

**PHENOTYPIC AND GENETIC TRENDS OF GROWTH
CHARACTERISTICS OF THE SMALL EAST
AFRICAN ZEBU AT SERERE STATION, UGANDA.**

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*Dedicated to my late parents, Eliezer and
Grace Rwabushaija, to my dear wife,
Annet and to the children, Brian, Vanessa
and Valeria*

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ACRONYMS AND ABBREVIATIONS

AI	Artificial Insemination
AIREML	Average Information Restricted Maximum Likelihood
DANIDA	Danish International Development Agency
GDP	Gross Domestic Product
GLM	General Linear Model
FAO	Food and Agriculture Organization
ILRI	International Livestock Research Institute
MOET	Multiple Ovulation and Embryo Transfer
MFPED	Ministry of Finance, Planning and Economic Development
NARO	National Agriculture Research Organization
SAARI	Serere Agricultural and Animal Production Research Institute
SEAZ	Small East African Zebu
SAS	Statistical Analysis System

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Abstract

Data on live weights collected over a 25 year period (1950-1974) at Serere Agricultural and Animal Production Research Institute, Uganda, were used to estimate phenotypic, genetic and environmental trends, and genetic progress in growth traits of the Small East African Zebu (SEAZ). Data were for 1421 progeny. The traits studied were: birth weight and live weights at 3 months interval up to 30 months of age. Fixed effects fitted in the statistical models were sex, year of birth, month within year and parity. Least squares means estimates were obtained by the GLM procedure of SAS. Variance and covariance components were estimated using AIREML procedure, fitting a sire model and individual animal models allowing for both additive and maternal effects and their covariance. The breeding values for all animals were obtained using the later package fitting a single trait animal model. Estimates of genetic trends were calculated by regression of the annual averages of breeding values for respective traits on year of birth, while the phenotypic trends were calculated by regression of least squares means on year of birth. Environmental trends were calculated as the difference between phenotypic and genetic trends.

Mean weights were: at birth, 19 kg; 122 kg at weaning weight (9 months); 134 kg at one year, 210 kg at 2 years and 246 kg at 2½ years. Male calves were significantly heavier than females at all ages. Of the environmental effects, sex was by far the most important source of variation in the preweaning phase, followed by year, month within year and parity. In the postweaning phase, year effects were the most important source of variation, followed by month within year, sex and parity. Year and sex were all highly significant for all traits, while month within year was highly significant for all traits except birth weight. Parity was significant for other traits except birth weight and weights at 21 and 30 months of age.

The heritability estimates from the sire model for birth weight, weaning weight and weight at 18 months were 0.49, 0.20 and 0.42, respectively. On the other hand, the heritability estimates from the individual animal model for direct effects (h^2_a) of birth weight, weaning weight and weight at 18 months were 0.40, 0.31 and 0.45, respectively. The heritabilities of maternal effects (h^2_m) were estimated as 0.09, 0.10 and 0.01 for the respective traits at the same ages. The correlations between direct and maternal genetic effects were essentially zero. The phenotypic correlations were between 0.08 and 0.41 whereas the genetic correlations estimates were in the range of 0.65-0.94.

The phenotypic trends for birth weight, weaning weight, and weight at 18 months were 0.32, 2.64 and 2.83 kg/year, respectively. The genetic trends were 0.07, 0.29 and 0.40 kg/year for the same traits and corresponding estimates for the environmental trends were 0.25, 2.37 and 2.44 kg/year. However, the trends were not linear over the entire period. The estimated annual genetic changes represented, on average, a genetic progress of 0.3 % in all the traits. Result of this study indicate that a positive genetic progress was made in growth performance of the SEAZ under a conventional selection programme.

CHAPTER ONE

INTRODUCTION

1.1 Overview of livestock sub-sector in Uganda.

Livestock production constitutes an important sub-sector of agricultural production in Uganda, contributing about 7.3 % of the total GDP and 17 % to Agricultural GDP (Uganda Statistical Abstract, 1998). From an economic point of view, cattle are the most important of all livestock in the country, although goats and to a lesser extent sheep, pigs and poultry make significant contributions in the local economy and diet. The ruminant livestock population for 1997 was estimated to be 5.46 million cattle, 0.98 million sheep and 5.86 million goats (Uganda Statistical Abstract, 1998); all constituting the bulk of the livestock economy.

Like in many other sub-Saharan African countries, the indigenous cattle (*Bos indicus*) predominate the national herd, constituting more than 95% of the total population. However, these indigenous cattle are low producing compared to cattle of the temperate areas (*Bos taurus*) as a consequence of both genetic and environmental factors. The importance of this low productivity is highlighted by the urgent need to avail more animal protein for the ever growing and malnourished population of Uganda. Per capita availability of livestock products is very low (22 litres of milk and 6 kg of beef in 1994 when human population was about 18 million (MFPEP, 1995)) as compared to FAO (1981) per capita recommendation of 200 litres of milk and 50 kg of beef annually. These per capita consumption figures are not expected to change much in the near future considering a current human population of approximately 20 million (1998) growing at a rate of about 2.5 %; and the projected real consumption of 521, 000 and 145, 316 metric tons of milk and meat, respectively by the year 2000 (MFPEP, 1995).

Efforts to get round the problem have involved introduction of genetically improved temperate breeds. These have rarely produced to expectation largely due to the failure by farmers to support high input production systems necessary for sustenance of suitable productivity enhancing environments. In general, however, the major constraints hindering livestock productivity have been largely attributed to presence of diseases and parasites, low genetic potential, poor nutrition and management, ineffective extension service and unconducive socio-economic/cultural issues including rampant poverty.

Nonetheless, the constraints notwithstanding, it is well established that, through natural selection over millennia, the indigenous cattle breeds (*Bos indicus*) have become adapted to the harsh tropical environment. They have developed tolerance to tropical diseases and are able to survive on low nutritional regimes and withstand other environmental stresses better than the relatively more “productive” exotics (*Bos taurus*). With this advantage of adaptability and a multitude of production constraints facing the tropics, the indigenous genotypes offer the greatest promise for sustainable livestock development. However, data on how to increase their productivity is lacking as not many studies have been undertaken on the indigenous genotypes. The absence of appropriate genetic parameter estimates also, make it difficult to develop selection programmes in developing countries as has been observed by Setshwaelo (1990).

1.2 Scope and objectives of the study

1.2.1 Scope of study

There are three main breed types of indigenous cattle in Uganda and these are the Ankole or Sanga, the Nganda (Sanga x Zebu) and the Zebu. These breeds are more or less zonally distributed; the Ankole being more prevalent in the west and south-west, the Nganda in the

central and the Zebu in the eastern and north-eastern region. This study involved the Small East African Zebu (SEAZ) which belongs to the broader Zebu group and is predominant in an area of high potential for beef production (see Figure 1).

The herd of SEAZ at Serere Research Station in eastern Uganda was established in 1939 with purchase of foundation stock from the local markets. The primary objective was to characterize the population for milk and beef production performance and to investigate the optimal methods of management under local conditions of the country. Starting in 1956, the breeding programme placed specific emphasis on improved growth of stock specifically focusing on efficiency of growth on pasture.

Earlier reports (Wilson, 1957; Stobbs, 1966; Mayanja *et al.*, 1970) show that there was considerable improvement in growth of all SEAZ stock. Heritability estimates for the growth rates, calving interval and age at first calving were also obtained from the early data and indicated that there was potential for genetic improvement especially, with regard to growth traits under Performance Testing (Stobbs, 1966). Unfortunately, in the previous reports, genetic improvement was not separated from environmental improvement. It is important to find out whether the programme made changes which were hoped for. Considering long term studies of this nature, environmental factors can change apart from the genetic merit of the animal. Therefore, to quantify genetic gains would require separation of the genetic and environmental portion of the phenotypic trend. This study was, thus, undertaken primarily to estimate the genetic trends in growth traits of the SEAZ at Serere Research Station now called Serere Agricultural and Animal Production Research Institute (SAARI).

1.2.2 Objectives

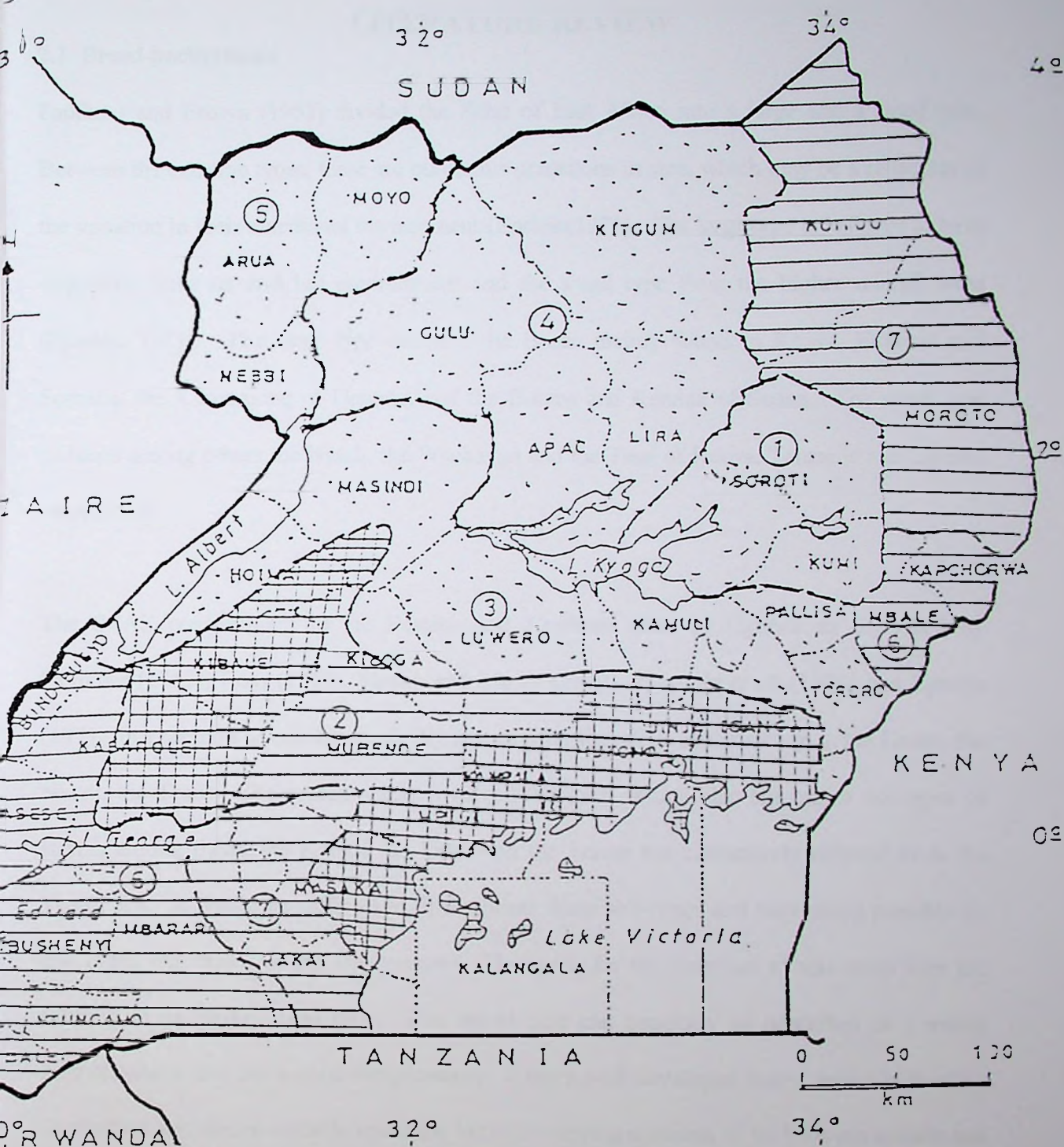
1.2.2.1 Overall objective

The overall objective was to evaluate the performance characteristics of the SEAZ (Teso type) for meat (beef) production and its potential for genetic improvement.

1.2.2.2 Specific objectives

- Review literature relating to the genetic and environmental effects on growth traits of beef cattle.
- Estimate the environmental effects associated with performance of the SEAZ herd at Serere.
- Estimate heritabilities, phenotypic and genetic correlations of growth traits of SEAZ.
- Estimate the phenotypic, genetic and environmental trends over 25 years of SEAZ selection programme and establish the rate of genetic progress achieved over the period.

Figure 1: Vegetation Potential for Meat Production



Kev

source: Based on Uganda Biomass Study (1994)

Low Potential

Moderate Potential

High Potential

Agricultural Systems

① Teso ② Banana/Coffee ③ Banana/Coron ④ Northern

West Nile (6) Montane (7) Pastoral

CHAPTER TWO

LITERATURE REVIEW

2.1 Breed background

Faulkner and Brown (1953) divided the Zebu of East Africa into a large and a small type. Between the extreme types, there are numerous gradations in size, which may be a reflection of the variation in their nutritional environment (Epstein, 1971). The large type is believed to have originated from an arid hot environment and the small type from the higher rainfall areas (Epstein, 1971). The large type includes the Boran mainly found in Kenya, Ethiopia and Somalia, the Karimajong of Uganda, and the Butana and Kenana of Sudan. The small type includes among others the Nandi, the Wachagga and the Teso of Kenya, Tanzania and Uganda respectively.

The SEAZ predominant in the Eastern and Northern parts of Uganda as described by Faulkner (1953), Ross (1958), Mason and Maule (1960), Mayanja *et al.* (1970) and Epstein (1971), is a mixture of sub-types usually named after the tribes of the area (e.g. the Lango, the Nkedi, the Teso). The present study involved the Teso, which also has minor sub-types or strains among them, the Kyoga, the Usuk and the Serere but collectively referred to as the Teso Zebu. It would be difficult to differentiate these sub-types and they could possibly be one breed but varied by the environment. However, for the purposes of this study they are referred to as SEAZ, Teso type. This breed type can generally be described as a robust animal, which also has a good temperament. It has a well-developed hump, which is thoracic in position and almost entirely muscular but with varying amounts of fat between muscle and skin. The horns are relatively short, round and thick at the base. Polledness is fairly common, occurring more frequently in females than in males. The predominant coat colours are black, black and white, but grey, roan and brindle also occur. It also shows tremendous

variation in performance, mature size and shape. . On the basis of this description, one would find it difficult to call this cattle type a breed. However, such variability is likely to have a large genetic component and could be important in selection or genetic study programmes in the indigenous cattle breed types as pointed out by Robelin and Tullow (1992)

Detailed information on the growth performance of SEAZ cattle is scanty. However, the mean maximum live weight for males does not usually exceed 340 kg and for females 255 kg (Williams and Bunge, 1952). Epstein (1955) noted that generally the body weight in the East African Zebu cattle was not always a constant hereditary feature and was largely dependent on environmental conditions. In some areas they could attain a live-weight of 450 kg and in others could be as low as 150 kg. Ross (1958) makes similar observations on the SEAZ in then Teso district of Uganda (now comprising of Soroti, Kumi and Katakwi districts) pointing out the influence of breed (sub-)type, climate, nutrition and management on body size.

Unpublished reports in Uganda say the SEAZ has potential for beef production. The animal is already being used for beef thus, there is need to investigate the possibilities of increasing its beef productivity. Growth rate is undoubtedly one of the most important factors that affect beef productivity though reproductive performance is also important. Both factors are influenced by environmental and genetic factors. Thus, knowledge of environmental and genetic factors that influence performance is necessary for evaluation of the potential of these animals. These factors are discussed below in relation to growth and associated traits and with reference to beef production, which was the focus of the Serere herd selection programme.

2.2 Environmental influences

Growth performance is known to be influenced by such factors as sex, type of birth, age of dam and parity, birth date, season, year and management, for which records should be adjusted in a selection programme to allow the making of valid comparisons among genetic groups. For example, Illoeje (1986) reported that herd effects accounted for 10 and 12% of variation in growth traits of Zebu and South Devon cattle, respectively, while year-season effects accounted for 10-12% of variation in preweaning growth traits and 11-17% in postweaning traits of the two herds. Wilson *et al.* (1986) reported that herd-year-season and management together accounted for 34.8% and 45.5% of variation in actual birth weight, 57.3% and 60.4 % in weaning weight and 80.9% and 85.7% in post-weaning gain in Hereford and Angus breeds, respectively. It is therefore, necessary to have an understanding of environmental factors that systematically influence the traits of interest.

2.2.1 Environmental influences on preweaning growth

Environmental factors influencing birth weight and pre-weaning weight in cattle have been extensively studied. Year, sex, season of birth, birth date, weight of dam at calving, parity of dam, previous parous state of dam, birth type (single or twin) and management or herd effects 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 preweaning growth performance of beef calves.

2.2.1.1 Year

Year effects have been reported by many workers to be a major source of variation (e.g Sacker *et al.*, 1971; Trail *et al.*, 1971, Thorpe *et al.*, 1980; Mwandoto, 1988) . Stress produced by climatic factors, particularly in the tropics cannot be predicted from previous years' data

and although carry-over effects are probably important, each year can be probably 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. Tawonezvi *et al.*, (1986a) reported that year of birth was significant for growth traits, but as in many cases, there was no significant pattern. Thus, this emphasizes the danger of attempting to set minimum weight selection standards in a herd without correcting for year effects.

2.2.1.2 Season of birth

There are many conflicting reports on the effect of season of birth on growth performance of beef animals in the tropics. This is partly because of the differences in definition of seasons as well as the differences in magnitude of seasonal differences within the tropics. But probably more important is the large year to year variation in seasons as a result of annual variations in such climatic factors as rainfall, temperature and humidity. Seasonal influence on growth from birth to weaning were reported by Wilson (1957), Kidner (1966), Mwandoto (1981), Kassa-Mersha and Arnason (1986). However, Wakhungu *et al.* (1991) and Banjaw and Haile-Mariam (1994) reported no seasonal influence on birth weight. These contrary reports imply that seasons as a source of variation in the tropics, where large differences may exist between years, for instance when there is drought in one year and abundant rainfall the following year, should be defined with caution, particularly in long term studies.

Allied to season is the effect of birth date. Beef production from pastures in almost all the world follows a management calendar that ensures among other things that birth of calves and their subsequent growth to weaning is not constrained by pasture deficiency for the dam, and

later for the calf. In other words, beef cows are bred during well-defined seasons (Rege and Moyo, 1993) to coincide with availability of pastures for the dam when it calves. Usually calves are categorised by birth dates as born early, mid or late in the breeding season. There may be an advantage of early birth in the breeding season on overall calf performance because early calves are reasonably old during the peak production of the dam and are thus able to utilize pastures to a greater advantage and to benefit from increased quantities of milk produced by the dam as she reaches peak production. This advantage has been reported to have carryover effects for example, Rege and Moyo (1993) reported calves born at the beginning of the season weighed 47.3 kg more at 12 months than those born at the end of the season. Sacker *et al.* (1971) also reported that period of birth had significant effect practically at all ages and weights of calves from birth to two years. Birth date could therefore be an important source of variation though its effects may be confounded in seasons.

2.2.1.3 Age and parity dam

Effects of age of the dam on birth weight have been extensively reported (e.g. Bosman and Harwin, 1966; Sacker *et al.*, 1971; Tawonezvi *et al.*, 1986a; Tawah *et al.*, 1993). Generally the weights of calves gradually increase as the age of dam increases, plateaus off then decreases gradually. Trail *et al.* (1971) found that weight of calves gradually increased with age of dam up to the age of 7 years. Tawonezvi *et al.* (1986a) reported that calf weight at birth and 100 days postpartum of Nkone cattle increased with age of dam, reached a maximum at about 7 years, after which it tended to decline. Trail *et al.* (1971) concluded that the influence of age of dam on calf weight probably also reflects changes in maternal ability with age. Weaning weight also increased with age of the dam but did not decline as age of the dam increased further (Tawonezvi *et al.*, 1986a). However, Tawah *et al.* (1993), found suprisingly that age of dam was not significant for birth weight. Sacker *et al.* (1971) reported

significant effect of age of the dam on calf weight at birth but not thereafter. Bosman and Harwin (1966), also found no significant age of dam effect though there was a pattern for birth weight and weaning weight to increase with age of the dam. Arnason and Kassa-Mersha (1987) found no significant effect and suggested it could have been because of the late age at which the heifers were served. Seifert *et al.* (1974) reported age of dam as having the largest effect on weaning weight. These results indicate that age of the dam should be included at least in the preliminary analyses to determine its importance, in analytical models for early growth performance of beef calves.

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. Usually, first calf heifers would produce lighter calves than multiparous cows (Winroth, 1990; Banjaw and Haile-Mariam, 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. Banjaw and Haile-Mariam (1994) reported that the highest weight was recorded for calves produced by cows in their third to fourth parturition and that heifers and cows calving for the ninth and later times weaned the lightest calves. Wakhungu *et al.* (1991) reported that birth weight increased from the first parity to the fourth followed by a decline. Winroth (1990) reported that calves born at first parity had 8-14 % lower weight at birth and weaning relative to those born at parities four to eight. Contrary reports on the effect of parity are reported, indicating that parity should also be included at least in the preliminary analysis to determine its importance in analytical models for growth performance.

2.2.1.4 Previous parous state of dam

Generally, calves raised by dams, which calved the previous year are lighter at birth and have a lower pre-weaning growth rate than those raised by cows, which did not calve the previous year (Trail *et al.*, 1971; Tawonezvi *et al.*, 1986a). Failure to account for this source of variation when selection is based on pre-weaning weight could result in slight prejudice against progeny from the more fertile dams or, similarly, from calves raised by heifers.

2.2.1.5 Weight of dam

Calf birth weight has been reported to be positively correlated with dam weight at calving. Cow weight tends to decline as age increases beyond 7 year Tawonezvi *et al.* (1986a) and this could partly explain the corresponding decrease in birth weight. Richardson *et al.* (1979) reported that increase in calf birth weight with age of the dam was partly due to an increase in cow weight with age. Trail *et al.* (1971) reported that cows heavier at parturition weaned heavier calves than lighter cows. There is no doubt that weight of dam is an important source of variation in pre-weaning weight and should be considered where practical if selection is to be based on such weights.

2.2.1.6 Sex

Male calves have consistently been reported to be significantly heavier than their female counterparts at practically all ages (Brown, 1960; Bosman and Harwin, 1966; Mwandoto, 1981) and thus contribute to the systematic environmental effects that must be corrected for in evaluation of the animals. It is standard practice, therefore, to include sex of calf in all models for calf growth performance. Not only differences in growth rates have been reported between male and females but also between intact males and castrates. Brinks *et al.*, 1961 reported castrates in a Hereford herd being slightly heavier than bulls at weaning.

2.2.1.7 Birth type

Type of birth could be the most important source of variation on birth and weaning weight in some cases as reported by Fahmy and Lalande (1973) in a study on Shorthorn calves. As well, Winroth (1990) reported that the weights of twins were 80%, 86 % and 99 % of weights of singles at birth, weaning and at one year of age, respectively. Though twinning is not common in cattle as in sheep and goats, when it occurs it could be an important source of variation which should be corrected for in a selection programme especially with preweaning weights.

2.2.1.8 Maternal effects

Growth of a calf during the suckling period is affected by the dam who furnishes the developmental environment (Koch, 1972). By definition, a maternal effect is a contribution to the phenotypic value of an offspring by the dam and thus the phenotypic differences among dams for the maternal effects are expressed in the phenotypic value of the offspring. Maternal effects represent mainly the dam's milk production and mothering ability though effects of uterine environment and extra-chromosomal inheritance may also subscribe to the total contribution (Baker, 1980; Robison, 1981).

The 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 complexity added to the genetic variability and thus, heritability estimates may be biased by the presence of maternal effects.

The trait as measured is the phenotypic value of the offspring but is composed of at-least two components constituted of the offspring's growth and the maternal effect contributed by the dam. Not only do the genes of the dam responsible for the maternal effect express themselves in the phenotypic value of the offspring, but also the dam contributes a sample half of her genes to the offspring.

It has usually been found that maternal influences decline after weaning (e.g Waldron *et al.*, 1993) but some reports in the literature indicate a continued maternal influence for some adult traits. Vesely and Robison (1972), Nelson and Robison (1976) and Robison *et al.* (1980) demonstrated important maternal effects lasting into adulthood in beef cattle, swine and dairy cattle, respectively. Meyer (1992) also reported a similar situation in beef cattle.

2.2.2 Environmental influences on post-weaning growth

Year and sex have been reported in the literature to consistently influence post-weaning growth in cattle. For example, Sacker *et al.*, 1971 reported a difference in body weights of 26.8 kg and 19 kg at 18 months and 24 months respectively in range cattle between two extreme years. Year differences in growth in the postweaning phase are expected especially in the tropics because animals rely mainly on range pastures which are directly affected by climatic factors. Conversely, sex influence seems to lie in the physiological aspects whereby, males maintain higher weights at all ages. Thus, year and sex effects should as a standard practice be taken into account when evaluating animals.

