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Signed ....
(R. O. Mosi)

This thesis has been submitted for examination with our approval as university supervisors

Signed ....
(Dr. R. B. Dolan)

Signed ....
(Dr. R. M. Mzee)

AN ASSESSMENT OF THE EFFICIENCY OF THE KENYA BEEF RECORDS' "PRODUCTIVITY INDEX"

Reuben Oyoo Mosi, B.Sc. (Agric.) (Makerere)

A thesis submitted in part fulfilment for the Degree of Master of Science in the University of Nairobi

1978

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SUMMARY

The present study was carried out to assess the efficiency of the Kenya Beef Records' "Productivity Index", as it is used currently to cull breeding Boran beef cows. The data came from Mogwooni ranch in the Laikipia District of Kenya and were collected between 1967 and 1976. A total of 384 Boran cows which weaned a minimum of four calves were selected for the study. In all 1526 weaning weight and calving interval records were available.

Weaning weights were corrected for the effects of sex and weaning age and calving interval was defined as the interval between the time of birth of the last calf reared to weaning and that of the calf under discussion. Repeatabilities were estimated for the "Productivity Index" and its component traits - weaning weight and 'productive' calving interval. The estimates were 0.05 ± 0.02, 0.13 ± 0.03 and 0.08 ± 0.02 respectively. The very low repeatability of this index implies that the accuracy with which cows may be culled would also be very low. As heritability estimates must be lower, the rate of genetic progress when this trait is selected for would be negligible.

The genetic correlation between the component traits was 0.32. But in practice, increased weaning weight and decreasing calving interval are antagonistic.

In cow-calf system of beef production, it would be preferable to have a short and regular calving interval of about one year and an average weaning weight. The difficulties of attempting to improve the two component traits in a simple index without the inclusion of heritability or genetic correlation estimates are discussed.

It was concluded from the present study that the Kenya Beef Records' "Productivity Index" would not be efficient as a basis for improving the productivity of Boran beef cows. Methods of improving this index are discussed.

ACKNOWLEDGEMENTS

I wish to express my deep gratitude to my supervisors, Dr. Rosemary B. Dolan and Dr. Rashid M. Mzee, for their patience, dedicated encouragement and wise guidance during this study.

I am also indebted to Dr. Ulrich von Poschinger-Camphausen for his guidance during the data preparation and his stimulating and constructive discussions, criticisms and suggestions.

My special thanks to Mr. and Mrs. John Kenyon of Mogwooni Limited (Nanyuki) who kindly allowed me to carry this study on their ranch, and for their very useful suggestions and the constructive discussions.

Finally, to Mrs. E. A. Onim, for the typing, and all those people, especially the staff of the Livestock Recording Centre - Naivasha - who helped in one way or another, to make this study a success.

This study was sponsored by the Ministry of Agriculture, Kenya.

CHAPTER 1

INTRODUCTION

The fertility of a cow and the growth potential of its calves are among the outstanding economic traits in a cow-calf system of beef production. At herd level the average length of calving interval, and hence the percentage calf crop is greatly determined by the fertility of breeding cows. The genotype of the calf and the milk yield of the dam both determine the pre-weaning growth of the calf, as measured by the weaning weight. Thus, the interest should be, to have beef cows which have a high level of fertility and wean heavy calves regularly.

In Kenya, the Boran has been recognized as a potential future beef breed, and attempts have been made to improve it genetically by selection. What is known now as the 'Improved' Boran is the result of nearly half a century selection. The improvement has been carried out on commercial ranches in better environments in the areas categorized by Pratt, Greenway and Gwayne (1966) as ecological zones four and five. It is envisaged that the Boran might compose the majority of breeding beef cows in Kenya in the near future (Wilkins, 1974). On the merit of the Boran cow, Mason and Maule (1960) and Meyn (1970) have reported that the Breed has excellent adaptability, mothering ability, milkiness and growth rate. Studies conducted at Naivasha indicate the existence of a substantial variation in performance within the breed

(Annual Report, 1972 - 73), suggesting that a further improvement by selection is possible. This calls for the use of a properly constructed and efficient selection index.

The construction of a proper and efficient selection index takes into account the heritability and the relative economic values of the component traits. Both the phenotypic and genetic correlations between the traits are also considered. The component traits are weighted by these factors and then summed up into a score or index for individual cows.

A beef recording scheme (Kenya Beef Records) has been set up within the Livestock Recording Centre, Naivasha, primarily to assist in the genetic improvement of the Boran cattle by selection. The scheme has evolved a type of index, referred to here as the Kenya Beef Records' "Productivity Index", to be used for selecting breeding Boran beef cows. The two component traits of this index are the weaning weight of a calf and the 'productive' calving interval of the dam. According to the system, the weaning weight is adjusted for the effects of sex and age of calf only. The 'productive' calving interval is defined as the interval between the date of birth of the last calf reared to weaning, and date of birth of the calf under discussion. The corrected weaning weight is divided by the 'productive' calving interval in days, to give the amount of weaning weight which a cow was able to raise per day of 'productive' calving interval. Due to the large ecological and seasonal variations that occur in Kenya, the cows are rated by this index on a within ranch and month basis.

The efficiency of the Kenya Beef Records' "Productivity Index", as a basis for improving the productivity of Boran beef cows genetically has, however, remained unknown. The construction of this index, unlike that of a proper selection index does not take into account the heritability and the relative economic values of the component traints, nor does it consider both the phenotypic and genetic correlations between them. This index is already being used by some three ranches in Laikipia District. It has also been integrated into the new computer programme which was introduced recently by the International Livestock Centre for Africa for beef data analysis. It is believed that the "Productivity Index" gives an efficient and reliable indication of the economic performance of a Boran beef cow per given time of 'productive' calving interval (Wilkins, 1974). However, the fact that this index is used to cull the less productive Boran cows makes it necessary to assess its efficiency as a basis for improving the productivity of these cows genetically.

CHAPTER 2

REVIEW OF LITERATURE

The theory of index selection was originated by Smith (1937) and improved later by Hazel and Lush (1942) and Hazel (1943). The method was first introduced to animal breeding work by Hazel (1943). The merit of index selection lies in the fact that it will offer maximum genetic improvement, relative to independent culling levels and tandem selection, when selection is made to improve more than one trait (Hazel and Lush, 1942 ; Young, 1961; Finney, 1962). The construction of a proper selection index takes into account both the heritability and the relative economic value of every component trait, and also the genetic and phenotypic correlations among the traits.

To the extent that the productivity of beef cows is determined by several traits, the use of index selection is justified. Different selection indices of varying efficiencies have been used to select beef cows for overall productivity. The variation in their efficiencies depends on which traits are considered to influence the productivity of beef cows in a particular beef enterprise. Rae and Barton (1970), Animal Production Research Unit (APRU) - Botswana (1975) and Preston and Willis (1970) have considered the reproductive performance milk production and mothering ability to be among the most important economic traits of a beef cow. Both the milk production and mothering ability of a beef cow are measured by the weaning weight of its calf, while the reproductive performance or fertility is measured by the length of calving interval. Unfortunately fertility traits, with the exception of gestation length (Dickey and Cartwright, 1961; APRU - Botswana, 1975; Preston and Willis, 1970) are of low heritability and will not give sufficient response to justify selection. This appears to be the reason why index selection in beef cows has dwelt more on growth and body measurement traits, than on fertility traits. However, this is not to say that fertility as such is of less economic importance in beef production.

The relative merits of the different selection indices which have been used to predict the future productivity of beef cows have been reported in literature. The merit of an index combining weaning weight and weaning grade (type or conformation score at weaning) was investigated by Rollins and Wagnon (1956); Magee, Nelson and Branaman (1961); Marlowe and Vogt (1965); Frey, Frahm, Whiteman, Tanner and Stephens (1970) and Frey et al. (1972). Their findings, as far as the efficiency of this index is concerned, were rather conflicting. Whereas a close genetic correlation between weaning weight and weaning grade was observed by Rollins and Wagnon (1956), indicating that both traits may be improved simultaneously by one index, Magee et al. (1961) and Frey et al. (1972) reported a rather low and negative genetic correlation between the two traits. The works of Lehman, Gaines, Bovard and Kincaid (1961) and Vesely and Robison (1961) showed that an index using weaning weight alone would be more efficient as a measure of the future productivity of a beef cow, than the one combining weaning weight and weaning grade.

These studies seem to point out that weaning grade is less efficient, as a measure of the future productivity of a beef cow, than weaning weight. The only justification, in many cases, for its inclusion in the index, will be where it is not possible to measure weaning weight, or if the market demands the sale of weaners on the basis of conformation. But then the inclusion of weaning grade in a selection index would only be useful where the genetic correlation between weaning grade and weaning weight is high.

Wilson, Dinkel, Ray and Minyard (1963) proposed an index combining weaning weight, pre-weaning and post-weaning daily gains to be used in the prediction of the future productivity of beef cows. They were probably prompted to propose this index by the close genetic correlations which they observed between the component traits. But then, the evaluation of productivity in beef cows based on the pre-weaning performance of their calves would be generally preferable for two reasons. Firstly weaning weight has a larger maternal component than post-weaning gains, and secondly selection based on weaning weight can be made at an earlier age.

The works of Gregory, Blunn and Baker (1950), Molinuevo (1966) and recently Tom (1975) indicate that the weight of a beef cow at the time its calf is weaned, should be considered when evaluating its productivity, especially under range conditions. All these workers have reported a rather close and positive phenotypic correlation between this cow weight and the weaning weight of its calf. It was also shown (Molinuevo, 1966) that the two traits have medium to high heritabilities, and could be expected to give sufficient response to selection. However, the increase in the metabolic body size of a cow, as measured by its weight at the time its calf is weaned, will also increase its requirement for maintenance energy. This, in turn, has a reductive effect on the net energy for milk production, which is essential for the effective pre-weaning growth of the calf. If a cow cannot get enough energy to maintain its body weight and at the same time produce enough milk for its calf, it will be forced to meet the deficit from the body reserves, thereby reducing its body weight. Brinks, Clark, Keiffer and Quesenberry (1962) and Godley, Wise and Tribe (1966) demonstrated the existence of a negative phenotypic correlation between dam weight at weaning and the weaning weight of its calf. It appears that a suitable selection aim should compromise between both the metabolic body size and maintenance energy requirement of a cow, and its ability to wean a heavy calf.

