may be the reason for higher WTS, as indicated earlier by Mulaudzi, Nesamvuni, Ramanyimi and Taylor, (2000). De Waal (1990) also reported WTS differences mainly due to feed shortage, availability and quality. In the case of communal grazing areas, the grazing area per herd of cattle influenced WTS gain. Carrying capacity markedly decreased due to overgrazing and high density of unpalatable vegetation. The number of cattle available at villages two, three and four in relation to their grazing areas compared to Tshithuthuni village may have caused overgrazing, which might explain the for lower WTS.

Sex: Live weights were affected (P<0.001) by sex of cattle. Bulls were 21.09kg heavier than cows (Table 3.2). This is in accordance with the results of Gosey (1984); Kertz, Reutzel, Barton and Ely (1997); Lubout, Lepen and Venter, 1986) and Park *et al. (1*993). Bulls gain weight more rapidly than cows.

Age: Age of cattle influenced (P<0.001) WTS. Body weight increased linearly with age of cattle (Table 3.2 and Figure 3.1), which confirms findings by Heinrichs *et al. (1*992) and Heinrichs & Hargrove (1987; 1994) and other reports in the literature. Body weight increases by lower margins when cattle are at their early ages of life and by higher margins as they grow older, which suggests that Nguni-type cattle grow slowly at an early age and vice versa. Body weight increased by 47kg, 53kg, 81kg and 61kg respectively between the ages of one and two, two and three, three and four, and four and five years. Poor milk production of Nguni dams may be the reason for lower weight gains from their calves before they are one year of age. Therefore, supplementary feeding to cattle during that stage may improve growth. The reason why cattle increase in weight by 81kg between three and four years seems to be that Nguni cows in the communal areas experience their first pregnancy when they are three years of age. Roberson, Sanders and Cartwright (1986) revealed that cattle weights increase with age up to nine years and then start to decline.

Month: The effect of month influenced (P<0.001) WTS. Body weights were highest during May and lowest during September. The heavy rainfall, which occurred from January to April at Muledzhi and the rest of the Northern Province improved pastures during the month of May. According to the Ministry of Agriculture (1998), under the communal setting cattle are subject to confines of both feed availability and continuous stress from tether to avoid crop damage. This is similar to the circumstances of this study. Cattle are confined during summer months, thus the higher WTS during May are not surprising.

Interaction: Village and age interaction influenced (P<0.001) BW. Tshithuthuni village had the highest WTS within all ages followed by Muledzhi, while Vuvha had the lowest (Table 3.3), which supports earlier reasons for better pastures at the village with the lower carrying capacity (Ministry of Agriculture, 1998; Kassa-Mersha & Arnason, 1986). Also, at the age between three and four years, cattle increased their WTS by bigger margins within all villages except village three (Vuvha). After these ages, cattle start to reduce their rates of increment.

The influence of village and breed interaction was highly significant (P<0.001). Nguni cattle had lower WTS within all villages except in village three, probably because of the very low number of Nguni cattle (two vs 273) compared to other breeds. Differences between breeds of cattle were found for WTS due to differences in breed genotypes (Morsy, El-Feel, Macarechian & Hassan, 1997; Baker, Long, Posada, McElhenney & Cartwright, 1989).

Breed and age interactions affected (P<0.001) BW of cattle. Body weight increased linearly with age within all breeds, although the Nguni-type breed was 0.86kg heavier than other breeds at the age of three years (Table 3.5).

Sex and age interactions influenced BW (P<0.01). At all ages, bulls were heavier than cows (Table 3.6). In bulls, WTS increased by bigger margins from the age of two to four years.

3.3.2 Environmental factors affecting heart girth

Breed type: The effect of breed type on HG was highly significant. The Nguni breed type had a 75.24cm smaller (P<0.001) HG than the other breeds. Heinrichs and Hargrove (1994) found that Brown Swiss had the greatest HG followed by Shorthorn, while Ayrshire had the smallest. According to Yerex *et al. (1*988) selection of animals based on higher HG would result in highly productive and efficient animals. Inbreeding may also contribute to progeny with a small HG in the communal setting, but the use of bulls with a larger HG, like Brahmans, can result in cattle with greater HG (size).

Sex: The effect of sex on HG was not significant. However, bulls seem to be 11.4cm greater in HG than cows. This is in line with results in other reports in the literature, for example Benyi (1997) and Davis, Swett and Harvey (1961).

Age: Heart girth increased linearly with age of cattle (Table 3.2 and Figure 3.1). Like WTS, HG increased by lower margins when the cattle were in the early ages of life and by bigger margins when they grew older. Heart girth increased by 59cm, 53cm, 63cm and 67cm respectively between the ages of one and two, two and three, three and four, and four and five years. Heinrichs and Hargrove (1994) also found HG to increase with age of cattle.

Month: The effect of month influenced (P<0.001) HG. Heart girth was highest during May and lowest during September. Because HG is a widely used proxy of WTS

(Enevoldsen & Kristensen, 1997) and WTS depend on pasture, therefore the rainfall from January to April improved pastures during the subsequent month of May, and this seems to also be the reason for higher HG. The Ministry of Agriculture (1998) added that fodder species available and the occurrence of diseases are some factors that affect HG.
Interaction: Breed and age interactions were significant for HG. Heart girth increased linearly with age within all breeds (Table 3.5). Ayrshire, Brown Swiss and Shorthorn had their HG increase with age up to 25 months, but Brown Swiss had the greatest HG followed by Shorthorn at almost all ages (Heinrichs & Hargrove, 1994).

Sex and age interactions were significant for HG. The effect of sex and age interaction on HG showed a fluctuating pattern between the two sexes but increased linearly within each sex. At the ages of one, two and four, cows were 13.9cm, 23.68cm and 2.61cm larger in HG than bulls. At age three and five, bulls were 8.08cm and 89.77 cm greater in HG than cows. The Ministry of Agriculture (1998) found that cows were 4.5cm greater in HG than bulls, but the difference was age related. Age of cows was very high (18 vs two years) compared to the age of bulls.

The effect of sex and month interaction influenced HG but was not significant. Like WTS, HG was highest during May within all sexes, but cows were 3.8cm greater in HG than bulls during September (Table 3.7).

3.3.3 Environmental factors affecting wither height

Village: The influence of village on WH was not significant, which supports the study by the Ministry of Agriculture (1998). Wither height between the two zones (deep soil and coral rag zones) of Pemba was found to be 102.5cm and 102.0cm. In this study, however, Muledzhi village had the highest WH while Tshithuthuni had the lowest (Table 3.2).

Sex: Sex affected ($P<0.001$) WH. Bulls were greater in WH than cows with bulls having a 4.42cm greater WH than cows (Table 3.2). The difference in WH between the two sexes is consistent with other studies in the literature, for example Ministry of Agriculture (1998).

***Age*:** Wither height increased linearly (P<0.001) with age of cattle (Table 3.2 and Figure 3.1). Wither height increased by eight centimeters, eight centimeters, three centimeters and 11cm respectively at the ages of one to two, two to three, three to four, and four to five years. Conversely, Heinrichs and Hargrove (1987; 1994) found that WH increased with age of cattle until the age of two years and then started to decline. This varies with the results of Kertz *et al. (1*998) who reported that there is an additional 14% increase in WH from two years until maturity. The standard WH suggested by Kertz *et al.* (1997) was 138cm to 141cm, which is greater than the mean 112cm obtained from this study. The difference could therefore be breed related.

Month: The influence of month on WH was not significant. Like HG, WH was highest during May and lowest during July. The rainfall that improved pasture during May may be responsible for this higher WH. This contradicts the results of Park *et al.* (1993) who reported that plane of nutrition had little effect on WH.