On the other hand, there are contrary reports for other non-genetic factors as discussed in the pre-weaning growth phase. For example, Banjaw and Haile-Mariam (1994) reported results which contradicted reports by Kassa-Mersha and Arnason (1987) on seasonal influence on

post-weaning weight for the same herd. The differences arose from month classification into seasons in their studies. However, seasonal influences are generally expected and should be put into consideration in analyses of growth rates especially in the postweaning phase.

Another aspect, which could contribute to variation in postweaning growth that may be misleading, is compensatory growth or tendency for individuals to reach same mature size despite the differences in early growth (O'Donovan, 1984). Interpretation of this aspect in relation to correction for environmental influences is rather difficult. However, what is definite in the postweaning phase is that most of the influence of environmental factors like age of the dam, previous parous state of the dam or parity and maternal effects will have been reduced or evened out. However, consideration should be made for these factors particularly, in the early postweaning phase. For example, Mackinnon *et al.* (1991) and Mavrogenis *et al.*, (1978) reported some evidence of maternal influence on postweaning growth.

2.3 Genetic influences on growth - genetic parameters

Genetic parameters *viz.* repeatability, heritability and genetic correlations depict the nature of variability of traits of interest in a population under consideration. Thus, their estimates provide information about the genetic nature of traits. They are necessary to determine as to whether or not selection is a viable option from the degree of genetic variation. They are needed to predict direct and correlated response to selection, to formulate selection indices, to determine the method of selection (Falconer, 1981; Mohuiddin, 1993). They are also necessary in prediction of breeding values (Pirchner, 1983; Mohuiddin, 1993) and prediction of future performance (Cunningham and Henderson, 1965), and in evaluating genetic progress (Smith, 1984).

2.3.1 Repeatability

Repeatability is defined as an estimate of the proportion of the variation among observations caused by permanent differences among animals. The permanent differences among individuals are caused by differences in genotypic and permanent environmental effects in expression of the trait ,during the subsequent production cycle. Repeatability represents the fraction of the differences from the mean in one record, which is expected in another record of the same animal and is calculated using intra-class correlation and/or the regression of subsequent records on earlier records. It ranges between 0 and 1.0 though negative repeatability estimates arising from negative estimates of variance components have been reported (Gregory *et al.*, 1950).

Repeatability estimates of growth traits are a measure of performance of the dam rather than of the calf (Cunningham and Henderson, 1965). The estimates for growth characters as traits of the cow (expressed through the calf) in various breeds as reviewed by Mohuiddin (1993) range between -0.03-0.41 for birth weight, 0.21-0.52 for weaning weight and 0.21-0.48 for yearling weight. The estimates for weaning weight appear to be higher than those for birth weight because of the dam's environmental influence on weaning weight compared to birth weight and could be used for selecting dams for maternal ability in this phase.

Like any other genetic parameter estimate, an estimate of repeatability is merely a descriptor of a particular population under certain conditions of environment. The applicability of the estimate is therefore limited to situations where animals are reared under conditions similar to those for which the estimate was obtained and the data adjusted for the same sources of variation.

2.3.2 Heritability

Conceptually, heritability is used to describe the magnitude with which a trait is inherited. It is defined as the proportion of the total phenotypic variation among individuals in a population, which is due to additive effects of the genes. The higher the heritability for any trait, the greater the rate of genetic change. Like repeatability, it is characteristic of the population structure and the environment. It is calculated from the variances and covariances derived usually using regression and correlation based methods. Of recent use, is the Restricted Maximum Likelihood method employed particularly in estimation of variances attributed to maternal effects. Heritability values range from 0-1 though could be on either side of the range particularly being influenced by the size of the data set. Gill and Jensen (1968) reported on the possibility of obtaining negative estimates when dealing with low heritable traits, and a small data set and using methods in which (co)variance estimates are not "forced" to fall within parameter space.

Heritability estimates vary from breed to breed. Mohuiddin (1993), in a review of genetic parameters, reported a range of 0.09 (Holstein x Zebu) to 1.0 (Hereford) for birth weight. Many workers have also reported on the differences in estimates among sexes (Alenda and Martin, 1987; Koots *et al.*, 1991). Heritability estimates have also been reported to vary depending on method of estimation. For example, estimates from paternal half-sibs do not include maternal effects which can be an important source of genetic variation in growth of cattle (Koch, 1972; Van Vleck *et al.*, 1977; Willham, 1980). Ignoring maternal effects will inflate direct heritability (Baker *et al.*, 1991; Meyer, 1992). Heritability estimates also are reported to vary between herds and environments. For instance, if the 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 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-energy diets. Thus, heritability estimates may be lower in indigenous cattle breeds kept in low input systems compared to the exotic breeds under high level management. However, the magnitude of genetic variation may be higher in the former than the latter. Other factors like previous selection and inbreeding have also been reported to influence heritability estimates (Tawonezvi *et al.*, 1986c).

The heritability estimates and ranges for various growth traits are given in Table 1. Comparative heritability estimates due to additive genetic effects (direct heritability) and the heritability due to maternal genetic effects are presented in Tables 2 and 3. Generally, the heritability estimates for growth traits are moderate, indicating significant improvement can be expected from selection within a breed.

Table 1. Heritability (h^2) estimates from the tropics for various traits in cattle.

Trait	Range	Average
Birth weight	0 - 0.48	0.27
Weaning weight	0.02 - 0.51	0.18
Adult weight	0.02 - 0.79	0.33
Weight gain (birth- weaning)	0.02 - 0.34	0.14
Weight gain (postweaning)	0.13 - 0.38	0.26
Milk Yield		
Indigenous breeds	0.11 - 0.48	0.25
Indigenous x Exotic	0.12 - 0.54	0.33
Exotic breeds	0.15 - 0.34	0.25
Age at first calving	0.01 - 0.69	0.30
Calving interval	0 - 0.40	0.12
Lactation length	0.06 - 0.51	0.29
Calf mortality	0 - 0.09	0.05

Source: Weigner (1994)

Table 2. Heritability (h^2) estimates of selected traits for various breeds with the maternal component(m) and the correlation (r_{am}) between additive (a) genetic effects and maternal (m) genetic effects.

Trait	Breed	Country	h^2_a	h^2_m	r_{am}
Birth	Hereford	USA	0.36	0.82	-0.51
Weight	Hereford	Australia	0.41	0.08	0.04
	Angus	Australia	0.42	0.22	-0.12
	Simmental	Canada	0.34	0.20	-0.22
Weaning	Hereford	USA	0.18	0.24	0.25
Weight	Hereford	USA	0.32	0.27	-0.57
	Simmental	Australia	0.35	0.18	-0.39
	Zebu cross	Australia	0.59	0.49	-0.74
Yearling	Hereford	Australia	0.15	0.14	-0.41
Weight	Simmental	Australia	0.37	0.11	-0.22
	Simmental	UK	0.27	0.03	-

Source: Adapted from Mohuiddin (1993).

Table 3. Relative magnitudes of direct and maternal heritability estimates in some indigenous tropical breeds.

Trait	Breed	h^2_a	h^2_m	r_{AM}	Country	Source
Birth weight	Boran	0.24(.08)	0.084(.03)	-0.55	Ethiopia	Haile-Mariam and Kassa-Mersha(1995)
	Gudali	0.39(.10)	0.06(.06)	-0.86	Cameroon	Tawah <i>et al.</i> (1993)
	Wakwa*	0.65(.15)	0.22(.08)	-0.93	Cameroon	Tawah <i>et al.</i> (1993)
Weaning weight	Boran	0.29(.07)	0.064(.03)	-0.37	Ethiopia	Haile-Mariam and Kassa-Mersha(1995)
	Gudali	0.27(.09)	0.020(.09)	-0.68	Cameroon	Tawah <i>et al.</i> (1993)
	Wakwa	0.29(.13)	0.27(.12)	-0.39	Cameroon	Tawah <i>et al.</i> (1993)
Yearling weight	Boran	0.34(.10)	0.04(.03)	-0.48	Ethiopia	Haile-Mariam and Kassa-Mersha(1995)

* composite breed; h^2_a = heritability for direct effects; h^2_m =heritability for maternal effects; r_{am} = direct-maternal genetic correlation.

2.3.2.1 Direct heritability estimates

Estimates of direct heritability (h^2_a) are higher than maternal heritability (h^2_m) for almost all growth traits. This implies that growth traits are determined more by the genetic characteristics of the calf than by those of the dam but this may not be a general situation as some reports indicate higher heritabilities due to maternal genetic effect (Nelsen *et al.*, 1984)

2.3.2.2 Maternal heritability estimates

A review by Mohiuddin (1993) indicated that estimates of maternal heritability for growth traits are highest for weaning weight than any other trait. The figures in Table 3 do not show this picture because these coefficients are influenced, as earlier alluded to, by many environmental factors including breed differences, size of data sets and method of estimation. But it is generally accepted that maternal effects may be more important for growth rate to weaning and weaning weight than birth weight or yearling weight (Buchanan *et al.*, 1982). It is thus, important to make an allowance for maternal effects if selection is to be based on preweaning weights.

2.3.2.3 Genetic correlation between additive and maternal genetic effects (r_{AM})

The correlation between additive direct and additive maternal genetic effects in beef cattle has been reported to be large and negative (Wright *et al.*, 1991; Meyer, 1992). The figures in Table 2 illustrate this. Most literature reports (see Mohiuddin, 1993) indicate that the correlation is highest for birth weight than weaning weight and yearling weight. Based on these, Garrick (1990) cited by Mouhiddin (1993), suggested that many of the same genes possess opposite effects on direct and maternal components of birth and weaning, indicating a tendency for animals with superior growth genes to have inferior maternal genes and vice versa.

The implications of the negative correlation between maternal and direct effects besides reducing the heritability of total genetic contribution have been of concern and recommendations on how to handle it have been discussed in literature. Koch and Cark (1955) were of the view that if this correlation, is negative, more emphasis should be placed

on selecting cows on the basis of their calf's weight, if selection for maternal ability is to keep pace with selection for growth response. If the correlation is zero, selection for the trait would tend to be more for the genes for growth in the offspring than maternal influence. If positive, selection improves both additive and maternal genetic components. However, in most literature reports the positive relationship does not seem to be expressed (see review by Mouhiddin, 1993). All in all, to achieve optimum progress in a selection programme, it seems appropriate that both the direct and maternal component should be taken into account, especially if an antagonistic relationship exists.

2.3.3 Correlations among growth traits

Genetic correlations among traits mainly arise as a result of pleiotropic action of genes whereby genes affecting the expression of one trait also affect the expression of another trait. A correlation may either be positive or negative. Like heritability, the potential for genetic change in economically important traits lies in the nature of relationships among traits. Rate of improvement in net merit is increased if the association among traits on which selection is based is favourable. Conversely, if antagonism exists among traits, the rate of improvement taken over all the considered traits is reduced.

Choice of selection criteria for improvement of growth, particularly, in beef cattle depends on heritabilities and correlations of body weights at different ages (Tonn, 1976; Tawonezvi *et al.* 1986b, Alenda and Martin, 1987) and correlations of weights and gains with traits such as dystocia (Smith *et al.*, 1976) since they provide an indication of what may happen to other traits if a particular trait is selected for. In addition, knowledge of genetic correlations is needed for multiple trait evaluation of individuals (Henderson and Quass, 1976) and in design of optimal breeding plans especially where antagonism may be anticipated. For example, the negative correlation between direct and maternal effects (Willham, 1972; 1980, Meyer, 1992) or the correlation between outside fat thickness and marbling of meat (Gregory, 1968) or the

unfavourable genetic correlation between growth rate and the various carcass freshness traits (Ferrall *et al.*, 1989; Aass, 1996), these need to be taken into consideration otherwise genetic change may occur in the opposite direction (Annala *et al.*, 1995).

Estimates of phenotypic correlations among growth traits in various breeds show a wide variation. Mohuiddin (1993), in a review, reported a range of 0.11 to 0.94 and 0.57 to 0.85 between birth weight and weaning weight and between weaning weight and yearling weight, respectively. Most of these estimates are from established beef breeds and from the temperate areas. However, similar ranges have been reported for the indigenous breeds in the tropics. (e.g. Iloeje *et al.*, 1986; Tawonezvi *et al.*, 1986b). Although, phenotypic correlation may give a fair guide to the nature of the relationship between two traits, it is not a reliable indicator of the underlying genetic correlation. This may be due to the environmental component of variance included in the parameter estimates. Thus, there is need to obtain genetic correlations.

Reports from a wide range of environments indicate that, in general, selection for increased live weights at any given age will result in increased live weight at all ages (Burrow *et al.*, 1991). Although there is a paucity of information regarding correlations among growth traits of the indigenous cattle breeds, there is no reason to believe that the same picture would not apply. Tawonezvi *et al.*(1986b) and Iloeje *et al.*(1986) have respectively, reported estimates between birth weight and weaning weight of 0.85 and 0.81, which fit in the range of 0.25 to 0.99 reported by Mohiuddin's (1993) review. Estimates between weaning weight and postweaning weights tended to cluster around 0.8 (Mohuiddin, 1993). These high genetic correlations seem to indicate that the growth traits are under the influence of similar genes and a genetic change in one is likely to be reflected in the other. Thus, the favourable

correlation between weaning weight and postweaning weights is of great advantage since selection can be done early. However, these favourable correlations also imply that improving growth traits will result into larger calves at birth. Large calves at birth have been associated with calving difficulty. This problem has been a subject of many studies (e.g. Koch *et al.* 1974, Cundiff *et al.*, 1975; Nelson and Beavers, 1982; MacNeil *et al.*, 1984) for selection for decreased birth weight would mean a correlated decrease in weights of subsequent ages which would be undesirable.

2.4. Trends over time

The main objective in selective breeding is to obtain genetic improvement in economically important traits. It is therefore important to find out whether the selection programme is making the changes, which were hoped for by looking at the trends. Because selection usually has to continue for several years, apart from the genetic merit of the animal, non-genetic factors can change (Smith, 1962; Wakhungu *et al.*, 1991) and the change may be in different direction than intended. It could be that only the environment is being improved. Thus, evaluation of progress requires separation of the genetic and environmental portion of the total phenotypic trend to quantify net merit (Nadarajah *et al.*, 1987; Haile-Mariam and Phillipson, 1995). Genetic trend estimation also allows fair comparisons among generations over a long term selection programme.

2.4.1 Phenotypic trends

Phenotypic trends in performance can be estimated straightforwardly by regressing actual performance records on time. However, unbiased estimates of either genetic or environmental trends are difficult to obtain because of the potential of confounding of changes in environment with changes in the genotype (Nadarajah *et al.*, 1987). Nonetheless, the

difference between the phenotypic and genetic trends would give a fair indication of the environmental trend. The phenotypic trends are expected to be closely allied to the environmental trends as changes in the environment would have a direct bearing on the phenotype.

2.4.2 Genetic trends

Several methods have been used to estimate genetic trends from livestock selection experiments. Use has been made of unselected control lines (Hill, 1972) and repeat mating techniques (Nakwalor *et al.*, 1976) in separating genetic and environmental changes in animal populations under selection experiments. However, it has been demonstrated that environmental trends can be separated without use of the above mentioned techniques provided genetic ties exist between years (Henderson, 1973; Blair and Pollak, 1984). Improved statistical techniques, now available, have increased greatly the ability to make allowances for all recorded factors which affect performance of an animal and inclusion of recorded information from relatives to build these into assessment of breeding values (Sorensen and Kennedy, 1984). For example, Elzo *et al.* (1987), Rege (1991) and Tawah *et al.* (1994) have applied best linear unbiased prediction (BLUP) procedures to estimate genetic trends, while Tawonezvi *et al.* (1986b) have used within-sire regression to estimate genetic trends in beef cattle.

Literature reports indicate that significant genetic progress can be achieved when selecting for growth traits (Nadarajah *et al.*, 1987). However, most of the reports are based on established beef breeds and from temperate areas. Some estimates of trends or genetic progress of growth traits among indigenous cattle breeds show varying degree of success in the selection programmes so far evaluated. For example, Tawah *et al.* (1994) reported estimates of annual

changes in estimated sire transmitting abilities (ETAs) for weaning weight of 0.67 kg per year and -0.03 kg per year in dam estimates of breeding values in a selection programme for Gudali cattle, a Zebu breed. On the other hand, Tawonezvi *et al.* (1986c), reported a genetic trend of 0.51 kg and 4.23 kg in birth weight and weaning weight respectively in an indigenous herd of Nkone but was concerned about the increased birth weight which represented 12% of the increase in weaning weight. However, no evidence of dystocia was observed from the herd and he concluded that the increase in birth weight was not sufficiently large to result in corresponding increase in incidence of dystocia. Haile-Mariam and Philipson (1995), reported genetic gain in aggregate breeding value of 0.25 kg of the mean weaning weight per year in a Boran herd in Ethiopia despite the good opportunity for selection as demonstrated by the more than 50 kg difference between the maximum and minimum breeding values for weaning and yearling weight. They attributed this low response to high levels of genetic antagonism between direct and maternal effects and also on problems in running the selection scheme.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Climate and location

The study was based on data obtained from a long-term breeding (selection) programme at Serere Research Station. The institute is located in Serere County in Soroti district, Eastern Uganda, just north of the Equator ($0^{\circ} 32' \text{ N}$ and $35^{\circ} 27' \text{ E}$). It is at an average altitude of 1128m above sea level. Serere has a relatively high rainfall (1950-1974, annual mean of 1427 mm), but is considered to be part of the low potential drier areas of Uganda, principally because of the large variations in rainfall within years and between years (Appendix A) and the thin, low organic content, sandy soils. Rainfall is bimodal with peaks in April/May and August/September. The early "main" rains (March -May) are reliable but the second rains (July-September) are erratic in amount and duration.

During the study period, the highest monthly average rainfall was in April (219 mm) and lowest in January (28 mm) (Appendix A). The main dry season is from December until February, though periods of up to 4 months with negligible rainfall between October and February have been reported (Kerkhan, 1946; Williams and Bunge, 1952). During the dry season, hot weather, usually accompanied by hot winds prevails, resulting into very high evapotranspiration. These conditions, coupled with the thin, rather sandy soils, are responsible for the fact this area is much drier than other parts of Uganda, which have lower rainfall (Kerkhan, 1946). The mean annual temperature was 24° C and the mean maximum and minimum annual temperatures were 29.4° C and 17.9° C , respectively during the study

period (1954-1974). Relative humidity ranged from monthly lowest means of 72% in January to highest means of 84% in July during this period.

3.2 Grazed pastures

Hosking and Stephens (1941), Kerkhan (1946) and Williams and Bunge (1952) have described the range pastures. The major indigenous grasses are *Imperata cylindrica*, *Hyparrhenia rufa*, *Sporobolus pyramidalis* and *Cynodon plectostachyum*. These grass species have been reported to be low in palatability and nutritive value. They are very rough when mature and animals graze them only when young. This necessitates burning off the mature grass during the dry season, a practice common with the traditional stockowners in the area. *Panicum maximum*, *Bracharia* species and *Chloris gayana* were introduced as improved grass species though with difficulty because they tended to be out-competed by the naturally occurring grasses mentioned above. Some legumes, mainly *Centrosema pubescens*, *Glycine gavanica*, *Stylo gracilis* and *Siratro* species were also introduced through over-sowing natural pasture. These were found to contribute most to animal production during the dry season, but tended to be relatively unpalatable during the wet season (Stobbs, 1965).

3.3 Description of the herd and animal management

Establishment of the herd, management and the breeding programme have been described in detail by Williams and Bunge (1952), Wilson (1957) and Stobbs (1966). The animals were fed on an all grass diet with supply of mineral salts and water ad lib. Prophylactic de-worming and tick control routines were adhered to. Dipping to control ticks was done once a week during the dry season and twice a week during the wet season. East coast fever (ECF) was the most important of the tick born diseases. Regular vaccination was also done against rinderpest and brucellosis.

All breeding was by natural service. Selected bulls were allowed to run continuously with a specific group of cows to ensure recognition of paternity of calves. Thus, calves were born in all months of the year. Each calf was identified individually with a number immediately after birth and its dam and sire as well as its birth weight were recorded. The calves were running with their dams at pasture during the day, but were separated and housed in calf pens at night until milking the following morning (semi-range system). Calves were weaned at 9 months of age and at that time male weaners were separated from female weaners to avoid premature breeding. Heifers were turned to bulls when about 30 months old.

3.4 Selection programme

The breeding programme in the early years of the project involved selection based on milk rather than beef as it was considered that one of the limiting factors to live-weight gain to weaning and early maturity was the low milk production of cows (Wilson, 1957). However, after 1956, having attained some good milking characteristics, the breeding programme placed more emphasis on growth rates with specific emphasis on pasture utilisation (Stobbs, 1966; Mayanja *et al*, 1970). Willams and Bunge (1952) and Stobbs (1966) described in detail the selection programme. There was performance testing for both sexes up to three years old by assessing the animal's relative growth rate compared with that of its contemporaries. Weights were taken once every month, animals having been fasted 16 hours prior to weighing. All weights were taken on a weighbridge except birth weight which was taken on a portable scale. All stock were reared under the same grazing environment. The main criterion of selection was the rate of live-weight gain. However, details on cut off points are not available at SAARI.

Young bulls that excelled in the performance test were mated to a random group of 50 cows over a 2-year period and growth of their offspring compared with growth rates of progeny of

other bulls in use at the time. The number of test bulls in one year varied but would not exceed 10 because of herd size. At the conclusion of the test, the bulls were held at co-operating centres in the region (Agricultural colleges, Farm Institutes, Prison Farms, Mission Farms) until the results of the test were known. Bulls with outstanding progeny were then returned for use as proven sires with cows that had consistently produced superior progeny.

3.5 Data

Records from 1950 to 1974 of progeny of the SEAZ were obtained from SAARI. Information on each animal included: identification number, date of birth, sex, birth weight, weights at 3 months interval starting from birth to 30 months of age, and sire and dam numbers. Basic data edits involved consistency checks of dates, duplicate animal identifications, outliers and any other irreconcilable inconsistency. No corrections were made for missing records. There were also few records for 1973 and 1974, which it was felt would bias the estimates and thus were pooled together with those of 1972.

The pedigree information was extracted for all known parents and grandparents of all animals with weight records. Identification numbers of animals were used to trace their pedigree backwards up to the base period (1950). Animals without birth dates (i.e. born before 1950) were treated as base animals. Date of birth was used to sort the data by age

3.6 Classification of fixed effects

The data were classified by sex, year of birth, month of birth and parity. Sex classes were 1 = Male, 2 = Female while 23 year classes were 1 = 1950 through 23 = 1972. Parity classes were 7. The first 6 consisted of the first 6 calving numbers and the last class, the 7th and greater calving numbers. Month classes were 1 = January through 12 = December. Seasons were not

defined because of the big variations within years and between years observed in the meteorological data especially rainfall (see Appendix A). 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. Age and weight of the dam were not included, as this information was not available in the original data set and could not be derived. There were no twins in the data and as such birth type could not be included. A summary of animals with records, sires and dams with progeny and animals in the pedigree is presented in Table 4. The summary of the data structure for the fixed effects is not presented because of the large number of levels in some effects which will, however, be reflected in the tables of results.

Table 4. Summary of the data structure used to estimate genetic parameters.

Trait	Animals with records	Sires with progeny	Dams with progeny	Animals in pedigree
Birth weight	1420*	34	443	1652
Wt. at 3 mo.	1422*	34	443	1652
Wt. at 6 mo.	1423*	34	443	1652
Wt. at 9 mo. ^{a)}	1423*	34	443	1652
Wt. at 12 mo.	1422*	34	443	1652
Wt. at 15 mo.	1414*	34	442*	1652
Wt. at 18 mo.	1422*	34	443	1652
Wt at 21 mo.	1357*	34	436*	1652
Wt at 24 mo	1254*	34	416*	1652
Wt at 27 mo.	1164*	34	392*	1652
Wt. at 30 mo.	1029*	34	367*	1652

^{a)} weaning was at 9 months.; * Disparity in number of records was due to missing records.

3.8 Statistical analyses

3.8.1 Fixed effects

The statistical analyses for fixed effects for all growth traits (birth weight, weight at 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 months) were performed using the General Linear Models (GLM) procedure of Statistical Analyses Systems Institute (SAS, 1988). Fixed effects included in the initial analysis were: sex, year of birth, month, birth date and parity.

Birth date (Julian Date) and month of birth were found in the preliminary analysis not to be contributing significantly to the variation and were therefore excluded in subsequent analyses. Detailed examination of the (monthly) climatic data revealed that there were substantial differences between years suggesting a factorial combination of year with month was inappropriate. It was consequently instructive to fit month within year to avoid year differences masking the months effects expected in such a tropical environment where range conditions do change greatly from rainy to dry months. The final fixed effects model used involved sex, year of birth, month within year and parity.

