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AUTHOR – AUTEUR

Full Name of Author – Nom complet de l'auteur

BENJAMIN KWADJO AHUNU

Date of Birth – Date de naissance

SEPTEMBER 22, 1950

Canadian Citizen – Citoyen canadien

☐ Yes / Oui ☑ No / Non

Country of Birth – Lieu de naissance

GHANA

Permanent Address – Résidence fixe

DEPARTMENT OF ANIMAL SCIENCE
UNIVERSITY OF GHANA
LEGON, GHANA

THESIS – THÈSE

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Name of Supervisor – Nom du directeur de thèse

M. MAKARECHIAN

AUTHORIZATION – AUTORISATION

ATTACH FORM TO THESIS – VEUILLEZ JOINDRE CE FORMULAIRE À LA THÈSE

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PREWEANING PERFORMANCE OF RANGE BEEF CALVES AND FACTOR ANALYSIS OF PREBREEDING TRAITS OF COW AND OFFSPRING

by

BENJAMIN KWADJO AHUNU

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

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IN

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NAME OF AUTHOR BENJAMIN KWADJO AHUNU

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(SIGNED) ....

PERMANENT ADDRESS:

Department of Animal Science
University of Ghana
Legon, Ghana.

DATED.....January 28 , 1985

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PREWEANING PERFORMANCE OF RANGE BEEF CALVES AND FACTOR ANALYSIS OF PREBREEDING TRAITS OF COW AND OFFSPRING submitted by BENJAMIN KWADJO AHUNU in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in ANIMAL BREEDING.

....

Supervisor

....

....

....

....

External Examiner

Date. Jan. 17, 1985 ....

Dedication

Finally brethren,

whatever is true, whatever is noble,
whatever is right, whatever is pure,
whatever is lovely, whatever is admirable,
if anything is excellent or praiseworthy
.... think about such things.

Philippians 4:8 (NIV translation)

ABSTRACT

Preweaning weights of spring born calves at the University of Alberta cattle ranch at Kinsella during a 14-year period were used in this study. The calves were from three different breeding populations; Hereford (HE), Beef Synthetic (SY) and Beef Crossbred (XB). In additon to birth weight and weaning weight, the calves were weighed three times during the preweaning period. Preliminary investigation of calving dates revealed that the heifers calved significantly earlier in the year than older dams while the three and four year old dams calved later than the others. After five years of age, the effect of age of dam on date of calving did not follow any regular pattern.

Covariance analysis of birth weight (BRWT), weaning weight (WNWT) and preweaning average daily gain (ADG) with birth date as a covariate showed year of birth, sex of calf and age of dam as significant sources of variation. BRWT, WNWT and ADG increased over the years and bull calves were significantly heavier than heifer calves ($p<.05$). WNWT and ADG performance increased in calves from heifers to a peak in five year old dams in the HE and XB populations while peak performance was observed in calves from six year old dams in the SY population. The linear effect of birth date on birth weight was positive in all breeding populations but was significant only in the HE and SY while the quadratic effect of weaning age was negative on WNWT and ADG.

In a separate analysis where calves were classified into early, mid-season and late born calves according to their birth dates, ADG between two consecutive weighings and relative growth rate (RGR) at each interval were analyzed by the least squares method and the adjusted means plotted against the mean age of the calves classified at 2-week intervals. SY calves had the highest ADG and RGR followed by XB and HE. Except for the very early stages of growth, growth rates in early and mid-season calves were higher than in late born calves. However a sharp decline was noticed in the mid-season and late born calves in late summer when pasture conditions had generally deteriorated.

Factor analysis was carried out on 12 defined pre- and post-breeding weight changes in the dam and preweaning traits of the calves. The analysis was carried out according to the "eigenvalue 1.0 criterion" and resulted in the extraction of four principal components for the HE population and five principal components for the SY and XB populations and also for the pooled data. Dam growth component exerted the greatest influence in the covariance structure accounting for over 20% of the variation in each set of analyses. It was observed that though differences in the nomenclature of corresponding components were evident after the first major component, the set of components extracted was the same, except for HE having no winter body condition component. That is, similar components of variability underlined the sets of data in the three populations thus showing that the three populations were not different so far as major factors of the breeding condition of the dams were concerned.

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1. GENERAL INTRODUCTION

Most growth studies have been confined to fixed ages, fixed time periods or, occasionally, fixed weight periods (Nelms and Bogart, 1956; Swigger *et al.* 1962; Thrift *et al.* 1970; Goonewardene *et al.* 1981). Such studies have utilized weights of animals recorded at wide intervals between birth and maturity. However as Brown *et al.* (1972) have pointed out, many aspects of developmental patterns and interperiodic relationships may have been overlooked as a consequence of using only a few selected measurements to evaluate growth.

Brown *et al.* (1972) noted that even though certain characteristics of growth such as rate of maturing and mature size cannot be measured directly on immature animals, related measures are necessary to give perspective to single measurements made on animals. Estimates of such growth characters should be useful in establishing breed parameters and to provide a means of measuring patterns of genetic variation in developing animals.

In cattle a critical analysis of the growth pattern for early calfhood, which necessitates several measurements before weaning time, has received limited consideration. Preweaning growth rates have usually been evaluated with measurements at birth and at weaning. Perhaps critical studies of preweaning growth rates have been overlooked due to the fact that multiple preweaning weight recordings are usually not routinely taken in most cattle management operations.

Fitzhugh (1976) noted that one important approach to the improvement of beef production efficiency is the exploitation of genetic variation in rate of growth by increasing early growth and efficiency relatively more than subsequent mature size. A more critical analysis of early growth of the calf and a feasible method of appraising calfhood growth rates may therefore enable animal breeders to exploit genetic variation in growth rates and thereby obtain higher weaning weights.

At the University of Alberta beef cattle ranch at Kinsella, Alberta, several preweaning weights of calves are recorded routinely. In addition to the calf weights, weight records of the dams at the time of calving, breeding and weaning of their calves are available. The accumulated data present an opportunity for investigating the inter-relationships among the post partum maternal conditions of the dams and the preweaning performance of the calves. Principal components analysis of these data may provide objective definitions and contrasts of the pre-breeding condition of the dams and such other components extraneous to the data which may aid in the interpretation of observed differences in calving dates of range beef cattle.

2. LITERATURE REVIEW

2.1 Description and measures of growth

Growth rate has always been of interest to animal scientists and in many selection programmes it has occupied a place of considerable importance. The rate at which an animal grows is generally determined by two sets of factors. The potential limits are set by hormonal relationships which are basically under genetic control while the realization of this potential depends upon the environment, particulary nutrition, and its interaction with genotype (Preston and Willis, 1974).

Growth rate is one of the most important factors for the economy of meat production because feed cost and most of the fixed expenditures decrease per unit of production with increasing growth rate. However, as weight increases storage of fat must be kept to a minimum otherwise the fat will negatively influence the efficiency of growth and the cost per unit of product. Barlow (1978) reviewed the available evidence of the consequences of selection for early growth and concluded that selection for either weaning weight or average daily gain will increase liveweight at all stages from birth to maturity. Bichard (1967), Dickerson (1970) and Morris and Wilton (1976) have pointed out some of the consequences of increased mature size. In brief, increased mature size results in an increase in the maintenance cost of the breeding stock and a delayed sexual maturity. This means an increase in the costs per animal.

