GROWTH, EXTRACTED MILK YIELD AND REPRODUCTIVE PERFORMANCE OF TESO CATTLE AND THEIR CROSSES WITH SAHIWAL AND BORAN AT SERERE, UGANDA

BY

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ABSTRACT

A study was carried out to evaluate growth, extracted milk yield and reproductive performance of Teso cattle and their crosses with Sahiwal and Boran at Serere Agricultural and Animal Research Institute, Serere, Uganda. Analysis of variance based on GLM of SAS 2002 was used to analyse the data. The overall means for weights at birth, weaning and pre-weaning ADG were 18.36 ± 0.076, 100.55 ± 0.48 kg and 304 ± 1.96 g/day respectively. Dry season born calves were significantly ($P<0.05$) superior to wet season born in both weaning and pre-weaning ADG. Sex of the calf was significant only for weaning weight whereby males were heavier than the females by 3.35 kg. Genetic group of the calf was significant ($P<0.001$) for all traits studied. Rankings of genetic groups for weaning weight and pre-weaning ADG were B_1Sx(SxT), F_1 (SxT), B_1(SxT)xT, B_1Bx(BxT), F_1(BxT) and Teso. Influence of year was significant ($P<0.01$) for weaning weight and pre-weaning ADG. Heritability estimates based on sire variance components for birth, weaning weight and pre-weaning ADG were 0.41, 0.02 and 0.02 and those based on dam plus sire variance components were 0.41, 0.16 and 0.36 respectively. The phenotypic correlation between birth and weaning weight was –0.07, birth weight and pre-weaning ADG was –0.44 while that between weaning weight and pre-weaning ADG was 0.93. The overall calving interval was 453 days. F_1(BxT) and F_1(SxT) crosses had calving intervals of 44.6 and 61.3 days longer than the pure Teso cows. The overall means for extracted milk yield and lactation length were 120 ± 3.4 kg and 173.6 ± 5 days respectively. Mean lactation length for F_1(SxT), F_1(BxT) and Teso were 182.9, 165.7 and 148.7 days respectively. F_1(SxT) had significantly ($P<0.05$) higher extracted milk yield (178 kg) than Teso (127.2 kg) and F1(BxT) crosses

(125.9 kg). Dry season calvers had 38.5 kg more extracted lactation milk yield than wet season calvers. Extracted milk yield of the third month after calving had high correlations 0.80 and 0.93 with 100 days milk yield and extracted lactation milk yield respectively. Lactation curve parameters for partially milked cows belonging to the three genetic groups studied were also estimated. Selection of animals for improved milk production can be done using the milk yields of the first three months of lactation.

DECLARATION

I Henry Earon Mulindwa do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for a degree award in any other University.

Signature...

Date 9|2|2005

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DEDICATION

To my mother late Annette Nanteza

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LIST OF ABBREVIATIONS AND SYMBOLS

ADG	Average daily gain
ANOVA	Analysis of variance
B_1	First backcross
B_1(SxT)Xt	First backcross to Teso
B_1Bx(BxT)	First backcross to Boran
B_1Sx(SxT)	First backcross to Sahiwal
CI	Calving interval
CV	Coefficient of variation
EASZ	East African Shorthorn Zebu
F_1	First filial generation
F_1(BxT)	First generation of Boran and Teso cattle crosses
F_1(SxT)	First generation of Sahiwal and Teso cattle crosses
GLM	General Linear Model
h^2	Heritability
h^2_S	Heritability based on sire variance component
h^2_{SD}	Heritability based on both the sire and dam variance components
Lsmeans	Least squares means
MFPED	Ministry of Finance, Planning and Economic Development
SAARI	Serere Agricultural and Animal Research Institute
SAS	Statistical Analysis System
Sd	Standard deviation
Se	Standard error

T	Teso cattle
TSZ	Tanzania Shorthorn Zebu
Y_{max}	Maximum milk production
Δ^2_D	Dam variance component
Δ^2_e	Error variance component
Δ^2_S	Sire variance component

CHAPTER ONE

INTRODUCTION

The importance and contribution of livestock to agricultural production is well acknowledged. Kaitho *et al.* (2001) reviewed that livestock accounted for about 25% of agricultural gross domestic product in Africa in 1988. In Uganda, livestock production contributed 9% and 17% of the total GDP and agricultural GDP respectively (MFPED, 1999). The national livestock and poultry were estimated to comprise 6 million cattle, 9.2 million goats, 1.6 million sheep, and 1.3 million pigs and over 25 million poultry (MFPED, 1999).

The cattle population in Uganda is dominated by the East African Shorthorn Zebu (EASZ), which provides most of the meat and milk as well as draft power. Selection for improved milk yield and beef within indigenous breeds is possible but it is an expensive and long-term process consequently crossbreeding is often the most common method of genetic improvement. Crossing of *Bos taurus* beef and milk breeds with indigenous *Bos indicus* as a quick means of increasing the output of beef and milk production under range conditions has received some attention in Uganda as well as in East Africa in general (Mahadeven and Hutchison, 1964; Kiwuwa, 1969; Sacker *et al.*, 1971; Trail *et al.*, 1985; Balikowa, 1997). These studies have shown that crossing could result in increased gain and productivity in terms of growth and milk from the progeny. The crosses respond quickly to better feeding including a high proportion of concentrates, and milk let down is less of a problem like in the EASZ.

However, the real success of such crosses depends not only on level of heterosis but also on a higher level of management than is ordinarily available in most tropical countries (Maule, 1990), where milk and meat are entirely from indigenous cattle. Such crosses given the right conditions are capable of giving perhaps double the milk yield of pure Zebu but liable to suffer from both the harsh climate, and lack of proper feeding.

In areas where husbandry remains relatively poor, disease control has not been perfected and where climate is unsuitable for European grades, there is need for the development of appropriate strategies such as improvement of indigenous cattle for adverse environmental areas and establishment of cross-breeding programmes to produce the most suitable type of animals for certain farming systems or particular environmental areas. Some *Bos indicus* breeds of cattle, such as the Sahiwal and Boran, combine adaptability to a tropical environment with an ability to produce substantial amounts of milk and meat respectively. Therefore, crossing of Sahiwal and Boran bulls on EASZ females would be a better alternative. Sahiwal and Boran grades are better adapted than European grades to the environmental conditions of tropical farming and that such grades would be able to maintain a reasonable production of milk and meat in spite of the varying standards of cattle management. The Sahiwal is thought to be a suitable dual-purpose dairy/beef Zebu for low potential areas and the improved Boran is bred only for beef production (Meyn and Walkins, 1974).

Several workers have described the East African Shorthorn Zebu (EASZ), which dominates the total population of cattle in Uganda, as a small breed with poor genetic potential for both milk and beef (Joshi, 1957; Galukande *et al.*, 1962; Payne, 1970; Mkonyi *et al.*, 1991). This breed, however, is well adapted and tolerant to the tropical environment due to the attributes described by Cunningham and Syrstad (1987), which include partial resistance to ticks, high degree of heat tolerance and low nutritional requirements because their small size, low metabolic rate and possibly also efficient digestion at low feeding levels. This is a result of natural selection over generations.

In an effort to improve the performance of the EASZ, quantitative genetic studies and genetic improvement schemes in the breed have, however, predominantly concentrated on aspects of crossing the EASZ with the exotic Europeans breeds so as to improve milk and meat production.

In view of the low production capacity associated with the EASZ and the relatively improved management requirements and supplementary feeding associated with European crosses, there is need to develop crosses between the EASZ and some of the tropically adapted breeds (Sahiwal and Boran) that are capable of producing moderate yields of milk, higher growth rate and have exceptional draft qualities. Such crosses would possibly be able to work long hours (ploughing/carting) on a diet of straw, rough grazing and provide moderate milk yields as well as faster growth rate.

Crossing Boran and Sahiwal bulls on EASZ females as a means of increasing the output of beef and milk has in the past received some attention in East Africa (Mahadeven *et al.*, 1962; Trail *et al.*, 1971a, b; Mwandotto, 1981; Gregory *et al.*, 1985; Mwandotto, 1988; Mwatawala, 2001). However, even within relatively small geographical areas, extreme differences may occur in prevailing environments, resulting in large genotype × environment interaction (Buck *et al.*, 1982). Thus research findings in previous work in Kenya and Tanzania may not be directly applicable to Uganda. Therefore, the purpose of this study was to evaluate the performance of Teso cattle (EASZ) and their crosses with Sahiwal and Boran with respect to extracted milk yield, growth and reproduction traits under Serere conditions in Uganda.

Specific objectives of the study were:

i) To assess the performance of traits related to growth, reproduction and lactation.

ii) To evaluate the influence of non-genetic factors on the performance of Teso cattle and its crosses with Sahiwal and Boran.

iii) To determine heritabilities estimates for growth traits

iii) To estimate phenotypic correlations of growth and lactation traits, of Teso breed and its crosses with Sahiwal and Boran.

iv) To estimate lactation curve parameters

CHAPTER TWO

LITERATURE REVIEW

2.1. Description of breeds

2.1.1 Sahiwal cattle

According to Joshi and Phillips (1953) the breeding track of Sahiwal cattle is Montgomery district in Pakistan. The approximate location of the area is between latitude 29^0 5' and 31^0 2' North and between longitude 69^0 4' and 74^0 8' East. The heat during the day is intense; the maximum temperature goes as high as 47.8^0 C. It is the best dairy breed of the Indian subcontinent. In size and conformation, Sahiwals are amongst the largest Zebu breeds, mature cows weighing 360 - 400 kg and bulls up to 500 kg. Cows have a deep body with well sprung ribs, good hind quarters and strong legs. The udder is large and pendulous and the teats large and fleshy. Coat colour is usually reddish but pale red or brown, occasionally with a few white patches are uncommon. The horns are short and slumpy. Bulls have a large hump, which tends to fall to one side, but in cows the hump is smaller and bulls have a massive appearance. Sahiwals are slow workers and have reputation of being lethargic, even when serving cows. The age at first calving ranges from 37 to 48 months and the calving interval from 430 - 580 days. The average production on large farms is about 2270 kg of milk in about 300 days.

2.1.2 Boran cattle

There are three related types of Boran breed: the Somali Boran, the Tanaland Boran and the Kenya Boran. Boran cattle originate from Borana province of Southern

Ethiopia (Payne, 1970). These cattle are fairly large, long legged animals with good body conformation. Coat colour is normally white or grey, but red or pied colours occur. They have got thin, loose and pliable skin. The head is medium to long. The horns are usually small, thick at the base, pointed and directed forward. Polled animals are not uncommon. The ears are small in comparison with the Indian breeds. The hump is well defined, upright and thoracic. It is sometimes folded on one side and larger in the male than in the female cattle. The dewlap and sheath are not excessively developed in the Somali Boran but so in the Tanaland Boran. The improved Kenya Boran is famous for its straight top line and well-developed hindquarters. The rump is long, wide and muscular in the male, and the buttocks well fleshed. Females have a well-formed udder of medium size. Semi nomadic people use them for milk production. The average live weight of mature males is 318 kg and mature females 225 kg, although many males can reach 500 kg or more.

2.1.3 Teso cattle

Teso cattle belong to the big grouping collectively identified as the East Africa Shorthorn Zebu. It is a relatively small, dual-purpose animal and stocky in appearance. The horns are short, thick at the base and curve slightly outwards and then inwards. The musculo-fatty hump is prominent and thoracic in position. The ears are medium-sized and directed outwards. Coat coloration varies and includes gray, gray-white, light red, black, and black and white. The skin is of medium thickness and the hairs are short and smooth. The hoofs are medium-sized and hard. Bukedi cattle are used for producing beef and draft power as well as milk production.

2.2 Growth performance

2.2.1 Birth weight

The birth weight of a calf is an important attribute since it could provide the basis for predicting its general health and prospective rate of gain between birth and weaning period. Birth weight is influenced by a number of factors such as genotype, maternal environment, parity, maternal age and intra-uterine foetal environment as well as sex of the calf (Hafez and Dyer, 1969).

2.2.2 Weaning weight

Pre-weaning calf growth rate and final weaning weight influence post-weaning growth performance. Higher growth rate and heavier weaning weight are, therefore, desirable characters for improving the overall production and ensure early sexual maturity (Azage *et al.*, 1990). The weaning weight of a calf results from both the genetic make up of the calf and the nutrition level on which the calf thrives. Therefore, weaning weight is affected by both genetic and environmental factors (Azage *et al.*, 1990).

Environmental factors influencing pre-weaning weight in cattle have been extensively studied. Year, sex, season of birth, parity of the dam and management have been reported to have significant influence on pre-weaning growth. In addition to these factors, maternal effects also constitute an important source of variation particularly, for pre-weaning growth performance of calves.

2.2.3 Factors affecting birth weight and weaning weight

Year effects have been reported by many workers (Sacker *et al.*, 1971; Trail *et al.*, 1971a; Thorpe *et al.*, 1980; Mwandoto, 1981) to be a major source of variation on birth weight. Stress produced by climatic factors, particularly in the tropics cannot be predicted from previous year's data and although carry-over effects are probably important, each year can be considered unique (DeNise, 1988). Sacker *et al.* (1971) and Thorpe *et al.* (1980) reported that large differences in rainfall led to marked differences between years in the quantity and quality of forage available, which in turn was reflected in differences in animal growth between years.

The influence of season of birth on birth weight is mostly mediated through the nutrition of the dam and is more pronounced on animals under range conditions. In Ethiopia, Abdinasir and Eskil (1998) reported a significant effect of season on birth weight where calves born during the main rains were the heaviest at birth. Rege *et al.* (1993) observed similar trends while working with White Fulani cattle. However, Tawah *et al.* (1993) observed that Gaduli calves born in the dry season were 0.7 kg heavier ($P<0.01$) at birth than those born in the wet season though no difference was observed among the Wakwa calves in Cameroon. In the work done by Msanga (1984), dry season calves were 1 kg heavier at birth than wet season born calves. However, Wakhungu *et al.* (1991) and Banjaw and Haile-Mariam (1994) reported no significant seasonal influence on birth weight.

The influence of year and season of birth on weaning weight have also been reported (Tawonezvi, 1989a; Sacker *et al.*, 1971) and severity of season varies from year to year and this is reflected in the performance of the animals. Significant seasonal influences on growth from birth to weaning were also reported by Wilson (1957), Kidner (1966), Mwandoto (1988), and Kassa-Mersha and Arnason (1986). Udo (1993) observed that calves born during the dry season had the highest weaning weight while Mwatawala (2001) reported that dry season born calves were 4.5 kg heavier at weaning than those born in wet season. In a study done by Tawah *et al.* (1993) on Gaduli and Wakwa beef cattle, significant seasonal effects were reported whereby calves born in a dry season had 169.1 and 178.6 kg in contrast to 144.9 and 162.1 kg for wet season born calves in those breeds respectively. Rege *et al.* (1993) while studying the White Fulani observed that calves born in late rainy season and early dry season were heavier than those born in early rainy season. But these seasons were associated with lower milk off-take. These contradictory reports imply that seasons as a source of variation should be defined especially in the tropics where large differences may exist as result of abundant rainfall in one year and drought in the following year.

Many studies have used parity as a proxy for age of dam, while others have fitted age of dam as a covariate within parity classes. First calf heifers would produce lighter calves than multiparous cows (Winroth, 1990; Banjow and Haile-Marian, 1994). However, Kassa-Mersha and Arnason (1986) reported no significant effect of parity on birth weight and suggested that it could have been due to comparatively high age at first calving. Rwabushaija (1998) while studying the phenotypic and genetic trends of growth characteristics of Small East African Zebu (Teso breed) at Serere (Uganda) observed no significant parity effects on birth weight. Ageeb and Hillers

(1991) observed similar results in Kenana and Butana cattle. However, Banjaw and Haile-Marian (1994) reported that the highest birth weight was recorded for calves produced by cows in their third to fourth parturition. Wakhungu *et al.* (1991) reported increased birth weight from the first parity to the fourth followed by the decline. In another study on Friesian calves Ibeawuch (1990) observed a general trend for the birth weight to increase from the first to the fourth parity and the analysis of variance showed that parity significantly ($P<0.05$) influenced birth weight. Winroth (1990) observed that calves born in the first parity had 8-14% lower weight at birth relative to those born in parities four to eight. These contrary reports on the effect of parity on birth weight indicate that there is need to include parity in the analysis of data.

There is a wealth of studies in which male calves have consistently been reported to be significantly heavier than their female counterparts at all ages (Brown, 1960; Mwandotto, 1981; Cunningham *et al.*, 1987; Tawah *et al.*, 1993; Mwatawala, 2001) and thus contribute to the systematic environmental effects that must be adjusted for in evaluation of the animals. Rege *et al.* (1993) reported males calves having 20.6 kg versus 18.6 kg for female calves at birth in White Fulani cattle while Tawonezvi (1989a) observed that males were 4.7% heavier than their female counterparts. A similar superiority of male over female calves was also reported by Shekimweri (1982) among dairy cattle crosses in humid coastal belt of Tanzania.

In their study on characterization of Sahiwal and Boran breeds, Trail *et al.* (1981a) observed that sex of calf had a significant ($P<0.01$) influence on weaning weight.

Tahir *et al.* (1984) reported that the average weaning weight at twelve weeks of age in Sahiwal, Friesian x Sahiwal and Jersey x Sahiwal were 46.9, 60.0 and 54.4 kg in male calves and 42.6, 60.6 and 55.9 kg in females respectively. Tawonezui (1989a) observed that male calves grew more rapidly and were 8 kg (6.2%) heavier than females at weaning. In yet another study by Udo (1993) on Mpwapwa cattle and their crosses, males were heavier than females at weaning by 3.1 kg.

Variations in birth weight of calves between breeds have been reported. Birth weight of European grades ranges from 19.1 to 27.8 (Trail and Gregory, 1981b; Shekimweri, 1982; Said *et al.*, 2001). When studying Sahiwal and Boran crosses with EASZ, Mwandotto (1981) reported that genotype had a highly significant ($P<0.01$) effect on weight at birth. He observed that Friesian crosses, pure Boran and Sahiwal calves were significantly heavier than crosses of the East African Shorthorn Zebu and Sahiwal. Wakhungu *et al.* (1991) observed similar results in the Sahiwal cattle in Kenya. The average birth weight of Butana calves was 26.4 ± 2.1 kg while Kenana calves averaged 25.2 ± 2.1 kg, the difference being not significant ($P>0.05$) (Ageeb and Hillers, 1991). In the review of literature, Nelsen *et al.* (1983) observed that additive direct effects accounted for an average of 44% of the variation in birth weight and that variation from maternal effects accounted for 4 to 30%. Mwatawala (2001) observed that at birth, Boran calves were significantly ($P<0.05$) superior to Tanzania Shorthorn Zebu (TSZ) and 1/2Boran1/2TSZ while 1/2Boran1/2TSZ were significantly ($P<0.05$) heavier than the Tanzania Shorthorn Zebu.