The model of fixed effects in matrix notation was : $y = Xb + e$ where y is the vector of observations X is the incidence matrix relating to elements of b to y , b is a vector of fixed effects and e is the error term.

3.8.2 Estimation of genetic parameters and breeding values

The average information restricted maximum likelihood (AIREML) procedure as described by Gilmour *et al.* (1995) was used to estimate variance and covariance components from which heritabilities and correlations were derived. All the relationships between animals were utilized to minimize bias due to selection and to increase accuracy of estimation through additional ties

between animals (Meyer, 1992). Four models were used: Sire model (model 1), individual animal model (IAM) with only the additive genetic effects (model 2); IAM with additive animal effect as well as additive maternal effects (model 3); and IAM with the two additive effects as well as a non-zero covariance between the two effects (model 4). Thus, model 4 facilitated the estimation of the genetic correlation between the additive direct and additive maternal components. The individual animal model is considered to be superior to the sire model (Mohuiddin, 1993) due to the fact that it accounts for the loss in degrees of freedom due to fixed effects in the model; it eliminates the bias due to selection; and it takes into account all the relationship in the pedigree. However, estimates of genetic parameters from an appropriate animal model are expected not to differ substantially from those of the corresponding sire model (Waldron *et al.*, 1993).

The models in matrix notation are given below :

The sire model was $y = Xb + Zs + e$ where y represents progeny record of the trait, b is a vector of fixed effects influencing the record, X is an incidence matrix relating elements of b to y , s is a vector of random animal effects (sires), Z is an incidence matrix relating to sires and e is a vector of residuals. The assumptions were $y = E(Y) = Xb$, $\text{var}(s) = A\sigma_s^2 = A' \frac{1}{4} \sigma_A^2$ and $\text{var}(e) = I \sigma_e^2$. A is the additive relation matrix and I is an identity matrix, σ_A^2 is the additive genetic variance, σ_e^2 is the error variance. In addition sires were assumed to be unrelated since information on their relationship was not available.

- The basic individual animal model was: $y = Xb + Zu + e$ where y is a vector of observations, X and Z are incidence matrices for fixed and random effects respectively, b is a vector of fixed effects, u is a vector of individual animal breeding values and e is a vector of residuals. Estimates of breeding values were obtained from the same model. The

assumptions were: $E(\mathbf{y}) = \mathbf{Xb}$, $E(\mathbf{u}) = E(\mathbf{c}) = 0$, $\text{Var}(\mathbf{u}) = \mathbf{A}\sigma^2_A$, $\text{Var}(\mathbf{e}) = \mathbf{I}\sigma^2_e$ and $\text{Cov}(\mathbf{u}, \mathbf{e}) = (\mathbf{c}, \mathbf{u}) = 0$.

- The individual animal model with maternal effect was: $\mathbf{y} = \mathbf{Xb} + \mathbf{Z}_a \mathbf{u}_a + \mathbf{Z}_m \mathbf{u}_m + \mathbf{e}$ where $\mathbf{y}$ is the vector of observations, $\mathbf{X}$ is an incidence matrix relating fixed effects to $\mathbf{y}$, $\mathbf{b}$ is a vector of fixed effects, $\mathbf{Z}_a$ is the incidence matrix relating direct additive genetic effects to $\mathbf{y}$, $\mathbf{u}_a$ is a vector of direct additive genetic effects, $\mathbf{Z}_m$ is the incidence matrix relating maternal additive genetic effects to $\mathbf{y}$, $\mathbf{u}_m$ is a vector of maternal additive genetic effects, and $\mathbf{e}$ is a vector of error terms. Permanent environmental effects of the dam were absorbed in the maternal effects variance. Thus, the following variance-covariance arrangement was assumed; $\text{var}(\mathbf{u}) = \mathbf{A}\sigma^2_A$, $\text{var}(\mathbf{m}) = \mathbf{A}\sigma^2_M$, $\text{Cov}(\mathbf{u}, \mathbf{m}) = \mathbf{A}\sigma_{AM}$, $\text{Var}(\mathbf{e}) = \mathbf{I}\sigma^2_e$ where σ^2_M is the maternal genetic variance, σ_{AM} the direct-maternal genetic covariance. Other assumptions were as above.

The fixed effects fitted were sex, year of birth, year and month, and parity. Month within year could not be used due to the limitations of the package, which does not allow nesting. However, month within year was used in the GLM procedure which allows nesting. All known pedigree information was included in the analysis to minimize the effect of selection and to increase the accuracy of estimation through additional ties between animals according to Meyer (1994). Phenotypic and genetic correlations were obtained using the same package fitting an individual animal model as described above, but fitting two traits at a time (bivariate procedure).

3.8.3 Estimation of trends over time

Least square means of year were assumed to be the estimates of annual phenotypic levels while the genetic component was obtained by taking the averages of the breeding values of animals within a year of birth. For each year, the differences between the two gave the environmental contribution to the performance.

The annual changes in the phenotypic component were estimated by regressing least squares means (phenotypic levels) on year. Correspondingly, annual genetic changes were estimated by regressing the annual averages of breeding values on year of birth for the respective traits. The difference between the phenotypic and genetic trends gave the estimate of the environmental annual changes. This was done for both sexes separately and then combined.

CHAPTER FOUR

RESULTS

4.1 Overall performance

The means and coefficients of variation of the growth traits studied are summarized in Tables 5-8. Birth weight, weaning weight (9 mo) and weights at 12, 18, 24 and 30 months were 19 kg, 122 kg, 134 kg, 169 kg, 210 kg and 246 kg, respectively. Coefficients of variation were birth weight, 16.1 %; weaning weight, 15.8 %; weight at 12 months, 15.0 %; weight at 18 months, 13.9 %; weight at 24 months, 13.2 % and weight at 30 months, 12.5 %.

4.2 Analyses of fixed effects

Of the environmental effects investigated, sex contributed about 70 % to the total variation in birth weight followed by year at 25% whereas month within year and parity accounted for the remaining 5%. However, by weaning age (9 months), year contributed the largest source of variation (73%) followed by month within year (19%), sex effects only contributed 5% and parity 3 %. This later pattern was maintained throughout the postweaning phase. Individual results of fixed effects are presented below.

4.2.1 Sex effects

Tables 7 and 8 summarize the results of effect of sex on traits studied. Sex had a highly significant effect ($P < 0.01$) on all traits. Males were heavier than females at all ages (Figure 2). Males weighed more on average than females by 1.6 kg at birth, 12.4 kg at weaning, 12.8 kg at one year, 17.7 kg at two years and 20.7 kg at two and half years.

Table 6. Estimated least square means (and standard errors) of year effect on body weights (kg) from 15 months to 30 months (at 3 months interval)

Effect	Trait																	
	Wt. at 15 mo.			Wt. at 18 mo.			Wt. at 21 mo.			Wt. at 24 mo.			Wt. at 27 mo			Wt. at 30 mo.		
	No.	Mean		No.	Mean		No.	Mean		No.	Mean		No.	Mean		No.	Mean	
Overall	1415	149.10		1423	169.04		1358	189.83		1255	210.13		1165	229.78		27	208.57	
C.V.(%)		14.07			13.88			13.52			13.17			12.83			12.54	
Year of birth																		
1950	37	113.16(4.56)	**	39	131.94(5.03)	**	40	154.33(5.51)	**	36	169.58(6.39)	**	30	182.43(6.88)	**	27	208.57(7.78)	**
1951	43	125.74(4.120)		44	143.79(4.59)		42	162.21(5.12)		37	180.85(5.78)		31	206.60(6.40)		28	219.81(6.83)	
1952	56	137.88(3.62)		58	154.83(4.02)		53	175.69(4.75)		51	193.66(5.19)		51	211.26(5.56)		49	230.40(5.96)	
1953	44	149.18(4.20)		44	171.21(4.70)		43	190.10(5.18)		42	207.82(5.61)		43	225.88(5.97)		42	240.82(6.29)	
1954	50	135.87(3.71)		50	153.47(4.15)		51	171.71(4.53)		51	182.09(4.90)		51	190.10(5.23)		51	196.47(5.49)	
1955	57	116.02(3.03)		58	122.86(3.34)		58	132.37(3.67)		58	143.76(3.97)		58	161.06(4.24)		57	179.26(4.50)	
1956	62	100.90(3.35)		62	113.08(3.75)		62	130.19(4.11)		62	151.26(4.45)		62	170.16(4.75)		61	187.78(5.01)	
1957	54	116.39(3.47)		54	127.56(3.88)		52	142.17(4.37)		48	156.04(5.04)		47	173.97(5.65)		45	193.17(6.07)	
1958	40	119.86(4.19)		40	135.02(4.68)		38	161.06(5.12)		35	187.88(5.86)		35	204.89(6.25)		35	214.15(6.55)	
1959	45	129.78(3.76)		45	148.24(4.21)		45	169.59(4.61)		45	186.80(4.98)		45	206.16(5.31)		45	231.33(5.57)	
1960	44	124.99(3.99)		45	142.41(4.46)		45	165.74(4.88)		45	187.84(5.27)		45	212.71(5.62)		43	235.90(5.99)	
1961	22	152.37(5.38)		22	173.05(6.02)		22	192.29(6.59)		22	214.94(7.12)		21	236.96(7.61)		21	256.85(7.99)	
1962	29	151.70(4.49)		30	172.73(5.01)		30	199.97(5.48)		30	225.31(5.92)		30	248.72(6.32)		30	266.74(6.63)	
1963	54	158.82(3.52)		54	180.15(3.93)		54	202.76(4.31)		54	227.96(4.66)		54	255.16(4.98)		53	276.44(5.28)	
1964	105	147.73(2.51)		105	173.80(2.81)		105	202.19(3.08)		105	226.03(3.34)		104	246.38(3.58)		102	264.42(3.80)	
1965	95	144.13(2.45)		95	169.54(2.75)		94	195.74(3.08)		93	223.42(3.28)		88	248.04(3.64)		79	267.99(4.14)	
1966	77	153.96(2.90)		77	178.90(3.24)		75	206.71(3.63)		72	230.69(3.97)		70	253.73(4.26)		59	282.61(4.83)	
1967	106	176.49(2.95)		106	200.72(3.30)		99	229.41(3.66)		96	257.20(3.97)		89	284.23(4.40)		62	306.69(4.54)	
1968	107	180.52(2.35)		107	206.30(2.63)		100	236.30(2.93)		93	258.99(3.23)		86	273.34(3.66)		74	279.96(4.19)	
1969	82	185.13(2.77)		82	200.18(3.10)		80	217.64(3.41)		67	237.52(4.16)		48	259.31(5.04)		29	264.59(6.88)	
1970	83	156.67(2.77)		83	171.64(3.10)		67	193.65(3.86)		46	215.04(5.04)		34	244.13(6.41)		21	269.75(7.92)	
1971	78	165.78(2.87)		78	187.04(3.21)		64	202.06(4.20)		42	213.88(5.44)		26	226.21(6.87)		10	246.81(11.83)	
1972	45	166.08(3.56)		45	180.69(3.99)		39	194.96(4.85)		25	197.63(6.90)		17	214.05(8.26)		7	247.07(12.26)	

4.2.2 Year effects

The results of year effects in this study are presented in Tables 5 and 6. Year of birth effects were highly significant ($P < 0.01$) on all the traits studied. Differences between consecutive years were small and not significant ($P < 0.05$). However, there was some significant pattern in the least squares means for years over the study period. Thus, the initial years of the selection programme (1950-1955) recorded lower weights at all stages of growth than the terminal years-period from 1966-1972. However, in between, there were large up and down swings in all traits with the period 1956-1960 registering the least herd means while period 1961-1965 recorded relatively higher means towards improved performance (see Figure 9 for phenotypic trends).

4.2.3 Month effects

The results of the effect of month on body weights are presented in Tables 7 and 8. These are further illustrated in Figure 3. The month of birth did not have any significant effect on all traits studied. However, there were some slight differences particularly in the postweaning phase between months as seen in Figures 3. Further investigation of monthly effects for possible seasonal influences by grouping period of birth as Dry (Jan. - Feb.), Neutral (Jul. - Aug.) and Wet (Oct. - Nov.) did not reveal much of the expected seasonal influences in such a tropical environment (Figure 4A). Similarly, a look at the precalving conditions defined as Wet and Long (July through November), Wet and Short (Mar - Apr- May), Dry and Short (Dec. - Feb.) (Figure 4B) did not reveal much. The growth curves were similar to when averages of successive months were plotted by age (Figure 3). However, when month was defined within year, effects were highly significant ($P < 0.01$) for all traits except birth weight. Results of effects of month within year are attached (Appendix B (1-11)). The effects can also be clearly seen from Figure 5 (A& B). This indicates that there are monthly effects

which are masked when the monthly averages of the entire period are considered and for a short period, seasonal influences would be evident

4.2.4 Parity effects

The parity effects on growth traits were highly significant ($P < 0.01$) for all pre-weaning weights except birth weight (Tables 7 and 8). In the postweaning phase, parity effects were significant ($P < 0.01$) for weights at 12 and 15 months, and significant ($P < 0.05$) for weights at 24 and 27 months of age. Parity had no effect on the weights at 21 and 30 months of age. In general, progeny born in the first and last parity (7th) were lighter than those born in other parities and the weights in the 7th parity were lower than in the 6th parity. Calves born in the second parity were heavier than in other parities and maintained their superiority up to 21 months of age.

Table 7. Estimated least squares means (and standard errors) of sex, parity and month effects and body weights (kg) from birth to 12 months (at 3 months interval)

Effect	Birth wt.		Wt. at 3 mo.		Wt. at 6 mo.		wt. at 9mo		Wt. at 12mo.	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Overall	1421	19.43	1423	60.18	1424	94.66	1424	121.67	1422	134.40
C.V.(%)		16.10		17.24		15.93		15.79		15.04
Sex	1	**		**		**		**		**
	2	19.73(.18)	721	59.86(.59)	721	94.23(.87)	721	122.26(1.10)	720	135.10(1.16)
	700	18.12(.18)	702	55.42(.61)	703	86.21(.89)	703	109.86(1.14)	702	122.32(1.20)
Parity	1	NS		**		**		**		**
	2	18.67(.16)	541	57.26(.53)	543	88.86(.77)	542	115.06(.98)	542	128.75(1.03)
	3	19.14(.19)	361	60.09(.64)	360	93.99(.94)	361	120.75(1.20)	360	133.32(1.26)
	4	19.11(.23)	239	58.87(.78)	239	92.23(1.14)	239	119.10(1.45)	239	131.23(1.53)
	5	18.74(.31)	132	59.09(1.04)	132	91.96(1.51)	132	117.70(1.92)	132	129.70(2.02)
	6	18.55(.39)	80	58.51(1.32)	80	93.12(1.92)	80	117.81(2.44)	80	130.45(2.57)
	7	19.62(.55)	40	56.34(1.83)	40	86.83(2.67)	40	112.49(3.40)	40	124.97(3.58)
Month	1	NS		NS		NS		NS		NS
	2	19.01(.30)	140	55.20(1.04)	140	89.16(1.50)	140	114.32(1.89)	140	127.55(1.98)
	3	18.68(.34)	97	58.52(1.21)	97	91.21(1.75)	97	114.16(2.20)	97	124.87(2.31)
	4	18.88(.34)	100	59.52(1.18)	99	91.10(1.72)	100	114.48(2.15)	100	125.36(2.25)
	5	19.51(.32)	121	57.65(1.10)	121	90.25(1.60)	121	115.25(2.01)	121	126.02(2.10)
	6	19.10(.28)	153	57.55(.98)	153	89.83(1.43)	153	115.05(1.80)	153	129.36(1.89)
	7	18.65(.31)	129	56.66(1.07)	130	89.60(1.55)	130	118.02(1.94)	130	128.39(2.04)
	8	18.36(.31)	129	57.42(1.09)	129	90.20(1.58)	129	112.77(1.98)	129	127.95(2.08)
	9	18.83(.34)	100	59.75(1.19)	100	90.38(1.73)	100	118.76(2.17)	100	133.47(2.27)
	10	19.30(.33)	107	57.86(1.16)	107	88.59(1.68)	107	116.88(2.11)	106	127.75(2.22)
	11	19.10(.35)	89	57.85(1.23)	90	91.49(1.80)	90	120.41(2.26)	89	129.28(2.38)
	12	19.10(.31)	130	56.82(1.08)	130	92.68(1.56)	130	117.98(1.96)	130	127.97(2.05)
	128	19.16(.31)	128	56.04(1.07)	128	91.97(1.55)	127	117.78(1.96)	128	128.83(2.05)

**=P<0.01, *=P<0.05, NS=Non significant

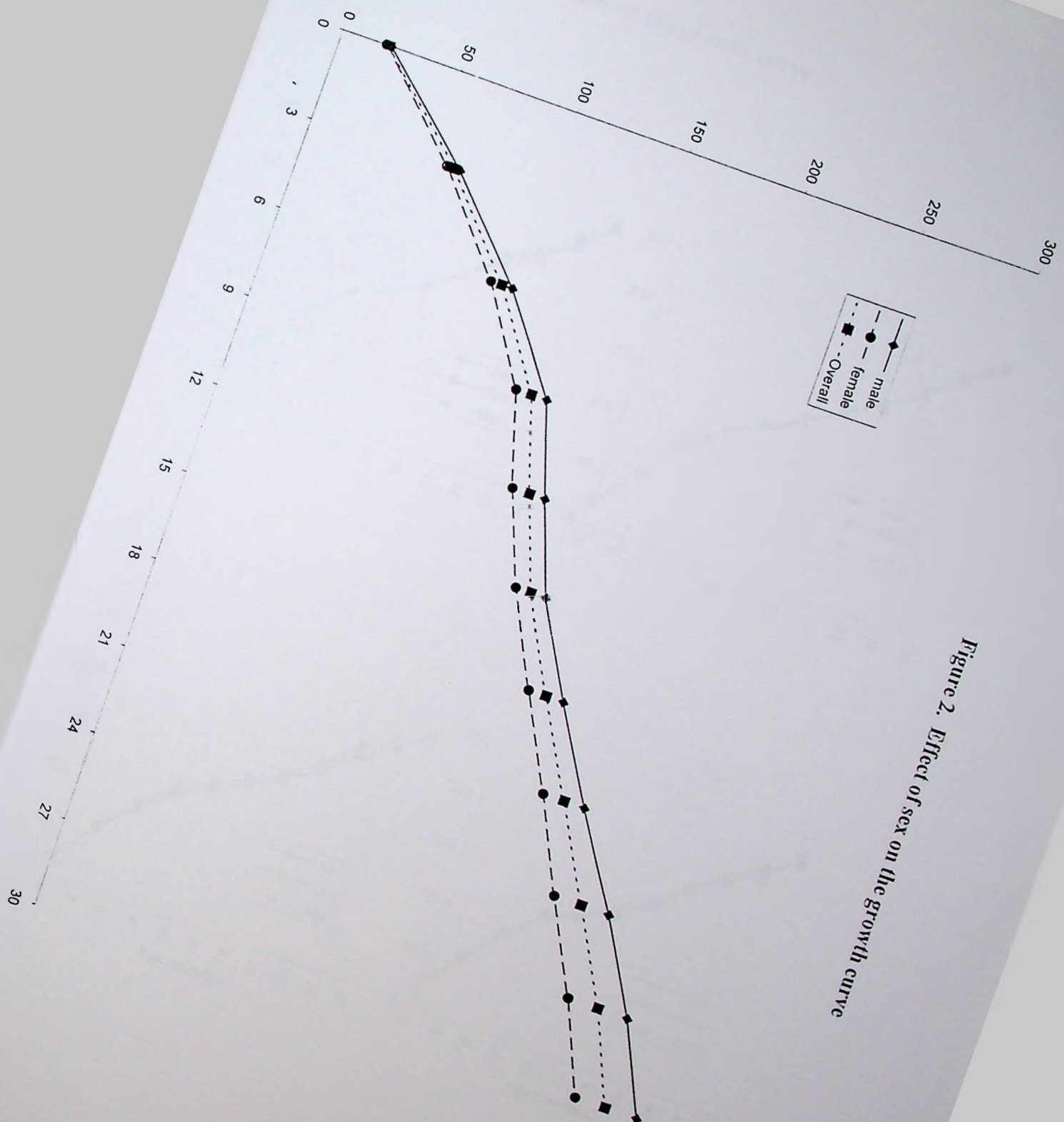


Figure 2. Effect of sex on the growth curve

Figure 3. Effect of month on the growth curve

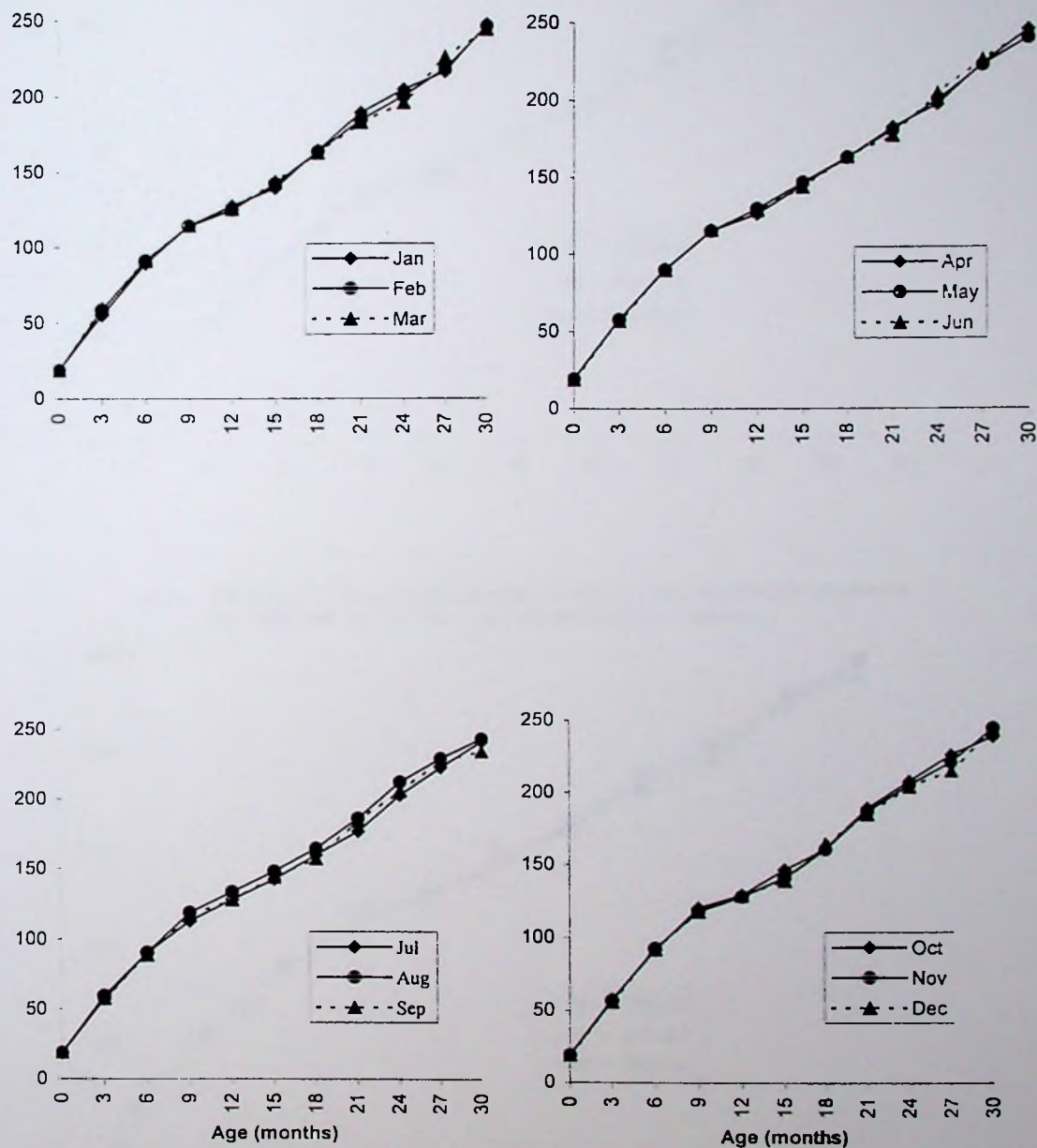
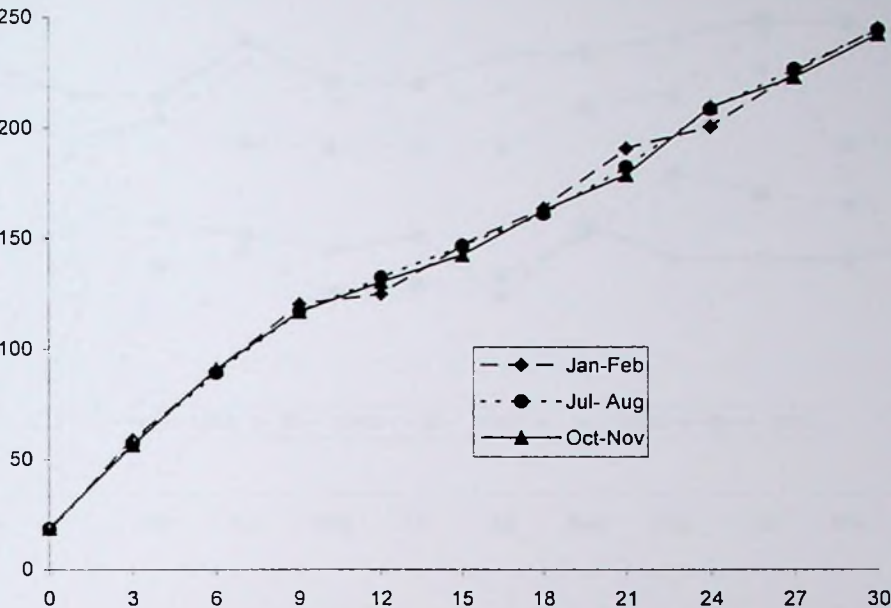


Figure 4 **Effect of period/season of birth on the growth curve**
A. Dry (Jan - Feb), neutral (Jul - Aug), wet (Oct - Nov)



B. Pre-calving conditions: wet and long, wet and short, dry and short for calves born Dec - Jan, Jun - Jul and Mar - Apr, for the respective conditions.