As pointed out by Bakker (1974), the increase in costs may restrict the advantage of increased growth rate. The early growth rate must therefore be increased without or with a restricted change of mature weight. However as Brody (1945), Bichard (1967) and Taylor (1968) pointed out, the genetic flexibility of the mean growth curve and mean body proportions is not very great, except, perhaps, in poultry where Abplanalp *et al*. (1963) have demonstrated genetic differences in growth curves of selected lines of turkeys. Laird and Howard (1967) also showed some genetic variation in the shape of the growth curve of mice.

According to Webster *et al*. (1982), if animals are selected for growth rate or feed conversion efficiency to a fixed weight or age, the process will inevitably tend to favour the less mature individuals resulting in the selection of bigger animals without necessarily affecting the overall efficiency of growth in the individual or the whole production enterprise. Fitzhugh (1976) reviewed strategies for altering the shape of the growth curve and reasons for wanting to do so. He tabulated expected responses in body weight and degree of maturity following selection for bodyweight at birth, 6, 12, and 18 months, and at maturity; the results indicated an increase in all other weights following selection for any bodyweight. Smith *et al*. (1976a) concluded that selection for preweaning relative growth rate would be better than selection for absolute growth rate if it was desired to improve growth from birth to 550 days. Seifert and Rudder (1976) however contended that selection for growth rate in cattle may not lead to increased mature size in sub-optimal environments.

Selection for weaning weight will result in a slight increase in feed utilization efficiency during the postweaning period when feeding is over a weight-constant or time-constant period but a slight decrease in feed utilization may actually result when feeding is from actual weaning weight (fixed age) to a fixed slaughter weight (Barlow, 1978). It has also been inferred that differences in magnitudes of correlations between weight at earlier ages and mature weight in different breeds may in fact suggest differences in physiological age between the breeds. Brown *et al.* (1972) working on Hereford and Angus data recorded correlations greater than 0.53 between earlier weights and mature weight in Hereford; however, in Angus cattle the correlations were near zero for weights up to 16 months and were still low up to 36 months.

To properly compare the efficiency of animals, it is important to have a knowledge of the patterns of growth from the time of birth to maturity. According to Bakker (1974), the growth curve can be represented either as cumulative weight (WEIGHT), average daily gain (ADG) or relative growth rate (RGR) versus time or age. Cumulative growth curves are often described by mathematical growth functions. The growth functions proposed notably by Winsor (1932), Brody (1945), von Bertalanffy (1957) and Richards (1959) have been widely used. None of these has been completely satisfactory; some fit adjusted data and part of the growth phase well, others are not flexible enough to accommodate exceptional cases (Aguilar *et al.* 1983)

For instance, the allometric equation used by Brody (1945), though very easy to compute, only fits parts of the growth curve, and different parameters are required to fit early as compared with later phases of growth. von Bertalanffy, Gompertz and logistic equations consistently overestimate weight at an early age. In addition logistic equations underestimate mature weight. Richards' function fits data more accurately but has a variable point of inflection which is laborious to compute. Also the four parameter estimates of the Richards' equation have little biological meaning. These points have been discussed recently by Aguilar *et al.* (1983).

Taylor (1965, 1968) developed the concept of metabolic age when he explored the relationship between mature weight and time taken to mature. In effect the concept states that at any given stage of maturity, the age in days (t) from shortly after conception is constant when divided by $A^{0.27}$, where A is the mature weight. Finney (1978) has remarked that any continuous curve, however irregular, can be represented by a mathematical function. However, with most biological phenomena, one is not likely to have exact mathematical formulations and must therefore use approximations that are plausible in respect of particular applications. Taylor (1978) advised that a simple and conceptually robust model, even though with relatively poor fit, is to be preferred to a more complex model that extrapolates to absurdity.

As a measure of growth, absolute growth rate (AGR) is defined as the weight increment per unit of time:

$$\partial W/\partial t = (W_2 - W_1)/(t_2 - t_1)$$

where $(W_2 - W_1)$ is the weight increment in the interval $(t_2 - t_1)$. This formula represents the average rate and is a good approximation of the real instantaneous growth rate when estimated at short intervals. A mathematical representation of the instantaneous growth rate at age t is $\partial W/\partial t$. When t is in days, AGR is synonymous with average daily gain (ADG).

Relative Growth Rate (RGR) is another measure of growth and is defined as weight gain during a given time interval divided by the average bodyweight in this interval. RGR is an estimate of the rate of weight change and as pointed out by Bakker (1974), selection for RGR does not necessarily result in a highly correlated change in mature weight. Moreover, RGR may be considered as a parameter for maturity. Brody (1945) defined RGR separately for the self-accelerating and self-inhibiting phases of growth. Before the inflection point is reached, RGR is defined as the absolute growth rate divided by the actual weight:

$$RGR = (\partial W/\partial t)/W.$$

The value of RGR may be found from

$$RGR = ADG/(W_2+W_1)/2$$

If the change in RGR is not linear between t_2 and t_1, this estimate gives a poor representation of the real values of RGR between t_1 and t_2.

After the inflection point, RGR is defined as the absolute rate divided by the weight increment (A - W) in which A is mature weight. Thus

$$RGR = (\partial W/\partial t)/(A-W).$$

RGR may be calculated as

$$RGR = -ADG/(A-(W_2+W_1)/2).$$

Thus the values of RGR before and after the inflection point are different and of opposite signs.

The precision with which mature size can be defined varies with the trait being tested. A simple definition of mature size as the final size actually reached may be adequate for traits which rarely display negative growth. However, for others like bodyweight which are more affected by environment, mature weight may be defined as the mean value over many years after positive growth of skeletal and muscular tissues have become insignificant (Brinks *et al*. 1962; Fitzhugh *et al*. 1967). In some situations this mean value may be estimated by the asymptote of a fitted growth curve (Joandet and Cartwright, 1969; Goonewardene *et al*. 1981).

Fitzhugh and Taylor (1971) developed a method of analyzing genetic and phenotypic relationships among maturing rates in terms of degree of maturity. They defined degree of maturity (μ) of a trait y as that part of mature size A attained at a given stage or age t:

$$\mu_t = y/A$$

Inherent in the concept of degree of maturity is the idea of maturing rate or change in μ over time which Fitzhugh and Taylor (1971) defined as absolute maturing rate (AMR). Another important parameter usually defined in growth studies is relative maturing rate (RMR) which is maturing rate relative to current degree of maturity.

Thus

$$RMR = 1/\mu \;.\partial\mu/\partial t$$

However Fitzhugh and Taylor(1971) demonstrated that RGR and RMR were equal.

Smith *et al*. (1976b) evaluated AGR, AMR and RGR over several intervals including birth to 200 days, 200 to 396 days and at puberty in straightbred and reciprocally crossed Hereford, Angus and Shorthorn cows and confirmed previous reports by Reynolds *et al*.(1963) and Laster *et al*. (1972) that differences in physiological maturing rates were more striking as breeds became more diverse in origin. Smith *et al*. (1976b) concluded that the possibility of increasing early rates of maturing and growth without a corresponding increase in subsequent growth and mature size seemed to offer the greatest returns from changing maturing patterns by crossbreeding.

