FACTORS AFFECTING WEANING WEIGHT OF THE SMALL EAST AFRICAN SHORTHORN ZEBU, BORAN, SAHIWAL, BORAN X E.A.S.Z., SAHIWAL X E.A.S.Z., FRIESIAN X BORAN AND FRIESIAN X SAHIWAL CATTLE AT KIBOKO AND BACHUMA (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 weaning weights of 1054 calves was analysed by the least squares method for fitting constants for non-orthogonal data, to estimate the effect of genotype, sex, year of birth, season of birth, age of dam, birth weight, weaning age and some two-way interactions of the main effects on weaning weights of beef calves. The data were collected at Kiboko and Bachuma Range Research Stations from 1971 through 1976.

The corrected mean weaning weights were 153.61 ± 32.48 kg. for 3 genotypes at Kiboko and Bachuma and 139.64 ± 34.74 kg. for 7 genotypes at Kiboko.

Genotype, sex, year of birth, birth weight and weaning age had significant effect on weaning weights ($P < 0.01$). Age of dam was also significant ($P < 0.05$). For the 7 genotypes at Kiboko and 3 genotypes at Kiboko and Bachuma, these had the following estimated contributions to the total variation in weaning weights respectively:- genotype 0.24 and 0.12%, sex 0.05 and 0.12%, year of birth 0.32 and 1.22%, weaning age 8.74 and 39.73%, birth weight 47.74% and age of dam 0.02%. Station and season of birth had no significant effect on weaning weights.

Of the 14 first order interactions tested, 2 had a significant effect on weaning weights ($P < 0.01$). These were year x place and year x season of birth. They contributed an estimated 0.23% and 0.44% respectively to total variation in weaning weights for

the 3 genotypes at Kiboko and Bachuma and year x season contributed an estimated 0.09% to the variation in the weaning weights for the 7 genotypes at Kiboko.

Friesian X Sahiwal crosses were 9.49% heavier than pure Sahiwal and Friesian X Boran crosses 10.19% heavier than pure Boran at weaning. Sahiwal X East African Shorthorn Zebu and Boran X East African Shorthorn Zebu crosses were 3.59 and 2.65% heavier respectively at weaning than the pure East African Shorthorn Zebu.

Steers were 8.10 and 8.42 kg. (5.42% and 6.19%) heavier than heifers at weaning for the 3 genotypes at Kiboko and Bachuma and the 7 genotypes at Kiboko respectively.

1972 had the highest weaning weights and 1975-76 had the lowest weights. The difference in weights between these extreme years were 36.50 kg. (30.82%) and 41.23 kg. (32.08%) for the 7 genotypes at Kiboko and the 3 genotypes at Kiboko and Bachuma respectively.

Calves born of cows which were two and three years old had the lowest weaning weights, and peak weaning weights were from calves born of cows which were six and seven years old. After this age of dam, weaning weights tended to decline.

Calves which were heavier at birth were also heavier at weaning. A linear regression coefficient of 1.562 ± 0.221 was found between weaning weight and birth weight for the 7 genotypes at Kiboko.

Older calves were heavier than younger ones at weaning. Linear regression coefficients of 0.234 $\pm$ 0.074 and 0.181 $\pm$ 0.058 were found between weaning weights and weaning age for the 3 genotypes at Kiboko and Bachuma and the 7 genotypes at Kiboko respectively.

In 1972 and 1974 Kiboko animals were heavier at weaning than Bachuma animals but in 1971, 1973 and 1975-1976 Bachuma animals had heavier weaning weights than Kiboko animals.

Generally, animals born in dry season had heavier weaning weights than those born in wet season. This was however not the case for both Kiboko and Bachuma genotypes in 1972. For the 7 genotypes at Kiboko, animals born in wet season in 1975 and 1976 were heavier at weaning than those born in dry season.

1. INTRODUCTION

About 80% of Kenya's land surface is semi arid or arid. In these areas, arable agriculture is too risky and therefore livestock production is the major enterprise. Nearly 60% of the country's estimated 9.9 million cattle are found in these areas. The predominant breed of cattle is the East African Shorthorn Zebu. This breed of cattle is highly adapted to adverse environmental conditions. It is more heat tolerant, resistant to endemic diseases and can withstand periodic malnutrition better than the exotic cattle breeds. Comparatively, it has a better water economy and can cope with walking longer distances than the exotic breeds. A great disadvantage of this breed however is its low productivity. Trail, Sacker and Fisher (1971 a and 1971 b) have shown that this breed has small body weights and low growth rates.

In order to improve beef production in the semi arid and arid areas of Kenya, two government research stations were established in these areas. One is situated at Kiboko and the other one at Bachuma. The main objective in the establishment of these stations was to identify suitable breeds and management practices for beef production in the arid areas. Research work along these lines was started in Bachuma in 1968 and in Kiboko in 1971.

In this study, weaning weights were analysed with the following objectives:-

a) to identify the main factors causing variation in weaning weights

b) to compare genotypes from a crossbreeding programme in Kiboko and Bachuma

c) to find the most suitable breeding season(s) in these semi arid and arid zones, and

d) to investigate any significant interactions between some of the main factors

2. LITERATURE REVIEW

2.1. Weaning weight

Most of the work in systematic crossing of breeds and in breed evaluation has been done in developed countries. Little similar work has been done in developing countries on the local breeds and their crosses with either other indigenous stock or exotic breeds.

It is important that animals be 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. Hassall (1970) concluded that in commercial beef production, the important measure is to locate the genetic material which performs best under the specific conditions of production.

Production traits of importance for beef production in the tropics are preweaning and postweaning growth rate, fertility and adaptability to environmental stress including endemic diseases. In this study, weaning weight is analysed. The trait is of importance because it represents kilograms of production per cow per year.

Tonn (1974) reported a heritability estimate of 0.30 in weaning weight in the Boran breed. Cruz (1973) reported an estimate of 0.25 and Mortojo (1973) reported heritability estimates ranging from 0.26 to 0.67 for different breeds of cattle. Wilson, Dinkel, Ray and

Minyard (1963) reported a heritability estimate in weaning weight of 0.38 while a higher estimate of 0.58 was reported by Swiger, Gregory, Sumption, Breidenstein and Arthaud (1965). This means that this trait will give a moderate response to selection.

Weaning weight is more a trait of the dam than that of the calf (Damon, Harvey, Singletary, McCraine and Brown, 1961). This is because it is strongly influenced by maternal effects such as milk production. Jeffrey, Berg and Hardin (1971) showed that 40 to 50% of variation in weaning weight was due to milk yield of the dam. Weaning weights are therefore suitable for selecting dams for their performance in rearing calves.

Weaning weights are significantly correlated with birth weights. Tonn (1976) reported a genetic correlation of 0.65 between the two traits. A similar figure of 0.63 was reported by Koch and Clark (1955). This indicates that if selection is made on the basis of weaning weights, birth weights will also be increased. Significant correlations also exist between weaning weights and weights at different ages. A genetic correlation of 0.54 between weaning weight and yearling weight was reported by Koch and Clark (1955). Swiger *et al.* (1965) and Wilson *et al.* (1963) reported a genetic correlation of 0.86 and 0.33 respectively between weaning weight and final weight. A significant genetic correlation in these traits was also reported by Blackwell, Knox, Shelby and Clark (1962), Brinks, Clark, Kieffer and Quesenberry (1962) and Nelson and Cartwright

(1968). It can be seen then that selection on weaning weight basis improves also other beef traits of economic importance.

2.2. Factors affecting cattle weaning weights

2.2.1. Genotype

Animal genotype has been shown in many studies to affect weaning weight. The tendency is for big breeds like the Charolais to weigh more at weaning than the light breeds (Preston and Willis, 1974). Meade, Kidder, Koger and Crockett (1963) working in Florida with 933 calves of 9 genotypes of beef cattle observed a significant breed effect on weaning weights. Variation in this trait of up to 45.1 kg. was caused by the breed effect. The weights in this study were adjusted to 205 - day weaning weights. Brahman - Angus crosses were heaviest and pure Angus lightest. Brahman - Devon crosses were average.

In another study Kennedy and Chirchir (1971) working with crosses of Brahman, Africander and British breeds found also that breed effect had a significant influence on weaning weight of calves. Difference between the three crosses ranged from 13.7 kg. to 28.1 kg. Brahman crosses were heaviest and the British breed crosses (Shorthorn-Hereford) the lightest. In an experiment in Ethiopia designed to test various crosses of animals, records of 149 crossbreeds and 227 pure Zebu showed that crossbreeds were 23.6% heavier at weaning than the pure Boran Zebu (Wagner, Holland and Mogess, 1969).

Weaning weights have been shown to be affected significantly by breed of sire, dam and own genotype in Uganda (Trail, Sacker and Fisher, 1971). Tonn (1974) reported similar results in range conditions of Kenya ranches. In the case of dams this effect could mainly be due to differences in maternal effects of the dams. Gaines, McClure, Vogt, Carter and Kincaid (1966) reported that maternal effects played an important role in affecting weaning weights. Trail et al. (1971) showed that progenies of Aberdeen Angus and Red Poll sires were significantly heavier at weaning than those of Boran sires in Uganda. In the same study, progenies of Boran and Ankole dams were heavier than those of Zebu dams at weaning. Tonn (1974) reported that crossing Boran with Charolais, Simmental and Friesian raised weaning weights of the cross by 15 to 25%. He also showed that crossbred dams in Kenya produced calves which were 8 to 28% heavier at weaning than pure Boran calves. Significant breed effects in weaning weights have also been reported by Gregory, Swiger, Koch, Sumption, Ingalls, Rowden and Rothlisburger (1966) and by Vernon, Harvey and Warwick (1964).

2.2.2. Sex

Sex has a definite effect on weaning weight. Male calves tend to be heavier at weaning than female calves. Male hormones (androgens) are dominant in males and oestrogens are dominant in females. Velardo (1958) reported that androgens increase the rate of synthesis of new protein and organic elements. This anabolic effect which comes as a result of increased retention of nitrogen and other tissue forming materials such as potassium, calcium and phosphorus has also been reported by Bell, Davidson and Scarborough (1970). Male animals have also been shown to have a higher basal metabolic rate than females (Mitchell, 1967). This makes male animals have higher appetites than females. The overall effect of all these factors is that males grow faster than females. Mortojo (1973) working with large numbers of animals and herds of Angus, Hereford, Santa Gertrudis and Brahman showed that sex contributed a significant 4.2% of the total variation in weaning weight. Brown (1960) recorded sex difference in weaning weight ranging from 10 to 25.9 kg. These calves were heavily supplemented. This could have enhanced considerably sex difference in weaning weight due to group feeding which favours the males more than females. Seventeen percent of total variation in weaning weight was accounted for by sex of calf by Cundiff, Willham and Pratt (1966).

Pahnish, Stanley, Bogart and Roubicek (1961) working with purebred Hereford in two ranches in Arizona, showed weaning weight difference between sexes to range from 20 to 45 kg. in one ranch and 24 to 35 kg. in the other. They were working with uncastrated bull calves which could have contributed to the big weight ranges. Meade <u>et al</u>. (1963) showed sex to affect weaning weights significantly with bull calves being 5.1 kg. heavier than steer calves which were also 9.2 kg. heavier than heifer calves. A significant difference of 14.5 kg. at weaning between steers and heifers was reported by Sacker, Trail and Fisher (1971) and of 15.8 kg. by Tonn (1974).

2.2.3. Year of birth

Year of birth effects on weaning weights can arise due to changes in the physical environment from year to year or in management regimes. Rainfall changes is one such factor. The amount and distribution of rainfall affects the amount and quality of forage available to dams and their calves. This phenomenon is even more dramatic in range areas where management practices are such that changes in nutrition status cannot be offset easily by supplementary feeding of the animals. Management practices which can vary from year to year are weaning age, castration age, grazing regimes and disease control.