Interaction: Sex and age interaction was significant for WH. At the age of one to two years, cows were 1.27cm and 0.38cm taller in WH than bulls, but at three years, bulls were taller in WH than cows (Table 3.6).

Wither height was affected (P<0.001) by the interaction between age and month. During May, all cattle at the age of one to two years had a higher WH than during the other months. During September, cattle at the age of four and five years had a higher WH compared to other months (Table 3.8).

3.4 CONCLUSION

Pasture availability and quality, as well as overgrasing caused a major variation between villages. Major improvements can be effected by strategic culling and selling coupled with winter feed supplementation. Cattle generally improve body condition in response to the prevailing rainfall pattern. Results of this study will form a baseline on which future intervention will be based.

Table 3.1: Analysis of variance for weight, heart girth and wither height of beef cattle.

	WTS (weights)		HG (heart girth)		WH (wither height)	
Sources	**DF**	**MS**	**DF**	**MS**	**DF**	**MS**
Breed			1	225163.34***		
Village	3	49822.35***			3	173.18 NS
Sex	1	93569.84***	1	28935.01 NS	1	3403.79***
Age	4	286745.65***	4	306764.05***	4	11921.64***
Month	4	81711.75***	4	4097006.93***	3	151.85 NS
Village X Age	12	13275**				
Village X Breed3	4	2806.56***				
Breed X Age	4	16588.60*	4	41408.70***		
Sex X Age	4	24290.57**	4	256825.05***	4	1700.84***
Sex X Month			4	9889.43 NS		
Age X Month					12	917.83***

***P<0.001 *P<0.10 NS= non-significant

**P<. 01 R^2 (WTS)= 0.55 R^2 (HG)= 0.72 R^2 (WH)= 0.30

Table 3.2: Least-squares means ± standard errors (LSM±SE) for weight, heart girth and wither height.

	WTS		HG		WH	
Factor	**No.**	**LSM±SE**	**No.**	**LSM±SE**	**No.**	**LSM±SE**
μ	**1222**	**251.31±102.52**	**1374**	**215.44±161.45**	**982**	**112.31±16.57**
Breed 1Nguni			1305	217.44±2.82		
2Others			69	292.68±13.06		
Sex 1(Males)	461	276.77±8.62	515	260.78±7.82	390	115.24±0.87
2(Females)	761	255.68±8.44	859	249.34±6.82	592	110.82±0.92
Age 1(<1yr)	168	152.06±21.88	195	137.18±24.33	116	97.99±1.67
2(>1-<2yrs)	306	199.17±12.71	362	196.64±11.79	256	106.24±0.92
3(>2-<3yrs)	287	252.04±12.10	322	249.41±11.50	244	114.44±1.03
4(>3-<4yrs)	212	333.77±11.84	229	312.41±11.26	181	117.63±1.10
5 (>5yrs)	249	394.10±11.01	266	379.68±11.42	185	128.83±1.50
[1]**Village** 1	510	322.39±10.20			468	112.11±0.78
2	328	284.02±10.02			211	114.02±1.08
3	275	211.76±25.36			222	112.65±1.02
4	109	246.73±12.75			81	113.3±1.57
Month May	212	299.64±9.42	345	351.93±7.93	319	114.03±0.87
July	258	252.69±9.13	258	290.63±8.25	227	111.75±1.28
Sept.	300	246.85±8.82	302	289.05±7.52	289	112.98±1.12
Dec.	294	254.53±9.18				

[1]Village 1= Tshithuthuni, 2= Muledzhi, 3= Vuvha, 4= Mapate 2 Others (Brahman, Bonsmara, Simmentaler, Jersey, Friesian and Afrikaner)

Table 3.3: Least-squares means ±standard errors (LSM±SE) for weight by village and age interaction.

Village	Age	No.	LSM±SE
1	1	75	206.45±20.92
1	2	136	253.45±14.19
1	3	135	316.43±14.77
1	4	68	408.80±16.63
1	5	96	426.38±12.71
2	1	33	151.47±23.57
2	2	79	215.63±12.94
2	3	79	282.54±11.09
2	4	73	354.58±10.90
2	5	64	415.86±13.09
3	1	44	119.08±34.37
3	2	58	143.62±29.29
3	3	53	200.59±28.89
3	4	55	255.92±26.21
3	5	65	339.61±26.04
4	1	16	130.77±29.67
4	2	33	183.98±15.78
4	3	20	208.60±19.31
4	4	16	315.72±22.00
4	5	24	394.56±18.49

Table 3.4: Least-squares means ±standard errors (LSM±SE) for weight by village and breed interaction.

Village	**Breed**	**No.**	**LSM±SE**
1	1	495	244.28±3.72
1	2	15	400.50±19.83
2	1	292	244.39±4.59
2	2	36	323.65±14.29
3	1	273	237.18±4.63
4	1	99	236.78±7.30
4	2	10	256.68±24.25

Table 3.5: Least-squares means ± standard errors (LSM±SE) for weight and heart girth by breed and age interaction.

		WTS		**HG**	
Breed	**Age**	**No.**	**LSM±SE**	**No.**	**LSM±SE**
1	1	165	117.11±6.28	192	89.85±6.20
1	2	295	187.55±4.61	349	187.67±4.56
1	3	273	252.47±5.27	308	235.64±4.86
1	4	197	294.10±5.90	213	264.76±5.92
1	5	229	352.04±7.65	243	309.30±8.65
2	1	3	187.00±42.97	3	184.50±48.03
2	2	11	210.80±25.11	13	205.62±23.14
2	3	14	251.61±23.48	14	263.18±22.40
2	4	15	373.41±22.41	16	360.05±21.37
2	5	20	436.16±1932	23	450.05±18.76

Table 3.6: Least-squares means ± standard errors (LSM±SE) for weight, heart girth and wither height by sex and age interaction.

		WTS		HG		WH	
Sex	Age	No.	LSM±SE	No.	LSM±SE	No.	LSM±SE
1	1	76	155.98±22.74	92	130.23±25.28	62	97.36±1.98
1	2	143	203.03±13.46	164	184.80±12.77	131	106.05±1.21
1	3	137	254.06±12.73	50	253.20±12.47	104	116.05±1.41
1	4	79	338.84±13.57	82	311.10±13.89	69	118.10±1.66
1	5	26	431.93±15.65	27	424.56±17.90	24	138.63±2.78
2	1	92	148.13±22.29	103	144.13±24.70	54	98.63±2.17
2	2	163	195.32±13.18	198	208.48±12.46	125	106.43±1.28
2	3	150	250.02±12.80	172	245.62±12.42	140	112.83±1.28
2	4	133	328.67±1207	147	313.71±11.33	112	117.17±1.35
2	5	223	356.27±10.07	239	334.79±9.25	161	119.03±1.13

Table 3.7: Least-square means ± standard errors (LSM±SE) for heart girth by sex and month interaction.

Sex	Month	No.	LSM±SE
1	May	141	358.94±9.87
1	July	91	288.73±10.88
1	Sept.	128	289.07±9.76
1	Oct.	63	325.13±12.71
2	May	204	344.91±8.58
2	July	167	292.53±8.94
2	Sept.	174	289.03±8.37
2	Oct.	95	303.97±10.75

Table 3.8: Least-squares means ± standard errors (LSM±SE) for wither height by age and month interaction.

