FACTORS AFFECTING THE LIVEWEIGHT OF SOME GENOTYPES OF BEEF CATTLE AT THIRTY MONTHS OF AGE AT KIBOKO AND BUCHUMA RANGE RESEARCH STATIONS (KENYA).

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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SUMMARY

The variation of body weights of 713 beef cattle was examined using data from 1969 to 1974 at Kiboko and Buchuma Range Research Stations which are located in the arid and semi-arid zone. The Least Squares Method of fitting constants for non-orthogonal data was used to estimate the effect of genotype, age of dam, season of birth, year of birth, sex, place of birth, weaning weight and some two-way interactions of the main effects on the weights of beef cattle.

The genotypes analysed included East African Shorthorn Zebu (EASZ), Sahiwal x EASZ, Boran x EASZ, Sahiwal, Boran, Friesian x Sahiwal and Friesian x Boran. In the first analysis data from Kiboko and Buchuma were analysed and only three genotypes, namely Sahiwal, Friesian x Sahiwal and Friesian x Boran were included in the model. The corrected mean body weight obtained was 322.46 $\pm$ 48.14 kg. In the second analysis only Kiboko data were analysed and all seven genotypes were included in the model. The corrected mean body weight obtained was 281.97 $\pm$ 53.75 kg.

Weaning weight, genotype, season of birth, year of birth, place of birth and sex had significant effects on the weight analysed together with some two way interactions. The weaning weight and the year of birth contributed 15.17% and 15.95% to the total variation in the first analysis and 10.51% and 17.41% in the second analysis, respectively.

The Sahiwal x EASZ and Boran x EASZ were 8.24 kg (3.23%) and 16.44 kg (6.44%) heavier than the EASZ respectively. The weights of the Sahiwal and the Boran, and their crosses with the Friesian were significantly heavier than those of the EASZ and its crosses with the Sahiwal and the Boran. Buchuma animals were 17.40 kg (5.50%) heavier than Kiboko animals. The steers were 4.68 kg (1.45%) and 9.68 kg (3.43%) heavier than the females in the first and second analyses respectively.

The most and least favourable years of birth were 1971 and 1973 respectively. In 1969 through 1973, Buchuma animals were heavier than Kiboko animals while the reverse was true for 1974. The performance of the genotypes varied from year to year and the ranking changes were found to be significant.

The most suitable season of birth for the Sahiwal, Boran and EASZ was the wet season while the end of the wet season was found most suitable for the Friesian x Sahiwal, Friesian x Boran and Boran x EASZ. The most suitable season of birth for the Sahiwal x EASZ was the dry season while the end of the dry season was the least favourable season of birth for most of the genotypes.

A phenotypic correlation coefficient of 0.55 was found between weaning weight and the liveweight at 30 months.

1. INTRODUCTION

Cattle play an important role in the agricultural production of Kenya. They contribute 85% of the total value of livestock production (Kenya Government Development Plan 1979-1983). Kenya has varied ecological zones and their agricultural potential is determined mainly by the amount of rainfall and its temporal distribution. About 85% of Kenya's land surface receives less than 750 mm of precipitation (Griffiths, 1962). Arable farming in such regions entails considerable production risks. More and more grazing land in high and medium potential areas is being turned to arable use. The range areas are now receiving more attention for livestock production. The development of arid and semi-arid areas is now a new high priority objective of the Government of Kenya. These areas carry 50% of livestock and 20% of human population. It is the intention of the Government to intensify livestock improvement in these areas (Kenya Government Development Plan 1979-1983).

The predominant cattle type in Kenya is the East African Shorthorn Zebu (EASZ). This type is highly adapted to adverse environmental conditions characteristic of range lands. It is more tolerant to heat and more resistant to endemic diseases than the *Bos taurus* breeds. The EASZ can withstand periodic malnutrition better than the exotic breeds. It is able to walk long distance in search of water and pasture. The EASZ is, however, characterised by low productivity (French, 1941), small body weights and low growth rates (Trail, Sacker and Fisher, 1971a, 1971b). The *Bos taurus* cattle breeds are less adapted to the hot and humid or dry tropical environment compared to the *Bos indicus*. Under optimum environmental conditions, they are more productive than the Zebu breeds Under the tropical conditions animals which combine the qualities of *Bos taurus* and *Bos inducus* breeds would be most desirable. This would improve beef cattle production. Such animals could result from a carefully designed crossbreeding program.

It is in view of this that the UNDP/FAO Range Management Project (1966-1973) was initiated to intensify livestock improvement in the arid and semi-arid areas (Kiboko, Annual Report, 1974). Kiboko and Buchuma Range Research Stations were set up. The main objective was to identify suitable breeds or crossbreds and the management practices for beef production in the arid and semi-arid areas.

It is important that animals are evaluated in areas they are used for production since the performance of a genotype may be different in different environments (Falconer, 1960). Roberts (1965) suggested that animals be evaluated in the least favourable environment likely to be faced by their progeny. However, Hassall (1970) concluded that in commercial beef production, the important measure is to locate the genetic material which performs best under specific conditions of production. Systematic crossbreeding has been undertaken to evolve a genotype that will be highly productive and at the same time be well adapted to the environment (Wagner, Holland and Mogess, 1968; Meadie, 1969;

Trail, Sacker and Fisher, 1971a; Kiboko Annual Report, 1974 and National Animal Husbandry Research Station (Naivasha) Annual Report, 1974).

The body weights of beef cattle are influenced by several factors. Each of these factors has its greatest influence on the body weights associated with a particular stage of the development of the animal (Cameron, 1970; Tonn, 1974). The sets of genes influencing growth rate from birth to maturity may be different at different stages of growth of the animal (Falconer, 1960).

Mwandotto (1978) studied the effect of genotype, sex, age of dam at birth, season of birth, year of birth and place of grazing on weaning weights of East African Shorthorn Zebu (EASZ), Boran, Sahiwal, Boran x EASZ, Sahiwal x EASZ, Friesian x Boran and Friesian x Sahiwal. In this study the effect of genotype, sex, age of dam at birth, season of birth, year of birth, place of birth and weaning weight as a covariate on weight at thirty months of age was analysed using the Least Squares Analysis described by Harvey (1960).

2. LITERATURE REVIEW

2.1.1 Postweaning growth

Among the most important production traits to consider in beef production are preweaning growth rate, postweaning growth rate, fertility, adaptability to environmental stresses, feed conversion efficiency and carcass traits. The rate of genetic improvement of any of these traits will depend on selection differential and heritability of the trait. Selection differential is the difference between the mean phenotypic value of the selected individuals and the population mean. Heritability of a trait is the most important determinant of the rate of genetic improvement.

The postweaning growth rate is the most important in terms of profitability to the farmer. The faster the postweaning growth rate the more the profit. It is with this in mind that factors which influence postweaning growth rate are analysed so as to maximize the improvement of this trait. Among the factors which have been shown to affect postweaning growth rate are birth weight, weaning weight, genotype, sex, season of birth, year of birth, place of birth and age of dam at birth.

2.1.2 Heritability of postweaning growth rate

Heritability is defined as the ratio of additive genetic variance to phenotypic variance:-

$$h^2 = \frac{V_A}{V_P}$$

Since the genetic and phenotypic variations will be different in different populations, heritability values are not fixed. The phenotypic variation includes environmental variation and genetic variation. When the environmental variation is reduced the heritability estimates will be high. For this reason, different workers have reported different heritability estimates. Different genes influence postweaning growth rate at different phases of growth (Falconer, 1960). For this reason heritability estimates for postweaning weight will also be different at different ages.

Several workers have reported heritability estimates of postweaning growth rate at different ages. Dinkel (1958) reported that the heritability of daily gain on test increased from 0.45 after 140 days to 0.65 after 196 days. Dearborn and Dinkel (1959) in a similar study reported heritability estimate of 0.39 to 0.45 in test periods of 140, 168 and 196 days; the highest value being for 168 days. For final weight they reported heritability estimate of 0.41-0.44. Swiger (1961) reported heritabilities of gain for each successive 28 days period with the highest value (0.28) in the second period and thereafter decreasing by 0.04 indicating an increased environmental effect with time on test. Brumby, Walker and Gallagher (1963) reported heritability value of 0.38 for weight at 21 months and 0.40 for growth rate between weaning and 21 months of age. Brinks, Clark, Kieffer and Urick (1964) reported heritability values of 0.50 and 0.52 for 18 month weight and mature weight respectively. Cole (1966) reported heritability values of 0.45-0.55 for 18 month weight and 0.50-0.70 for mature cow weight.

Trail, Sacker and Fisher (1971b) reported heritability values of 0.31, 0.11, 0.06 and 0.19 for weights at 15, 18, 21 and 24 months of age. Dinkel and Busch (1973) reported a very high heritability value of 0.85 for mature weight. As it can be seen most of these workers have reported high values for heritability of postweaning growth rate. Selection for this trait should therefore result in rapid genetic improvement.

2.2 Factors and interactions of factors affecting postweaning weights and growth rate upto thirty months of age

2.2.1 Genotype

Different breeds have been selected for different purposes under varying environmental conditions. For this reason different populations may represent different gene pools (genotype). Certain breeds have been selected intensively for high postweaning growth rate. They, therefore, exhibit real genetic difference between and within breeds for this trait.

In several studies, genotype has been shown to affect postweaning growth rate. Trail *et al.* (1971b) reported highly significant breed effect on postweaning weight at 24 months. Trail, Sacker and Marples (1971) found that the progeny of Boran and Ankole dams were significantly heavier (14.0%) than those of Zebu dams ($P< 0.05$). Trail *et al.* (1971) reported that at 3 years, steers sired by Angus and Red Poll were 7.0% heavier than those sired by Boran. Kyomo, Hutchison and Salehe (1972) reported that the Boran were 7.7 kg heavier than Mpwapwa breed at 30 months. They also reported that Boran heifers were 57.2 kg heavier than the Tanzanian Shorthorn Zebu. Kennedy and Chirchir (1971) reported that Brahman were 50.6 kg heavier than Hereford x Shorthorn and the former were 12.6 kg heavier than Africander.

The analysis was at 18 months of age. Under night Kraaling system Wigg and Owen (1973) reported that Angus x Boran were 34.0 kg heavier than Boran. With continuous grazing the Angus x Boran were 36.0 kg heavier than the Boran.

Rudder, Seifert and Bean (1975) reported that Charolais x Brahman were heavier than Brahman at any age and they had higher postweaning growth gains. Lapworth, Bean, Seifert and Rudder (1976) analysed steers and found a significant breed of sire effect of 3.0 percent at 890 days. Meadie (1969) in a crossbreeding trial reported that Hereford were 37.0 kg heavier than Hereford x Boran; Hereford were 156.0 kg heavier than Boran and Hereford x Boran were 119.0 kg heavier than Boran at 30 months. In another cross-breeding experiment carried out at Naivasha National Animal Husbandry Research Station (N.A.H.R.S.) (Annual Report 1974), differences in breed were found significant at 24 and 32 months. In the same report it was found that Friesian x Boran females were 80.0 kg heavier than Boran and the males were 84.0 kg heavier. The Friesian x Sahiwal steers were 25.0 kg heavier than Sahiwal and the females were 98.0 kg heavier at 32 months. Baker and Quesenberry (1942) reported that Hereford x Shorthorn were 50.9 kg (7.02%) and 88.0 kg (8.38%) heavier than the Hereford at 18 and 30 months respectively. Lodge and Lamming (1967) reported that Friesian were 40.0 kg (13.70%) heavier than Hereford.

Koger, Kiddler, Peacock, Kirk and Hammond (1961) found that Brahman x Devon were 40.5 kg (14.66%) heavier than Devon at 18 months. Cobb, Burns and Koger (1964) reported that Santa Gertrudis were 66.36 kg (17.34%) heavier than the Angus at 30 months. Ellis and Cartwright (1963) found that Brahman x Hereford F_1 mature cows were 14.6 percent heavier than Hereford cows. Under the same management conditions, French (1943) reported that Ankole cattle were 34.55 kg (14.1%) and 119.55 kg (38.3%) heavier than the Zebu cattle at 2 and 3 years respectively.

2.2.2 Age of the dam at the birth of the calf

Age of the dam at birth affects the birth weight and weaning weight significantly (Koch and Clark, 1955; Sacker, Trail and Fisher, 1971b; Tonn, 1974; Rudder *et al*. 1975 and Mwandotto, 1978). This is due mainly to maternal effects. However, age of dam at birth has little influence on postweaning growth. The performance of the beef calves after weaning would be a reflection of the inherent potential of the calf and its adaptability to the environment.

Hidiroglon, Carman, Bernard, Jordan and Charette (1966) and Sacker *et al*. (1971b) found that age of dam at birth did not significantly affect weight at one year. Sacker, Trail and Fisher (1971a) and from studies carried out by the International Livestock

Centre for Africa (I.L.C.A.) (1977), it was reported that the age of dam at birth had no significant influence on all postweaning weights. Tonn (1974) reported a significant effect of age of dam at birth on weight at 600 days. He generally observed that the age of dam at birth effect diminished from weaning to 600 days and was no longer significant at 800 days of age.