Year of birth showed greatest effect on weaning weight in the factors analysed by Meade et al. (1963) with a range from 123.5 to 189.3 kg. A difference between the best and worst years of 27.2 kg. was reported by Sacker et al. (1971) and of 33.6 kg. by Tonn (1974). Of the total variation in weaning weight reported by Mortojo (1974), 0.9% was due to year effects. Kennedy and Chirchir (1971) recorded high variations in weaning weight ranging from 161.3 kg. in 1965 to 195.3 kg. in 1968. Part of this variation due to years was explained by weaning age which varied between years. Significant year effects in weaning weights were also reported by Pahnish *et al.* (1961), Harwin, Brinks and Stonaker (1966), Gregory *et al.* (1966) and Cruz (1973).

2.2.4. Season and month of birth

Season and month of birth have also been shown to affect weaning weights. The same factors causing variation in weaning weights of animals due to years also operate for seasons. Their management implications are however different. Physical year effects are beyond the scope of a farmer to change but seasonal effects within year can be overcome by identifying suitable breeding season(s) so as to maximise weaning weights. In Kenya, the basis of seasonal classification is normally on previous records of either dry or wet months. These seasons are therefore closely related to abundancy of natural fodder and hence weaning production of calves.

Brown (1960) in Arkansas reported that 1.6 to 9.3% of total variation in weaning weights was due to season of birth. Cundiff *et al.* (1966) reported 7% of total variation in the same trait to be accounted for by month of birth. A difference of 8.4 kg. in weaning weight due to seasonal effect was reported by Meade *et al.* (1963). Season of birth was reported to affect weaning weights in Uganda by Sacker *et al.* (1971) and that this effect varied with years. In four ranches in Kenya, Tonn (1974) observed a significant season of birth effect on weaning weight and reported a suitable calving season to be from November through April. Ranches can limit their calving seasons within this range depending on their individual ecological location. Kidner (1966) working with Red Poll-Boran crosses in Kitale concluded that season of calving is an important factor to consider in beef production. This was based on weaning weights. This shows that seasonal influences are also important even in high potential areas where both calves and their dams were exposed to improved ley pastures. Cruz (1973) however reported that month of birth did not affect weaning weights at all in Florida. No possible explanation was advanced.

2.2.5. Age of dam at birth

Almost every worker studying effects on weaning weights has reported significant effects of age of dam at birth on this trait. This is due to maternal effects eg milk production which change with the age of the dam. Tonn (1976) observed that maternal effects are more emphasized in ranching situations where the dam has to defend the calf against predators to guarantee its survival. Mortojo (1973) reported a contribution of 1.3% of total variation in weaning weight to be associated with age of dam at birth. Kohli, Suri, Bhatnagar and Kumar (1962) reported a higher contribution of 20% of this factor on weaning weights. Brown (1960) who was working with weights of animals at various ages showed that weight at 240 days was significantly affected by age of dam. 20.9% of total variation in weight at this age was associated with this factor. Cundiff et al. (1966) observed that age of dam contributed 7% of total vaxiation in weaning weight.

Minyard and Dinkel (1965) reported that the lowest weaning weights were from calves of 2 year old cows. This age giving lowest weaning production was also reported by Meade et al. (1963) and Tonn (1974). Sacker et al. (1971) reported that lightest calves were produced by dams of 3 years of age. This early age is when the maternal environment is not yet fully developed. Examples of these are the uterus and mammary glands.

The age of dam exhibiting rapid changes in weaning weight has been shown to be 2 to 4 years (Cundiff et al., 1966; Koch and Clark, 1955; Tonn, 1974 and Minyard and Dinkel, 1955). Cundiff et al. (1966) in fact suggested that this period be divided into 3 - 5 months discrete intervals for proper evaluation because of this rapid change. Age of dam giving peak weaning weights has been reported to be 4 years by Tonn (1974). He associated this early age with accelerated aging process of the cows under predominantly difficult environmental conditions of the particular ranch the animals were. The age of dam giving maximum weaning weights has been shown to range from 4 to 11 years (Meade *et al.*, 1963 and Tonn, 1974). The range contains the ages also associated with peak milk production (Lush and Shrode, 1950).

2.2.6. Place and herd

These factors cause variation in weaning weight of cattle due to environmental effects unique to different places. Also difference in herd structures , composition and management imposed on them contribute to the variation. Pahnish *et al.* (1961) observed a significant difference in weaning weights of cattle between 2 ranches though the places had similar management regimes and all kept purebred Hereford. Cundiff *et al.* (1966) also found that area of birth had a significant influence on weaning weights and that this factor accounted for 5% of the total variation in weaning weights. Pahnish *et al.*(1961) observed that sex differences in calves at weaning varied between ranches. Herd effects have been reported by Mortojo (1973) who recorded a significant 7.2% of total variation in weaning weights to be due to herd effects. Other workers who have worked on factors influencing weaning weights have not included herd effects in their analyses and in most cases they analysed data from one place. There is not much information therefore on the effect these factors have on weaning weights.

2.2.7. Birth weight

This factor positively influences weaning weights. This is due to genetic correlation which exists between the two traits. A genetic correlation of 0.65 was reported by Tonn (1974) in one ranch in Kenya. Pahnish, Roberson, Taylor, Brinks and Clark (1964) reported a correlation of 0.42 between these traits. Kohli *et al.* (1962) observed that 26% of total variation in weaning weight to be due to variation in birth weight. Jeffrey *et al.* (1971) reported an increase of 1 kg. birth weight to be associated with 1.59 - 1.74 kg. in weaning weight. Heavy calves at birth were also heavy at weaning in a study by Singh, Schalles, Smith and Kessler (1970). They found a regression coefficient of weaning weight on birth weight of 2.01. Similar results were also reported by Christian, Hauser and Chapman (1965) and Gregory, Blunn and Baker (1950).

2.2.8. Weaning age

Age at weaning of calves has also been shown to affect weaning weight. Since this factor is entirely management controlled, its effect can be eliminated by weaning calves at a fixed age. Weaning age significantly affected weaning weight in Kenya (Tonn, 1974). The effect of age on weaning weight was reported to be linear by Swiger (1961). He further noted that this effect varied between sex and suggested that regressions be fitted for different sexes. Swiger, Koch, Gregory, Arthand, Rowden and Ingalls (1962) reported that regression of age on weaning weight was only linear from birth to 130 days after which it was curvilinear to 200 days of age. Evans, Craig, Cmark and Webb (1955) found regression of age of calf to weaning weight to be significant and that the regression differed significantly between purebred and grade herds used. Singh et al. (1970) found a significant regression of weaning age on weaning weight of 0.68.

Significant age of calf effect on weaning weights has also been reported by Koch (1951), Burgess, Nellie, Landblom and Stonaker (1954), Hamann, Nearden and Smith (1963), Minyard and Dinkel (1965), Cruz (1973), Mortojo (1973) and Bovard and Weinland (1975). Vanmiddlesworth, Brown and Johnson (1977) however found no significant effect of weaning age on weaning weight. This was attributed to uniformity of the birth dates. Other workers have been adjusting the weaning age of calves to a standard age using birth weight of the calves and their growth rates. 180 and 205 days have been commonly used as standard weaning age (Brinks, Clark, Kieffer and Quesenberry, 1962 and Cundiff et al., 1966).

2.3. First order interaction of factors affecting weaning weights

Where interaction of main factors is important, an assumption that main effects act in an additive manner leads to some loss of accuracy in estimating the main effects. It also leads to the development of universal correction factors for the main effects which may not effectively reduce these effects under all circumstances. For a particular place, a clear knowledge of some of these interactions is therefore important.

Some interactions which have been found to affect weaning weights significantly are year x sex, year x month of birth and year x breed (Meade et al., 1963), year x ranch and year x age of dam (Pahnish et al., 1961), year x breed of sire (Lapworth, Bean, Seifert and Rudder, 1976), breed x age of dam, breed x season and age of dam x season (Sellers, Willham and DeBaca, 1970).

In other studies however, some of these interactions have not been found to affect weaning weights at all. These are breed x year, breed x sex and sex x year (Kennedy and Chirchir, 1971), age of dam x sex (Cunningham and Henderson, 1965), age of dam x breed and sex x breed (Rudder, Seifert and Bean, 1975).

3. MATERIALS AND METHODS

This study is based on weaning weights of 1054 calves collected from 1971 through 1976 in Kiboko and Bachuma Range Research Stations.

3.1. Climate and location

The two stations are in a semi arid zone. Pratt, Greenway and Gwynne(1966) classified this area under ecological zone V. The location of the stations is shown on Figure 3.1. Kiboko is located about 2.3^{o}S and 37.8^{o}E. It is 1000 metres above sea level with an average annual rainfall of 615 mm. The rainfall data were obtained from Makindu meteorological station which is alongside the station. Bachuma is located about 3.6^{o}S and 38.9^{o}E. It is 500 metres above the sea level with an average annual rainfall of 630 mm. The rainfall data for Bachuma station were obtained from Mackinnon Road meteorological station which is adjacent to the station. Rainfall is bimodally distributed. The long rains usually fall from March to May and the short rains from October to early December. Long dry spells from June to September, sometimes even longer, are characteristic of these areas. Monthly rainfall figures for the two stations during the years of study are shown in Table 3.1.

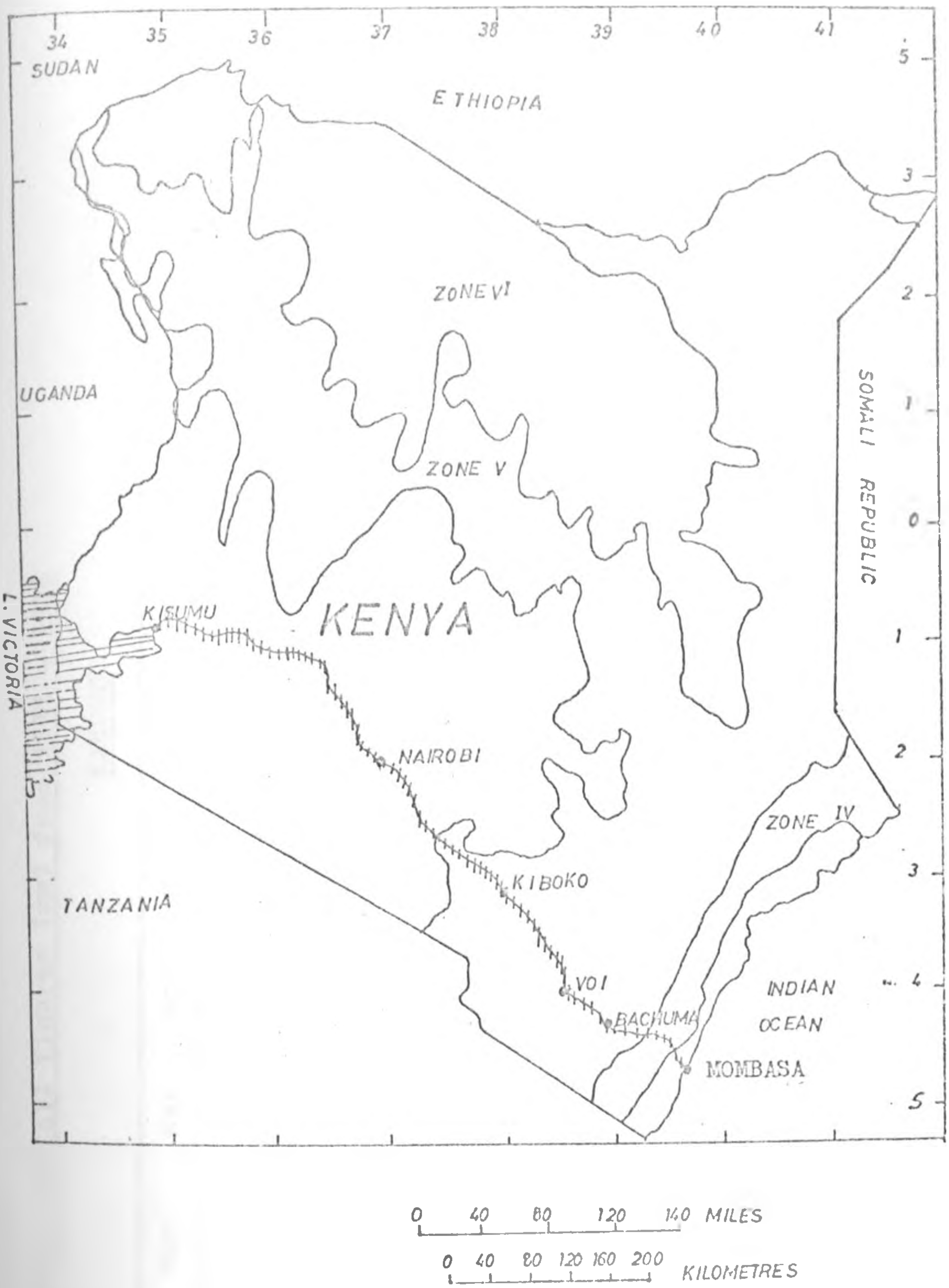

Fig. 3.1. Geographical location of Kiboko and Buchuma Range Research Stations, Kenya.