Breed differences in weaning weight have been reported among the ***Bos indicus*** cattle (Msanga, 1984; Hamad, 1997). Weaning weights of 87.2 kg and 90.1 kg for

EASZ and Boran × EASZ crosses respectively were reported by Hamad (1997) while Msanga (1984) reported a weaning weight of 60.2 kg for the Mpwapa cattle and their crosses. Said *et al.* (2001) observed that Boran and Friesian-sired calves had significantly lower weaning weights ($P<0.05$) than calves sired by Angus, Charolais, Chianina, Hereford, Limousin and South-Devon. Kasonta (1992) reported mean weaning weight of Boran, TSZ and 1/2Boran 1/2TSZ to be 104.7, 94.0 and 88.2 kg respectively. Trail and Gregory (1981b) reported an increase in weaning weight of Sahiwal x Ayrshire calves as the proportion of the Ayrshire breed increased in the crossbreeds. Das *et al.* (1988) reported mean weaning weight of TSZ calves to be 103.5 at the age of seven months. In addition, Trail and Gregory (1981c) noted that the average 8-month weaning weights of Sahiwal and their crosses with East African Shorthorn Zebu cattle at Ilkerin in Kenya to be 100 kg when dams were milked twice a day.

2.2.4 Maternal effects on pre-weaning growth

Growth of a calf during the suckling period is affected by the dam that furnishes the developmental environment (Koch, 1972). By definition, a maternal effect is a contribution of the dam's attributes genetic or environmental to the phenotypic value of an offspring. Maternal effects represent mainly the dam's milk production and mothering ability though effects of extra-chromosomal inheritance may also subscribe to the total contribution (Baker, 1980; Robison; 1981). This is very essential in traditional herds and beef industry where calves are allowed to suckle their dams throughout the pre-weaning period. Maternal effect is less pronounced in calves from dairy herds during the pre-weaning period since they are reared artificially. Maternal effect is strictly environmental relative to the offspring, but is often considered a quantitative trait with a genetic and environmental component. Hence traits in mammals influenced by a major maternal component, as is the case in beef cattle, have an additional effect on its performance. The genetic component is reflected in the milk yield of the dam as well as its mothering ability. The environmental component is manifested mainly through the age of the dam. Mwatawala (2001) observed that weaning weight tended to increase with age until 9.5 years and thereafter begun to decline.

2.2.5 Growth rate

Mwatawala (2001) reported a significant effect ($P<0.001$) of sex and breed on average daily gain from birth to weaning in Tanzania shorthorn zebu (TSZ), Boran and their crosses. Hutchison (1964) reported a pre-weaning growth rate of Tanzania Shorthorn Zebu steers raised on a relatively high plane of nutrition to be 0.29 kg per day versus 0.33 kg/day for the Boran steers. Aminatta and Kwaku (1991) observed a pre-weaning growth rate of 0.38 ± 0.14 kg in N'Dama cattle herd in Gambia. In a study by Trail *et al.* (1981b), Boran male calves under trypanosomiasis risk grew 7% faster than the female calves. Udo (1993) observed that calves born in the dry season gained faster than those born during the rainy season.

Mwatawala (2001) reported significant genetic influence on pre-weaning growth rate. He reported a superiority in growth rate of 405.5 ± 0.01 g/day for Boran calves, 356.8 ± 0.03 g/day for 1/2Boran1/2TSZ and 337.8 ± 0.01 g/day for the TSZ calves but did not observe significant influence of season of calving on pre-weaning growth rate. In another study on the performance of straight bred and half breed beef cattle, Getz *et al.* (1975) reported average daily gain from birth to weaning (36 weeks) for Boran, TSZ ad 1/2Boran1/2TSZ to be 508, 405 and 431 g/day respectively. Das *et al.* (1988) also reported rate of gain from birth to weaning for TSZ of 405 g/day. General management and nutrition of the dam affects pre-weaning growth of calves: For example, Cossins (1985) reported that Boran calves raised by pastoralists in Ethiopia gained on averaged 140 g/day while the same genotype averaged 436 g/day on Laikipia ranches in Kenya.

2.2.6 Heritability for growth traits

Heritability is defined as the proportion of the total variance that is attributable to the average effects of genes (Falconer and Mackay, 1996). Heritability is also said to be a property, not only of a character, but also of the population, of the environmental circumstances to which the individuals are subjected, and of the way in which the phenotype is measured. It should also be mentioned that all the genetic components are influenced by gene frequencies and may therefore differ from one population to another, according to the past history of the population.

Estimates of genetic variance are also known to be dependant on the feeding regime adopted. Harsher environments give rise to more environmental variation and therefore lower heritability than in more standardized, intensive farming systems, where environmental variation is much reduced and heritability is likely to be higher (Payne, 1970). For instance, if management and nutrition of a group of animals is particularly uniform, the heritability estimates are likely to be higher than estimates from a group kept in a less uniform environment (Koots *et al.*, 1991). DeNise (1988) reported lower heritability estimates for birth weight in poor years and Baker *et al.* (1991) reported lower estimates under pasture feeding than on high-level management.

The variation in heritability can be clearly seen in the work done by Mwandotto (1986) and Mwatawala (2001). In the study of heritability of growth of Sahiwal heifers to bulling age, Mwandotto (1986) reported heritability of 0.17 ± 0.06 for birth weight. Heritability estimates based on sire variance component for weights at birth and weaning were 0.44 ± 0.10 and 0.30 ± 0.10 respectively in Boran and its crosses with the East African Shorthorn Zebu (Mwatawala, 2001). The above heritability estimates are close to the range reported by Payne (1970).

The sex of the experimental material has also been observed to cause some variation in heritability estimates (Alenda and Martin, 1987; Mohiuddin, 1994; Koots *et al.*, 1991). Mohiuddin (1994) while working on estimates of genetic and phenotypic parameters of some performance traits in beef cattle observed heritability estimates for weight at birth, weaning and yearling to be 0.46, 0.39 and 0.24 respectively for male calves but were 0.26, 0.23 and 0.2 for female calves, and 0.49, 0.49 and 0.41 across sexes.

Heritability estimates have also been reported to vary depending on the method of estimation. For example, estimates from paternal half-sibs do not include maternal effects, which can be an important source of variation in growth of cattle (Koch, 1972; Van Vleck *et al.*, 1977; Willham, 1980). Ignoring maternal effects will inflate heritability (Baker *et al.*, 1991; Mayer, 1992).

2.2.7 Phenotypic correlations between body weights

The birth weight of a calf could provide the basis for predicting its general health and prospective rate of gain between birth and weaning period. Birth weight can be measured early in life and is highly correlated to growth rate and mature weight (Warwick and Legates, 1979). In the study on growth performance of Mpwapwa cattle and their crosses, Msanga (1984) reported positive phenotypic correlations between body weights, which ranged from low to medium (0.008 – 0.221). Udo (1993) reported similar results whereby a significant correlation (r=0.174) was observed between birth weights and weaning weights.

Singh *et al.* (1970) found a significant influence of birth weight on pre-weaning growth rate and weaning weight. Mwandotto (1995) working with Sahiwal females observed that animals growing faster up to puberty tended to be heavier at maturity (genetic correlation = 0.69), and animals that were more mature up to 9 months of age had low mature weights (genetic correlation of 0.86).

2.3 Reproductive performance: Calving Interval

The reproductive efficiency of cattle determines the size of the calf crop, which is important for herd replacement. The differences in breeding efficiency may be due to environmental or may be as a result of combined effects of genetic and environmental influences. Between breeds, heredity plays some part in influencing reproductive performance. High producing breeds have low adaptability reserve towards poor environmental conditions compared to less productive breeds. Calving interval is determined by gestation period, postpartum anoestrous and first postpartum oestrous to conception interval. It is affected by both genetic and environmental factors.

2.3.1 Genetic effects on calving interval

Variations in calving interval among the *Bos indicus* breeds and their crosses have been reported. Trail and Gregory (1981a) reported a significant ($P<0.01$) effect of genotype on calving interval in which Sahiwal cows had a calving interval of 23 days shorter than Boran cows. Similar genetic differences were reported by Borsotti *et al.* (1976) while working with Brahman cows in Venezuela. Halle and Kassa (1994) reported a calving interval of 442 days in Boran cows in Ethiopia. In his study on comparative growth and reproductive performance of EASZ, Boran and their crosses, Mwatawala (2001) observed an overall calving interval of 15.4 ± 0.08 months and was significantly ($P< 0.001$) affected by breed. In the coastal region of Tanganyika, Mahadeven and Hutchison (1964) reported *Bos indicus* cows to have a mean calving interval of 12.5 months, and the introduction of *Bos taurus* genes into these cattle resulted in a decline in their reproductive efficiency. Sahiwal grades had significantly ($P<0.01$) longer calving intervals than the East African Shorthorn Zebu (Mahadeven, 1965). Studying milk production in East African Zebu in Kenya Galukande *et al.* (1962) reported a mean calving interval of 11.87 months with a coefficient of variation of 19%.

2.3.2 Effects of year and season on calving interval

In some African areas where cattle are subjected to pronounced seasonal underfeeding, calving intervals may be as long as two years and in others, where nutrition is somewhat more adequate, the low-producing indigenous cattle may calve regularly once every 12-13 months, but more productive breeds tend to have longer intervals (Mahadevan, 1966). While working with Butana and Kenana cattle in Sudan, Ageeb and Hillers (1991) reported significant ($P<0.05$) season, year as well as breed x year interactions on calving interval. Year effect on calving interval has also been reported by Choudhuri *et al.* (1984) in Haryana cows in India and Miranda *et al.* (1982) among Nellore cows in Brazil. Kasonta (1988) reported that previous year of calving affected calving interval significantly ($P<0.01$) but season of previous calving was not significant. In another study on N'dama cattle herd in Gambia, Aminatta and Kwaku (1991) reported that previous year of calving had a significant ($P<0.01$) influence on calving interval. Olivera (1974), working with Nellore cattle, observed that animals calving in the dry season had an average subsequent calving interval of 13.9 months, compared with 14.5 months for those that calved in the wet season. Mrode and Akinokun (1986) observed significant effects of season of calving on calving interval where wet season calvers had 429 days calving interval while those that calved in dry season had 421 days. The difference could be due to the fact that cows calving in the dry season could take advantage of improved nutritional conditions during the subsequent rainy season to meet their requirements for maintenance, growth and lactation. In addition, a larger proportion of dry-season calves die due to inadequate nutrition. Both factors lead to earlier re-establishment of oestrous in cows that calve in the dry season.

2.3.3 Effect of age of the cow and sex of the calf

Age and parity of the dam also affect calving interval. In Zebu cattle, calving interval is longest in first calving heifers and older cows, and shortest in cows of intermediate age (6-9 years of age). Wilson (1985) reported a trend that appeared to be one of reducing calving interval with increasing parity until older ages are reached when the interval between the calvings increases sharply. Million and Tadelle (2003) reported that the first and second calving intervals were significantly ($P<0.05$) higher than the subsequent calving intervals. Kasonta (1988) reported that parity did not significantly influence calving interval. Sex of the calf has also been reported to influence calving interval. Reinhardt (1978),. Wilson (1985) and Montoni *et al.* (1981) observed that cows with male calves had a longer calving interval than those with female calves. Plasse *et al.* (1968) reported similar results in which sex of the calf significantly ($P<0.01$) affected calving interval in Brahman cows. However, Wakhungu *et al.* (1991) working with Sahiwal cattle in Kenya reported a significant effect ($P<0.01$) of sex of calf whereby male calves were associated with shorter calving intervals.

2.4 Lactation milk yield and factors affecting it

Variations in milk yield are more pronounced under tropical than temperate conditions (Mchau, 1991). Zebu cattle are widely recognised as poor producers of milk and that their level of production varies with the severity of the prevailing climatic and environmental conditions. However, even within the African breeds variations have been reported for example, Boran in Kenya (545-1818kg/139-303days; Payne, 1970); Ankole in Uganda (318-817 kg/212-238 days; Payne, 1970);

Arsi in Ethiopia (809kg/272 days; Schaar *et al.*, 1981). Milk production in African cattle is usually lower than that in Indian cattle (Mahadevan, 1966). Meyn and Wilkins (1973, 1974) reported 1519 and 931 kg as the mean milk yield for the first lactation in the Sahiwal herd at Ngong Livestock Improvement Centre in the semiarid Kenya highlands and at Naivasha in Kenya respectively. Galukande *et al.* (1962) have reported on the performance of the East African Zebu at three locations in Kenya where the mean for lactation yield was 832 litres. In another study on Boran cattle at Tanga, Tanzania, Mahadevan and Hutchison (1964) reported that first lactation milk yield averaged 1050 litres. Half-bred Sahiwals showed a 55% increase in milk yield over the indigenous East African Zebu (Mahadevan and Galukande, 1962) indicating that replacement of 50% of the East African Zebu genes by Sahiwal genes might be expected to result in an increase in milk production of approximately the same percentage. Ageeb and Hillers (1991) reported 1465 and 1344 kg lactation milk yield among the Butana and Kanana breeds in Sudan.

Various studies have shown that parity is one of those major sources of variation in milk yield. Wakhungu *et al.* (1991) reported a significant effect ($P<0.01$) of parity on milk yield in the Kenyan Sahiwal cattle. Mahadevan *et al.* (1962) observed an increase in milk yield of only 9% between the first and second lactation. Gregory and Trail (1981a) cited an increase of milk yield of only 10% from first to second lactation. Kiwuwa (1973) observed a 23% increase from the first to the third lactation in *Bos taurus* cows, while in *Bos indicus* cows the increase was only 16%.

The season of calving has been reported to have a significant effect on milk yield (Rege, 1991; Pyne *et al.*, 1991; Queroz *et al.*, 1994). Other studies have suggested that influence of season on milk yield is variable probably depending on such factors as location, climate and possibly also breed type (Kidner, 1966; Kiwuwa and Redfern, 1969; Kiwuwa, 1972, 1973). Wilson *et al.* (1987) observed no significant differences in lactation yield among cows that calved in different seasons in Kenana breed in Sudan. In their study of milk production of Zebu, Holstein Friesian and their crosses in Ethiopia, Million and Tadalle (2003) reported non-significant effects of season of calving on lactation yield. Kiwuwa (1973) concluded that season effects on complete 300-day lactation were in general not significant. He explained that milk yield would tend to deviate in opposite directions in wet and dry seasons and hence the two effects would cancel in complete lactation yields. He further reported that when lactation was partitioned into short intervals, seasonal effects on milk yield became significant and therefore concluded that short periods are suitable for studying the effect of season on milk yield. Kiwuwa and Redfern (1969) observed that heifers calving for the first time during the dry season produced more milk and maintained a higher body weight after calving than in the wet season.

Adjustment of lactation records for year is one of the most important components of any animal evaluation procedure. A young sire may have all his available daughters born in the same year. If this happens to be an exceptionally good year, estimated breeding values (EBVs) will be over-estimated of the true genetic worth of the sire.

Conversely, if the year in question happens to be a bad year, the EBV will be an under estimate (Rege and Mosi, 1989).

Amount of milk yield in lactation also depends on the records or measurements of milk yield. Partial suckled lactations are lower than full lactations. For example in several studies on traditional pastoral systems where calves are left to run with their dams during the day and separated at night so as to milk the dams the following morning, have indicated that extracted (partial) milk yield of *Bos indicus* cattle to be 200 kg per lactation from Maasai cattle in Kenya (Semenye and De leeuw, 1984), 235 kg per lactation for the Mali transhumant system (Diollo *et al.*, 1981) and 312 kg per lactation for the Borana in Ethiopia (Nicholson *et al.*, 1983).

2.5 Lactation length

Variations in the length of lactation with respect to both genetic and environmental influences have widely been reported. Cows of temperate breeds under intensive management usually continue to lactate until milk secretion is suppressed by the advanced stage of gestation. Hence lactation length is almost completely determined by length of calving interval (Syrstad, 1994). However in the tropical cattle, milk production ceases several months before next calving and before the depressive effect of new gestation on milk production is noticeable. Hence length of lactation is not so greatly influenced by calving interval. Wilson *et al.* (1987) reported a correlation coefficient of only 0.08 between lactation length and calving interval in Kenana cattle. The mean lactation length for *Bos indicus* cattle in East Africa range from 240 to 280 days (Mahadevan, 1966; Sacker and Trail, 1966; Kiwuwa and Kyomo, 1971). The mean lactation length in Zebu cattle varies considerably between breeds in the sense that Sahiwals are reputed to havc relatively longer lactations of about ten months while the East African Shorthorn Zebu have an average lactation of about eight months or less (Mahadevan, 1966). The first lactation length was 234 days for Sahiwal breed at Naivasha in Kenya (Meyn and Wilkins, 1974). Galukande *et al.* (1962) reported that lactations in East African Shorthorn Zebu were not only short (239 days) but also variable and the length accounted for 53% to 66% of the total variance in milk yield. He reported a range of 236 to 246 days with an overall coefficient of variation of 24%. Mahadevan *et al.* (1962) working on a genetic study of Sahiwal grading up scheme in Kenya observed significant differences ($P<0.01$) between East African Shorthorn Zebu and Sahiwal grades in lactation length of 239 and 283 days respectively.

Parity has a significant effect on lactation length. Cows in their first lactations tend to have shorter lactations than older ones. It increases up to 5th lactation and then starts to decline in subsequent lactations (Kiwuwa, 1973, 1974). A similar observation was reported by Reis *et al.* (1986) in which lactation length was lowest in the first lactation (264.9 days) and highest in the fifth lactation (310.8 days).

Kasonta (1988) observed that lactation length of Mpwapwa cattle in Tanzania was significantly influenced by both season and year of calving whereby lactations that started in the dry season were longer than those that started in the wet season. However, contrary to the former observation was a study done by Ageeb and Hillers (1991b) where cows calving in the wet summer season had longer lactations than those calving in the dry summer season. Kifaro (1995) reported that the season of calving did not affect the duration of lactation but the year of calving was an important factor, contributing 3 to 8% of the total variation in lactation length.

2.6 Lactation curve traits and factors affecting them

The knowledge of a cow's lactation curve could be an effective tool to make selection decisions in dairy breeding programmes. To obtain an accurate shape of a lactation curve a variety of mathematical models have been used in which parameters of peak production, inclining and declining phases of milk production over the course of lactation have been estimated by linear or nonlinear techniques. Among the non-linear functions include the incomplete Gamma function, inverse quadratic polynomial function, exponential function and polynomial regression function. Of these, the Gamma function of Wood (1967) has been widely used (Yadev *et al.*, 1977; Rao and Sundaresan, 1982; Batra *et al.*, 1987; Tekerli *et al.*, 2000) in the estimation of the lactation curve parameters:

$$Y_n=an^be^{-cn}$$

Where Y_n is the milk yield measured in time period n of the lactation, e is the natural logarithm, and a = a scaling factor to represent yield at the beginning of lactation, and b and c are coefficients associated with the inclining and declining slopes of the lactation curve. Genetic group differences in the shape of a lactation curve have been reported in previous studies (Yadev *et al.*, 1977; Rao and Sundaresan, 1982). Yadev *et al.* (1977) reported a significant effect of genetic group on constants *a* and *c* while studying factors affecting the components of gamma-type function of a lactation curve in Hariana and its Friesian crosses. He further observed no significant effect of genetic group on constant *b*. A similar trend of observations were reported by Rao and Sundaresan (1982) in their study on factors affecting the shape of the lactation curve in Friesians and Sahiwal cross bred cows. Tekerli *et al.* (2000) did not observe any significant effect of parity on magnitude of the lactation curve traits though there was a tendency for constant *a* values to increase with parity while the reverse was true for constant *b* values. No definite trend was observed for the constant c values. However, Rao and Sundaresan (1982) reported significant effects of parity on constants *a* and *c* but not *b*. All the three lactation curve traits *a*, *b* and *c* were significantly affected by parity (Yadev *et al.*, 1977). The differences in these previous findings could be explained by differences in age of the experimental materials used.