Rudder *et al.* (1975) reported that age of dam had a significant effect on weaning weight but not on 553 day weight and subsequent weights. Straw and Jones (1977) found that age of dam did not significantly influence yearling weight. In other studies, Swiger, (1961); Brinks, Clark, Kieffer and Quesenberry, (1962); Vorster, (1964) and Burgess and Bowman, (1965) reported negligible age of dam effects on postweaning weights and gains. Lapworth *et al.* (1976) found that the age of dam effect was significant on weights at 698 days but not at 890 days. Brown, Brown and Butts (1972) reported that age of dam at birth significantly affected all postweaning weights upto 3 years in Hereford cattle. Brown *et al.* (1972) found similar results for the Angus breed except at 3 years of age when the age of dam effect was no longer significant.

2.2.3 Season of birth

Season of birth effects are primarily due to differences in the amount and distribution of rainfall in the year. It is the amount and temporal distribution of precipitation that chiefly affect vegetation growth and thus the quality and quantity of pasture. It is important, therefore, in beef production that suitable breeding and/or calving seasons can be identified in order to increase the productivity of beef cattle beside enabling the beef producer to plan other management and marketing programmes.

Tonn (1974) under range conditions in Kenya reported significant season of birth effects on weights at 800 days. He found that cattle born in June and between October and December were 58.0 kg heavier than those born between January and May and between July and September. In a study carried by I.L.C.A., (1977) it was reported that season of birth had a significant effect on weight at 2 years ($P < 0.01$) but not at 2.5 years. They had six seasons of two months each starting from January to December. Sacker *et al*. (1971a) found that season of birth had a significant effect on weight at 2 years. Sacker *et al*. (1971a) pointed out the importance of taking season of birth into consideration in the analyses of weight-for-age data in various environments and particularly in range areas where conditions change greatly from month to month.

Kidner (1966) found that season of birth had significant effect on weights at 2 and 2.5 years. He included three seasons of birth (early rains, late rains and dry seasons). The Red Poll x Boran cattle had access to reasonably good ley pastures. At 2.5 years, Kidner (1966) recorded that animals born during the early rains were heavier (ranging from 18.18 kg to 31.36 kg) than those born during the late rains.

2.2.4 Year of birth

Year of birth has been shown by various workers to have significant effects on postweaning weights. These effects arise from changes in physical environment from year to year. Yearly influences are also dependent on changes in management. Management practices can vary from year to year like castration age, disease control measures, grazing regimes and supplementation rates. The chief factor contributing to the physical environmental changes is rainfall since its amount and distribution determines the quality and quantity of forage that is available to both calves and their dams.

Sacker *et al*. (1971a, 1971b) reported significant year of birth effects on weights at 2 years. They reported that animals born in 1965 were 19.1 kg (7.9%) heavier than those born in 1966. The superiority in 1965 was due to its fairly evenly distributed rainfall whereas in 1966 the animals were born during the dry spell. Significant year of birth effects on 550 day weight were reported by Gregory, Swiger, Koch, Sumpton, Ingalls, Rowden and Rothlisberger (1966) and Laster, Smith and Gregory (1976). Tonn (1974) found significant year of birth effects on 600 and 800 day weight between 1968-1970. He reported differences ranging from 5.7 kg to 42.4 kg at 600 days of age and 9.6 kg to 28.0 kg at 800 days of age. The same trends were reported by Lapworth *et al*. (1976) at 698 and 890 days of age. Lapworth *et al*. (1976) observed that the year of birth effects tended to diminish with age. In Tonn's study (1974) the year 1969 and 1970 were dry years, while in the study of Lapworth *et al*. (1976), 1972 was indicated to have been the most favourable year of birth.

In a study carried out by I.L.C.A. (1977) on Zebu cattle at 2 years of age, it was established that the effects of year of birth had significant influence on the weights. The years 1972 and 1968 were the most suitable and the least favourable respectively. The same trends were reported by Brown *et al*. (1972) at 2 years of age. Brown *et al*.

(1972) found that at 3 years, the year of birth effect was significant only on the weights of Angus heifers and not Hereford.

2.2.5 Sex of the animal

Male animals have been shown to have a higher basal metabolic rate than the females (Mitchell, 1967). This makes male animals have more appetite than the females. The males have a greater feed intake and a better efficiency of feed conversion over a fixed weight or age interval than the females (Lodge and Lamming, 1967). The result is that males grow faster and attain heavier weights at postweaning growth period than the females.

Several workers have reported significant sex differences in postweaning weights. Sacker *et al.* (1971a) reported that sex had significant effect ($P < 0.01$) on weights at 2 years. Sacker *et al.* (1971a) reported that steers were 16.8 kg (6.0%) and 10.9 kg (5.0%) heavier than heifers in 1965 and 1966 respectively. In another study, I.L.C.A. (1977) reported that males were 14.0% and 17.0% heaiver than females at 2 and 2.5 years of age respectively.

In a crossbreeding experiment at Naivasha N.A.H.R.S., (Annual Report, 1974), it was found that male animals were heavier than female animals though the difference varied from breed to breed. In a study of the Ankole breed of cattle, French (1943) reported that bulls were 31.36 kg and 95.00 kg heavier than heifers at 2 and 3 years of age respectively. Bradley, Cundiff, Kemp and Greathouse (1966) found that Steers were significantly heavier ($P < 0.05$) than heifers at weaning and final weight. Rudder et al. (1975) reported that male animals were significantly heavier ($P < 0.05$) per day of age at 553 days and gained more during the postweaning growth period.

2.2.6 Genotype-environment Interaction

A specific difference of environment may not always have the same effect on different genotypes. When this is so there is an interaction in the statistical sense (Falconer, 1960). The genotype-environment interaction may be because a specific difference of environment may have a greater effect on some genotypes than others; or there may be a change in the order of merit of a series of genotypes when measured under different environments.

In evaluating genotypes, environmental effects and herd structure and composition should be accounted for. Physical environmental effects are unique in different places. The types of management in various environments may contribute significantly to the variation in weight of beef cattle. In analysing the environmental factors affecting body weights, several workers have tended to use animals in one environment while others simply omitted both place and herd effects from their models of analysis of data. There is, therefore, scarcity of literature on the effects of genotype-environment interaction on the weights of beef cattle. Whenever possible however, the genotype-environment interaction should be analysed since it gives rise to an additional component of variance.

Tonn (1974) in his study of the Boran reported significant environmental effects ranging from 4.8 kg to 26.6 kg for 600 day weights and 0.5 kg to 24.4 kg for 800 day weights. Rennet, Light, Rutherford, Miller, Fisher, Pratchett, Capper, Buck and Trail (1977) reported that the environment significantly affected the weights at 18 months. Rennet et al. (1977) reported differences of 47.9 kg for cattle under traditional management and 50.5 kg for cattle under improved ranching. In his study of weaning weights Mwandotto (1978) found that genotype-environment interaction did not significantly influence the weights. He was analysing weights of beef catle in two environments in the same ecological zone.

2.2.7 Other first order interactions of factors

Evaluation of the interaction of main effects is important in animal breeding work. It is inappropriate to assume that the main effects interact additively. This not only lead to erroneous estimation of the main effects but also to the use of correction factors which may be inaccurate. In postweaning growth rate studies there is a scarcity of literature on interactions of main effects because most of the workers analysed weights of beef cattle under the same environment.

Trail et al. (1971) reported a significant breed of dam x breed of sire interaction on weights at 2, 2.5 and 3 years of age. Trail et al. (1971b) reported that year of birth x breed of dam interaction had a significant influence on weight at 2 years of age while year of birth x breed of sire interaction had none. Lapworth et al. (1976) recorded a significant year of birth x breed of sire interaction on the weights at 698 and 890 days of age. Laster et al. (1976) reported a similar result to that of Lapworth et al. (1976) using weights at 400 and 550 days of age.

In another study, Koch and Clark (1955) reported that sex x age of dam interactions did not significantly affect yearling weight. Similar results were reported by Bair, Wilson and Ziegler (1972). Bradley et al. (1966) found that the following interactions had small effects which were not significant on final weight:- Sex x Breed of dam, Sex x Sire, Sire x Breed of dam. Rudder et al. (1975) reported the following interactions as having no significant effect on 553 day weights:- Age of dam x Sex, Age of dam x Breed, Sex x Breed.

2.2.8 Birth weight

The results of various workers indicate that heavy calves at birth were also heavy at weaning, Gregory, Blunn and Baker, (1950); Christian, Hauser and Chapman (1965) and Tonn (1974). Several workers have reported high genetic and phenotypic correlation coefficients between birth weight and weaning weight. This indicates that heavy calves at birth will be an early indication of heavy weaners. Koch and Clark (1955) reported phenotypic and genetic correlation coefficients of 0.39 and 0.63 respectively. Trail et al. (1971b) found a phenotypic correlation coefficient of 0.34. Christian et al. (1965) reported a phenotypic correlation coefficient of 0.62. Tonn (1974) also reported genetic and phenotypic correlation coefficients of 0.65 and 0.32 respectively. Heritability values for birth weight range from medium to high; Bock (1971), Trail et al. (1971b) and Tonn (1974) reported 0.21, 0.40 and 0.44 respectively. The high genetic correlations indicate that birth weight and weaning weight are influenced by some common genes. The high phenotypic correlations indicate that weaning weights can be increased by selecting for higher birth weights. However, selection for higher birth weights can lead to unwanted calving difficulties. The post-natal growth of the calf is therefore a better selection criterion. The post-weaning growth is the best since weaning weight serves as a measure of the productivity of the beef cow and only partly reflects the growth ability of the calf.

2.2.9 Weaning weight

In several studies, workers have reported positive genetic and phenotypic correlation coefficients between weaning weight and postweaning weights in beef cattle. Weaning weight is known to have positive influences on postweaning growth rate. Evaluation of breeds at postweaning growth phase should take into account variation in weaning weight.

Trail *et al.* (1971b) reported a phenotypic correlation coefficient of 0.84 between weaning weight and 18 month weight. Brinks *et al.* (1964) recorded a phenotypic correlation coefficient of 0.66 between weaning weight and 18 month weight. Brumby et al. (1963) in Australia reported phenotypic correlation coefficients ranging from 0.5 to 0.6 between weaning weight and weight at 21 months. In another study Brinks et al. (1964) found a phenotypic correlation coefficient of 0.45 between weaning weight and mature weight. Christian et al. (1965) reported a phenotypic correlation coefficient of 0.55 between weaning weight and weight at final slaughter. Similar results to those of Brinks et al. (1964) and Christian et al. (1965) were found by Kidner (1966) who reported correlation coefficients ranging from 0.41 to 0.55 between weaning weight and weight at 2.5 years.

From the reports of various workers, there is a general pattern of progressive decrease in correlation coefficients between weaning weight and postweaning weights of beef cattle as they age. The correlation coefficients reported by several workers were highly significant ($P < 0.01$). The significance of these correlation values makes the weaning weight assume considerable economic importance in beef cattle production, indicating that selection for future breeding could be done at weaning stage.

3. MATERIALS AND METHODS

This study is based on the weights of 718 beef cattle at 30 months of age collected from Kiboko and Buchuma Research Stations between 1969 and 1974.

3.1 Climate and Location

Kiboko and Buchuma Research Stations are both located in the arid and semi-arid zone. Pratt, Greenway and Gwynne (1966) classified this area under Eco-climatic zone V.

Buchuma is located about 3.7°S and 38.9°E and is 396 m above sea-level. It has a mean annual rainfall of 630 mm. The soil type is that of dark red sandy loam, latosolic soil. The general area is characterized by red-brown sandy soils overlying undifferentiated Basement system rocks (Saggerson, 1962). Kiboko is located about 2.3°S and 37.8°E and is 1000 m above sea-level. It has a mean annual rainfall of 615 mm. The soil type is that of dark or dark reddish brown loams and sandy clays derived from the Basement system rocks. The location of the two stations is shown in Figure 3.1.