Table 3.1.: Monthly rainfall figures (mm) from 1971 - 1976

KIBOKO

Month / Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
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
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
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
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
1975	10.1	12.1	0.8	133.7	5.6	0.0	5.2	0.0	4.2	4.3	124.7	42.7	343.4
1976	0.0	4.1	0.0	132.1	0.0	0.0	0.0	0.0	12.8	0.8	98.9	114.8	363.5
1971-76	21.9	20.9	36.3	116.2	14.6	1.6	1.0	0.1	3.7	10.8	144.1	55.9	426.9

BACHUMA

Month / Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
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
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
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
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
1975	29.5	0.0	17.7	41.3	50.1	0.0	14.3	1.5	35.4	7.8	3.0	25.5	226.1
1976	1.8	21.8	74.5	33.4	90.8	31.8	5.2	10.5	80.0	5.2	69.1	37.9	462.7
1971-76	30.1	18.0	30.8	50.7	58.7	18.5	12.8	7.4	53.1	18.4	47.7	50.0	396.1

3.2. Vegetation

The main grass species in the two places are: Chloris roxburghiana, Eragrostis caespitosa, Cenchrus ciliaris, Themeda triandra, Digitaria milanjiana, Eragrostis superba, Enteropogon macrostychus, Panicum maximum and Sporobolus pellucidus. Commiphora species form the dominant trees and privide shade when in leaf. They shed leaves during the dry season. Both tall and low Acacias, Pallenitis and thorn bushes are also found. During dry periods, grazing decreases considerably. Competing with domestic animals for this vegetation are wild animals. Predation from lion, leopard and hyenas occurs occasionally.

3.3. Source of experimental animals and breeding policies

The foundation stock in 1968 at Bachuma consisted of Sahiwal, Boran and East African Shorthorn Zebu. From 1968 to 1971 there were no definite breeding programmes formulated. In 1971 some of these animals were sent as foundation stock to Kiboko Research Station. In the same year a three breed rotational cross-breeding programme was started at both stations. In this programme the Sahiwal and Boran females were crossed with Friesian bulls and the F_1 were crossed with Charolais bulls. The East African Shorthorn Zebu females were crossed with Sahiwal and Boran bulls. Artificial insemination was used with semen obtained from the Central Artificial Insemination Station, Kabete.

In 1972 another group of Boran and East African Shorthorn Zebu cattle were purchased for Kiboko. Some of the East African Shorthorn Zebu cattle were crossed with either Boran or Sahiwal bulls with the aim of upgrading them to the Boran or Sahiwal breed. Natural service was used in this group.

The animals at Kiboko were divided into seven groups. The general breeding herd was made up of all breeding females of the rotational cross breeding programme. There were four herds in the upgrading programme. Two of these were pure Boran and pure East African Shorthorn Zebu. The other two were East African Shorthorn Zebu females running with Boran bulls in one herd and Sahiwal bulls in another. All these herds grazed separately. After weaning heifer and Steer calves were also managed in separate herds. Bachuma animals were divided into three herds. The general breeding herd consisting of breeding females was used for the rotational cross breeding programme. Heifer and steer herds were managed separately.

3.4. Management of the herds

The systems of management in the two places were similar. Before 1974, all year round breeding was practiced after which a 6-month breeding season from January to June was started. This period was later reduced to 3 months from January to March in Kiboko and April to June in Bachuma. In the two stations many

The animals were confined at night to minimize losses by predators and theft. This practice of yarding animals at night without supplementary feeding had been shown to reduce their growth rate significantly especially during the dry season (Kyomo, Hutchison and Salehe, 1972), (Wigg and Owen, 1973). All animals were raised entirely on natural pasture without any supplementary feeding except for mineral licks given *ad libitum* in the night kraals. Water was provided in the kraals only. This was to prevent wild animals from having access to the water.

All animals except very young calves were dipped/sprayed twice a week. Vaccinations against Anthrax, Black Quarter, Foot and Mouth, Rinderpest and Brucellosis were regularly done. All animals were drenched after the rains. Chemoprophylaxis was provided for trypanosomiasis.

3.5. Data collection and classification

Weaning weights collected from 1971 through 1976 were used in this study. All the 1054 weaning weights in this period were used. The age first weight of an animal was taken could be up to 2 weeks from birth. Because animals were weighed monthly, the age the second weight was taken varied from one day to thirty days. All the weights were taken using a mobile weighbridge. The weights were recorded on an animal's data card which also had the identification number of the animal, sex, genotype, identification number of the dam, breed of sire and date of birth.

The classification of the data and the number of calves per cell is shown in Table 3.2. The year 1976 had only few observations and preliminary results showed no difference between the year and 1975. Because of limited capacity of the computer programme, these years were combined. 35 mm. of rainfall in a month was used as the dividing line between dry and wet seasons. Age of dam at birth was classified into 2 to 3, 4 to 5, 6 to 7 and 8 and older years together with a total number of calves of 89, 135, 118 and 699 for each sub-class respectively. Cross tabulation against this factor was not done because it was more randomly distributed than the other factors.

Plate 3.1.: Calves of the genotypes mentioned in the text. Grazing at the height of drought in Kiboko. October, 1976.

Plate 3.2.: Eroded and leached range. Immediately after the first rains following the long drought in Kiboko. December, 1976

Table 3.2.: Classification of the data and the No. of calves per cell

Place of birth	Genotype	Sex	Year and season of birth										Total
			1971		1972		1973		1974		1975-6		
			D	W	D	W	D	W	D	W	D	W	
KIBOKO	F x S	M	2	3	8	6	23	6	12	5	14	9	88
		H	2	4	15	2	23	16	7	2	7	3	81
	F x B	M	5	3	13	8	12	7	3	1	2	-	54
		H	4	3	13	5	7	4	2	-	2	2	42
	S x EASZ	M	2	2	4	-	8	4	9	5	15	5	54
		H	1	3	5	5	5	2	13	3	7	8	52
	B x EASZ	M	-	-	3	2	11	3	8	9	17	1	54
		H	-	-	2	4	9	3	9	4	11	6	48
	S	M	8	7	2	3	4	2	2	1	1	-	30
		H	20	5	9	1	3	9	1	5	-	1	54
	B	M	2	-	3	-	15	13	9	8	8	13	71
		H	2	1	3	1	10	9	10	3	14	4	57
	EASZ	M	-	-	4	3	7	2	10	8	19	5	58
		H	-	-	5	2	10	6	9	4	15	5	56
	Total		43	30	89	42	147	86	104	58	132	62	798
BACHUMA	F x S	M	2	-	2	8	17	-	11	12	16	4	72
		H	1	-	1	1	8	4	5	10	18	1	49
	F x B	M	-	-	1	4	17	-	9	7	20	3	61
		H	-	-	-	-	5	4	8	6	12	1	36
	S	M	12	3	4	4	1	1	2	-	1	1	29
		H	3	-	-	2	1	1	-	2	-	-	9
	Total		18	3	8	19	49	10	35	37	67	10	256
	Grand Total		66	33	97	61	196	96	139	95	199	72	1054

D = Dry, W = Wet, M = Steers, H = Heifers, F = Friesian, S = Sahiwal, B = Boran, and EASZ = East African Shorthorn Zebu

3.6. Method of analysis

The weaning weights were analysed in two stages due to the limited capacity of the programme used. In the first analysis data on 3 genotypes common to the two places were analysed. The genotypes were Friesian X Sahiwal, Friesian X Boran and pure Sahiwal. In the second analysis, only the Kiboko data were analysed and all the 7 genotypes were included in the model. Weaning weight, weaning age and birth weight were analysed as covariates.

The analyses were done on an I.C.L. Computer of the Institute of Computer Science, University of Nairobi using a programme (SYSNOVA) written by Seebeck (1976). This programme uses the LEAST-SQUARES method for fitting constants (Harvey, 1960), using a forwards stepwise regression procedure to arrive at a final regression model. It also includes a non-orthogonal analysis of variance and covariance.

The following model was used for weaning weights in the first analysis:-

$$
\begin{aligned}
Y_{ijklmno} = {} & u + a_i + b_j + c_k + d_l + f_m + g_n \\
& + (ac)_{ik} + (dc)_{lk} + (cg)_{kn} + (cf)_{km} \\
& + (ad)_{il} + (af)_{im} + (df)_{lm} + (ga)_{ni} \\
& + (gd)_{nl} + (gf)_{nm} + B_1(H_{ijklmno} - \bar{H}) \\
& + e_{ijklmno}
\end{aligned}
$$

and in the second analysis, the following model was used:-

$$Y_{ijklmo} = u + a_i + b_j + c_k + d_l + f_m + (ab)_{ij} + (cb)_{kj} + (ac)_{ik} + (cd)_{kl} + (fb)_{mj} + (db)_{lj} + B_1(H_{ijklmo} - \bar{H}) + B_2(I_{ijklmo} - \bar{I}) + e_{ijklmo}\text{ , where}$$

$Y_{ijklm(n)o}$ = weight of the calf at weaning

u = effect common to all calves

a_i = effect of the ith. genotype of the calf

b_j = effect of the jth. sex of the calf

c_k = effect of the kth. year of birth

d_l = effect of the lth. season of birth

f_m = effect of the mth. age of dam at birth

g_n = effect of the nth. station of birth

$(ac)_{ik}$ = effect of the ith. genotype X kth year interaction

$(cd)_{kl}$ = effect of the kth. year X lth. season of birth interaction

$(ag)_{in}$ = effect of the ith. genotype X nth. station interaction

$(cg)_{kn}$ = effect of kth. year of birth X nth. station of birth interaction

$(fg)_{mn}$ = effect of the mth, age of dam at birth X nth. station of birth interaction

$(dg)_{ln}$ = effect of the lth. season X nth. station of birth interaction

$(ad)_{il}$ = effect of ith. genotype X lth. season of birth interaction

$(af)_{im}$ = effect of the ith. genotype X mth. age of dam at birth

$(cf)_{km}$ = effect of the kth. year of birth X mth. age of dam at birth

$(df)_{lm}$ = effect of the lth. season of birth X mth. age of dam at birth

$(ab)_{ij}$ = effect of the ith. genotype X jth. sex of the calf

$(bc)_{jk}$ = effect of the jth. sex of calf X kth. year of birth

$(bf)_{jm}$ = effect of the jth. sex of calf X mth. age of dam at birth

$(bd)_{jl}$ = effect of the jth. sex of calf X lth. season of birth

$B_{(1)}$ = partial regression coefficient of weaning weight on weaning age

$H_{ijklm(n)o}$ = independent continuous variable weaning age

$\bar{H}$ = mean weaning age

B_2 = partial regression coefficient of weaning weight on birth weight

I_{ijklmo} = independent continuous variable birth weight

$\bar{I}$ = mean birth weight

$E_{ijklm(n)o}$ = effect peculiar to an individual

In the analyses of variance, each treatment mean square was tested against that of the residual as the models were fixed. An F-test to check if some significant interactions were left out of the models was given. χ^2 - values were also given for homogeneity of within cell variances. A significant CHI-SQUARE value would weaken the tests in the above non-orthogonal analyses. Standard errors of contrast between levels of treatments were generated for testing differences between the treatment levels. Difference between the coefficients of two levels divided by their respective standard error of contrast gives a value distributed as "t" for the residual degrees of freedom. This test is exact in the case of treatments with two levels but it would tend to give too high a level of significance for more than two levels. Borderline significant results in those cases would have to be interpreted with caution.