2.2 Factors affecting growth rate

Growth rate and weight for age are parameters that are often estimated in animal production research. These parameters are influenced by numerous environmental factors. Therefore to obtain more accurate estimates of growth rate or production potential, adjustments for identifiable environmental factors are necessary. If this is not done, genetic effects may be concealed by environmental factors which could confound the breeder and hinder the accuracy of selecting animals with superior breeding value. A knowledge of how these factors influence performance and their relative magnitude will enable the animal breeder to measure genetic differences more accurately (Brown, 1960; Neville, 1962; Bovard *et al*. 1963; Berg, 1967). Among the many factors which influence growth in beef cattle, breed, sex, season of birth or birth date, age and size of dam and birth weight predominate.

2.2.1 Birth date and cow and calf productivity

The date of birth may be a major factor to consider in range beef production because of the marked effect of season on pasture growth and productivity. Grazing cattle which are not provided with supplemental feeding during periods of sub-optimal pasture growth may lose weight and depending on the severity of this weight loss, the productivity of the cow may be impaired. Also if weight losses are excessive, the dam may fail to conceive during a limited breeding period and long calving intervals may be experienced.

In most studies the calving period is very short so that the effects of season are minimized. However, calving periods of six months or longer are not uncommon in some beef cattle operations and in the Southern USA many ranches calve for at least 90 days (Wiltbank, 1970). Long breeding and calving seasons may perpetuate lowered production in beef calves. Since beef calves are usually weaned at a particular time rather than on a weight constant or age constant basis, calves born late following the normal breeding season are usually lighter in weight at weaning than those born early. Lighter calves result in a decrease in the total lifetime production of their dams (Burris and Priode, 1958; Roberts *et al.* 1970; Lesmeister *et al.* 1973).

Alexander *et al.* (1960) studied many factors influencing birth weight in Hereford calves. The effect of time of birth was studied by the regression of birth weight on age at weaning. The regression coefficient was negative and significant, indicating that calves born toward the end of the calving period were heavier than those born earlier. Koch and Clark (1955) and Holland *et al.* (1977) also found this effect to be significant at the 1% probability level. Pooled estimates by Holland *et al.* (1977) showed an increase of 1.0 kg per month or 0.033 kg/day in calf birth weight from mid-autumn to mid-winter. In the studies by Alexander *et al.* (1960), calf birth weight was found to increase by 0.43 kg for each ten days during the spring calving season.

However, the small (r=0.18) but significant ($p<.01$) correlation coefficient showed that only about three percent of the variation in calf birth weight was related to time of calving.

Franke and Turner (1983) defined eight calving periods over a 75-day calving season and found that birth weight increased linearly over the calving periods at an average rate of 0.605 kg/calving period or approximately 4.81 kg over the calving season. However, calving period did not significantly influence variation or the trend in average daily gain. The results suggested that calf birth weight was positively associated with calving date; calves born later in the calving season being heavier. The findings are in general agreement with the results of earlier workers (Seifert *et al.* 1974; Winks *et al.* 1978; Low and Wood, 1979).

According to Plasse *et al.* (1968) the number of days required by the cow to conceive after parturition is one of the best criteria for determining reproductive ability under range conditions. When active and fertile bulls are present, the average interval from parturition to conception of a viable embryo reflects the post-partum interval of ovulatory estrus and the fertilization and embryonic survival rate. Thus the post-partum interval to ovulatory estrus determines the length of the breeding season necessary for a satisfactory calf crop.

A number of factors may contribute to earliness or lateness of the dam showing estrus in the breeding season. Wiltbank (1970) lists four major reasons:

i. The length of time from calving to start of the breeding season

ii. The interval from calving to first estrus

iii. Age of the cow and

iv. The level of nutrition before and after calving.

Late calving cows may not have enough time to return to estrus during the breeding season.

Two studies point out the effect of reproductive performance in the previous year on reproductive performance in the following year. Reynolds *et al.* (1963) showed that cows which became pregnant early in the breeding season of one year had a better opportunity to become pregnant the following year. Their results indicated that 75% of the 145 young cows which were pregnant within 42 days of the beginning of the breeding season during the previous year also became pregnant the following breeding season. By contrast only 40% of those which became pregnant between 43 and 75 days of the first breeding season were pregnant during the second year. Similar trends were observed for the older cows. Burris and Priode (1958) reported a regression of 0.3 of a day for calving date on the previous calving date.

Young cows have been observed to have longer intervals from first calving to first oestrus than older cows.

Wiltbank (1970) reported that the average interval from calving to first estrus was 53.4 days in cows which were five years and older, 60.2 days in four year old cows, 66.8 days in three year old cows and 91.6 days in heifer dams. Lesmeister *et al.* (1973) determined five calving groups based on the three or four successive 21-day intervals that calves were born. They found that heifers calving in the early groups tended to calve earlier throughout the remainder of their productive lives than heifers calving initially in later groups. However repeatabilities for calving groups ranged only from 0.09 to 0.11 indicating that only moderate improvement might be made by culling cows that calved late during the normal calving season.

Lesmeister *et al.* (1973) also found that calves born in earlier calving groups grew faster from birth to weaning and weighed more at weaning than calves born in later groups. Early calving heifers also had higher average annual lifetime production than late calving heifers. These findings indicate that a heifer should conceive early during the first breeding season to achieve good reproductive performance throughout her life.

Feed supplementation has had a variable effect on calving date. Bellido *et al.* (1981) worked with production data from a five-year study with Hereford and Angus x Hereford cows. They defined two breeding seasons, early and late, and found that in the early breeding group, calves from cows supplemented during the previous year were born 14 days later than those from unsupplemented cows. No difference ($p>.05$) due to supplementation was noted in the late breeding group. Similary Furr and Nelson (1964) and Harms *et al.* (1974) reported no effect of supplementation on calving date. However, Parker *et al.* (1974) indicated that cottonseed supplementation of 0.45 kg/day led to early calving of about 24 and 18 days in second and third calvings respectively. Supplementation had no effect on date of calving in heifers.

Relatively high feeding levels were given by Burris and Priode (1958) in an experiment with cows calving in early spring. They estimated a regression of second calving date on first calving date to be 0.37 days per day of difference ($r= 0.32$). Doornbos *et al.* (1977), however, reported no significant effect of calving previous date on pregnancy after 21 or after 45 days of joining with the bull, although there was a highly significant relationship with post-partum anoestrus interval.

Differences in date of calving lead to differences in age at the time that heifer calves were ready to be bred. Milagres *et al.* (1979) reported that the age of the heifers at the beginning of the first breeding season significantly affected their calving rate. Only 52% of heifers aged 12 months or less at the beginning of the breeding season calved as two year olds whereas 72% of those aged between 13 and 15 months at the start of the breeding season calved as two year olds. The number of services per conception was not associated with the age at the start of the breeding season. Ellis (1974) also reported that in five out of the 13 herd-years investigated, heifers subsequently becoming pregnant were significantly older at first mating than heifers remaining non-pregnant.

Chapman *et al.* (1978) began a comparison in 1965 of Herefords bred to calve first at two and three years of age. Culling was only exercised on cows non-pregnant in two consecutive years. The herd was spring calving and the comparison was followed for ten years. There was no significant difference in calving percentage, calving date, birth weight, weaning weight and cow survival, although the tendency was for calves from the two year old calving group to be born later and were lighter at weaning than calves from the three year old calving group.