Weaning weight

Several factors have been known to influence the weaning weight of a calf. Previous studies (Koch and

Clark, 1955; Creek and Nestle, 1964; Cunningham and Henderson, 1965; Burgess and Bowman, 1965; Godbey et al. 1966; Tonn, 1974) have shown that among these factors, are birth weight, sex and weaning age of calf, month, season and year of both calving and weaning, and herd, previous calving interval, age and parity of the dam. These studies have also shown that the relative magnitude of these influences vary with the environment in which the dams have reared their calves. Therefore, in evaluating productivity in beef cows on the basis of weaning weight of calves, adjustments must be made for all those factors which influence this trait significantly in a particular environment.

The effect of birth weight on weaning weight is precisely known. Carter and Kincaid (1959), Shelby, Clark and Woodward (1963), Swiger, Gregory, Sumption, Breidenstein and Arthunds (1965) and Beruecos and Robison (1968) have all demonstrated the existence of a close phenotypic correlation between the two traits. They also observed a significant variation in weaning weights of calves which was due to differences in their birth weights. Further evidence for the significant effect of birth weight on weaning weight was provided by Jeffery, Berg and Hardin (1971), who found that an increase of 1 kg. in birth resulted in 1.74 and 1.59 kg. increases in weaning weights of male and female calves respectively. In an earlier study, Nelms and Bogart (1956) showed that for every difference of 10 lbs. in birth weight, there was a significant difference of

0.115 lbs. per day of pre-weaning rate of gain. Recently Belič and Panič (1974) observed that the effect of birth weight on weaning weight, as measured by the coefficients of determination, were 12.9 - 49.7% and 13.2 - 20.7% for male and female calves respectively. The calves were born between the first and third calvings. These close phenotypic correlations between birth weight and weaning weight suggest that, selection to increase weaning weight will also increase birth weight indirectly.

There is, however, the risk of increasing the level of dystocia in a herd due to the indirect increase in size of calves at birth, as measured by their birth weights (Bellows and Verner, 1973). Empirical evidence for the indirect and significant effect of weaning weight on the level of dystocia in a beef herd has also been given recently by Laster, Glimp, Cundiff and Gregory (1976) and Wilson, Willis and Davidson (1976). The same workers also showed that losses such as reduction in both the conception rate and percentage calf crop are some of the direct results of dystocia. It seems that while artificial selection may aim at increasing weaning weight, and hence, birth weight indirectly, natural selection aims an average weaning weight, with an average birth weight. In artificial selection, it would also appear reasonable to aim at an average weaning weight giving an average birth weight.

The existence of a significant sex difference in the weaning weight of beef calves has been confirmed in a number of studies. Martojo (1974) found that sex alone accounted for 4.2% of the total weaning weight variation. He based his study on 9773 weaner calves of mixed breeds. Sex differences in weaning weight ranging from 4.7 - 10% were reported by Tonn(1974) from some four herds of Boran, Friesian X Boran crosses and Aberdeen Angus in Kenya. This range of differences is in agreement with that reported from Australia by Seifert, Rudder and Lapworth (1974) for Brahman crosses. In America, Cudiff, William and Pratt (1966) found, from 13,937 Hereford and Angus weaning weight records, that sex alone accounted for more than 5% of the total variation in weaning weight. Creek and Nestle (1964) working in the West Indies, were able to show that the relative pre-weaning performance of male and female calves varied with both the environment and season. They observed that in a good season, a male calf was more capable of expressing its genetic potential for growth, than a female calf. This finding implies that sex correction factors for weaning weight must be developed within the different environments and seasons.

The weaning age of a calf has been regarded by many workers as one of the factors whose influence on weaning weight is highly significant (Minyard and Dinkel, 1965; Marlowe, Mast and Schalles, 1965; Godley, Wise and Tribe, 1966). The fact that calves of different ages will have different weights at weaning is well understood. Botkin and Whatley (1953), Gottlieb, Wheat and Smith (1962), Preston and Willis (1970) and Tonn(1974) all reported linear regression of weaning weight on weaning age of calves of different breeds. Their regression coefficient estimates were in the range of 0.25 - 0.77 kg. per day, and were all significantly different from zero. The need to correct weaning weight for the influence of age of calf at weaning is probably too obvious a point to stress.

The relative effect of season, herd and year of weaning on weaning weight has been investigated. Recently Kennedy and Henderson (1975) estimated, from 61,688 and 22,333 Hereford and Angus calf records, that herd alone accounted for 25 - 44% of the total variation in weaning weight. Year alone accounted for less than 4% of the total variation in the same trait, while year X herd component accounted for less than 10%. From 1,363 calves belonging to six Angus herds and 2,042 calves from four Hereford herds, Matojo (1974) found that herd and year effects accounted for only 7.2 and 0.9% of the total weaning weight variation, respectively. The amount of the total variation in the same trait, accounted for by year X herd interraction was 3.7%, which was much lower than the estimate of Kennedy and Henderson (1975). In another study Shelby et al. (1960) estimated the magnitude of year effect to be 36 - 44% of the total variation in weaning weights of some 542 Hereford bull calves.

Koch and Clark (1955); Nelms and Bogard (1956); and Swiger et al. (1962), all working in America, reported on the effect of season on weaning weight, but in each case season was confounded with either age of calf or age of dam. In India, Lima (1974) observed a significant effect of season on weaning weights of 663 calves of Gir, Nellore and Guzerat zebus. This effect was significant in all breeds, ranging from 159.9 kg. for calves weaned in June - July to 199.3 kg. for calves weaned in February - March. The effects of season and year are somehow similar, in that they can be explained in terms of forage availability, and milk yield of the dams, as measured by the weaning weights of their calves. All these studies point out that season, year and herd of weaning all influence weaning weight significantly and should be corrected for.

Studies on the effect of age of dam on weaning weight show that the influence of this factor is more pronounced in the *Bos taurus* breeds of cattle than in the *Bos indicus*. Ton (1974) found no significant influence in one of the ranches included in his study, where only Boran cattle were kept. His findings agree with those of Koger *et al.* (1962) and Preston and Willis (1970), who also reported no significant effect of age of dam in *Bos indicus* cattle. The significant effect of age of dam on weaning weight of *Bos taurus* breeds of cattle was dmonstrated by Brinks *et al.* (1962); Fitzhugh, Cartwright and Temple (1966); and Marlowe and Gaines (1957). However, it should be noted that the *Bos indicus* breeds, such as the Boran, calve when they are at least three years old, and it would appear that at this age their milking ability is similar to that in subsequent lactations.

Other studies have also reported on the effect of age of dam on weaning weight. Martojo (1974) showed that 1.3% of the total variation in weaning weights of 9,773 Hereford, Angus, Santa Gerrudis and Brahman calves, was due to the effect of age of dam. Burgess and Bowman (1975) observed that age of dam, year and season of weaning, all combined, accounted for less than 10% of the total sum of squares for weaning weight. It was also noted in the same study that two and three year old cows weaned calves which were 34.3 and 13.5 lbs. lighter than the population mean, while four to eight year old cows weaned calves which were 13.5 lbs. above the population mean. It appears that there is an optimum age at which beef cows reach their maximum production, as measured by the weaned weight of their calves. This age (Swiger et al. 1962; Rutledge, Robison, Ahschwelde and Legates, 1971; Burgess and Bowman, 1965; Tonn, 1974) lies within the range of four to eight years, and probably coincides with the age at which a cow attains full maturity. The majority of these studies point out the need to correct weaning weight for the age of dam effect, especially in the Bos taurus breed. The correction should be based on mature age.

The rationale in considering weaning weight as a character of the dam, rather than of the calf, has been shown in previous studies (Botkin and Whatley, 1953; Koger and Knox, 1947; Koch, 1951; Trail, Sacker and Fisher, 1971). The merit of weaning weight, as a measure of the future productivity of beef cows is greatly dependent on its genetic parameters. Preston and Willis (1970) presented some American estimates of the weaning weight repeatability. They considered the acceptable range to be 0.25 - 0.55, suggesting that the trait is of medium repeatability. A high repeatability means that poorer cows can be accurately culled as early as possible - after weaning the first calf. Consequently, the generation interval is shortened and the rate of response is improved. There is also the advantage of saving both the time and recording expenses by culling poorer cows as early as possible. The work of Koger and Knox (1947) based on weaner calves born to 436 beef cows, showed that the highest weaning weight correlation occurred between the first and second calves of the same cow. This correlation was, however, reduced only slightly between the first calf and the various other combinations of subsequent calves up to the fifth one, indicating that the first weaning weight measurement would be a reliable predictor of the future productivity of a beef cow upto the fifth year.

The heritability of weaning weight, has also been shown to be of medium value (Shelby et al. 1955; Preston and Willis, 1970; Tonn, 1974). A summary of some American estimates which gives the acceptable range as 0.20 - 0.50 was reported by Preston and Willis (1970). Estimates of 0.28 $\pm$ 0.08 and 0.30 $\pm$ 0.12 were obtained by Tonn(1974) for 998 Boran and Boran crosses, respectively. The majority of reports from previous investigations, however, seem to agree that weaning weight, as a character of the calf is of medium heritability and would give sufficient response if calves are selected to join breeding mobs on the basis of this trait.