In order to estimate the percentage contribution to total variation for each effect, a variance "component" for each effect was calculated using the following formula:-

$EMS_i = \sigma^2_R + K_i\sigma^2_i$ where

EMS_i = estimated mean square for the ith. effect

σ^2_R = residual variance

K_i = constant estimated for the ith. effect

σ_i^2 = variance "component" for the ith. effect

$$\therefore \sigma_i^2 = \frac{EMS_i - \sigma_R^2}{K_i}$$

In a non-orthogonal design using a fixed model, the generated constants for the individual effects and their respective variances are only gross estimates. Estimates for each effect were summed to give a total and the proportionate contribution of each effect given as a percentage of the total.

4. RESULTS

4.1. First analysis

Results of the first analysis are shown in Table 4.1.

Table 4.1.: The analysis of variance and covariance of weaning weights and % contribution of individual effects to total variation (1st analysis)

Source of variation	DF	Mean square	% contribution
Place of birth	1	448.24	0.00
Year of birth	4	14645.51**	1.22
Age of dam at birth	3	1301.21	0.04
Season of birth	1	507.72	0.00
Genotype	2	2939.44*	0.12
Sex	1	8520.29**	0.12
Interactions			
Genotype X place	2	463.31	0.00
Year X place	4	2635.63**	0.23
Place X age	3	1002.85	0.03
Place X season	1	270.10	0.00
Genotype X year	8	601.63	0.00
Genotype X season	2	757.07	0.00
Year X season	4	5116.59**	0.44
Age X genotype	6	44.50	0.00
Age X year	12	396.40	0.00
Age x season	3	651.65	0.00
Weaning age	1	10792.78**	39.73
All sources	58	4612.21**	41.92
Residual	547	677.49	58.08
Total	605	1054.70	

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

Homogeneity of residual within cell variance χ^2 = 89.51

DF = 135 R^2 = 0.[illegible]

These results indicate that variation in weaning weight is significantly influenced by year, sex, genotype and weaning age of the calf. Two of the ten first order interactions analysed were significant and both of these involved year. Comparison between years is shown in Table 4.2.

Table 4.2.: The difference and its standard error between LSO-constants for the individual years (1st analysis)

	1972	1973	1974	1975-6
1971	12.83* ± 6.24	8.10 ± 6.41	18.57** ± 6.45	30.76*** ± 7.15
1972		4.73 ± 4.76	31.40*** ± 4.99	43.59*** ± 6.16
1973			26.67*** ± 4.46	38.86*** ± 5.92
1974				12.19* ± 6.10

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

The years with the highest weaning weights were 1972 and 1973 and the lowest weights were in 1975 and 1976. These were 169.76 kg. and 128.53 kg. respectively, giving a weight increase between these extreme years of 41.23 kg. (32.08%). The difference between the years which had above average weights and those that were below average was highly significant.

Year effects had the second highest estimated contribution to total variation in weaning weights following weaning age. LSQ-constants for year effects are shown on Figure 4.1.A.

LSQ-constants for genotype effects are depicted on Figure 4.1.B. Friesian X Sahiwal crosses had the heaviest weaning weights and pure Sahiwals had the lowest weights. This gave a difference of 13.11 kg. (9.00%). Comparison of the 3 genotypes and 2 sexes is shown in Table 4.3.

Table 4.3.: The difference and its standard error between LSQ-constants for the individual genotypes and sexes (1st analysis)

	FRIESIAN X BORAN	SAHIWAL	STEERS
FRIESIAN X SAHIWAL	2.43±3.80	13.11**±4.45	
FRIESIAN X BORAN		10.67*±5.09	
HEIFERS			8.10***± 2.28

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

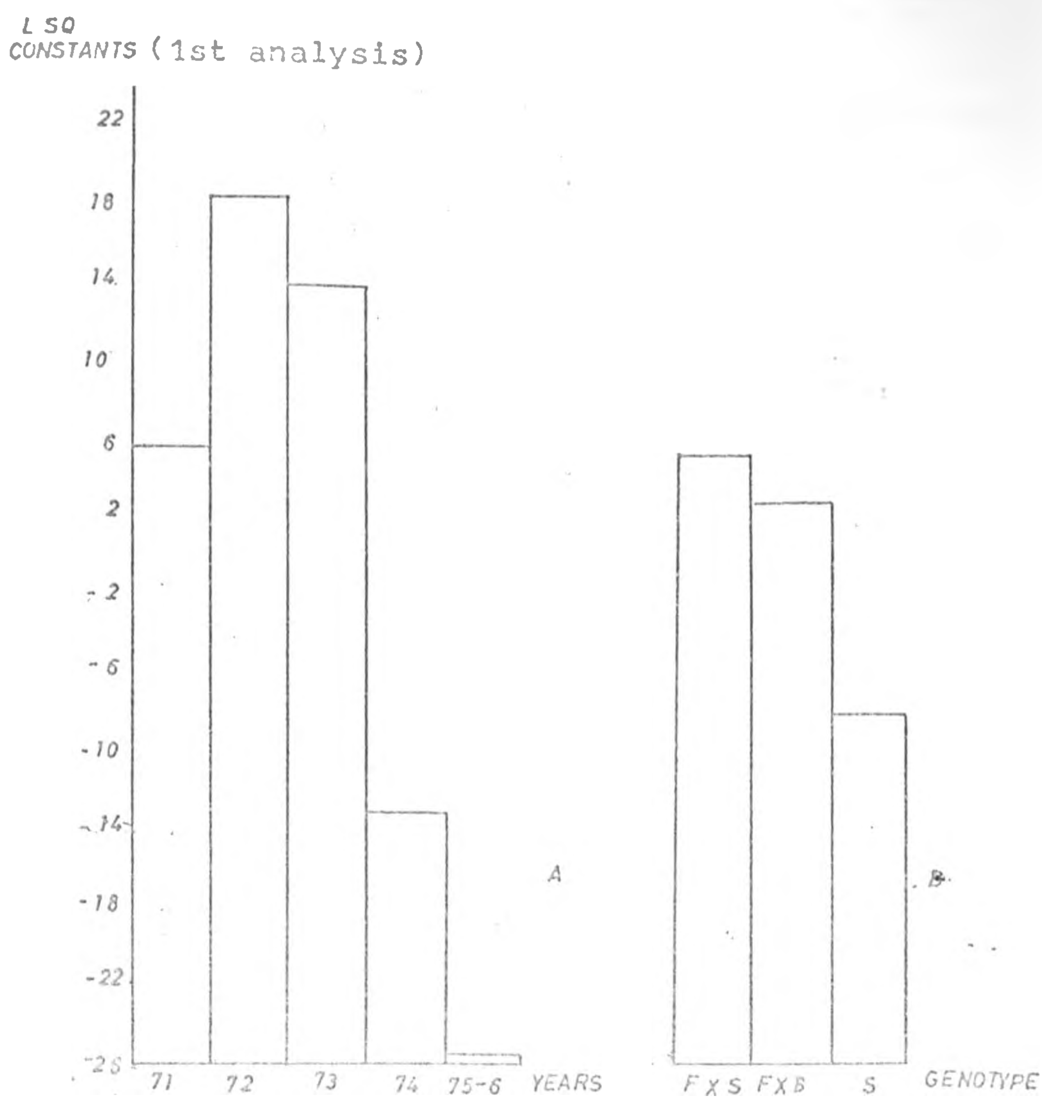

Fig. 4.1. Influence of year of birth and genotype on Weaning weight.

F X S - Friesian - Sahiwal Cross

F X B - Friesian - Boran Cross

S - Sahiwal

There was a significant difference between the weaning weights for the Sahiwal and the Friesian crosses of Sahiwal and Boran; but not between Friesian X Boran and Friesian X Sahiwal crosses. Genotype effects had 0.12% estimated contribution to total variation in weaning weights.

Steers were 8.10 kg. heavier than heifers at weaning. This was a weight difference of 5.42% which was highly significant. Sex had also 0.12% contribution to total variation in weaning weights.

Station and season of birth had no significant effect on weaning weights. Calves born in Kiboko and Bachuma had similar weights. Also calves born in dry and wet seasons had similar weaning weights.

However interactions of place and season of birth with year had a highly significant effect on weaning weights. These interaction effects are depicted on Figure 4.2.A and B. In 1971 Bachuma animals were heavier than the Kiboko ones but in 1972 when animals had the heaviest weights, Kiboko animals were heavier than the Bachuma ones. The following year, 1973, Bachuma animals were again superior to Kiboko animals in weaning weights. Kiboko animals were heavier than Bachuma animals by 20.1 kg. in 1974.