Other factors correlated with calving date were shown by Pattulo (1973) in the form of significant positive regressions of birth weight on calving date. On the other hand the effect of breed on calf birth date was not observed to be significant by Rankin and Holland (1974) and Bellido *et al.* (1981).

2.2.2 Age of calf

Since birth dates vary, it would be necessary to secure weights daily over a period of time to obtain actual weights at a constant age. In practice, especially under farm conditions, this procedure is not feasible and usually the whole group is weighed once at weaning. The weights thus obtained vary in age at which they were taken and in making comparisons it is frequently desirable to adjust weights for differences in age.

Age at weaning has been included by many workers in the analysis of weaning weights but to a lesser extent in preweaning average daily gain. One reason for the latter observation may be that average daily gain is perhaps intrinsically adjusted for age of calf effect (Kennedy and Henderson, 1975b). In most studies, older calves have been found to grow more slowly. Mason *et al.* (1970) found a significant negative regression of average daily gain on weaning age for heifers but not for bulls. Barlow *et al.* (1974) also found non-significant negative quadratic regression of average daily gain on weaning age. It was evident in their analysis that much of the variation between herds and years within herds was accounted for by weaning age.

Barlow *et al.* (1974) reported that of the 72 regressions of weight gained from birth to weaning and average daily gain on weaning age in several breeds, the majority were positive and significant. However the small number of animals used in the study precluded the estimation of meaningful values in some years. Among the regressions of average daily gain on weaning age, they found a little less than half to be significant. Among the heifers and steers there were more significant negative regressions while among bulls there were more significant positive regressions. These observations indicate that there was a tendency for younger heifers and steers to grow faster to weaning than older contemporaries while the reverse was true for the bulls.

Pell and Thayne (1978) working with Angus and Hereford data established that both linear and quadratic effects of age at weaning on weaning weight were highly significant in both breeds. The significant quadratic components were negative in each case indicating that the change in weaning weight for each additional increment of age was not linear but rather decreased in magnitude with increasing age. Thus a curvilinear relationship described the growth pattern of calves from birth to 300 days of age more accurately than a rectilinear one. The results agreed with trends in growth rates observed by Marlowe and Gaines (1958) and Warren *et al.* (1965). Kock and Clark (1955) found the regression of gain on weaning age to be -0.02 kg/day which was considered to be too small for practical purposes. Therefore among range beef calves, these workers concluded that the difference in growth rates of early and late born calves was not as important as many workers had thought. However, the majority of the studies indicate otherwise.

2.2.3 Sex of calf

Although it is generally recognized that males in most domestic species are heavier than females at birth, the sex effect is confounded with differences in gestation length since bull calves are usually carried a day or two longer than heifer calves. Male calves also grow more rapidly and reach greater weaning weights than females. However, on a low nutritional plane, superiorty of male calves over females may not be significant at time of weaning (Creek and Nestel, 1964). Preston and Willis (1974) indicated that when calves were weaned at 90 days which was earlier than the conventional weaning age of approximately 210 days, sex effect was not significant presumably because weaning might have been done before sex hormone influences had begun.

The superiority of male calves at birth has been reported. At birth females calves have been reported to be four to six percent lighter than bull calves (Tudor, 1972; Harricharian *et al*. 1976; Pabst *et al*. 1977) but the difference generally increased with increasing age and increasing size of the breed. Sex differences are generally larger and growth rates faster among calves from older dams (Rollins and Guilbert, 1954; Pahnish *et al*. 1958; Barlow *et al*. 1974). Among calves which are creep fed, Marlowe and Gaines (1958), Marlowe *et al*. (1965), Cundiff *et al*. (1966), and Harwin *et al*. (1966) reported that sex differences in weaning weight of calves from young dams were smaller than sex differences from mature cows and that, because of their greater growth potential, male calves may have been more severely limited by the lower nutritional environment provided by the young dams.

Pabst *et al.* (1977) studied seven breeds of pedigree beef cattle in Britain and reported that sex effect as a source of variation in weaning weight increased with age of the calf. They observed for instance that while heifer calves at birth weighed only about six percent less than bull calves, at 200-day and 400-day weights, the heifer calves weighed about 18% and 30% less respectively, than the bull calves. The authors also indicated in their results that sex of calf effect tended to increase with the size of the breed.

In another study the relationship between sex differences and environment was simply expressed as an interaction of sex with herd or years (Sellers *et al.* 1970) and where herd and year means were given, larger sex differences were generally shown to be associated with a more favourable environment.

2.2.4 Age and size of dam

Dams influence the preweaning growth of their calves both by the genes they transmit to the calf and by the maternal environment which they provide for their calves up to weaning. Presumably changes in size, weight and physiological function which accompany ageing influence the environment and consequently have a direct effect on birth and weaning weight of the calf.

A vast body of information has been published on factors affecting weaning performance. Most studies indicated an increase in weaning weight with an increase in age of dam up to five or six years of age and a gradual decline thereafter. The age at which the decline occurred varied considerably between studies. The largest increase usually occurred between three and four year old dams (Minyard and Dinkel, 1965; Barlow *et al.* 1974; Schaeffer and Wilton, 1974a,b; Kennedy and Henderson, 1975a,b; Winks *et al.* 1978)

Age of dam effect appears to be more important during the early post-calving period than the later stages of the preweaning period (Neville, 1962; Lammond *et al.* 1969; Barlow *et al.* 1978). This is consistent with the shape of the lactation curve. Some workers (Barlow *et al.* 1978) have suggested that creep feeding could be expected to limit the importance of maternal effect over the preweaning period. However, the need for a high degree of accuracy in determining the age of dam effect in younger dams appeared of little importance from studies by Cundiff *et al.* (1966) and Schaeffer and Wilton, (1974a).

The majority of studies on age of dam effect indicate that calves from two and three year old dams averaged 6.8 to 27.3 kg less at weaning than those from five to six year old dams (Brown, 1960; Swiger *et al.* 1965; Warren *et al.* 1965; Sellers *et al.* 1970; Hohenboken and Brinks, 1971). Pell and Thayne (1978) classified age of dams at six month intervals between 23 and 47 months, and 12 month intervals beyond 47 months and reported that weaning weight in Angus increased by 23 kg as the age of dam increased from 23 months to about nine years, with peak production occuring in the eight to nine year age groups. There was a slight decrease in weaning weight after nine years. In the Hereford calves, weaning weight was observed to increase by 23 kg from 23 months to eight years with peak production in the seven to eight year group, remaining the same through 12 years of age. A slight decrease in production was observed in cows which were 12 years and older.

Some studies have not been able to establish significant differences in performance of calves from different age of dam groups. Butson *et al.* (1980) observed that although differences in adjusted weaning weight between four year old dams and mature dams were small and not significant, increases were noted for two to four year old dams similar to the general trend of other published reports. Bair *et al.* (1972) noted that the difference between weights of calves from two and three year old Angus-Holstein cows was not significant at either 120 or 205 days, thus indicating that milk production of heifers was comparable to three year olds when measured over a seven month lactation period. However, at 305 days the difference in calf weights was significant ($p \leq .01$) indicating lesser lactation persistency in the heifers. Thus the heifers may not have been able to continue high milk production throughout a 305-day lactation. Bair *et al.* (1972) also did not record any significant differences between weights of calves produced by five through nine year old dams for 120, 205 and 305 day weights, thus indicating that maximum production was achieved at five to nine years of age.