Generally a positive and large genetic correlation has been reported between weaning weight and other beef traits which are considered to be of economic importance (Koch and Clark, 1955; Dinkel and Bush, 1973; Boston, Whiteman and Frahm, 1975). The importance of this correlation is that it determines both the magnitude and direction of response, when selection is made to improve more than one trait simultaneously. Carter and Kincaid (1959); Shelby et al. (1963) and Swiger et al. (1965) have reported a close genetic correlation between weaning weight and birth weight. A fairly close genetic correlation between weaning weight and both pre-weaning and post-weaning growth rates were also reported by Lehman et al. (1961); Swiger et al. (1962); Beruecos and Robison (1968) and Dickerson (1974). However, it was pointed out (Carter and Kincaid, 1959; Brinks et al. 1964) that under bad environmental conditions, a low or even negative genetic correlation could occur between these traits. The positive and close genetic correlation reported in the majority of studies has two important implications. Firstly, a unidirectional response would be expected from a selection based on an index combining all the three traits, thereby bringing about their genetic improvement simultaneously. Secondly, where selection is made to improve weaning weight only, there will be a correlated response in the same direction in both the pre-weaning and post-weaning growth rates and both traits would thus be improved indirectly.

Calving interval

The relevance of calving interval to the productivity of beef cows is well known. This trait is considered to be among the most efficient measures of the fertility of beef cows (Baker and Quesenberry, 1944; Rae and Barton, 1970; Preston and Willis, 1970; APRU-Botswana, 1975). A significant relationship between the average calving interval of a cow and the total calf crop during its productive life has been reported by Rae and Barton (1970) and Preston and Willis (1970). Cows with shorter calving intervals produce more calves in their productive life compared to those with longer intervals. Thus, to the extent that calving interval greatly determines the productivity of beef cows, it is of great economic importance in beef production.

However, not much attention has been paid to the genetic improvement of calving interval, despite its great economic importance. This is mainly because the trait is of low genetic variability. Legates (1954) observed almost no genetic variation in calving interval to justify selection. He noted that, although the repeatability of this trait was 0.13, its heritability was nearly zero. Further evidence for the low genetic variability of calving interval was given by Mahadevan and Marples (1961); Galukande, Mahadevan and Black (1962) and Rutledge *et al.*(1971). All these workers reported very low heritabilities which were generally nearing zero. The low genetic variability of calving interval indicates that the trait is influenced mainly by environmental factors, and that its rate of genetic improvement by selection is likely to be slow indeed.

The effect of the length of preceding calving interval on weaning weight has been investigated. Tonn(1974) found no significant effect of the length of preceding calving interval on weaning weight in three of the four ranches included in his study. The effect in one ranch was, however, significant, though rather small. In this ranch he observed a linear regression of weaning weight on the length of preceding calving interval of 0.018 + 0.008 kg. per day, excluding beifers. A cow with a longer preceding calving interval had enough time to recover from previous lactational stress as opposed to the one which had a shorter interval. This cow should, therefore, produce more milk for the calf during its pre-weaning growth. Galukande *et al.*(1962) found a significant increase in the current lactation yield of a cow, which was attributable to the long preceding calving interval. A similar observation had been made earlier by Mahadevan and Marples (1961), but they noted that the increase was only true in the second and third lactations and not in the subsequent ones. However, a longer preceding calving interval would be undesirable to the extent that it reduces the average annual calf crop of a herd (Rae and Barton, 1970). It would, therefore, appear reasonable to have an average length of calving interval of, say one year.

Although there is empirical evidence to show that calving interval is mainly influenced by environmental factors, reports on which of these factors are implicated are rare. A significant effect of the month and year of calving, and age of dam on the length of following calving interval was reported by Schalles and Marlowe (1967). Cows which calved in May and August had shorter following calving intervals than those which calved in June and July. The significant effects of both year and season could have been caused by the differences in forage availability between the different seasons and years. The availability of feed greatly determines the nutritional status of a cow and hence, its fertility.

The Kenya Beef Records' "Productivity Index"

Wilkins (1974) described the method used in the construction of the Kenya Beef Records' "Productivity Index". This method is different from the standard one which was recommended by Smith (1937), Hazel and Lush (1942) and Hazel (1943) for the construction of a proper selection index. In the construction of the 'Productivity Index', the component traits - weaning weight and 'productive' calving interval - are not weighted by their heritabilities and relative economic values. Neither are the phenotypic and genetic correlations between them considered. According to the Kenya Beef Records, weaning is corrected for the effects of sex and weaning age of calf only. But it is well known that other factors such as season of both calving and weaning, dam weight at weaning and herd are also implicated significantly (Swiger *et al.* 1962; Martojo, 1974; Tonn , 1974; Kennedy and Henderson, 1975). Since season of weaning affects weaning weight significantly, the use of the factor of 1.1 to correct for the effects of sex in all seasons, as is currently done may give only a rough approximation. The inclusion of calving interval as a component trait of this index, despite its low genetic variability, could reduce its efficiency substantially, as far as the genetic improvement of the cows is concerned. Thus, the method of constructing the 'Productivity Index' makes it necessary to assess its merit as a basis for improving the productivity of Boran beef cows genetically.

It was against this background that this research project was conceived, with the following primary objectives:-

i) to estimate the repeatabilities of the 'Productivity Index', as it is at the present time, and of its component traits - weaning weight and 'productive' calving interval;

ii) to estimate the phenotypic, genetic and environmental correlations between the component traits;

iii) to estimate the relative importance of the two component traits, as far as the determination of the index is concerned;

and iv) finally, to draw conclusions, based on the research findings, on the efficiency of the index.

CHAPTER 3

MATERIALS AND METHODS

3.1. DESCRIPTION OF THE ENVIRONMENT AND STOCK

3.1.1. The Environment

Mogwooni ranch is located to the North-West of Mount Kenya, in the semi-arid zone, classified by Pratt *et al.* (1966) as Zone 4. The ranch is about 25 km. from Nanyuki town, on the Nanyuki-Rumuruti road. About 1600 cattle are kept in an area of 6,454 hectares, giving a stoking rate of about four hectares per animal. This stocking rate varies with the different seasons of the year.

The rainfall is low, poorly distributed and varies both within and between years. Generally the hottest and driest months are December, January, and February. There are two different rainy seasons - the long rains fall from March to June and short rains from October to November, the latter are, however, highly variable. In some years the feed supply is depleted if the short rains fail and the long rains are delayed. Table 1 shows a ten year (1967 - 1976) mean annual rainfall on this ranch. The highest annual rainfall recorded during this period was 847.4 mm. in 1967, while the lowest was 383.5mm., recorded in 1973. The mean annual rainfall was 555.6 mm. May had the highest monthly rainfall record of 1070.6 mm. - total for the ten years - while January had the lowest record of 20.6 mm.

A permanent river, the Nanyuki, passes through the ranch from its source on Mount Kenya. The ranch has installed its own pump to tap this water, giving the cattle permanent access to drinking water.

The soil types vary between the different parts of the ranch. However, the bulk of the ranch has red-loam sandy soils. Fertile 'black cotton' soils are commonly found in the valleys. A wide range of bushes and trees are found all over the ranch. Acacia and thorn-bushes of many types are the outstanding ones. The pasture is unimproved.

Wild animals such as antelopes and gazelles are always present on the ranch, while buffaloes, zebras, elephants and giraffes trespass into the ranch from the nearby Samburu Game Reserve. Cases of animals, especially calves and sheep, falling prey to predatory animals are common. Stock theft is a problem to all the ranches in this area.

3.1.2. The Stock

The main livestock kept on the ranch are cattle, of which Boran forms the major breed. A few sheep are also kept. Cattle are kept in different herds. There are four breeding cow herds, four steer herds, three heifer herds and one bull herd. There are also separate herds for the culled cows and sick animals. One of the four cow herds is composed of the Friesian X Boran F_1 cows, which are kept in the dairy ranching system to provide milk for domestic use. The F_1 cows

Table 1: Mean annual rainfall (mm) on Mogwooni Ranch (1967 - 1976)

Year	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total amount of rainfall recorded (mm)	847.4	664.7	462.0	424.2	539.2	546.9	383.5	457.7	698.5	531.9

(Source: Mogwooni Ranch)

are crossed back to Boran bulls to produce backcrosses which are sold as fatteners. The F_1 males are also sold as fatteners.

Senility, low productivity (as measured by weaner production per month of 'productive' calving interval) and infertility are among the main criteria for culling breeding cows. All breeding cows are allowed a maximum productive life of ten years before they are culled on age basis.

The selection of replacement heifers is done at 24 months of age. This means that all heifer calves are retained at weaning. The bulling of heifers is done mainly on the bases of their weight at 18 months, general body conformation and performance records of both parents.

The bull calves, unlike the replacement heifers are selected at weaning. The selection is based on their weaning weights and on the performance records of the dams and grand dams. The unselected ones are castrated at weaning.

The majority of the breeding bulls used on the ranch are home-bred. A few have, however, been bought in from other ranches, to avoid the occurance of an undesirable level of inbreeding.

3.2. MATERIALS

3.2.1. Source of data

The data used in the present study were taken from records of 1274 breeding cows, kept on Mogwooni Ranch in the Laikipia District of Kenya between 1961 and 1976. The data had been collected earlier, under the supervision of the Kenya Beef Records of the Ministry of Agriculture's Livestock Recording Centre, and kept at their offices in Naivasha. The study was conducted within the Boran breed. Only cows which had four or more calves, with both birth and weaning dates, and weaning weight records available were included in the study. Out of the total of 1274 cows, only 384 Boran cows qualified, with a total of 1526 calves. Most of the cows were born between 1961 and 1969, although some foundation cows were born earlier than 1961. The 1526 calves were born between 1967 and 1976. The ranch started weighing calves at weaning in 1967, thus only calves born from 1967 onwards were included in the present study. The cows calved for the first time at about 36 months of age. The average weaning age of calves was about nine months. All calves were left with their dams from birth to weaning, without access to any supplementary feed.