Age	Month	No.	LSM±SE
1	May	69	103.02±11.63
1	July	09	100.00±16.07
1	Sept.	14	90.43±7.48
1	Oct.	24	96.58±9.27
2	May	94	110.89±6.72
2	July	51	101.39±8.52
2	Sept.	72	102.36±8.87
2	Oct.	39	109.00±6.57
3	May	75	113.89±7.73
3	July	48	112.71±21.69
3	Sept.	97	112.90±12.69
3	Oct.	24	116.17±5.45
4	May	40	114.55±11.33
4	July	44	116.66±4.75
4	Sept.	70	119.39±6.40
4	Oct.	27	118.93±6.45
5	May	41	119.22±11.54
5	July	75	117.60±7.33
5	Sept.	36	134.17±49.09
5	Oct.	33	115.36±7.97

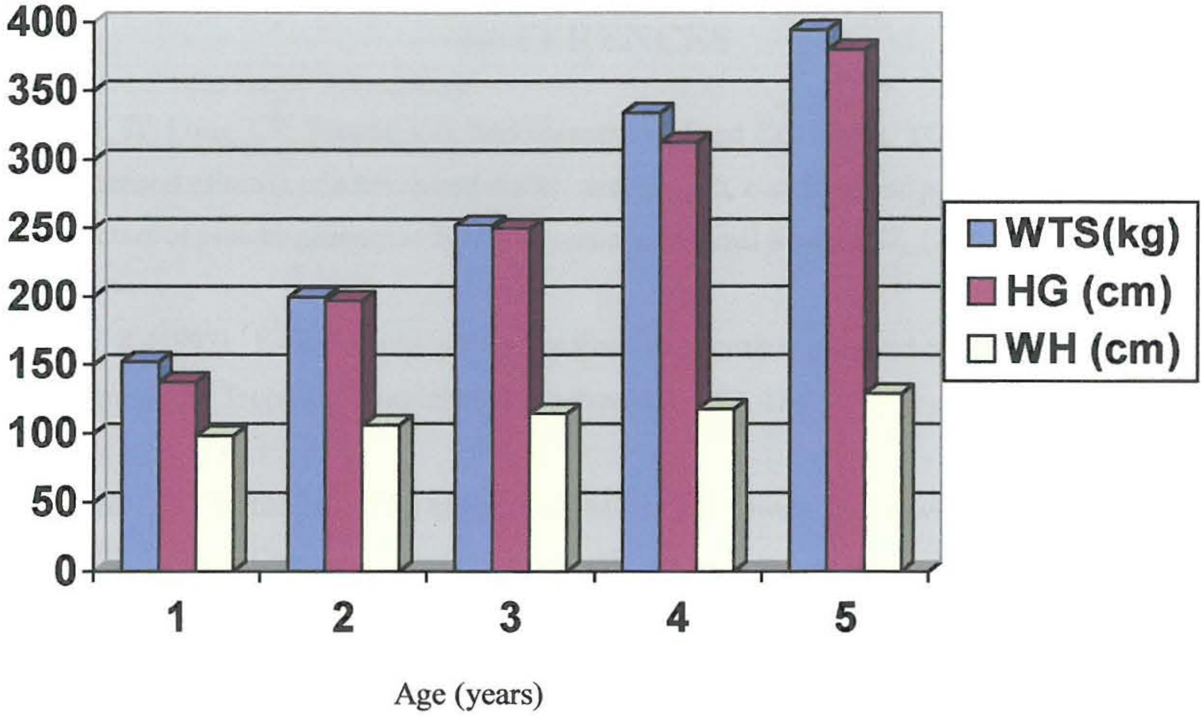

Figure 3.1: Live weight, heart girth and wither height in relation to age of beef cattle.

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CHAPTER 4

RELATIONSHIP BETWEEN BODY WEIGHT AND BODY MEASUREMENTS

4.1 INTRODUCTION

Body weight (BW) is a frequently recorded variable in animal and health investigations. It is the measurement exclusively used to evaluate growth, condition and the value of beef, and a basis for evaluating feed requirements for cattle (Otte, Woods & Abuabara, 1992). Normally it is determined with the aid of a scale. In field observations or rural areas, cattle scales are only found on some ranches, while mobile scales are difficult to transport, especially under poor road conditions (Mayaka, Tchoumboue, Manjeli & Teguia, 1995). However, cattle measuring tapes have been devised as an alternative means and they are easily available at a minimum cost (Otte *et al.*, 1992). Such measurements include heart girth, wither height and body length to estimate BW, but heart girth is generally accepted as the most satisfactory single variable (Benyi, 1997).

4.2 THE INFLUENCE OF ENVIRONMENTAL FACTORS ON WITHER HEIGHT

Wither height (WH) is an important measurement in measuring frame size (Morsy, El-Feel, Makarechian & Hassan, 1997) or conformation, and it is relatively easy to obtain with precision, because its anatomical locations are easy to identify (Wilson, Egan & Terosky, 1997). According to Enevoldsen and Kristensen (1997) skeletal development is progressive and relatively slow and therefore few measurements are needed to determine precisely a valid growth curve for an individual animal through interpolation and extrapolation. Every animal has an inherent mature body size and grows at a genetically controlled rate. Although influenced by environmental factors, there is little influence on the resulting mature body size (Heinrichs & Hargrove, 1987; 1994). Gosey (1984) maintains that skeletal development should be monitored using frame scores according to WH. Recent instruments for measuring WH include a metal tape attached to a horizontal sliding bar of a restraining chute above the animal (Morsy *et al.*, 1997) or are which is calibrated in ,645 cm intervals and equipped with a level (Heinrichs & Hargrove, 1994).

4.2.1 Age

Wither height increases with age of cattle. Approximately 50% of WH from birth until first calving at 24mo occurs during the first six months of life. An additional increase of 25% WH occurs in the seven- through 12-month segment of life, followed by a further 25% increase occurring at thirteen through 24 months of age. An additional 14% WH increase occurs from 24mo until maturity at parity three. Because one-half of the WH increase that occurs prior to first calving occurs during the first six months, this period is critically important in stabilising mature WH (Kertz, Barton & Reutzel, 1998). This change in WH due to age is similar in BW, which implies that BW can best be estimated from WH when age is included.

Correlations between WH and BW were higher for calves than for cows. Correlations from birth to 24mo were as follows: birth 0.69, 6mo 0.78, 12mo 0.70, 18mo 0.72 and 24mo 0.65 (Davis, Swett & Harvey, 1961). Correlations of immature measurements to performance at four months and eight months indicate that an increase in any single body dimension was associated with increased gains, weight and feed consumption (Gosey, 1984).

At the age of 25mo, Kertz *et al.* (1998) found WH to be 138cm, 132cm (in Penysylvinia field data), 131cm (research herds) at 30 to 35d postpartum over an 18-year period, 129cm (Israeli commercial herds) and 138cm in Holstein cattle (Wisconsin field data). The standard WH suggested by Kertz, Reutzel, Barton and Ely (1997) was 138cm to 141cm. The mean estimated WH at 6, 12, 18 and 24mo in cm for Ayrshire was 98.7, 114.4, 122.8 and 127.6 respectively, for Brown Swiss 102.6, 199.4, 128.7 and 134.0, and for Shorthorn 98.0, 113.6, 122.6 and 126.0 in the same order.

4.2.2 Breed type

Relationships between live weight and height may differ in different breeds due to breed genotypes (Morsy *et al.*, 1997). Correlations of WH and live weight were 0.73 for Shorthorn and 0.80 between WH and slaughter weights in beef breeds (Davis *et al.*, 1961). Brown Swiss had the highest WH followed by Ayrshire and then Shorthorn with the lowest (Heinrichs & Hargrove, 1994). Holstein and Jersey heifers had the highest and lowest weight:height ratios among purebreeds, with Brahman, Angus and Hereford respectively following after Holstein. Among crossbreeds, Holsteins and Jerseys also had the highest and lowest ratios respectively. Brahman, Hereford and Jersey followed Angus and Holstein in generation one (Baker, Long, Posada, McElhenney & Cartwright, 1989).