From 1974 to'76, Bachuma animals showed a slight increase in weaning weights while Kiboko animals had a high loss in weights. Kiboko animals lost 29 kg. and the Bachuma ones gained 2.5 kg. The Bachuma animals were therefore 9.4 kg. heavier than the Kiboko ones in

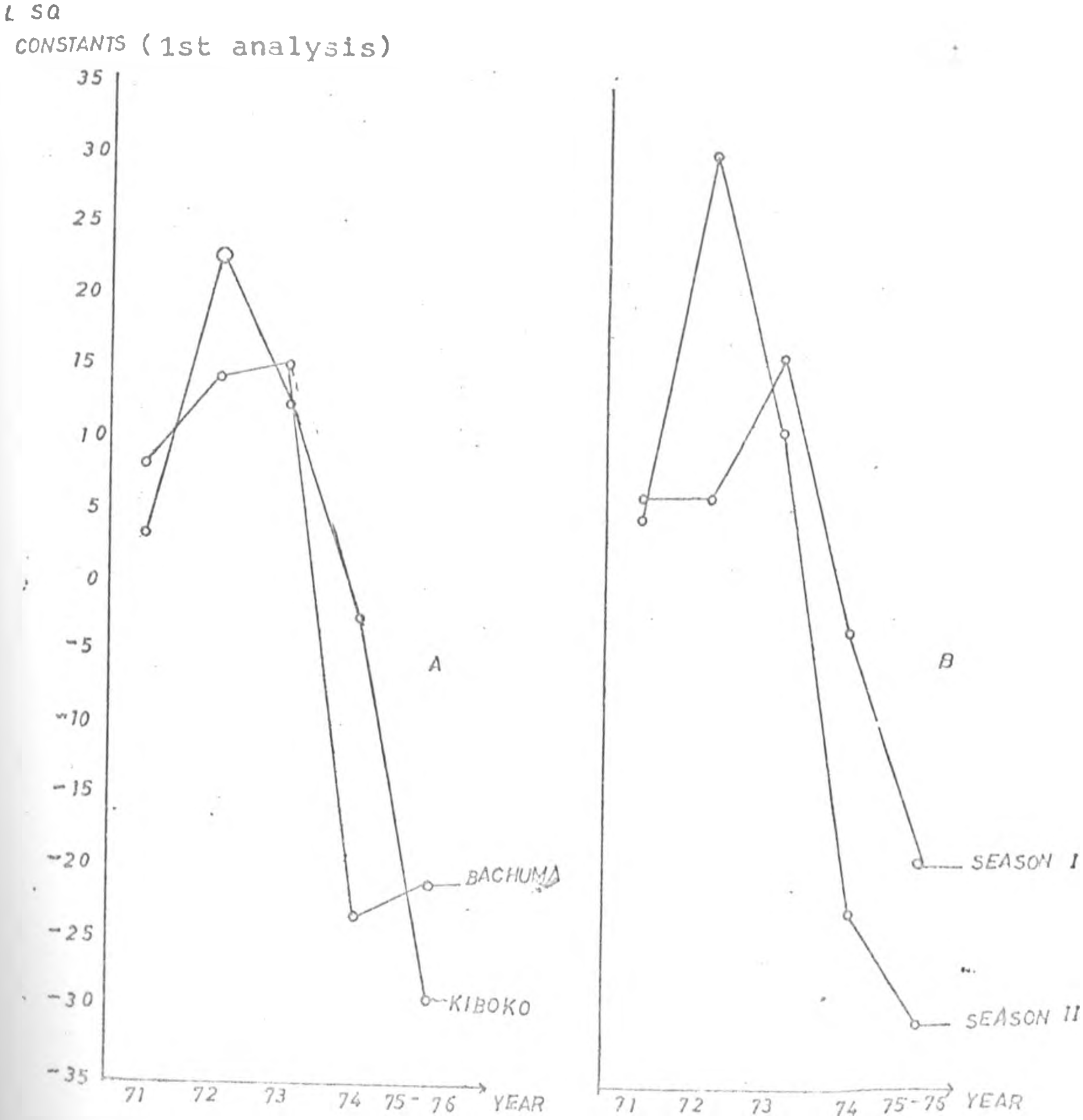

Fig. 4.2. Weaning weight least square constants for year of birth computed between place and season.

Season I = dry season; and Season II = wet season

In 1971 animals born in dry and wet seasons had a slight difference in weaning weights but in 1972 animals born in wet seasons had weighed 25.5 kg. more than animals born in the dry season. From 1972 to 1973 animals born in wet season showed a decline in weight while the dry season ones showed rapid increase in weaning weights. From 1973 to 1976 animals born in the dry season were superior in weaning weights than those born in wet season. Thus generally animals born in dry season had heavier weaning weights than those born in wet season in all years except 1972 which showed the reverse to be true.

Age of dam at birth with its interactions with place, year, month of birth and genotype had no significant effect on weaning weights.

Weaning age as a continuous variable had a highly significant positive influence on weaning weights. Older calves at weaning had heavier weights than the younger ones. A linear regression coefficient between weaning weights and weaning age of 0.294 ± 0.074 was obtained. This factor had the highest estimated contribution of 39.73% to the total variation in weaning weights.

This analysis also showed that there were other interactions left out of the model which had a significant influence on weaning weights. This is depicted in Table 4.4.

Table 4.4.: Non-orthogonal analysis of the variance and covariance of weaning weights. Test of remaining interaction between main effects (1st analysis)

Source of variation	DF	Mean square
Interaction	169	789.53**
Within cell residual	378	627.39

** = $P < 0.01$

These could be interactions involving sex or weaning age as these were the only first order interactions left out. A possibility exists also of higher order interactions affecting weaning weights. None of these were tested in this analysis due to the limited capacity of the computer programme used.

4.2. Second analysis

Results of the second analysis are shown in Table 4.5.

Table 4.5.: The analysis of variance and covariance of weaning weights and % contribution of individual effects to total variation (2nd analysis)

Source of variation	DF	Mean square	% contribution
Genotype	6	133031.28**	0.24
Sex	1	3166.01*	0.05
Year of birth	4	24082.37**	0.32
Age of dam at birth	3	1731.21*	0.02
Season of birth	1	1778.57	0.01
Interactions			
Genotype X Sex	6	287.93	0.00
Year X sex	4	581.73	0.00
Year X season	4	4032.90**	0.09
Age X sex	3	654.43	0.00
Month X sex	1	1357.81	0.01
Birth weight	1	28575.86**	47.74
Weaning age	1	5681.37**	8.74
All sources	35	15439.87**	56.18
Residual	762	553.23	43.82
Total	797	1206.97	

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

Homogeneity of residual within cell variance

X^2 = 122.47   DF = 144 R^2 = 0.5618

Results from this analysis indicate that genotype, sex, the year the animal was born and the age of dam at birth had a significant effect on weaning weights. Birth weight and weaning age as continuous variables affected weaning weights significantly also. Of the five interactions tested, one was significant. This was year X season of birth interaction.

Breed comparisons are shown in Table 4.6.

The performance of the Sahiwal and Boran at weaning was similar. The Sahiwal and Boran crosses with Friesian had also similar weaning weights. Though the Sahiwal and its cross with Friesian was slightly heavier than its Boran counterparts, this difference was not significant. The East African Shorthorn Zebu and its crosses with Sahiwal and Boran had similar weaning weights though there was slightly better performance by the crosses especially the Sahiwal cross.

LSQ-constants for genotype effect are depicted on Figure 4.3.B. The East African shorthorn Zebu with its crosses to Sahiwal and Boran had the lowest weaning weights and the Friesian crosses with Sahiwal and Boran had the heaviest weights. Pure Sahiwal and Boran were average. Crossing the East African Shorthorn Zebu with Sahiwal or Boran improved the weaning weights of the former by 3.59 and 2.65% respectively, though the difference between the three genotypes was not statistically significant. A highly significant improvement in weaning weights of

Table 4.6.: The difference and its standard error between LSQ-constants for individual genotypes (2nd analysis)

	F X B	S X EASZ	B X EASZ	S	B	EASZ
F X S	2.49 ± 3.89	27.74*** ± 3.89	28.91*** ± 8.23	13.63** ± 4.82	16.81*** ± 4.26	32.28 ± 27.55
F X B		25.28*** ± 4.47	26.45** ± 8.21	11.16* ± 5.40	14.32** ± 4.64	29.80 ± 27.38
S X EASZ			1.17 ± 8.33	14.11** ± 5.30	9.73* ± 4.32	4.53 ± 27.75
B X EASZ				15.28 ± 8.87	12.13 ± 7.93	3.36 ± 25.97
S					3.15 ± 5.58	18.65 ± 27.93
B						15.50 ± 26.46

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

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

Sahiwal and Boran of 9.49 and 10.19% respectively was achieved by crossing them with Friesian.

The difference between the weights of East African Shorthorn Zebu and those of the other genotypes was not significant because of their large standard errors.

The pattern of the year effects on Figure 4.3.A is consistent with the results of the first analysis. Comparison between years is shown in Table 4.7.

Table 4.7.: The difference and its standard error between LSQ-constants for individual years (2nd analysis)

	1972	1973	1974	1975-6
1971	9.65 ± 22.58	2.40 ± 22.84	12.30 ± 22.36	26.85 ± 23.21
1972		7.24* ± 3.15	21.95*** ± 3.48	36.50*** ± 4.03
1973			14.71*** ± 2.97	14.55*** ± 3.58
1974				14.55*** ± 3.74

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

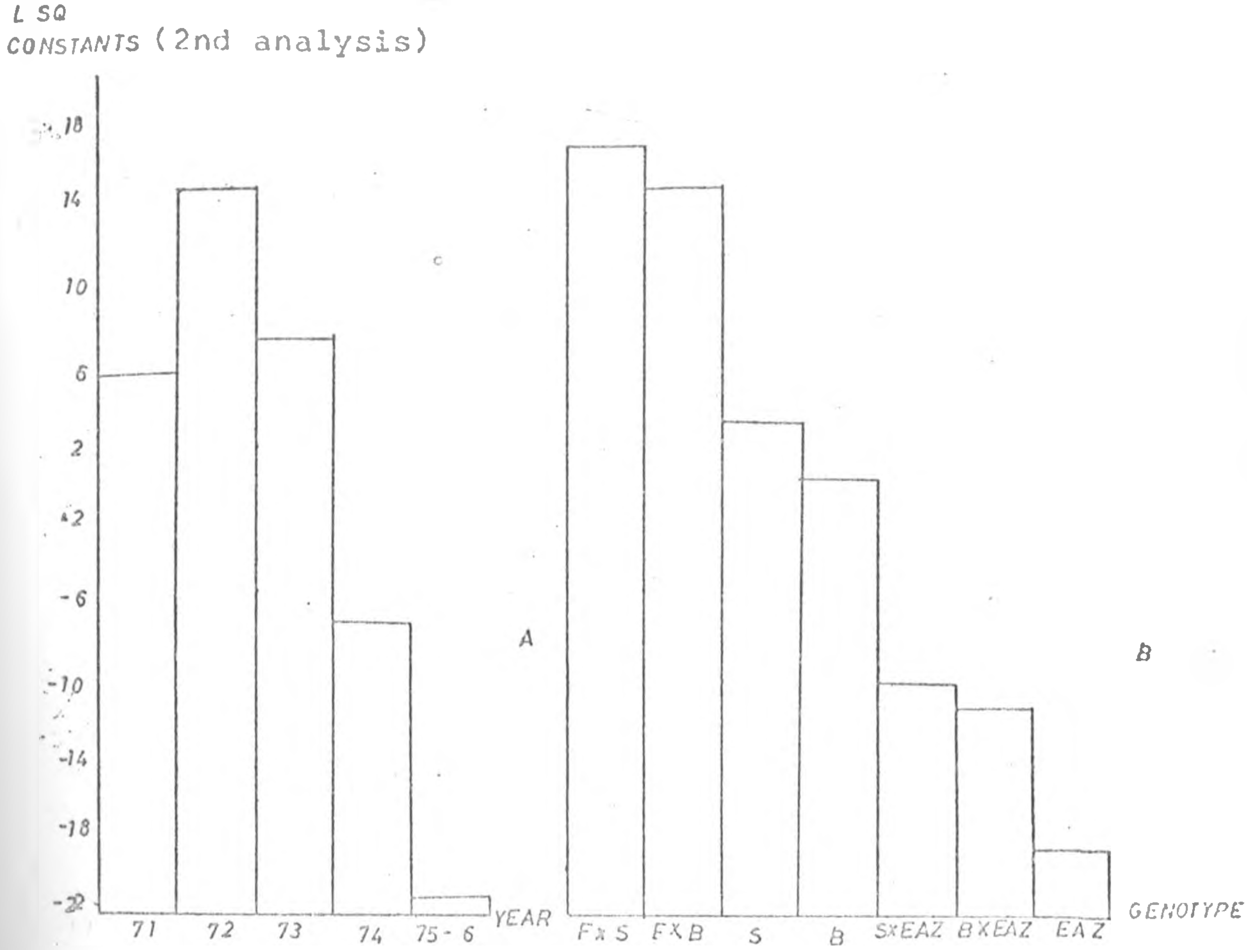

Fig. 4.3. Influence of year of birth and genotype on Weaning weight.
F - Friesian, S - Sahiwal, B - Boran
EAZ - East African Shorthorn Zebu

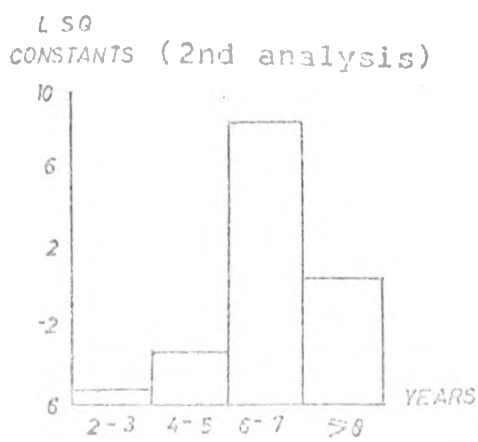

Fig. 4.4. Influence of age of dam on Weaning weight.