3.3. METHODS

3.3.1. Data preparation

The records kept at the Livestock Recording Centre, Naivasha, were checked for accuracy and also updated during the initial stage of data preparation. The main records of interest at this stage were the breed and parity of dam, breed of sire, calving and weaning dates, weaning age, weaning weight, sex and breed of calf. The checks were done individually for all the 1274 cows and their calves. At the end of the initial check, all the records were taken to Mogwooni Ranch, where a further check was made, this time against the original records on the ranch from which the data at Naivasha had been extracted.

The data codes were established following a satisfactory checking and updating of all the available records. The establishment of data codes was a necessary process before the data could be put onto the coding sheets, ready for punching. The codes were established for the breed and origin of sire, type of birth, sex and breed of calf. Codes were also established to show whether both the present and previous calves were weaned or not, and whether the calving and weaning dates were complete or not.

Knowledge of the type of calving, whether single or multiple, was essential in the calculation of both the 'productive' calving interval and 'Productivity Index'. Also of importance, as far as the calculation of the 'productive' calving interval was concerned, was the knowledge of whether both the present and the previous calves were weaned or not. According to the Kenya Beef Records, the definition of the 'productive' calving interval considers whether the previous calf was weaned or not. The breed of calf was derived from the breeds of both parents, and for a calf to qualify for use in the study, both parents had to be Boran.

The date codes were used to show how complete both the calving and weaning dates were. Where only the month and year of calving or weaning were present, and not the exact day, the exact day was fixed at the 15th of every month. Weaning on this ranch is done at around the middle of the month.

3.3.2. Corrections of data and calculations

The corrections and calculations were done in exactly the same way as the Kenya Beef Records. The weaning weights were adjusted for the effects of weaning age and sex of calf. A standard weaning age of 250 days was used, while the sex adjustment was based on the age corrected weaning weight of a male calf. Thus, the female age corrected weaning weight was multiplied by a factor of 1.1 to put it on male basis. The same standard birth weights of 28 and 26 kg. were used respectively, for male and female calves in the weaning weight corrections.

The formula used to correct weaning weight for the influence of age was:-

$$Wwt_A = \left(\frac{Wwt - Bwt}{W.age} \times 250\right) + Bwt$$

where, Bwt = birth weight in kg.;

Wwt = raw weaning weight in kg.;

Wwt_A = age corrected weaning weight in kg.;

and W.age= actual weaning age in days.

The 'productive' calving interval was calculated as the difference in days, between the date of calving of the last calf reared to weaning, and the date of calving of the calf under discussion.

The 'Productivity Index' was calculated from the age and sex corrected weaning weight and 'productive' calving interval according to the formula:-

$$PI = \frac{Wwt_{AS}}{CI_p} \times 30.4$$

where, PI = 'Productivity Index' in kg. per month of 'productive' calving interval;

CI_p = 'Productive' calving interval in days;

Wwt_{AS} = age and sex corrected weaning weight

The factor of 30.4 is the average number of days in any one month of the year.

The 'Productivity Index' gives an indication of how much weaning weight a cow was able to raise per month of 'productive' calving interval. The ranch weans calves once every month, and all cows weaning calves in any particular month have this index calculated for them. The relative productivity of each cow is then expressed as a percentage of the monthly mean 'Productivity Index' of all the cows weaning calves in that month, using the formula:-

$$\text{Rating} = \frac{PI}{\frac{PI}{n}} \times 100$$

where, n is the number of cows weaning calves in a particular month. This rating was not, however, done in the present study.

3.3.3. Data analysis

All the variables which were essential in the analyses were stored on a master tape. Among them were the 'Productivity Index', sex and age corrected weaning weights, and the 'productive' calving interval. The analysis tapes were created from the master tape according to the desired analyses. All the analyses were carried out at the Institute of Computer Science of the University of Nairobi on an ICL 1902 Computer.

3.3.3.1. Analysis of variance and the estimation of repeatability

The analysis of variance, one way classification, was done separately for each of the three variables - the 'Productivity Index', weaning weight and 'productive' calving interval. The repeatability of each of the three traits was estimated by the method of intraclass correlation. This method was described by Falconer (1960). Table 2 gives the model of the analysis of variance table used.

Table 2: A Model of the analysis of variance table used for the estimation of repeatability

Source of Variation	Degree of freedom	Mean Squares	Expected Mean Squares
Between cows	a-1	MS_B	$\sigma^2_W + k_o \sigma^2_B$
Within cows (between calves)	N-a	MS_W	σ^2_W

where, a = total number of cows (384) used in the analysis;

N = total number of calves (1526) born to the 'a' cows;

σ^2_B and σ^2_W = the between and within cow components of variance;

MS_B and MS_W = between and within cow mean squares;

and k_o = the average number of calves per cow ('average' group size).

The repeatability or the intraclass correlation coefficient (t) of each of the three traits was then calculated as the variance between cows (σ^2_B), expressed as a fraction of the total variance ($\sigma^2_B + \sigma^2_W$). The following formula was applied:-

$$t = \frac{\sigma_B^2}{\sigma_B^2 + \sigma_W^2}$$

The 'average' group size (k_o factor) was calculated using the formula:-

$$k_o = \frac{1}{a-1} \left(\frac{N-\Sigma n_i^2}{N}\right)$$

where, n_i = total number of calves born to the $_i$th cow; i ranged from 1 to 384.

The standard error of the intraclass correlation coefficient (t) was taken as the square root of its variance using the following formula:-

$$SE_t = \sqrt{\frac{2(1 + (k_o-1)^2 (1 + t)^2 (N - 1)}{k_o^2 (n - a) (a - 1)}}$$

where, SE_t is the standard error of the estimated intra-class correlation coefficient. This formula was taken from Turner and Young (1969).

3.3.3.2. <u>The estimation of the phenotypic, genetic and environmental correlations</u>

The phenotypic, genetic and environmental correlation coefficients between weaning weight and 'productive' calving interval, were estimated by the method of the covariance analysis as shown in Table 3. This method was described by Falconer (1960) and Turner and Young (1969).

Table 3: A model of the analysis of covariance table used for the estimation of phenotypic, genetic and environmental correlations

Source of Variation	Degrees of Freedom	Sum of Squares (x)	Mean Squares (x)	Sum of Squares (y)	Mean Squares (y)	Sum of Products (xy)	Mean Products (xy)
Between cows	a−1	SS_B	MS_B	SS_B	MS_B	SP_B	MP_B
Within cows (between calves)	N−a	SS_W	MS_W	SS_W	MS_W	SP_W	MP_W
Total	N−1	SS_T	MS_T	SS_T	MS_T	SP_T	MP_T

	E(MS)x	E(MS)y	E(MP)xy
Between cows	$\sigma_W^2 + k_o\sigma_B^2$	$\sigma_W^2 + k_o\sigma_B^2$	$Cov_W + k_oCov_B$
Within cows (between calves)	σ_W^2	σ_W^2	Cov_W

where, cov_B and cov_W = the covariance components between and within cows;

x = weaning weight;

y = 'productive' calving interval;

SS = sum of squares;

MP = mean cross product of the two independent variables (x and y);

SP = sum of cross products of the two independent variables;

Cov_{xy} = covariance between the two independent variables;

and E(MS) and E(MP) = expected mean squares and expected mean products consecutively

The phenotypic correlation coefficient (r_p) was estimated by the formula:-

$$r_p = \frac{cov_{xy}}{(\sigma_x)\ (\sigma_y)}$$

where, σ_x and σ_y = the standard deviations of the two variables - weaning weight and 'productive' calving interval respectively.

The genetic correlation coefficient (r_A) was estimated as:-

$$r_A = \frac{cov_{xy}}{(\sigma_{B_x})\ (\sigma_{B_y})}$$

The environmental correlation coefficient (r_E) was estimated using the formula:-

$$r_E = \frac{cov_B - cov_W}{(\sigma_a - \sigma_e)\ (\sigma_b - \sigma_f)}$$

where, σ_a and σ_e = between and within standard deviations of weaning weight;

and σ_b and σ_f = within and between standard deviations of 'productive' calving interval.

The regression coefficient (b_{xy}) of weaning weight (x) on 'productive' calving interval (y) was estimated as:-

$$b_{xy} = \frac{cov_{xy}}{\sigma^2_y}$$

Standard partial regression coefficients were calculated to determine the relative importance of the two component traits, as far as the determination of the index is concerned. The formula applied was:-

$$\text{Standard Partial Regression Coefficient} = b_i \sqrt{\Sigma x_i^2 / \Sigma y^2}$$

where, b_i = the partial regression coefficient of the 'Productivity Index' on its trait i;

x_i = the i^{th} component trait of the index. The two component traits (weaning weight and 'productive' calving interval) were the independent variables;

and y = the 'Productivity Index' - a dependent variable.

This formula was taken from Snedecor and Cochran (1973).

CHAPTER 4

RESULTS

4.1. Results of the preliminary analysis

The frequency distribution of weaning weight, 'productive' calving interval and 'Productivity Index' are presented by histograms in Figures 1, 2 and 3 respectively. The histograms show that except for 'productive' calving interval, the actual distribution of these variables in the population studied were normal. From the histogram in Figure 2, it can be seen that the distribution curve for 'productive' calving interval would be skewed to the left, with the majority of the cows having calving intervals of about one year (365 days). This kind of distribution curve is in order for this trait.