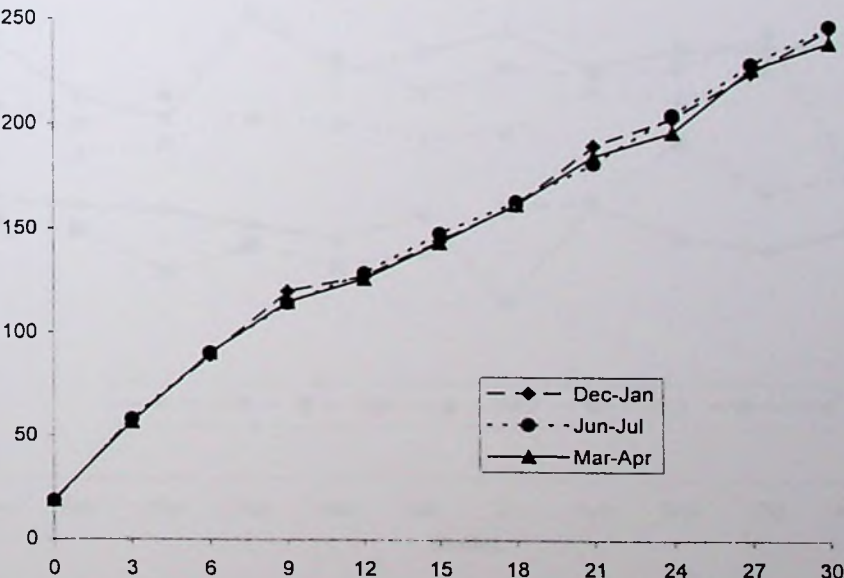


Figure 5A. Effect of month within year on weaning weight (1965 - 1969)

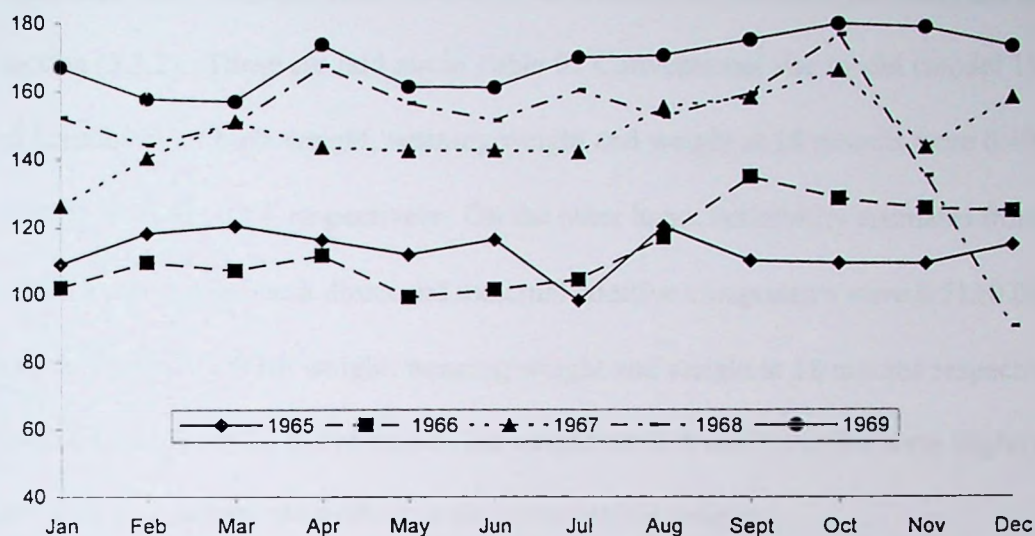
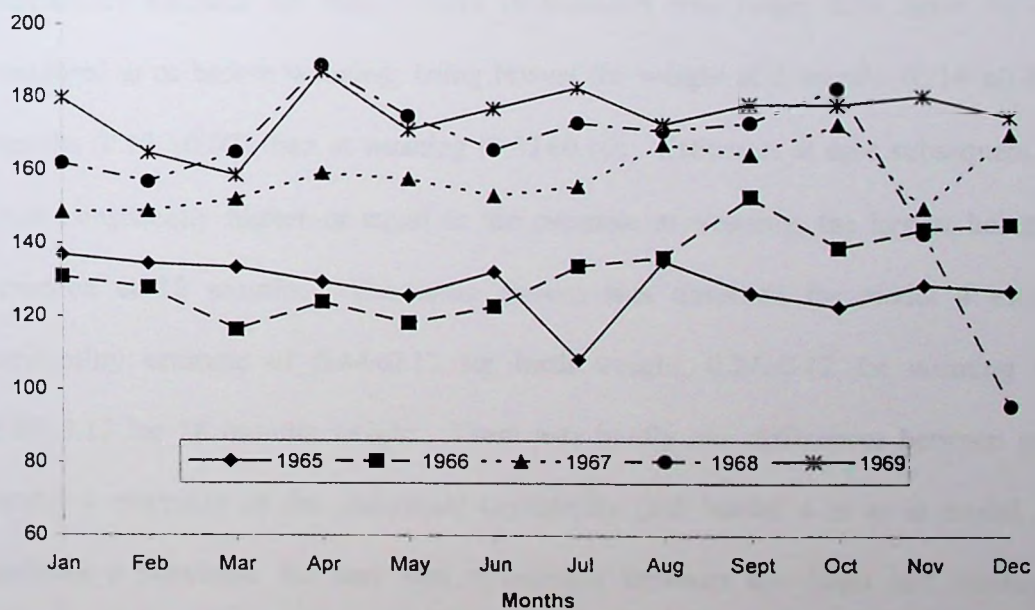


Figure 5B. Effect of month within year on yearling weight (1965 - 1969)



4.3 Genetic parameters

4.3.1 Heritability estimates

Estimates were obtained from the four models earlier described in the materials and methods section (3.3.2). These are laid out in Table 9. Conventional sire model (model 1) estimates of heritability of birth weight, weaning weight and weight at 18 months were 0.49 ± 0.15 , 0.20 ± 0.09 , 0.42 ± 0.14 , respectively. On the other hand, heritability estimates from model 2 which encompasses both direct and maternal additive components were 0.51 ± 0.08 , 0.51 ± 0.08 and 0.47 ± 0.08 for birth weight, weaning weight and weight at 18 months respectively. Estimates from model 1 (sire model) for weights at 3, 6 and 9 months were slightly lower than in model 2, a pattern not evident in the postweaning weights. .

From Model 3 (with additive animal effect as well as additive maternal effect), direct heritability estimate for birth weight (0.40 ± 0.09) was larger than those for other traits measured at or before weaning, being lowest for weight at 3 months (0.14 ± 0.07) and at 6 months (0.13 ± 0.07) than at weaning (0.31 ± 0.10). Estimates at ages subsequent to weaning were consistently higher or equal to the estimate at weaning, the largest being (0.45 ± 0.1) recorded at 18 months. The same pattern was observed for model 4 estimates with heritability estimate of 0.44 ± 0.13 for birth weight, 0.24 ± 0.12 for weaning weight and 0.48 ± 0.17 for 18 months weight. There was hardly any differences between model 3 and model 4 estimates of the individual heritability (*NB* Model 4 is as in model 3 except it includes a provision for non zero covariance between the direct and maternal additive effects). These estimates are also generally comparable to those obtained from the sire model.

Maternal heritability estimates were generally low and, with the exception of model 3 estimates for weight at 3 months (0.18 ± 0.04), 6 months (0.15 ± 0.04) and at weaning (0.10 ± 0.05) are trivial. Estimates of maternal heritability by model 3 and 4 were generally similar. All direct-maternal genetic correlations were "zero" (Table 9), but ranged from a low negative to a low positive.

Table 9. Heritability estimates.

Trait	No of records	Model 1 (Sire Model)	Individual Animal Model					
		h^2 (s.e)	Model 2	Model 3		Model 4		
			h^2 (s.e)	h^2a (s.e)	h^2m (s.e)	h^2a (s.e)	h^2m (s.e)	r_{AM} s.e)
Birth weight	1421	0.488(.145)	0.509(.076)	0.398(.094)	0.088(.043)	0.437(.128)	0.113(.068)	-0.040(.083)
Wt. at 3 mo	1423	0.166(.084)	0.390(.076)	0.139(.066)	0.175(.044)	0.122(.077)	0.138(.097)	0.040(.097)
Wt. at 6 mo	1424	0.106(.068)	0.403(.078)	0.128(.069)	0.153(.043)	0.096(.084)	0.078(.103)	0.087(.101)
Wt. at 9 mo (Weaning)	1424	0.196(.089)	0.508(.077)	0.310(.102)	0.099(.047)	0.244(.116)	0.037(.070)	0.094(.061)
Wt. at 12 mo	1423	0.245(.104)	0.467(.077)	0.320(.100)	0.081(.045)	0.376(.131)	0.093(-.001)	-0.024(-.041)
Wt. at 15 mo	1415	0.400(.138)	0.459(.076)	0.425(.098)	0.020(.039)	0.405(.135)	0.011(.055)	0.015(-.059)
Wt. at 18 mo	1423	0.424(.142)	0.466(.076)	0.446(.096)	0.012(.037)	0.484(.169)	0.024(.021)	-0.025(.056)
Wt. at 21 mo	1358	0.413(.141)	0.447(.078)	0.421(.100)	0.016(.041)	0.425(.136)	0.030(-.000)	-0.015(.017)
Wt. at 24 mo	1255	0.366(.135)	0.336(.079)	0.304(.094)	0.024(.043)	0.319(.360)	0.041(.136)	-0.023(-.086)
Wt. at 27 mo	1165	0.414(.148)	0.348(.082)	0.346(.003)	0.000(.003)	0.418(.043)	0.003(-.001)	-0.037(-.002)
Wt. at 30 mo	1030	0.437(.157)	0.364(.057)	0.352(.103)	0.010(.044)	0.447(.169)	0.046(.064)	-0.080(.083)

4.3.2 Phenotypic and genetic correlations

Phenotypic and genetic correlation estimates are presented in Tables 10 and 11, respectively. The phenotypic correlations (Table 10) involving birth weight were 0.41 ± 0.03 with weight at 3 months, 0.35 ± 0.03 with weight at 6 months, 0.36 ± 0.03 with weight at 9 months, 0.33 ± 0.03 with weight at 12 months, 0.33 ± 0.03 with weight at 18 months and 0.08 ± 0.02 with weight at 30 months. Such a pattern was not obvious among genetic correlations (Table 11) where estimates between birth weight and weights at 3, 6, 9, 18 and 30 months of age were 0.76 ± 0.09 , 0.65 ± 0.10 , 0.68 ± 0.09 , 0.66 ± 0.09 and 0.94 ± 0.07 respectively. Genetic correlations were thus, generally higher than phenotypic correlations. Indeed, other than a few correlations involving birth weight and those which due to non-convergence, were not estimated, most genetic correlations were greater or equal to 0.8 and not significantly different from unity. On the other hand, phenotypic correlations showed a pattern in which estimates generally decreased as the age difference between the two points of measurement (trait-pair) increased.

Postweaning correlation estimates between different stages of growth were high and positive. The phenotypic correlation between weaning weight (9 mo) and weights at 18, 24 and 30 months were 0.71 ± 0.01 , 0.63 ± 0.02 and $0.62 \pm$, respectively. The genetic correlation estimates however, were higher; registering 0.97 ± 0.02 and 0.97 ± 0.03 between weaning weight and at 18 and 24 months respectively.

Table 10. Phenotypic correlations (and standard errors) among weights at different ages.

Weight	months										
at:	0	3	6	9	12	15	18	21	24	27	30
0 (birth weight)											
3 mo.	0.406 (.031)										
6 mo.	0.345 (.031)	0.821 (.011)									
9 mo.	0.360 (.032)	0.684 (.018)	0.846 (.010)								
12 mo.	0.328 (.033)	0.602 (.022)	0.757 (.014)	0.873 (.006)							
15 mo.	0.333 (.030)	0.596 (.022)	0.731 (.016)	0.829 (.011)	0.899 (.004)						
18 mo.	0.327 (.032)	0.575 (.023)	0.710 (.010)	0.785 (.013)	0.848 (.010)	0.929 (.005)					
21 mo.	0.172 (.031)	0.544 (.024)	0.666 (.019)	0.745 (.015)	0.791 (.009)	0.872 (.008)	0.906 (.006)				
24 mo.	0.096 (.025)	0.528 (.026)	0.630 (.021)	0.707 (.018)	0.758 (.012)	0.835 (.008)	0.866 (.009)	0.928 (.003)			
27 mo.	0.038 (.031)	0.544 (.026)	0.621 (.019)	0.686 (.020)	0.727 (.017)	0.812 (.012)	0.832 (.011)	0.896 (.007)	0.928 (.003)		
30 mo.	0.079 (.019)	0.521 (.019)	0.616 (.024)	0.678 (.014)	0.722 (.012)	0.786 (.015)	0.810 (.013)	0.861 (.010)	0.890 (.008)	0.938 (.003)	

Table 11. Genetic correlations (and standard errors) among weights at different ages.

Weight At:	months										
	0	3	6	9	12	15	18	21	24	27	30
0 (birth weight)		0.759 (.087)	0.652 (.102)	0.680 (.087)	0.698 (.089)	0.831 (.089)	0.661 (.094)	0.712 (.185)	n.e	n.e	0.938 (.066)
3 mo.			0.962 (.021)	0.881 (.045)	0.894 (.050)	0.895 (.056)	0.822 (.071)	0.860 (.067)	0.849 (.076)	0.822 (.079)	n.e
6 mo.				0.977 (.016)	0.968 (.023)	0.977 (.024)	0.940 (.034)	0.957 (.035)	0.928 (.049)	n.e	n.e
9 mo.					n.e	0.955 (.011)	0.973 (.019)	0.978 (.023)	0.967 (.030)	0.928 (.044)	n.e
12 mo.						n.e	0.967 (.030)	n.e	n.e	0.961 (.031)	n.e
15 mo.							0.992 (.006)	0.996 (.009)	n.e	0.986 (.018)	0.968 (.006)
18 mo.								0.977 (.006)	0.981 (.016)	0.977 (.020)	0.964 (.026)
21 mo.									n.e	0.966 (.010)	0.987 (.017)
24 mo.										n.e	0.987 (.016)
27 mo.											n.e
30 mo.											

n.e: No estimates due to non-convergence.



4.5 Trends over time

4.5.1 Phenotypic (and environmental trends).

The regression coefficients of the phenotypic and environmental components on year (annual trends) for the traits studied and in both sexes are presented in Table 12. They are further illustrated in Figure 6 together with genetic trends. Summarized in Table 13 are the expressions of these components over specifically variable periods of years over the entire breeding period of 25 years, the periods having been formed by grouping together years with either positive or negative phenotypic trends.

Overall estimates of phenotypic trends (kg/year) were 0.32, 2.64, 2.54, 3.15, 3.60 for birth weight, weaning weight, yearling weight and weights at 2 years and 2½ years, respectively. Corresponding environmental trends were 0.25, 2.37, 2.30, 2.67, 3.11 kg/year. The trends were highly significant ($P < 0.01$). However, there were substantial fluctuations in the trends and in all traits (Table 13 and Figure 6). There were periods characterized by declining performance and periods with positive phenotypic trends. For example, annual phenotypic trends in birth weight in Period 1 (1950-53) were -0.42 kg. Corresponding trends in Period 2 (1954-56) were 0.41 kg. The annual phenotypic changes in weaning weight during Period 1 were 9.50 kg. Corresponding trends in the second period were -11.34 kg. Noteworthy in Tables 12 and 13 and Figure 6, is that the environmental trends were closely allied to the phenotypic trends; implying that the greatest contribution to the phenotypic trends was from the environmental component. Furthermore, the trends were similar in both sexes. Thus, the estimates for each of the sexes were more or less similar to the overall estimates obtained when data for both sexes were combined.

Table 12. Regression coefficients (and standard errors) for phenotypic (P), genetic (G) and environmental (E) trends

	Male			Female			Overall		
Trait	P	G	E	P	G	E	P	G	E
Birth weight	0.339(0.04)	0.073(0.01)	0.265(0.03)	0.302(0.03)	0.054(0.01)	0.242(0.04)	0.319(0.03)	0.065(0.01)	0.253(0.03)
Wt. at 3 mo.	1.359(0.30)	0.105(0.03)	1.254(0.27)	1.117(0.24)	0.033(0.03)	1.092(0.23)	1.252(0.27)	0.068(0.02)	1.183(0.25)
Wt. at 6 mo.	2.113(0.47)	0.237(0.03)	1.876(0.45)	1.819(0.36)	0.159(0.03)	1.659(0.37)	1.991(0.42)	0.199(0.02)	1.791(0.42)
Wt. at 9 mo. (Weaning)	2.767(0.52)	0.336(0.05)	2.431(0.52)	2.512(0.38)	0.250(0.06)	2.259(0.42)	2.637(0.45)	0.291(0.05)	2.366(0.49)
Wt. at 12 mo.	2.652(0.48)	0.279(0.06)	2.373(0.47)	2.515(0.35)	0.220(0.07)	2.294 (0.38)	2.545(0.40)	0.248(0.06)	2.302(0.41)
Wt. at 15 mo.	2.585(0.56)	0.362(0.07)	2.228(0.55)	2.741(0.40)	0.398(0.07)	2.342(0.43)	2.600(0.55)	0.358(0.06)	2.4500(0.56)
Wt. at 18 mo.	2.7989(0.67)	0.386(0.08)	2.412(0.65)	2.985(0.48)	0.450(0.10)	2.534(0.51)	2.828(0.55)	0.400(0.07)	2.437(0.56)
Wt. at 21 mo.	2.964(0.76)	0.500(0.10)	2.464(0.75)	3.277(0.55)	0.509(0.11)	2.768(0.59)	3.007(0.63)	0.478(0.08)	2.541(0.65)
Wt. at 24 mo.	3.125(0.89)	0.511(0.08)	2.613(0.87)	3.262(0.63)	0.477(0.09)	2.788(0.64)	3.151(0.74)	0.476(0.07)	2.674(0.75)
Wt. at 27 mo.	3.660(0.96)	0.478(0.09)	3.181(0.94)	3.284(0.70)	0.476(0.01)	2.808(0.72)	3.361(0.80)	0.459(0.07)	2.901(0.82)
Wt. at 30 mo.	3.397(1.00)	0.377(0.13)	3.020(0.95)	3.821(0.66)	0.529(0.10)	3.335(0.68)	3.589(0.78)	0.478(0.08)	3.110(0.77)

Table 13. Regression coefficients for phenotypic (P), genetic (G) and environmental (E) trends by periods

	1950-1953 (Period 1)			1954-1956 (Period 2)			1957-1966 (Period 3)			1967-1969 (Period 4)			1970-72 (Period 5)		
Trait	P	G	E	P	G	E	P	G	E	P	G	E	P	G	E
Birth wt	-0.12	-0.19	0.07	0.41	0.18	0.23	0.41	0.07	0.34	0.94	0.13	0.80	-0.44	0.03	-0.50
Wt. at 3mo	4.79	-0.36	5.15	-6.71	0.12	-6.83	1.42	0.11	1.30	5.11	-0.34	5.45	0.15	0.12	-0.09
Wt. at 6mo	7.09	-0.77	7.85	-11.94	0.72	-12.66	1.74	0.27	1.47	11.19	-0.30	11.49	-0.77	0.35	-1.36
Wt. at 9mo	9.50	-1.15	10.65	-11.34	1.58	-12.92	2.47	0.37	2.39	10.62	-1.64	12.26	0.59	0.41	-0.17
Wt. at 12mo	7.99	-1.00	8.99	-11.88	1.68	-13.56	3.10	0.47	2.63	8.51	-2.26	10.77	2.77	0.34	2.09
Wt. at 15mo	8.96	-1.40	10.36	-17.49	1.86	-19.34	4.23	0.41	3.82	4.32	-1.97	6.29	4.71	0.50	3.78
Wt. at 18mo	9.48	-1.45	10.93	-20.20	1.92	-22.11	5.72	0.36	5.36	-0.27	-2.32	2.05	4.53	0.56	3.51
Wt. at 21mo	8.76	-1.95	10.71	-20.76	2.66	-23.42	6.69	0.29	6.40	-5.89	-2.56	-3.32	0.66	0.96	-0.91
Wt. at 24mo	12.75	-1.76	14.51	-15.41	2.34	-17.76	7.56	0.32	7.24	-9.81	-1.97	-7.87	-8.71	-0.03	-8.84
Wt. at 27mo	13.50	-1.50	15.00	-9.97	2.66	-12.63	8.24	0.29	7.95	-12.46	-1.54	-10.92	-15.04	-0.15	-14.99
Wt. at 30mo	10.73	-1.84	12.57	-4.35	2.55	-6.89	8.96	0.34	8.62	-21.05	-1.16	-19.88	-11.34	-0.27	-10.59

Table 14. Estimated Breeding Values (kg) (annual averages) relative to base year

Year	TRAIT														
	BWT	WT 03	WT 06	WT 09	WT 12	WT 15	WT 18	WT 21	WT 24	WT 27	WT 30				
1950	0	0	0	0	0	0	0	0	0	0	0				
1951	-0.609	-0.838	-2.778	-5.276	-4.15	-6.358	-6.647	-8.733	-8.078	-7.713	-8.412				
1952	-0.674	-0.686	-2.211	-4.469	-3.377	-5.465	-5.723	-8.171	-7.37	-6.629	-7.435				
1953	-0.600	-1.259	-2.752	-4.115	-3.591	-4.957	-5.135	-6.702	-6.102	-5.362	-6.445				
1954	-0.602	-0.876	-1.839	-2.331	-2.69	-3.422	-4.482	-5.76	-5.975	-5.335	-6.693				
1955	-0.302	-0.461	-1.066	-0.998	-1.36	-1.516	-2.657	-3.433	-3.653	-2.455	-3.924				
1956	-0.245	-0.633	-0.393	0.838	0.675	0.293	-0.646	-0.439	-1.288	-0.016	-1.594				
1957	-0.349	-1.352	-1.993	-1.018	-1.468	-2.131	-3.294	-2.673	-1.403	0.268	-0.060				
1958	-0.678	-1.279	-1.270	-0.053	-1.268	-1.941	-0.794	-2.785	-2.857	-2.822	-3.050				
1959	-0.493	-2.145	-1.617	-1.152	-2.571	-3.253	-3.018	-3.189	-2.439	-1.378	-2.877				
1960	-0.014	-2.170	-1.490	0.209	-1.072	-1.599	-1.298	-0.148	0.594	2.057	2.980				
1961	0.186	-2.000	-1.457	-0.791	-1.564	-2.096	-2.003	-1.537	0.015	0.490	2.492				
1962	-0.322	-1.248	-0.047	0.244	-1.238	-2.895	-3.977	-5.197	-3.112	-3.018	-0.240				
1963	-0.272	-1.940	-0.764	-0.739	-2.276	-3.621	-4.428	-4.518	-1.448	-0.674	1.454				
1964	-0.191	-1.741	-0.437	1.061	-0.861	-1.399	-0.964	-1.613	-0.489	1.049	0.583				
1965	0.030	-0.708	-0.030	1.820	1.369	0.489	0.264	-0.946	-0.784	-0.399	-0.348				
1966	0.275	-0.094	0.906	3.355	4.549	3.217	2.694	2.284	2.733	3.654	2.901				
1967	0.468	1.052	2.072	4.751	5.174	5.598	6.639	7.398	6.774	5.789	4.648				
1968	0.147	-0.503	1.037	2.827	2.724	2.806	3.726	4.189	4.93	4.759	4.714				
1969	0.734	0.364	1.474	1.463	0.659	1.665	1.994	2.269	2.839	2.714	2.324				
1970	0.817	0.389	1.253	0.814	0.434	1.474	1.543	1.468	2.539	3.497	4.930				
1971	1.022	1.202	2.312	2.591	2.010	3.588	3.917	3.653	4.336	5.125	1.255				
1972	0.946	0.877	2.439	2.327	1.388	3.306	3.583	4.606	2.807	2.902	3.422				
*b	0.065**	0.068**	0.199**	0.291**	0.248**	0.357**	0.400**	0.478**	0.476**	0.459**	0.478**				

*b = annual genetic change; ** = $P < 0.01$

Table 15. Estimated genetic progress (% of mean of base period-1950).