The influence of season on the shape of the lactation curve has been widely discussed (Wood, 1969, 1972; Yadev *et al.*, 1977; Rao and Sundaresan, 1982; Tekerli *et al.*, 2000; Dĕdková and Nĕmcová, 2003). The significant effects due to season on constant *a*, indicted that the initial production was favourable in spring calvers compared to those calving in the rainy season (Yadev *et al.*, 1977). High initial milk production was also observed by Wood (1969) in Holstein cattle calving during spring.

Rao and Sundaresan (1982) reported of 2.2568, 0.3356 and 0.0468 for parameters *a*, *b* and *c* respectively in Friesian x Sahiwal crossbred cows while Yadev *et al.* (1977) reported values of 3.9609, 0.0424 and 0.2972 respectively in Hariana and its Friesian crosses. Okantah (1992) while studying the partial milking of cattle in smallholder herds on Accra plains reported parameter estimates for partial milking lactation curves for cows in third lactation to be 1047.1, 0.21 and 0.28 for parameter *a, b* and *c* respectively. It appears as seen from the above estimates, that the magnitude of parameter *a* varies with the magnitude of the values used to estimate it. It does not affect the shape of the lactation curve but instead indicates the level of initial milk production.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study location

The study was carried out at Serere Agricultural and Animal Research Institute (SAARI) in Uganda. It is located at 0^0 32' N and 35^0 27' E at 1128 m above sea level. The station has sandy soils with low organic matter content. It receives an annual mean rainfall of 1427 mm but is considered to be among the low potential drier areas of Uganda because of the large variation in rainfall between years. The rainfall is bimodal with peaks in April/ May and August/September. The rainfall in March-May is reliable but the second rains (July-September) are unreliable. During the study period, the highest monthly average rainfall was in April (228 mm) and lowest in January (26.5mm, Figure 1). The main dry season is from December until March. The mean annual temperature is 24^0C and the mean minimum and mean maximum annual temperatures are 17.9^0C and 29.4^0C respectively. The relative humidity ranges from 72% to 84%.

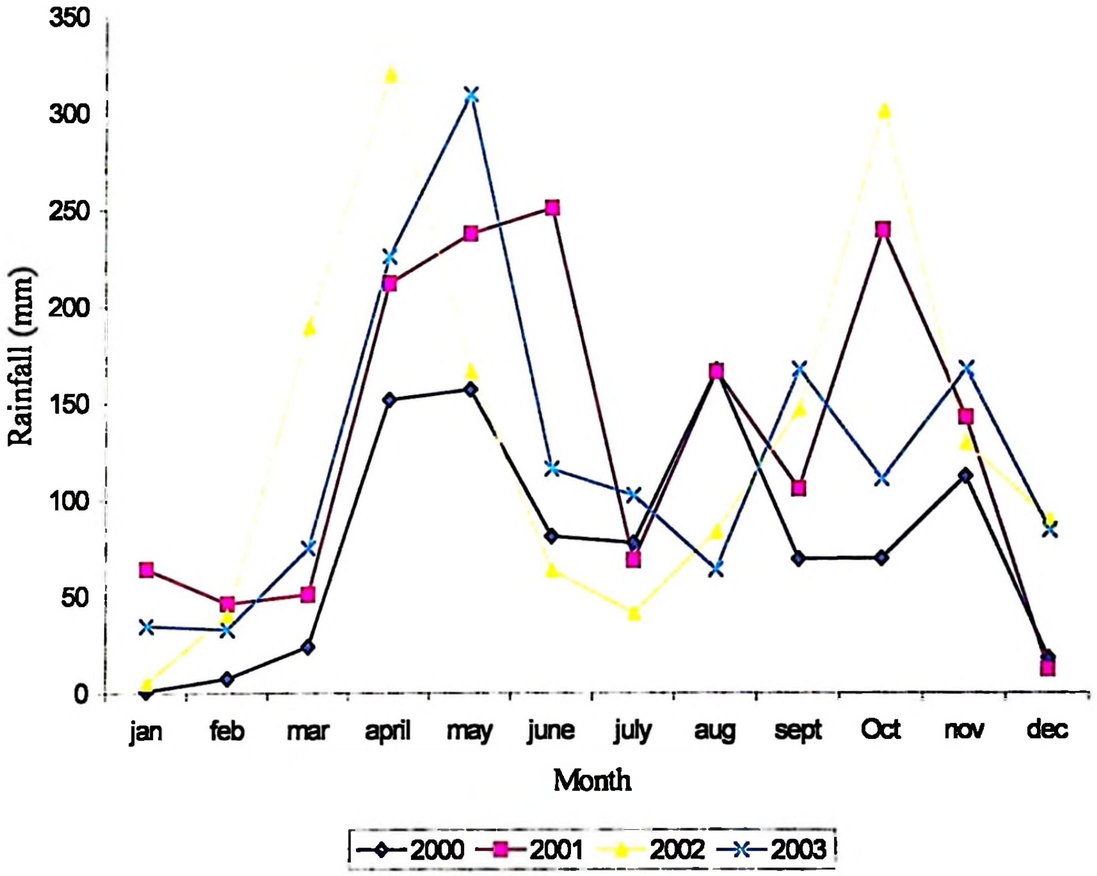


Figure 1: Rainfall distribution during the study period

3.2 Breeding programme at SAARI

The data for the study was obtained from a crossbreeding programme at the SAARI in Uganda aiming at producing dual purpose crosses. The data collected covered a period of nine years (1995-2003). In this crossbreeding program, Teso (T) females (which belong to the East African Shorthorn Zebu) were mated to Sahiwal (S) and Boran (B) bulls to produce F_1 of SxT and BxT genotypes respectively. Contemporary pure Teso calves were also produced alongside. Some F_1 of BxT and SxT females were mated to Boran and Sahiwal bulls respectively. Also F_1 SxT bulls were mated to Teso females. Therefore, F_1(BxT), F_1(SxT), B_1Sx(SxT), B_1Bx(BxT), B_1(SxT)xT and Teso genotypes were available for evaluation for growth traits. On the other hand F_1(BxT), F_1(SxT) and Teso genotypes were available for milk production and reproduction traits evaluation. All breeding was by natural service. Selected bulls were allowed to run continuously with a specific group of cows to ensure indentification of paternity of calves. Thus calves were born throughout the year.

3.3 Raising of calves and dams

Calves were weaned at 9 months of age. After weaning males were separated from the female weaners to avoid premature breeding. Heifers were turned to bulls when about 30 months of age. Calves were left to run with their mothers during the day and penned separately from their dams overnight. This prevented suckling and facilitated partial milking the next morning. Milking was done once a day. Health management involved routine dipping against ticks, deworming and vaccination for the control of rinderpest and brucellosis. Weights were taken once every month having starved the animals for 16 hours prior to weighing. All weights were taken on a weighbridge except birth weight, which was taken on a portable scale. All the stock was reared under the same grazing environment.

3.4 Management of the animals

The animals were raised entirely on natural pastures without any supplementary feeding except minerals and *ad-lib* supply of water. The major indigenous grasses were *Imperata cylindrical, Sporobolus pyramidalis, Hyparrenia rufa and Cynodon plectostachyus*. Improved pastures such as *Brachiaria spp*, *Pannicum maximum* and *Chloris gayana* were sparsely distributed within the rangeland. A few legumes such as *Centroscema pubescens*, *Siratro spp* and *Stylo gracilis* did exist.

3.5 Data classification for cattle weights

Two seasons of birth were identified that is wet and dry season where by April-May and September- November represented the wet seasons while June- August and December-March represented the dry seasons.

Years of birth were identified as 2000, 2001, 2002, and 2003

Six genotypes were identified F_1 (BxT), F_1(SxT), B_1Sx(SxT), B_1Bx(BxT), B_1(SxT)xT and Teso (T).

Data was also classified by sex into female and male.

Three parities of dams were identified and dams in fourth and fifth parity were grouped together. Only parity was a derived variable, as it was not recorded as such in these data. It was instead derived by examining birth dates of consecutive calves of each cow.

Weaning dates, and age of the dam were not included in the models, as this information was not available in the original data set and could not be derived. Data was collected on birth and weaning weights. Information on sex, birth dates, dam and sire of the calf as well as their breeds for each of the calf was collected. Records for milk production were only for three years, that is 2000-2002.

3.6 Statistical analyses

3.6.1 Growth traits

Growth traits were analysed by fitting a fixed effects model using the least-squares procedure of the Generalized Linear Model (GLM) of the statistical analysis systems institute (SAS) (2002). The fixed effects included in the analysis were genotype, year of calving, season of calving, sex of the calf and parity for birth weight, weaning weight, and pre-weaning average daily gain (ADG). The number of records that were available for analysis are given in Table 1.

The following model was used:

Model 1

$Y_{ijklmn} = \mu + A_i + B_j + S_k + G_l + L_m + (AB)_{ij} + (GB)_{lj} + (GS)_{lk} + e_{ijklmn}$

Where;

Y_{ijklmn} = Weight of the animal at birth or weaning or growth rate.

μ = Overall mean common to all observations

A_i = Effect due to i^{th} year of birth (1, 2, 3, 4)

B_j = Effect due to j^{th} season of birth ($j=1, 2$),

S_k = Effect due to k^{th} sex of animal ($k=1,2$)

G_l = Effect due to l^{th} genetic group of animal ($I=1, 2, 3,4,5,6$)

L_m = Effect due to mth parity of the dam (m= 1, 2, 3, 4)

$(AB)_{ij}$ = effect due to interaction between ith year and jth season.

$(GB)_{lj}$ = effect due to interaction between lth genetic group and jth season

$(GS)_{lk}$ = effect due to interaction between lth genetic group and kth sex

E_{ijklmn} = random residual error ~ $N(0, I\,\delta^2_e)$

Since weaning dates were not available, adjustment for age at weaning was not possible.

Growth rate was calculated as daily weight gain from birth to a weaning age. For example;

$$\text{Growth rate} = \frac{\text{Body weight at weaning - Birth weight}}{\text{Number of days}}$$

Table1: Summary of number of records available for analysis

Trait	Number of records
Birth weight	244
Weaning weight	236
Pre-weaning gain	236
Calving interval	134
Lactation milk yield	145
Lactation length	145

3.6.2 Heritability estimates for growth traits

Heritability was estimated based on the sire variance component and both the sire and dam variance components. Data of offsprings were used to estimate heritability. The data were adjusted for effects of season, sex, year and parity of the dam. Interactions such as season-year, genetic group x season and genetic group x sex were also included in the model. VARCOMP procedure of SAS (2002) was used to obtain estimates of sire and dam variance components using MIVQUE method .The following model was adopted for analyzing data for heritabilities. Dams were nested within sires.

Model 2

$Y_{ijklmnop} = \mu + A_i + B_j + S_k + G_l + L_m + (AB)_{ij} + (BG)_{jl} + P_n + D_{no} + e_{ijklmop}$

Where;

$Y_{ijklmnop}$ = Birth, weaning weight and pre-weaning ADG of the animal

μ = Overall mean common to all observations

A_i = Effect due to i^{th} year of birth (I=1, 2, 3, 4)

B_j = Effect due to j^{th} season of birth (j=1, 2)

S_k = Effect due to k^{th} sex of animal (k=1,2)

G_l = Effect due to l^{th} genetic group of animal (I=1, 2, 3, 4, 5, 6)

L_m = Effect due to m^{th} parity of the dam (n= 1, 2, 3, 4)

$(AB)_{ij}$ = Effect due to interaction between i^{th} year and j^{th} season.

$(BG)_{jl}$ = Effect due to interaction between l^{th} genetic group and j^{th} season.

P_n = effect due to n^{th} sire as a random effect (0=1,............18).

D_{on} =Effect due to the o^{th} dam mated to the n^{th} sire as a random effect

$E_{ijklmnop}$ = random residual error ~ N $(0, I\,\delta^2_e)$

Heritability estimates were then calculated as:

$h^2_S = 4\delta^2_S / (\delta^2_S + \delta^2_D + \delta^2_e) = 4\delta^2_S / \delta^2_P$

$h^2_{SD} = 2(\delta^2_S + \delta^2_D) / (\delta^2_S + \delta^2_D + \delta^2_e) = 2(\delta^2_S + \delta^2_D) / \delta^2_P$

Where,

δ^2_S and δ^2_D were the sire and dam variance components respectively and

δ^2_e the error variance component

h^2_S and h^2_{SD} heritability estimates based on sire; and both sire and dam components of variance

Heritability was estimated for weights at birth, weaning and pre-weaning ADG.

Standard error of heritabilities were estimated according to Falconer (1989)

$SE=(h^2)= 2/\sqrt{N}$

Where SE (h^2) = standard error of heritability

N = Total number of progeny.

3.6.3 Phenotypic correlations

Phenotypic correlations between the growth traits and also the various stages of milk production and lactation curve parameters were evaluated using Multivariate Analysis of variance (MANOVA) procedure as described in SAS (2002).

3.6.4 Calving interval

Calving interval was calculated as the number of days between two successive calvings. The data for calving interval (CI) was analysed using the General Linear Model (GLM) procedure of SAS (2002). In analyzing CI, the year and season of previous calving, parity, genetic group and season x year of previous calving interaction and genetic group x season interaction were considered as fixed effects. The following model was used for calving interval.

Model 4

$Y_{ijklmn} = \mu + A_i + B_j + G_k + D_l + L_m + (AB)_{ij} + (BG)_{jk} + e_{ijklmn}$

Where;

Y_{ijklmn} = Calving interval

μ = Overall mean common to all observations

A_i = Effect due to i^{th} year of previous calving (I = 1,2,3)

B_j = Effect due to j^{th} season of previous calving (j = 1,2)

G_k = Effect due to k^{th} genetic group of animal (I=1,2,3)

D_l = Effect due to n^{th} parity of the dam (n= 1,2,)

$(AB)_{ij}$ = effect due to interaction between i^{th} year and j^{th} season.

$(BG)_{jk}$ = effect due to interaction between k^{th} genetic group and j^{th} season

E_{ijklmn} = random residual error ~ N (0, I δ^2_e)

3.6.5 Milk production performance

3.6.5.1 Extracted lactation yield

Extracted lactation milk yield was calculated by addition of extracted daily milk yields for the whole lactation period. Season, year, parity and genetic group were used as fixed effects while lactation length was included as a covariate and the following model was adopted.

Model 5

$$Y_{ijklm} = \mu + S_i + A_j + P_k + G_l + (GS)_{il} + (SA)_{ij} + b(X_{ijkl} - \overline{X}) + e_{ijklm}$$

Where,

Y_{ijklm} =Extracted lactation milk yield

μ = Overall mean common to all observations

S_i = Effect of i^{th} season (1 and 2)

A_j = Effect of j^{th} year (1, 2 and 3)

P_k = Effect of k^{th} parity (1, 2, 3, 4)

G_l = Effect of l^{th} genotype (1, 2 and 3)

$(GS)_{il}$ = Effect due to interaction of l^{th} genotype and i^{th} season

$(SA)_{jj}$ = Effect due to interaction of i^{th} season and j^{th} year

b = Linear regression coefficient of lactation length on extracted milk yield

X_{ijklm} = Lactation length

$\overline{X}$ = Average lactation length

e_{ijklm} = random residual error distributed as $N(0, I\,\delta^2_e)$

Lactation length was also analysed as a dependent variable. Lactation length was obtained by counting the number of days from the date of calving till the cow cease to produce milk. The model below was used.

Model 6

$Y_{ijklm} = \mu + S_i + A_j + P_k + G_l + (GS)_{il} + (SA)_{ij} + e_{ijklm}$

Where,

Y_{ijklm} = Lactation length

μ = Overall mean common to all observations

S_i = Effect of i^{th} season (1 and 2)

A_j = Effect of j^{th} year (1, 2 and 3)

P_k = Effect of k^{th} parity

G_l = Effect of l^{th} genotype (1, 2 and 3)

$(GS)_{il}$ = Effect due to interaction of l^{th} genotype and i^{th} season

$(SA)_{jl}$ = Effect due to interaction of l^{th} season and j^{th} year

e_{ijklm} = Random residual error distributed as $N(0, I\,\delta^2_e)$

3.6.6 Lactation curves

Lactations were divided into periods of 30 days. Thus the first 30- days period covered the first month of lactation and the eighth 30- days period covered the eighth month of lactation. Monthly milk yields were determined by adding up the daily milk yields of 30 days. Arithmetic means were used to construct the lactation curves for the respective fixed effects such as genetic group, season of calving and parity.

3.6.7 Lactation curve traits

Gamma model of Wood (1967) was transformed logarithmically into a linear form and fitted to monthly milk yields so as to estimate the lactation curve parameters.

$$Y_n = an^b e^{-cn}$$

$$\ln(y_n) = \ln(a) + b[\ln(n)] - cn$$

Where,

y_n = milk yield in month n,

a = a scaling factor to represent yield at the beginning of lactation and

b and c = factors associated with the inclining and declining slopes of the lactation curve respectively

The model was fit to each cow's lactation record and the parameters of the lactation function In(a), b and c) were estimated by linear regression using the procedure REG of SAS (2002).

The index of persistency was calculated for each lactation according to Wood (1967), Madsen (1975) and Tekerli *et al.* (2000):

i) *s* from the gamma function definition where

$S = -(b+1)\ln(c)$

ii) the ratio of lactation yield to peak yield (y/y_{max});

iii) coefficient of variation(CV) for monthly milk yield.

The months in milk at peak yield (Y_{max}) was defined as b/c, and y_{max} was calculated as

$a(b/c)^{b}e^{-b}$.

Due to limited data, analysis of variance was not carried out on the lactation curve traits however, adjustment of the data for fixed effects of genotype, calving year, calving season, parity was done when calculating phenotypic correlation coefficients between the various lactation traits.

CHAPTER FOUR

RESULTS

4.1 Birth weight

The least squares means, standard errors and levels of significance of parity, sex and season are presented in Table 2. The overall mean birth weight was 18.36 ± 0.195 kg and CV was 16.50%. Sex of the calf did not significantly affect birth weights although male calves were heavier than female calves by 0.64 kg (3.6%). Analysis of variance showed that parity did not significantly ($P>0.05$) influence birth weight. There was a general trend for the birth weight to increase from the first to the third parity and to start declining from the fourth parity. Season of birth had no significant effect ($P>0.05$) on birth weights. However, calves born in the dry season were 0.40 kg (2.2%) heavier than their counter parts born in the wet season. The effects of year of birth and genotype of the calf are presented in Table 3. Genotype of the calf had a highly significant ($P<0.001$) influence on birth weight. Superiority ranking (in descending order) in terms of birth weight among the genotypes was F_1(BxT), F_1(SxT), Teso, B_1Sx(SxT), B_1Bx(BxT) and B_1(SxT)xT. Birth weight of purebred Zebu did not differ significantly ($P>0.05$) from birth weight of the crosses except B_1(SxT)xT, which had the lowest birth weight. Influence of year of birth on birth weight was not significant ($P>0.05$) though calves born in year 2001 were the heaviest followed by those born in year 2000, 2003 and 2002 respectively. None of the interactions included in the model significantly ($P>0.05$) influenced birth weight (appendix table 1).