There was a highly significant decrease in weaning weights from 1972 through 1975-76. The difference in the weights between 1972 and 1975-76 was 36.50 kg. (30.82%). Year effects had an estimated contribution of 0.32% of total variation in weaning weights.

Steers were significantly heavier than heifers by 8.42 kg. (6.19%) at weaning.

The age of dam effects are shown on Figure 4.4. and comparison between the ages is shown in Table 4.8.

Table 4.8.: The difference and its standard error between LSQ-constants for individual ages of dam (2nd analysis)

	4-5 years	6-7 years	≥8 years
2-3 years	2.05 ± 3.87	$14.05^{**} \pm 4.74$	6.08 ± 3.60
4-5 years		$12.11^{**} \pm 4.29$	4.03 ± 3.36
6-7 years			8.07 ± 4.19

** = $P < 0.01$

Calves from 2 to 3 year old cows had the lightest weaning weights and those from 6 to 7 year old cows had the heaviest weights. There was a significant increase in weights of calves between the dams' ages of 4-5 and 6-7 years. Calves from 8 year old cows and above had lower weights than those from 6-7 year old cows though this difference was not significant.

Season of birth had no significant influence on weaning weights. Animals born in wet and dry seasons had similar weights. This is what was also found in the first analysis.

Year X season of birth interaction effects are shown on Figure 4.5. In 1971 animals born in the dry season were heavier at weaning than those born in wet season by 18 kg. In 1972 the animals born during wet season were heavier than those born in dry season by 12.6 kg. In 1973 and 1974 the calves born in dry season were heavier than those born in wet season. This picture changed again in 1975-76 when animals born in the wet season were slightly heavier than those born in dry season. Like in the first analysis, these results show a tendency for animals born in dry season to be heavier at weaning than those born in wet season. The years 1972 and 1975-76 did not however fit into this trend.

Birth weight and weaning age had a contribution of 47.74 and 8.74% respectively to total variation in weaning weights. Heavy calves at birth were also heavy at weaning. A linear regression coefficient of 1.562 ± 0.221 between birth weight and weaning weight was found. Also older calves at weaning were heavier than young calves. A linear regression coefficient between weaning age and weaning weight of 0.181 ± 0.058 was found in this analysis.

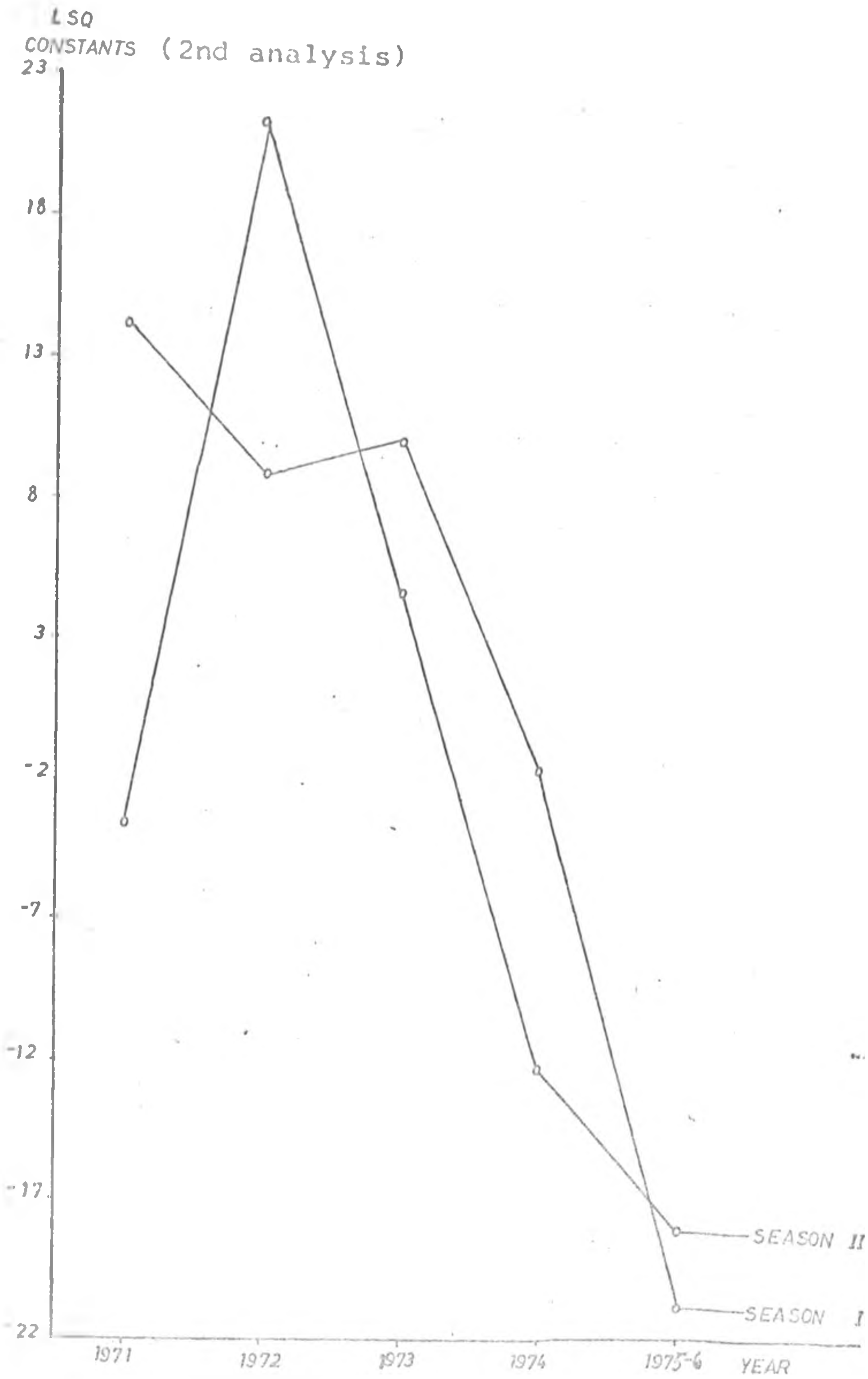

Fig. 4.5 Weaning weight least square constants for year of birth computed between season.

Season I = dry season; and Season II = wet season

Also in this analysis, it was shown that some interactions between main effects were left out of the analysis which had a significant influence on weaning weights. This is shown in Table 4.9.

Table 4.9.: Non-orthogonal analysis of variance and covariance of weaning weights. Test of remaining interaction between main effects. (2nd analysis)

Source of variation	DF	Mean square
Interaction	171	670.02**
Within cell residual	591	519.44

** = $P < 0.01$

Year X genotype interaction could be one of the significant interactions left out. Also higher order interactions which were not tested at all could be a possibility.

LSQ-constants for the effects of all factors considered in the two analyses and the corrected means are shown in the appendices. Standard errors are also shown. Standard errors of the first levels for each treatment were not computed by the programme. Constants for the first levels of the interactions which were not significant were not calculated.

5. DISCUSSION AND CONCLUSIONS

Results from this study show that both genetic and environmental factors have significant influence on weaning weights of cattle at Kiboko and Bachuma. Some interactions have also a significant effect on weaning weights.

5.1. Genotype

The significant effect of genotype on weaning weights in this study agrees with the results of Tonn (1974) and Trail *et al.* (1971). The mean weights in this study were however generally lower than those reported by Tonn (1974) for comparable genotypes. The former study was based in Laikipia District and in the Rift Valley Province of Kenya which, though generally classified under range area, tend to have higher rainfall than the one recorded in Kiboko and Bachuma. Those areas have therefore better fodder supply for their stock than Kiboko and Bachuma.

The management of the animals in the two places was also different. The animals studied by Tonn (1974) had access to grazing throughout 24 hrs. The animals in Kiboko and Bachuma were confined at night. Night kraaling has a retardation effect on growth of animals (Kyomo *et al.*, 1972 and Wigg and Owen, 1973) and this could have lowered the overall growth performance of the Kiboko and Bachuma animals to weaning.

It was shown in this study that Friesian crosses with Boran and Sahiwal had heavier weaning weights than the other genotypes tested there. This superiority over pure Boran and Sahiwal, though smaller than the one reported by Tonn (1974), was maintained even in drought years like 1975 and 1976. Weaning weights of Boran and Sahiwal crosses with East African Shorthorn Zebu were intermediate between those of pure Boran or Sahiwal and pure East African Shorthorn Zebu. This is what was expected. Pure Boran and Sahiwal had average weights at weaning and therefore these would form a good foundation stock in the range areas. The Boran has been shown by Tonn (1974) to be a suitable basis for crossbreeding with Bos taurus cattle for beef production in these areas. Since the majority of farmers in the semi-arid and arid zones keep the small East African Shorthorn Zebu, they will improve weaning weights of their cattle if they upgrade them to either Boran or Sahiwal. A further improvement will be obtained by crossing the Sahiwal and Boran upgrades to Friesian. Since pure Friesian bulls are difficult to keep in the arid zones, extension of artificial insemination services to these areas, especially those with good infrastructure, will be beneficial to the farmers.

Both Sahiwal and Boran had similar weights at weaning. The slight advantage of the Sahiwal and its crosses over the Borans could be due to superior milk yield of the Sahiwal compared with the Boran. Maternal effects given by different breeds of dam do influence weaning weights (Gaines et al., 1966 and Trail et al., 1971). However, this argument could not be extended to explain the slight difference between the crosses of East African Shorthorn Zebu with Boran and Sahiwal since the calves were both nursed by East African Shorthorn Zebu dams.

Comparisons between East African Shorthorn Zebu with the rest of the genotypes in the second analysis showed no statistical significance despite the big differences in their means. This was caused by large standard errors between the means which was due to a large variation in weaning weights of the East African Shorthorn Zebu. Weaning weights in this genotype ranged from 52.0 to 182.0 kg.

5.2. Sex

The weaning weight difference of 5.42% and 6.19% found in this study between steers and heifers for the 2 analyses is what was expected. This difference was however smaller than the figures mostly found in literature due to difference in genotypes used, management practice of supplementation or time of castration (Brown, 1960; Pahnish et al., 1961 and Sacker et al., 1971).

5.3. Year of birth

The year effect on weaning weights followed more or less the rainfall pattern of the years in the study. The year 1972 was the only one which had rainfall above average in Bachuma. This is the year which had the heaviest weaning weights. Long drought then followed from 1973 through 1976 in both Kiboko and Bachuma. This is reflected in the steady decline in weaning weights giving the lowest weights in 1975 and 1976. The range of variation in weaning weights caused by year effects in this study agrees with those reported by Meade *et al.* (1963), Kennedy and Chirchir (1971), Tonn (1974) and Mortojo (1973) though it was higher than the figure found by Sacker *et al.* (1971). In a situation where calves and their dams are not supplemented, as it is common in semi arid and arid zones, weaning weights of calves seem to vary with rainfall amounts and distribution in each year. This determines the amount and quality of forage available to the animals.