There are additional sources of bias which could be involved in estimating age of dam effects in field data. Lush and Shrode (1950), Koch and Clark (1955), Marlowe *et al.* (1965) and Kennedy and Henderson (1976) have considered age of dam effects resulting from continuous culling of dams. As records accumulate and averages of all records made each year are compared, the less productive individuals are usually culled and the more productive ones therefore would have more opportunity to have records in each ensuing year. This means that improved performance in each older age group is not due to age alone but also to inherent genetic superiority.

Although the potential for considerable bias exists if culling is based entirely on measured performance, Kennedy and Henderson (1976) have indicated that the actual bias was less than 1 kg between consecutive age groups of young cows in Canada. On the other hand Hopkins and James (1977) have observed that there is the opportunity for higher breeding values among younger females. Besides, Barlow *et al.* (1974) have also mentioned that the practice of mating young females to smaller bulls with the intention of reducing difficult calvings can also contribute significantly toward biases in estimating age of dam effects in field data.

2.3 Growth mediated effects on breeding performance

Selection for growth rate results in advancement of puberty and early maturation. Comparisons of the rate of growth and the relative sexual maturity of different breeds within a species, and of individuals within a breed, suggest that high growth rates are not only associated with early puberty but also with heavier bodyweights at puberty. Studies supporting this conclusion in cattle and other species were reviewed by Barlow (1978).

Preweaning average daily gain has been related to age at puberty with a correlation of r= -0.24 and bodyweight at puberty with a correlation of r= 0.54 (Arijie and Wiltbank, 1971; Laster *et al.* 1972). Such effects of preweaning growth rate appear to be consistent among a number of studies, whereas the relationship between post-weaning growth rate and the onset of puberty is more variable. Post-weaning growth rates are frequently affected not only by available nutrition following weaning but also by preweaning performance. Therefore, a knowledge of the overall characteristics of the growth curve is of great importance. In cattle, genetic differences in growth rate potential are reflected in differences in the rate of sexual maturity, with high early growth rates in particular, advancing sexual maturity.

Work by Wiltbank *et al.* (1969) suggests that considerable interaction exists between genotype and the level of nutrition which Foxcroft (1980) contends is suggestive that the effects of growth on reproductive function may depend on the exact pattern of growth established. Thus in late maturing breeds the advancement of puberty due to high plane of nutrition may be associated with lower bodyweight at puberty as observed by Gardner (1968) in Holstein-Friesians. On the other hand an increase in nutrition in the faster maturing breeds would, in general, result in heavier bodyweights at first estrus.

Blahoc (1976) and Khozei (1978) indicated that fertility is in fact enhanced in heifers bred at lighter weights and younger ages, although milk yield during the first lactation may be reduced. Foxcroft (1980) suggested that the problem for the future would be to optimize the effect of intermediate levels of growth since there is no evidence in the literature to suggest that early breeding of heifers, as a result of enhanced growth rates, is associated with any long term deleterious effects on breeding performance.

2.4 Liveweight change and breeding condition of the dam

Lowered fertility which can be so important is taken as a failure to breed as often or as regularly as required. Lowered bovine fertility is recognized as a serious economic problem resulting in loss of milk, reduced calf crop and early culling of potentially useful cows. Low conception rates to first service in dairy herds, where estrous cycles appear to be occurring normally, can be associated with a slow recovery of body weight during early lactation.

Observation by McClure (1970) on Jersey herds in New Zealand in which this syndrome was observed showed that the infertile cows were those which lost most weight between calving and mating and/or were still losing weight at the time of mating, while the mean bodyweight of the fertile cows was rising at the time of mating.

King (1968) showed that cows which gained in body weight had a higher conception rate than those which lost weight. Trimberger *et al.* (1954), Salisbury and VanDemark (1961) and Duward (1969) have shown that conception rates averaged about 35% for cows bred at 20 days post partum and increased until about 80 days post partum.

2.5 Overview of principal components analysis

Although studies involving two or more variables (whether independent or dependent) are multivariate by a lay definition, the term multivariate in statistical jargon has come to mean two or more dependent variables analyzed simultaneously (Gill, 1981a). Multivariate statistics refers to an assortment of descriptive and inferential techniques that may be used to analyze multiple measurements that have been made jointly on one or more samples of individuals. It is concerned with the jointness of the measurements of each individual and the relationships among the measurements across individuals.

According to Brown *et al.* (1973), path coefficient, multiple regression and multiple correlation procedures are the multivariate techniques which have had the greatest application in large animal research. Although the concept of principal components has of late been receiving more consideration by beef and dairy cattle and swine research groups (Young *et al.* 1977, 1978; Carpenter *et al.* 1978; McCurley and McLaren, 1981), earlier use of the technique in application to livestock research was largely confined to quantifying breed differences in shape and size (Wright, 1932; Touchberry, 1951; Tanner and Burt, 1954; Brown *et al.* 1973).

While principal components analysis (PCA) may improve the interpretation of data, Gill (1981a,b) has pointed out that the real meaning can easily be obscured behind a façade of sophisticated manipulations poorly chosen and interpreted. The analysis involves the regrouping of voluminuous data into patterns that one hopes to be able to interprete meaningfully; whether meaning is achieved, often depends on insights of the investigator that are extraneous to the sample of data.

The basic assumption of principal components analysis is that a battery of intercorrelated variables has common factors running through it and that the scores of individuals can be represented more economically in terms of these reference factors. The technique makes linear combinations of the available variables into factors or components. The procedure reduces a correlation matrix into a set of orthogonal components with each component explaining some of the variation in the correlation matrix. The major component explains the largest amount of variation in the variance-covariance structure and minimizes the residual correlation among the variables. Each successive component explains the largest portion of the remaining variation while satisfying the requirement that each component be independent of the others (McCurley and McLaren, 1981).

A useful property of the technique is a more parsimonious description of the system. The number of components estimated usually depends on the adequacy of each successive component to explain the variation in the dependency structure and upon the arbitrary decision as to the fraction of the total variation in the n-dimensional structure it is desired to explain. A more detailed and technical discussion of principal components analysis has been given by Morrison (1976) and Green (1978).

3. SOURCE OF DATA

3.1 The Ranch

The University of Alberta Beef Cattle Ranch at Kinsella was started in 1960 with a goal of developing cattle adapted to and productive under conditions imposed by the natural environment. The ranch is at the edge of the boreal forest where native short grass predominates with a recent invasion of aspen poplar spreading from moist pockets of the rolling topography. About 800 hectares of the total land area of 2800 hectares consists of improved pasture of brome, alfalfa and creeping fescue. The native grass is mainly fescue and porcupine grass. The precipitation at Kinsella is about 500 mm annually (Berg, 1975; Arthur, 1982)

3.2 The Breeding Populations

The breeding plan and general management of the herd at Kinsella have been periodically described in the University of Alberta, Department of Animal Science Annual Feeders' Day Reports. (Berg, 1975, Berg and Peebles, 1983). In brief, beginning in 1960, a start was made with two lines of cattle; a Hereford control and a composite of Angus, Charolais, and Galloway breeds called Beef Synthetic.