Table 2: Least squares means (LSM) and standard errors (s.e) for the effect of sex, season and parity on birth weight, weaning weight (kg) and pre-weaning ADG (g)

	Trait					
	Birth weight		Weaning weight		Pre-weaning ADG	
Effect	N	Mean (kg)	N	Mean (kg)	N	Mean (g)
Overall	241	18.36 (0.195)	236	100.55 (0.48)	236	304.28 (1.97)
CV (%)		16.50		7.32		9.93
Season		NS		***		***
Wet	110	17.82 (0.75)	108	92.07^{a} (2.26)	108	271.90^{a} (0.01)
Dry	131	18.22 (0.40)	128	101.92^{b} (0.99)	128	309.48^{b} (0.01)
Sex		NS		*		NS
Female	125	17.70 (0.48)	123	95.32^{a} (1.35)	123	285.48 (0.01)
Male	116	18.34 (0.57)	113	98.67^{b} (1.55)	113	295.90 (0.01)
Parity		NS		NS		NS
1	47	17.51 (0.62)	47	96.39 (1.65)	47	290.20 (0.01)
2	105	18.37 (0.50)	103	96.56 (1.46)	103	287.45 (0.01)
3	69	18.92 (0.53)	67	97.12 (1.47)	67	288.09 (0.01)
≥ 4	20	17.29 (0.79)	19	97.90 (1.98)	19	297.02 (0.01)

Levels of significance ***=P<0.001, **=P<0.01, *=P<0.05 and NS=not Significant

In brackets are standard errors for the respective means

4.2 Weaning weight

The overall weaning weight was 100.55 ± 0.48 kg, and a 7.32% coefficient of variation (CV) was observed (Table 2). Season of calving significantly ($P<0.001$) influenced weaning weight. Calves born in the dry season weighed on average 9.85 kg more at weaning than those born in the wet season. The influence of sex of calf on weaning weight was significant ($P<0.05$). Male calves were 3.35 kg (3.5%) heavier than the female calves. Parity of the dam had no significant effect ($P>0.05$) on weaning weight though there was a mild trend of weaning weight to increase with increasing parity.

The effects of year of birth and genotype of the calf on weaning weight are presented in Table 3. Genotype of the calf had a significant ($P<0.001$) influence on weaning weight. $B_1Bx(BxT)$, $B_1Sx(SxT)$, $B_1(SxT)xT$, $F_1(BxT)$ and $F_1(SxT)$ crosses were 18.09, 26.99, 18.50, 16.19 and 24.96 kg respectively heavier ($P<0.05$) at weaning than the Teso pure breed . Both $B_1Sx(SxT)$ and $F_1(SxT)$ crosses were significantly ($P<0.05$) heavier than both $B_1Bx(BxT)$ and $F_1(BxT)$ crosses. Year of calving was an important source of variation ($P<0.01$). Largest weaning weights were observed in calves born 2001 followed by 2002, 2000 and 2003 respectively. Season x year interaction was also significant ($P<0.01$) (appendix table 2).

Table 3: Least squares means (LSM) and standard errors (s.e) for the effect of genotype and year on birth weight, weaning weight (kg) and pre-weaning ADG (g)

	Trait					
	Birth weight		Weaning weight		Pre-weaning ADG	
Effect	N	Mean (kg)	N	Mean (kg)	N	Mean (g)
Genotype		***		***		***
B_1Bx(BxT)	6	17.06^{ab} (1.57)	6	97.68^{b} (3.87)	6	296.84^{bc} (0.02)
B_1Sx(SxT)	40	18.35^{a} (0.57)	39	106.48^{a} (1.60)	39	324.64^{a} (0.01)
B_1(SxT)xT	64	16.21^{b} (0.50)	63	98.05^{b} (1.32)	63	301.94^{b} (0.01)
F_1(BxT)	22	19.22^{a} (0.76)	21	95.67^{b} (2.03)	21	280.25^{c} (0.01)
F_1(SxT)	62	18.94^{a} (0.51)	60	104.56^{a} (1.39)	60	315.43^{a} (0.01)
Teso	47	18.35^{a} (0.55)	47	79.52^{c} (1.48)	47	225.05^{d} (0.01)
Year		NS		**		**
2000	38	18.15 (0.59)	38	98.30^{b} (1.44)	38	296.94^{a} (0.01)
2001	124	18.41 (0.39)	123	101.49^{a} (0.95)	123	307.73^{a} (0.01)
2002	53	17.67 (0.54)	53	100.58^{ab} (1.33)	53	306.74^{a} (0.01)
2003	26	17.84 (1.19)	22	87.61^{c} (3.99)	22	251.36^{b} (0.02)

Levels of significance ***=P<0.001, **=P<0.01, *=P<0.05 and NS= Not Significant
In brackets are standard errors for the respective means
For crossbred calves, the breed of sire is listed first

4.3 Pre-weaning ADG

The overall pre-weaning ADG was 304.3 ± 1.96 with a coefficient of variation of 9.9% (Table 2). Genotype of the calf significantly ($P<0.001$) influenced pre-weaning ADG (Table 3). B_1Sx(SxT) crosses had the highest pre-weaning ADG (333.09 ± 0.01) though it was not significantly ($P>0.05$) different from F_1(SxT) crosses while purebred Teso calves had the least pre-weaning ADG (225.05 ± 0.01 g/day).The influence of year of birth was significant ($P<0.01$) whereby calves born in year 2001 showed the highest pre-weaning ADG followed by those born in 2002 and 2000 with those born in 2003 having the least pre-weaning ADG (251.36 ± 0.02 g/day) (Table 3). Parity of the dam did not show any significant ($P>0.05$) importance and there was no definite trend for the various lactations. Sex of the calf did not significantly affect pre-weaning ADG though male calves gained 10.42 g per day more than the females calves. Season of calving significantly ($P<0.05$) influenced pre-weaning ADG in the sense that calves born in the dry season gained 37.58 g per day more than dry season born calves. Season x year interaction had significant ($P<0.001$) influence while genetic group x season interaction was not significant ($P>0.05$) (appendix table3).

4.4 Heritability for birth, weaning weight and pre-weaning ADG

Variance component estimates for birth, weaning and pre-weaning ADG are presented in Table 4. Heritability for birth weight based on either the sire component or both the sire and dam components was 0.41 ± 0.129 (Table 4), which was moderate. Estimates of heritability for weaning and pre-weaning ADG based on the sire component of variance were 0.02 ± 0.130 and 0.02 ± 0.130 while heritability estimates based on both the sire and dam components of variance were 0.16±0.130 and 0.36±0.130 respectively (Table 4).

Table 4: Variance components and heritabilities for birth weight, weaning weight and pre-weaning gain

	Trait		
Variance component	Birth weight	Weaning weight	Pre-weaning gain
δ^2_S	0.96629	0.30747	0.000004817
δ^2_e	7.61219	52.32172	0.0007963
δ^2_D	0.96561	4.08215	0.0001714
h^2_S	0.41	0.02	0.02
h^2_{SD}	0.41	0.16	0.36
s.e(h^2)	0.128	0.130	0.130

δ^2_S= Sire variance component δ^2_e= error variance component
δ^2_D = Dam variance component h^2_S = heritability based on sire variance component
h^2_{SD}= heritability based on both the sire and dam variance components

4.5 Phenotypic correlation coefficients for growth traits

Correlation coefficients between body weights are presented in Table 5. Correlation between birth weight and weaning weight was –0.07, between birth weight and pre-weaning ADG was –0.44 while that between pre-weaning ADG and weaning weight was 0.93. All correlations were highly significant except that between birth weight and weaning weight.

Table 5: Correlation coefficients among growth traits

Trait	Weaning weight	Pre-weaning ADG
Birth weight	-0.07[1]	-0.44
Weaning weight		0.93

[1] Not significant at P>0.05; all other correlations are significant at P<0.001

4.6 Calving interval

Least squares means and coefficient of variation for calving intervals are presented in Table 6. The overall mean calving interval was 453 ± 1.06 days with a coefficient of variation of 27.7%. Parity did not significantly (P>0.05) affect calving intervals although cows in their first parity had longer calving intervals than those in the second parity. Year of previous calving significantly influenced (P<0.01) the calving intervals. Cows that had previously calved in 2001 had the longest calving intervals followed by those that calved in year 2000. Cows that calved in 2002 had the least mean calving interval. Calving intervals was not significantly (P>0.05) influenced by genetic group of the cows. However, Sahiwal x Teso crosses had the longest calving intervals (458 days) followed by Boran x Teso crosses while purebred Teso cows had the least mean calving interval (397 days). The effect of season of previous calving was not statistically significant but cows that previously calved in the dry season had longer calving intervals (440 days) than their counterparts that previously calved in the wet season (about 425 days). Genetic group x season of previous calving interaction as well as genetic group x year of previous calving interactions were not significant (P>0.05) sources of variation (appendix table 4).

Table 6: Least squares means (LSM) and standard errors (s.e) for calving interval (days)

		Calving interval (days)	
Factor	N	LSMean	S.e
Overall	134	453.0	1.06
CV (%)		27.7	
Year of previous calving		**	
2000	54	432.2^{b}	29.09
2001	75	499.7^{a}	21.80
2002	5	365.1^{b}	65.93
Parity		NS	
1	114	447.7	29.09
2	20	416.9	36.56
Genetic group		NS	
Boran x Teso	6	441.6	56.19
Sahiwal x Teso	18	458.3	35.36
Teso	110	397.0	23.51
Season of previous calving		NS	
Wet season	77	424.6	35.06
Dry season	57	440.0	47.08

Levels of significance **=P<0.01, and NS= not significant

4.7 Lactation Curves

The monthly extracted milk yields for wet and dry season of calving are presented in Table 7. In both seasons, monthly extracted milk yields and standard deviations were observed to decrease with the progression of lactation. The lactation curve fitted using these means is shown in Figure 2 .The distribution of milk yields in two seasons is quite different. Cows calving in the dry season had relatively lower yields in the first 1.5 months than the wet season cows but the trend changes after 1.5 months whereby cows that calved in the dry season were producing at a higher level in the subsequent months up to the fifth month after calving. From fifth month after calving the conditions favoured cows that calved in the wet season.

Table 7: Means of monthly milk yields for wet and dry season of calving

	Milk yield (kg)					
	Wet season			Dry season		
Month of lactation	N	Mean	s.d	N	Mean	s.d
1	60	26.95	9.44	53	25.92	11.23
2	59	24.88	10.96	53	25.36	10.09
3	57	22.33	8.82	46	23.66	12.24
4	49	21.20	7.53	36	22.21	9.01
5	38	19.38	7.34	27	19.75	7.86
6	29	18.55	7.56	23	16.82	5.80
7	17	18.34	7.53	12	17.23	5.66
8	9	17.72	10.04	10	15.68	5.00

s.d= Standard deviation

The monthly milk yields for the three genotypes under study are presented in Table 8. The lactation curves fitted using these means is shown in Figure 3. The level of milk production was highest among F_1(S x T) crosses followed by F_1(B x T) crosses and Teso respectively over all the stages of lactation.

Table 8: Means of monthly milk yields for the genotypes studied

	Genotype								
	F_1(BxT)			F_1(SxT)			Teso		
Month of lactation	N	Mean (kg)	s.d	N	Mean (kg)	s.d	N	Mean (kg)	s.d
1	8	30.19	11.99	15	29.93	10.41	90	25.56	10.03
2	8	28.41	10.97	14	29.13	9.83	90	24.19	10.49
3	8	24.94	12.39	14	28.39	15.43	81	21.78	8.95
4	6	25.13	10.26	10	29.45	13.65	69	20.19	6.11
5	4	19.94	10.26	9	27.97	11.74	52	18.04	5.28
6	2	21.25	1.77	8	24.98	8.50	42	15.78	4.76
7	2	22.13	3.71	3	27.00	2.60	24	15.55	4.45
8	2	17.25	3.89	2	29.50	9.19	15	13.52	4.22

s.d= Standard deviation

The monthly milk yields for the three parities under study are presented in Table 9. The lactation curve, fitted using these means is shown in Figure 4.

Table 9: Means of monthly milk yields for the three parities studied

	Milk Yield								
	Parity 1			Parity 2			Parity 3		
Month of lactation	N	Mean (kg)	s.d	N	Mean (kg)	s.d	N	Mean (kg)	s.d
1	27	27.33	12.72	50	26.73	9.25	36	25.45	9.84
2	27	27.38	12.18	49	24.45	9.94	36	24.29	9.99
3	27	23.69	10.46	42	22.82	11.07	34	22.45	9.92
4	20	21.38	7.70	33	22.53	9.85	32	20.85	6.49
5	13	18.56	7.15	26	20.90	8.99	26	18.64	5.94
6	9	18.22	8.79	22	17.30	7.38	21	18.10	5.52
7	4	13.31	5.94	14	16.68	4.36	11	17.43	7.45
8	3	12.83	4.57	10	16.10	7.93	6	14.46	6.42