5.4. Season and month of birth

Contrary to many studies, season of birth had no significant influence on weaning weights at all. Cruz (1973) reported similar results that month of birth had no significant effect on weaning weights. The management of the calves in his study was, however, different from that of calves in the current study in that they were creep fed. Lack of significance in the season of birth could be a reflection of inappropriate classification of dry and wet seasons in this study. Morgan (1969) had suggested a rainfall figure of 50 mm. per month as a dividing line between dry and wet seasons in East Africa. In the arid zones grass germination and growth tends to respond to much less rainfall than this. A monthly rainfall figure of 35 mm. was thought to be adequate. This is one area of work which requires more research.

No suitable breeding season could therefore be identified from this study. Allen (1973) tentatively suggested suitable breeding months of April, May and June for Bachuma and January, February and March for Kiboko based on limited rainfall and animal data. Recently this breeding season was changed to start from February through May for both stations in order to have uniform breeding management and calf crop. This coincides with the breeding season of February through July recommended by Tonn (1974) and it should therefore be continued until there is more work done in the stations to justify any changes.

5.5. Place of birth

Kiboko and Bachuma animals had similar weaning weights. The classification of these two stations in the same ecological zone based on climate and vegetation (Pratt et al., 1966) is also reflected in the weaning performance of cattle. Other workers have found contradictory results to this (Pahnish et al., 1961 and Cundiff et al., 1966). Results from this study show that in the ecological zone V, similar cattle genotypes are expected to have similar weaning weights and that one research station in that zone is representative enough of the whole zone.

5.6. Age of dam at birth

Age of dam at birth was found to affect weaning weights in the second analysis of 7 genotypes at Kiboko. Lightest calves were produced by dams 2 and 3 years old. This similar age was found by many workers (Minyard and Dinkel, 1965; Meade et al., 1963; Tonn, 1974 and Sacker et al., 1971). Dams age of 6 and 7 years producing the heaviest weaners in this study does not agree with the early age of 4 years reported in one ranch in Kenya by Tonn (1974). The age giving the heaviest weaning weights in this study does however coincide with the age of 7 and 8 years giving peak milk production reported by Lush and Shrode (1950). This high milk production is expected to have a high influence on weaning weights (Jeffrey et al., 1971).

Calves from 8 year old dams in the second analysis had average weaning weights. Dams older than this age were also analysed in the same age group and since this was also the trait with a lot of missing data, more work is required in the classification of the older dams in order to conclude when to cull dams on the basis of low weaning weights due to old age.

Lifetime beef production of a cow depends on how many calves it produces (Chapman, Young, Morrison and Edwards, 1978) This study shows that heifers can be bred so as to calve at the age of 2 years. The first and second weaners from those dams will however be expected to have lower than average weights.

5.7. Birth weight

Heavy calves at birth were also heavy at weaning in the second analysis. This agrees with the results of many workers (Jeffrey *et al.*, 1971; Singh *et al.*, 1970; Christian *et al.*, 1965; and Gregory *et al.*, 1950). This shows that heavy calves at birth will be an early indicator of heavy weaners. In this study nearly all the percentage variation in weaning weights accounted for in the second analysis was contributed by the variation in birth weight. This is due to high variation in birth weight within some of the genotypes especially the East African Shorthorn Zebu. Birth weight in this genotype ranged from 11.0 to 27.3 kg.

5.8. Weaning age

Variation in weaning age contributed nearly all the variation accounted for by the statistical model in the first analysis with younger calves weighing lightest and older calves weighing heaviest. Many studies have shown the significance of weaning age on weaning weights (Tonn, 1974; Swiger, 1961; Swiger *et al.*, 1962; Evans *et al.*, 1955 and Singh *et al.*, 1970). The results in this study is what was expected and they show the importance of including weaning age in the two analyses.

5.9. Significant first order interactions affecting weaning weights

The significant interactions affecting weights in this study show that year effects vary from place to place within the same ecological zone (first analysis) and with season of calving, either in dry or wet months (first and second analyses). Year x ranch effects were also reported by Pahnish *et al.* (1961) and Harwin *et al.* (1966). These effects are mainly due to local variation in rainfall patterns and management practices. It is not surprising in the arid areas to find one area being dry and the next one being very wet. This means that in order to evaluate and compare animals at weaning born in different years and in different ranches, correction for ranch effects is necessary.

Year x month of birth interaction was reported to affect weaning weights by Meade et al. (1963). In this study, there was a general tendency for calves born in dry season to have heavier weaning weights than those born in wet season. This agrees with the current practice in some semi-arid areas where calves are born before a rainy season in anticipation for a rising plane of forage availability after birth. The reverse was however true in 1972 in the two analyses and in 1975-76 in the second analysis. This could be tied up with the classification of dry and wet seasons in this study and the low repeatability of these seasons from year to year. Tonn (1974) indicated that calves born in dry and wet seasons have a chance of going through at least 2 and 1 wet season(s) respectively before weaning. If these seasons are unpredictable, the weaning performance of calves born at different seasons is bound to vary from year to year.

There were other significant interactions affecting weaning weights which were not tested in this study. Year x genotype is one of the most likely ones. Trail et al. (1971) working with 9 genotypes in Uganda found this interaction to be significant. In this study, this interaction was tested only in the first analysis with 3 genotypes which did not differ greatly in weaning weights. The opportunity for the interaction to manifest its significance could have been lowered by this limitation. Also interactions involving covariates and higher order interactions which were not tested at all in this study, could be the possible ones left out.

5.10. Conclusions

It can be concluded from this study that for accurate estimate of the genetic potential of our cattle, correction is required for environmental influences. Friesian crosses with Sahiwal and Boran maintain their superior weights over Sahiwal and Boran even in drought years. The Boran and Sahiwal have similar performance in the semi arid and arid areas and they would form a good foundation stock there. One research station in ecological zone five is representative enough for that zone in terms of cattle weaning performance. More research is required in the classification of dry and wet seasons as related to animal performance. Animal performance is expected to vary greatly from year to year following rainfall patterns. Heifers can be bred to first calve at the age of two years. More work is also required in identifying the age when dams should be culled on the basis of low weights of their progeny. Heavy birth weights are an early indicator of heavy weaners. A similar study on eighteen month and slaughter weights should be undertaken in order to further understand the factors limiting the potential of our range areas for beef production.

6. LITERATURE CITED

Abs = Abstracts

Allen, C. (1973). Supplement to a proposed long term Range Management Research Programme to provide technical information needed for effective development of rangeland in Kenya. Ministry of Agriculture.

Bell, G. H., Davidson, J. N. and Scarborough, H. (1970). Text book of Physiology and Biochemistry, Longmans Group Limited, Edinburgh.

Blackwell, R. L., Knox, J. H., Shelby, C. E. and Clark, R. T. (1962). Genetic analysis of economic characteristics of young Hereford cattle. J. Anim. Sci. 21: 101.

Brown, C. J. (1960). Influence of year and season of birth, sex, sire and age of dam on weights of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19: 1062.

Bovard, K. P. and Weinland, B. J. (1973). Monthly weights of beef calves to weaning. J. Anim. Sci. 36: 198. Abs.

Brinks, J. S., Clark, R. T., Keiffer, N. M. and Quesenberry, J. R. (1962). Mature weight in Hereford range cows - heritability, repeatability and relationship to calf performance. J. Anim. Sci. 21: 501.

Brinks, J. S., Clark, R. T., Kieffer, N. M. and Quesenberry, J. R. (1962. Genetic and environmental factors affecting performance traits of Herefore bulls. J. Anim. Sci. 21: 777.

Burgess, J. B., Nellie, L., Landblom and Stonaker, H.H (1954). Weaning weights of Herefore calves as affected by inbreeding, sex and age. J. Anim. Sci. 13: 843.

Chapman, H. D., Young, J. M., Morrison, E. G. and Edwards, N. C. Jr. (1978). Differences in lifetime productivity of Herefords calving first at 2 and 3 years of age. J. Anim. Sci. 46: 1163.

Christian, L. L., Hauser, E. R. and Chapman, A. B (1965). Association of preweaning and postweaning traits with weaning weight in cattle. J. Anim. Sci. 24: 652.

Cruz, O. (1973). Genetic and environmental parameters of production in Brahman cattle. Dissert. Intern. Abs. B. 34: 6-B.

Cundiff, L. V., Willham, R. L. and Pratt, C. A. (1966). Effects of certain factors and their two-way interadtions on weaning weight of beef cattle. J. Anim. Sci. 25: 972.

Cunningham, E. P. and Henderson, C. R. (1965). Estimation of genetic and phenotypic parameters of weaning traits in beef cattle. J. Anim. Sci. 24: 182.

Damon, R. A. Jr., Harvey, W. R., Singletary, C. B., MacCraine, S. E. and Crown, R. M. (1961). Genetic analysis of crossbreeding beef cattle. J. Anim. Sci. 20: 849.

Evans, L. E., Craig, J. V., Cmark, G. F. and Webb, R. J. (1955). Influence of age of calf, sex, and age of dam on weaning weight in Hereford. J. Anim. Sci. 14: 1181, Abs.

Falconer, D. S. (1960). Introduction to Quantitative Genetics, Oliver and Boyd, Edinburgh.

Gaines, J. A., McClure, W. H., Vogt, D. W., Carter, R.C. and Kincaid, C. M. (1966). Heterosis from crosses among British breed of beef cattle - fertility and calf performance to weaning. J. Anim. Sci. 25: 5.

Gregory, K. E., Blunn, C. T. and Baker, M. C. (1950). A study of some of the factors influencing the birth and weaning weights of beef calves. J. Anim. Sci. 9: 338.

Gregory, K. E., Swiger, L. A., Koch, R. M., Sumption, L.J., Ingalls, J. E., Rowden, W. W. and Ruthlisburger, J.A. (1966). Heterosis effects on growth rate of beef heifers. J. Anim. Sci. 25: 290.

Hamann, H. K., Nearden, S. and Smith, W. H. (1963). Estimation of genetic and environmental factors affecting weaning weights of creepfed cattle. J. Anim. Sci. 22: 316.

Harvey, W. R. (1960). Least-squares analysis of data with unequal subclass numbers. U.S.D.A. ARS-20-8.

Harwin, G. O., Brinks, J. S., and Stonaker, H. H. (1966). Genetic and environmental interactions affecting weaning weights of Hereford calves. J. Anim. Sci. 25: 779.

Hassall, A. C. (1970). Beef production in the dry tropics. A challenge to genetic progress. Aust. Soc. Anim. Prod. Proc. 8: 91.

Jeffrey, H. B., Berg, R. T. and Hardin, R. T. (1971). Factors affecting preweaning performance of beef cattle. Can. J. Anim. Sci. 51: 581.

Kennedy, J. F. and Chirchir, G. A. (1971). A study of growth rates of F_2 and F_3 Africander cross, Brahman cross and British cross cattle from birth to 18 months in a tropical environment. Aust. J. Exp. Agric. Anim. Husb. 11: 593.

Kidner, E. M. (1966). Some factors involved in the live weight progress of calves from birth to slaughter. E. Afr. agric. For. J. 31: 389.

Koch, R. M. (1951). Size of calves at weaning as a permanent characteristic of range Hereford cows. J. Anim. Sci. 10: 768.

Koch, R. M. and Clark, R. T. (1955). Influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Anim. Sci. 14: 386.

Kohli, M. L., Suri, K. R., Bhatnagar, V. K. and Kumar, S. (1962). Study of growth in Hariana calves. Ind. J. Dairy Sci. 15: 52.

Kyomo, M. L., Hutchison, H. G. and Salehe, I. (1972). Effect of yarding cattle at night without supplementary feeding on the growth of Zebu heifers. E. Afr. agric. For. J. 37: 279.