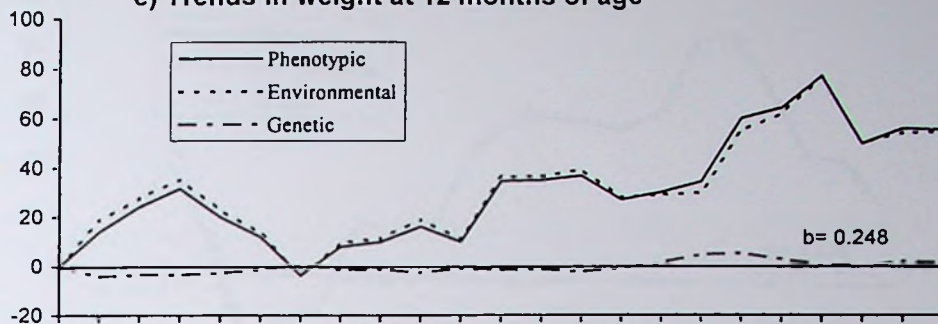
Trait	Male	Female	Overall
Birth weight	0.40	0.35	0.40
Weight at 3 month	0.23	0.08	0.15
Weight at 6 month	0.34	0.24	0.28
Weight at 9 month	0.38	0.30	0.34
Weight at 12 month	0.27	0.23	0.25
Weight at 15 month	0.30	0.37	0.32
Weight at 18 month	0.26	0.37	0.30
Weight at 21 month	0.30	0.36	0.30
Weight at 24 month	0.28	0.30	0.28
Weight at 27 month	0.25	0.27	0.25
Weight at 30 month	0.17	0.28	0.23

4.5.2 Genetic trends

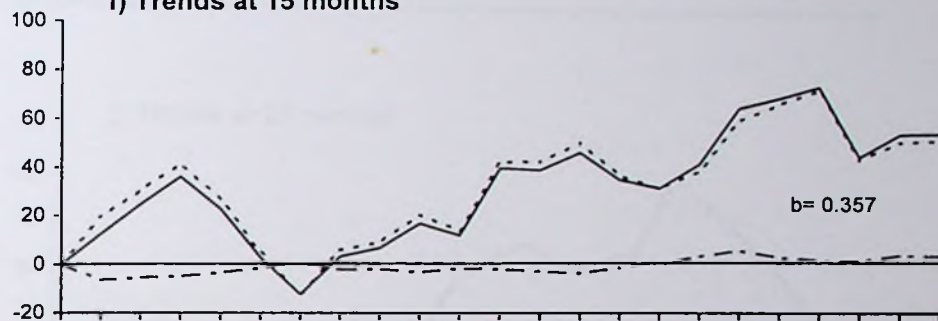
Estimated breeding values (EBVs) relative to base period are presented in Table 14. Regression of these averages on year (genetic trends) for respective traits are presented in Table 13 together with environmental and phenotypic trends. The genetic trends are further illustrated in Figure 6 together with environmental and phenotypic trends. On the whole, genetic change (kg/year) was 0.065 for birth weight, 0.29 kg for weaning weight, 0.25kg for yearling weight and around 0.40 for weights at 15 months to 30 months of age. These genetic changes were highly significant ($P < 0.01$). However, and like with environmental and phenotypic trends there were fluctuations in genetic trends over the study period. For example, all traits exhibited negative genetic trends in the initial years of the study period (1950-53), but became positive between 1954 and 1966. Later between 1967 and 1969, the trends were negative and became positive in the last phase of the study period (Table 14).

Genetic progress (estimated annual genetic changes expressed in relation to the means of base period - 1950) was in the range of 0.17 % to 0.40 % for males, 0.08 - 0.37 % for females and 0.15 - 0.40 % when both sexes were combined (Table 15). On the average, this represents a genetic progress of 0.3% in all traits studied and in both sexes (Table 15). However, there was a slight difference in the rate between males and females in the preweaning phase being higher in the males than females, but this was the reverse in the postweaning phase.

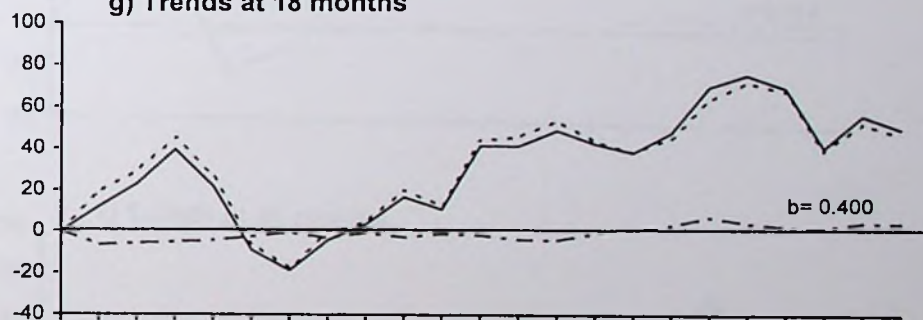
e) Trends in weight at 12 months of age



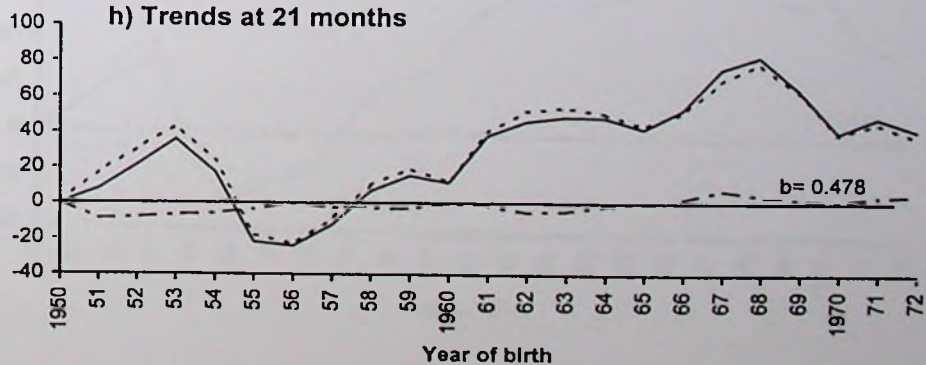
f) Trends at 15 months

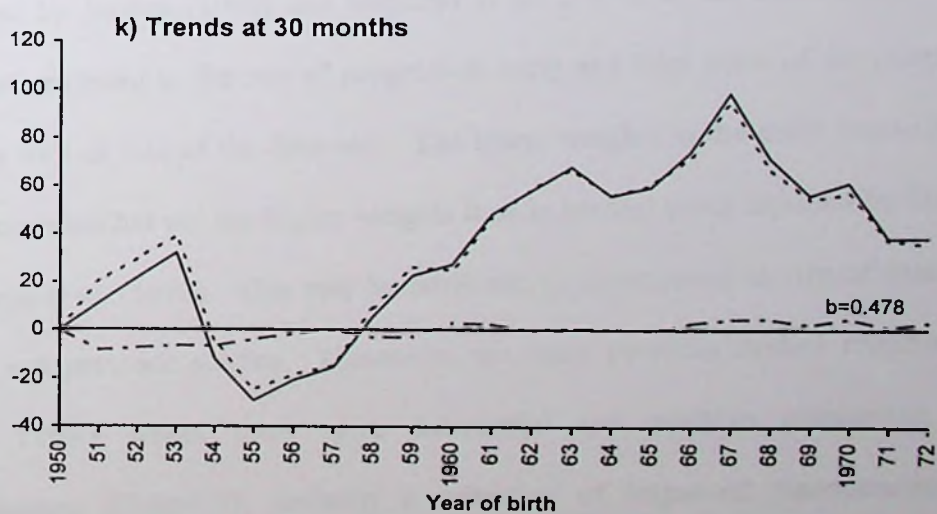
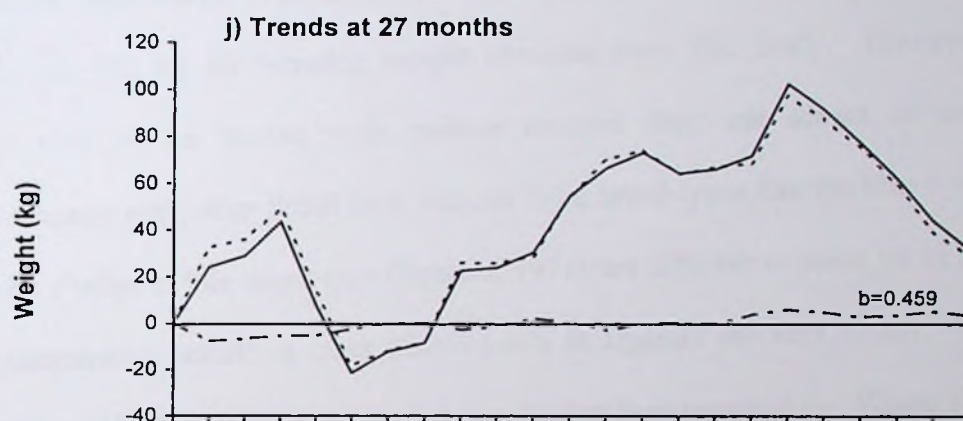
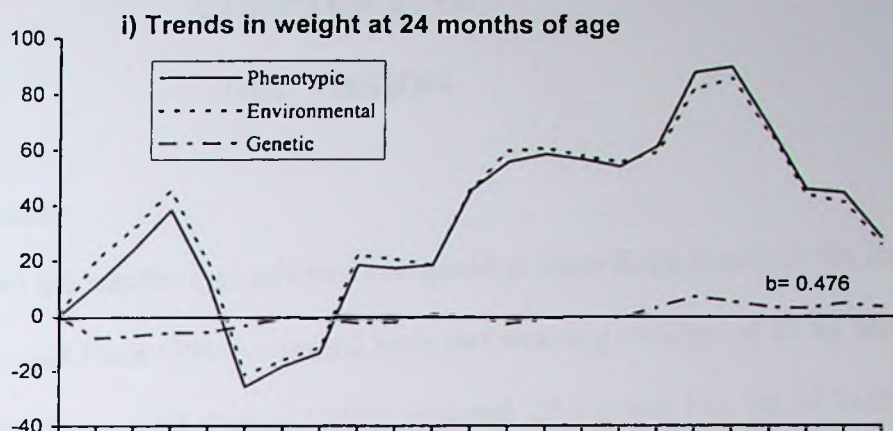


g) Trends at 18 months



h) Trends at 21 months





CHAPTER FIVE

DISCUSSION

5.1 Overall performance

The SEAZ (Teso type) is a smaller type of breed compared to other Zebu breeds in the region. For example, Banjaw and Haile (1994) reported birth and weaning weights of 25 kg and 171 kg respectively in the Boran and Osman (1985) reported 25 kg and 160 kg of birth and yearling weights respectively, in the Butana, which figures are much higher than the 19 kg for birth weight and 122 kg for weaning weight obtained from this study. However, these comparisons need to be treated with caution because they cut across environments. Comparative results with other Small East African Zebu breed types like the Nandi which are reported to be similar to this breed type (Epstein, 1971) are difficult to come by in literature. Similarly, comparative results in other SEAZ herds in Uganda are very scanty. However, yearling weights (134 kg) in the present study are higher than reported by Wilson (1957) but lower than reported by Stobbs (1966) and Mayanja *et al.* (1970) in the same herd. The differences may be attributed to the rate of progress in early and later years of the selection programme and as well as size of the data sets. The lower weights in the early years of the experiment were expected but not the higher weights than in present study reported by Stobbs (1966) and Mayanja *et al.* (1970). This may be attributed to discrepancy in size of data sets of present study and previous studies. Moreover, the latter previous studies reported on weights in the 1960's where there were substantial and positive phenotypic and environmental changes (Figure 9), probably a reflection of improved management and availability of good pastures. Therefore, means of the in the present study may be fairer and representative of EASZ growth characteristic in this area. Moreover, under non station

conditions little attention is paid to optimal nutrition and disease control and thus mean weights are likely to be much lower.

5.2. Fixed effects

As expected, environmental influences which were included in the analysis in this study on growth traits varied in the degree of extent. Year and sex were systematic for all traits whereas month and parity varied. This implies that some environmental influences may not affect some traits. Therefore, there is need to exclude some of these influences in analytical models or in making correction factors for some traits. The environmental influences looked at in this study are further discussed below.

5.2.1 Sex effects

These were highly significant and as expected, male calves were significantly heavier than females at all ages. The sex differences as found in this study are consistent with many reports on the influence of sex on body weight (e.g. Brown, 1960; Bosman and Harwin, 1966; Mwandoto, 1981). It appears these sex differences are due to physiological differences particularly hormonal since there are also differences in growth rates between steers and bulls (Brinks *et al.*, 1961). Sex effects should therefore, be corrected for in selection programmes involving both sexes.

5.2.2 Year effects

The differences in growth between years were expected and are consistent with many reports in the literature (e.g. Sacker *et al.*, 1971; Trail *et al.*, 1971, Thorpe *et al.*, 1980; Mwandoto, 1988). Yearly differences are usually attributed to random fluctuations in weather conditions and concomitant effects on feed availability. Like with sex effects, it should therefore, be a

standard practice to include yearly effects among the systematic environmental effects that influence growth traits.

5.2.3 Month effects

Monthly effects were not significant for any of the traits studied. This is an interesting result in view of the fact that range conditions do change greatly from rainy to dry months in such a tropical environment. This was a result of taking monthly averages in such a long term study, thus, effects being evened out. However, some slight differences between months in the growth curve are evident in the postweaning phase (Figure 3), an indication of monthly effects. Monthly effects are not likely to be seen in the preweaning phase because the calves are on milk, as shown by the linearity of the growth curve from birth to weaning (Figure 3). Further, evidence of monthly effects was shown when months were defined within year (Figure 5A & B). Thus, this emphasises the need to define months within year or within seasons in order to assess the true picture of monthly effects particularly in the tropics and with long term studies of this nature.

Seasons were not defined in this study because of the big variations between years observed in the meteorological data, especially rainfall (Appendix A). Even when an attempt was made to look at possible seasonal influences on the growth curve by grouping months into season / period of birth and into precalving conditions (Figures 4 A & B), the results were similar to when averages of respective traits for successive months were plotted. This is also quite interesting because of expected seasonal influences in such a tropical environment. This could be partly due to the masked monthly variations in climatic conditions because of the long term nature of this study and the all year-round calving at the station, whereby the monthly/ seasonal influences are evened out. The implications of this result is that seasons should be defined with caution, particularly in long term studies. Further, on the basis of this result, a limited breeding

season as recommended in management of beef improvement programmes (Plasse, 1976), would not be easy to define. However, relatively higher weaning weights are reported in this study during the months of August through November (Appendix B4)), which would imply that it would be better to breed animals to calve in February–April and be weaned August–November. In this case, the calves will benefit from increased milk production of the dams during the rainy months and will also have had ample pastures before the onset of the dry season. Relatively higher weaning weights in this study are found in the months of August through November (Appendix B4).

5.2.4 Parity effects

It is surprising that parity was not significant for birth weight and highly significant for weight at immediate ages. Nevertheless, the result is in agreement with the report of Kassa-Mersha and Arnason (1986) who attributed the lack of significance to the high age of the Boran heifers at first calving in their study. In this case, parity was not recorded as such in these data. It was instead derived by examining birth dates of consecutive calves of each cow. It is possible that, due to mis-recording or missing records, that there was less than perfect match between actual and derived parity class. This may, partially, explain the lack of significance for parity.

It is noteworthy in the present results that there was no pattern of increase in weights with increase in parity number as has been reported by some workers (e.g. Winroth, 1990; Wakhungu *et al.*, 1991; Banjaw and Haile-Mariam, 1994), possibly for the same explanation as with birth weight. However, in general all weights in the first and 7th parities were lower than those born in the other parities. This is in agreement with some reports in literature (e.g. Wilson, 1957; Trail *et al.*, 1971), that with increasing age of dam beyond 7 years (which

influence of maternal effect on birth weight implies that selection for this trait should not be based on birth weight but on subsequent weights to weaning.

In the postweaning phase, heritability estimates were also similar to values reported in literature. The estimates were also consistent across models. Weight at 18 months showed the most consistent heritability estimate across models. This implies that weight at 18 months in this breed could be a good criterion for selection for growth performance since it would also not be affected by maternal influence.

Maternal heritability (h^2_m) estimates from this study (Table 9) are also within the ranges of 0.03-0.85 for birth weight, 0.04-0.49 for weaning weight, 0.02-0.20 for yearling weight reported by Mohuiddin, 1993. The values obtained are also consistent with the literature estimates for birth weight and weaning weights reported for some indigenous tropical breeds (Tawah *et al.*, 1993; Haile Mariam and Kassa-Mersha 1995). However, and contrary to some literature reports on over estimation of direct heritabilities (in particular for growth till weaning) when maternal effects were not included in the model of analysis (e.g. Meyer, 1992; Waldron *et al.*, 1993), this was not evident in this study since the estimates were more or less similar in all models used in this analysis. In this case, it is difficult to speculate whether the low influence of maternal effects observed in this study is a characteristic for the SEAZ in this local environment, or perhaps a result of the relatively small data set used in this study or an incomplete analysis model.

The relatively high estimates of maternal heritability for weights at 3 and 6 months indicate the strong influence of maternal effects during preweaning period. Calves depend entirely on milk in the first few months and gradually develop capacity to utilize roughage. Maternal influence thus wanes off as calves become less and less dependent on milk.

The estimates of direct-maternal genetic correlation (r_{AM}) are in contrast to the consistently moderate and negative estimates reported in literature (e.g. Bertrand and Benyshek, 1987; Johnson *et al.*, 1992), but in agreement with the report of Mackinnon *et al.* (1991) for Zebu crosses in a tropical environment. However, high and negative estimates have been reported in some similar studies among the indigenous tropical breeds when maternal heritability estimates were more or less similar. For example, Tawah *et al.* (1993) reported a correlation of -0.86 and -0.68 in regard to birth and weaning weights respectively, in a study involving the in the Gudali (a Zebu) in Cameroon; Haile-Mariam and Kassa-Mersha (1995) reported a correlation of -0.55 and -0.37 for same traits in a study involving Boran cattle in Ethiopia. In the present study the values were essentially zero. These contrasting reports may indicate that breed differences exist in maternal influence on growth traits, and in magnitude of antagonism between direct additive and maternal additive genetic effects.

5.3.2 Correlations

The genetic correlations among body weights obtained in this study are consistent with literature reports on established beef breeds (see a review by Mohuiddin, 1993). They are also similar to the estimates reported in some indigenous tropical breeds (Iloeje, 1986; Tawonezvi, 1986c). These high and positive correlations among body weights suggest that many of the same genes affect body weights at different ages. This implies that selection for one trait will lead to correlated increase in body weight at all ages. On the other hand, selection for decreased birth weight would mean a correlated decrease in weights of subsequent ages which is also productively undesirable.

The positive and high genetic correlation between birth weight and later weights is undesirable, for increased birth weight has been reported to be the single most important factor affecting calving difficulty (Bellows *et al.*, 1971). The implication of this has been a subject of many studies (e.g Koch *et al.*, 1974; Bourbon and Brinks, 1982) for selection for decreased birth weight would mean a correlated decrease in weights of subsequent ages. Koch *et al.* (1974) suggested selection for gain rather than weight as a means of limiting correlated response in birth weight. However, Bourbon and Brinks (1982) found only a reduction in correlated response in birth weight would be only 9 % when selection was based on gain, which they concluded was not a complete solution. They in turn suggested a form of selection index to optimize both birth weight and subsequent growth. On the other hand, the positive and high genetic correlations among the body weights would be of advantage, in that selection could be done early which would be economical but caution should be taken because of the low repeatability and heritability associated with preweaning traits due to maternal influence.

The pattern observed with the phenotypic correlations i.e. tendency for close weights to have similar estimates and the decreasing order of phenotypic correlations between birth weight and latter weights, was expected because of the common environmental influence which would be associated with adjacent weights.

In general, results of genetic parameters in this study have shown that

- Direct heritability (h^2a) was larger than heritability due to maternal genetic effect (h^2m) for all traits implying that additive direct effects are more important than additive maternal effects and therefore good response can be expected if selection is based on direct effects.

- Birth weight was a highly heritable trait across all models implying that birth weight is more dependent on the calf's genes than on maternal influence.
- Selection should be more effective at 18 months because of the consistent high heritability estimates across models. This would also minimize error due to the effect of maternal influences which are more prevalent during the early stages of growth and their "carryover effects" into the early postweaning phase.
- The correlation between direct and maternal genetic variance was small and close to Zero and therefore little association between them in this breed type. This implies ignoring the maternal effects in a selection programme in this breed would not sway selection for direct effects.
- Genetic correlations among body weights were as expected very high.

5.4 Trends overtime

5.4.1 Phenotypic and environmental trends

It is noteworthy that although the overall trends were positive and highly significant, there were substantial periodic fluctuations in trends over time (Figure 6; Table 13). The initial period (1950-53) was characterized by positive environmental and phenotypic trends which could have resulted from improved management particularly in nutrition and disease control as has been reported by previous workers (Williams and Bunge, 1952; Stobbs, 1966). During the period 1954-56, the phenotypic and environmental trends were negative. The possible explanation for the decline in phenotypic and environmental trends under this period could rest on the impact of climatic conditions. The years 1953 and 1954 received the lowest amount of rainfall during the study period (see appendix A) and this could have had carryover effects to subsequent years. In the subsequent period (1957-66), the rate of change was positive and for all traits. This period also enjoyed relatively high annual rainfall thus, the positive trends were expected. During 1967-69, phenotypic and environmental trends were large and positive only from birth to weight at 15 months (being largest for weights at 3 and 6

months). They were negative and large for subsequent weights up to weight at 30 months. The sharp increase in phenotypic and environmental trends observed in this short period could have been due to management. For example, tendency to graze young animals on better pastures during this period and hence, the comparatively large phenotypic and environmental trends for weights from birth to 15 months.). However, in the later period (1970-72) the trends in phenotypic and environment components exhibited an erratic pattern, being negative to weaning, and positive from weaning to 21 months and then negative to 30 months. These erratic patterns could be attributed to inconsistent management patterns.

5.4.2 Genetic Trends

The negative genetic trends observed in the early phase of the study period (Table 14) were expected as initially the selection programme had put emphasis on milk production rather than growth rates as it was considered that one of the limiting factors to live-weight gain to weaning and early maturity was the low milk production of cows (Wilson, 1957). However, after 1956, emphasis was shifted towards growth rate and beef production (Stobbs, 1966). Further, the herd was increasing in numbers which implies increased variation. Thus, the corresponding positive genetic trends in growth rates in the later phase of the study period. The up-and-down swings in genetic trends may be attributed to the fact that selection was based on phenotypic values and since only natural mating was practised, a genetically inferior bull or loss of a good bull could cause such swings in the trends. This may further be supported by Stobbs's report of 1966 on a bull which grew 29 % faster up to three years than another and yet produced inferior progeny.