According to Berg (1975), the Hereford was chosen because of its dominant position in the beef cattle industry in Alberta. The Hereford line has been maintained as a purebred line from its initiation with limited continued introduction from outside. The breeds for the Synthetic were chosen to complement each other in their good characteristics. Thus Charolais was chosen for growth and leanness, Angus for mothering ability and Galloway for hardiness.

The breed composition of the Synthetic population has varied somewhat over the years but has been fairly stable since 1970 at about 37% Angus, 34% Charolais, 21% Galloway, 5% Brown Swiss and 3% from other breeds like Jersey, Shorthorn and Brahman, which came from the foundation animals which were not always purebreds. A Dairy Synthetic population was started in 1967-68 with Holstein and Holstein crossbreds with later additions of Brown Swiss and Simmental breeds. The Dairy Synthetic has stabilized since about 1978 with very minor fluctuations.

There is also the Beef Crossbred population which is either progeny of crossbreeding among Hereford and Beef Synthetic or progeny which have been derived from a line in which the suitability of various combinations of Beef type x Beef type or Beef type x Dairy type were being investigated (Goonewardene, 1978). The crossbreds therefore have a varied composition of the above mentioned breeds.

3.3 Management and selection procedure

The management practice of the breeding herds has been described as a practical low cost commercial operation (Berg, 1975). The breeding herds were on the range year-round and depended on the natural grazing except for about four months in the winter when supplementary feed was provided. During this time the two and three year olds were separated from the older cows and were given more grain than the older cows. A summary of the winter feeding plan has been reported by Berg (1978). During breeding, females in single sire groups were pastured separately except for the Dairy Synthetic which was bred in multiple sire group in one pasture.

Breeding season was limited to July and August for calving in April and May. Calves and their dams were weighed as soon after birth as possible. After the end of the calving season calves were weighed during the months of June, July and August. Calves were weighed and weaned in October when they were slightly over five months old. The male calves were placed on a 140-day feed test over the winter during which they were fed a high concentrate ration while the heifers were limited to about 2.3 kg of concentrate and 2.3 kg of hay/day. Straw, which was provided as bedding to both groups, was partially consumed. The dams were again weighed in June before breeding and again at the time of weaning of their calves in October.

Selection of bulls was made when they completed the performance test at about one year of age, the major criteria being preweaning and postweaning gain. Attempts were made to limit the number of bulls selected from a particular sire each year. Bull calves were mostly used as yearlings and only about 25% were held over for an additional year (Berg, 1975).

All physically sound heifers were bred as yearlings to calve as two year olds; those failing to become pregnant were fed out for slaughter. Breeding cows were required to calve each year; those failing to do so were culled. In the early years however, when herd expansion was taking place, some cows were allowed one dry year and were culled on a second dry year. Other criteria for culling cows included unsoundness or defects such as eversion of the reproductive tract, lameness, temperament, cancer eye and crippling. After cows had weaned three calves, cows surplus to needs might be culled on the basis of weaning weight of their calves (Berg and Peebles, 1983).

3.4 Data Editing

For the purposes of the study, initial editing of the records was neccessary. Calves were selected if they had complete birth, weaning and yearling records. All cases involving twins, foster dams or any other abnormal mothering conditions, or calves from multiple sire matings in which specific sires could not be be identified, were eliminated. This excluded all the Dairy Synthetics. The three populations used in the analyses were the Hereford (HE), Beef Synthetics (SY) and the Beef Crossbreds (XB).

4. FACTORS AFFECTING PREWEANING PERFORMANCE

4.1 INTRODUCTION

Performance testing to measure growth rate in beef cattle has proven to be important in identifying superior animals and has gained broad acceptance by the beef industry (Pell and Thayne, 1978). Faster growth rate increases the proportion of feed intake used for tissue synthesis and reduces total inputs per unit of weight gain. The main premise of selecting for weight gain is that weight is an easily measured trait closely related to efficiency and economy of production. The major limitation as noted by Barlow (1979) is that the measures of efficiency used have been mostly related to growing animals during the postweaning period when they are being finished on high grain rations. When animals are finished on pasture, such as in Australia, management practices and market requirements may differ greatly, making different selection objectives more desirable.

For selection aims to be realized through controlled breeding programmes, genetic differences among animals need to be identified by removing variation due to environmental factors. In the analyses of preweaning growth traits, several environmental factors including the effects of sex of the calf, age of the dam, herd and year have been documented for many purebred cattle. However, only limited information is available on such estimates for multi-breed populations. Willms (1981) and Sharma *et al.* (1982) have provided some adjustment factors for the Hereford and Beef Synthetic populations but the comparisons excluded the Beef Crossbred population.

The effect of season of birth has not been studied extensively in beef cattle. Perhaps this is because in most beef operations, the calving period does not traverse the seasons of the year. Nevertheless, Franke and Turner (1983) have indicated a potential bias in the adjustment of preweaning traits when seasonal or periodic classifications are overlooked in conventional analyses of field data. Birth date may therefore be a significant source of variation in preweaning growth traits in range beef cattle.

4.1.1 Objectives of the study

The purpose of this study was to estimate and compare the effects of sex of the calf, age of the dam, year of calving, age of calf or date of birth, on birth weight, weaning weight and preweaning average daily gain in three range beef populations.

4.2 EXPERIMENTAL

4.2.1 Preliminary investigation of calving dates

In the preliminary analysis, nine age of dam categories were defined starting from two years through 10+ years. Dates of birth of the calves were analyzed using a fixed model least squares procedure as outlined by Harvey (1976). The analyses were carried out within populations. Attempts were made to fit all possible 2-way interactions except where, by the inclusion of such terms, programme limitations were encountered due to degrees of freedom that can be handled.

The following fixed model (model 1) was assumed to describe the birth date under observation:

$$Y_{ijkl} = \mu + A_i + D_j + S_k + AS_{ik} + DS_{jk} + \epsilon_{ijkl} \qquad \text{MODEL 1}$$

where

Y_{ijkl} = the observed birth date

μ = the overall mean

A_i = the effect of the *i*th age of dam

D_j = the effect of the *j*th year of calving

S_k = the effect of the *k*th sex of calf

AS_{ik} = the *i*th age of dam by *k*th sex of calf interaction

DS_{jk} = the *j*th year of calving by *k*th sex of calf interaction

ϵ_{ijkl} = the random error term.

Using the procedure for mean separation for unequal numbers as outlined by Harvey (1979), the Student-Newman-Keuls test was used to test differences between means when significant differences were established by the least squares analyses of variance.

4.2.2 Covariance analysis of preweaning traits

In analyzing birth weight and preweaning data it was deemed important to remove the effects of the differences in date of birth. The data were therefore re-analyzed with birth date as a covariate. All calves without complete preweaning records were excluded from further analyses. The age of dam categories were also reduced from nine to seven by combining age classes seven and eight into one category and by coding all dam ages nine years or greater as 9+. This reduction was necessary because of the progressively fewer numbers observed with increasing age levels of the dams due to culling.

Furthermore since the crossbreds were so heterogeneous because of the introduction of several breeds, a more homogeneous definition was deemed to be necessary. Therefore a selected group of crossbreds was defined as those animals which had at least 50% British beef breeding in them, the British breed in question being any combination of Angus, Hereford and Galloway. By this definition a few animals which had very high components of the large beef types (for example Charolais and Limousin) or those with high components of dairy type (for example Holstein, Brown Swiss and Simmental) were eliminated from the records in further analyses.