s.d= Standard deviation

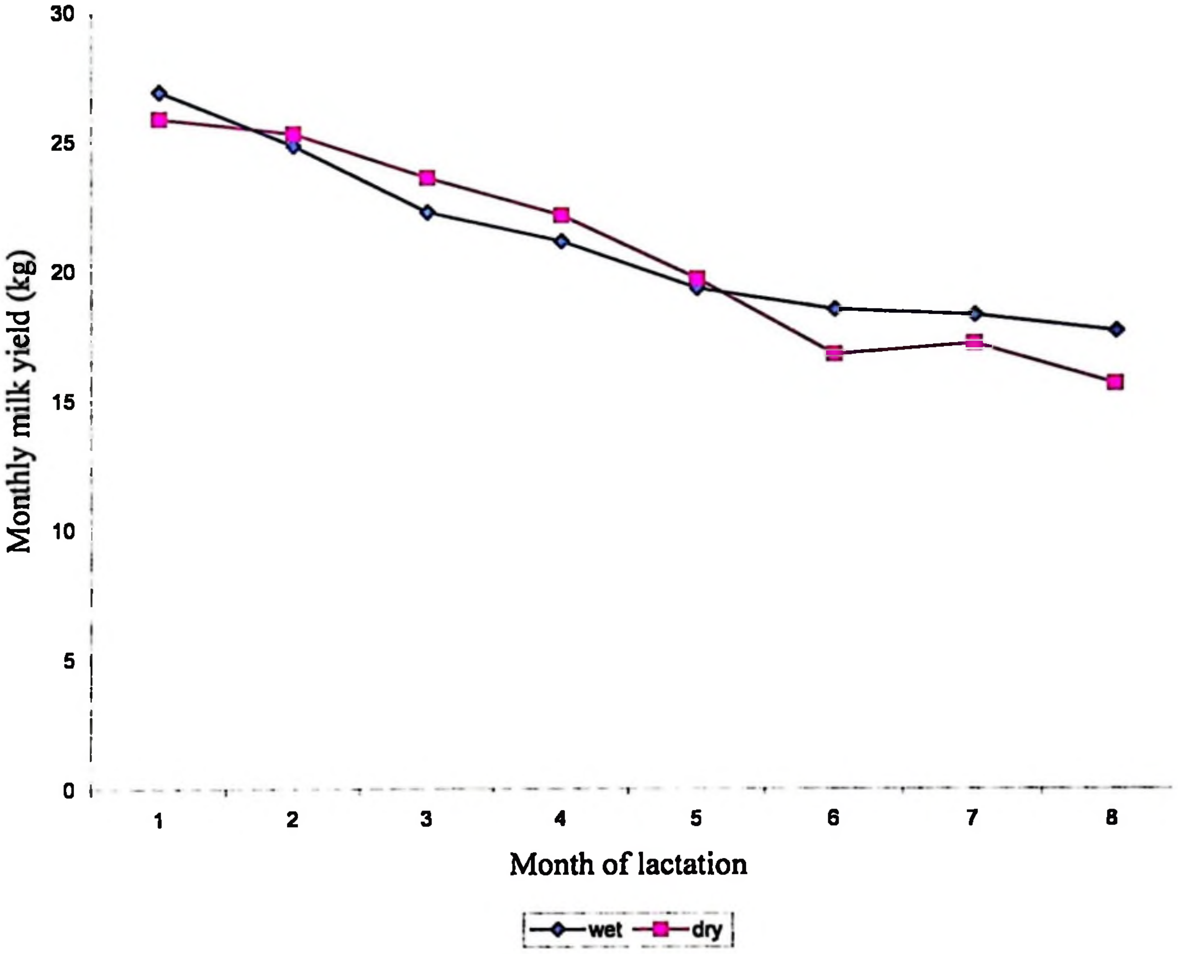


Figure 2: Effect of season of calving on the lactation curve

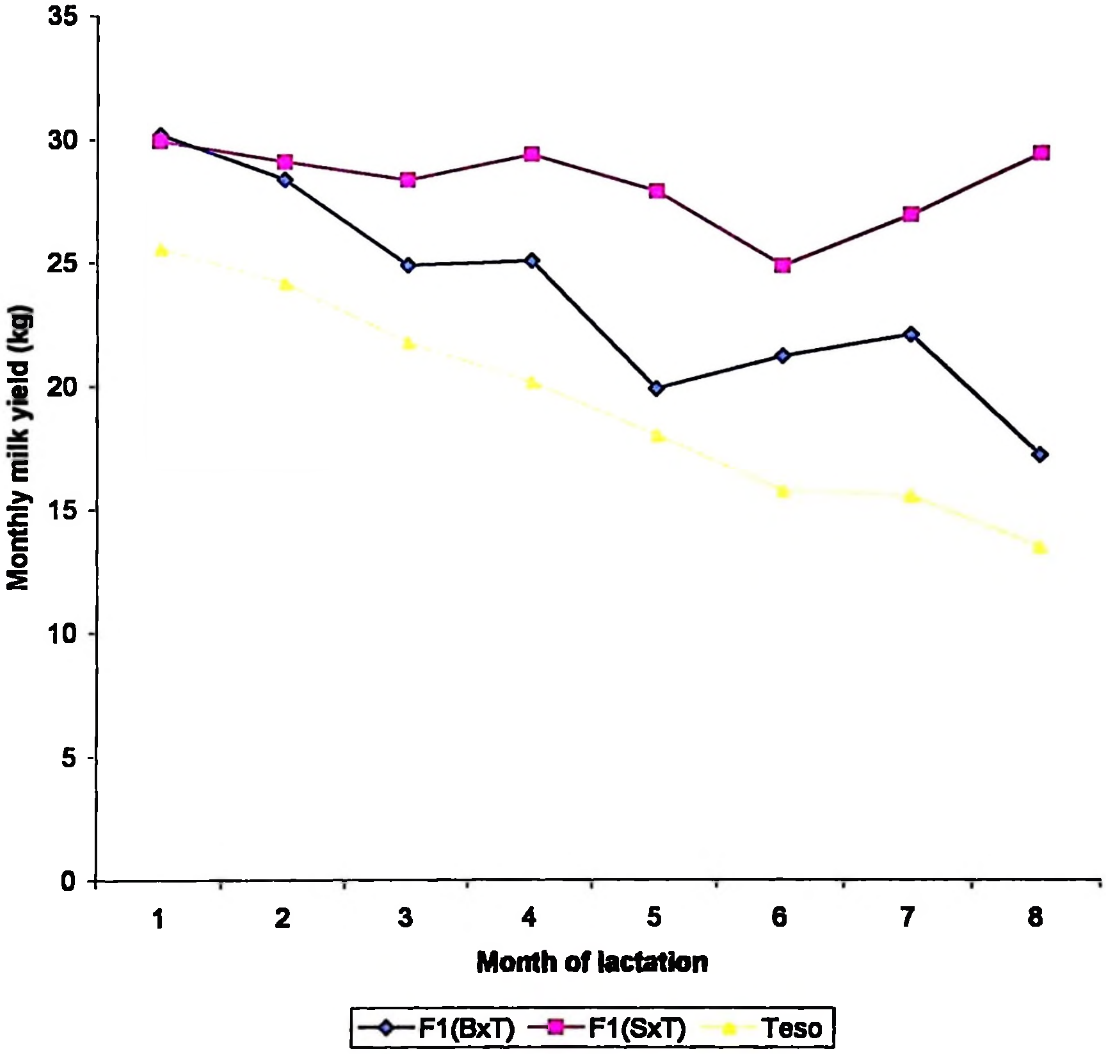


Figure 3: Effect of genetic group on the lactation curve

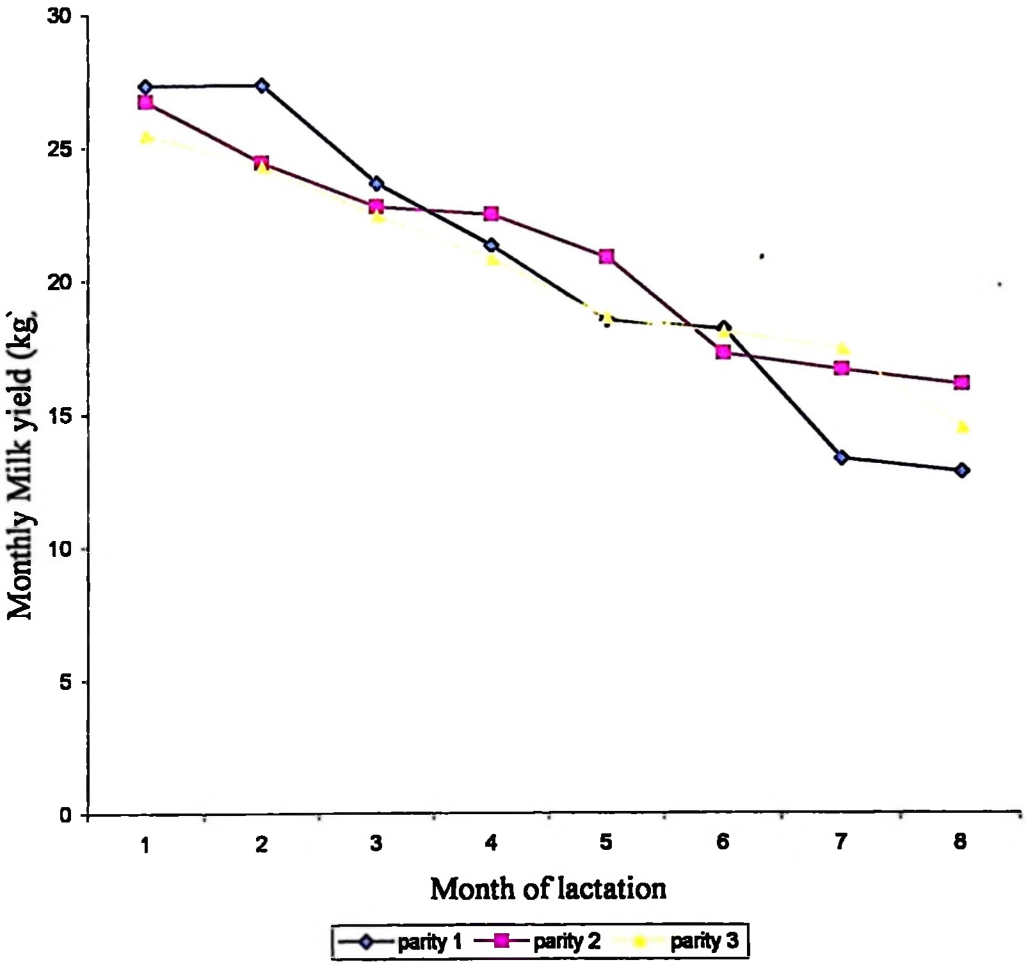


Figure 4: Effect of parity on the lactation curve

4.8 Extracted lactation milk yield and lactation length

The solutions for fixed effects for extracted lactation milk yield and lactation length are shown in Table 10. The overall means for extracted lactation milk yield and lactation length were 120.0 ± 3.4 kg and 173.6 ± 5.0 days respectively. The respective coefficients of variation were 34% and 35%. In both traits parity was not a significant ($P>0.05$) source of variation. However, extracted lactation yield tended to increase with increase in parity though the increments were marginal while no definite trend was observed with regards to lactation length. Genotype of the cow significantly ($P<0.01$) influenced extracted lactation milk yield. Sahiwal x Teso crosses significantly produced 52.1 and 50.3 litres of milk more than Boran x Teso crosses and Teso dams respectively. No significant ($P>0.05$) difference was observed between Teso dams and Boran x Teso crosses. Year and season of calving significantly ($P<0.05$) influenced extracted lactation yield. Cows that calved in year 2002 produced the highest milk yield followed by 2000 calvers and those that calved in 2001 produced the least extracted milk yield. Extracted milk yields in 2000 and 2002 did not differ significantly ($P>0.05$). Cows that calved in dry season produced 38.5 litres more of extracted milk yield than those that calved in the wet season.

Season of calving, year of calving as well as genotype of the cow did not significantly ($P>0.05$) influence lactation length. However, Sahiwal x Teso crosses were observed to have longer lactation lengths followed by the Teso cows and Boran x Teso crosses had the least lactation length. Cows that calved in the wet season had longer lactation length (by 8 days) than those that calved in the dry season. Cows that calved in year 2002 had the longest (168 days) lactation length followed by 2001 and

2000 in that order. Year x season interaction was significant for extracted milk yield (P<0.05) and for lactation length (P<0.001). Genotype x season interactions were not significant (P>0.05) for both traits (appendix table 5 and appendix 6).

4.9 Phenotypic correlations among milk production traits

Phenotypic correlation coefficients (r_c) between monthly extracted milk yields with 100-day partial milk yield ranged from 0.35 to 0.84 (Table 11). The correlation coefficient between monthly extracted milk yields in the second month of lactation and 100 days milk yield was the highest (r_c=0.84). All correlations were highly significant (P<0.01) except for the sixth month of lactation, which was significant at P<0.05. The correlations increased from the first month up to the second and thereafter decreased in the subsequent months. Correlation coefficients between the monthly extracted milk yields and extracted lactation milk yield were high ranging from 0.67 to 0.93. All correlations were significant (P<0.01) with monthly extracted milk yields in the third month of lactation having the highest correlation (r_c =0.93). Correlation coefficient between 100-day and total extracted milk yield was 0.78.

Table 10: Least squares means (LSM) and standard errors (s.e) for extracted milk yield and lactation length

	Trait			
	Extracted lactation milk yield (kg)		Lactation length (days)	
Effect	N	Mean	N	Mean
Overall	145	120.0 ± 3.4	145	173.6 ± 5.0
CV (%)		34.0		35.0
Genotype		**		NS
F_1(BxT)	8	125.9^{b} ± 16.3	8	148.7 ± 24.0
F_1(SxT)	14	178.0^{a} ± 12.0	14	182.9 ± 17.7
Teso	123	127.7^{b} ± 6.0	123	165.7 ± 8.9
Year		*		NS
2000	56	145.3^{a} ± 10.3	51	151.0 ± 15.0
2001	69	119.3^{b} ± 7.7	70	169.3 ± 11.3
2002	20	166.7^{a} ± 14.4	20	177.0 ± 21.3
Season		*		NS
Wet	91	124.5^{a} ± 8.5	55	169.8 ± 12.6
Dry	52	163.0^{b} ± 12.9	98	161.8 ± 19.0
Parity		NS		NS
1	37	136.8 ± 9.5	37	168.9 ± 14.0
2	55	145.2 ± 9.0	55	171.2 ± 13.3
3	41	145.3 ± 9.6	41	162.9 ± 14.2
4	12	147.7 ± 14.2	12	160.1 ± 20.9

Levels of significance ** =$P<0.01$, * =$P<0.05$ and NS= not significant

Table 11: Phenotypic correlation coefficients between monthly extracted milk yields and 100-day partial and extracted lactation yield

	Correlation coefficients	
Milk yields	100-day	Extracted lactation milk yield
Month one	0.79 **	0.83 **
Month two	0.84 **	0.86 **
Month three	0.80 **	0.93 **
Month four	0.66 **	0.79 **
Month five	0.56 **	0.83 **
Month six	0.35 *	0.67 **
100-day		0.78 **

Levels of significance **=P<0.01, *=P<0.05

Means for lactation curve parameters for the three breeds under study are presented in Table 12. The lactation curves fitted using these estimated curve parameters are shown in Figure 5.

Table 12: Means of lactation curve parameters, persistency indices and milk production traits

Genotype	Variable	No.	Mean	SD	Se	Min	Max
F_1(BxT)							
	cv	3	5.116	1.112	0.642	4.246	6.369
	Ina	3	5.671	0.616	0.356	3.029	4.258
	b	3	0.473	0.348	0.201	0.250	0.875
	c	3	-0.272	0.148	0.085	-0.427	-0.133
	s	3	1.972	0.559	0.323	1.595	2.614
	Y/y_{max}	3	6.010	2.278	1.315	3.380	7.349
	b/c	3	1.750	0.673	0.389	0.979	2.222
	y_{max}	3	32.563	1.879	9.759	16.143	54.726
F_1(SxT)							
	cv	5	4.418	2.410	1.078	2.509	7.984
	Ina	5	3.623	0.658	0.294	2.701	4.428
	b	5	0.748	0.505	0.226	0.128	1.427
	c	5	-0.320	0.232	0.104	-0.627	-0.027
	s	5	2.249	1.122	0.502	1.135	4.067
	Y/y_{max}	5	7.749	3.369	1.506	4.301	12.675
	b/c	5	2.790	1.094	0.489	2.144	4.721
	y_{max}	5	33.662	1.760	9.074	15.997	67.581
Teso							
	cv	32	4.320	1.776	0.314	1.227	9.618
	Ina	32	3.432	0.742	0.131	0.488	4.969
	b	32	0.654	0.500	0.088	0.031	2.005
	c	32	-0.348	0.230	0.041	-0.994	-0.075
	s	32	1.799	0.708	0.125	0.017	3.145
	Y/y_{max}	32	5.209	1.301	0.230	2.421	8.029
	b/c	32	1.828	0.822	0.145	0.199	3.712
	y_{max}	32	25.270	1.943	1.982	11.823	67.921

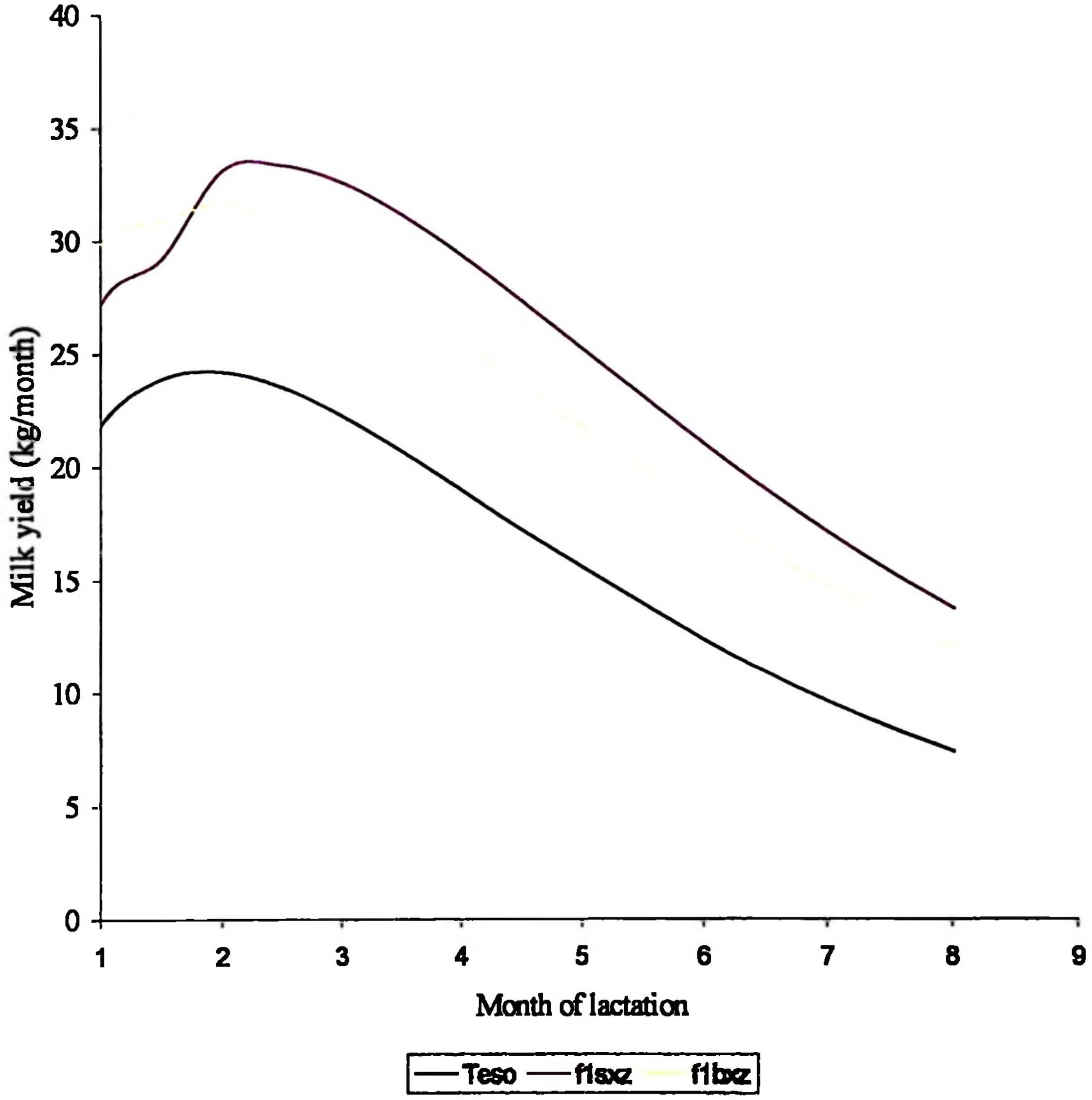


Figure 5: Lactation curves of Teso cows and their F_1 crosses with Sahiwal and Boran breeds

4.10 Phenotypic correlations between lactation curve traits, production traits and indices of persistency

The correlations between the lactation curve parameters are presented in Table 13. The parameter of the lactation function, c, was negatively correlated with the other parameters of Gamma model. High positive correlation occurred between persistency s and parameter c (0.909) though it was negatively correlated with both lna (-0.791) and b (-0.755). The number of days in milk at the peak production was negatively correlated with parameter lna (-0.538) while positively correlated with persistency s. Parameter, lna and peak yield (y_{max}) were positively correlated with lactation yield (Y) while parameter b, b/c and s were negatively correlated with Y though neither of the correlations were significant (P>0.05). High and moderate positive correlations occurred between lactation function lna and peak milk yield (y_{max}) (0.924) and lactation yield Y (0.555).

Table 13: Phenotypic correlations between lactation curve traits, production traits and indices of persistency

			Persistency measures					
Trait	b	c	S	cv	Y/y_{max}	b/c	y_{max}	Y
Ina	0.413*	-0.633**	-0.791**	0.326	-0.671**	-0.538**	0.924**	0.555**
b		-0.938**	-0.755**	0.412*	-0.493**	0.229	0.274	-0.071
c			0.909**	-0.498**	0.644**	0.046	-0.447*	0.016
s				-0.370*	0.816**	0.440*	-0.584**	-0.072
cv					0.052	0.100	0.227	0.139
Y/y_{max}						0.586**	-0.532**	0.077
b/c							-0.436*	-0.148
y_{max}								0.368*

Levels of significance, **=$P<0.01$ and *=$P<0.05$.

a= scaling factor to represent yield at the start of lactation

b= coefficient associated with inclining slope

c= coefficient associated declining slope

s= persistency index determined from the gamma function [$s= -(b+1)\text{In}(c)$]

cv = coefficient of variation for monthly milk yield

Y/y_{max}= Lactation yield/ peak yield

b/c = inclining slope coefficient/declining slope coefficient

Y = lactation yield

y_{max}= peak yield

CHAPTER FIVE

DISCUSSION

5.1 Birth weight

The average birth weight in this study was comparable to that reported by Rwabushaija (1998) but lower than those reported for the East African Shorthorn Zebu crossbreeds (Mwandotto, 1981; Trail *et al.*, 1985; Mwatawala, 2001). This is because the Teso type is a smaller breed compared to other Zebu breeds in the region (Rwabushaija, 1998).

The effect of sex on birth weight was not significant (P>0.05), which is consistent with findings by Mbap and Ngere (1991) and Rege *et al.* (1993) but contrary to the significant sex influences reported by Mwandotto (1981), Kifaro and Mchau (1986), Saeed *et al.* (1987), Ibeawuch (1990) and Tawah *et al.* (1993). Kifaro and Mchau (1986) reported male calves to be heavier than the females by 2.7 kg; Mwandotto (1981) and Tawah *et al.* (1993) reported a difference of 1.28 kg and 1.0 kg respectively. Though the difference between the male and female calves in this study was not significant, male calves were 4% heavier than the female calves. That male calves are heavier than females is attributed to the longer gestation period of males as was observed by Ibeawuch (1990).

Significant breed influences on birth weight have been reported (Sacker *et al.*, 1971; Mwandotto, 1981; Mbap and Ngere, 1991; Mwatawala, 2001; Said *et al.*, 2001). In this study, there was no significant difference in birth weight between F_1 Sahiwal and

Boran crosses with the Teso calves though Sahiwal and Boran crosses were slightly heavier. Mwandotto (1981) reported a superiority of 1.02 kg (5%) and 1.85 kg (10%) of Sahiwal and Boran crosses over the EASZ respectively while Mwatawala (2001) reported 2.1 kg (10.3%) superiority for Boran crosses over the Tanzania Shorthorn Zebu. The difference between the findings of this study and those of other reports could be due to difference in climatic conditions. The magnitude of birth weight for Teso calves in this study (18.35 kg) was comparable with 19.43 kg earlier reported in the same herd by Rwabushaija (1998).

Birth weight was increasing with parity up to the third parity and thereafter declined. This is similar to findings reported elsewhere (Kifaro and Mchau, 1986; Wakhungu *et al.*; 1991; Banjaw and Haile-Marian, 1994; Winroth, 1990). This trend is due to the fact that young dams, which have not reached adult size, continue to grow during their first pregnancies and thus compete with the foetus for available nutrients. In addition, the maternal environment also apparently changes with parity and possibly the degree of development and vascularity of the uterus (Hafez and Dyer, 1969).