Generally there are few comparative studies in the literature which have looked at genetic trends in growth traits at close intervals. Many studies have looked at trends in birth weight,

weaning and/or yearling weight performance. The improvement of 0.30 kg and 0.25 kg per year for weaning and yearling weight (Table 12), respectively due to genetic improvement is in agreement with the estimates reported by Haile-Mariam and Phillipson, (1995) for the respective traits in the Boran herd in Ethiopia in which selection was also based on phenotypic performance. The results from this study are also in agreement with the estimates of genetic trends for birth weight and weaning weight reported by Zhang *et al* (1991) for a Hereford herd in USA maintained in a stressful environment and selected by visual appraisal. Tawah *et al.* (1994) reported similar results for birth weight and weaning weights in the Gudali (a Zebu) in Cameroon. On the other hand, Tawonezvi *et al.* (1986b) reported a higher estimate of genetic trend per year of 0.5 kg, 2.4 kg, 4.2 kg and 3.4 kg for birth weight, 100 days of age, 210 days and 18 months of age respectively in a herd of Nkone (a Sanga) in Zimbabwe. Although, these comparative results need a cautious interpretation, because they are dependent on genetic variances which may differ according to breed and production systems (Robinson, 1996) among other factors, the important result was that a positive genetic improvement was possible in an indigenous breed in a usually stressful tropical environment of Eastern Uganda. This further demonstrates that an opportunity exists for genetic improvement of indigenous cattle and therefore, an encouragement for increased utilisation and conservation of the indigenous breeds.

The average estimate of genetic progress of 0.3 % from this study in all traits and in both sexes conforms to the fact that both sexes were performance tested for the same period as earlier reported by Stobbs (1966) and possibly under same selection pressure on both sexes. On the other hand, these estimates are within the range of -0.11-3.65% for weight gain in beef cattle reported in a review by Mrode (1988) though much lower than the theoretical expectation in annual genetic gain of 2.6% for weight gain (Smith, 1984). It is also in

agreement with the estimated annual genetic progress for weaning weight of 0.2% reported by Haile and Philipson (1995) in a Boran herd in Ethiopia. Although genetic progress may be low as the results of this study have indicated, it is still appreciable considering that selection was based on phenotypic performance rather than breeding values. With improved breeding infrastructure and logistics, which are expected of such programmes but lacking most of the tropics, it is possible to achieve higher gains, especially if feeding and management could be improved. Moreover, breeds such as the Tuli and the Boran have been improved through selection within the indigenous types (Trail, 1985), and it would not be impossible to duplicate these experiences with other breeds in some locations.

The foregone observations notwithstanding, this study has been accomplished bearing in mind the disturbances of the 1970's /1980's that led to the abandonment of the selection scheme and complete destruction of the Serere cattle herd through looting and plundering slaughter of the animals. Had it not been for such socio-political turmoils, perhaps additional data through another 25 years (up to 1996) could have generated the final picture of genetic progress which had begun showing positive trends starting from 1965 (Figure 6).

CHAPTER SIX

Conclusion and recommendations.

The results from this study have shown that selection was effective in improving growth performance and that there is potential for genetic improvement in the SEAZ. However, higher genetic progress could have been possibly achieved if selection was based on estimated breeding values (EBVs) instead of contemporary comparisons. Further, on the basis of the moderately strong heritability estimates for growth traits found in this study particularly for postweaning traits, performance testing should provide a useful means of improving the genetic potential of SEAZ without progeny testing. Efforts could then be concentrated on bull selection. This would also lessen on logistics and infrastructure associated with progeny testing which are often lacking in developing countries. Further, use of AI and/ or MOET instead of natural mating could lead to consistent and faster genetic change.

Of significance, is how the results from this study could be exploited in future breeding programmes of this breed type in view of the fact that this particular herd was lost during the internal political turmoils of the 1970's through the mid 1980's. The results of genetic trends/progress in growth characteristics though appreciable are not impressive. It can be argued that increased growth may not be suitable in such a variable environment because of probable consequences of loss of adaptability and increased feed requirements, but, the small mean weights at 2½ years as found in this study may not have a speedy impact on meat production. There is therefore, need for patience and continued studies to evaluate further this breed type for optimum economic utilization. It would thus, be relevant to study other characteristics of this breed type, especially other traits of economic importance like draught

power, reproduction, survival and later carcass quality. Such a study would further highlight their worth in the existing environment, since breed substitution and/ or crossbreeding for beef may not favour the current animal breeding policy which puts emphasis on increased utilization and conservation of indigenous animal genetic resources (AGR).

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Appendix A1: Monthly rainfall (mm) 1950 – 1972, at Serere Research Station, Uganda

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
1950	15.7	20.8	164.6	182.6	119.6	56.6	159.8	152.9	138.7	81	6.4	19.1	1117.8
1951	20.8	29.5	114.3	206.2	186.2	99.1	157.7	69.6	138.2	196.6	150.4	141	1509.6
1952	2.8	60.2	178.3	209.8	199.1	54.6	135.6	233.7	195.8	105.2	43.4	5.3	1423.8
1953	22.9	0.8	36.6	317.2	89.4	121.2	114.3	76.2	45.2	236.5	84.1	22.4	1166.8
1954	2	24.4	74.4	218.9	367	132.6	76.2	141.7	77.5	71.1	20.3	55.9	1262
1955	80.8	27.4	69.1	186.7	258.6	84.1	88.9	137.9	110	93.9	65.3	104.9	1307.6
1956	22.1	48.5	124.2	288.8	211.1	71.9	100.8	247.9	104.9	166.9	28.7	4.9	1420.7
1957	36.1	58.9	104.9	263.7	184.2	151.9	80.5	154.9	39.1	91.7	84.6	54.1	1304.6
1958	47.2	72.1	91.7	231.1	196.3	96	63	123.4	95.5	110.5	50.3	96.8	1273.9
1959	24.1	44.5	169.9	193.8	144	85.9	104.9	76.7	156.7	175.3	232.4	3.8	1412
1960	20.6	65	144.3	145.5	270.3	55.1	79.2	296.7	182.1	113.8	99.8	27.9	1500.3
1961	5.3	16.8	134.6	150.9	145.3	169.4	177.5	266.2	207.3	144.8	243.1	159.8	1821
1962	26.7	0	221.5	161.8	204.7	121.2	85.9	137.4	151.1	174.8	177.5	2	1464.6
1963	82.6	212.6	123.2	320	150.6	84.1	75.2	285.5	123.2	103.6	233.7	42.2	1836.5
1964	17.8	88.9	82.8	237.2	212.9	88.4	190.2	84.1	158.8	232.2	41.7	63.8	1498.8
1965	0.8	30	135.4	116.1	155.7	85.1	89.2	112.3	49.3	242.6	121.2	88.4	1226.1
1966	64.3	147.1	163.6	339.6	145.8	66.5	93.7	113.8	184.9	286.5	71.1	12.2	1689.1
1967	2.8	11.2	116.1	214.4	92.5	134.6	120.4	139.4	95.3	189.2	154.7	9.7	1280.3
1968	1.3	118.6	104.6	354.8	189	83.6	100.1	146.3	89.2	228.9	77.2	92.5	1586.1
1969	51.8	114.8	79.5	116.1	228.1	47.8	124.7	55.6	70.1	191.8	153.7	84.6	1318.6
1970	53.8	35.1	151.3	228.2	199	57.7	94.3	273.7	113.1	92.8	94	66	1459
1971	6.1	8.1	36.7	232.5	190.3	65	95	199.1	168.5	82.2	131.2	10.5	1225.2
1972	38.1	84.5	86.1	126.6	177.5	102.8	73.5	130.9	220.2	270.8	291.3	104.9	1707.2
Average	28.1	57.3	117.7	219.2	187.7	91.9	107.8	158.9	126.7	160.1	115.4	55.3	

Appendix A2: Monthly maximum temperature °C 1954 – 1974, at Serere Research Station, Uganda

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1954	32.7	33.9	33.4	29.2	28.4	27.6	26.6	27.7	28.2	30.2	31.5	30.9
1955	32.6	31.2	32.6	30.2	28.6	28.9	27.6	26.4	27.3	28.9	29.6	29.6
1956	30.1	31.4	31.9	28.8	28.2	27.6	26.9	27.4	28.6	29.2	30.6	31.4
1957	31.3	30.8	29.7	28.6	28.1	28	28.2	28.3	31	31.5	30.4	31.2
1958	33.2	32.1	32.6	30.6	29.2	27.7	26.5	28	29.6	30.3	32.7	31.7
1959	32	32	31	30.4	29.2	29.1	27.7	28.2	29	29.1	29.5	31.7
1960	31.4	32.1	29.7	29.5	28.6	29.4	27.6	28.5	28.9	29.7	30.4	32.1
1961	33.5	31.6	31.6	29.4	28.9	28.1	26.4	27	27.7	27.7	26.6	28.1
1962	29.9	32.4	30.6	29.4	28.1	28.3	27.9	27.7	28.5	28.8	29.7	30.5
1963	29.9	29.6	30.3	28.8	28.6	28.2	21.8	28.2	29.7	30.3	26.4	28.3
1964	31.6	30.8	31.2	28.8	28.7	27.7	26.7	26.9	27.6	28.2	30.5	29.2
1965	31.6	32.2	30.9	29.2	29	29.1	28.3	28.4	29.2	28.7	29.5	30.5
1966	32.2	30.1	29.6	28.6	30	28.6	28.1	28.5	29.1	29.3	29.7	31.5
1967	33.1	33.1	32.1	28.8	28.2	27.6	26.9	27.6	28.7	28.3	27.9	29.8
1968	32	29.8	28.4	27.8	28	27.6	26.8	27.7	29	29.4	29.2	29.2
1969	29.9	29.7	30.2	30.8	28.7	28.8	27.8	28.5	29.1	29.7	29.9	30.9
1970	29.7	32.1	29.9	29.2	28.6	28.3	27.9	27.2	28.5	29.1	30.1	30
1971	31.1	32.8	33.3	28.7	27.9	27.1	27.3	27.4	28.2	28.6	29.2	29.8
1972	31.8	29.5	30.8	30.1	28.4	27.3	27.9	28.2	29	28.4	28.4	29.9
1973	30.6	32.4	33.6	30.9	28.6	27.9	27.4	27.6	28.1	29.2	28.7	30.4
1974	31.1	33.2	30.6	28.8	27.2	27.9	26.3	27.6	28.5	29.5	29.4	31.6
Average	31.4	31.5	31.1	29.3	28.5	28.1	27.0	27.7	28.7	29.2	29.5	30.3

Appendix A3: Monthly minimum temperature °C 1954 – 1974, at Serere Research Station, Uganda

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1954	18	18.9	19.5	18.5	17.6	17.7	17	17.1	17.2	18.6	21.8	18
1955	18.3	18.3	18.8	18.3	17.4	17.8	17.1	17.3	17.3	18.2	18.2	18.1
1956	17.9	18.3	18.5	18.4	18.1	17.6	17.2	17.6	17.8	17.7	18.5	18.2
1957	18.1	18.6	17.6	18.6	18.5	18.3	18	18.2	18.2	18.9	18.7	18.9
1958	20	19.3	19.5		18.9	18.3	18	17.7	17.8	18.3	19	19.2
1959	19.1	19.1	19	18.8	18.8	18.2	17.7	17.7	17.7	18.2	18.2	18.3
1960	18.6	18.7	18.3	18.5	18.2	18	17.6	18	17.8	18.5	18.2	18.7
1961	19.2	18.6	19.1	19	18.7	18.1	17.5	17.8	17.6	17.9	17.9	17.6
1962	17.6	18.6	18.2	18.2	18	17.7	17.7	17.7	17.6	18.2	18.3	18.2
1963	17.8	17.9	17.8	18.3	18.3	17.8	17.8	17.8	17.6	17.4	17.9	18.1
1964	18.4	18.5	19	18.6	18.4	17.8	17.6	17.4	17.7	17.5	18.1	17.4
1965	18.1	18.2	18.3	18.1	18	18.1	18	17.8	17.8	18	18.3	18.1
1966	18.5	18.5	18.3	18.4	18.6	17.9	17.6	17.4	17.3	17.7	18	17.9
1967	18	18.7	18.9	18.3	17.9	17.6	17.4	17.3	17	18.3	17.6	17.4
1968	17.6	18.7	17.8	18	18	17.6	17.6	18.3	17.9	18.2	18.4	17.8
1969	18.2	18.7	19.1	19.4	17.7	18.2	17.9	17.8	18.3	17.9	18.4	18.2
1970	18.3	19.1	18.8	18.6	17.2	18.2	17.6	17.7	17.7	18.3	18.3	17.8
1971	18	17.9	18.4	17.6	17.5	17.1	16.7	16.5	16.6	17	16.8	16.6
1972	17.6	17.4	17.6	18.1	17.6	17.1	17.5	17.1	18.3	18	17.2	16.8
1973	17	18.6	18.8	18.1	17.7	17.4	17.3	17.1	16.7	17.3	17.1	16.6
1974	16.8	18.2	18.3	17.2	17.3	17	16.2	16.6	16.5	17	17.2	16.9
Average	18.1	18.5	18.5	17.4	18.0	17.7	17	17.5	17.5	17.9	18.1	17.8

Appendix A4. Relative humidity (%) 1960 – 1974, at Serere Research Station, Uganda

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average
1960	76	73	80	84	82	77	85	82	78	73	74	65	77.4
1961	61	73	73	82	83	81	87	82	83	83	87	83	79.8
1962	72	62	79	79	84	82	85	86	85	80	75	76	78.7
1963	82	77	80	85	85	83	85	85	78	75	86	81	81.8
1964	67	78	82	85	81	78	80	88	87	82	74	77	79.9
1965	65	78	81	85	81	78	80	80	79	81	79	65	77.6
1966	69	78	82	84	79	81	85	80	83	80	76	70	78.9
1967	64	68	77	85	85	83	88	86	80	82	83	74	79.5
1968	72	87	87	85	89	85	86	83	78	76	73	77	81.5
1969	78	81	76	80	86	79	83	78	75	75	76	77	78.6
1970	81	77	83	83	85	81	83	86	80	76	74	70	79.9
1971	61	72	67	84	83	84	83	83	81	78	71	65	76
1972	76	79	76	79	83	86	86	83	79	81	82	76	80.5
1973	80	70	78	85	65	75	79	85	88	79	68	89	78.4
1974	73	77	81	61	83	85	81	76	75	70	74	76	76
Average	71.8	75.3	78.8	81.7	82.2	81.2	83.7	82.8	80.6	78.0	76.8	74.7	

**Appendix B - LEAST SQUARE MEANS FOR MONTH
WITHIN YEAR CLASS**

Appendix B1: Birth weight

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	17.29(1.80)	-	-	16.68(2.22)	16.54(1.2)	16.33(1.12)	16.29(1.29)	16.93(3.13)	15.70(1.19)	16.35(2.22)	17.10(1.57)	22.13(3.13)
1951	13.76(3.13)	16.92(1.57)	18.29(3.13)	20.77(3.13)	17.18(1.1)	16.84(1.29)	16.33(1.41)	14.11(1.81)	15.69(1.40)	17.37(1.81)	16.97(1.41)	19.91(1.57)
1952	17.94(1.57)	17.48(2.21)	12.59(3.13)	15.95(1.81)	15.81(0.9)	16.02(1.28)	14.33(1.19)	16.09(1.28)	14.87(2.22)	14.55(1.57)	16.43(1.19)	14.53(2.21)
1953	16.57(1.19)	17.12(3.13)	-	16.14(1.41)	17.38(1.2)	15.79(3.13)	17.84(1.57)	18.26(2.22)	19.30(2.21)	17.27(2.21)	17.18(1.00)	16.80(1.57)
1954	17.79(1.29)	15.95(1.81)	16.62(1.19)	17.57(2.22)	15.67(1.8)	17.94(2.22)	15.57(3.13)	13.82(2.21)	12.72(1.81)	17.33(1.19)	16.61(1.05)	16.55(1.28)
1955	19.53(1.57)	16.85(1.57)	16.91(1.40)	17.92(1.41)	18.93(1.4)	18.03(1.81)	15.25(1.57)	18.96(1.81)	18.04(1.40)	17.19(1.19)	17.53(1.11)	18.08(1.40)
1956	18.27(1.28)	19.28(1.19)	16.33(1.05)	17.14(1.40)	13.97(2.2)	14.59(1.05)	16.33(1.28)	17.59(3.13)	18.04(1.28)	-	17.90(1.40)	17.45(1.28)
1957	15.03(0.99)	16.74(1.28)	16.43(1.57)	18.67(1.40)	14.68(3.1)	13.99(1.81)	16.19(2.22)	16.52(1.57)	15.23(1.81)	17.12(1.41)	16.28(1.81)	15.68(1.1)
1958	14.58(1.57)	17.57(3.13)	16.01(2.22)	20.42(1.41)	20.49(3.1)	16.05(1.57)	17.78(2.22)	15.12(3.13)	14.71(1.28)	18.08(1.81)	17.45(1.41)	18.15(1.28)
1959	18.08(1.19)	18.99(1.58)	19.63(1.81)	18.28(1.81)	19.07(1.1)	21.65(2.22)	15.32(3.13)	15.90(2.22)	18.29(1.81)	14.76(2.22)	17.37(1.81)	17.30(1.19)
1960	16.55(2.22)	17.62(1.81)	19.25(1.28)	17.25(1.05)	17.39(1.1)	18.75(1.57)	15.32(3.13)	15.68(2.22)	17.39(3.13)	17.90(2.22)	17.48(1.57)	12.38(1.81)
1961	17.39(3.13)	-	15.47(1.81)	18.42(1.28)	20.94(3.1)	18.03(3.13)	22.48(2.22)	19.55(1.81)	17.49(2.22)	-	18.95(3.13)	15.90(2.21)
1962	15.35(2.22)	-	21.01(2.22)	21.86(1.40)	20.39(1.5)	20.40(2.21)	16.68(3.13)	15.40(1.81)	21.08(1.40)	18.04(3.13)	21.22(1.81)	20.31(2.22)
1963	17.99(1.19)	15.67(2.22)	17.99(1.28)	16.38(1.40)	18.43(1.1)	23.69(1.57)	19.20(3.13)	20.56(1.81)	19.57(1.19)	16.07(1.28)	18.06(2.22)	20.83(1.57)
1964	18.95(2.22)	20.23(0.95)	18.95(1.28)	19.36(0.88)	19.99(1.1)	19.15(0.19)	18.07(0.78)	20.27(0.91)	20.01(1.18)	20.32(1.28)	19.32(1.40)	22.93(1.28)
1965	20.48(1.18)	18.21(1.28)	18.24(0.84)	18.20(1.19)	18.82(0.8)	18.49(0.95)	17.74(1.28)	20.09(1.12)	24.33(1.57)	20.37(1.05)	19.72(1.57)	18.51(1.29)
1966	17.55(2.22)	23.51(2.22)	21.01(1.11)	22.00(0.87)	19.94(0.9)	18.31(1.28)	17.01(1.81)	19.35(1.57)	21.09(1.40)	21.18(1.40)	20.26(1.40)	20.88(1.00)
1967	19.26(0.79)	20.93(1.05)	22.81(3.13)	22.15(1.81)	22.07(0.7)	21.22(0.99)	20.39(0.75)	20.00(1.28)	22.96(1.40)	20.00(1.81)	21.25(1.19)	21.49(0.99)
1968	22.12(1.57)	19.65(0.99)	22.10(1.11)	24.59(1.41)	21.65(0.7)	21.34(0.85)	21.46(0.87)	20.81(1.00)	22.37(1.41)	22.12(1.19)	20.58(0.99)	23.48(1.40)
1969	22.57(0.99)	21.02(1.40)	20.90(2.21)	24.02(1.40)	21.27(1.1)	22.33(1.19)	22.82(1.40)	23.83(0.95)	25.00(1.57)	25.38(1.81)	24.98(0.91)	22.82(0.99)
1970	24.11(0.79)	22.40(1.18)	26.51(1.40)	20.26(1.57)	24.06(1.8)	22.28(1.04)	23.54(1.11)	24.18(1.28)	24.98(1.18)	18.63(2.21)	23.22(1.00)	21.35(1.28)
1971	23.99(0.81)	20.87(1.28)	22.02(1.40)	22.13(1.41)	24.44(1.8)	24.01(2.22)	23.79(1.19)	22.33(1.40)	21.88(0.87)	20.16(1.81)	21.24(1.11)	21.99(1.28)
1972	24.04(1.57)	21.32(1.57)	18.48(2.22)	24.38(1.81)	22.06(1.4)	20.77(1.81)	23.68(1.40)	19.13(2.22)	-	26.31(1.81)	20.71(1.57)	21.98(1.00)

Appendix B2: Weight at 3 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	41.54(6.03)	-	-	46.23(7.37)	41.36(4.28)	44.25(3.72)	43.58(4.29)	50.67(10.40)	39.81(3.97)	43.46(7.36)	46.27(5.23)	51.22(10.40)
1951	54.75(10.4)	51.96(5.23)	70.63(10.40)	50.76(10.40)	51.44(4.68)	45.83(4.28)	46.79(4.68)	49.54(6.03)	48.96(4.67)	55.99(6.01)	56.11(4.28)	67.47(5.22)
1952	63.28(5.22)	58.60(7.35)	32.97(10.40)	60.51(4.67)	61.86(3.17)	57.03(3.96)	53.73(3.95)	51.32(4.27)	48.55(7.36)	51.94(5.22)	62.20(3.96)	54.29(7.35)
1953	59.91(3.95)	76.52(10.40)	-	52.28(4.68)	66.96(4.27)	52.78(10.41)	60.58(5.22)	65.40(7.37)	68.13(7.35)	47.64(7.36)	54.69(3.32)	62.14(5.22)
1954	55.03(4.27)	54.73(6.02)	53.44(3.95)	65.38(7.37)	60.80(6.02)	52.13(10.40)	40.69(10.40)	69.76(7.36)	48.02(6.01)	55.29(3.95)	56.67(3.49)	59.56(4.27)
1955	71.52(5.22)	54.02(5.21)	56.67(4.66)	48.69(4.69)	58.80(4.66)	54.34(6.02)	64.92(5.21)	60.46(6.02)	50.29(4.66)	51.98(4.27)	58.38(3.70)	55.57(4.67)
1956	53.02(4.27)	47.54(3.97)	51.99(3.49)	47.11(4.66)	43.76(7.37)	40.50(3.48)	37.99(4.25)	34.44(10.40)	33.91(4.27)	38.68(4.67)	-	39.09(4.27)
1957	38.30(3.31)	41.19(4.27)	42.07(5.20)	44.51(4.65)	44.52(10.41)	34.86(6.01)	35.79(7.37)	47.76(5.20)	40.95(6.01)	44.02(4.70)	34.06(6.01)	35.56(3.70)
1958	30.19(5.23)	46.13(10.40)	41.38(7.38)	49.99(4.68)	65.17(10.43)	47.16(5.22)	50.09(7.36)	61.10(10.40)	45.86(4.25)	46.33(6.02)	45.99(4.67)	42.61(4.26)
1959	47.72(3.95)	47.46(5.25)	47.49(6.02)	50.19(6.02)	46.99(3.69)	52.88(7.37)	37.16(10.40)	51.34(7.39)	48.93(6.02)	47.66(7.39)	42.23(6.01)	45.23(3.96)
1960	32.08(7.38)	42.94(6.03)	44.69(4.26)	43.24(3.49)	48.26(3.70)	42.30(5.21)	48.95(10.40)	49.53(7.39)	51.58(10.40)	44.76(7.36)	46.38(5.22)	38.22(6.01)
1961	43.86(10.40)	-	44.38(6.02)	53.72(4.27)	67.89(10.43)	52.93(10.40)	60.70(7.36)	54.51(6.02)	58.20(7.36)	-	48.95(10.4)	46.91(7.36)
1962	42.78(7.36)	-	64.22(7.36)	48.01(4.66)	50.24(5.21)	48.44(7.36)	48.95(10.40)	56.71(6.02)	60.03(4.66)	53.49(10.40)	66.49(6.03)	59.78(7.39)
1963	48.10(3.95)	54.80(7.36)	63.91(4.24)	59.21(4.67)	53.09(3.94)	67.98(5.21)	58.38(10.40)	52.23(6.02)	58.94(3.95)	48.47(4.25)	59.46(7.36)	51.70(5.22)
1964	52.98(7.39)	55.97(3.17)	52.36(4.26)	51.63(2.93)	57.82(3.69)	49.48(3.03)	48.44(2.59)	54.44(3.02)	50.90(3.94)	53.39(4.26)	46.60(4.67)	53.59(4.26)
1965	54.96(3.93)	49.64(4.26)	53.90(2.80)	49.41(3.95)	46.68(2.91)	51.76(3.17)	51.51(4.26)	56.13(3.71)	54.63(5.22)	54.73(3.48)	55.90(5.22)	59.36(4.27)
1966	52.12(7.37)	58.98(7.38)	58.42(3.70)	54.66(2.91)	50.91(3.16)	51.74(4.27)	50.25(3.93)	52.10(5.21)	61.18(4.66)	59.55(4.67)	57.48(4.66)	52.03(3.49)
1967	53.10(2.63)	66.03(3.49)	66.44(10.40)	62.14(6.02)	61.99(2.48)	67.02(3.31)	71.91(2.49)	78.95(4.25)	83.98(4.67)	77.91(6.01)	72.00(3.95)	78.69(3.31)
1968	84.48(5.21)	74.80(3.31)	81.35(3.70)	79.89(4.68)	75.25(2.61)	73.75(2.82)	74.02(2.91)	67.98(3.31)	71.85(4.69)	76.75(3.94)	60.11(3.31)	38.97(4.66)
1969	73.46(3.30)	77.04(4.66)	72.37(7.36)	75.81(4.66)	77.47(3.69)	80.45(3.95)	85.89(4.67)	89.06(3.15)	77.11(5.21)	83.69(6.02)	87.00(3.01)	83.41(3.30)
1970	82.06(2.64)	82.14(3.94)	80.50(4.66)	80.43(5.22)	88.00(6.01)	73.80(3.47)	78.72(3.70)	74.11(4.26)	83.13(3.94)	54.45(7.36)	72.77(3.32)	71.54(4.26)
1971	71.30(2.70)	82.99(4.26)	72.65(4.67)	77.36(4.68)	79.73(6.01)	74.97(7.37)	72.93(3.95)	75.53(4.67)	74.22(2.90)	82.25(6.02)	68.24(3.70)	74.74(4.25)
1972	72.09(5.21)	66.63(5.22)	73.34(7.38)	78.21(6.02)	72.08(4.67)	86.03(6.02)	82.66(4.66)	87.22(7.37)	-	91.66(6.01)	75.49(5.21)	66.42(3.32)