The monthly rainfall figures for the two stations during the 1969 to 1974 period is shown in Table 3.1. The rainfall data for Buchuma Station was obtained from

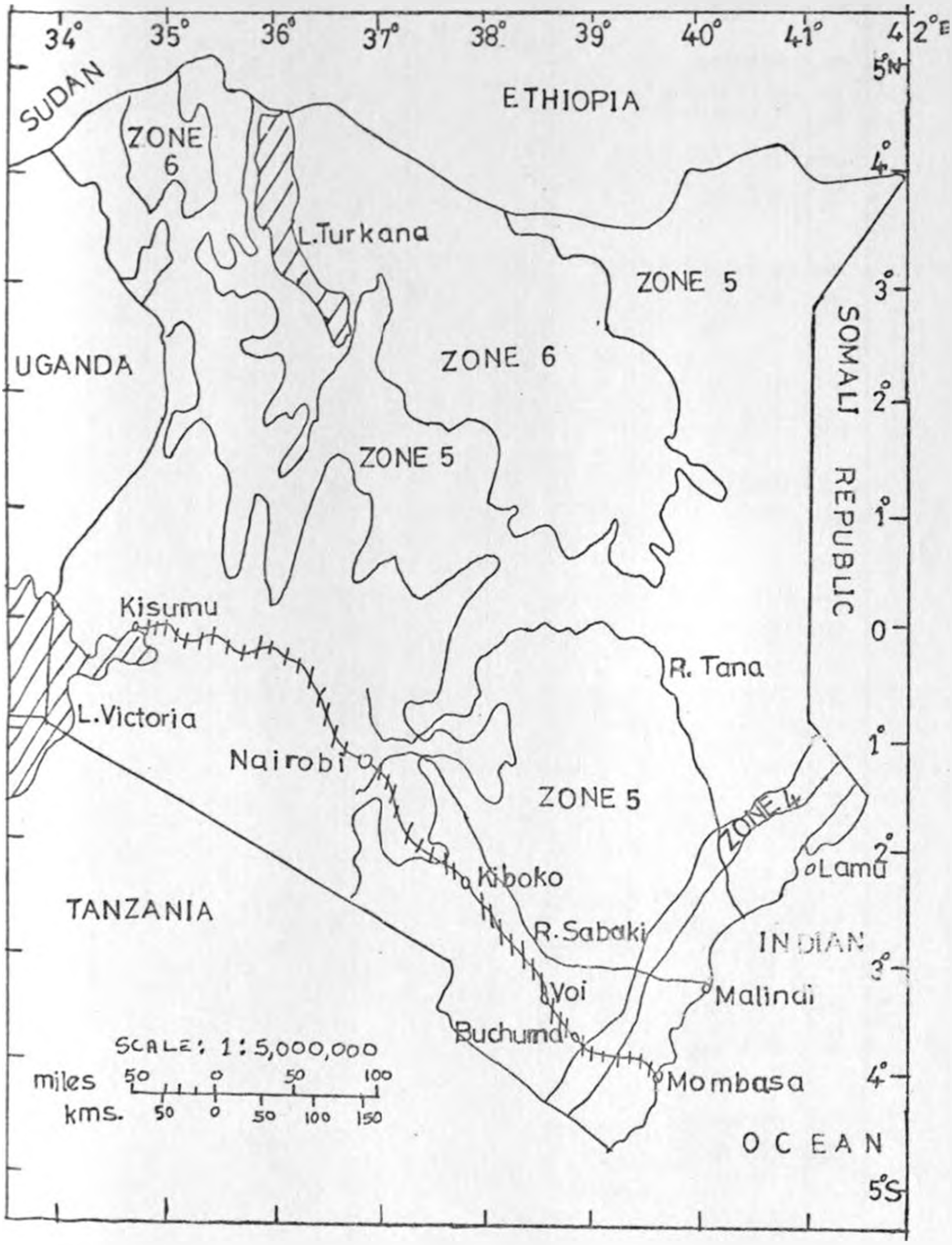

FIGURE 3.1: GEOGRAPHICAL LOCATION OF KIBOKO AND BUCHUMA RANGE RESEARCH STATIONS, KENYA.

Table 3.1 Monthly rainfall figures (mm) from 1969-1974

KIBOKO

Month / Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1969	105.1	61.3	93.5	24.4	3.4	0.0	0.0	0.0	0.0	6.8	204.5	25.1	524.1	43.7
1970	22.7	0.0	148.9	44.3	7.8	0.2	0.0	1.9	0.0	0.0	38.0	0.0	263.8	22.0
1971	24.6	5.0	14.8	243.6	29.9	9.3	0.6	0.4	0.4	2.2	173.5	79.1	583.4	48.6
1972	24.9	24.1	0.6	9.2	13.6	0.0	0.0	0.0	2.4	32.7	243.9	74.5	416.9	34.7
1973	58.4	70.9	81.1	83.4	33.8	0.0	0.0	0.0	1.5	9.5	135.9	3.0	477.5	39.8
1974	13.6	8.9	120.5	94.9	4.8	0.0	0.3	0.3	0.6	15.1	96.5	21.3	376.8	31.4
Mean 1969-74	41.6	28.4	76.6	83.3	15.6	1.6	0.2	0.4	0.8	11.1	148.7	33.8	440.4	36.7

BUCHUMA

Month / Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Mean
1969	63.5	88.7	83.4	49.7	40.6	20.0	5.8	59.6	14.6	42.6	215.1	20.4	692.4	57.7
1970	108.5	0.0	26.2	40.4	36.8	1.4	15.6	9.1	16.1	5.2	11.6	115.8	386.7	32.2
1971	39.7	0.0	37.9	40.9	19.1	44.1	16.7	1.0	19.8	1.3	60.1	22.6	303.2	25.3
1972	79.7	52.9	0.4	19.1	97.1	0.4	26.2	7.8	160.8	64.3	65.0	91.2	664.9	55.4
1973	22.7	31.4	2.3	83.2	53.7	19.3	2.9	11.1	15.2	24.2	34.2	36.7	336.9	28.1
1974	7.1	2.0	51.7	86.0	41.3	15.2	11.7	12.2	7.5	7.3	54.6	86.2	382.8	31.9
Mean 1969-74	53.5	29.2	33.7	53.2	48.1	16.7	13.2	16.8	39.0	24.2	73.4	62.2	461.2	38.4

the adjacent Meteorological Station at Mackinnon Road. The rainfall data for Kiboko station was obtained from Makindu Meteorological Station which is alongside the Research Station.

The rainfall has a bimodal distribution. The long rains usually fall from March to May and short rains from October to early December. Long dry spells from June to September are a common feature of these areas. Short dry spells in January and February is not uncommon.

3.2 Vegetation

The main species of grass found in the two areas under study are as follows:- *Digitaria milanjiana*, *Eragrostis superba*, *Enteropogon macrostychyus*, *Panicum maximum*, *Sporobolus pellucidus*, *Chloris roxburghiana*, *Eragrostis caespitosa*, *Cenchrus ciliaris* and *Themeda triandra*.

The most common woody plants include *Acacia tortilis*, *Acacia brevispica*, *Commiphora africana*, *Commiphora riparia* and *Commiphora aegyptiaca*. Also to be found are Cordia *Spp*., Grewia *Spp*. and Combretum *Spp*. The *Commiphora* species are the dominant trees. They shed their leaves during the dry season but provide shade when in leaf.

Competition for the available forage between the cattle and the wild animals (Zebra, gazelles etc.) is very predominant and becomes stiff in the dry season. Though protected, occasional predation of the cattle occurs from hyenas, leopards and lions.

3.3 Sources of Experimental Animals and Breeding policies

Buchuma Research Station was established in 1968 with a foundation stock consisting of Sahiwal, Boran and EASZ. From 1968 to 1971, there was no definite breeding programme and in 1971, some of these animals were transferred to Kiboko Station to form another foundation stock for the station. In 1971, a three breed rotational crossbreeding programme was simultaneously initiated in Kiboko and Buchuma. In this programme, the Sahiwal and Boran females were mated with Friesian bulls and the F_1 crossbred females were mated to Charolais bulls. The semen used was from Central Insemination Station (C.A.I.S.) Kabete. The East African Shorthorn Zebu (EASZ) females were crossed with Sahiwal and Boran semen from C.A.I.S., Kabete.

In 1972 another group of Boran and EASZ cattle were purchased at Kiboko. Some of the EASZ were crossed with either a Boran or a Sahiwal bull with the aim of upgrading them to the Boran or Sahiwal breed. In this group natural service was used.

At Kiboko the animals were divided into seven herds. Herd one consisted of breeding females for the rotational crossbreeding programme. There were four herds in the upgrading programme. Two of these four herds consisted of Boran and EASZ cattle. The other two consisted of EASZ females running with Boran bulls in one herd and Sahiwal bulls in the other. At Buchuma the cattle were divided into three herds. Herd one consisted of breeding females for the rotational crossbreeding programme. The heifer and steer calves were managed separately after weaning at both Kiboko and Buchuma Stations.

3.4 Management of the herds

The management in Kiboko and Buchuma were similar Initially year-round breeding was practised. In 1974, a 6-month breeding season from January to June was started. This period was later reduced to three months. This period was January to March and April to June at Kiboko and Buchuma respectively. Sire effects were not investigated as source of variation in the liveweight at thirty months of age because many sires were used at the same time in the same herds in both stations.

After birth each calf was identified using a serial number and a code. At the same time the dams' identification numbers and the date of birth of the particular calf were noted. The code for each calf indicated both place and year of birth. The calf serial number and the code were printed on ear-tags and the serial numbers were in addition notched on the ear. Dehorning by hot iron was done to all calves. The males were castrated at the age of 2 to 3 months using a burdizzo.

The calves ran with their dams until they were weaned about 8 months of age. At about 2 years, all the heifers were bred and no selection was carried out on the females. Animals were culled when they were sterile and also on reaching old age when fertility was low. These could form about 2 % of the herds per year. The grazing of the animals was in paddocks demarcated by fire-breaks. During the dry season, the animals were allowed to graze outside these demarcated paddocks. On the average the animals were allowed to graze for about ten hours. At night the animals were put in kraals in order to minimize losses through predation and theft. All the animals were raised entirely on natural pastures without supplementary feeding except for mineral licks given ad libitum in the night kraals. Water was provided in the kraals to prevent wild animals from having access to it.

Routine disease control measures were undertaken. These included dipping/spraying twice a week for all animals except for the very young calves. Regular vaccinations against Anthrax, Black Quarter, Food and mouth, Rinderpest and Brucellosis were carried out. Chemoprophylaxis was provided for trypanosomiasis. All animals were drenched after the rains.

The animals were weighed once a month and the weights recorded in the animals' data cards. This was done until an animal was disposed off.

3.5 Data collection and classification

In this study 718 liveweights of beef cattle at thirty months of age were collected from all animals born from 1969 to 1974. Not all the calves were weighed immediately or within a short time after birth. Some calves were first weighed when they were already 2 weeks of age. The monthly weights were taken using a mobile weighbridge. At both stations, separate data cards were kept for each animal. On each card, the identification number, sex, genotype, identification number of dam, breed of dam, breed of sire and date of, birth of each animal were recorded. The monthly weights were also recorded on this card. It was from these data cards that most of the information needed for this study was extracted and coded for all the 718 animals.

The classification of the data and the number of animals per cell is shown in tables 3.2 and 3.3 for Kiboko data and for both Kiboko and Buchuma data respectively. The number of animals per cell in the first order interaction is shown in appendices A.1 and A.2. Seven genotypes were included in the analysis. These were East African Shorthorn Zebu (EASZ), Sahiwal, Boran, Sahiwal x EASZ, Boran x EASZ, Friesian x Sahiwal and Friesian x Boran. There were few animals born in 1969. For this reason and that of the limited capacity of the computer, it was necessary to combine the year 1969 and 1970. From the preliminary analysis and in

Table 3.2 Classification of the data and the number of animals per cell

KIBOKO

GENOTYPE	SEX	1969/70	1971	1972	1973	1974	TOTAL
EASZ	M	-	-	6	6	5	17
	H	-	-	7	13	12	32
S x EASZ	M	3	2	3	6	1	15
	H	5	3	10	5	12	35
B x EASZ	M	-	-	4	9	2	15
	H	3	-	4	14	10	31
S	M	13	5	4	3	-	25
	H	24	15	4	11	5	59
B	M	5	-	4	17	11	37
	H	-	-	3	16	2	21
F x S	M	4	3	17	31	19	74
	H	7	14	18	46	16	101
F x B	M	11	7	23	19	7	67
	H	32	14	14	14	12	86
TOTAL		107	63	121	210	114	615

M = Steers, H = Females, F = Friesian, S = Sahiwal, B = Boran and
EASZ = East African Shorthorn Zebu.

Table 3.3 Classification of the data and the number of animals per cell

KIBOKO AND BUCHUMA

Genotype	Sex	1969/70	1971	1972	1973	1974	Total
S	M	13	5	4	3	-	25
	H	24	15	4	11	5	59
F x S	M	4	3	17	31	19	74
	H	7	14	18	46	16	101
F x B	M	11	7	23	19	7	67
	H	32	14	14	14	12	86
Total		91	58	80	124	59	412

M = Steers, H = Females, F = Friesian, S = Sahiwal, B = Boran.

order to test more interactions, the limited capacity of the program necessitated the combination of the years 1969/70 with those of 1971/72 in analysis two. The age of dam at birth was classified into 2 to 3, 4 to 5, 6 to 7 and 8 and over with a total number of animals of 120, 272, 172 and 154 for each subclass respectively.

The seasons were classified according to the amount of rainfall. In East Africa, the mean monthly precipitation needed to stimulate pasture growth was found to be 50 mm (Morgan, 1969). However, this figure is too high for range areas where pasture growth is very sensitive to slight precipitation. 35 mm was therefore used to classify a month dry or wet. Table 3.4 shows the classification of months into dry or wet for all the years in the study. A consideration was given to the subclass of month of birth, month preceeding birth and month following birth. This gave a maximum of 6 seasons composed of 3 months each; 2 of these 6 seasons were grouped with others to facilitate analysis as shown in Table 3.5.

3.6 Method of analysis

After a series of preliminary analyses, the live-weights at thirty months of age of the beef cattle were analysed in two models. This was primarily due to the limited capacity of the computer used. In the first analysis data on three genotypes common to the two places

Table 3.4: Classification of months into wet or dry

	KIBOKO						BUCHUMA						
Year / Month	1969	1970	1971	1972	1973	1974	Year / Month	1969	1970	1971	1972	1973	1974
Jan.	W	D	D	D	W	D	Jan.	W	W	W	W	D	D
Feb.	W	D	D	D	W	D	Feb.	W	D	D	W	D	D
March	W	W	D	D	W	W	March	W	D	W	D	D	W
April	D	W	W	D	W	W	April	W	W	W	D	W	W
May	D	D	D	D	D	D	May	W	W	D	W	W	W
June	D	D	D	D	D	D	June	D	D	W	D	D	D
July	D	D	D	D	D	D	July	D	D	D	D	D	D
Aug.	D	D	D	D	D	D	Aug.	W	D	D	D	D	D
Sept.	D	D	D	D	D	D	Sept.	D	D	D	W	D	D
Oct.	D	D	D	D	D	D	Oct.	W	D	D	W	D	D
Nov.	W	W	W	W	W	W	Nov.	W	D	W	W	D	W
Dec.	D	D	W	W	D	D	Dec.	D	W	D	W	W	W

W = Wet (monthly rainfall > 35 mm).
D = Dry (monthly rainfall ≤ 35 mm).