The attempt was to select animals from the crossbreds which would be of comparable weight and genetic composition and therefore to have approximately similar growth potential so as to be conveniently classified as one breeding group. In addition, since records were not available for the crossbreds before 1965, all records collected prior to 1965 in the HE and SY were excluded from further analysis.

The analyses of the data were first carried out on a within population basis for each of the three populations and thereafter for the combined data of all three populations. The combined data analysis was necessary for the investigation of the breed (or population) effect and its interactions with other main effects in the model. Date of birth was used as a covariate in the analysis of birth weight (BRWT) while age of the calf at weaning was used as the covariate in the analysis of weaning weight (WNWT) and preweaning average daily gain (ADG). An attempt was made to fit both linear and quadratic terms of the covariate. For the quadratic term to be included, it was required to be significant in at least one of the three populations. Thus in the within population analysis of the birth weights, the quadratic effect of birth date was not significant in all three populations so the following fixed model (subsequently referred to as model 2) was assumed to describe the observations:

$$Y_{ijkl} = \mu + D_i + S_j + A_k + DS_{ij} + SA_{jk} + \beta(X_i - X) + \epsilon_{ijkl}$$

MODEL 2

where

Y_{ijkl} = the observed birthweight

μ = the overall mean birthweight of the population

D_i = the effect of ith year of birth

S_j = the effect of the jth sex of calf

A_k = the effect of the kth age of the dam

DS_{ij} = the effect of the ith year of birth and jth sex of the calf interaction

SA_{jk} = the effect of the jth sex of the calf and kth age of the dam interaction

β = the linear regression of birthweight on the date of birth

X = the overall mean date of calving of the populations

X_i = the individual date of birth

ϵ_{ijkl} = the random error term.

The following model (model 3) was assumed to describe the analysis of the weaning weights (WNWT) and the preweaning average daily gain (ADG) on a within population basis.

$$Y_{ijkl} = \mu + D_i + S_j + A_k + DS_{ij} + SA_{jk} + \beta_1(X_i - X) + \beta_2(X_i^2 - X^2) + \epsilon_{ijkl}$$

MODEL 3

where

Y_{ijkl} = the observed trait being WNWT or ADG.

μ, D_i, S_j, A_k, DS_{ik} and SA_{jk} have similar definitions as in model 2.

X = the overall weaning age of the calves (pooled for all years)

X_i = the observed weaning age of the individual calf

X^2_i = weaning age squared

β_1 = the linear regression of WNWT or ADG on age of the calf at weaning

β_2 = the quadratic regression of WNWT or ADG on age of the calf at weaning

ϵ_{ijkl} = the random error term.

The combined data analyses for birth weights and weaning weights were carried out with models analogous to models 2 and 3, except that breed effect and breed interactions with year of birth, sex of calf and age of dam were also investigated.

In all the models, the attempt was made to fit all 2-way interaction terms except where the inclusion of such interaction terms resulted in exceeding the programme limitation of degrees of freedom. Therefore year of calving by age of dam interaction could not be fitted in the models. Second order interactions were not envisaged to be of biological importance. Significant differences were tested by the Student-Newman-Keuls test.

4.2.3 Analysis of the Traced Data: within population analysis

Since the management practice on the ranch was such that, to stay in the breeding herd, cows were required to calve each year, it can be appreciated that, in comparison with younger dams, older dams were a group highly selected for calving regularity. Therefore, observed differences between performance of different aged dam groups would not only be attributable to age of dam effects but also to truncated selection. It was therefore deemed important to investigate the preweaning performance of calves for each of the calvings in six year old dams and to compare these results with those of their respective populations.

To achieve this comparison involving six year old dams, the data were sorted within dams and the calving performance traced back in years. Since the classification of breeding populations was originally based on the genotype of the calves, some cows could not necessarily be classified with the same breeding population each year. Therefore to obtain sufficient data for each breeding population, the criterion for selection in the Traced Data was to include the record of all six year old dams which had produced at least three calves in the same breeding population. The data obtained (Traced Data) were analyzed using statistical models 2 and 3 (previously described) in the analyses of birth weight, weaning weight and average daily gain.

4.3 RESULTS AND DISCUSSION

4.3.1 Analysis of calving dates

Table 4.1 shows the mean dates of calving for age of dam classes and sex of calf in the three populations. In all three populations, the heifer dams calved significantly earlier ($p<.05$) than the three and four year old dams. The earliness of calving in the heifers relative to the three year old dams ranged from about one week (7 days) in the SY population to about two weeks (13.7 days) in the XB population, with the HE population being intermediate at 9.4 days.

After five years of age, the effect of age of dam on date of calving did not follow a regular pattern. Within the Beef Crossbreds (XB), there was no significant difference between the dates of calving of dams which were three years or older even though the two year old dams calved significantly earlier than the rest of the group. Within the HE and SY populations however, the situation was somewhat irregular, with significant differences existing among some older age groups. This irregularity may have arisen as a result of sampling error with progressively fewer numbers of observations in the older age groups.

The earliness of calving observed in the two year old dams and the lateness of calving in the three and four year old dams suggest a relation between age and body condition at the time of breeding. Puberty in heifers has been

Table 4.1 Least squares means and standard errors of date of calving in the populations for the age of dam and sex of calf.

	BREEDING POPULATION					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	202	113.95 ± 1.11 *a*[1]	407	112.94 ± 0.75 *a*	211	111.49 ± 1.05 *a*
3	127	123.36 ± 1.62 *c*	324	119.90 ± 0.88 *bc*	143	125.21 ± 1.26 *b*
4	130	121.76 ± 1.42 *bc*	258	122.24 ± 1.02 *c*	110	125.85 ± 1.65 *b*
5	119	119.62 ± 1.32 *abc*	240	117.40 ± 1.04 *ab*	65	124.30 ± 1.93 *b*
6	92	117.56 ± 1.81 *abc*	154	116.90 ± 1.30 *ab*	86	120.89 ± 1.84 *b*
7	60	115.38 ± 1.92 *ab*	108	118.84 ± 1.50 *bc*	89	122.24 ± 1.71 *b*
8	57	117.44 ± 2.16 *abc*	80	118.46 ± 1.97 *abc*	70	122.04 ± 2.06 *b*
9	23	121.57 ± 3.89 *abc*	46	113.80 ± 2.31 *ab*	57	122.23 ± 1.98 *b*
10+	44	125.30 ± 2.35 *c*	61	118.02 ± 1.81 *abc*	27	123.15 ± 2.56 *b*
SEX OF CALF						
Females	440	117.09 ± 0.76 *a*	829	116.25 ± 0.56 *a*	456	120.52 ± 0.75 *a*
Males	420	120.71 ± 0.84 *b*	849	118.96 ± 0.55 *b*	402	120.67 ± 0.81 *a*
TOTAL	860	119.04 ± 0.57	1678	117.57 ± 0.39	858	120.59 ± 0.57

[1] subclass means followed by different letters are significantly different ($p<.05$)

reported to occur as early as eight months of age though a more realistic average range is 10 to 15 months of age (Beardon and Fuquay 1980). Therefore the heifers had been cycling for some time prior to being put with the bulls at the beginning of the breeding season. Hence the heifers were likely to be impregnated in their first ovulation, that is, within 21 days of the start of breeding. All other females had recently had a calf and had not yet returned to regular cycles so they would not necessarily be impregnated for some time after the start of breeding. Therefore the results indicated that the heifers conceived readily when bred.