Influence of season of birth on birth weight was not significant (P>0.05) in this study though dry season born calves were 0.48 kg heavier than those born in a wet season. This small difference could be attributed to the abundant forages available during the last stages of pregnancy for animals calving in the wet season. Hafez and Jainudeen (1975) showed that the growth of the foetus during the last trimester is apparently dependent on the caloric intake of the dam hence maternal nutrition exerts an important effect on the foetal growth.

Insignificant year effects were observed in this study, which supports Rege *et al.* (1993) findings among the White Fulani cattle. The environmental differences between the years were probably not diverse to cause any significant variation in birth weight.

5.2 Weaning weight and pre-weaning ADG

The effect of sex on weaning weight was significant ($P<0.05$) whereby weaning weight of male calves was 3.35 kg (3.5%) heavier and grew 3.6% faster than female calves. This was consistent with earlier reports by Mwandotto (1988), Sacco *et al.* (1989) and Udo (1993). Further Sacco *et al.* (1989) had demonstrated that male calves were 17.9 kg heavier ($P<0.01$) at weaning than females. Gregory *et al.* (1978) reported that males gained 0.04 kg faster than females. Higher weaning weight and pre-weaning ADG among male calves is attributed to higher androgen concentrations in males than in females.

The effect of year on weaning weight was highly significant ($P<0.01$). The ratio of effect of year in total variability of weaning weight was 3.6%. As observed in this study, the significant effect of year on weaning weight was also reported elsewhere in the tropics (Oni, *et al.*, 1988; Mwandotto, 1988). Because of the changes that occur in climate and pasture conditions from year to year, differences in weaning weight among years are expected. Annual rainfall pattern is translated into a clear pattern in milk production of the dams from which the suckling calves benefit.

Highest rainfall was received in year 2001 followed by 2002, 2003 and 2000 in that sequence. Weaning weights showed a similar trend though not for 2003 and 2000.

The seasonal differences in weaning weight and pre-weaning growth rate indicate an advantage for dry-season born calves and this is consistent with previous results in the tropics (Drewry *et al.*, 1959; Lhoste, 1968; Abassa *et al.*, 1993; Msanga, 1984; Tawah *et al.*, 1993; Udo, 1993; Mwantawala, 2001). In view of the findings in this study, having calvings during the start of the dry season is advantageous because supplementary feeding of the pregnant dams may not be necessary. However, its implementation under traditional management is limited by lack of controlled breeding in communal grazing areas where all age groups, both male and female, are grazed together.

Previous studies have shown the effect of genetic group on weights at weaning (Trail *et al.*, 1971a; Tahir *et al.*, 1984; Kasonta, 1992). Mwandotto (1988) observed no significant difference between Boran x EASZ and Sahiwal x EASZ crosses whereas in the current study, F_1(SxT) were significantly ($P<0.001$) heavier than F_1(BxT) crosses. The superiority sequence for average weaning weight and pre-weaning ADG was in the order of B_1Sx(SxT), F_1(SxT), B_1(SxT)xT, B_1Bx(BxT), F_1(BxT), and T (Teso breed). For B_1Sx(SxT) crosses to show the highest weaning weight (106.48 ± 1.6) kg in this study, is not surprising because the feed of the calves during the suckling period is based largely on milk hence their weights at weaning reflect to a considerable extent the milk production level of their dams. Therefore, the heavy weaning weight of B_1Sx(SxT) crosses is probably due to the fact that these calves were born by F_1(SxT) dams, which have been found, in this study, to have a relatively higher milk production potential than other breeds. Anido and Topps (1993) reported a similar observation in which calves born to Sahiwal crosses gained live weight at a significantly faster rate than the Boran, Boran-Hereford and East African Zebu dams. Phenotypic correlations between milk yield, total or cumulative milk production and gain from birth to weaning or weaning weight are of the order of 0.5 - 0.8 (Koch, 1972; Robison *et al.*, 1978), suggesting important differences in maternal ability as measured by milk production. Secondly, it is probable that the Sahiwal genes have a greater potential for growth than the other genetic groups. This is mainly manifested by the fact that B_1(SxT)xT crosses, although they had the lowest birth weight, they managed to attain a relatively higher weaning weight than the Boran crosses and Teso pure breed. The Teso calves had the lowest weaning weight and it's magnitude (79.52 ± 1.48 kg) was lower than the 146, 121.67 ± 0.49, 108 ± 2.5 and 86.10 ± 1.85 kg reported by Trail *et al.* (1985), Mwandotto (1988), Rwabushaija (1998) and Mwatawala (2001) respectively but higher than the 65 kg for the Kenya Maasai cattle (Semenge and De leeuw, 1984) or 61kg reported for cattle in Mali pastoralists system (Diollo *et al.*, 1981). Figures in Table 3 indicate that the growth rate was higher in the crossbreds than the purebreds. This agrees with the results of Mwatawala (2001), Mwandotto (1988) and Trail and Gregory (1981c) and indicates that crossbreeds mature at much earlier age than the pure Teso Zebu. Heavier weights at weaning of Sahiwal and Boran crosses show that tremendous increase in weight can be achieved by crossing the Teso cattle to Sahiwal and Boran bulls. Backcrossing to respective Boran and Sahiwal sire breeds was not advantageous because there was no difference between F_1 and the backcrosses. This is because heterosis is reduced by 50% when backcrossing is carried out.

5.3 Heritability estimates.

Estimate of heritability of 41% for birth weight based on the sire variance component was within the range of estimates (39 - 44%) reported from other tropical studies (Tonn, 1976; Tawah *et al.* 1993; Rwabushaija, 1998; Wakhungu *et al.*, 1991; Mwatawala, 2001) but greatly higher than those reported by Trail *et al.* (1971b), Mwandotto (1986), Arnason and Kassa-Mersha (1987), Saeed *et al.* (1987) and Galip *et al.* (2004). The heritability estimate in this study indicates that birth weight could give an appreciable response to direct selection for this particular trait.

Heritability estimates for both the weaning weight and pre-weaning ADG using both methods in this study were lower than corresponding estimates in the literature (Tawonezvi, 1989b; Tawah *et al.*, 1993; Mekonnen, 1996; Mwatawala, 2001). This difference could be due to the fact that previous studies on genetic parameters for birth and pre-weaning growth of calves were done under different environments and management. For calves suckling their dams, growth during pre-weaning period is mostly dependent on the dam's milk production. This is reflected by low heritability for weight at weaning (Acker, 1983). Trail *et al.* (1971b) observed that growth to weaning, especially under fairly harsh range conditions is very subject to maternal influences, and calf genotype may be masked to a greater degree. This could have been the case in this study because the dam variance component was higher than the sire component. Heritability estimate of weaning weight based on both the sire and dam component was higher than the estimate based on sire component indicating that weaning weight was highly influenced by maternal effects. Birth weight being less affected by the environmental conditions than the weaning weight had heritability estimates from sire component, and sire plus dam components being similar.

5.4 Correlation coefficients between body weights and pre-weaning ADG

Kifaro and Mchau (1986), Arnason and Kassa-Mersha (1987), and Mwatawala (2001) reported significant positive correlations between pre-weaning ADG and weaning weight. In the present study, a significant ($P<0.001$) correlation of 0.929 was observed indicating that calves that gain more weight per day obtain a higher weaning weight.

A negative correlation (–0.07) between birth and weaning weight was observed in the present study, which is contrary to previous reports. For example, Mwatawala (2001) observed a correlation of 0.5 in TSZ and its crosses with Boran while Arnason and Kassa-Mersha (1987) and Kifaro and Mchau (1986), reported a correlation of 0.15 and 0.286 in the Ethiopian Boran and Friesian calves in Tanzania respectively. The negative correlation in the present study could be attributed to the fact that B_1(SxT)xT crosses had the lowest birth weight among all the genetic groups studied but exhibited a superior weaning weight. The significant negative correlation observed in the present study between birth weight and pre-weaning ADG is consistent with Kifaro and Mchau (1986) findings.

5.5 Calving interval

The influence of genetic group was not important (P>0.05) in this study, which is contrary to earlier reports by Mahadevan *et al.* (1962), Mahadevan (1965), Kasonta (1992) and Mwatawala (2001). However, Sahiwal and Boran crosses had longer calving intervals than purebred Teso cows an observation that was also reported by the workers mentioned above. The calving intervals for the respective breeds in this study are longer than those reported by Mahadevan *et al.* (1962) but shorter than those reported by both Kasonta (1992) and Mwatawala (2001). The differences between the findings of the present study and those reported earlier could be attributed to differences in management especially failure to detect heat on time and late weaning (9 months) of the calves resulting in extended calving intervals. The relatively large standard errors associated with the present study on calving interval could be due to the effects of small number of animals and the low standards of animal management.

Lack of seasonal effects on calving interval in this study supports the findings of Wilson *et al.* (1987), Nkala (1992), Udo (1993), and Million and Tadelle (2003). However, animals that previously calved in the dry season had longer calving intervals than their counterparts that previously calved in the wet season. Mwatawala (2001) reported calving intervals of 15.7 ± 0.21 and 15.2 ± 0.18 months for dry and wet season respectively. The shorter calving intervals associated with cows that previously calved in the wet season, in this study, is attributed to better availability of forage during this period hence cows returned to estrous earlier as a result of minimum nutritional and lactation tress.

Calving interval was longer in cows of first parturition than those in the second parturition. This was consistent with previous findings (Buck, *et al.*, 1976; Hinojosa *et al.*, 1980; Trail and Gregory, 1981; Udo, 1993, Mwatawala, 2001). The longer calving interval in the young cows is probably due to delay in onset of oestrous after calving in lactating heifers (Warnick, 1963, cited by Hinojosa *et al.*, 1980) and is reflecting a higher nutritive requirement because they still had a nutritive requirement for growth in addition to lactation and maintenance.

Significant influence of year of previous calving has been reported elsewhere (Trail and Gregory, 1981a; Trail *et al.*, 1985a; Miranda *et al.*, 1982; Choudhuri *et al.*, 1984; Kasonta, 1988; Ageeb and Hillers, 1991) and longer calving intervals between years were attributed to the severe drought conditions, which likely resulted in greater nutritive stress. In this study, cows that previously calved in 2001 had significantly (P<0.05) longer caving intervals than those that calved in 2000 and 2002. However, in this study the differences could be due to management rather than drought because highest total rainfall (1600mm) was received in 2001, which had a long calving interval.

5.6 Extracted lactation milk yield and lactation length

The overall extracted lactation milk yield (120 kg) reported in the present study is lower than values reported for extracted milk yields of *Bos indicus* cattle from traditional pastoral production systems which ranged from 200 kg per lactation from the Maasai in Kenya (Semenye and De leeuw, 1984) to 235 kg per lactation for the Mali transhumant system (Diollo *et al.*, 1981) to 312 kg per lactation for the Borana in Ethiopia (Nicholson *et al.*, 1983). The differences between the present study and the previous studies could be due to differences in management system related to the amount of milk extracted and breed differences. Substantial amounts of milk could have been left in the udder for calf suckling hence higher weaning weights (100 ± 0.48 kg) in contrast to 65 kg weaning weight reported for Kenyan Maasai cattle (Semenye and De leeuw, 1984) and 61 kg weaning weight for nomadic pastorists in Mali (Diollo *et al.*, 1981).

Significant genetic group influences on extracted lactation milk yield has been observed in this study. Sahiwal x Teso crosses produced on average 52.1 and 50.3 kg of milk more than the Boran x Teso crosses and Teso dams respectively. Mahadevan and Galukande (1962) reported a 55% increase in milk yield by Sahiwal x EASZ crosses over the indigenous EASZ. In the present study, a 39.4% increase was observed. The difference in the genetic merit of Sahiwal over Boran breed in terms of milk production could have contributed to the variation in performance of their crosses with the Teso breed.

When the overall extracted lactation milk yield is divided by the overall lactation length (173 days) to obtain the average daily extracted milk yield (691g/day), the performance was higher than 510 g reported by Rege *et al.* (1993) and comparable to average daily extracted milk yield of 670-791 g in White Fulani cattle in agropastoral herds in Nigeria (Otchere, 1993) and 875 g in Fulani cattle in Accra plains in Ghana (Okanth, 1992).

Parity is one of the major sources of variation in milk yield. In the present study, the highest extracted lactation milk yield was observed in cows in fourth parity followed by those in lactation numbers 3, 2 and 1 in that order. Although not significant, the trend in extracted lactation milk yield in the present study is consistent with normal lactations with minor differences. Million and Tadelle (2003) reported significant effects of parity on milk yield and observed higher milk yields in the third lactation than in the subsequent parities in the Zebu and Holstein Friesian and their crosses in Ethiopia. Trail and Gregory (1982) reported similar observations in Sahiwal and Aryrshire breeds and their crosses. Cattle in the tropics attain peak production in their third or fourth lactation, which is earlier than the exotic dairy cattle (Okantah, 1992; Million and Tedelle, 2003; Rege *et al.*, 1993). This is attributed to the late age at first calving in the tropics (Mahadevan, 1966).

Dams that calved in the dry season produced more extracted lactation milk yields than their counterparts that calved in the wet season an observation that is consistent with Kiwuwa and Redfern's (1969) report but contrary to Ageeb and Hillers (1991) findings. The observed seasonal effects in the present study are related to quality and quantity of forage available to the animals prior to and after calving periods. The bimodal type of rainfall in the study area makes it possible for dry season calvers to benefit from grazing on abundant and high quality pasture as a result of rains prior to calving. This high plane of nutrition corresponds to the last third of pregnancy during which time reserve energy is being built up. On the other hand, wet season calvers go through much of their late pregnancy on relatively poor pastures, which are characteristic of the dry season. After calving, seasonal effects are such that for animals calving in the dry season, the lactation peak, which occurs between one and two months after calving, coincides with the pasture of high feeding value. Those calving in the wet season reach the maximum milk production when the quality and availability of pasture is poor. Dry season calvers experience a relatively poor nutritional period towards the end of the lactation but their production requirements at this time are not high since daily milk yield decreases. This phenomenon is illustrated in Figure 3.

The lactation curves depicting seasonal effects showed an alternate pattern in milk production between the dry and the wet season of calving. Mchau and Syrstad (1991) reported a similar trend in Mpwapwa cattle. The reason for this kind of pattern is explained by the fact that favourable seasons occur at different stages of lactation among the wet and dry season calvers.

Significant (P<0.05) year effects on extracted lactation milk yield were observed in the present study, which concurs with a report in previous work by Wilson *et al.* (1987). However, the trend of extracted milk yields associated with year of calving in this study does not follow the annual rainfall pattern in which case high annual rainfall is translated into high quality and quantity of pastures and hence high milk production. Extracted milk yield of 2001 was the lowest and yet this year received the highest amount of rainfall (Appendix Table 8). This indicates that the between year partial milk yield fluctuations were probably due to changes in management practices such as inconsistent milking but not changes in levels of feed availability per se.

The overall lactation length reported in this study is lower than those reported in for *Bos indicus* cattle in the region (Mahadevan, 1966; Sackers and Trail, 1966; Kiwuwa and Kyomo, 1971). The coefficient of determination (R^2) was 0.24 and with the exception of season x year interaction, all other fixed effects included in the model were not significant. This indicates that other important factors might have been left out of the model used for data analysis.

Sahiwal x Teso crosses had relatively longer lactation lengths than either Boran x Teso crosses or Teso pure breed. This is in agreement with Mahadevan's *et al.* (1962) findings.

Season of calving was not significant in the present study confirming previous observation by Kifaro (1995) and Rege *et al.* (1993). However, lactations starting in the wet season were longer than those that started in the dry season. This is similar to Ageeb and Hillers (1991b) but contrary to Kasonta (1988).

5.7 Correlation coefficients between milk yields at different stages

Correlation coefficients between extracted lactation milk yield and the various monthly extracted milk yield showed a maximum in the third month of lactation and decreased towards the end of lactation. Mchau and Syrstad (1991) reported a similar observation while studying the production characteristics of Mpwapwa cattle in Tanzania. The observed high correlation between the extracted lactation milk yield and the extracted milk yield in the third month indicates that selection can be done based on the extracted milk yield of the third month. This would allow early selection of better producing cows rather than waiting for total lactation yield. The high correlation between the 100-day yield of lactation and the extracted lactation yield suggests that cows produced much of their total milk yield during their first hundred days of lactation. Mchau and Syrstad (1991) reported that Mpwapwa cattle produced 46.6% of their 305-days' milk yield during their first 100 days while Auran (1973) reported 43.9% in the temperate breeds.

5.8 Phenotypic correlation for lactation curve traits

Correlations between parameter b and the other lactation curve parameters, Ina and c, was contradicting with earlier findings by Grossman *et al.* (1986), Batra *et al.* (1987) and Tekerli *et al.* (2000) in Holstein cows. The difference could be attributed to the difference in the genetic make up of the experimental materials. The positive correlation between Ina and b implies that higher initial milk yield is associated with a higher rate of increase until peak yield. The negative correlation between b and c indicates that cows that peak more rapidly have a slower decline after peak. Correlation between period at peak yield and persistency measures indicate that cows that reach peak yield later during lactation would have higher persistency. Because of the positive and statistically significant ($P<0.01$ and $P<0.05$) correlations between lactation milk yield (y) with Ina and maximum milk yield (y_{max},) cows with higher initial yield and high peak yield would be expected to have higher lactation yields.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

- The evidence from this study indicates that Sahiwal x Teso and Boran x Teso crosses under Serere conditions have lower birth and weaning weights but are comparable with their counterparts in other parts of East Africa.
- This study has shown that through crossbreeding, besides increasing milk production, beef production could also be increased. Female Sahiwal x Teso crossbred calves can be raised for milk production, while both female and male Boran x Teso as well as male Sahiwal x Teso crosses may be raised more economically than Teso pure breed for beef production.
- Effects of environmental factors such as year, season, parity, sex and year have been found to be non significant for birth weight. However, season and year significantly affected weaning weight and pre-weaning ADG as well as extracted milk yield. Hence selection programmes under Serere conditions can be improved if weaning weight and extracted milk yield are corrected for season and year of calving.
- Selection of animals for improved milk production can be done using the milk yields obtained in the third month of lactation or during the first three months of lactation hence eliminating the need of waiting until the end of lactation.
- Backcrossing to either Sahiwal or Boran has no advantage over their F_1 crosses in terms of growth. In addition, F_1 crossbred bulls of Sahiwal provide an equivalent growth attribute as compared to pure Boran bulls when mated to Teso cattle.

- Heritability estimates for birth weight was high hence selection for growth can be based on birth weight.
- High milk extraction from suckling crossbred cattle derived from crossing Teso cows with Sahiwal bulls is attainable provided the weather conditions are favourable for pasture growth. It would however, be beneficial to provide first lactating dams with additional feeds in order to attain quicker rebreeding of the animals.
- The positive correlation between lactation yield with peak yield and persistency showed that one of those traits could be used as a selection criterion to improve all the three traits. However, the moderate negative correlation between peak yield and persistency should be considered.

REFERENCES

Abassa, P.K.; Mbah, D.A.; Zambia, P.; Tawah, L.C.; Messine, O and Oumate, H. (1993). Factors which affect Gudali and Wakwa calf weights at birth and weaning on the Adamawa plateau, Cameroon. *Tropical Animal Health and Production* 9: 143-149.