Table 3.5: Seasonal classification based on three months

Nature	Season	Comment: Animals born
WWW	1	During rainy season
WWD WDD	2	During end of rainy season
DDD	3	During dry season
DDW DWW	4	During end of dry season

Key: D = Dry month ($\leq$ 35 mm)
W = Wet month (> 35 mm)

were analysed. In the second analysis, only Kiboko data were analysed including all the seven genotypes.

The analyses were carried out on the I.C.L. computer of the Institute of Computer Science, University of Nairobi. The computer programme used was "SYSNOVA" written by Seebeck (1976). This programme carries out an analysis of variance and covariance for non orthogonal data, and fits a regression model based on the method described by Harvey (1960).

In the first analysis of the liveweights at thirty months of age of the beef cattle, the following model was used:-

$$Y_{ijklmno} = u + a_i + b_j + c_k + d_l + f_m + g_n + (ac)_{ik} + (af)_{im} + (ag)_{in} + (fg)_{mn} + (bg)_{jn} + (cg)_{kn} + (dg)_{ln} + h(H_{ijklmno} - \bar{H}) + e_{ijklmno}$$

and the following model was used for the second analysis:-

$$Y_{ijklmo} = u + a_i + b_j + c_k + d_l + f_m + (ac)_{ik} + (af)_{im} + (fd)_{ml} + (ad)_{il} + h(H_{ijklmo} - \bar{H}) + e_{ijklmo}$$

Where $Y_{ijklm(n)o}$ = Liveweight of the o^{th} animal at 30 months.

u = Effect common to all animals.

a_i = Effect of the i^{th} genotype of the animal.

b_j = Effect of the j^{th} age of dam at birth.

c_k = Effect of the k^{th} season of birth.

d_l = Effect of the l^{th} year of birth.

f_m = Effect of the m^{th} sex of the animal.

g_n = Effect of the n^{th} place of birth.

$(ac)_{ik}$ = Effect of the i^{th} genotype x k^{th} season of birth interaction.

$(af)_{im}$ = Effect of the i^{th} genotype x m^{th} sex of the animal interaction.

$(ag)_{in}$ = Effect of the i^{th} genotype x n^{th} place of birth interaction.

$(fd)_{ml}$ = Effect of the m^{th} sex of the animal x l^{th} year of birth interaction.

$(fg)_{mn}$ = Effect of the m^{th} sex of the animal x n^{th} place of birth interaction.

$(ad)_{il}$ = Effect of the i^{th} genotype x l^{th} year of birth interaction.

$(bg)_{jn}$ = Effect of the j^{th} age of dam at birth x n^{th} place of birth interaction.

$(cg)_{kn}$ = Effect of the k^{th} season of birth x n^{th} place of birth interaction.

$(dg)_{ln}$ = Effect of the l^{th} year of birth x n^{th} place of birth interaction.

h = Partial regression coefficient of liveweight at 30 months of age on weaning weight.

$H_{ijklm(n)o}$ = Independent continuous variable weaning weight.

$\bar{H}$ = Mean weaning weight.

$e_{ijklm(n)o}$ = Effect peculiar to an animal

The mean square for each factor was calculated when simultaneously all other effects were removed. An F-test was done to see if the main effects or the two way interactions of the main effects had any significant effect on the liveweight at 30 months. Chi-square values (χ^2) were also given for homogeneity of within cell variances. For greater than 100 degrees of freedom, the formula below was used (Thomson, 1941).

$$\chi^2_p = \tfrac{1}{2} (Z_p + \sqrt{2V - 1})^2$$

Where χ^2_p and Z_p are the p^{th} percentiles of the Chi-square and normal distributions respectively and V is the number of degrees of freedom.

The programme generated standard errors of contrast between levels of treatments. These were used to test for significant differences between treatment levels. The difference between the coefficients of two levels divided by their respective standard errors of the contrast gives a value distributed as "t" for the residual degrees of freedom. For treatments with more than two levels this test tends to give too high a level of significance. Some caution should therefore be exercised when trying to interpret borderline significant results.

The percentage contribution to the total variation in weights was calculated for each of the main effects, the covariates and the interactions. The mean squares calculated by the programme were converted to sum of squares by multiplying them by their respective degrees of freedom. Each of the sum of squares obtained was then expressed as a percentage of the total sum of squares.

These percentages were taken as the respective contributions of each of the main effects, the covariates and the interactions to the total variation of the weight examined.

4. RESULTS

4.1 First analysis: The analysis of 3 genotypes at Kiboko and Buchuma.

Table 4.1: The analysis of variance of liveweights at 30 months of age and % contribution of individual effects to total variation.

Source of Variation	DF	Mean square	% Contribution
Genotype	2	545.56	0.20
Age of dam at birth	3	1210.78	0.65
Season of birth	3	2202.62	1.19
Year of birth	4	22151.23**	15.95
Sex	1	1192.59	0.21
Place	1	9477.47**	1.71
Weaning weight	1	144509.70**	15.17
Interactions:			
Genotype x season	6	4481.16**	4.84
Genotype x sex	2	1668.64	0.60
Genotype x place	2	1272.17	0.46
Sex x place	1	185.60	0.03
Age x place	3	2736.27	1.48
Season x place	3	1424.77	0.77
Year x place	4	4179.91*	3.01
All sources	36	12241.34	46.27
Residual	375	1364.41	53.73
Remaining Interactions	207	1402.38	
Within cell residual	168	1317.64	

* = $P< 0.05$ ** = $P< 0.01$

Homogeneity of residual within cell variance χ^2 = 70.68

DF = 97 R^2 = 0.4627

The results of the first analysis are shown in Table 4.1. These indicate that the liveweights of beef cattle studied at 30 months of age are significantly affected by weaning weight, place and year of birth, genotype x season and year x place interactions.

Weaning weight as a continuous variable and the year of birth contributed 15.17% and 15.95% respectively to the total variation in weight. In a preliminary analysis, a high correlation coefficient of 0.55 between weaning weight and liveweight at 30 months was found.

The comparisons of the years and places are shown in Table 4.2.

The influence of the years 1969 through 1972 was significantly different from that of the years 1973 and 1974 as shown in Table 4.2. The Figure 4.1.A indicates that the years 1973 and 1974 were the least favourable years of birth while 1971 was the most favourable. The animals born in 1971 and 1973 were 22.89 kg and 30.66 kg above and below the corrected mean respectively. Buchuma animals were 17.40 kg heavier than Kiboko animals as shown in Figure 4.1.B.

The Sahiwal and its cross with Friesian were 0.50 kg and 2.12 kg above the corrected mean respectively. The Friesian x Boran were 2.62 kg below the corrected mean. The effects of genotype, sex, season of birth and age of dam at birth were not significant on the weights.

The results of the first analysis are shown in Table 4.1. These indicate that the liveweights of beef cattle studied at 30 months of age are significantly affected by weaning weight, place and year of birth, genotype x season and year x place interactions.

Weaning weight as a continuous variable contributed almost all the variation that was accounted for (R^2) by the model used. In a preliminary analysis, a high correlation coefficient of 0.55 between weaning weight and liveweight at 30 months was found.

The comparisons of the years and places are shown in Table 4.2.

The influence of the years 1969 through 1972 was significantly different from that of the years 1973 and 1974 as shown in Table 4.2. The Figure 4.1.A indicates that the years 1973 and 1974 were the least favourable years of birth while 1971 was the most favourable. The animals born in 1971 and 1973 were 22.89 kg and 30.66 kg above and below the corrected mean respectively. Buchuma animals were 17.40 kg heavier than Kiboko animals as shown in Figure 4.1.B.

The Sahiwal and its cross with Friesian were 0.50 kg and 2.12 kg above the corrected mean respectively. The Friesian cross with Boran were 2.62 kg below the corrected mean. The effect of genotype, sex, season of birth and age of dam at birth had no significant influence on the liveweights.

Table 4.2: The differences and their standard errors between LSQ-constants for the individual years and places.

	1971	1972	1973	1974	BUCHUMA
1969-70	6.75 ± 10.43	0.85 ± 10.07	46.80*** ± 8.48	41.50*** ± 9.15	
1971		5.90 ± 11.80	53.55*** ±10.59	48.25*** ±10.50	
1972			47.65*** ± 8.13	42.35*** ± 9.22	
1973				5.30 ± 7.63	
KIBOKO					17.40**± 6.60

** = P < 0.01 *** = P< 0.001

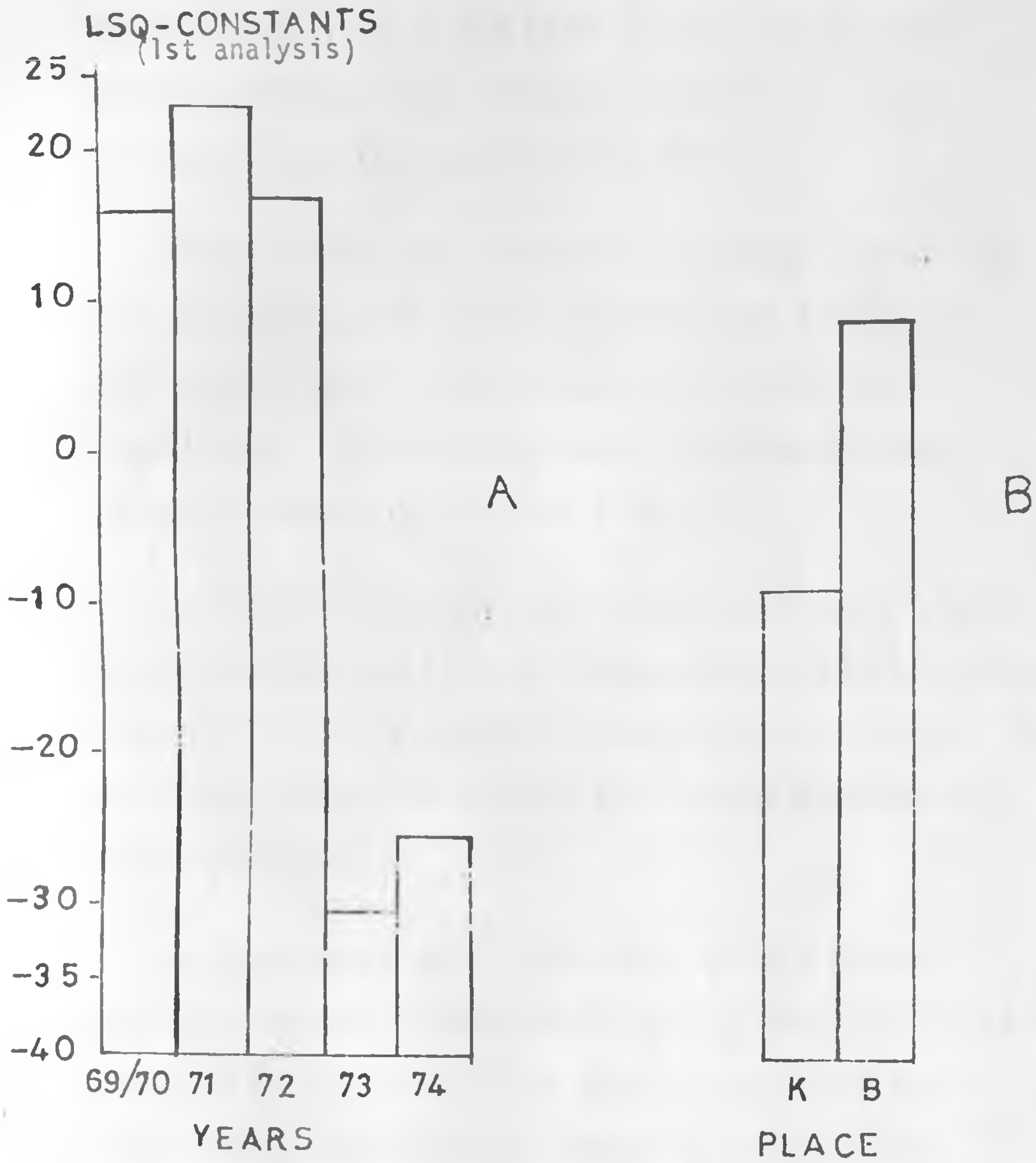

Fig. 4.1 Influence of year of birth and place of birth on liveweight at 30 months of age.

K = Kiboko B = Buchuma

The least square constants for the genotype x season interaction effects are shown in Figure 4.2. Of the animals born during the end of the wet season, the Sahiwal were 5.10 kg below the corrected mean. The Friesian crosses with Sahiwal and Boran were 11.40 kg and 18.30 kg above the corrected mean respectively. The difference between the heaviest and lightest genotypes was 23.40 kg (7.40 %).