Lapworth, J. W., Bean, K. G., Seifert, G. W. and Rudder, T. H. (1976). Factors affecting the performance of steers growing under commercial conditions in a sub-tropical environment. Aust. J. Exp. Agric. Anim. Husb. 16: 636.

Lush, J. L. and Shrode, R, R. (1950). Changes in milk production with age and milking frequency. J. Dairy Sci. 33: 338.

Meade, J. H., Kidder, R. W., Koger, M. and Crockett, J.R. (1963). Environmental factors affecting weaning weights of beef cattle in the Everglades. Agric. Exp. Sta. Univ. Florida Tech. Bull. No. 663.

Minyard, J. A. and Dinkel, C. A. (1965). Weaning weights of beef calves as affected by age and sex of the calf and age of the dam. J. Anim. Sci. 24: 1067.

Mitchell, H. H. (1967). Comparative nutrition of man and domestic animals, Academic press, New York.

Morgan, W. T. W. (1969). East Africa: its peoples and resources. Oxford University Press, Nairobi.

Mortojo, H. (1973). Genetic and environmental factors affecting weaning weights and weaning type score in beef cattle. Dissert. Intern, Abs. 34: 8 - B.

Nelson, L. A. and Cartwright, T. C. (1968). Inter-age correlations among weights of heifers. J. Anim. Sci. 27: 284. Abs.

Pahnish, O. F., Stanley, E. B., Bogart, R. and Roubicek, C. B. (1961). Influence of sex and sire on weaning weights of South Western range calves: J. Anim. Sci. 20: 454.

Pahnish, O. F., Boberson, R. L., Taylor, R. L., Brinks, J. S., Clark, R. T. and Roubicek, C. B. (1964). Genetic Analyses of economic traits measured in range-raised Herefords at preweaning and weaning ages. J. Anim. Sci. 23: 562.

Pratt, D. I., Greenway, P. I. and Gwynne,M. D. (1966). A classification of East African Rangelands, J. Appl. Ecol. 3: 369.

Preston, T. R, and Willis, M. B. (1974). Intensive beef production, Pergamon Press, New York.

Roberts, R. C. (1965). Some contributions of the laboratory mouse to animal breeding research. Anim. Breed. Abs. 33: 339.

Rudder, T. H., Seifert, G. W. and Bean, K. G. (1975). Growth performance of Brahman and Charolais x Brahman cattle in a tropical environment. Aust. J. Exp. Agric. Anim. Husb. 15: 156.

Sacker, G. D., Trail, J. C. M. and Fisher, I. L. (1971). Cross-breeding beef cattle in Western Uganda. 2. Environmental influences on body-weight. Anim. Prod. 13: 143.

Seebeck, R. M. (1976). Sysnova version 8 reference manual. C.S.I.R.O., division of animal production, Rockhampton. Queensland.

Seifert, G. W., Rudder, T. H. and Lapworth, J. W. (1974). Factors affecting weaning weight of beef cattle in a tropical environment. Aust. J. Exp. Agric. Anim. Husb. 14: 277.

Sellers, H. I., Willham, R. L. and DeBaca, R. C. (1970). Effect of certain factors on weaning weight of beef calves. J. Anim. Sci. 31: 5.

Singh, A. R., Schalles, R. R., Smith, W. H. and Kessler,F. B. (1970). Cow weight and preweaning performance of calves. J. Anim. Sci. 31: 27.

Swiger, L. A. (1961). Genetic and environmental influences on gain of beef cattle during various periods of life. J. Anim. Sci. 20: 183.

Swiger, L. A., Koch, R. M., Gregory, K. E., Arthaud, V. H., Rowden, W. W. and Ingalls, J. E. (1962). Evaluating preweaning growth of beef calves. J. Anim. Sci. 21: 781.

Swiger, L. A., Gregory, K. E., Koch, R. M., Rowden, W.W., Arthaud, V.H. and Ingalls, J. E. (1963). Evaluating postweaning gains of beef calves. J. Anim. Sci. 22: 514.

Swiger, L. A., Gregory, K. E., Sumption, L. J., Breidenstein, B. C. and Arthaud, V. H. (1965). Selection indexes for efficiency of beef production. J. Anim. Sci. 24: 418.

Trail, J. C. M., Sacker, G. D. and Fisher, I. L. (1971). Crossbreeding beef cattle in Western Uganda.

1. Performance of Ankole, Boran and Zebu Cows. Anim. Prod. 13: 127.
3. Genetic analysis of body weights. Anim. Prod. 13: 153.

Tonn, R. (1974). The suitability of Boran and its crosses with European breeds for beef production under range conditions in Kenya. Ph.D. Thesis. Univ. of Gottingen.

Tonn, R. (1976). Selection criteria for beef cattle breeding under extensive conditions - as illustrated by the example of Kenya. Anim. Res. Dev. 3: 105.

Vanmiddleworth, J., Brown, C. J. and Johnson, Z. B (1977). Repeatability of calf weight and ratio of calf weight to cow weight in Hereford and Angus. J. Anim. Sci. 45: 1247.

Velardo, J. T. (1958). The endocrinology of reproduction, Oxford University Press, New York.

Vernon, E. H., Harvey, W. R. and Warwick, E. J. (1964). Factors affecting weight and score of crossbred-type calves. J. Anim. Sci. 23: 21.

Wagner, D. G., Holland, G. L. and Mogess, T. (1969). Crossbreeding studies with Ethiopian beef cattle using imported semen. E. Afr. agric. For. J. 34: 427.

Wigg. P. M., and Owen, M. A. (1973). Studies on water consumption, night grazing and growth of Boran and crossbred steers at Kongwa, Tanzania. E. Afr. agric. For. J. 38: 361.

Wilson, L. L., Dinkel, C. A., Ray, D. E. and Minyard,J.A. (1963). Beef cattle selection indexes involving conformation and weight. J. Anim. Sci. 22: 1086.

7. APPENDICES

Appendix A1. Least square coefficients ± standard error for treatments in the first analysis (kg.)

Corrected mean	153.61 ± 32.48*

Main effects:

Year of birth:

1971	5.68
1972	18.51 ± 3.30
1973	13.78 ± 3.12
1974	-12.89 ± 3.28
1975-6	-25.08 ± 4.27

Season of birth:

Dry season	1.35
Wet season	-1.35 ± 1.56

Place of birth:

Kiboko	1.40
Bachuma	-1.40 ± 1.72

Sex:

Steers	4.05
Heifers	-4.05 ± 1.14

Age of dam:

2-3 years	-4.89
4-5 years	1.87 ± 3.23
6-7 years	5.36 ± 2.84
≥8 years	-2.34 ± 2.27

Genotype:

Friesian X Sahiwal	5.18
Friesian X Boran	2.75±2.60
Sahiwal	-7.93 ± 2.93

Weaning age: 0.29 ±0.07

Interactions:

Year X place:

Yr_2 X pl_2	-2.93 ± 3.02
Yr_3 X pl_2	2.60 ± 3.49
Yr_4 X pl_2	-9.23 ± 2.73

Genotype X place:

Ge_2 X pl_2	- 2.04 ± 2.30
Ge_3 X pl_2	3.17 ±2.72

Year X genotype

Yr_2 X ge_2 -2.47 ± 3.80

Yr_2 X ge_3 - 1.00 ± 4.43

Yr_3 X ge_2 2.39 ± 3.40

Yr_3 X ge_3 -4.13 ±4.39

Yr_4 X ge_2 2.97 ± 4.59

Yr_4 X ge_3 3.56 ± 5.57

Yr_{5-6} X ge_2 -1.66 ± 5.35

Yr_{5-6} X ge_3 -3.00 ± 7.96

Year X season

Yr_2 X se_2 13.43 ± 2.66

Yr_3 X se_2 -1.22 ±2.21

Yr_4 X se_2 -8.64 ±2.58

Yr_{5-6} X se_2 -4.20 ± 2.92

Age of dam x year

Ad_2 X Yr_2 6.89

Ad_3 X Yr_2 -0.41 ± -5.25

Ad_4 X Yr_2 -1.28 ± 3.91

Ad_2 X Yr_3 -0.56 ± 3.73

Ad_3 X Yr_3 4.11±4.73

Ad_4 X Yr_3 3.10 ± 3.34

Ad_2 X Yr_4 -0.04 ± 4.74

Ad_3 X Yr_4 -2.04 ±4.70

Ad_4 X Yr_4 1.25 ± 4.12

Ad_2 X Yr_{5-6} -7.15 ± 5.55

Ad_3 X Yr_{5-6} -2.50 ± 5.04

Ad_4 X Yr_{5-6} -7.13 ± 5.01

Age of dam X genotype

Ad_2 X ge_2 - 5.61 ±4.34

Ad_3Xge_2 -0.70 ±4.06

Ad_4 X ge_2 -0.49 ±2.95

Ad_2 X ge_3 4.12 ± 4.19

Ad_3 X ge_3 -3.04 ±5.16

Ad_4 X ge_3 0.56 ± 3.58

Place x age of dam

Pl_2 X ad_2 4.68 ± 2.50

Pl_2 X ad_3 -1.20 ± 2.47

Pl_2 X ad_4 1.30 ± 2.14

Place X season

Pl_2 X se_2 0.90 ± 1.42

Age X season

Ad_2 X se_2 3.19 ± 2.31

Ad_3 X se_2 -2.34 ± 2.46

Ad_4 X se_2 -1.98 ± 1.97

Genotype X season

Ge_2 X se_2 2.72 ± 1.87

Ge_3 X se_2 -2.66 ± 2.24

Appendix A2. Least square coefficients ± standard error for treatments in the second analysis (kg.)

Corrected mean - 139.86 ± 34.74 *

Main effects:

Genotype:

Friesian X Sahiwal	17.40
Friesian X Boran	14.94±5.19
Sahiwal	3.77±5.45
Boran	0.62±6.61
Sahiwal X E.A.S.Z.	-10.34±6.05
Boran X E.A.S.Z.	-11.51±4.44
E.A.S.Zebu	-14.88±23.05

Sex:

Steers	4.21
Heifers	-4.21±1.70

Age of dam:

2-3 years	-5.57
4-5 years	-3.52±2.25
6-7 years	8.59±2.92
≥ 8 years	0.51±2.09

Years of birth:

1971	5.42
1972	15.07±4.88
1973	7.83±4.98
1974	-6.88±4.63
1975-76	-21.43±5.55

Season of birth:

Dry month	1.37
Wet month	-1.37±1.01

Covariates:

Birth weight	1.56±0.22
Weaning age	0.18±0.06

Interactions:

Genotype X sex:

Ge_2 X Sx_2	-0.50±2.47
Ge_3 X Sx_2	-0.52±2.33
Ge_4 X Sx_2	-0.05±2.34
Ge_5 X Sx_2	-1.30±2.90

Year X sex:

Yr_2 X Sx_2	-2.10±1.94
Yr_3 X Sx_2	-1.73±1.58
Yr_4 X Sx_2	1.72±1.83
Yr_{5-6} X Sx_2	1.92±1.78

* = Standard Deviation

Ge_6 X Sx_2	3.20±2.16	Year X season:	
Ge_7 X Sx_2	-0.71±2.28	Yr_2 X Se_2	7.68±2.06
Age of dam X Sex:		Yr_3 X Se_2	-0.81±1.66
Ad_2 X Sx_2	2.34±2.21	Yr_4 X Se_2	-4.00±1.86
Ad_3 X Sx_2	1.54±2.81	Yr_{5-6} X Se_2	4.75±1.80
Ad_4 X Sx_2	-0.10±2.03	Season X Sex:	
		Se_2 X Sx_2	-1.54±0.93