Figure 1: Frequency distribution histogram for weaning weight

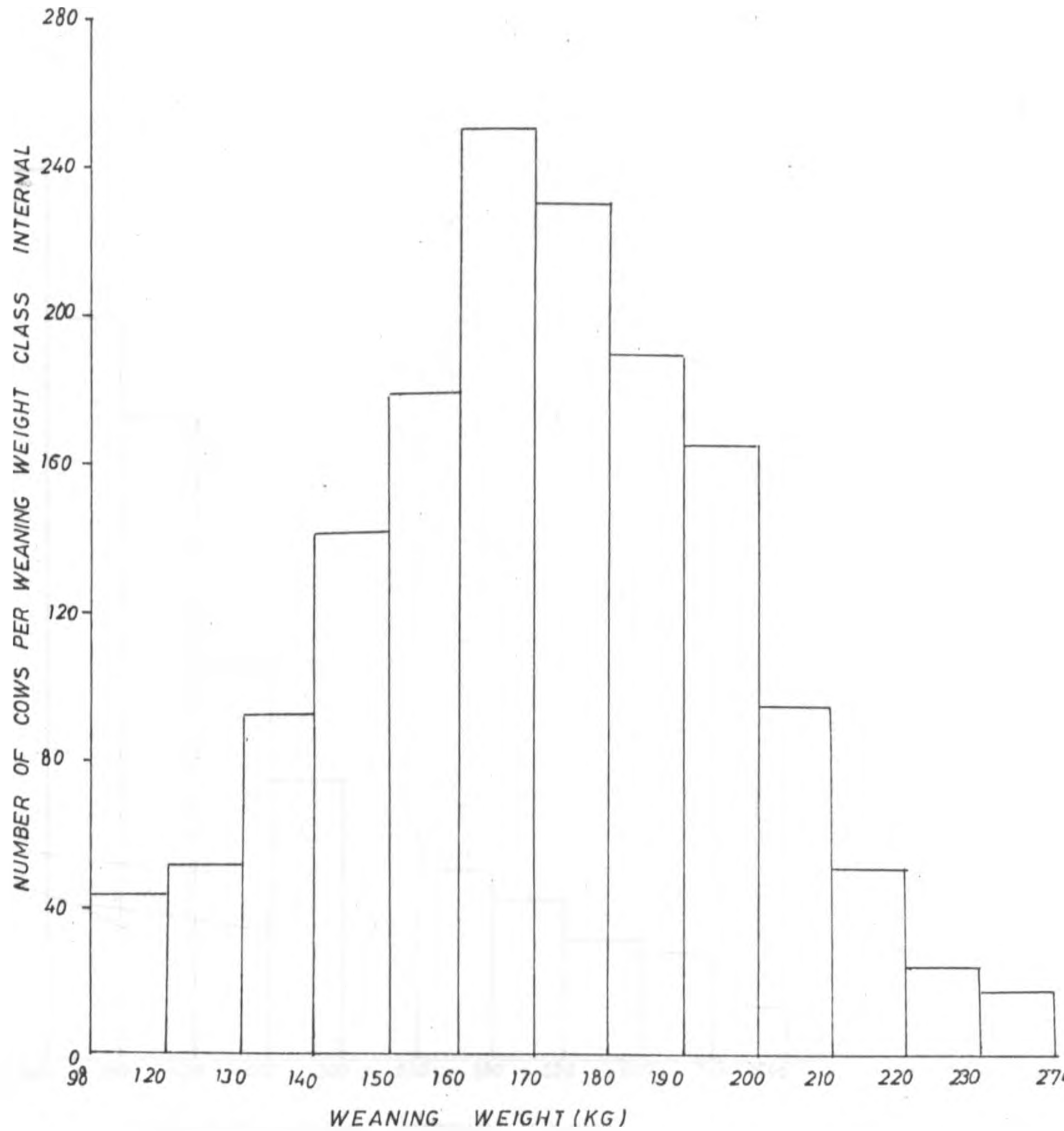


Figure 2: Frequency distribution histogram for 'productive' calving interval

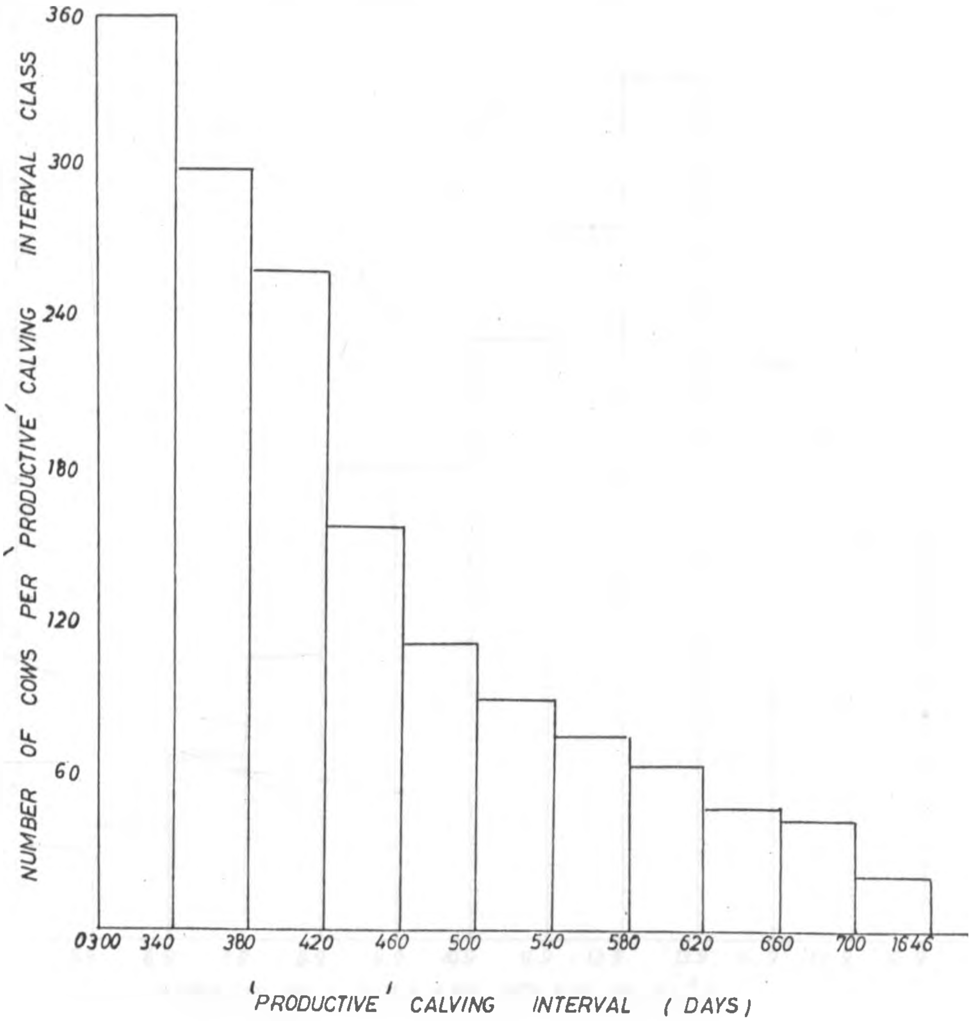
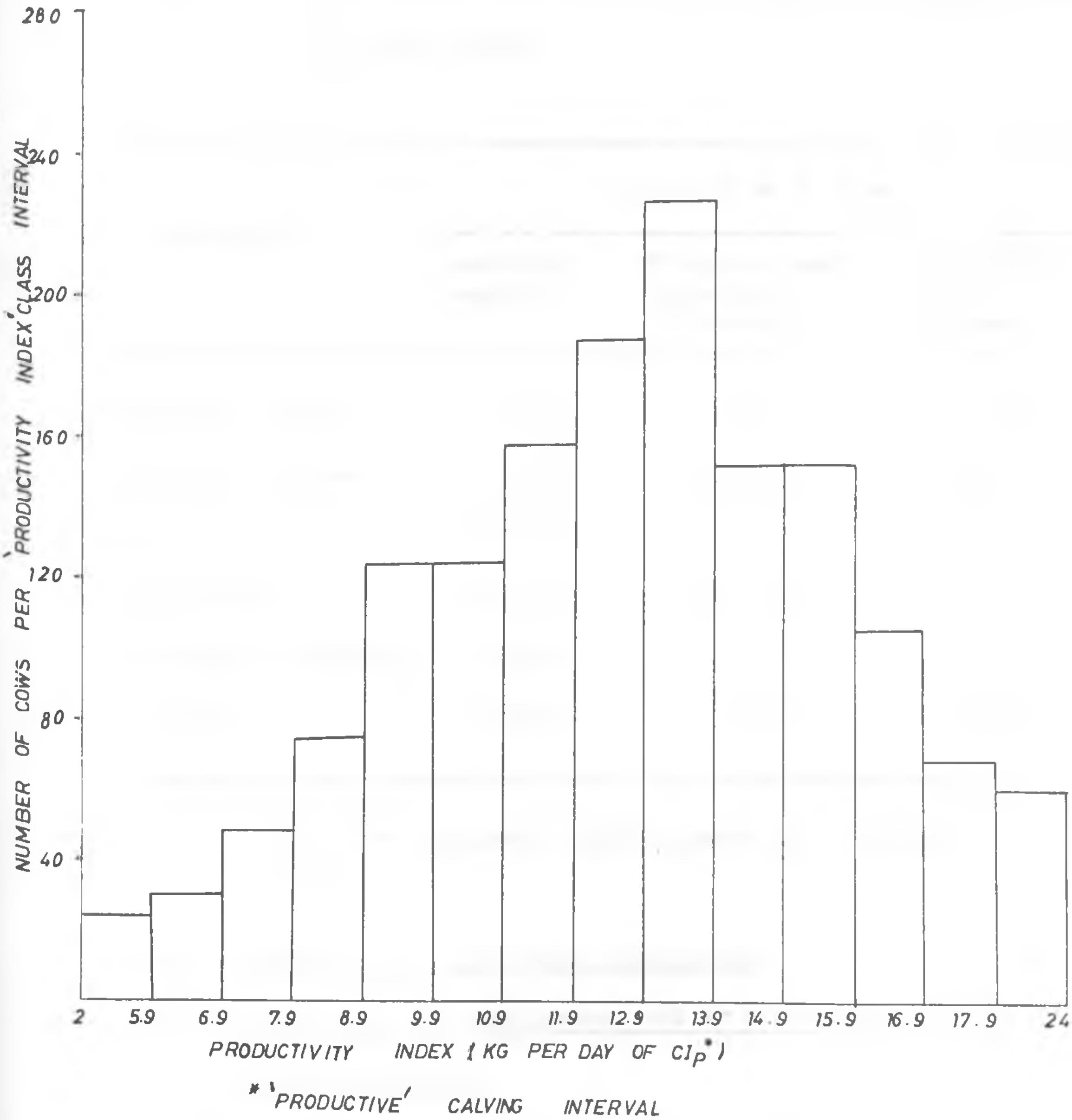


Figure 3: Frequency distribution histogram for 'Productivity Index'



The minimum, maximum and mean values, variance, standard deviations and coefficients of variation of the three variables have been presented in Table 4 below.