Of the animals born during the wet season, Sahiwal and Friesian crosses with Sahiwal and Boran were 8.00 kg and 7.80 kg above and 17.90 kg below the corrected mean respectively. The difference between the heaviest and lightest genotypes was 25.90 kg (8.50 %).

As regards the animals born in the dry season, Friesian x Sahiwal, Sahiwal and Friesian x Boran were 0.90 kg and 11.70 kg above and 11.90 kg below the corrected mean respectively. The difference between the heaviest and lightest genotypes was 23.60 kg (7.59 %).

Of the animals born at the end of the dry season, Friesian x Sahiwal, Sahiwal and Friesian x Boran were 11.70 kg and 12.60 kg below and 0.90 kg above the corrected mean respectively. The difference between the heaviest and lightest genotypes was 13.50 kg (4.36%).

All the genotypes were heaviest for all the animals born during the end of the wet season except for the Sahiwal. All the genotypes were lightest for all the animals born

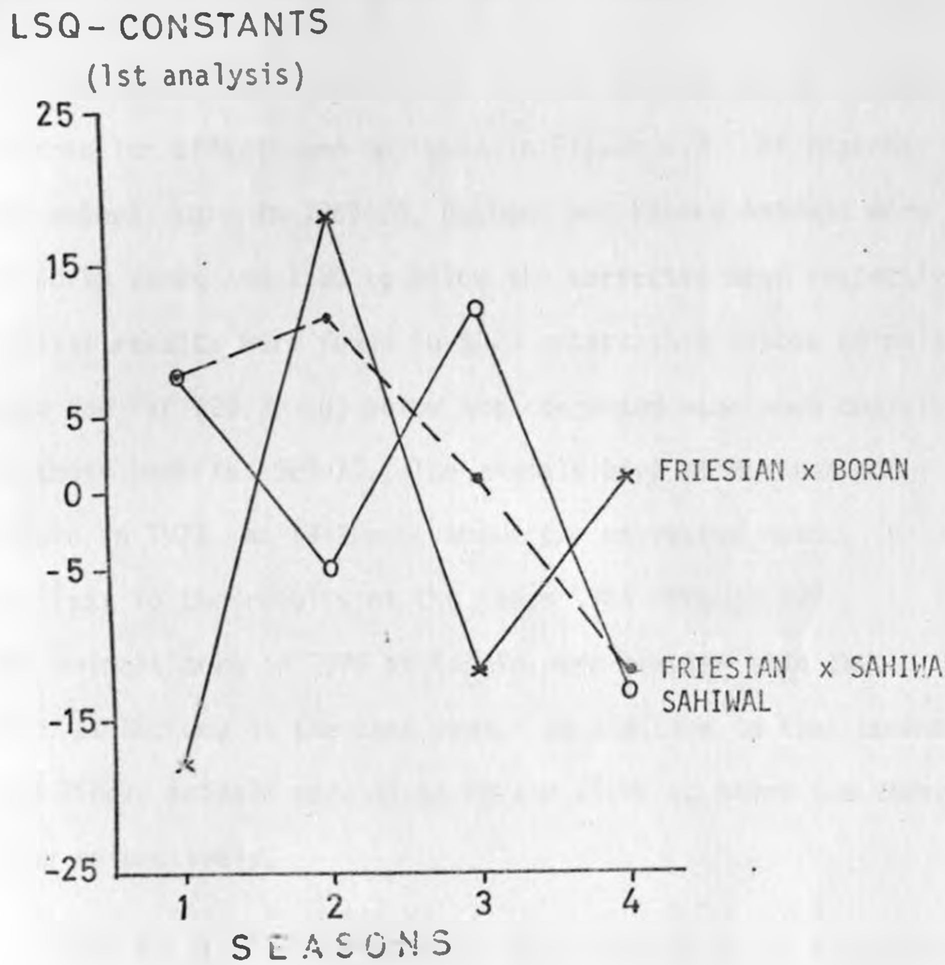

Fig. 4.2 Liveweights at 30 months of age least square constants for season of birth computed between genotypes.

SEASONS:

1. Wet season
2. End of wet season
3. Dry season
4. End of dry season

during the end of the dry season except for the Friesian x Boran. As shown in Figure 4.2, the heaviest Sahiwal animals were those born during the dry season while the lightest Friesian x Boran animals were those born during the wet season.

The least square constants for the year of birth x place interaction effects are depicted in Figure 4.3 As regards the animals born in 1969-70, Buchuma and Kiboko animals were 33.60 kg above and 1.30 kg below the corrected mean respectively. Similar results were found in 1973 except that Kiboko animals were too far (29.30 kg) below the corrected mean when compared to those born in 1969-70. The animals born at Buchuma and Kiboko in 1971 and 1972 were above the corrected mean. In contrast to the results of the years 1969 through 1973, the animals born in 1974 at Kiboko were heavier than those born at Buchuma in the same year. In addition to that Buchuma and Kiboko animals were 31.80 kg and 19.00 kg below the corrected mean respectively.

The results indicated that there were no other interactions left out of the model which had significant influence on the liveweights at 30 months.

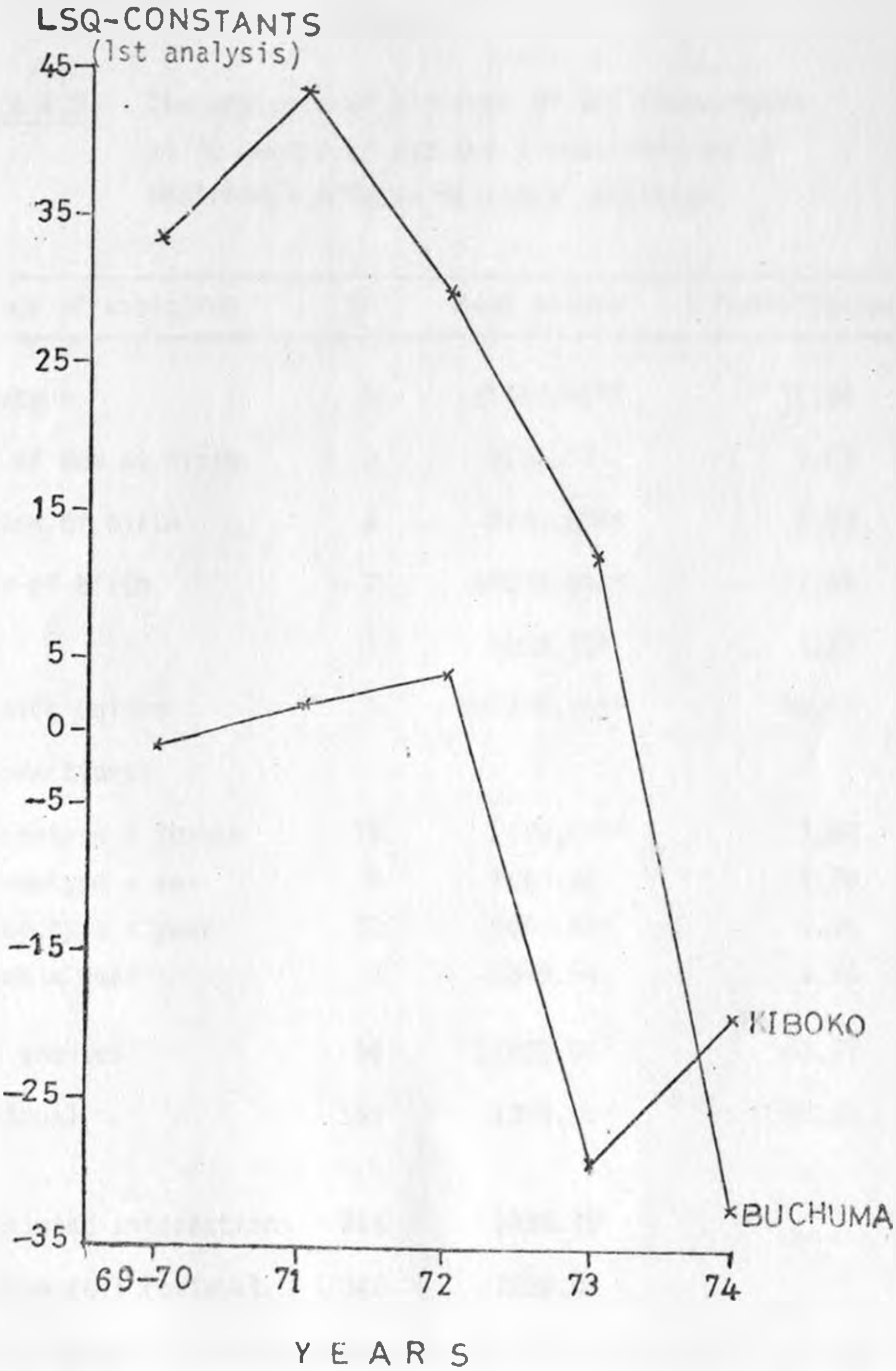

Fig. 4.3 Liveweights at 30 months of age least square constants for year of birth computed between places of birth.

4.2 Second analysis: The analysis of 7 genotypes at Kiboko.

Table 4.3: The analysis of variance of the liveweights at 30 months of age and % contribution of individual effects to total variation.

Source of variation	DF	Mean square	% Contribution
Genotype	6	11477.65**	12.34
Age of dam at birth	3	3110.77	1.67
Season of birth	3	6741.83**	3.63
Year of birth	2	48579.99**	17.41
Sex	1	7094.12*	1.27
Weaning weight	1	207792.10**	10.51
Interactions:			
Genotype x season	18	2459.67**	7.94
Genotype x sex	6	1583.86	1.70
Genotype x year	12	2465.56*	5.30
Sex x year	2	2049.54	0.74
All sources	54	22892.56	62.51
Residual	560	1324.05	37.49
Remaining Interactions	218	1487.19	
Within cell residual	342	1220.06	

* = $P < 0.05$ ** = $P < 0.01$

Homogeneity of residual Within cell Variance $\chi^2 = 111.72$

DF = 143 $R^2 = 0.6251$

The results of the second analysis are shown in Table 4.3. They indicate that weaning weight, genotype, season of birth, year of birth and sex had a significant effect on the liveweights at 30 months. Of the four interactions tested, two were significant. These were genotype x season of birth and genotype x year of birth interactions.

Similar to the results of the first analysis, the weaning weight and the year of birth had relatively large contributions of 10.51% and 17.41% respectively to the total variation in weight.

The comparison between the genotypes is shown in Table 4.4.

Crossing the East African Shorthorn Zebu (EASZ) with Sahiwal and Boran improved the liveweights by 8.24 kg and 16.44 kg respectively. However, this improvement was not significant. Similarly by crossing Friesian with Sahiwal and Boran, there was no significant improvement in the weights at 30 months. The Sahiwal and Boran, and their crosses with Friesian were significantly heavier than the EASZ and its crosses with Sahiwal and Boran. The least square constants for genotype effects are depicted on Figure 4.4.A. The Sahiwal and its cross with Friesian are shown to have the heaviest weights. This result is similar to that found in the first analysis.

The comparison of the years and sexes is shown in Table 4.5.

Table 4.4: The difference and its standard error between LSQ-constants for individual genotypes

	S x EASZ	B x EASZ	S	B	F x S	F x B
EASZ	8.24 ± 10.88	16.44 ± 10.38	49.10*** ± 11.84	30.80* ± 11.84	46.25*** ± 9.12	36.02*** ± 9.43
S x EASZ		8.20 ± 9.76	40.86*** ± 10.33	22.61* ± 11.12	38.01*** ± 8.22	27.78*** ± 8.45
B x EASZ			32.66*** ± 9.00	14.41 ± 10.76	29.81*** ± 7.03	19.58** ± 7.59
S				18.25 ± 11.38	2.85 ± 8.30	13.08 ± 8.53
B					15.40 ± 9.30	5.17 ± 9.52
F x S						10.23 ± 5.06