Abdinasir, I. and Eskil, B. (1998). Growth performance of crossbred dairy cattle at Asella livestock farm, Arsi Ethiopia. [http://inasp.org.uk/ajol/journals.htm]. Site visited on 20/8/2003.

Acker, D. (1983). Animal Science and Industry. Third edition. Prentice-Hall. New Jersey USA.. 131-141 pp.

Ageeb, A.G. and Hillers, J.K. (1991a). Production and reproduction characteristics of Butana and Kenana cattle of the Sudan. *World Animal Review* 67: 49-56.

Ageeb, A.G. and Hillers, J.K. (1991b). Effects of crossing local Sudanese cattle with British Friesian on performance traits. *Bulletin of Animal Health and Production* 39(1): 69-76.

Alenda, R. and Martin,T.G. (1987). Genetic parameters and consequences of selection for growth traits in a beef herd selected for yearling weight. *Journal of Animal Science* 64: 366-372.

Aminatta, N. and Kwaku, A. (1991). Performance of a station-managed N'Dama herd in the Gambia. *Tropical Animal Health and Production* 23: 45-54.

Anido, A.O. and Topps, J.H. (1993). The effects on production of milking crossbred suckler cows grazing a semi-arid area of Kenya. II. The performance of calves from birth to weaning. *East African Agricultural and Forestry Journal* 59(2): 113-122.

Arnason, T. and Kassa-Mersha, M. (1987). Genetic parameters of growth of Ethiopian Boran cattle. *Animal Production* 44: 201-208.

Auran, T. (1973). Studies on monthly and cumulative monthly milk yield records: The effects of age, month of calving, herd and length of first-period. *Acta Agricultural Scandinavica* 23: 189-199.

Azage,T.; Mukasa, M.E. and Hizkias, K. (1990). Effect of early weaning on the growth performance of Boran and Boran x Friesian bull calves. *Bulletin of Animal Health and Production in Africa* 38(2): 103-106.

Balikowa, D. (1997). Reproductive and lactation performance of dairy cattle on smallholder farms in Iringa and Mbeya regions. Unpublished Dissertation for Award of MSc. Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 177 pp.

Baker, R.L. (1980). The role of maternal effects on the efficiency of selection in beef cattle. *Animal Production* 40: 285-303.

Baker, R.L.; Morris, C.A.; Johnson, D.L.; Hunter, J.C. and Hickey, S.M. (1991). Results of selcction for yearling or 18-month weight in Angus and Hereford cattle. *Livestock Production Science* 29: 277-296.

Banjaw, K. and Haile-Mariam, M. (1994). Productivity of Boran cattle and their Friesian crosses at Abernossa ranch, rift valley of Ethiopian. *Tropical Animal Health and Production* 26: 49-57.

Batra, T.R.; Lin, C.Y.; McAlister, A.J. and Lee, A.J. (1987). Multitrait estimation of genetic parameters of lactation curves in Holsteins heifers. *Journal of Dairy Science* 70:2105-2111.

Borsortti, N.P.; Verde, O. and Plasse, D. (1976). Repeatability of calving interval in Brahman cows. *Animal Breeding Abstracts* 46: 1259.

Brown, C.J. (1960). Influence of year and season of birth, sex, sire, and age of dam on weights of beef calves at 60, 120, 180, and 240 days. *Journal of Animal Science* 19 (4): 1062-1070.

Buck,N.G.; Light, D.; Rutherford, A.; Miller, M.; Rennie, T.W.; Pratchett, D.; Capper, B.S. and Trail, J.C.M. (1976). Environmental factors affecting beef cow reproductive performance in Botswana. *Animal Production* 25: 357-363.

Buck,N.G.; Light, D.; Lethola, L.L.; Rennie, T.; Mlambo, M. and Muke. B. (1982). Beef cattle breeding system in Botswana. The use of indigenous breeds. *Bulletin of Animal Health and Production in Africa* 39(4): 335-337.

Choudhuri, G.; Banerjee, G.C. and Guha, H. (1984). Studies on the breeding efficiency traits and some of the factors affecting them in the Hariana-type cows. *Indian Veterinary Journal* 61:585-590.

Cossins, N.J. (1985). The productivity and potential of pastoral systems. International Livestock Center for Africa. Bulletin No. 21. ILCA. Addis Ababa, Ethiopia. 27-38.

Cunningham, E.P. and Syrstad, O. (1987). Crossbreeding *Bos indicus* and *Bos taurus* for milk production in the tropics. FAO, *Animal Production and Health* 68: 38-49.

Cunningham, B.E.; Magee, W.D. and Ritchie, H.D. (1987). Effects of using sires selected for yearling weight and crossbreeding with beef and dairy breeds: Birth and weaning traits. *Journal of Animal Science* 64(6): 1591-1600.

Das, S.M.; Mpiri, D.B. and Msechu, J.K.K. (1988). Growth of the Zebu cattle and their crosses in Central Tanzania. In: *Proceedings of Tanzania Livestock Research Organization Scientific Conference*, Arusha Tanzania, February 1988. 38-41.

Dědková, L. and Němcová, E. (2003). Factors affecting the shape of lactation curves of Holstein cows in the Czech Republic. *Czech Republic Journal of Animal Science* 48(10): 395-402.

DeNise, S.K.; Torabi, M.; Ray, D.E.; and Rice. R. (1988). Genetic parameters estimates for pre-weaning traits of beef cattle in a stressful environment. *Journal of Animal Science* 66:1899-1906.

Diollo, A.; Wagenaar, K. and De leeuw, P.N. (1981). Livestock productivity and nutrition systems research in the arid zones of Mali. *International Livestock Center for Africa.* Addis Ababa, Ethiopia. Research Report 5: 37 – 46.

Drewry, K. J.; Brown, C.J. and Honea, R.S. (1959). Relationships among factors associated with mothering ability in beef cattle. *Journal of Animal Science* 18*:* 938-946.

Falconer, D.S. (1981). *Introduction to quantitative genetics.* Longman Group U.K. LTD. England. 318 pp.

Falconer, D.S. and Mackay, T.F.C. (1996). *Introduction to quantitative genetics.* Longman Group U.K. LTD.England. Fourth Edition. 464 pp.

Galip, B.; Kaygisiz, A. and Ulker, H. (2004). Estimates of genetic and phenotypic parameters for birth weight in Holstein Friesian cattle. *Pakistan Journal of Biological Sciences* 7(7): 1221-1224.

Galukande, E.B.; Mahadeven, P. and Black, J.G. (1962). Milk production in East Africa Zebu cattle. *Animal Production* 4: 329-336.

Getz, W. R.; Kifaro. G.C. and Msuya, D. (1975). Comparative performance of straight bred and half bred beef cattle. Pre-weaning growth. Paper presented at the 2nd Scientific Conference of *Tanzania Society for Animal Production.* 19-21 May, Arusha, Tanzania. 53-56.

Gregory, K.E.; Cundiff, L.V.; Smith, G.M.; Laster, D.B.; and Fitzhugh, H.A. (1978). Characterisation of biological types of cattle-cycle II: Birth and weaning traits. *Journal of Animal Science* 47 (5): 1022-1030.

Gregory, K.E.; Trail, J.C.M.; Marples, H.J.S. and Kakonge, J. (1985). Characterization of breeds of *Bos indicus* and *Bos taurus* cattle for maternal and individual traits. *Journal of Animal Science* 60: 1165- 1174.

Grossman, M.; Kuck, A.L. and Norton, H.W. (1986). Lactation curves of purebred dairy cattle. *Journal of Dairy Science* 69: 195-203.

Hafez, E.S.E and Dyer.I.A. (1969). *Animal Growth and Nutrition*. Lea and Febiger. 402 pp.

Hafez, E.S.E. and Jainudeen, M.R. (1975). Reproductive failure in females. In: *Reproduction in Farm Animals*. Lea and Febiger. Philadephia. 351-372 pp.

Halle, M.M. and Kassa, M.H. (1994). Genetic and environmental effects on age at first calving and calving interval of naturally bred Boran Zebu cows in Ethiopia. *Animal Production* 58(3): 329-334.

Hamad, A.H. (1997). Review on performance characteristics of East African shorthorn zebu and Boran cattle. Unpublished Special Project for Award of BSc. at Sokoine University of Agriculture, Morogoro, Tanzania. .74 pp.

Hinojosa, A.; Franco, A. and Bolio, I. (1980). Genetic and environmental factors affecting calving interval in a commercial beef herd in a semi-humid tropical environment. *Tropical Animal Production and Health* 5(2): 165-171.

Hutchison, H.G. (1964). Ranching in Tanzania. *East African Agricultural and Forestry Journal* 29: 20-25.

Ibeawuch, J.A. (1990). A study of some factors influencing the birth weight of Friesian calves in a tropical environment. *Bulletin of Animal Health and Production in Africa* 38(2): 107-111.

Joshi, N.R. and Phillips, R.W. (1953). *Zebu cattle of India and Pakistan*. Agriculture study. No. 19. FAO. ROME, Italy. 256 pp.

Joshi, N.R. (1957). *Types and breeds of African cattle*. FAO. ROME. 297 pp.

Kaitho, R.J.; Eddleman B.R.; Chen.C. C.; Mcarl, B.A.; Angerer, J. and Stuth, J.W. (2001). Policy and technology options for dairy systems in East Africa: Economic and environment assessment: A paper presented to the SANREM CRSP research scientific ynthesis conference. [http://www.Sanrem.Uga.edu./sanrem/conference/nov 2001/waf.policy.htm]. Site visited on 3/5/2003.

Kassa-Mersha, H. and Arnason, T. (1986). Non-genetic factors affecting growth of Ethiopian Boran cattle. *Animal Production 22:45-55.*

Kasonta, J.S. (1988). Population analysis and model calculations for a breeding scheme in the Mpwapwa cattle of Tanzania. Unpublished Thesis for Award of PhD Degree at University of Hohenhein, Germany. 218 pp.

Kasonta, J.S. (1992). Comparative growth and reproductive performance of Tanzania Shorthorn Zebu and Mpwapwa cattle breeds and various crosses. Mimeograph, ILCA, Addis Ababa, Ethiopia. 83 pp.

Kidner, E.M. (1966). Beef production from pastures. Some factors involved in the live weight progress of calves from birth to slaughter. *East African Agricultural and Forestry Journal* 31(2): 389-391.

Kifaro,G.C. and Mchau, K.W. (1986). Environmental factors affecting birth and weaning weights of Friesian calves at Uyole Agricultural Center. *The Uyole Agricultural Bulletin* 1(1): 30-35.

Kifaro, G.C. (1995). Performance of exotic dairy cattle in the Southern highlands of Tanzania and prospects for genetic improvement. Unpublished Thesis for Award of PhD Degree at Sokoine University of Agriculture, Morogoro, Tanzania. Pp 291.

Kiwuwa, G.H. and Redfern, D.M. (1969). The influence of management and season of calving on milk production in a herd of crossbred cattle in central Uganda. *East African Agricultural and Forestry Journal* 34 (5): 342-349.

Kiwuwa, G.H. and Kyomo, M.L. (1971). Milk composition and yield of the Mpwapwa cattle. *East African Agricultural and Forestry Journal* 36: 290-295.

Kiwuwa, G.H. (1972). The effect of non-genetic factors in dairy performance in East Africa. *East African Agricultural and Forestry Journal* 38: 252-287.

Kiwuwa, G.H. (1973). Estimation of the effects of season and parity on cumulative and partial lactation milk yield of dairy cattle in East Africa. *East African Agricultural and Forestry Journal* 39: 110-119.

Kiwuwa, G.H. (1974). Age, year and season effects on dairy performance of Friesian cattle on privately owned farms in Kenya. *East African Agricultural and Forestry Journal* 39(3): 298-306.

Koch, R.M. (1972). The role of maternal effects in animal breeding. VI. Maternal effects in beef cattle. *Journal of Animal Science* 35(6): 1316-1323.

Koots, K.R.; Gibson, J.P. and Wilton, J.W. (1991). Analysis of genetic parameters for beef cattle. *Journal of Animal Science* 69:205-206.

Lhoste, P. (1968). Seasonal behaviour of Zebu cattle in Adamawa, Cameroon. II. Preweaning growth of indigenous and half-breed Brahman calves. *Revue d'Elevage et de Médecine Veterinaries des Pays Tropicaux* 21:499-517.

Madsen, O. (1975). A comparison of some suggested measures of persistency of milk yield in dairy cows. *Animal Production* 20: 191-197.

Mahadevan, P. (1965). Dairy cattle breeding in East Africa. *East African Agricultural and Forestry Journal* 30:320-327.

Mahadevan, P. (1966). *Breeding for milk production in tropical cattle.* Morrison and Gigg, LTD, London and Edinburgh. Pp 154.

Mahadevan, P.; Galukande, E.B. and Black, J.K. (1962). A genetic study of the Sahiwal grading up scheme in Kenya. *Animal Production* 4: 337-342.

Mahadevan, P. and Hutchison, H.C. (1964). The performance of crosses of *B.taurus* and *B.indicus* cattle for milk production in the coastal region of Tanganyika. *Animal Production* 6: 331-336.

Maule, J.P. (1990). The pattern of cattle breeding in the tropics. In: *The cattle of the tropics*. Redwood press Limited, Melksham, Wilts, England. 1-10 pp.

Mayer, K. (1992). Variance components due to direct and maternal effects for growth traits of Australian beef cattle. *Livestock Production Science* 31: 179-204.

Mbap, S.T. and Ngere, L.O. (1991). Breed and environmental factors affecting the performance of some imported and crossbred cattle in Ibadan, Nigeria. *Bulletin of Animal Health and Production in Africa* 68: 181-185.

Mchau, K.W. (1991). The impact of upgrading the Tanzania Shorthorn Zebu on smallholder dairy production in Mbeya region. Unpublished Thesis for Award of PhD. Degree at Sokoine University of Agriculture, Tanzania, Morogoro. 199 pp.

Mchau, K.W. and Syrstad, O. (1991). Production characteristics of Mpwapwa cattle. II. Shape of the lactation curve. *World Animal Review* 66: 49-54.

Mekonnen, H. (1996). Genetic evaluation of Ethiopian Boran cattle for growth traits. Papar presented in: All African conference on Animal Agriculture. 1-4 April 1996. Pretoria. Conference handbook and abstracts. 1.D.16.

Meyn, K. and Wilkins, J. V. (1973). *National cattle breeding programmes in Kenya*. Paper presented at the third World Conference on Animal Production, Melbourne 1973, 5(e)-1–10.

Meyn, K. and Wilkins, J.V. (1974). Breeding for milk production in Kenya with particular reference to the Sahiwal stud. *World Animal Review* 11: 24-30.

Million, T. and Tadelle, D. (2003). Milk production of Zebu, Holstein Friesian and their crosses in Ethiopia. www.cipav.org.co.htm. Site visited on 28/6/2003.

Ministry of Finance, Planning and Economic Development (MFPED). (1999). Abstracts and background to the budget, 1999, Government printer, Kampala, Uganda.

Miranda, J.J.F.; de Garneiro, G. G.; Penna, V. M. and Fonsea, C. G. (1982). A study of environmental factors affecting age at first calving of Nellore heifers. *Animal Breeding Abstracts* 51: 183.

Mkonyi, J.I.; Kasonta, J.S. and Msechu, J.K.K. (1991). Suitability of crossbred cattle for smallholder systems. In: P*roceedings of a seminar on milk production from smallholder systems with emphasis on feeding strategies in Semi-arid areas.*(Edited by Masao,A.P. *et al*) 22-24 January 1991, Morogoro Tanzania, pp 159-163.

Mohiuddin, G. (1994). Estimates of genetic and phenotypic parameters of some performance traits in beef cattle. *Animal Breeding Abstracts* 62:(1) 12.

Montoni, D.; Manrique, U.; Sabino, L.; Bastida.S.J. and Garcia, E. (1981). Reproductive performance in a herd of Gir and Zebu cows in Venezuela. I. Calving interval. *Animal Breeding Abstracts* 52: 6513.

Mrode, P. and Akinokun, J. (1986). Genetic parameters and factors affecting reproductive performance in White Fulani cattle in Southern Nigeria. *Tropical Animal Health and Production* 18: 81-85.

Msanga, Y.N. (1984). Growth performance of Mpwapwa cattle and their crosses from birth to 108 weeks of age. Unpublished Dissertation for Award of MSc. Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 100 pp.

Mwandotto, B.A.J. (1981). Some factors affecting birth weights of cattle in Kiboko Kenya. *Bulletin of Animal Health and Production in Africa* 29 (3): 225-235.

Mwandotto, B.A.J. (1986). A note on heritability of growth of Sahiwal heifers to bulling age and its correlation with milk yield. *East African Agricultural and Forestry Journal* 52 (2): 127- 129.

Mwandotto, B.A.J. (1988). Weaning weight and 18-month weights of Boran, East Africa Shorthorn Zebu and Sahiwal breeds or crosses in Kenya. *Tropical Agriculture (Trindad)* 65(3): 257-264.

Mwandotto, B.A.J. (1995). Phenotypic, genetic and environmental parameter estimates of weight, growth and maturing patterns in Sahiwal females. *Animal Breeding Abstracts* 63(5): 305.

Mwatawala, H. (2001). Comparative growth and reproductive performance of Tanzania shorthorn Zebu, Boran and their crosses. Unpublished Dissertation for Award of MSc.. Degree at Sokoine University of Agriculture, Morogoro, Tanzania. 96 pp.

Nelson, T.C.; Short, R.E.; Urick, J.J. and Reynolds, W.L. (1983). Genetic variation components of birth weight in a herd of unselected cattle. *Journal of Agricultural Science* 59(6): 123-129.

Nicholson, A.; Wagenaar, K. and De leeuw, P.N. (1983). Calf growth, milk off take and estimated lactation yields of Boran cattle in the southern rangelands of Ethiopia. JEPSS. Report No.6 *International Livestock Center for Africa,* Addis Ababa, Ethiopia.

Nkala, P.V. (1992). Growth performance and milk production of dairy cattle in the coastal zone of Tanzania. Unpublished Dissertation for Award of MSc. Degree at Sokoine University of Agriculture. Morogoro, Tanzania. 138 pp.

Okantah, S.A. (1992). Partial milking of cattle in Smallholder herds on the Accra plains: some factors affecting daily partial milk yield and milk composition. *Animal Production* 54: 15-21.

Olivera, F.E.B. de. (1974). Age at first calving, service period and calving interval in a Nellore herd. *Animal Breeding Abstracts* 43: 5799.

Oni, O.O.; Buvanendran, V. and Dim, N.I. (1988). Factors affecting birth weight and performance to weaning of Bunaji calves. *Journal of Agricultural Science, Cambridge* 111: 407-410.

Otchere, E.O. (1983). The productivity of Bunaji (White Fulani) cattle in pastoralist herds on the Kaduma plains of Nigeria. International Livestock Centre for Africa, Sub humid programme Kaduna, Nigeria. Internal communication No.46.

Payne, W.J.A. (1970). *Cattle production in the tropics*. Longman Group Ltd. London. Volume I. 336 pp.

Payne, A.K.; Maitra, D.N.; Misra, S.K. and Dahaguta, R. (1991). Effects of season of birth and birth weight on some economic traits of Jersey X Hariana half-bred cows. *Animal Breeding Abstracts* 59 (1): 14.