Table 4: Minimum, maximum and mean values, variance, standard deviations and percent coefficients of variation

Statistic	Variable		
	Weaning weight	'Productive' calving interval	'Productivity Index'
Minimum value	98.21	300.0	2.44
Maximum value	274.23	1646.0	23.73
Mean value	171.39	430.67	12.73
Variance	685.75	14960.06	8.98
Standard deviation	26.19	122.31	3.0
% C.V.*	15.28	28.40	23.54

* percent coefficient of variation

4.2. Results of the main analysis

4.2.1. Analysis of variance and the estimation of repeatability

The analyses of variance for weaning weight, 'productive' calving interval and 'Productivity Index' are laid out in Tables 5, 6 and 7 respectively. The proportion of the phenotypic variance attributable to each of the two components - between and within cows - has been shown for each variable. The estimates of repeatability, calculated F-statistics and 'average' group size have also been presented. The 'average' group size or the 'k_o' factor in all the three analyses was 3.97.

Table 5: Analysis of variance for weaning weight

Source of variation	Degrees of Freedom	Sum of Squares	Mean Squares
Between cows	383	360998.16	942.55
Within cows (between calves)	1142	684773.39	599.63

Variance Components

$$\sigma^2_B = 86.31$$

$$\sigma^2_W = 599.0$$

Repeatability (t)

$$t = \frac{86.31}{86.31 + 599} = 0.13 \pm 0.025$$

This repeatability estimate was significantly different from zero (P/0.005). The calculated F-value of 1.572 was greater than the tabulated one of 1.00 at 383 and 1142 degrees of freedom.

Table 6: Analysis of variance for 'productive' calving interval

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares
Between cows	383	7126531.13	18607.13
Within cows (between calves)	1142	15688163.62	13737.45

Variance Components

$$\sigma^2_B = 1225.62$$

$$\sigma^2_W = 13737.45$$

Repeatability (t)

$$t = \frac{1225.62}{1225.62 + 13737.45} = 0.08 \pm 0.02$$

This repeatability estimate was significantly different from zero ($P < 0.005$). The calculated F-value of 1.354 was greater than the tabulated one of 1.00 at 383 and 1142 degrees of freedom.

Table 7: Analysis of variance for 'Productivity Index'

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares
Between cows	383	3993.90	10.43
Within cows (between calves)	1142	9704.83	8.50

Variance Components

$$\sigma^2_B = 0.49$$

$$\sigma^2_W = 0.50$$

Repeatability (t)

$$t = \frac{0.49}{0.49 + 0.50} = 0.05 \pm 0.02$$

This repeatability estimate was significantly different from zero ($P \angle 0.005$). The calculated F-value of 1.227 was greater than the tabulated one of 1.00 at 383 and 1142 degrees of freedom.

4.2.2. Analysis of covariance and estimation of phenotypic, genetic and environmental correlations

The phenotypic, genetic and environmental correlations were estimated between weaning weight and 'productive' calving interval from the analysis of covariance presented in Table 8.

Table 8: Analysis of covariance and the estimation of phenotypic, genetic and environmental correlations

Source of Variation	Degrees of Freedom	Sum of Squares (Wwt)	Mean Squares (Wwt)	Sum of Squares (CI_p)	Mean Squares (CI_p)	Sum of Products (Wwt x CI_p)	Mean Products (Wwt x CI_p)
Between cows	383	360998.16	942.55	7126531.92	18607.13	486925.51	1271.35
Within cows (between calves)	1142	684773.39	599.63	15688163.62	13737.45	978825.06	857.11

'Average' group size = 3.97

Covariance and variance Components

$$Cov_B = 104.34$$

$$Cov_W = 857.11$$

$$\sigma^2_B\text{-Wwt} = 86.38$$

$$\sigma^2_W\text{-Wwt} = 599.63$$

$$\sigma^2_B\text{-CI}_p = 1226.62$$

$$\sigma^2_W\text{-Wwt} = 13737.45$$

The phenotypic correlation coefficient (r_p) of 0.208 was estimated. This correlation was significantly different from zero ($P \angle 0.005$).

Genetic correlation coefficient (r_A)

$$r_A = \frac{104.34}{\sqrt{(86.38)\ (1226.62)}} = 0.32$$

Environmental correlation coefficient (r_E)

$$r_E = \frac{104.34 - 857.11}{\sqrt{(86.38-599.63)\ (1226.62-13737.45)}}$$

$$= -0.30$$

These correlation coefficient estimates were both significantly different from zero ($P \angle 0.005$).

Regression of weaning weight on 'productive' calving interval

The regression graph of weaning weight on 'productive' calving interval is shown in Figure 4.

The linear regression coefficient (b_{xy}) of weaning weight (y) on 'productive' calving interval (x) was:-

$$b_{xy} = \frac{1465750.57}{22814694.75} = 0.06$$

This regression coefficient was significantly greater than zero (P$\angle$0.005). The regression equation developed was:-

$$\hat{Y} = 145.55 + 0.06x$$

Where $\hat{Y}$ is the estimated weaning weight in kg. The intercept (α) on the vertical axis was 145.55 kg.

The standard partial regression coefficient of the index on weaning weight was:-

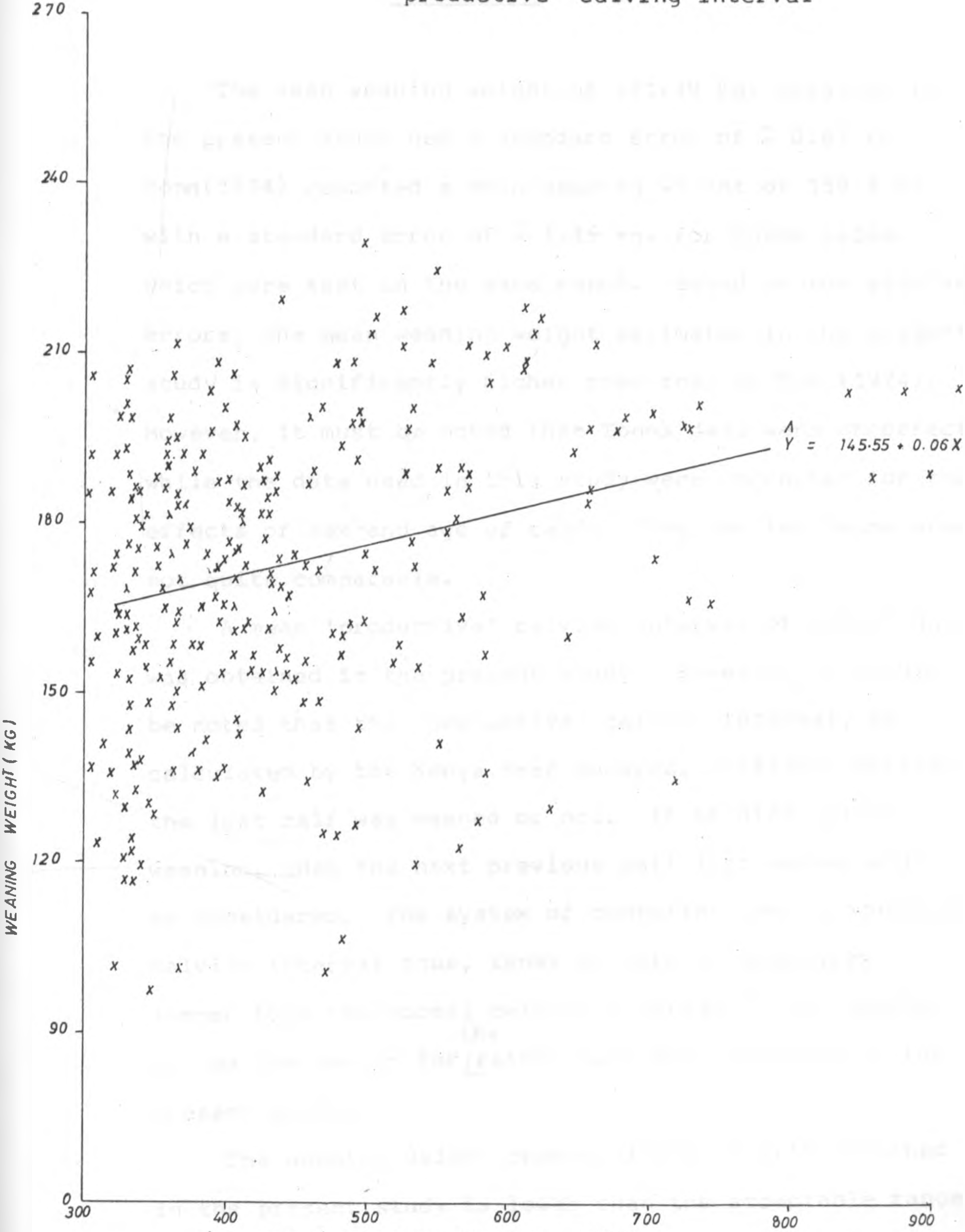
$$\text{Standard Partial Regression Coefficient} = 0.068\sqrt{\frac{1022.63}{117.09}} = 0.59$$

The standard partial regression coefficient of the index on 'productive' calving interval was:-

$$\text{Standard Partial Regression Coefficient} = 0.021\sqrt{\frac{4776.47}{117.09}} = -0.86$$

These coefficients show that 'productive' calving interval is more important than weaning weight, as far as the determination of the 'Productivity Index' is concerned.