* = P< 0.05 ** = P< 0.01 *** = P< 0.001

EASZ = East African Shorthorn Zebu, S = Sahiwal, B = Boran, F = Friesian

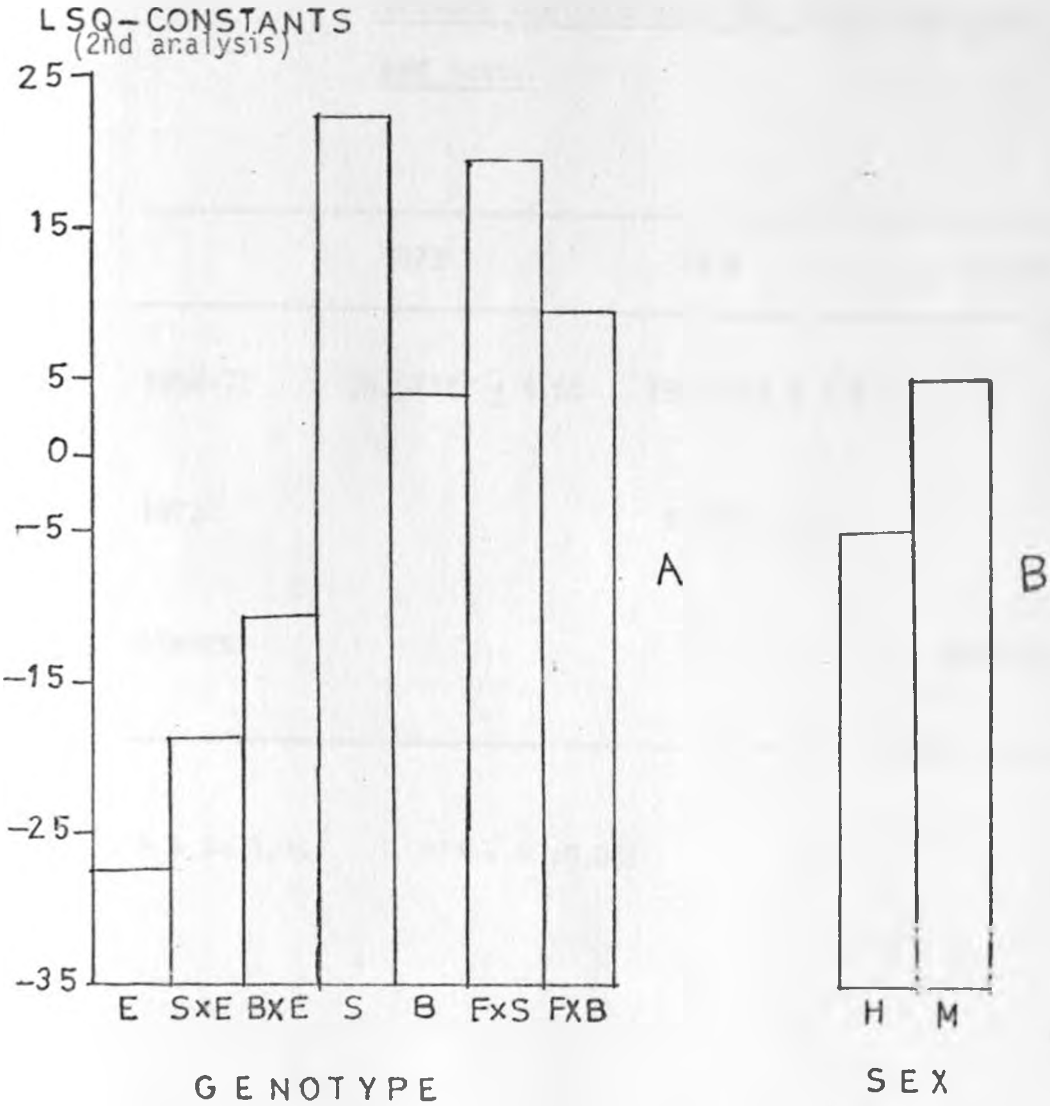

Fig. 4.4 Influence of genotype and sex on liveweight at 30 months of age.

E = East African Shorthorn Zebu F = Friesian
S = Sahiwal B = Boran H = Females M = Steers

Table 4.5: The differences and their standard errors between LSQ-constants for individual years and sexes.

	1973	1974	Females
1969-72	38.07*** ± 4.55	28.35*** ± 6.07	
1973		9.72 ± 6.16	
Steers			9.68* ± 4.19

* = P< 0.05 *** = P <0.001

In contrast to the result of first analysis, steers were significantly heavier than females by 9.68 kg.

The least square constants for year effects are shown in Figure 4.5.B. The animals born during 1969-72 were significantly heavier than those born in 1973-74. Both 1973 and 1974 were found the least favourable years of birth. This is what was also found in first analysis.

The comparison of the seasons is shown in Table 4.6.

Table 4.6: The difference and its standard error between LSQ-constants for individual seasons.

	End of wet	Dry	End of dry
Wet	0.25 ± 7.86	7.62 ± 7.29	19.85* ± 7.82
End of wet		7.37 ± 4.70	19.60*** ± 5.39
Dry			12.23** ± 4.63

* = $P < 0.05$ ** = $P < 0.01$ *** = $P < 0.001$

The weights of the animals born in wet, end of wet and dry seasons were not significantly different but were significantly greater than those of animals born during the end of dry season.

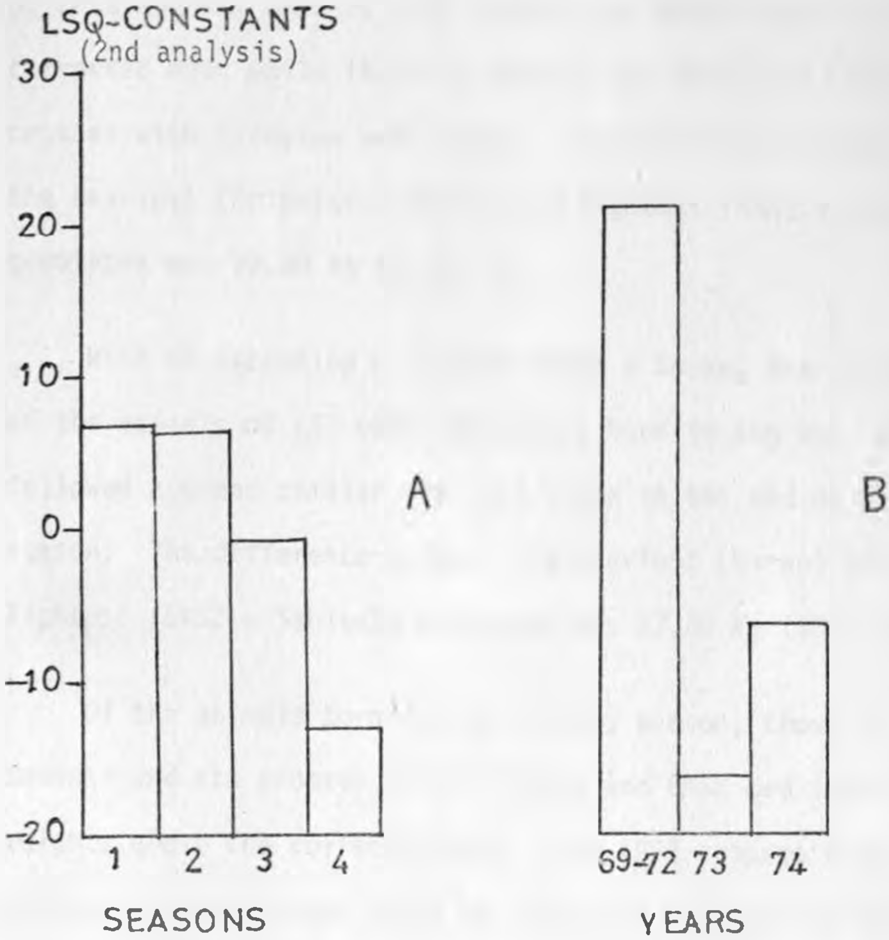

Fig. 4.5 Influence of season of birth and year of birth on liveweight at 30 months of age.

SEASONS:
1 Wet season
2 End of wet season
3 Dry season
4 End of dry season

The genotype x season of birth interaction effects are shown in Figure 4.6. In the end of wet season, the weights of EASZ and its crosses with Sahiwal and Boran were below the corrected mean while those of Sahiwal and Boran, and their crosses with Friesian were above. The difference between the heaviest (Friesian x Boran) and lightest (EASZ x Sahiwal) genotypes was 59.80 kg (21.66 %).

With an exception of the Friesian x Boran, the performance of the animals of all other genotypes born in the wet season followed a trend similar to that found in the end of wet season. The difference between the heaviest (Boran) and lightest (EASZ x Sahiwal) genotypes was 77.30 kg (30.67 %).

Of the animals born during the dry season, those of Sahiwal and its crosses with Friesian and EASZ had their weights above the corrected mean. The EASZ crosses with Sahiwal and Boran were 32.90 kg and 24.10 kg heavier than EASZ respectively. The difference between the heaviest (Sahiwal) and lightest (EASZ) genotypes was 56.20 kg (22.31 %).

Animals with lowest body weights were those born during the end of dry season for all the genotypes except Friesian x Boran and EASZ x Sahiwal. The genotypes which had their weights above the corrected mean were Sahiwal and Friesian crosses with Sahiwal and Boran. The difference between the heaviest (Friesian x Boran) and lightest (EASZ) genotypes was 51.30 kg (21.32 %). The end of dry season was found the least favourable season of birth in first and second analyses.

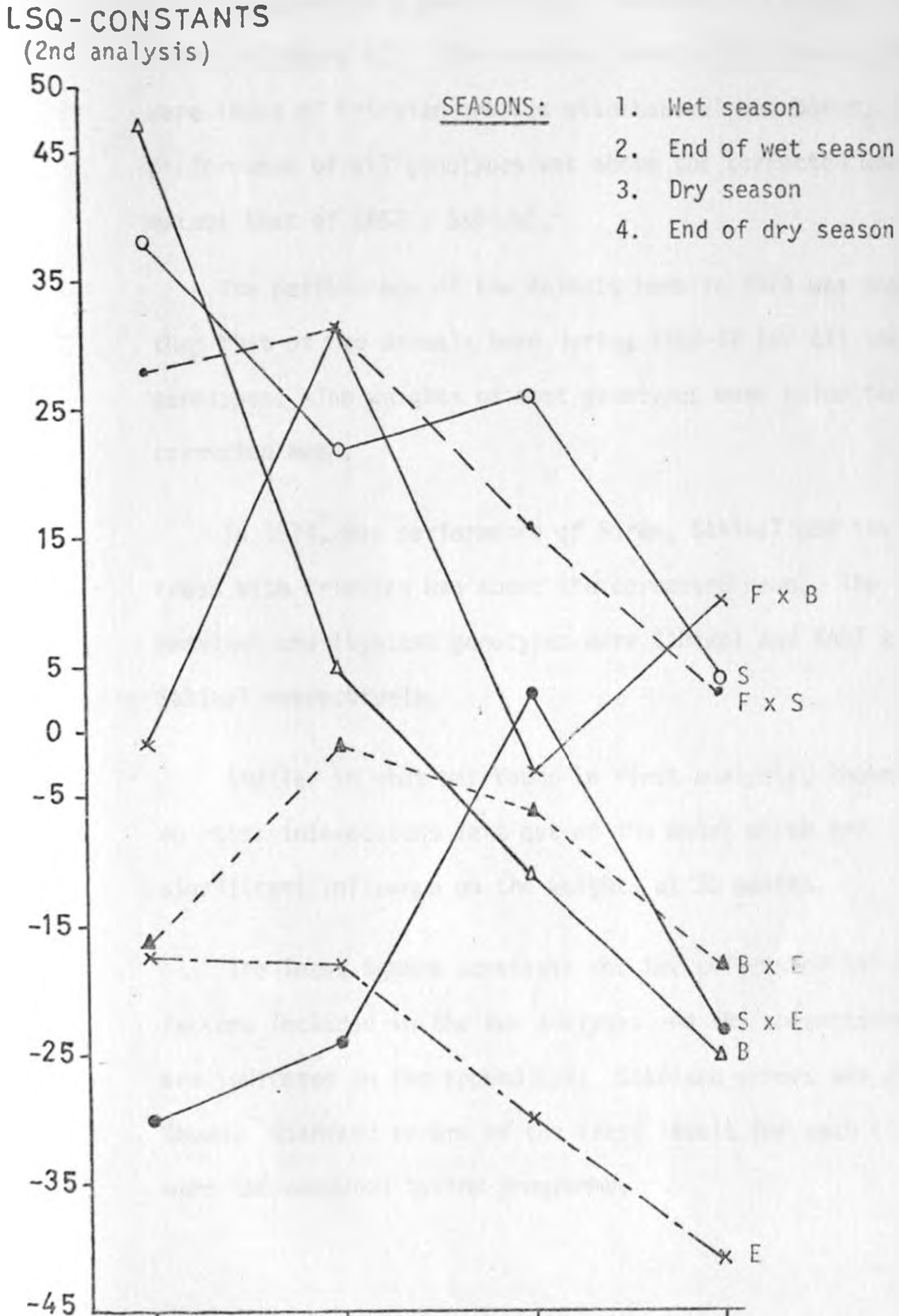

Fig. 4.6 Liveweights at 30 months of age LSQ-constants for seasons computed between genotypes.

E = East African Shorthorn Zebu F = Friesian
S = Sahiwal B = Boran

The genotype x year of birth interaction effects are shown in Figure 4.7. The heaviest animals born during 1969-72 were those of Friesian crosses with Sahiwal and Boran. The performance of all genotypes was above the corrected mean except that of EASZ x Sahiwal.

The performance of the animals born in 1973 was poorer than that of the animals born during 1969-72 for all the genotypes. The weights of most genotypes were below the corrected mean.

In 1974, the performance of Boran, Sahiwal and its cross with Friesian was above the corrected mean. The heaviest and lightest genotypes were Sahiwal and EASZ x Sahiwal respectively.

Similar to what was found in first analysis, there were no other interactions left out of the model which had significant influence on the weights at 30 months.

The least square constants for the effects of all the factors included in the two analyses and the corrected means are indicated in the appendices. Standard errors are also shown. Standard errors of the first levels for each treatment were not computed by the programme.