4.2.3 Parity

Parity by age was significant for WH at six months by 0.90 and by 0.95 from 15mo until the end of lactation (Bonczek, Richardson, Moore, Miller, Owen & Dowlen, 1992). Wither height averaged 138cm at first parity and increased by three centimeres from first to second parity. During the fifth and sixth parity, WH peaked at an additional two to three centimetres. The maximum WH was 144cm, and initial height for first-parity heifers was 138cm. Variability of WH due to parity was quite low and was one-third or one-fourth of the variability in BW (Kertz *et al.*, 1997). This change also occurs during lactation cases, because cows experience change in type of diet, amount of dry matter intake, body condition, BW and foetal development. The difference in the change in WH due to parity to change in BW is that BW, peaks at parity seven (Negash, 1999).

4.2.4 Sex

Wither height, like BW, is greater in bulls than heifers of the same age and breed. The mean WH and estimated live weight for bulls were 99.9cm and 162.9kg respectively and those for cows were 102.8cm and 179kg in the same order. The difference was related to sex and age. Age of bulls was generally low, therefore the low values for these quantitative variables are not surprising (Ministry of Agriculture, 1998).

4.2.5 Season

With little information on season, Bonczek *et al.* (1992) found that season by age on WH was highly significant at 6mo ($P<0.001$) and 18mo ($P<0.01$) until at interval after lactation ($P<0.05$). Park, Bishop and Davis (1993) found that plane of nutrition had little effect on WH.

4.3 LINEAR MEASUREMENTS FOR WITHER HEIGHT, GROWTH AND CARCASS TRAITS

Correlations between WH and hot carcass weight were low (0.23%), retail yield (0.30%), lean yield (0.23%) and carcass weight (0.23%) (Gosey, 1984) and this led to the conclusion that linear measurements are more correlated to weight than to percentage of carcass components.

Weight information alone does not indicate the composition of that weight. Height measurements, used in conjunction with complete performance records, could aid in evaluating the composition of weight taken at various stages of development. They might be helpful in describing and mechanising feeder cattle in commercial herds and in monitoring changes in skeletal size in seed stock herds. Within a workable range of skeletal sizes (from the standpoint of slaughter weights necessary to meet packer specifications), Gosey (1984) indicated that further increases in skeletal size would have no beneficial impact on net profit.

4.4 ESTIMATION OF LIVE WEIGHT FROM WITHER HEIGHT

Wither height has been used on many occasions with other body measurements to predict BW. This may be due to its low correlations with live weight e.g. 0.47 between BW before and rate of BW loss at calving (Markusfeld & Ezra, 1993) but before and after calving; correlation coefficient was higher (0.76) with a mean estimate BW of 485kg at 129cm. Wither height together with hip height predicts BW rather accurately (Enevoldsen & Kristensen, 1997). However the precision of these estimates might have been overestimated because the occurrence of multiple measurements per heifer was not sufficiently considered. Predictions from body size measurements of cows must be expected to explain less variability than in the case of heifers, because growth rate of cows is much slower.

Wither height, together with hip width, may be the best skeletal parameters to measure in certain instances because they are influenced the least by body condition (Heinrichs, Rogers & Cooper, 1992). As weight increases, bone and muscle develop first, followed by fat deposition (Gosey, 1984). It is important that growth recommendations be based on BW gains within the parameters of desired skeletal growth. The general idea is that WH in conjunction with other measurements yield better results than heart girth, but could not be recommended in practice due to the possible high degree of variability (Heinrichs *et al.*, 1992).

4.5 WITHER HEIGHT AND EFFICIENCY OF PRODUCTION

Large-size cattle are significantly taller than smaller cows, but they are less efficient (2.8%) than smaller-size cattle under extensive conditions (Yerex, Young, Donker & Marx, 1998; Markusfeld & Ezra, 1993). Cattle with short WH have a normal BW (Nicholson & Sayers, 1987; Markusfeld & Ezra, 1993) because short animals can efficiently utilise high-energy feed and lower protein. The nature of protein affects WH, but not BW (Markusfeld & Ezra, 1993). Bulls that are large in all measurements grow well on test. Tall and narrow bulls eat more and gain more but are less efficient than short, wide bulls under intensive conditions (Gosey, 1984). Large BW gains during early life without corresponding skeletal growth may result in impaired development and reduced milk production (Heinrichs *et al.*, 1992). This suggests that the use of indigenous Sanga cattle in breeding may have some beneficial effects.

Response to selection has been rapid and significant for BW and WH. Up to the third generation, BW and WH were significantly higher for larger frame cattle, but after the third generation, the differences between larger and smaller size cattle were 5.6cm for WH and 50.2kg for BW (Yerex *et al.*, 1988). This rapid selection coupled with selection for cattle resistance to ticks and strategic tick control can play a major role in developing an integrated improvement of growth traits. Wither height has two important roles, namely in the selection of the right skeletal size for breeding and finally in predicting BW for selling.

4.6 THE INFLUENCE OF ENVIRONMENTAL FACTORS ON HEART GIRTH

The establishment of more precise methods of estimating live weight from body measurements seems to have lagged during the last quarter of the previous century (Davis *et al.*, 1961). During 1904 few reports were published dealing with estimation of weight in cattle from tape-line measurements. Tape-line measurements for heart girth-weight relationships were published for different classes of cattle in varying degrees of condition. Apart from tapes, it was practice in New England 100 years ago for cattlemen to use a "girthing chain" in estimating growth and in connection with buying and selling. With the chain circumscribing the chest, the ring-makers made it possible to estimate live weight with sufficient accuracy to establish a basis for dealing, that was acceptable to both parties of a transaction.

More recently, a notable increase in interest and in research has occurred as is evident by countless reports dealing with the estimation of live weight in cattle using heart girth (HG) tapes. Recent measuring tapes include a plastic sewing tape (Mayaka *et al.*, 1995), a plastic-coated fibre tape (Wilson *et al*., 1997) and a flexible steel or cloth measuring tape and metal clippers used to measure HG immediately posterior to the shoulder (Park *et al*., 1993). Recent studies have been focused on determining changes in HG during the growth period of cattle (Wilson *et al*., 1997), correlating HG and BW and deriving prediction equations of BW using HG as a sole regressor, as well as assessing the accuracy thereof (Mayaka *et al*., 1995).

4.6.1 Age

Correlations between live weight and HG have been higher at weaning (up to 0.85) than at birth, which implies that prediction of live weight from HG is more reliable at weaning than at birth. Mayaka *et al. (1*995) found a correlation coefficient of 0.976 in ages 9-12 months. From birth to one month, Ayrshire calves were 80.9cm and Brown Swiss 83.1cm. Shorthorn had the smallest HG (Heinrichs & Hargrove, 1994). At the age of two weeks, Holstein calves had the greatest HG (Wilson *et al*., 1997).

Correlations between live weight and HG at 365d, 540d and mature ages were 0.78, 0.78 and 0.73 respectively (Davis *et al*., 1961), which is lower than at weaning. At 365d, HG's were 152.5cm, 146.2cm and 144.9cm for Brown Swiss, Shorthorn and Ayrshire respectively. At 540d and mature age respectively, HG's were 168cm and 183.5cm for Shorthorn, 169.7cm and 183.9cm for Brown Swiss and 163.0cm and 177.1cm for Ayrshire (Heinrichs & Hargrove, 1994).

4.6.2 Sex

Using geometric regression, Benyi (1997) found that HG accounted for 98% of the variation in live weight in both sexes, and supports his earlier findings that live weight could be estimated from HG with the same degree of reliability in bulls and cows. However, this contradicts the findings by Dlamini (1988) in indigenous Swazi cattle that HG is a more reliable predictor of live weight in males than in females. Mayaka *et al.*

(1995) found R^2 of 0.946 to 0.966 in males and 0.795 in females, which means accountability of variation in BW and HG is greater in males than females.