Figure 4: Regression graph of weaning weight on 'productive' calving interval



CHAPTER 5

DISCUSSION

The mean weaning weight of 171.39 kg. obtained in the present study had a standard error of ± 0.67 kg. Tonn(1974) reported a mean weaning weight of 159.4 kg. with a standard error of ± 1.15 kg. for Boran calves which were kept in the same ranch. Based on the standard errors, the mean weaning weight estimated in the present study is significantly higher than that of Ton (1974). However, it must be noted that Tonn's data were uncorrected, while the data used in this study were corrected for the effects of sex and age of calf. Thus the two means are not quite comparable.

A mean 'productive' calving interval of 430.67 days was obtained in the present study. However, it should be noted that the 'productive' calving interval, as calculated by the Kenya Beef Records, considers whether the last calf was weaned or not. If it died before weaning, then the next previous calf last weaned will be considered. The system of computing the 'productive' calving interval thus, tends to make it generally longer than the normal calving interval. This appears to be the reason for the rather high mean obtained in the present study.

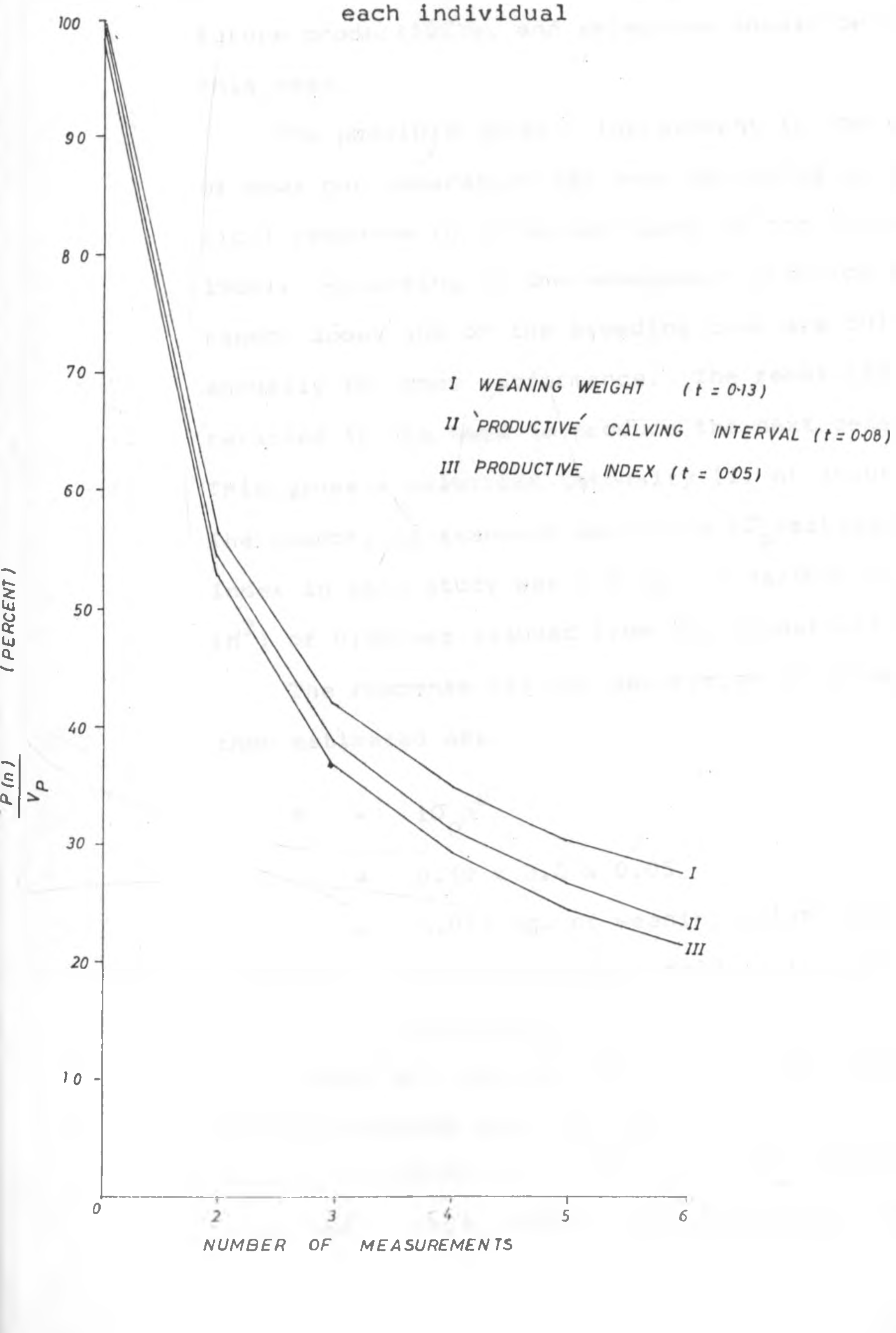
The weaning weight repeatability of 0.13 obtained in the present study is lower than the acceptable range of 0.25 - 0.50, reported by Preston and Willis (1970) in their summary of some American estimates. In Uganda, Trail *et al.* (1970) also reported a higher value of 0.47 for Boran cows whose calves were weighed at nine months of age. The majority of workers (Preston and Willis, 1970; Trail *et al.* 1971; Ton, 1974) have corrected this trait for the effects of more factors. In the present study corrections were made for the effects of sex and age of calves only. This might be the reason for the low repeatability estimated here.

The repeatability of 'productive' calving interval was estimated as 0.08 in the present study. This estimate falls within the general range reported from other studies (Legates, 1954; Mahadevan and Marples, 1961; Galukande *et al.* 1962; Rutledge *et al.* 1971). Although this estimate was significantly different from zero, it confirms the general conclusion from the majority of studies - that calving interval is a trait of low genetic variability, and cannot be expected to respond greatly to selection.

The very low repeatability of 0.05 reported from this study for the 'Productivity Index', shows that a large proportion of the total variation in this character is accounted for by environmental factors. It also implies that the probability that a cow will repeat the same productivity record in the next year is very low. Therefore, selecting cows by their first productivity records would be less accurate compared to the use of the mean of two or more measurements. Figure 5 (Falconer, 1960) shows that when the number of measurements of any of the three variables is increased on the same cow, the amount of variance due to temporary environment that appears in the phenotypic variance is reduced. This reduction results from the use of the mean of two or more measurements, instead of a single one. The temporary environmental variance is reduced by a factor of $\frac{1}{n}$, where 'n' is the number of measurements contributing to the mean (Falconer, 1960). Thus, the larger the temporary environmental variance, the greater the reduction. This reduction in the phenotypic variance represents the gain in the accuracy of measurement.

The three graphs in Figure 5 all illustrate that by increasing the number of measurements from one to three, the corresponding reductions in the phenotypic variance are 58, 61.2 and 63.1% for the weaning weight, 'productive' calving interval and 'Productivity Index' respectively. The three graphs together with the corresponding calculations were all based on the results obtained in this study. In all the three traits, the amount of reduction in the phenotypic variance, as represented by the fall in slope, was not substantial after the third measurement of an individual cow. This demonstrates that the corresponding gain in the accuracy of measurement would also not be substantial. Therefore, in practice it will not pay, in terms of gain in accuracy, to take more than three measurements of an individual cow.

Figure 5: Gain in accuracy from multiple measurements of weaning weight, 'productive' calving interval and 'Productivity Index' taken on each individual



The mean of the first three records of 'Productivity Index' of a cow should give an accurate picture of its future productivity, and selection should be based on this mean.

The possible genetic improvement in the productivity of cows per generation has been estimated as the theoretical response to selection based on the index (Falconer, 1960). According to the management practice on this ranch, about 10% of the breeding cows are culled annually for poor performance. The remaining 90% are retained in the herd to produce the next generation. This gives a selection intensity (i) of about 0.19. The phenotypic standard deviation (σ_p) estimated for the index in this study was 3.0 kg. A maximum heritability (h^2) of 0.05 was assumed from the repeatability estimate.

The response (R) per generation of selection was then estimated as:-

$$R = i\sigma_p h^2$$

$$= 0.19 \times 3.0 \times 0.05$$

= 0.029 kg. of weaning weight per month of 'productive' calving interval per generation.

Thus, the mean productivity of the female progeny of the selected cows, as predicted by this index, would be only 0.029 kg. or 0.23% above the parental mean before selection. This represents the expected genetic improvement in the productivity of cows after one generation of selection on the basis of the index.

In practice, the true response is likely to be different from the one predicted here. The prediction was based on the maximum heritability of the index, because the structure of the data did not allow the estimation of the actual heritability. The phenotypic standard deviation (σ_p) of the index used in the prediction was calculated from the preselected lot of 384 cows, which had weaned at least four or more calves, with weaning weight records available. More phenotypic variation would be expected in the whole population of breeding cows, giving a larger phenotypic standard deviation than the one used in the present study.

As the ranch has to keep a constant population of breeding cows or expand it, the intensity (i) cannot be increased by selecting only a few breeding cows to produce the next generation. Other factors such as the fertility of the breeding cows and the available replacement heifers would also determine the selection intensity. Generally i can only be increased at the expense of t, the generation interval which would appear in the denominator of equation for response. However, despite the fact that this estimated response is rather exaggerated, it is still too low to promise a rapid rate of genetic improvement in this trait.