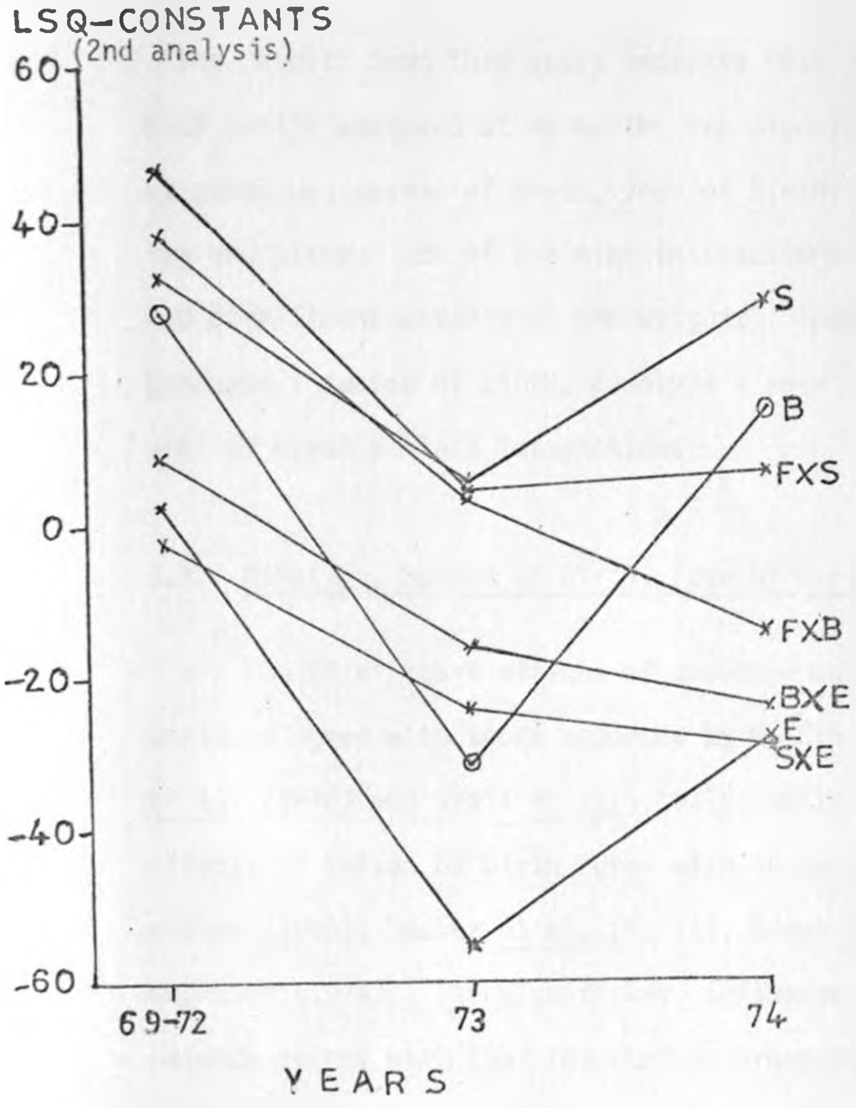

Fig. 4.7 Liveweights at 30 months of age LSQ-constants for years computed between genotypes.

E = East African Shorthorn Zebu
F = Friesian S = Sahiwal B = Boran

5. DISCUSSION AND CONCLUSIONS

The results from this study indicate that the weights of beef cattle analysed at 30 months are significantly influenced by genotype, season of birth, year of birth, weaning weight, sex and place. Out of the nine interactions tested three had significant effects on the weights. These were the genotype x season of birth, genotype x year of birth and year of birth x place interactions.

5.1 Genotype, Season of Birth, Year of Birth and Place

The significant effects of genotype on the weights analysed agree with those reported by Meadie (1969), Trail et al. (1971) and Trail et al. (1971a) while the significant effects of season of birth agree with those reported by Kidner (1966), Sacker et al. (1971a), Brown et al. (1972) and Tonn (1974). The significant influence of year on the weights agrees with that reported by Greogry et al. (1966), Sacker et al. (1971a, 1971b), Brown et al. (1972), Tonn (1974), Lapworth et al. (1976), Laster et al. (1976) and ILCA (1977).

The significant interactions of genotype with both season and year of birth indicate that the genotypes cannot be discussed in isolation without reference to the respective seasons and years of birth. The significant place effects need also to be discussed in reference to the years of birth of the animals of the seven genotypes.

The results from both analyses indicate that some seasons of birth had greater effects on some genotypes than others. There was also a change in the order of merit of the genotypes when animals were compared in all the seasons. For instance the animals that were heaviest in the wet, end of wet, dry and end of dry seasons were Boran, Friesian crosses with Sahiwal and Boran, Sahiwal and Friesian x Boran genotypes respectively. All the animals born in the end of the dry season were lightest at 30 months except Friesian x Boran and Sahiwal x East African Shorthorn Zebu (EASZ). This was found the least favourable season of birth for most of the genotypes. The most suitable season of birth for the Sahiwal, Boran and EASZ breeds was the wet season. This period could be between mid October and mid December thus suggesting a breeding season of January to the end of March at Kiboko and Buchuma. The suggested wet season of birth falls within the short rain season. The effect of the wet season in terms of pasture growth and its availability to the animals is not immediately felt. The pastures need 6 - 8 weeks to grow to a stage when they can be effectively grazed by the animals. The suitability of the wet season as the season of birth for the Sahiwal, Boran and EASZ could have the following explanation. It indicates the adaptability of the dams of the three breeds to the dry and the end of dry seasons before birth when compared to the dams of all other genotypes. The dams of

Sahiwal, Boran and EASZ are able to cope with the dry environment and thereby do not lose condition as much as other genotypes. By calving during the wet season, the dams are able to regain their body weights when they graze on the pastures which are abundant at this period. The calves are also able to attain high growth rates through the utilization of the available pastures beside the dams' milk supply.

The most suitable season of birth for the Friesian x Sahiwal, Friesian x Boran and Boran x EASZ genotypes was the end of the wet season which could be from December through January. This would mean having a breeding season of March through April. The end of the wet season is associated with plenty of pastures of high nutritive value. The dams of the three genotypes are able to regain their lost body weights during the wet season. They are also able to build up body reserves as the wet season progresses. At the end of the wet season, the dams give birth to calves of good condition and high birth weights. By calving at the end of the wet season both the dams and their calves are able to benefit from the available forage. Such a favourable season of birth enables the three genotypes exploit heterosis effects. Such effects would be reflected in the growth rates of the calves upto 30 months. This result indicates clearly the importance of adequate nutrition for the calf before and after calving. The wet season means good maternal environments for the calves while the end of the wet season of birth implies abundant pastures of high quality for the calves.

The most suitable season of birth identified for the Sahiwal x EASZ genotype was the dry season. This season could be in January and February thus suggesting a breeding season of April and May. Both January and February fall within the short dry season. Both July and August are dry months and fall within the long dry season which is commonly known for its severity and is at times prolonged. If the cows are bred to calve during the two months, the calves would be from undernourished dams and would also have less pastures of low nutritive value to graze on. By calving in January and February, the Zebu dams are therefore able to build up and maintain their body reserves throughout the wet and the end of the wet seasons. During the dry season, unless very long and severe, there is still some grass although of deteriorating nutritive value. The Sahiwal x EASZ calves are therefore able to benefit from both the milk of their Zebu dams and the available grass. The heterosis effect could also play a part in enhancing the growth rates of these animals. The Sahiwal and the EASZ are known and have been found (National Animal Husbandry Research Station, Annual Report, 1974) to be adapted to the harsh environmental conditions which are common in range areas. This possibly helps to explain why the Sahiwal x EASZ cross was outstanding when born during the dry season and compared to the rest of the seasons.

The end of the dry season was found the least favourable season of birth. This season is associated with diminished pastures of low nutritive value. The effect of this, is loss in condition of the dams. The calves are born weak and have low birth weights. Such seasonal effects lead to reduced growth rates and when severe, loss in body weights.

Initially, at Kiboko and Buchuma, there was an all round breeding season which was reduced to 6 months (January to June). Allen (1973) tentatively suggested breeding seasons of 3 months: January to March at Kiboko and April to June at Buchuma for all the genotypes. The whole breeding period found in this study falls between January and May. This agrees well with the recommendations of Allen (1973) except that in Allen's case the genotype x season of birth interaction was not given consideration. Currently, the breeding season starts from mid January to end of May at both Kiboko and Buchuma. It is, however, essential to consider the change in the ranking of the genotypes through the influence of season of birth. This would enable the ranchers under ecological zone V to breed their animals during the most favourable seasons to improve beef production. The significance of the genotype x season of birth interaction shows that seasons of birth cannot be recommended without reference to the genotypes kept for beef production at Kiboko and Buchuma.

The performance of the genotypes varied from year to year. The ranking changes that were found significant were those of Boran and EASZ. For instance in 1973, the Boran animals were found second lightest while in 1974 they were second heaviest when compared to other genotypes. Similar results were found with EASZ animals which were lightest when born in 1973 and second lightest when born in 1974.

The differences in years of birth were found to have greater effects on some genotypes than others. This is well illustrated when we compare the performances of Sahiwal with Boran, Friesian x Sahiwal with Friesian x Boran and Boran x EASZ with EASZ. In all these pairs of genotypes, the year differences between 1973 and 1974 had greater effects on the former than the latter genotypes. Although there was drought in 1973 and 1974, the Boran animals born in 1974 showed a better performance than those animals of same genotype born in 1973. This suggests that there were favourable conditions prevailing in 1974, despite the drought, which enhanced the growth of the Boran animals. In genotype evaluation involving animals born in different years, there is, therefore, need to correct for genotype x year of birth interaction effects since the performance of the genotypes is significantly influenced by the years of birth of the animals.

The year of birth effects were found dependent on place of birth within the same ecological zone V. It would, therefore, be erroneous to compare the performance of the animals at Kiboko with those at Buchuma without considering the year of birth x place interaction. The significance of this interaction could arise from slight differences in management practices and rainfall amount and distribution at Kiboko and Buchuma in each year. In situations where cattle are not supplemented, which is not uncommon in arid and semi-arid areas, the body weights of animals seem to vary with the amount and distribution of rainfall in each year. The amount of rainfall and its distribution determines the quantity and quality of pastures in each particular year and this is also different from place to place.

The severe drought of 1973 - 76 was experienced in both Kiboko and Buchuma. The animals born in 1974 at Kiboko were, however, heavier than those born at Buchuma in the same year. The results of 1973 indicate the contrast. In order to compare the performance of beef animals born in several places, it is essential to take into account the year of birth x place interaction to meaningfully evaluate the merit of the genotypes.

When the EASZ cows were crossed with Sahiwal and Boran, the improvement in body weights realised was 8.24 kg (3.23 %) and 16.44 kg (6.44 %) respectively. In arid and semi-arid areas, the majority of the farmers keep the small EASZ. In upgrading their small EASZ stock to either Sahiwal or Boran, they would be able to increase the growth rates of their stock upto the age of 30 months.

5.2 Weaning Weight

Weaning weight had a highly significant effect on the weights analysed at 30 months. In this study, a high phenotypic correlation coefficient of 0.55 was obtained between weaning weights and the weights studied. Similar high phenotypic correlation coefficients were reported by various workers using postweaning weights. Brumby et al. (1963);

Brinks et al. (1964); Christian et al. (1965) and Kidner (1966) reported phenotypic correlation coefficients of 0.5 - 0.6, 0.45 and 0.66, 0.55 and 0.41 - 0.55, respectively. They were analysing body weights at 21 months, 18 months and slaughter weight, final slaughter weight and 30 months respectively.

In all the beef cattle studies reviewed, there was an observed tendency for a decrease in the phenotypic correlation coefficients between the weaning weights and all the postweaning weights as the experimental animals aged. The high phenotypic correlation coefficients indicate a positive and significant influence of weaning weight on postweaning weights and growth rates. Some workers have shown weaning weight to have medium to high heritability estimate. Swiger et al. (1965), Dinkel and Busch (1973) Tonn (1976) and Neumann (1977) have reported heritability values of 0.58, 0.40, 0.30 and 0.30 respectively thus indicating that selection for higher weaning weights would lead to rapid improvement in the trait. Weaning weight has, therefore, some economic importance in beef production.

In both analyses weaning weight accounted for a large proportion of the total variation in the weight examined. The positive and significant influence of weaning weight suggests that selection could be done at weaning age as was also suggested by Mwandotto (1978). The significant effect of weaning weight means that correction for this trait in genotype evaluation is essential. The weaning weight has some positive correlation with the milk production and the mothering ability of the dams prior to weaning. In postweaning growth studies, it is possible to identify the factors that influence the weights of beef animals before slaughter. Despite the high significance of weaning weights on post-weaning weights as found in this study, the postweaning weights could still be used for selection since such weights reflect not only the inherent genetic potential of the animal but also its adaptability to the imposed environment after weaning. However, when it is not economically feasible to wait for selection at a postweaning stage, this study has shown that selection could be done at weaning. In fact, dams are currently selected on the basis of their calves' weaning weights in most of the ranches in Kenya.

5.3 Sex

Weight differences of 4.68 kg (1.45%) and 9.68 kg (3.43 %) were found in this study between steers and heifers for first and second analyses respectively. The sex differences in body weights were expected since a poorer performance from females compared to males is expected from their sex hormone balance. The predominating secretion of oestrogens from the ovaries has a depressing effect on growth rate (Mathews, Schwabe and Emery, 1942).