Park *et al.* (1993) found purebred Angus bulls to have higher HG than heifers. Bulls had 181.1cm on average and heifers had 168.8cm. Bulls were also larger, taller and heavier than heifers. The study by the Ministry of Agriculture (1998) revealed that cows were significantly superior to bulls with respect to these traits. Mean HG and estimated BW for bulls were 123.9cm and 162,9kg respectively, and for cows 128.4cm and 179kg in the same order. Age of bulls was generally low (range was two to three years for bulls and two to 18 years for cows) which confirms the lower values in bulls compared to cows.

4.6.3 Breed type

Correlations of HG and BW varied with different breeds and types of cattle, but were positive, highly significant, and of high magnitude in nearly all cases. In various studies reviewed, correlations from various breeds varied from 0.84 for Swedish cattle to 0.98 for Holsteins and Guernseys. Wilson *et al.* (1997) found a correlation of 0.95 in Holsteins and Jerseys.

4.6.4 Season

Little has been found regarding the influence of season on HG. Because of its correlation with body condition, which is highly influenced by season, it is considered that HG and season are also related. Body condition and HG were highly correlated at the end of the dry season, but over the period as a whole the relationship was poor (Nicholson & Sayers, 1987). Season had a highly significant influence on HG at six months, 15mo, first calving, end of lactation ($P<0.001$) (Bonczek *et al.*, 1992).

4.6.5 Parity

The influence of parity on HG was highly significant at 6 mo ($P<0.001$), 15mo ($P<0.05$), first lactation ($P<0.01$) and end of lactation ($P<0.05$) (Bonczek *et al.*, 1992).

4.7 ESTIMATION OF BODY WEIGHT FROM HEART GIRTH

Heart girth has been described as an excellent and the foremost predictor of BW (Nicholson & Sayers, 1987; Heinrichs *et al.*, 1992; Mayaka *et al.*, 1995). Correlations between the two traits were very high at 0.76 (Ministry of Agriculture, 1998), 0.95 (Mayaka *et al.*, 1995) and linear (Nicholson & Sayers, 1987). Breed, size and condition of the animal may affect the accuracy of the estimation of BW from HG. The addition of age increases the accuracy of the individual estimates by allowing the use of separate distinct regressions within age intervals (Heinrichs *et al.*, 1992). Regression of BW against HG (cm) gave the following equation: $BW = -38.6 + 0.95HG$ (cm) (Ministry of Agriculture, 1998), while Mayaka *et al. (1*995) found that prediction did not differ from zero with errors not exceeding 3.5kg from absolute value.

Heart girth has often been used as a single component to estimate BW, with few occasions where it was used in combination with other measurements. Although HG is a favoured means for predicting BW, in practice, however, its measurement tends to be a rapid measurement since time to ensure posture and positioning would lessen its usefulness in all but the most tractable animals. The need for rapidity in measurement inevitably reduces the accuracy (Nicholson & Sayers, 1987; Enevoldsen & Kristensen, 1997).

Otte *et al.* (1992) investigated how tapes and scales differ in measuring the weight of cattle. In cattle up to 200kg the difference between weight estimate by scale and by tape was highly significant. Weight estimates by tape exceed weight estimates by scale by an average of 6.8kg. Because the difference between tape and scale depended on the weight of cattle, it was desirable to carry out a full analysis on a log scale. The weight estimate by tape was generally 5% higher than the respective estimate obtained by a scale, and limits may ly between seven percent below and 20% above the scale measurement. Cattle above 200kg BW had a mean difference between scale and tape of 2.9kg, and limits may be between 12% below and 14% above the scale reading.

The measuring tape can be a viable alternative to scales in trials in which BW is the dependent variable, e.g. a comparison of weight of weaning in cattle receiving different treatments. When correctly calibrated, tape measurements will provide estimates of the mean weight of each group of cattle (Otte *et al.*, 1992). Unlike WH, HG has been least reported as a measure of skeletal development, but most reported for the prediction of BW.

4.8 CONCLUSION

Body weight increases with an increasing parity, age, HG and WH. The male sex is higher in all measurements (BW, HG and WH) than the female sex. Body weight, HG and WH increase in the summer season when compared to winter and differ within breed types. It is hypothesised, therefore, that careful selection of cattle for growth and skeletal sizes using HG and WH can form an integrated system of growth trait improvement in communal farming.

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CHAPTER 5

ESTIMATION OF LIVE BODY WEIGHT FROM HEART GIRTH AND WITHER HEIGHT IN BEEF CATTLE UNDER COMMUNAL MANAGEMENT CONDITIONS

5.1 INTRODUCTION

Body weight is an important economic trait and is used for several management purposes, including assessment of feed efficiency, the value of culled cows, and the efficiency of rearing heifers (Enevoldsen & Kristensen, 1997). However, due to the unavailability of scales, this knowledge is often unavailable to the small-scale cattle farmer.

In the developing areas of South Africa the majority of small-scale beef cattle farmers own Nguni-type cattle. However, their performance is rarely reported due to unavailability of scales. This is further compounded by poor road conditions that make transportation of mobile scales difficult (Mayaka, Tchoumboue, Manjeli & Teguia, 1995). Farmers therefore rely on inaccurate "guesstimation" of body weight when selling their cattle and when dosing antiparasitics. Heinrichs, Rogers and Cooper (1992) reported that commercial farms do not have complete restraint and handling systems, and few have animal scales to determine body weight. These difficulties can be overcome by developing a simple, yet reasonably accurate method of predicting body weight, for example measuring tapes (Otte, Woods & Abuabara, 1992). They are derived from regression equations including the use of body measurements other than the traditional heart girth measurement (Heinrichs *et al.*, 1992). Such tapes exploit a high correlation between body measurements and body weight (Otte *et al.*, 1992). Although measuring tapes are not as consistent as weighing scales, they are the best estimates of weight in the absence of weighing scales. The objective of this study was to derive prediction equations for live weight using heart girth and wither height.

5.2 MATERIALS AND METHODS

5.2.1 Study site

The study was conducted at Muledzhi Communal Dip Tank situated 50km north of Thohoyandou in the Northern Province of South Africa. The area is located at 22, 41°S latitude and 30, 16°E longitude. Muledzhi is comprised of four villages, namely Tshithuthuni, Vuvha, Muledzhi and Mapate. Veld type is classified as savannah-mixed-bushveld. The climate is dry tropical characterised by a hot, wet summer period (wet season) followed by a cold, dry winter period (dry season).

5.2.2 Animals and management

Cattle were Nguni type with 5.29% other breeds, including Brahman, Bonsmara, Simmentaler, Jersey, Friesian and Afrikaner. Management practices include dipping cattle every week in summer and fortnightly in winter, but due to the current financial limitations, the system seems to be changing to fortnightly dipping throughout the year. Traditional medications are still used to control diseases. Diseases such as anthrax, blackquarter and contagious abortion are controlled by the state. Cattle graze on the natural communal land with no supplements except during drought, and are bred by natural mating to calve every season of the year. Branding has been the main method of identifying cattle until recently when eartagging was also introduced by this study and were also used to fight against theft.

5.2.3 Measurements

All cattle were eartagged at the beginning of the study. Cattle were weighed using a mobile weighing scale (KD1A DATA COLLETA) with its platform placed inside the crushpen. At the same time heart girth (HG) was measured using a Glassfiber (a plastic-coated fibre tape) just posterior to the shoulder. Wither height (WH) was measured using a wooden tape that was attached to a horizontal sliding bar of a restraining chute above the animal and which was equipped with a level. One person was responsible for measuring HG and WH. All measurements were taken during September, October and December (1999) and May and July (2000). No data were recorded from January to April 2000 due to the heavy rainfall in the Northern Province. Data consisted of 1222 live weight (WTS) records, 1374 HG records and 982 WH records.