Plasse, D.; Koger, M. and Warnick, A.C. (1968). Reproductive behaviour of *Bos indicus* females in a subtropical environment III. Calving intervals from first exposure to conception and intervals from first exposure to conception and intervals from parturition to conception. *Journal of Animal Science* 27: 105- 112.

Queroz, S.A.; Lob, R.B. and Martinez, M.L. (1994). Effects of inbreeding on some production traits of economic importance in Gir cattle. *Animal Breeding Abstracts.* 62 (10) 775.

Rao, M.K. and Sundaresan, D. (1982). Factors affecting the shape of lactation curve in Friesian x Sahiwal crossbreds. *Indian Journal of Dairy Science* 35(2): 160-167.

Rege, J.E.O. and Mosi, R.O. (1989). An analysis of the Kenyan Friesian breed from 1968 to 1984: Genetic and environmental trends and related parameters of milk production. *Bulletin of Animal Health and Production in Africa* 37(3): 267-278.

Rege, J.E.O. (1991). Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. I. Genetic and phenotypic parameters. *Journal of Animal Breeding and Genetics* 108(6): 412-423.

Rege, J.E.O.; Von Kaufmann, R.R.; Mwenya, W.N.M.; Otchere, E.O. and Mani, R.I. (1993). On-farm performance of Bunaji (White Fulani) cattle. Growth, reproductive performance, milk offtake and mortality. *Animal Production* 57: 211-220.

Reinhardt, V. (1978). Effect of a suckling calf on the reproductive performance of its dam. (Bos indicus). *Animal Breeding Abstracts* 47: 2288.

Rcis, S.R.; Carneiro, C.G.; Tones, T.R. Samparro, I.B.M. and Huetas, A.G. (1986). Some environmental factors effecting lactation length in a crossbred herd. *Animal Breeding* Abstracts 54(1) 9.

Robison, O.W. (1981). The influence of maternal effects on the efficiency of selection. *Livestock Production Science* 8: 121-137.

Rwabushaija, B. (1998). Phenotypic and genetic trends of growth characteristics of the Small East African Zebu at Serere Agricultural and Animal Production Research institute, Uganda. Unpublished Dissertation for Award of M.Sc. Degree at Makerere University, Kampala, Uganda. 96 pp.

Sacco, R.E.; Baker, J.F.; Cartwright, T.C.; Long, C.R. and Sanders, J.O. (1989). Production characteristics of straight-bred, F_1 and F_2 cows: Birth and weaning characteristic of terminal cross calves. *Journal of Animal Science* 26: 1972-1979.

Sacker, G.D. and Trail, J.C.M. (1966). A note on milk production of Ankole cattle in Uganda. *Tropical Agriculture Trinidad* 43: 247-250.

Sacker, G.D.; Trail, J.C.M. and Fisher, I.L. (1971). Crossbreeding of beef cattle in western Uganda.2. Environmental influences on body weight. *Animal Production* 13: 143-152.

Saeed, A.M.; Ward, P.N.; Light, D.; Durkin, J.W. and Wilson, R.T. (1987). Characterisation of Kenana cattle at Um Banein, Sudan. *International Livestock Center for Africa Addis Ababa, Ethiopia.* Research Report. No. 16.

Said, R.; Bryant, M.J. and Msechu, J.K.K. (2001). *Growth and survival of crossbred beef cattle in Tanzania.* A paper presented at the 28th Scientific conference of the Tanzania Society of Animal Production. Arusha International conference center. 6th-10th August 2001. Arusha, Tanzania.

Schaar, J.; Brannang, E. and Meskel, L.B. (1981). Breeding activities of the Ethio-Swedish intergrated rural development project. *World Animal Review* 37: 31-36.

Semenye, P.P. and De leeuw, P.N. (1984). Milk for calves or man in a Maasai pastoral system in East Africa. *International Livestock Center for Africa.* Nairobi, Kenya.

Shekimweri, T.J.M. (1982). A comparative study of dairy cattle crosses in the humid coastal belt of Tanzania. Unpublished Dissertation for Award of MSc. Degree at University of Dar es salaam. 80 pp.

Singh, A.R.; Schalles, R.R.; Smith, W.H. and Kessher, F.B. (1970). Cow weight and preweaning performance of calves. *Journal of Animal Science* 31: 27-30.

Statistical Analysis System SAS (2002). The Statistical Analysis System, Version 8.01for windows. SAS Institute, inc., Cary, N.C.USA.

Syrstad, O. (1994). Milk yield and lactation length in the tropical cattle. www.fao.org/ag/aga/htm. Site visited on 5/4/2004.

Tahir, M.; Ahmed, N. and Shah, S.I.H. (1984). Comparative study on birth weight and weaning weights of purebred and crossbred Sahiwal calves in Pakistan. *Indian Journal of Animal Science* 54(1): 102-103.

Tawah, C.L.; Mbah, D.A.; Rege, J.E.O.; and Oumate, H. (1993). Genetic evaluation of birth and weaning weight of Gaduli and two breed synthetic Wakwa cattle populations under selection in Cameroon:Genetic and Phenotypic parameters. *Animal Production* 57: 73-79.

Tawonezvi, H.P.R. (1989a). Growth of Mashona cattle on range in Zimbabwe. Environmental influences on live weight and weight gain. *Tropical Animal Health and Production* 21: 37-42.

Tawonezvi, H.P.R. (1989b). Growth of Mashona cattle on range in Zimbabwe. II. Estimation of genetic parameters and predicted response to selection. *Tropical Animal Health and Production* 21: 170-174.

Tekerli, M.; Akinci, Z.; Dogan, I.; and Akcan, A. (2000). Factors affecting the shape of lactation curves of Holstein cows from the Balikesir provice of Turkey. *Journal of Dairy Science* 83: 1381-1386.

Thorpe,W.; Cruickshank, D.K.R. and Thompson, R. (1980). Genetic and Environmental influence in beef cattle production in Zambia. Factors affecting weaner production from Angoni, Barose and Boran dams. *Animal Production* 30: 217-234.

Tonn, R. (1976). Selection criteria for beef cattle breeding under extensive conditions. *Animal Research and Development* 3: 105-111.

Trail, J.C.M.; Sacker, G.D. and Fisher, I.L. (1971a). Crossbreeding of beef cattle in western Uganda. I. Performance of Ankole, Boran and Zebu cows. *Animal Production* 13: 127-141.

Trail, J.C.M.; Sacker, G.D. and Fisher, I.L. (1971b). Crossbreeding beef cattle in western Uganda. Genetic analysis of body weight. *Animal Production* 13:153-163.

Trail, J.C.M. and Gregory, K.E. (1981a). Characterizations of the Boran and Sahiwal breeds of cattle for economic characters. *Journal of Animal Science* 52: 1286-1293.

Trail, J.C.M. and Gregory, K.E. (1981b). Rotation crossbreeding with Sahiwal and Ayrshire cattle in the tropics. *Journal of Dairy Science* 64: 1978-1984.

Trail, J.C.M. and Gregory, K.E. (1981c). Sahiwal cattle: an evaluation of their potential contribution to milk and beef production in Africa. International Livestock Centre for Africa, Addis Ababa, Ethiopia. Mimeograph . No. 3. Pp 137.

Trail, J.C.M. and Gregory, K.E. (1982). Production characters of the Sahiwal and Ayrshire breeds and their crosses in Kenya. *Tropical Animal Health and Production* 14: 45-57.

Trail, J. C.M.; Gregory, K.E.; Marples, H.J.S. and Kakonge, J. (1982). Heterosis, additive maternal and additive direct effects of Red Poll and Boran breed of cattle. *Journal of Animal Science* 54: 517-532.

Trail, J.C.M.; Gregory, K.E.; Marples, H.J.S. and Kakonge, J. (1985a). Comparison of *Bos taurus-Bos indicus* breed crosses with straight bred *Bos indicus* breeds of cattle for maternal and individual traits. *Journal of Animal Science* 60: 1165-1174.

Trail, J.C.M.; Sones, K.; Jibbo, J.M.C.; Durkin, J.; Light, D.E. and Marry, M. (1985b). Productivity of Boran cattle maintained by chemoprophylaxis under trypanosomiasis risk. *International Livestock Center for Africa.* Addis Ababa, Ethiopia. Research Report. No.9.

Udo, M. G. (1993). Comparative study on growth and lactation performance of different crosses in Mpwapwa cattle herd. Unpublished Dissertation for Award of M.Sc. Degree at Sokoine University of Agriculture, Morogoro, Tanzania.147 pp.

Van Vleck, L.D.; St Louis, D. and Miller, J.I. (1977). Expected phenotypic response from selection for direct and maternal effects. *Journal of Animal Science* 44: 354-360.

Wakhungu, J.W.; Rege, J.E.O. and Tulya, S. (1991). Genetic and Phenotypic parameters and trends in production and reproductive performance of the Kenya Sahiwal cattle. *Bulletin of Animal Health and Production in Africa* 39 (4): 365-372.

Warwick, A.C. (1963). Mothering ability In: *Cross breeding beef cattle*. University of Frorida press Gainsville, USA. 258 pp.

Warwick, E.J and Leagates, J.E. (1979). *Breeding and improvement of farm animals*. 7th Ed. Inc. Graw. Hill book company. 394-434 pp.

Willham,R.L. (1980). Problems of estimating maternal effects. *Livestock Production Science* 7: 405-418.

Wilson, D.N. (1957). Further notes on the development of Serere herd of Shorthorn Zebu cattle. *Journal of Experimental Agriculture* 25: 263-277.

Wilson, R.T. (1985). Livestock production in central Mali: Reproductive aspects of sedentary cow. *Animal Reproductive Science* 9(1): 1-9.

Wilson, R.T.; Ward, P.N.; Saeed, A.M. and Light, D. (1987). Milk production characteristics of the Kenana breed of *Bos indicus* cattle in Sudan. *Journal of Dairy Science* 70: 2673-2679.

Winroth, H. (1990). Effects of non-genetic factors and development of adjustment factors for live-weight at different ages in beef breeds. *Proceedings 4th World Congress on Genetics applied to livestock Production*. XV. Pp 229-303.

Wood, P.D.P. (1967) Algebric model of the lactation curve in cattle. *Nature, London* 216: 164-165.

Wood, P.D.P. (1969) Factors affecting the shape of lactation curve in cattle. *Animal Production* 11: 307-316.

Wood, P.D.P. (1972). A note on seasonal fluctuations in milk production. *Animal Production* 15: 89-92.

Yadev, M.C.; Katpatal, B.G. and Kaushik, S.N. (1977). Components of gamma-type function of a lactation curve and factors affecting them in Hariana and its Friesian crosses. *Indian Journal of Animal Science* 47(9): 520-525.

APPENDICES

Appendix Table 1: The effects of year of birth, parity, genotype, season, sex, genotype x season interaction, year x season interaction and genotype x sex interaction on birth weight

Source	DF	Type III SS	Mean square	F Value	Pr > F
Year	3	18.1892579	6.0630860	0.66	0.5771
Parity	3	69.7111950	23.2370650	2.53	0.0580
Genotype	5	273.7533302	54.7506660	5.97	<. 0001
Season	1	2.0241381	2.0241381	0.22	0.6391
Sex	1	9.2969678	9.2969678	1.01	0.3153
Genotype x season	5	85.5674672	17.1134934	1.86	0.1017
Year x season	3	50.9402826	16.9800942	1.85	0.1390
Genotype x sex	5	55.5612270	11.1122454	1.21	0.3050

R-Square	Coefficient of Variation	Root MSE	Mean birth weight
0.271963	16.50202	3.029251	18.35685

Appendix Table 2: The effects of year of birth, parity, genotype, season, sex, genotype x season interaction, year x season interaction and genotype x sex interaction on weaning weight

Source	DF	Type III SS	Mean square	F Value	Pr > F
Year	3	851.68422	283.89474	5.24	0.0017
Parity	3	31.69617	10.56539	0.19	0.8998
Genotype	5	19125.51309	3825.10262	70.58	<. 0001
Season	1	860.34721	860.34721	15.87	<. 0001
Sex	1	248.01892	248.01892	4.58	0.0336
Genotype x season	5	427.15044	85.43009	1.58	0.1681
Year x season	3	1047.23679	349.07893	6.44	0.0003
Genotype x sex	5	565.13335	113.02667	2.09	0.0685

R-Square	Coefficient of Variation	Root MSE	Mean weaning weight
0.67794	7.321472	7.361802	100.55

Appendix Table 3: The effects of year of birth, parity, genotype, season, sex, genotype x season interaction, year x season interaction and genotype x sex interaction on pre-weaning ADG

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	3	13098.6506	4366.2169	4.78	0.0030
Parity	3	1400.8151	466.9384	0.51	0.6750
Genotype	5	261868.0927	52373.6185	57.33	<.0001
Season	1	12516.0932	12516.0932	13.70	0.0003
Sex	1	2407.2682	2407.2682	2.64	0.1060
Genotype x season	5	8499.8153	1699.9631	1.86	0.1025
Year x season	3	19418.7657	6472.9219	7.09	0.0001
Genotype x sex	5	13098.0115	2619.6023	2.87	0.0158

R-Square	Coefficient of Variation	Root MSE	Pre-weaning ADG Mean
0.634177	9.933368	30.22491	304.2765

Appendix Table 4: The effect of year of previous calving (YPC), season of previous calving (SPC), genotype, parity, year x season of previous calving interaction and season of previous calving x genotype interaction on calving interval

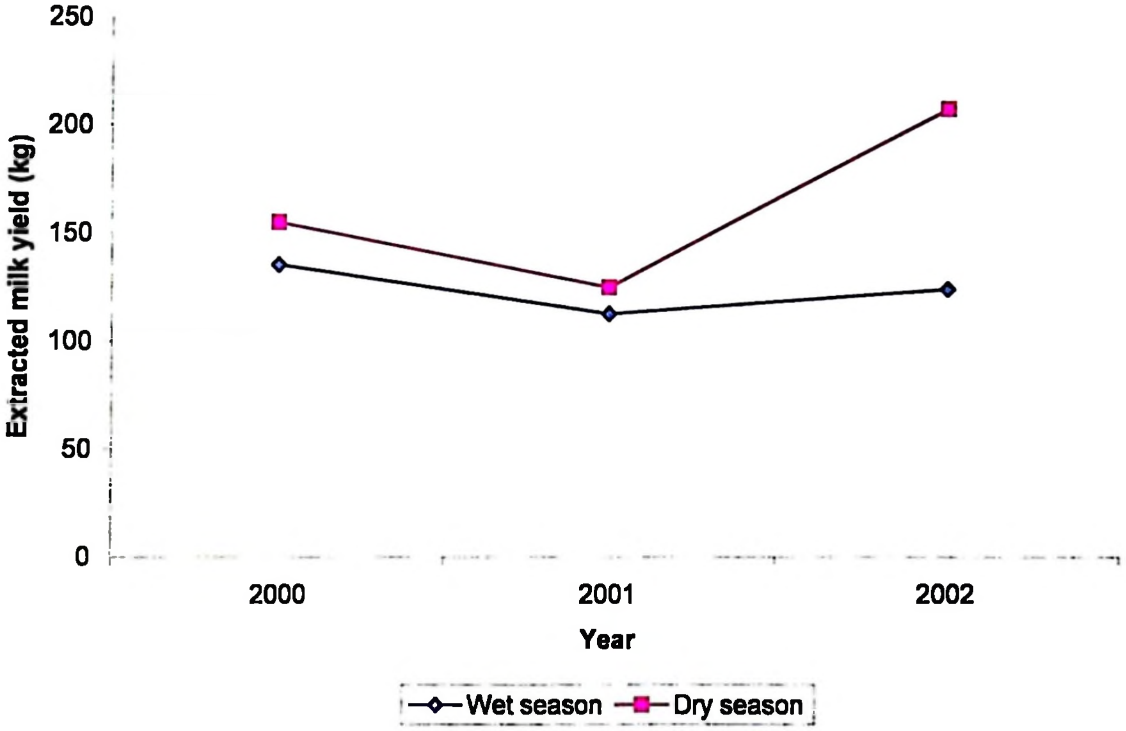
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YPC	2	158195.7665	79097.8833	6.34	0.0024
SPC	1	881.9809	881.9809	0.07	0.07
Genotype	2	62537.1142	31268.5571	2.50	0.0859
Parity	1	14176.0770	14176.0770	1.14	0.2887
YPC x SPC	2	13977.8513	6988.9257	0.56	0.5728
SPC x genotype	2	0.5728	7221.2664	7221.2664	0.5623

R-Square	Coefficient of Variation	Root MSE	Mean calving interval
30.22491	24.66503	111.7400	453.0299

Appendix Table 5: The effect of parity, season of birth, year of birth, genotype, season x year interaction, season x genotype interaction and lactation length on extracted lactation milk yield

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Parity	3	1706.2586	568.7529	0.34	0.7950
Season	1	10683.5199	10683.5199	6.42	0.0124
Year	2	27718.2066	13859.1033	8.33	0.0004
Genotype	2	26779.7828	13389.8914	8.05	0.0005
Season x Year	2	10744.4552	5372.2276	3.23	0.0427
Season x Genotype	2	2325.8623	1162.9311	0.70	0.4988
Lactation length	1	161793.5977	161793.5977	97.30	<.0001

R-Square	Coefficient of Variation	Root MSE	Mean Extracted LMY
0.557299	33.97555	40.77884	120.0241



Appendix Chart 1: The effect of season x year interaction on extracted lactation milk yield

Appendix Table 6: The effect of parity, season of birth, year of birth, genotype, season x year interaction and season x genotype interaction on lactation length

Source	DF	Type III SS	Mean Square	F Value	F Value
Parity	3	2024.66635	674.88878	0.19	0.9058
Season	1	468.00123	468.00123	0.13	0.7201
Year	2	7509.69947	3754.84973	1.03	0.3583
Genotype	2	5429.06593	2714.53296	0.75	0.4754
Season x year	2	81534.33857	40767.16928	11.23	<.0001
Season x Genotype	2	15533.47841	7766.73920	2.14	0.1218

R-Square	Coefficient of Variation	Root MSE	Mean lactation length
0.244495	34.69675	60.24791	60.24791

Appendix Table 7: Least squares means and standard errors (s.e) for the effect of season x year interaction on extracted lactation milk yield

Season	Year	Lactation length lsmean	Standard Error
Wet	2000	183.29	14.162
Wet	2001	139.48	16.416
Wet	2002	186.64	18.280
Dry	2000	118.77	25.286
Dry	2001	199.21	15.031
Dry	2002	167.28	37.774

Appendix Table 8: Rainfall distribution during the study period (mm)

	Year				
Month	2000	2001	2002	2003	Total
January	1.2	64.4	5.4	34.9	105.9
February	7.7	46.4	40.5	33.1	127.7
March	24.2	51.3	189.8	75.2	340.5
April	152.2	212.5	321	226.4	912.1
May	157.5	238.1	166.8	310.2	872.6
June	81.2	251.3	63.5	116.2	512.2
July	77.8	68.7	41.4	102.5	290.4
August	167.5	166.6	83.5	64.1	481.7
September	69.5	105.7	147	167.7	489.9
October	69.8	239.9	301.8	111	722.5
November	112.3	142.8	129.3	167.9	552.3
December	18.3	12.4	89.3	84.4	204.4
Total	939.2	1600.1	1579.3	1493.6	