Appendix B3: Weight at 6 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	64.62(8.77)	-	-	62.20(10.7)	59.28(6.23)	64.51(5.41)	65.79(6.23)	83.83(15.12)	64.24(5.78)	79.82(10.71)	84.21(7.60)	69.92(15.12)
1951	88.82(15.12)	74.15(7.60)	85.65(15.12)	83.07(15.1)	76.34(6.80)	71.52(6.23)	76.04(6.81)	82.68(8.77)	75.43(6.79)	97.04(8.74)	91.39(6.22)	105.30(7.59)
1952	97.36(7.58)	84.06(10.6)	43.92(15.12)	91.69(6.79)	83.95(4.61)	83.99(5.75)	82.46(5.74)	84.50(6.20)	87.44(10.71)	86.47(7.59)	102.55(5.76)	84.97(10.69)
1953	95.88(5.75)	110.15(15.12)	-	82.08(6.80)	97.25(6.21)	84.24(15.13)	87.57(7.59)	100.20(10.7)	107.87(10.7)	73.83(10.69)	90.32(4.82)	96.79(7.59)
1954	81.61(6.22)	89.15(8.75)	78.85(5.74)	97.41(10.7)	83.27(8.75)	85.27(10.71)	63.42(15.12)	107.98(10.7)	82.46(8.74)	94.64(5.74)	95.79(5.07)	89.05(6.21)
1955	95.76(7.58)	75.81(7.58)	85.43(7.58)	72.87(6.81)	91.67(6.77)	84.53(8.76)	100.58(7.58)	83.94(8.75)	83.05(6.78)	80.51(5.75)	90.13(5.38)	87.44(6.79)
1956	85.61(6.20)	79.50(5.77)	77.64(5.07)	67.70(6.78)	62.83(10.7)	59.53(5.06)	53.86(6.18)	42.25(15.12)	44.75(6.20)	63.29(6.79)	-	61.89(6.21)
1957	60.32(4.81)	70.48(6.21)	69.85(7.57)	70.69(6.77)	74.57(15.1)	57.38(8.74)	67.46(10.71)	76.87(7.57)	68.59(8.74)	71.95(6.83)	58.51(8.74)	62.24(5.38)
1958	54.91(7.61)	63.88(15.1)	66.03(10.73)	77.00(6.80)	94.34(15.1)	69.80(7.58)	74.29(10.71)	96.99(15.22)	72.99(6.18)	77.65(8.75)	78.47(6.80)	67.29(6.20)
1959	78.98(5.74)	68.40(7.63)	76.12(8.75)	78.11(8.75)	73.69(5.37)	88.56(10.71)	66.29(15.12)	80.18(10.74)	75.56(8.79)	81.02(10.74)	69.22(8.74)	75.19(5.76)
1960	58.32(10.73)	73.56(8.76)	67.69(6.19)	67.91(5.08)	76.12(5.39)	72.94(7.58)	78.99(15.12)	72.47(10.74)	76.57(15.12)	70.04(10.70)	75.59(7.58)	78.83(8.74)
1961	79.30(15.12)	-	76.22(8.76)	89.63(6.21)	87.99(15.1)	74.76(15.12)	96.38(10.71)	85.90(8.76)	93.20(10.71)	-	80.35(15.12)	83.29(10.70)
1962	70.28(10.70)	-	96.01(10.70)	83.16(6.78)	82.67(7.57)	83.94(10.70)	73.54(15.12)	85.65(8.75)	93.58(6.78)	92.60(15.12)	104.69(8.77)	96.36(10.75)
1963	77.39(5.75)	90.94(10.7)	96.51(6.17)	89.77(6.78)	79.32(5.73)	96.67(7.58)	85.65(15.12)	76.70(8.75)	89.14(5.75)	72.11(6.18)	85.12(10.70)	85.25(7.59)
1964	81.16(10.75)	89.03(4.61)	78.18(6.19)	77.86(4.26)	88.20(5.37)	77.70(4.41)	73.52(3.76)	80.05(4.39)	76.87(5.73)	80.08(6.19)	73.88(6.79)	84.66(6.20)
1965	86.80(5.72)	81.60(6.19)	86.93(4.07)	85.29(5.75)	82.52(4.24)	89.61(4.61)	77.48(6.19)	84.97(5.40)	84.63(7.59)	85.67(5.07)	86.15(7.59)	91.15(6.22)
1966	78.57(10.71)	85.06(10.7)	83.44(5.37)	82.72(4.22)	74.56(4.60)	80.38(6.21)	80.20(5.72)	80.10(7.58)	86.95(6.78)	93.29(6.79)	95.34(6.77)	87.61(5.08)
1967	87.75(3.83)	98.20(5.07)	92.76(15.12)	100.48(7.5)	109.26(3.6)	117.81(4.81)	113.38(3.62)	117.65(6.18)	123.12(6.79)	128.96(8.74)	117.57(5.75)	125.68(4.81)
1968	125.04(7.58)	112.64(4.8)	125.80(5.38)	127.71(6.8)	120.17(3.7)	117.99(4.09)	123.14(4.23)	112.55(4.82)	121.81(6.81)	129.67(5.73)	101.67(4.81)	75.35(6.78)
1969	128.0(4.80)	132.51(6.7)	124.86(10.6)	132.78(6.7)	126.48(5.3)	134.50(5.7)	145.74(6.7)	138.06(4.59)	127.43(7.58)	131.70(8.75)	141.36(4.38)	137.69(4.80)
1970	132.36(3.8)	129.70(5.7)	128.59(6.78)	123.60(7.5)	130.33(8.7)	117.00(5.0)	122.41(5.3)	118.54(6.19)	119.33(5.73)	72.70(10.69)	112.64(4.83)	116.23(6.20)
1971	119.85(3.9)	122.80(6.1)	100.81(6.79)	112.41(6.8)	118.76(8.7)	110.3(10.7)	112.35(5.7)	104.05(6.79)	101.90(4.22)	118.64(8.75)	111.70(5.38)	122.65(6.18)
1972	110.73(7.5)	113.95(7.5)	121.94(10.7)	121.53(8.7)	122.27(6.8)	119.40(8.7)	130.18(6.7)	100.05(10.7)	-	108.78(8.74)	120.31(7.57)	118.87(4.83)

Appendix B5: Weight at 12 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	94.57(11.76)	-	-	85.20(14.37)	93.92(8.35)	106.78(7.26)	91.31(8.36)	113.40(20.27)	90.25(8.36)	113.13(14.35)	115.76(10.19)	77.94(20.2)
1951	104.78(20.27)	99.75(10.19)	95.71(20.27)	127.38(20.27)	105.17(9.12)	105.78(8.35)	105.09(9.13)	125.58(11.76)	99.82(9.11)	125.73(11.73)	124.11(8.34)	129.20(10.1)
1952	127.64(10.17)	123.32(14.34)	72.91(20.28)	121.41(9.10)	131.76(6.18)	131.74(7.72)	129.03(7.70)	127.19(8.32)	141.54(14.35)	106.42(10.17)	128.73(7.72)	128.54(14.3)
1953	141.64(7.71)	127.79(20.28)	-	128.38(9.12)	138.79(8.32)	123.54(20.2)	118.64(10.18)	156.92(14.36)	135.34(14.34)	112.35(14.34)	122.29(6.47)	122.35(10.1)
1954	110.07(8.33)	113.67(11.74)	113.83(7.69)	125.83(14.36)	143.77(11.73)	112.68(14.3)	113.85(20.27)	130.57(14.35)	108.83(11.72)	120.94(8.30)	116.08(6.8)	109.25(8.3)
1955	120.57(10.17)	104.83(10.17)	102.15(9.09)	102.67(9.13)	130.74(9.08)	108.75(11.7)	122.80(10.17)	142.22(11.73)	99.50(9.09)	92.02(7.71)	93.25(7.21)	103.00(9.1)
1956	82.66(8.32)	86.31(7.74)	91.82(6.81)	85.00(9.09)	105.87(14.38)	99.70(6.79)	90.78(8.29)	82.48(20.27)	90.78(8.32)	107.68(9.10)	-	116.70(8.3)
1957	107.33(6.45)	121.17(8.33)	105.30(10.14)	110.79(9.08)	104.57(20.29)	105.38(11.7)	115.11(14.36)	114.86(10.15)	100.47(11.72)	111.71(9.16)	90.79(11.7)	87.30(7.22)
1958	91.41(10.20)	83.80(20.28)	103.26(14.39)	115.11(9.12)	150.09(20.32)	98.11(10.17)	109.56(14.36)	122.02(20.27)	95.68(8.29)	112.08(11.73)	114.40(9.1)	102.38(8.3)
1959	124.25(7.70)	101.73(10.23)	121.33(11.73)	110.56(11.74)	107.62(7.19)	128.32(14.3)	105.16(20.27)	114.87(14.40)	116.20(11.74)	120.29(14.40)	113.64(11.7)	109.33(7.7)
1960	93.45(14.38)	100.33(11.75)	94.05(8.30)	97.78(6.81)	103.20(7.22)	117.09(10.1)	110.15(20.27)	101.03(14.40)	123.83(20.27)	118.76(14.35)	123.90(10.1)	113.87(11.7)
1961	122.02(20.27)	-	118.60(11.74)	129.36(8.33)	122.88(20.32)	132.33(20.2)	147.83(14.35)	140.98(11.74)	143.30(14.35)	-	128.29(20.2)	142.94(14.3)
1962	118.04(14.35)	-	149.89(14.35)	136.79(9.09)	121.55(10.15)	125.36(14.3)	125.12(20.27)	131.77(11.73)	136.57(9.10)	134.19(20.27)	150.21(11.7)	136.37(14.4)
1963	119.15(7.71)	146.47(14.35)	147.22(8.28)	130.51(9.10)	134.89(7.69)	152.93(10.1)	129.28(20.27)	133.62(11.74)	136.86(7.71)	121.03(8.29)	133.79(14.3)	133.47(10.1)
1964	127.98(14.41)	127.76(6.18)	117.64(8.31)	110.09(5.71)	128.02(7.20)	121.86(5.92)	116.78(5.04)	131.03(5.89)	121.47(7.68)	126.06(8.30)	131.84(9.1)	143.32(8.3)
1965	136.97(7.67)	134.42(8.30)	133.39(5.46)	129.41(7.71)	125.62(5.68)	132.09(6.18)	108.34(8.30)	135.01(7.24)	126.35(10.18)	122.63(6.80)	128.58(10.1)	126.90(8.3)
1966	130.99(14.36)	127.87(14.38)	116.42(7.21)	123.98(5.67)	118.26(6.16)	122.75(8.33)	133.71(7.67)	135.99(10.16)	152.42(9.09)	138.59(9.10)	143.62(9.0)	144.77(6.8)
1967	148.57(5.13)	148.76(6.80)	151.91(20.28)	159.03(11.74)	157.36(4.84)	152.76(6.45)	155.36(4.86)	166.75(8.29)	163.89(9.10)	172.02(11.73)	149.39(7.7)	169.24(6.4)
1968	161.94(10.16)	156.69(6.46)	164.72(7.22)	188.41(9.12)	174.46(5.08)	165.25(5.49)	172.51(5.67)	170.36(6.46)	172.57(9.14)	181.86(7.69)	142.51(6.4)	95.60(9.09)
1969	179.67(6.43)	164.57(9.08)	158.39(14.34)	186.81(9.09)	170.69(7.19)	176.44(7.07)	182.10(9.10)	172.10(6.15)	177.61(10.16)	177.36(11.73)	179.65(5.8)	173.87(6.4)
1970	158.71(5.15)	149.81(7.68)	165.16(9.09)	143.84(10.18)	135.68(11.72)	142.14(6.76)	155.81(7.22)	146.00(8.30)	152.73(7.69)	123.01(14.34)	152.89(6.4)	148.96(8.3)
1971	155.37(5.27)	149.04(8.30)	129.57(9.11)	143.76(9.13)	149.05(11.73)	151.15(14.37)	152.19(7.71)	168.52(9.10)	149.12(5.66)	168.12(11.73)	149.16(7.2)	183.01(8.2)
1972	134.53(10.16)	140.53(10.18)	170.66(14.3)	161.22(11.75)	157.77(9.11)	144.69(11.73)	168.09(9.10)	148.66(14.36)	-	149.89(11.72)	161.39(10.1)	150.30(6.4)

Appendix B6: Weight at 15 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	108.08(12.20)	-	-	95.76(14.90)	103.89(9.47)	116.24(7.53)	106.82(9.49)	125.51(21.03)	111.43(8.04)	136.15(14.89)	130.33(12.18)	97.34(21.03)
1951	97.84(21.03)	110.18(10.57)	122.33(21.03)	150.87(21.03)	116.78(10.56)	117.02(8.66)	114.12(9.47)	146.99(12.20)	116.48(9.45)	141.11(12.16)	136.72(8.65)	138.38(10.55)
1952	136.19(10.55)	133.29(14.87)	86.18(21.04)	142.60(9.44)	146.31(6.41)	150.25(9.44)	142.39(7.99)	141.47(8.63)	162.77(14.89)	131.46(10.55)	147.65(8.01)	133.97(14.87)
1953	156.20(7.99)	171.91(21.04)	-	149.94(9.47)	152.75(8.63)	135.48(21.05)	128.91(10.56)	172.55(14.89)	150.98(14.87)	141.38(14.87)	141.65(6.71)	139.24(10.56)
1954	128.80(8.65)	134.05(12.17)	130.18(7.98)	150.19(14.90)	150.64(12.17)	130.25(14.89)	134.58(21.03)	153.26(14.88)	127.59(12.16)	132.53(7.98)	139.52(7.06)	118.92(9.44)
1955	139.67(10.55)	122.52(12.17)	124.24(9.43)	120.03(9.48)	144.08(9.42)	107.14(12.18)	126.12(10.55)	118.20(12.17)	103.61(9.42)	96.99(8.00)	91.01(7.48)	98.68(9.44)
1956	82.88(8.63)	99.73(8.03)	101.71(7.06)	92.87(9.43)	101.64(14.91)	105.36(7.04)	92.85(8.60)	89.18(21.03)	97.40(8.63)	119.32(9.44)	-	126.98(6.64)
1957	116.23(6.69)	131.98(8.64)	123.95(10.52)	127.3(9.41)	108.76(21.05)	107.20(12.16)	115.36(14.89)	125.04(10.53)	115.67(12.16)	126.18(9.50)	102.02(12.15)	96.88(7.49)
1958	102.86(10.58)	94.80(21.04)	118.37(14.93)	120.66(9.46)	152.01(21.08)	104.97(10.55)	122.66(14.89)	127.32(21.03)	116.50(8.60)	131.16(12.17)	132.44(9.45)	114.57(8.62)
1959	131.47(7.98)	117.77(10.61)	135.43(12.17)	131.54(12.18)	116.82(7.46)	145.88(14.90)	132.27(21.03)	134.43(14.94)	132.13(12.18)	138.14(14.94)	122.67(12.16)	118.80(8.01)
1960	100.52(14.92)	113.48(12.19)	113.20(8.61)	114.09(7.07)	123.65(8.00)	136.45(10.54)	130.91(21.03)	111.97(14.94)	146.83(21.03)	129.08(14.88)	144.47(10.55)	135.23(12.15)
1961	141.38(21.03)	-	135.20(12.18)	144.52(8.64)	137.04(21.08)	161.03(12.04)	166.31(14.89)	162.12(12.18)	159.28(14.89)	-	150.87(21.03)	165.97(14.88)
1962	136.27(14.89)	-	162.11(14.88)	163.64(9.43)	145.50(10.53)	150.76(14.88)	141.80(21.03)	143.89(12.17)	155.41(10.53)	151.32(21.03)	166.14(12.20)	151.87(14.95)
1963	140.35(7.99)	171.75(14.89)	177.57(8.58)	162.37(9.44)	158.50(7.97)	164.93(10.54)	148.64(21.03)	156.05(12.17)	165.03(7.99)	147.16(8.60)	161.20(14.88)	152.25(10.55)
1964	142.34(14.95)	143.09(6.41)	141.54(8.62)	134.85(5.92)	153.62(7.47)	145.71(6.14)	137.02(5.23)	154.17(6.11)	147.30(7.97)	153.57(8.61)	155.22(9.45)	164.34(8.62)
1965	151.95(7.96)	153.07(8.61)	157.27(5.66)	148.46(7.99)	144.18(5.90)	144.66(6.41)	123.74(8.61)	148.74(7.51)	145.46(10.56)	137.11(7.05)	139.92(10.55)	135.03(8.65)
1966	150.74(14.89)	140.66(14.92)	145.34(7.48)	153.20(5.88)	141.51(6.39)	148.07(8.64)	157.91(7.96)	154.70(10.54)	172.08(9.43)	167.92(9.44)	156.69(9.42)	158.70(7.07)
1967	161.14(5.32)	177.65(7.06)	166.86(21.03)	179.10(12.17)	182.70(5.02)	169.42(6.69)	171.42(5.04)	180.79(8.60)	177.62(9.44)	190.73(12.16)	170.22(8.00)	190.10(6.69)
1968	185.00(10.54)	179.43(6.70)	177.88(7.49)	203.86(9.46)	197.78(5.27)	192.20(5.70)	194.13(5.88)	183.67(6.71)	190.75(9.48)	201.98(7.98)	153.96(6.70)	105.65(9.43)
1969	193.18(6.67)	191.24(9.42)	171.77(14.87)	204.88(9.43)	187.70(7.46)	183.80(7.99)	189.18(9.44)	188.02(6.38)	177.89(10.54)	181.86(12.17)	182.65(6.10)	169.39(6.68)
1970	151.02(5.34)	151.13(7.97)	165.60(9.43)	169.18(10.56)	145.29(12.16)	152.13(7.01)	161.59(7.49)	165.60(8.61)	164.67(7.97)	133.67(14.87)	159.55(6.72)	160.56(8.62)
1971	169.94(5.46)	165.74(8.61)	141.85(9.44)	155.64(9.47)	162.73(12.16)	169.38(14.91)	172.17(8.00)	178.76(9.44)	159.75(5.87)	180.73(12.17)	161.05(7.49)	171.88(8.60)
1972	132.32(10.54)	153.32(10.56)	191.64(14.92)	176.24(12.18)	178.58(9.45)	159.41(12.17)	182.99(9.44)	158.77(14.90)	-	181.13(12.16)	155.53(10.53)	157.01(6.72)

Appendix B7: Weight at 18 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	120.94(13.65)	-	-	103.55(16.67)	117.3(9.69)	131.36(8.99)	119.66(9.70)	148.92(23.52)	129.80(8.99)	156.85(16.66)	151.64(11.83)	139.38(23.52)
1951	114.90(23.52)	130.77(11.82)	148.02(23.52)	174.76(23.52)	135.28(10.59)	134.09(9.69)	132.29(10.59)	153.23(13.64)	135.07(10.57)	154.38(13.61)	149.01(9.68)	163.69(11.80)
1952	161.52(11.80)	155.76(16.64)	105.90(23.53)	153.23(10.56)	159.23(7.17)	163.85(8.95)	164.34(8.94)	152.33(9.65)	168.52(16.6)	149.66(11.80)	165.58(8.96)	158.03(16.64)
1953	180.39(8.94)	181.65(23.53)	-	164.58(10.59)	168.62(9.66)	168.10(23.54)	148.22(11.81)	200.83(16.66)	182.52(16.64)	158.96(16.64)	168.83(7.50)	160.58(11.81)
1954	151.27(9.67)	148.13(13.62)	149.29(8.93)	169.80(16.66)	175.05(13.61)	145.51(16.66)	153.01(23.52)	171.34(16.65)	138.13(13.60)	141.09(9.63)	152.30(7.89)	146.73(9.66)
1955	153.60(11.80)	130.14(11.80)	126.36(10.55)	118.90(10.60)	142.93(10.54)	118.91(13.62)	124.59(11.80)	114.35(13.61)	104.04(10.54)	107.53(8.95)	112.68(8.37)	120.30(10.57)
1956	97.73(9.65)	112.11(8.98)	108.33(7.90)	97.13(10.55)	102.28(16.68)	117.93(7.88)	110.82(9.62)	104.45(23.52)	115.59(9.65)	136.85(10.56)	-	140.60(9.66)
1957	136.40(7.49)	145.97(9.66)	144.00(11.77)	138.76(10.53)	114.59(23.54)	117.67(13.60)	125.29(16.16)	132.75(11.78)	119.58(13.60)	133.82(10.63)	114.14(13.60)	107.78(8.38)
1958	111.23(11.84)	111.79(23.53)	128.46(16.70)	135.93(10.58)	171.54(23.58)	120.65(11.80)	123.85(16.66)	152.55(23.52)	128.85(9.62)	148.83(13.61)	152.23(10.58)	135.02(9.65)
1959	152.75(8.93)	139.67(11.87)	154.11(13.61)	153.60(13.62)	130.71(8.35)	178.87(16.66)	149.81(23.52)	146.70(16.71)	142.03(13.62)	146.29(16.71)	140.17(13.61)	144.14(8.96)
1960	116.02(16.69)	133.32(13.63)	133.51(9.63)	131.07(7.90)	138.95(8.38)	150.16(11.79)	144.37(23.52)	136.72(16.71)	168.43(23.52)	147.11(16.65)	154.04(11.80)	155.19(13.59)
1961	157.99(23.52)	-	156.19(13.62)	166.78(9.66)	159.29(23.58)	184.37(23.53)	190.87(16.66)	182.65(13.62)	173.41(16.61)	-	167.50(23.52)	191.44(16.64)
1962	156.52(16.66)	-	189.33(16.65)	186.63(10.55)	167.12(11.78)	160.90(16.65)	162.06(23.52)	166.35(13.61)	171.60(10.55)	171.59(23.52)	191.70(13.65)	176.18(16.72)
1963	166.27(8.94)	198.58(16.66)	199.48(9.60)	176.93(10.56)	182.34(8.92)	192.31(11.79)	167.07(23.52)	179.40(13.62)	177.03(8.94)	161.26(9.62)	172.10(16.65)	189.09(11.81)
1964	165.75(16.72)	170.87(7.17)	172.05(9.64)	159.73(6.63)	178.26(8.36)	181.58(6.87)	163.87(5.85)	177.81(6.83)	169.34(8.92)	178.67(9.64)	179.34(10.57)	188.28(9.65)
1965	191.35(8.90)	182.67(9.63)	176.24(6.34)	162.93(8.94)	167.28(6.60)	170.87(7.17)	146.36(9.63)	169.61(8.40)	156.23(11.82)	156.60(7.89)	172.46(11.80)	181.82(9.67)
1966	185.16(16.66)	157.15(16.69)	175.87(8.36)	180.54(6.58)	165.05(7.15)	173.41(9.66)	182.78(8.90)	178.31(11.79)	188.94(10.55)	185.53(10.56)	186.20(10.54)	187.80(7.91)
1967	189.62(5.96)	209.07(7.89)	178.94(23.53)	199.99(13.62)	208.71(5.62)	195.95(7.48)	197.29(5.64)	202.70(9.62)	197.68(10.56)	213.31(13.61)	193.95(8.95)	221.48(7.49)
1968	229.22(11.79)	205.26(7.49)	202.92(8.38)	239.11(10.59)	218.63(5.90)	215.44(6.37)	227.11(6.58)	212.71(7.50)	212.07(10.60)	215.43(8.92)	175.35(7.49)	122.35(10.55)
1969	224.95(7.47)	212.53(10.53)	190.49(16.64)	231.94(10.55)	199.84(8.34)	196.37(8.94)	201.66(10.56)	200.37(7.14)	185.79(11.79)	177.89(13.61)	191.10(6.82)	189.21(7.47)
1970	182.44(5.97)	168.90(8.91)	179.98(10.55)	188.28(11.81)	143.16(13.60)	172.21(7.85)	169.79(8.38)	169.75(9.63)	177.98(8.92)	138.10(16.64)	182.03(7.51)	187.02(9.64)
1971	189.38(6.41)	184.78(9.64)	170.73(10.57)	177.40(10.59)	194.85(13.61)	182.20(16.68)	186.14(8.95)	213.61(10.56)	165.70(6.57)	189.65(13.61)	176.17(8.38)	213.84(9.62)
1972	156.31(11.79)	183.78(11.81)	204.55(16.69)	186.31(13.63)	186.28(10.58)	172.72(13.61)	182.63(10.55)	160.94(16.66)	-	191.65(13.60)	183.41(11.78)	178.98(7.51)