5.4.4 Data analysis

Regression of LW on each of the independent variables (sex, age and month) was performed using the Regression Analysis Procedure of SAS (1989). Linear, quadratic and cubic effects of the independent variables were considered. Also, LW was regressed to the combination of HG and WH. The general model used was:

$Y_i = b_o + b_1X_i + b_2X^2_i + b_3X^3_i + e_i$ where:

Y_i = LW observation i

b_o = Intercept

b_1, b_2, b_3 = Corresponding linear, quadratic and cubic regression coefficients

X_i = Body measurements i (HG, WH)

e_i = Residual error term

5.3 RESULTS AND DISCUSSION

Factors influencing the prediction of live weight from body measurements

Sex: The regression equations for predicting LW from HG and WH are indicated in Table 5.1. The regressions for predicting LW did not show any significant difference between two sexes, and regressions for females were more similar to those of bulls. Estimation of LW using linear regressions for HG and WH (LW_1 and LW_5) gave the lowest ($P<0.001$) R^2 (0.63 and 0.76). Using linear equations, Benyi (1997) found no significant difference between sex of animals, while males were 0.03 higher in R^2 than females, which means that accountability of estimating LW from body dimensions is slightly more in males than in females. It was warned that the use of linear equations could result in under-estimates. The reason for better R^2 in males was because females experience stress caused by calving and lactation under poor nutrition (Markusfeld & Ezra, 1993; Benyi, 1997).

The quadratic regressions for both HG and WH improved R^2 by 0.12 and 0.04. The cubic equation for HG further improved the R^2 by 0.03 (LW_3), while the cubic equation for WH decreased the R^2 by 0.01(LW_7). However, the third-degree polynomials for HG and WH in combination with linear measures of the WH and HG produce the best predictions (0.86 and 0.84). This is consistent with earlier results by Nesamvuni, Mulaudzi, Ramanyimi and Taylor (2000). Heinrichs *et al.* (1992) reported that the cubic regression with added body measurements yields little benefit from the addition of the second measure. This differs in the results of this study. The R^2 in this study, however, improved by 0.08 and 0.05 for HG and WH. The prediction of LW using the third-degree polynomials of HG when combined with the linear measure of WH was 0,02 greater than WH.

Age: The regression equations for predicting LW from HG and WH by age are indicated in Tables 5.2, 5.3, 5.4, 5.5 and 5.6. Linear equations significantly gave lowest R^2 in all age groups for HG and WH. Linear regressions for HG (LW_1) at one and three years had the highest ($P<0.001$) R^2 (0.74 and 0.70) followed by two and four years (0.30), while at five years linear regressions showed the lowest R^2 (0.11). The linear regressions for WH were generally higher at all ages except for HG at one and three years (LW_5). At five years, WH showed the best R^2 (0.89) followed by three and four years (0.66 and 0.67), while at one year the linear regressions had the lowest R^2 (0.47). WH in general had more R^2 than HG at all ages.

Quadratic equations for both HG and WH (LW_2 and LW_6) further improved the R^2 in all age groups except for WH at five years. The quadratic equations for HG significantly improved R^2 by 0.04, 0.07, 0.12, 0.43 and 0.48 at one, two, three, four and five years.

For the same categories, the quadratic equations for WH improved R^2 by 0.01, 0.02, 0.04, 0.01 and decreased by 0.02. The quadratic equations for HG proved to have a better R^2 than for WH at one, three and four years, but at two and five years, WH had better R^2 than HG. Generally, equations for HG were more accountable in predicting LW for WH at all ages.

Cubic regressions for HG and WH (LW_3 and LW_7) further improved the R^2 for both age groups except at two, four and five years for WH. The cubic equations for HG improved the R^2 by 0.06, 0.40, 0.02, 0.06 and 0.36 at one, two, three, four and five years. For the same categories, WH improved by 0.15, 0.01, 0.01, decreased by 0.02 and zero. The third-degree polynomial equation for HG was more accountable for predicting LW than for WH.

The cubic regressions for HG and WH (LW_4 and LW_8) in combination with linear measures of WH and HG were the best predictors of LW, except at one and five years for WH. Although the cubic regression for HG, combined with WH at five years, had equal R^2 with cubic regression for HG, the cubic equation for HG was significant and was the best predictor of LW. The R^2's for HG were better than for WH at all ages, meaning that accountability of estimating LW is greater when using cubic regression for HG combined with WH than for WH. The R^2's improved by 0.01, 0.03, zero, 0.05 and zero for WH at one, two, three, four and five years. For the same categories WH improved R^2 by 0.21, 0.04, 0.08, 0.14 and decreased by 0.03.

Combination of HG and WH gave the highest R^2 at five years (0.87) followed by one year (0.83), followed by three and four years (0.76 and 0.70), while the age of two years had the lowest (0.62). Although the cubic regression for WH combined with HG had the highest R^2 at age one, the combination of WH and HG seems to be a better ($P<0.001$) predictor of LW than the former. Also, at five years, a combination of WH and HG had a higher R^2 than the cubic regression for WH combined with the linear measure of HG.

In summary, the cubic equations for both HG and WH in combination with linear measures of other traits are the best predictors of LW. The equations for HG were better than for WH in almost all age groups and for both sexes. It was indicated in the literature that prediction of LW from body dimensions and LW is more accountable in young animals and declines gradually as an animal grows older. Otte *et al.* (1992) reported that the repeatability of weight estimates by tape was quite good in young cattle, but that in adult cattle the difference could be as high as 45kg and was often overestimated. In young animals the difference could be as low as 2.9kg. Heinrichs and Hargrove (1994) revealed that regressions often show almost equal R^2 when narrow ages are used.

5.4 CONCLUSION

Equations presented herein can be utilised to estimate LW from HG and WH. Heart girth and WH can provide valid and precise estimates of LW. The third degree polynomials in combination with linear measures of other traits proved to be the best predictors of LW. HG showed to be a better predictor of LW than WH. In cases for which the management of beef cattle or limiting facilities do not allow the use of a scale for LW or HG measurement, WH can be utilised.

Table 5.1: Regression equations for predicting live weight in beef cattle using heart girth and wither height in bulls.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	55.06	$0.68HG^{***}$	-	-	-	0.63
LW_2	169.94	$-0.30HG^{*}$	-	$172\times10^{-3}HG^{2***}$	-	0.75
LW_3	231.30	$-1.36HG^{***}$	-	$6.27\times10^{-3}HG^{2***}$	$-5.30\times10^{-6}HG^{3***}$	0.78
LW_4	-180.55	$-0.62HG^{**}$	$3.78WH^{***}$	$2.56\times10^{-3}HG^{2**}$	$-1.58\times10^{-6}HG^{3}$	0.86
LW_5	-532.59	$7.04WH^{***}$	-	-	-	0.76
LW_6	631.61	$-14.65WH^{***}$	-	$9.97\times10^{-2}WH^{2***}$	-	0.80
LW_7	474.50	$-10.29WH$	-	$5.99\times10^{-2}WH^{2}$	$1.20\times10^{-4}WH^{3}$	0.79
LW_8	416.10	$-8.33WH$	$0.27HG^{***}$	$3.87\times10^{-2}WH^{2}$	$1.42\times10^{-4}WH^{3}$	0.84
LW_9	-387.90	$5.01WH^{***}$	$0.29HG^{***}$	-	-	0.81