The possible genetic improvement in productivity, when replacement heifers are selected on the basis of their weaning weights, was predicted using the 1977 cattle records of the ranch. There were 538 breeding cows during this year. About 18% of the cows would be culled for low productivity and for other different causes; and about 45% of the heifers weaned would be selected for replacement, giving a selection intensity of 0.88. The phenotypic standard deviation of weaning weight calculated in this study was 26.19 kg. Based on the majority of estimates in literature, heritability of 0.25 was assumed reasonable for this trait (Preston and Willis, 1970; Ton, 1974). The response per generation of selection was then predicted as 5.76 kg. of weaning weight. This would give an annual genetic progress of 0.96 kg. or 0.51%. The corresponding figures for the index would be 0.005 kg. or 0.04% respectively. The possible bias carried in the latter prediction are the same as those already described for the same prediction based on the index. However, it is evident, from the two different predictions, that more genetic progress would be achieved by selecting replacement heifers on the basis of their weaning weights.

The structure of the data analysed allowed the estimation of heritability of weaning weight, as a character of the calf rather than of the dam. The method of sib-analysis was used since all the calves were groups of maternal half-sibs, having a quarter of their genes in common. The heritability was, therefore, taken as four times the intraclass correlation coefficient (t) - Falconer (1960) and Turner and Young (1969). The standard error (SE) of the estimated heritability ($\hat{h}^2$), was calculated as the square root of the variance of the interclass correlation coefficient according to the formula (Turner and Young, 1969):-

$$V(\hat{h}) = \frac{32\hat{h}}{T}$$

where, V is the variance of the estimated heritability and T, the whole population size (1526 calves) in which the heritability was estimated. The standard error was then taken as the square root of this variance

$$SE_{(\hat{h}^2)} = \sqrt{\frac{32\hat{h}}{T}}$$

The estimated weaning weight heritability was 0.50 ± 0.10. This is generally higher than other estimates in literature. Ton (1974) reported estimates of 0.28 and 0.30 for the same trait for Boran calves kept in the same environment. The calves were paternal half-sibs. The summaries of Preston and Willis (1970) of some American estimates were in the range of 0.20 - 0.50. The estimate obtained in the present study could be exaggerated, mainly for two reasons. Firstly, it was estimated from the variance component of the maternal half-sibs, and there was, therefore, the bias arising from the strong maternal effect on the pre-weaning growth of the calves.

In the majority of other estimates in literature, this bias has been overcome by using paternal instead of maternal half-sibs. Secondly, there was the bias due to the common ranch in which these calves were reared to weaning. For these two reasons, this heritability estimate was not used in the prediction of the possible genetic progress when replacement heifers are selected by their weaning weights.

The standard partial regression coefficient estimates of 0.59 and 0.86, of the index on weaning weight and 'productive' calving interval respectively, demonstrate that the 'productive' calving interval and not weaning weight, is the more important determinant of the index, though negatively. The genetic correlation of 0.32 estimated between the two component traits is, in practice, negative. According to the standard method of constructing a proper selection index the heritabilities and economic values of the component traits are considered, and also the phenotypic and genetic correlations among them (Smith, 1937; Hazel and Lush, 1942; Hazel, 1943). In the case of the Kenya Beef Records 'Productivity Index' these factors are not considered. The aim of using this index is to give an average weaning weight at regular 'productive' calving intervals, thereby improving both the annual offtake per cow (as measured by the weaning weight of its calf) and the percentage calf crop. But as calving interval is negatively correlated with weaning weight, and has such a low heritability, its inclusion as a component trait of this index is likely to be a hindrance rather than anything else.

On the other hand, calving interval, as a measure of the fertility of a beef cow, is of great economic importance in beef production and should be improved. Under range conditions, as in some areas of Kenya, fertility may reflect adaptability, and might be demonstrated to have a higher heritability than that reported elsewhere (Rae and Barton, 1970; Brinks, 1970). Thus under such conditions, it might be possible to select for improved fertility (Wilkins, 1974). There may also be a positive genetic correlation between weaning weight and fertility, as weaning weight is also a measure of adaptability.

A significant regression coefficient of 0.06 kg. of weaning weight on 'productive' calving interval was obtained in the present study. Ton (1974) also reported a significant regression coefficient 0.018 kg. of weaning weight on the length of preceding calving interval. It appears that cows with longer preceding calving intervals wean heavier calves than those with shorter intervals, because they have had ample time to recover from the previous lactational stress. Consequently they are able to produce more milk which is essential for the pre-weaning growth of calves. Mahadevan and Marples (1961) and Galukande et al. (1962) have reported a significant effect of the length of previous calving interval on the next lactation yield in dairy cattle in East Africa.

Whereas a long preceding calving interval would be expected to increase the weaning weight of the next calf, it should be considered whether this increase would be substantial enough, to compensate for the reduced calf crop arising from the prolonged preceding calving interval. This appears to be unlikely, both biologically and economically. There should thus, be a compromise between the length of the preceding calving interval of a cow and the weaning weight of the calf under consideration.

The 'Productivity Index' is used by the Kenya Beef Records on a within month basis. This could improve its efficiency in so far as the season component of variation in weaning weight, and hence in the index, is corrected for. This is important because the cows can then be rated on a within year basis, to conform with the management practice in this ranch, where stock evaluation is done annually. Unpublished work (Kenya Beef Records, 1977) based on 1970 - 1976 data, showed that there was a significant effect of season on weaning weight in all the seven years, and hence the need to correct for this factor.

Weaning weight, as a component trait of this index, was corrected for the influence of sex and age of calf only. Evidence from other studies (Creek and Nestle, 1964; Trail et al. 1971; Ton, 1974) indicate that more factors would affect this trait significantly under similar environments. Some of these factors would be year of weaning, dam weight at weaning, parity, herd and length of preceding calving interval. It might, therefore, be necessary to assess the relative influences of these factors and establish suitable correction constants for them.

The standard birth weights of 28 and 26 kg. used for male and female calves respectively, for weaning weight adjustment, were simply means calculated from large samples of the original birth weights (Wilkins, 1974). Ton (1974) reported birth weight means of 29 and 27.4 kg. respectively, for male and female Boran calves kept in the same ranch. It was also shown by Ton (1974) that factors such as season and year of calving, age of dam and length of preceding calving interval, all caused a significant variation in birth weight on the same ranch, and should be corrected for. However, the use of original birth weights in the weaning weight correction may not improve the accuracy of this index, as a predictor of the future productivity of cows, to the extent that the ranch could be advised to weigh calves at birth. Both the difficulty in recording accurate birth weight within the right period after parturition and the economic gain accruing from such an involvement, might also not justify taking such a record.

According to the Kenya Beef Records, the same constant of 1.1 is used permanently in all seasons to adjust weaning weight for the effect of sex. The adjustment is based on the age corrected weaning weight of a male Boran calf. Creek and Nestle (1964) in the West Indies, pointed out that the relative performance of male and female calves could fluctuate with season, year and environment in which they are kept. In a good season, a male calf is more able to express its genetic superiority for growth than a female calf, while in a bad season, this may not necessarily be true. The Kenya Beef Records' factor of 1.1 falls within the rather narrow range of 1.03 - 1.15 (Poschinger - Personal Communication, 1977). It might be possible that, because of the narrow range in which the factor of 1.1 lies, the error introduced by using the same factor in all seasons may not be substantial enough to justify the use of different factors in different seasons. However, it is necessary to investigate and establish the need to use different constants in different seasons.

A standard weaning age of 250 days was adopted by the Kenya Beef Records because the majority of ranches weaned calves between 240 to 270 days of age (Meyn and Creek, 1968). The age of 250 days was, therefore, found to be a suitable compromise. The ranch in which the present study was conducted weaned Boran calves at 270 days of age and Friesian X Boran calves at 210 days. In Botswana, under similar environmental conditions calves are weaned at 210 days (APRU - Botswana, 1975). It might be necessary to practice early weaning insofar as it would give the dam ample time to recover from the previous lactational stress before the next breeding period starts. It has been shown in Botswana (APRU - Botswana, 1975) that an increase up to 12% in conception rate could be attributed to the previous porous state of cows at the time of breeding.

Early weaning has also the advantage that weaning weight records can be taken at an earlier age and this gives a more accurate measure of the productivity of a cow. Growth becomes more divergent at a later age, when the calf becomes more capable to express its true genetic potential for growth independently.

GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

General Conclusions

1. It can be concluded from the present study that the Kenya Beef Records' 'Productivity Index', as far as it was assessed, is not efficient as a predictor of the future productivity of Boran beef cows. Its low repeatability (0.05) shows that it is mainly influenced by environmental factors. Consequently only a very slow rate of genetic improvement in productivity may be expected when cows are selected on the basis of this index.

2. If cows are to be selected by this index then the mean of the first three 'Productivity Index' records should be used. This is because the gain in accuracy is at maximum when the number measurements of an individual cow is increased from two to three.

3. The weaning weight repeatability of 0.13 obtained in this study is lower than mean value of 0.3, the generally reported from the majority of studies. This could be due to the fact that this trait was corrected for only a few of the important factors which affect it significantly in this particular environment. Selecting cows straight by the weaning

weights of their calves would, however, give a faster rate of genetic improvement in productivity than using the index.

4. The very low repeatability (0.08) of the 'Productive' calving interval obtained in the present study, might have been a contributory factor to the low repeatability of the Index. It was also demonstrated that the 'productive' calving interval, and not the weaning weight, was the more important determinant of the index. However, its inclusion as a component trait of the index may not be justified, unless it is weighted by its heritability.

Recommendations for future work

In making recommendations for some possible future studies, the results obtained in the present study and their implications have been taken into account. It has also been considered that a more elaborate analysis of beef data is now possible, using the new computer program provided by ILCA. This program can do Least Squares analysis, with up to seven different factors taken into account. The following studies are proposed:-

1) An investigation of the factors affecting the 'Productivity Index' and its component traits;

2) The effect of birth weight, dam weight and dam weight change during the pre-weaning period, on subsequent cow productivity;

and 3) Comparison of the efficiency of the 'Productivity Index', in its present form, with its efficiency when the component traits (phenotypes assessed on corrected data) are weighted by their economic values, heritabilities and genetic values included.

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