Appendix B8: Weight at 21 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	141.04(14.94)	-	-	132.27(18.25)	134.91(10.62)	150.47(9.23)	138.05(10.62)	173.77(25.74)	149.47(9.85)	185.91(18.23)	172.92(12.95)	164.47(25.74)
1951	141.11(25.74)	148.71(12.94)	166.97(25.74)	165.38(25.74)	156.46(11.59)	147.92(10.61)	137.37(11.60)	171.98(18.24)	156.45(11.57)	182.06(14.89)	184.01(11.60)	188.07(12.92)
1952	178.35(14.89)	162.79(25.75)	116.75(25.75)	188.13(12.92)	173.85(7.86)	172.45(9.80)	172.02(10.56)	185.53(10.57)	204.14(18.23)	174.21(12.92)	206.19(10.58)	173.84(18.21)
1953	205.86(9.79)	184.34(25.75)	-	176.65(12.93)	190.49(10.57)	184.47(25.76)	187.40(12.93)	217.54(18.23)	200.15(18.21)	177.08(18.21)	180.89(8.22)	186.19(12.93)
1954	170.81(10.59)	170.52(14.91)	162.81(9.77)	185.74(18.24)	192.99(14.90)	158.46(18.23)	176.95(25.74)	197.01(18.22)	170.57(14.88)	165.67(9.78)	161.06(8.64)	148.00(10.57)
1955	153.94(12.92)	134.38(12.91)	125.46(11.55)	120.19(11.60)	141.08(11.54)	113.30(14.91)	139.19(12.91)	137.80(14.90)	129.53(11.54)	129.44(9.79)	133.30(9.16)	130.85(11.56)
1956	104.57(10.57)	123.68(9.83)	126.14(8.65)	112.81(11.55)	119.93(18.26)	139.32(8.63)	128.35(10.53)	126.82(25.74)	137.18(10.57)	159.35(11.56)	-	153.98(10.58)
1957	157.59(8.19)	158.56(10.58)	155.32(12.88)	147.05(11.55)	125.28(25.76)	131.21(14.88)	140.65(18.24)	149.65(12.89)	144.35(14.88)	154.02(12.96)	123.30(18.22)	119.07(9.17)
1958	121.52(15.00)	-	149.25(18.28)	154.71(11.58)	192.81(25.81)	136.44(12.92)	165.72(18.23)	186.93(25.74)	153.32(10.53)	175.31(14.89)	176.09(11.58)	159.54(10.56)
1959	178.73(9.78)	156.68(13.00)	177.34(14.90)	173.12(14.91)	139.28(9.14)	186.42(18.24)	158.12(25.74)	172.47(18.29)	170.68(14.91)	176.73(18.29)	172.68(14.89)	172.77(9.81)
1960	153.17(18.27)	146.78(14.92)	149.82(10.54)	143.70(8.65)	161.70(9.18)	166.51(12.90)	162.66(25.74)	153.87(18.29)	204.62(25.74)	184.26(18.22)	178.06(12.92)	183.73(14.88)
1961	166.52(25.74)	-	170.64(14.91)	195.74(10.58)	138.83(25.81)	207.47(25.75)	215.16(18.23)	211.31(14.91)	200.65(18.23)	-	200.31(25.74)	216.27(18.21)
1962	180.33(18.23)	-	215.91(18.22)	210.39(11.55)	189.68(12.89)	182.72(18.22)	185.34(25.74)	193.82(14.90)	201.06(11.55)	211.65(25.74)	222.38(14.94)	206.38(18.30)
1963	187.18(9.79)	227.18(18.23)	225.07(10.51)	202.71(11.55)	201.39(9.76)	209.19(12.90)	177.86(25.74)	188.62(14.90)	204.19(9.79)	193.62(10.53)	206.39(18.22)	209.67(12.92)
1964	194.13(18.30)	203.86(7.85)	203.99(10.55)	193.08(7.26)	208.07(9.15)	204.46(7.52)	186.76(6.42)	201.91(7.48)	198.68(9.76)	209.75(10.55)	209.43(11.57)	212.12(10.56)
1965	211.66(9.74)	211.14(10.54)	204.82(6.94)	187.27(9.79)	185.74(7.22)	179.08(7.85)	163.85(10.54)	207.74(9.20)	188.19(14.94)	194.24(8.63)	205.49(12.92)	209.69(10.59)
1966	212.09(18.24)	191.68(18.27)	202.22(9.16)	202.58(7.20)	185.93(7.83)	189.78(10.58)	205.55(10.55)	203.79(14.88)	231.29(11.55)	217.65(11.56)	219.71(11.54)	218.24(8.66)
1967	213.21(6.52)	225.58(8.64)	207.70(25.75)	225.56(14.91)	229.41(6.15)	215.73(8.62)	221.88(6.74)	229.23(11.53)	236.54(11.56)	245.06(14.89)	226.93(9.79)	226.15(9.16)
1968	212.40(12.91)	232.35(8.20)	247.65(9.79)	274.32(11.59)	251.65(6.46)	242.22(7.52)	241.68(8.64)	242.59(8.21)	246.13(11.61)	254.56(9.77)	193.87(8.20)	136.23(11.55)
1969	241.84(8.17)	234.56(11.53)	204.30(18.21)	255.88(11.55)	213.26(9.13)	196.76(9.79)	206.69(11.56)	216.62(8.20)	206.44(12.91)	197.46(14.90)	227.93(7.47)	209.92(8.61)
1970	205.85(7.84)	190.10(10.53)	195.69(11.55)	208.09(18.21)	165.29(18.24)	186.14(9.74)	199.09(9.17)	185.46(12.89)	200.75(9.76)	159.84(18.21)	212.96(8.23)	214.58(14.88)
1971	215.95(7.19)	202.87(11.57)	182.70(11.57)	188.52(11.60)	207.74(14.89)	192.62(18.26)	199.54(9.80)	219.57(25.81)	188.42(7.48)	202.14(18.23)	193.37(11.56)	229.23(12.90)
1972	171.68(12.90)	201.22(14.90)	177.99(25.75)	201.85(18.23)	208.32(11.58)	183.66(14.90)	204.13(12.90)	177.80(18.24)	-	219.29(14.89)	200.56(12.89)	198.10(9.17)

Appendix B9: Weight at 24 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	156.73(16.12)	-	-	148.41(19.68)	151.66(11.46)	167.01(9.97)	165.57(11.47)	201.48(27.75)	161.69(10.63)	204.88(19.66)	-	168.83(27.76)
1951	155.21(27.75)	159.64(13.9)	176.98(27.75)	182.43(27.76)	160.70(12.50)	183.06(11.44)	177.48(12.51)	193.98(19.67)	172.16(19.67)	195.78(19.63)	206.01(13.99)	204.74(13.94)
1952	201.76(16.06)	174.20(27.7)	120.23(27.77)	189.15(12.47)	197.37(8.48)	202.05(11.41)	198.67(12.46)	205.35(11.40)	223.97(19.66)	197.72(16.06)	219.30(11.41)	194.19(19.63)
1953	219.50(10.56)	218.66(27.7)	-	202.12(13.94)	216.54(12.48)	195.71(27.79)	191.71(13.94)	228.46(19.67)	217.55(19.63)	196.78(19.64)	199.97(8.87)	198.97(13.94)
1954	186.19(11.42)	179.01(16.0)	175.93(10.54)	203.93(19.67)	220.07(16.07)	178.80(19.66)	189.68(27.75)	203.74(19.65)	166.87(16.05)	164.08(10.55)	166.08(9.33)	150.73(11.40)
1955	153.54(13.93)	129.99(13.9)	131.14(12.46)	132.09(12.53)	162.83(12.44)	139.82(16.08)	157.17(13.93)	154.11(16.07)	138.35(12.45)	133.86(10.57)	142.44(9.88)	149.71(12.48)
1956	123.19(11.40)	147.92(10.6)	144.38(9.33)	129.93(12.46)	146.98(19.69)	165.92(9.31)	150.96(11.36)	160.21(27.76)	150.24(11.40)	178.73(12.47)	-	165.35(11.41)
1957	167.30(8.84)	170.71(11.4)	171.92(13.89)	161.19(12.43)	130.84(27.78)	156.60(16.05)	159.75(19.67)	165.12(13.90)	167.97(16.05)	168.85(13.99)	112.10(27.84)	140.09(12.48)
1958	-	-	164.65(19.72)	178.62(12.50)	237.75(27.84)	165.43(13.93)	187.70(19.67)	196.94(27.75)	172.08(11.35)	192.37(16.06)	199.87(12.49)	183.43(11.40)
1959	197.10(10.55)	167.84(14.0)	179.37(16.07)	177.06(16.08)	154.94(9.86)	201.21(19.67)	186.52(27.76)	203.56(19.73)	197.55(16.09)	194.23(19.73)	192.39(16.06)	189.80(10.59)
1960	172.34(19.70)	159.40(16.1)	169.90(11.37)	158.96(9.34)	185.24(9.91)	191.43(13.91)	196.04(27.76)	177.48(19.73)	230.51(27.75)	205.75(19.65)	201.92(13.93)	205.13(16.05)
1961	191.95(27.75)	-	194.51(16.09)	220.97(11.42)	148.39(27.84)	238.17(27.77)	246.16(19.66)	240.17(16.09)	217.58(19.66)	216.91(27.76)	234.63(19.64)	208.54(19.66)
1962	208.54(19.66)	-	226.62(19.65)	231.04(12.45)	212.83(13.90)	213.27(19.65)	216.91(27.76)	219.13(16.07)	225.23(12.46)	236.41(27.76)	249.72(16.12)	238.72(19.75)
1963	206.33(10.56)	235.50(19.6)	237.10(11.33)	214.13(12.46)	221.86(10.53)	241.41(13.92)	223.25(27.75)	225.15(16.08)	232.58(10.56)	219.07(11.35)	238.41(19.65)	240.75(13.94)
1964	215.36(19.75)	222.94(8.48)	224.89(11.38)	215.96(7.84)	230.85(9.87)	230.99(8.12)	215.01(6.94)	229.95(8.07)	225.56(10.52)	230.47(11.38)	231.12(12.48)	239.28(11.39)
1965	240.01(10.50)	232.27(11.3)	209.27(7.49)	203.96(10.57)	211.77(8.10)	224.73(8.88)	202.90(11.37)	240.00(9.93)	222.42(13.95)	224.34(9.32)	231.82(13.94)	237.54(11.43)
1966	223.23(19.67)	224.89(19.7)	225.32(10.56)	222.89(7.77)	209.62(8.45)	216.44(12.47)	224.68(11.38)	222.84(16.05)	257.66(12.46)	241.40(12.47)	239.26(12.44)	240.02(9.93)
1967	244.98(7.04)	260.49(9.32)	226.36(27.76)	248.26(16.08)	258.11(7.26)	246.78(9.89)	257.94(7.28)	269.42(12.44)	264.59(12.47)	265.13(16.06)	263.67(10.57)	280.67(9.33)
1968	299.55(13.92)	255.21(8.85)	268.77(11.40)	296.97(12.50)	288.36(8.39)	272.20(8.49)	269.72(9.32)	270.10(8.86)	266.30(12.53)	269.75(10.54)	205.78(8.85)	145.12(12.46)
1969	254.99(8.81)	250.44(12.4)	201.77(19.64)	287.41(19.66)	208.60(9.85)	218.88(11.39)	220.65(13.92)	253.78(10.54)	237.43(16.09)	221.48(19.66)	264.80(8.82)	230.06(9.84)
1970	202.82(9.33)	204.04(12.4)	226.24(16.07)	225.01(27.77)	200.46(19.67)	214.58(10.50)	230.16(12.47)	214.41(19.67)	217.07(16.04)	176.14(19.64)	232.14(12.52)	237.14(12.52)
1971	231.98(8.40)	199.10(13.9)	182.55(13.94)	168.24(16.07)	234.96(19.71)	-	225.00(12.47)	258.61(27.84)	207.23(9.88)	-	203.35(19.68)	227.79(19.75)
1972	171.67(16.04)	206.53(19.6)	181.92(27.77)	206.87(27.77)	216.73(16.14)	187.10(27.79)	-	161.10(27.84)	-	244.50(16.06)	196.46(16.06)	203.44(10.58)

Appendix B10: Weight at 27 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	177.17(17.18)	-	-	167.35(20.98)	165.92(12.22)	191.28(10.63)	179.70(13.36)	-	175.38(17.15)	226.67(20.96)	-	175.96(23.58)
1951	212.96(29.58)	183.69(14.89)	217.49(29.58)	231.76(29.58)	196.48(14.87)	200.70(13.33)	195.43(20.93)	210.6(20.97)	187.55(20.97)	220.60(20.93)	224.98(14.92)	196.9(17.12)
1952	208.22(17.12)	195.84(29.59)	143.42(29.59)	222.04(13.30)	214.04(9.05)	226.64(11.28)	210.81(13.28)	217.99(12.16)	228.97(20.96)	216.39(17.12)	232.86(13.33)	217.88(20.93)
1953	243.24(11.26)	244.57(29.59)	-	208.61(14.87)	236.27(12.17)	221.54(29.62)	209.47(14.87)	252.27(20.97)	226.95(20.93)	212.03(20.93)	217.26(9.46)	212.52(14.87)
1954	205.85(12.18)	193.40(17.14)	192.75(11.24)	218.31(20.97)	231.97(17.13)	179.26(20.96)	212.96(29.58)	201.79(20.94)	177.87(17.11)	159.49(11.24)	157.51(9.94)	150.03(12.16)
1955	176.82(14.85)	147.37(14.85)	153.85(13.28)	152.64(13.36)	180.57(13.26)	146.85(17.15)	160.41(14.85)	163.05(17.13)	157.38(13.27)	155.01(11.27)	168.46(10.53)	170.30(13.31)
1956	145.36(12.16)	173.30(11.33)	168.58(9.96)	159.12(13.28)	167.26(20.99)	183.49(9.92)	168.65(12.11)	175.51(29.58)	160.76(12.15)	193.27(13.30)	-	176.45(12.17)
1957	173.70(9.43)	188.58(12.18)	197.31(14.81)	183.09(13.25)	147.85(29.62)	172.82(17.11)	167.35(29.58)	187.98(14.81)	188.91(17.11)	191.43(14.92)	131.46(29.69)	157.14(13.31)
1958	-	-	201.76(21.02)	206.99(13.33)	247.58(29.69)	180.53(14.85)	198.49(20.96)	213.41(29.58)	194.83(12.10)	210.86(17.12)	207.81(13.32)	186.62(12.15)
1959	195.20(11.24)	179.35(14.97)	213.17(17.13)	207.80(17.14)	182.98(10.51)	223.75(20.97)	201.37(29.58)	219.30(21.03)	215.64(17.15)	205.97(21.03)	215.10(17.12)	214.34(11.29)
1960	208.27(21.00)	185.27(17.16)	200.41(12.12)	190.21(9.96)	212.65(10.56)	218.04(14.83)	212.71(29.58)	208.87(21.03)	264.21(29.58)	219.09(20.95)	213.20(14.85)	219.55(17.10)
1961	205.70(29.58)	-	222.57(17.15)	233.69(13.32)	182.26(29.69)	260.45(29.59)	263.86(20.96)	259.31(17.15)	235.74(20.96)	-	241.28(29.58)	264.71(20.93)
1962	229.23(20.95)	-	253.61(20.95)	263.73(13.28)	241.85(14.82)	246.25(20.94)	243.55(29.58)	239.93(17.13)	247.93(13.28)	249.90(29.58)	269.71(17.18)	250.24(21.05)
1963	219.47(11.26)	262.05(20.96)	279.01(12.08)	252.25(13.29)	251.23(11.23)	273.78(14.84)	249.24(29.58)	247.10(17.14)	266.55(11.26)	250.81(12.10)	262.91(20.95)	247.52(14.86)
1964	240.72(21.05)	245.33(9.47)	243.61(12.13)	237.17(8.37)	255.18(10.52)	254.31(8.67)	235.48(7.41)	249.43(8.60)	249.87(11.22)	250.13(12.13)	250.05(13.30)	245.26(12.14)
1965	247.94(11.20)	247.31(13.28)	253.82(7.98)	247.89(11.27)	238.74(9.02)	249.84(9.04)	228.69(12.12)	259.40(10.59)	240.87(14.88)	251.22(11.26)	255.30(14.86)	255.43(14.89)
1966	255.87(20.96)	247.20(21.01)	260.76(11.26)	250.27(8.61)	231.65(9.01)	240.95(13.30)	263.87(12.13)	237.79(17.11)	279.97(13.28)	262.74(13.30)	253.77(13.26)	259.86(11.30)
1967	268.74(7.51)	301.39(11.29)	254.35(29.59)	285.57(20.93)	291.25(8.64)	272.68(10.55)	284.47(7.77)	296.34(13.26)	265.91(13.30)	289.13(17.12)	288.95(11.27)	291.94(10.58)
1968	312.31(17.13)	259.61(11.23)	300.96(13.29)	320.18(14.88)	299.38(8.94)	282.80(9.06)	288.40(9.94)	276.34(9.45)	288.82(13.37)	286.77(11.23)	229.27(9.94)	135.28(13.29)
1969	247.79(12.09)	242.20(13.25)	223.15(20.93)	322.53(20.95)	246.87(11.20)	246.66(17.14)	257.92(20.95)	295.14(13.27)	287.38(20.95)	238.27(20.96)	267.82(9.89)	235.98(17.14)
1970	231.73(10.53)	218.87(14.81)	266.59(20.97)	247.75(29.59)	-	254.41(13.24)	277.96(17.16)	240.52(29.68)	252.75(17.10)	164.18(29.62)	255.99(14.90)	274.69(20.93)
1971	218.55(10.48)	213.66(17.10)	204.70(17.18)	212.92(29.62)	-	-	250.60(17.13)	-	225.59(14.83)	-	224.93(20.98)	248.74(21.06)
1972	194.06(17.10)	237.61(20.98)	217.81(29.59)	223.71(29.59)	182.53(29.62)	216.10(29.62)	-	180.65(29.68)	-	250.54(20.97)	221.69(29.59)	215.80(14.84)

Appendix B11: Weight at 30 months

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1950	195.25(17.99)	-	-	213.24(30.94)	185.28(12.81)	204.83(12.80)	204.56(13.99)	-	198.90(17.95)	245.58(21.92)	-	220.95(30.94)
1951	199.89(30.93)	213.56(17.9)	239.35(30.93)	-	209.54(17.92)	227.72(13.96)	205.08(21.88)	226.74(21.94)	196.1(21.94)	222.0(21.88)	249.3(15.62)	228.5(17.91)
1952	232.84(17.91)	218.79(30.9)	164.01(30.95)	227.60(15.55)	223.84(9.93)	232.10(11.81)	233.02(13.90)	247.30(12.73)	249.17(21.92)	233.54(21.92)	268.32(12.74)	234.34(21.88)
1953	263.34(11.79)	256.55(30.9)	-	227.02(15.56)	247.52(13.94)	234.98(30.98)	231.90(15.57)	271.16(21.94)	240.47(21.88)	216.30(21.89)	229.47(9.90)	230.30(15.56)
1954	223.80(12.76)	201.82(17.9)	193.16(11.77)	224.32(21.94)	228.55(17.93)	182.98(21.92)	212.59(30.93)	201.85(21.91)	168.22(17.90)	174.80(11.77)	176.99(10.41)	168.53(12.73)
1955	196.35(15.54)	163.53(15.5)	159.15(13.90)	158.05(14.00)	186.30(13.87)	164.24(17.94)	184.02(15.54)	190.57(17.92)	180.92(13.88)	177.64(11.80)	192.83(11.03)	197.51(15.54)
1956	171.73(12.73)	202.15(12.7)	190.77(10.43)	180.30(13.90)	186.49(21.97)	199.77(10.39)	176.49(12.67)	185.57(30.94)	169.26(12.72)	204.27(13.92)	-	198.79(12.75)
1957	202.75(9.87)	206.39(12.6)	211.35(15.49)	209.87(15.51)	169.47(30.98)	186.79(21.94)	191.92(30.94)	206.10(15.50)	195.96(17.90)	207.50(15.63)	151.00(31.07)	179.00(13.94)
1958	-	-	213.43(22.00)	214.41(13.96)	261.23(31.07)	203.93(15.54)	182.34(21.94)	223.93(30.93)	186.74(12.66)	208.93(17.92)	233.88(13.94)	212.69(12.72)
1959	232.12(11.77)	210.51(15.6)	241.59(17.92)	228.19(17.93)	202.5(11.01)	234.98(21.94)	224.58(30.94)	251.06(22.01)	240.96(17.94)	227.58(22.01)	238.50(17.91)	243.41(11.82)
1960	236.99(21.97)	221.56(22.0)	228.95(12.68)	217.75(11.05)	235.62(11.07)	240.96(15.52)	244.54(30.94)	219.31(22.01)	266.57(30.93)	237.12(21.91)	236.90(15.55)	244.53(17.89)
1961	223.02(30.93)	-	240.98(17.94)	260.11(13.94)	202.72(31.07)	286.48(30.95)	289.57(21.92)	286.95(17.94)	261.68(21.92)	-	223.67(30.94)	293.29(21.89)
1962	246.93(21.92)	-	264.63(21.91)	289.60(13.89)	265.47(15.50)	266.95(21.91)	260.42(30.94)	253.23(17.92)	260.81(13.90)	273.57(30.94)	286.57(17.99)	265.90(22.03)
1963	251.51(11.79)	283.22(21.9)	293.93(12.63)	277.02(13.91)	273.35(11.75)	301.38(15.52)	263.39(30.93)	273.18(17.93)	277.53(11.79)	258.52(12.66)	271.67(21.91)	292.55(17.91)
1964	260.68(22.03)	266.81(9.92)	260.73(12.70)	266.25(8.77)	274.34(11.76)	276.88(9.08)	261.20(8.00)	256.26(9.01)	252.58(11.74)	261.19(12.69)	259.06(13.93)	277.02(12.71)
1965	285.00(11.71)	278.94(13.8)	281.15(9.01)	274.71(11.80)	268.11(9.89)	269.12(9.92)	253.67(13.88)	264.88(11.09)	237.17(15.57)	258.67(13.89)	254.18(21.89)	290.28(15.59)
1966	296.75(21.94)	268.22(21.9)	287.43(11.79)	274.23(9.40)	258.12(9.44)	266.09(15.52)	282.34(15.51)	254.87(17.90)	300.37(15.54)	293.57(15.55)	301.84(17.89)	307.54(15.55)
1967	294.03(13.90)	337.01(13.9)	-	309.62(21.89)	314.64(10.40)	291.57(11.05)	302.51(9.44)	317.29(13.87)	285.06(15.50)	301.60(17.91)	319.71(13.92)	300.60(13.94)
1968	314.03(21.92)	285.15(11.7)	301.95(15.52)	331.06(15.58)	308.92(10.33)	294.09(10.47)	295.08(11.07)	290.53(9.90)	267.46(14.01)	272.98(12.68)	235.96(12.73)	162.28(15.58)
1969	285.32(12.65)	272.12(17.9)	163.12(30.98)	353.28(21.92)	239.77(17.92)	255.25(17.93)	266.90(21.91)	261.14(15.55)	272.21(30.94)	214.12(30.98)	316.39(22.00)	275.40(30.95)
1970	270.37(15.50)	263.37(21.8)	307.24(31.07)	276.96(30.95)	-	275.13(17.90)	309.21(30.93)	-	255.55(21.92)	177.18(30.98)	261.97(15.59)	300.55(21.89)
1971	271.41(17.92)	241.38(30.9)	180.60(30.95)	-	-	-	295.36(30.95)	-	245.28(15.51)	-	-	-
1972	245.35(31.07)	265.67(21.9)	-	-	234.07(30.98)	-	-	175.70(31.07)	-	278.78(30.98)	-	282.87(30.98)