***P<0.001 **P<0.01 *P<0.1 Combin.=combination Adj.= adjusted

Table 5.2: Regression equations for predicting live weight in beef cattle using heart girth and wither height in relation to age at one year.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	34.55	$0.667HG^{***}$	-	-	-	0.74
LW_2	80.16	$0.06HG$	-	$4.36\times10^{-4}HG^{2**}$	-	0.82
LW_3	103.55	$-0.87HG^{**}$	-	$8.4\times10^{-3}HG^{2***}$	$1.22\times10^{-6}HG^{3**}$	0.88
LW_4	68.00	$-0.72HG$	$0.33WH$	$7.41\times10^{-3}WH^{2*}$	$1.07\times10^{-6}HG^{3*}$	0.87
LW_5	-225.54	$3.82WH^{***}$	-	-	-	0.47
LW_6	-989.32	$8.87WH$	-	$-7.3\times10^{-2}WH^{2}$	-	0.48
LW_7	15896	$-479.6WH^{**}$	-	$4.78WH^{2**}$	$-1.56\times10^{-2}WH^{3***}$	0.63
LW_8	5063.87	$-147.44WH$	$0.53HG^{***}$	$1.42WH^{2}$	$-4.42\times10^{-3}WH^{3}$	0.84
LW_9	-128.87	$1.92WH^{***}$	$0.53HG^{***}$	-	-	0.83

***P<0.001 **P<0.01 *P<0.1 Combin.= combination Adj.= adjusted

Table 5.3: Regression equations for predicting live weight in beef cattle using heart girth and wither height in relation to age at two years.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	94.94	$0.45HG^{***}$	-	-	-	0.30
LW_2	190.68	-0.45HG	-	$1.88x10\text{-}^{3}HG^{2**}$	-	0.37
LW_3	373.23	$-4.18HG^{***}$	-	$2.18x10^{-2}HG^{2***}$	$-2.99x10^{-5}HG^{3***}$	0.77
LW_4	144.76	$-3.34HG^{***}$	$1.91WH^{**}$	$1.72x10^{-2}HG^{2***}$	$-2.36x10^{-5}HG^{***}$	0.80
LW_5	-357.02	$5.28WH^{***}$	-	-	-	0.61
LW_6	595.45	-13.21WH	-	$8.91x10^{-2}WH^{2*}$	-	0.63
LW_7	1223.02	-31.8WH	-	$2.71x10^{-1}WH^{3}$	$-5.9x10^{-4}WH^{3}$	0.62
LW_8	-1772.99	57.43WH	$0.15HG^{*}$	$-6.1x10^{-1}WH^{2}$	$2.26x10^{-3}WH^{3}$	0.64
LW_9	-321.02	$4.66WH^{***}$	0.13HG	-	-	0.62

***P<0.001 **P<0.01 *P<0.1 Combin.= combination Adj.= adjusted

Table 5.4: Regression equations for predicting live weight in beef cattle using heart girth and wither height in relation to age at three years.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	62.93	0.66^{**}	-	-	-	0.70
LW_2	184.57	$-0.23HG^{***}$	-	$1.43x10^{-3}HG^{2***}$	-	0.82
LW_3	228.35	$-0.99HG^{**}$	-	$4.55x10^{-3}HG^{2**}$	3.6x10-6HG3	0.84
LW_4	76.61	$-0.86HG^{*}$	1.41WH	$3.91x10^{-3}HG^{2***}$	-2.94x10-6HG3*	0.84
LW_5	-649.72	$8.02WH^{***}$	-	-	-	0.66
LW_6	1222.8	-25.59WH	-	$1.46x10^{-1}WH^{2*}$	-	0.70
LW_7	16590	-421.48WH	-	$3.53WH^{2}$	$-9.58x10^{-3}WH^{3}$	0.71
LW_8	10357	-261.46WH	$0.35HG^{**}$	$2.18WH^{2}$	$-5.89x10^{-3}WH^{3}$	0.77
LW_9	-306.8	$3.92WH^{**}$	$30.41WH^{**}$	-	-	0.76

***P<0.001 **P<0.01 *P<0.1 Combin.= combination Adj.= adjusted

Table 5.5: Regression equations for predicting live weight in beef cattle using heart girth and wither height in relation to age at four years.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	136.88	0.47HG	-	-	-	0.30
LW_2	309.47	$-1.22HG^{**}$	-	$3.28x10-3HG2^{***}$	-	0.73
LW_3	355.4	$-2.69HG^{**}$	-	$1.08x10-2HG^{*}$	$-1.0x10^{-5}HG^{3*}$	0.79
LW_4	-187.44	-0.53HG	$4.24WH^{*}$	$6.62x10^{-4}HG^2$	$1.94x10^{-6}HG^3$	0.84
LW_5	-151692	$6.94WH^{***}$	-	-	-	0.67
LW_6	511.11	-12.12WH	-	$8.72x10^{-2}WH^2$	-	0.68
LW_7	-322.95	11.11WH	-	$-1.26x10^{-4}WH^2$	$6.46x10^{-4}WH^3$	0.66
LW_8	-15552	447.96WH	$0.44HG^{**}$	$-4.26WH^2$	$1.35x10^{-2}WH^3$	0.80
LW_9	-1465.32	$5.98WH^{***}$	$0.20WH^{***}$	-	-	0.70

***P<0.001 **P<0.01 *P<0.1 Combin.= combination Adj.= adjusted

Table 5.6: Regression equations for predicting live weight in beef cattle using heart girth and wither height in relation to age at five years.

Model	Intercept	Linear	Combin.	Quadratic	Cubic	Adj. R^2
LW_1	271	0.29HG	-	-	-	0.11
LW_2	385.78	-1.62HG	-	$3.47x10^{-3}HG^{2*}$	-	0.59
LW_3	456.92	$-4.87HG^{**}$	-	$1.86x10^{-2}HG^{2**}$	$-1.78x10^{-5}HG^{3**}$	0.95
LW_4	239.52	-3.82HG	1.69WH	$1.43x10^{-2}HG^2$	$-1.35x10^{-5}HG^3$	0.95
LW_5	-544.49	$7.63WH^{***}$	-	-	-	0.89
LW_6	-665.04	9.91WH	-	$-1.05x10^{-2}WH^2$	-	0.87
LW_7	15999	-454.19WH	-	$4.2WH^2$	$-1.23x10^{-2}WH^3$	0.87
LW_8	16323	-463WH	0.01HG	$4.3WH^2$	$-1.29x10^{-2}WH^3$	0.84
LW_9	-545.98	7.64WH	0.004HG	-	-	0.87

***P<0.001 **P<0.01 *P<0.1 Combin.= combination Adj.= adjusted

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CHAPTER 6

GENERAL CONCLUSIONS

The Northern Province is characterised by high temperatures, humidity and summer rainfall. Rainfall causes fluctuation in feed availability and quality, as well as occurrence of diseases, parasite burdens, etc. Beef cattle production under traditional (communal) farming faces problems in relation to dealing with those environmental problems. Such problems are mainly financially related and results in the absence of an effective programme for breed improvements. It is therefore important to identify the constant environmental factors that can be considered for the improvement of cattle performance, and to derive means to cope with them.

This study identifies the environmental factors affecting growth of beef cattle under communal farming conditions. Environmental factors affecting growth are sex, breed, age, month and their interaction. Bulls were heavier ($P<0.001$) and had greater HG and WH than cows. Live weight, HG and WH increased linearly ($P<0.001$) with age of cattle. Rainfall played a major role ($P<0.001$) as indicated by the effect of month. During periods of scarce rainfall (winter or drought), nutrition affects the performance of cattle. In this study, however, the month of May had the highest performing cattle of all the summer months as a result of unusual rainfall before May. Due to poor financial background amongst the communal beef cattle farmers, the solution of poor nutrition by feed supplementation seems difficult. The other possible solution as indicated in the literature may be the use of indigenous cattle, which have adapted to the local conditions, and therefore it is recommended that farmers either avoid using exotic breeds for breeding or that they acquire the necessary information before crossing their cattle. The use of short animals (preferably indigenous Sanga) may solve the problem of high nutritional demands, as they have been reported in the literature as eating little and being efficient. Farmers should undertake selection, culling and selling, especially during periods of feed shortages. Performance of cattle was affected ($P<0.001$) by differences in village. The better pasture conditions in some villages compared to others seemed to be the reason for the differences. Stocking density was another factor that seemed to affect the performance and it needs further investigation. Camps in the communal setting are of overriding importance and would help reduce overstocking and improve the management of cattle.