The sex differences found in this study were significant only in second analysis. In all, the sex differences found were smaller than are reported in the literature (Mathews et al., 1942; Bradley et al., 1966; Sacker et al., 1971a and Naivasha (N.A.H.R.S.) Annual Report, 1974). The small sex differences could be due to the early time of castration (Brown, 1960 and Sacker et al., 1971a) and the impact of the severe drought of 1973-76.

5.4 Age of dam at birth

The age of dam at birth had no significant effect on the weights analysed at 30 months. This result agrees with those of Hidiroglon et al. (1966), Sacker et al. (1971b), Brown et al. (1972), Tonn (1974) and Rudder et al. (1975). Other research workers reported negligible age of dam effects on postweaning weights and growth (Swiger, 1961; Brinks et al., 1962; Vorster, 1964 and Burgess and Bowman, 1965). The tendency is for age of dam to have effect on preweaning upto weaning performance.

The age of dam is part of maternal effect. This effect would be expected to diminish with age as the animal gets old. The performance of weaned calves would therefore be a reflection of the inherent potential of the calf and its adaptability to the environment. Over 83% of the dams studied were over 4 years old at calving. Most of them were, therefore, already mature at calving and possibly at their peak of milk production. Tonn (1974) associated early peak of milk production with accelerated aging process of the cows under predominantly difficult environmental conditions of the range areas.

5.5 Conclusions

The results of this study show that the weights analysed are significantly affected by weaning weight, genotype, season of birth, year of birth, sex, place and the following interactions: genotype x season, genotype x year and year x place. For accurate evaluation of the genetic potential of beef cattle, there is need to consider and correct for environmental factors.

The weights of Sahiwal, Boran, Friesian x Sahiwal and Friesian x Boran were not significantly different. The East African Shorthorn Zebu (EASZ) crosses with Sahiwal and Boran were heavier than EASZ. Upgrading of the EASZ to the Sahiwal and Boran through continued backcrossing to Boran and Sahiwal is recommended in ecological zone V. Such an upgrading programme would significantly improve the growth rates of the calves upto 30 months of age.

The age of dam at birth had no significant influence on the weights studied. It seems, therefore, that at later ages after weaning, we do not need to correct for this effect.

The wet season was found the most favourable season of birth for the Sahiwal, Boran and EASZ. This could be mid October to mid December, thus suggesting a breeding season of mid January to mid March. The most suitable season of birth for the Friesian x Sahiwal, Friesian x Boran and Boran x EASZ was the end of the wet season. This could be

December to the end of January, thus suggesting a breeding season of March and April. For the Sahiwal x EASZ, the most suitable season of birth was the dry season. This could be in January and February, thus suggesting a breeding season of April and May. Therefore Kiboko and Buchuma can continue to breed their animals from January to May because of mixed genotypes and in other related areas, actual months of breeding depend on actual breeds (genotypes) kept.

In the first and second analyses, the weaning weight as a continuous variable contributed 15.17% and 10.51%, respectively to the total variation in the weight examined at 30 months of age. The positive and significant influence of the weaning weight on the weights at 30 months means that selection of heifers for breeding could be done at weaning or a few months after weaning.

For breeds (genotypes) recommendations to be valid, there is also need for their evaluation over many years in view of the significant genotype x year of birth interaction. Further research is needed in getting more accurate data on the survival rates of the various genotypes upto 30 months or more of age than was possible in this study. This would aid in assessing the adaptability of the genotypes to the arid and semi-arid areas and thereby evaluate their overall performance to slaughter. An economic study should also be incorporated to assess the carcass qualities of the animals after slaughter at the prevailing prices. This would enable the ranchers in ecological zone V to relate their profits to the production costs per genotype and hence calculate whether it would be economically feasible to effect supplementation programmes on more paying genotypes (breeds) in times of droughts.

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7. APPENDICES

Appendix A.1: Cross-tabulations (1st analysis)

Genotype x Season:

Seasons	Wet	End of wet	Dry	End of dry	Total
Friesian x Boran	21	34	56	42	153
Friesian x Sahiwal	20	32	66	57	175
Sahiwal	10	23	43	8	84
Total	51	89	165	107	412

Place x Season:

Seasons	Wet	End of wet	Dry	End of dry	Total
Kiboko	38	58	146	67	309
Buchuma	13	31	19	40	103
Total	51	89	165	107	412

Genotype x Place:

	Friesian x Boran	Friesian x Sahiwal	Sahiwal	Total
Kiboko	118	120	71	309
Buchuma	35	55	13	103
Total	153	175	84	412

Appendix A.1. Cont'.......

Age x Place:

	2-3 years	4-5 years	6-7 years	$\geq$ 8 years	Total
Kiboko	80	109	61	59	309
Buchuma	12	23	31	37	103
Total	92	132	92	96	412

Sex x Place

	Steers	Females	Total
Kiboko	122	187	309
Buchuma	44	59	103
Total	166	246	412

Year x Place:

	1969-70	1971	1972	1973	1974	Total
Kiboko	81	50	70	91	17	309
Buchuma	10	8	10	33	42	103
Total	91	58	80	124	59	412

Appendix A.2.: Cross-tabulation (2nd analysis)

Genotype x Season:

Seasons	Wet	End of wet	Dry	End of dry	Total
EASZ	2	11	18	18	49
Sahiwal x EASZ	4	8	23	15	50
Boran x EASZ	2	9	21	14	46
Sahiwal	10	23	43	8	84
Boran	7	21	20	10	58
Friesian x Sahiwal	20	32	66	57	175
Friesian x Boran	21	34	56	42	153
Total	66	138	247	164	615

EASZ = East African Shorthorn Zebu.

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Appendix A.3.: Least square coefficients ± standard error for treatments in the first analysis (kg)

Corrected mean	322.46 ± 48.14*

Main effects

Genotype:

Friesian x Boran	- 2.62
Friesian x Sahiwal	2.12 ± 3.74
Sahiwal	0.50 ± 5.25

Place of birth:

Kiboko	- 8.70
Buchuma	8.70 ± 3.30

Appendix A.3. Cont'.....

Sex:

Steers 2.34
Females - 2.34 ± 2.50

Season of birth:

Wet - 0.67
End of wet 8.18 ± 5.55
Dry 0.27 ± 4.94
End of dry -7.78 ± 4.89

Age of dam:

2-3 years 4.89
4-5 years -0.22 ± 4.07
6-7 years -6.18 ± 3.99
≥ 8 years 1.51 ± 3.85

Year of birth:

1969-70 16.14
1971 22.89 ± 7.37
1972 16.99 ± 6.21
1973 -30.66 ± 4.98
1974 -25.36 ± 5.53

Covariate:

Weaning weight 0.67 ± 0.07

Interactions:

Genotype x Sex:

GE_2 x Sx_2 2.35 ± 2.82
GE_3 x Sx_2 1.75 ± 3.61

Genotype x Place:

GE_2 x PL_2 -[illegible].33 ± 3.71
GE_3 x PL_2 6.92 ± 5.24

Sex x Place:

Sx_2 x PL_2 - 0.84 ± 2.29

Genotype x Season:

GE_2 x SE_2 6.38 ± 5.78
GE_3 x SE_2 8.22 ± 7.85
GE_2 x SE_3 -1.51 ± 4.40
GE_3 x SE_3 10.86 ± 5.50
GE_2 x SE_4 -5.98 ± 5.26
GE_3 x SE_4 -5.30 ± 7.70

Season x Place:

SE_2 x PL_2 -7.03 ± 4.95
SE_3 x PL_2 3.04 ± 4.6[illegible]
SE_4 x PL_2 5.33 ± 3.86

Age of dam x Place:

DA_2 x PL_2 4.09 + 4.09
DA_3 x PL_2 1.35 ± 4.02
DA_4 x PL_2 -9.05 ± 3.81

Year x Place:

YR_2 x PL_2 12.19 ± 7.42
YR_3 x PL_2 4.23 ± 6.14
YR_4 x PL_2 -10.10 ± [illegible].9[illegible]
YR_5 x PL_2 -15.13 ± 5.36

*Standard deviation

Appendix A.4.: Least square coefficients ± Standard error for treatments in the second analysis (Kg.)

Corrected mean	281.97 ± 53.75*

Main effects

Genotype:

EASZ	-26.70
Sahiwal x EASZ	-18.46 ± 6.64
Boran x EASZ	-10.26 ± 5.96
Sahiwal	22.40 ± 6.83
Boran	4.15 ± 7.67
Friesian x Sahiwal	19.55 ± 3.90
Friesian x Boran	9.32 ± 4.34

Sex:

Steers	4.84
Females	-4.84 ± 2.09

Season of birth:

Wet	6.93
End of wet	6.68 ± 5.34
Dry	-0.69 ± 2.93
End of dry	-12.92 ± 3.52

Age of dam:

2-3 years	2.41
4-5 years	-1.11 ± 2.66
6-7 years	-7.18 ± 3.19
≥ 8 years	5.88 ± 3.09

Year of birth:

1969-72	22.14
1973	-15.93 ± 2.99
1974	- 6.21 ± 3.79

Covariate:

Weaning weight 0.70 ± 0.06

Interactions:

Genotype x season:

$GE_2 \times SE_2$	- 18.32 ± 13.61
$GE_3 \times SE_2$	36.26 ± 18.71
$GE_4 \times SE_2$	8.71 ± 10.27
$GE_5 \times SE_2$	- 12.99 ± 10.66
$GE_6 \times SE_2$	1.19 ± 7.[illegible]3
$GE_7 \times SE_2$	- 17.17 ± 7.83

Genotype x year:

$GE_2 \times YR_2$	10.20 ± 8.48
$GE_3 \times YR_2$	-19.08 ± 7.02
$GE_4 \times YR_2$	- 0.62 ± 8.25
$GE_5 \times YR_2$	10.26 ± 6.90
$GE_6 \times YR_2$	1.13 ± 4.35
$GE_7 \times YR_2$	10.59 ± 5.56

Appendix A.4. Cont'......

$GE_2 \times SE_3$	21.95 ± 7.76
$GE_3 \times SE_3$	- 14.16 ± 8.93
$GE_4 \times SE_3$	4.38 ± 6.35
$GE_5 \times SE_3$	4.95 ± 7.32
$GE_6 \times SE_3$	- 2.60 ± 4.87
$GE_7 \times SE_3$	- 11.85 ± 5.00
$GE_2 \times SE_4$	8.79 ± 9.17
$GE_3 \times SE_4$	- 16.40 ± 9.84
$GE_4 \times SE_4$	- 5.76 ± 9.73
$GE_5 \times SE_4$	5.22 ± 9.64
$GE_6 \times SE_4$	- 3.74 ± 5.23
$GE_7 \times SE_4$	13.61 ± 5.69

Sex x Year:

$Sx_2 \times YR_2$	4.22 ± 2.42
$Sx_2 \times YR_3$	- 2.69 ± 3.01

$GE_2 \times YR_3$	- 4.30 ± 8.48
$GE_3 \times YR_3$	17.34 ± 8.14
$GE_4 \times YR_3$	12.34 ± 11.07
$GE_5 \times YR_3$	- 6.95 ± 8.24
$GE_6 \times YR_3$	- 6.37 ± 5.43
$GE_7 \times YR_3$	- 17.18 ± 6.43

Genotype x Sex:

$GE_2 \times Sx_2$	4.20 ± 5.66
$GE_3 \times Sx_2$	- 0.18 ± 5.61
$GE_4 \times Sx_2$	4.82 ± 4.70
$GE_5 \times Sx_2$	- 3.04 ± 5.04
$GE_6 \times Sx_2$	5.00 ± 3.11
$GE_7 \times Sx_2$	- 0.34 ± 3.30

* Standard deviation

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Appendix A.5.: Least square constants for year of birth computed between places (1st analysis)

	1969-70	1971	1972	1973	1974
Kiboko	- 1.3	2.0	4.0	- 29.3	- 19.0
Buchuma	33.6	43.8	30.0	11.9	- 31.8

Appendix A.6.: Least square constants for season of birth computed between genotypes (1st analysis)

Seasons	Wet	End of wet	Dry	End of dry
Friesian x Boran	-17.9	18.3	-11.9	0.9
Friesian x Sahiwal	7.8	11.4	0.9	-11.7
Sahiwal	8.0	- 5.1	11.7	-12.6

Appendix A.7.: Least square constants for season of birth computed between genotypes (2nd analysis)

Seasons	Wet	End of wet	Dry	End of dry
EASZ	-17.5	-17.9	-30.1	-41.3
Sahiwal x EASZ	-29.9	-24.3	2.8	-22.6
Boran x EASZ	-16.4	- 0.8	- 6.0	-18.0
Sahiwal	38.0	21.8	26.[illegible]	3.7
Boran	47.4	5.2	-10.7	-25.1
Friesian x Sahiwal	27.7	31.4	16.3	3.0
Friesian x Boran	- 1.0	31.5	- 3.3	10.0

EASZ = East African Shorthorn Zebu

Appendix A.8.: Least square constants for year of birth computed between genotypes (2nd analysis)

Years	1969-72	1973	1974
EASZ	2.5	-55.0	-27.6
Sahiwal x EASZ	-2.2	-24.3	-29.0
Boran x EASZ	8.5	-15.9	-23.5
Sahiwal	32.8	5.9	28.5
Boran	28.1	-30.8	15.3
Friesian x Sahiwal	47.0	4.8	7.0
Friesian x Boran	38.0	5.0	-14.1

EASZ = East African Shorthorn Zebu