Chapter five deals with estimation of LW from HG and WH. Live weight can be estimated from HG and WH. When age groups were included in the prediction equations, the accuracy of estimating LW was improved. The cubic regressions for HG combined with WH were the best predictors of LW, but in case they cannot be used, regressions for WH are the alternatives. Under the communal setting where weighing scales are not available, the use of regression equations (through measuring tapes) can be the solution. With measuring tapes, small-scale farmers can sell their cattle at the best possible prices.

AN INTEGRATED SYSTEM OF GROWTH TRAIT IMPROVEMENT IN BEEF CATTLE UNDER COMMUNAL MANAGEMENT CONDITIONS

BY

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ABSTRACT

Data which were collected from Muledzhi Communal Dip Tank were used for two purposes: (i) to characterise live weight and linear body measurements in communal management conditions, and (ii) to derive prediction equations for live weight using heart girth (HG) and wither height (WH). The main variables investigated were body weight (BW), HG and WH. Data were collected for five months: September, October and December 1999, and May and July 2000. The data consisted of 1222 BW records, 1374 HG records and 982 WH records.

Variation in BW, HG and WH occurred due to changes in environmental factors. The average BW, HG and WH were 251.31kg, 215.44cm and 112.31cm respectively. Bulls

were heavier and had greater HG and WH than cows. As BW increased, HG and WH also increased. Both variables increased with an increasing number of years. Body weight increased by 47kg, 53kg, 81kg and 61kg at the age of one to two, two to three, three to four and four to five years. For the same age groups heart girth increased respectively with 59cm, 53cm, 63cm and 67cm while HW also increased by 8cm, 8cm, 3cm and 11cm respectively. Tshithuthuni village had the highest BW (322.39kg) while Mapate had the lowest (113.3kg). The month of May had the highest BW, HG and WH of 299.64kg, 351.93cm and 114.03cm. The rainfall that had occurred earlier improved pastures during May.

Linear equations for sex had the lowest R^2, but WH had a greater R^2 than HG. Quadratic equations improved R^2 for both sexes. When fitted with linear measures of other traits, cubic regressions for HG and WH were the best predictors of live weight (LW). However, cubic regressions for HG had a greater R^2 than for WH. The regression equations for males are slightly higher in R^2 than in females.

Linear equations gave the lowest R^2's for all age groups, but linear equations for WH were higher in R^2 than HG, except at one and three years of age. The quadratic equations improved R^2's in all age groups for HG and WH, except for WH at three years of age. However, the quadratic equations for HG were greater in R^2 than for WH, except for the same WH at five years. The cubic regressions further improved the R^2 in all age groups except at two, four and five years. Cubic regressions for HG were greater than for WH at all ages. The cubic regressions combined with other measurements further improved R^2 and were the best predictors of LW except at one, three and five years. Heart girth had a greater cubic R^2 than WH at all age groups. Combinations of HG and WH also gave a high R^2 but were just below cubic equations for WH combined with HG, except at five years of age.

`N GEÏNTEGREERDE SISTEEM VIR DIE VERBETERING VAN GROEI-EIENSKAPPE VAN VLEISBEESTE ONDER TOESTANDE VAN GEMEENSKAPLIKE BESTUUR

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UITTREKSEL

Data wat van die Muledzhi gemeenskaplike dip versamel is, is vir twee doelwitte gebruik: (i) om lewendige gewig en liniêre liggaamsmates in toestande van gemeenskaplike bestuur te kenmerk, en (ii) om voorspellingsvergelykings vir lewendige gewig af te lei deur gebruik te maak van hartomvang (HO) en skofhoogte (SH). Die hoofveranderlikes wat ondersoek is, is liggaamsmassa (LM), HO en SH. Data is vir die volgende vyf maande versamel: September, Oktober en Desember 1999, en Mei en Julie 2000. Die data het uit 1222 LM-rekords, 1374 HO-rekords en 982 SH-rekords bestaan.

Variasie in LM, HO en SH het voorgekom as gevolg van veranderinge in omgewingsfaktore. Die gemiddelde LM, HO en SH was onderskeidelik 251.31kg,

251.44cm en 112.31cm. Die bulle het swaarder as die koeie geweeg en het groter HO en SH ten toon gestel. Soos die LM toegeneem het, het HO en SH ook toegeneem. Beide veranderlikes neem toe met `n toename in die aantal jare. Liggaamsgewig het onderskeidelik met 47kg, 53kg, 81kg en 61kg toegeneem op `n ouderdom van een tot twee, twee tot drie, drie tot vier en vier tot vyf jaar. Vir laasgenoemde onderdoms groepe het hortomvang met 59cm, 53cm, 63cm en 67cm onderskeidelik toegeneem terwyl SH ooreerstemmed met 8cm, 8cm, 3cm, en 11cm toegeneem het. Die Tshithuthuni-nedersetting het die hoogste LM getoon (322.39kg), terwyl Mapate die laagste getoon het (113.3kg). In die maand van Mei is die hoogste LM, HO en SH aangeteken, naamlik 299.64kg, 351.93cm en 114.03cm. Die reënval van vroeër het vir beter weiding gedurende Mei gesorg.

Liniêre vergelykings vir geslag het die laagste R^2 getoon, maar SH het `n groter $R^2$ as HO getoon. Kwadratiese vergelykings het $R^2$ vir beide geslagte verbeter. Wanneer dit op liniêre mates van ander eienskappe toegepas is, was kubieke regressies vir HO en SH die beste voorspellers van lewendige gewig (LG). Kubieke regressies vir HO het egter `n groter R^2 gehad as vir SH. Die regressievergelykings vir manlike diere is effens hoër in R^2 as in vroulike diere.

Liniêre vergelykings het die laagste R^2`s vir alle ouderdomsgroepe getoon, maar liniêre vergelykings vir SH was hoër in R^2 as HO, behalwe op een- en driejarige ouderdom. Die kwadratiese vergelykings het R^2's in alle groepe vir HO en SH verbeter, behalwe vir SH op driejarige ouderdom. Die kwadratiese vergelykings vir HO was egter groter in R^2 as vir SH, buiten vir dieselfde SH op vyfjarige ouderdom. Die kubieke regressies het die R^2 in alle ouderdomsgroepe verbeter, buiten op tweejarige, vierjarige en vyfjarige ouderdom. Kubieke regressies vir HO was groter as vir SH op alle ouderdomme. Die kubieke regressies, gekombineer met ander mates, het R^2 verder verbeter, en was die beste voorspellers van LM, buiten op eenjarige, driejarige en vyfjarige ouderdom. Hartomvang het `n groter kubieke $R^2$ as SH by alle ouderdomsgroepe. Kombinasies van HO en SH het ook `n hoë R^2 gegee, maar was net onder kubieke vergelykings vir SH gekombineer met HO, buiten op vyfjarige ouderdom.

APPENDIX A

Table A1: Simple statistics for weight, heart girth and wither height.

Variable	N	Mean	SD	Sum	Min.	Max.
HG	1556	215.44	161.45	335230	0	640
WH	1102	112.31	16.58	123767	90	331
WTS	1389	251.31	102.52	349073	20	625

HG = heart girth WH = wither height WTS = weights

TableA2: Summary of Analysis of Variance for weight, heart girth and wither height.

Source	WTS	HG	WH
DF	36	22	27
C.V.%	28.20	38.95	11.84
R^2	0.55	0.72	0.30
Error	1185	1351	954
Correced total	1221	1373	981