On the other hand the three and four year old dams having been bred the previous year, when they were just two and three years old, were at the time of breeding still nursing their calves and were themselves growing animals. These particular age groups were under the greatest stress during the breeding season. This is because they did not only need to meet their own growth requirements but they also had to lactate to nurse their calves. They were therefore the group most likely to be under greater stress at the time of breeding, more so than in other age groups in which either the additional demands of individual growth was minimized, such as in mature cows (five years and older), or when the demand of lactation was not pertinent, such as in the heifers.

The cumulative effect of this stress may be exhibited by the heifers in such manner that they may not show estrus early in their second breeding season. Wiltbank (1970) reported an average interval from calving to first estrus to be 91.6 days in two year old cows, 66.8 days for three year old cows and 60.2 days for five year old cows. The results of the present study suggest that the late calving dates observed for the three and four year old dams was due to a delay in return to first estrus during the breeding season.

The relationship between parturition and conception has been studied by Anderson, (1966); Flores, (1972); and De Kruif, (1975). All these authors reported that the interval between calving and conception was longer in those animals which had calved for the first time ,that is in primiparous cows, than it was for older cows. However, some investigators did not attribute reduced conception rates in primiparous cows to their age but to the fact that it was precisely in these animals that more problems arose at the time of calving.

Table 4.1 also shows that male calves were usually born later than the female calves. This was a direct consequence of a slightly longer gestation length of male calves than female calves. Some workers (Singh *et al.* 1958; Lasley *et al.* 1961; Sagebiel *et al.* 1967) did not find significant differences between the gestation lengths of male and female calves, while others have reported heifer calves to be carried longer than bull calves (Burris and Blunn, 1952; Foote *et al.* 1960). However, the majority have reported males to be carried longer in utero than females (Herman et al. 1953; Ahmed and Tantawy, 1956; De Fries *et al.* 1959; Preston and Willis, 1974). In the present study both HE and SY female calves were born significantly earlier (p<.05) than the male calves, the difference being 3.6 and 2.7 days in the HE and SY populations respectively. The difference of 0.2 days observed between the mean calving dates of the sexes in XB population was not significant (p>.05).

A summary of the within population analyses of variance tables for birth weight (model 2) and for weaning weight and average daily gain (model 3) are presented in Tables 4.2, 4.3 and 4.4 respectively for the three populations. The various main effects, interactions and the covariates in the equations will now be discussed.

4.3.2 Year effect

Year of birth was a highly significant source of variation in all the three preweaning traits analysed for all three populations. The least squares constants of years for birth weight, weaning weight and average daily gain (ADG) are indicated for the populations in Appendix Table 1. A regression of least squares constants for birth weight, weaning weight and ADG on years of birth, gave indications of trends toward heavier birth weight and weaning weight and higher ADG in calves born in later years of the programme. The regression coefficients along with correlations between year of birth and the least squares constants for each trait within the breeding populations are shown in Table 4.5. The

Table 4.2 Summary of the analyses of variance tables of birth weights for the populations

	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
SOURCE OF VARIATION	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	13	106.65**	13	319.70**	13	135.8**
Sex of Calf (S)	1	650.12**	1	1502.80**	1	676.25**
Age of Dam (A)	6	464.12**	6	929.69**	6	411.64**
YS	13	18.24	13	35.10*	13	42.40**
SA	6	12.50	6	25.74	6	14.56
Birth date	1	136.04**	1	247.52**	1	0.87
Error	726	13.62	1395	18.49	612	17.84

* significant at ($p<.05$)

** significant at ($p<.01$)

Table 4.3 Summary of the analyses of variance tables of weaning weights for the populations

SOURCE OF VARIATION	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	13	4059.25**	13	10854.73**	13	9167.71**
Sex of Calf (S)	1	3502.13**	1	50021.74**	1	5265.26**
Age of Dam (A)	6	9927.96**	6	34699.52**	6	9769.42**
YS	13	363.31	13	514.53	13	952.88*
SA	6	710.37	6	573.26	6	1480.67**
Age (Linear)	1	76628.49**	1	289161.72**	1	137657.40**
Age (Quadratic)	1	1127.79	1	471.33	1	4054.52**
Error	725	364.16	1394	389.46	611	499.79

* significant at ($p<.05$)

** significant at ($p<.01$)

Table 4.4 Summary of the analyses of variance tables for average daily gain in the populations

SOURCE OF VARIATION	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	13	0.1234**	13	0.3000**	13	0.2767**
Sex of Calf (S)	1	0.0494	1	0.3193**	1	0.0871*
Age of Dam (A)	6	0.2676**	6	0.9063**	6	0.2258**
YS	13	0.0118	13	0.0149	13	0.0285*
SA	6	0.0202	6	0.02[illegible]3	6	0.0497**
Age (Linear)	1	0.0050	1	0.0637*	1	0.0762*
Age (Quadratic)	1	0.0243	1	0.0005	1	0.1137**
Error	725	0.0137	1394	0.0128	611	0.0164

* significant at (p<.05)

** significant at (p<.01)

Table 4.5 Correlations between least square constants of years and year of birth and the the regression coefficients of least squares constants on year of birth in the populations.

	BREEDING POPULATIONS			
	HEREFORD	BEEF SYNTH	BEEF CROSSBRED	POOLED DATA
TRAIT				
Birth weight				
r	0.84	0.89	0.41	0.85
b	0.301 ± 0.057**	0.359 ± 0.054**	0.180 ± 0.112**	0.277 ± 0.050**
Weaning weight				
r	0.78	0.87	0.82	0.87
b	1.91 ± 0.44**	2.54 ± 0.41**	2.88 ± 0.580**	2.55 ± 0.42**
ADG				
r	0.72	0.80	0.74	0.83
b	0.0098 ± 0.0027**	0.0127 ± 0.0027**	0.0342 ± 0.0091**	0.0133 ± 0.00259**

** significant at ($p<.01$)

linear increases in birth weights were 0.30, 0.36, and 0.18 kg/year for HE, SY and XB respectively. The linear increases in weaning weights were 1.91, 2.54 and 2.88 kg/year with corresponding linear increments of 9.8, 12.7 and 34.2 g/day in ADG for the HE, SY and XB respectively.

These positive regression coefficients cannot be attributed to genetic improvement *per se* during the years because the present analysis does not lend itself to this kind of interpretation. As noted by Thrift (1964), year effects generally resulting from year to year fluctuations in temperature, precipitation and other climatic factors markedly affect the availability of forage and forage quality. Such year effects are therefore highly confounded with those originating from changes in management practices. Also, with the addition of new animals to the programme and the introduction of fresh genetic material by crossbreeding there would be a change in the average genetic merit of those animals included in the programme.

4.3.3 Sex effect

The least squares means and standard errors for BRWT, WNWT and ADG for the sexes and age of dam classes are shown in Tables 4.6, 4.7 and 4.8. Male calves exceeded ($p<.01$) female calves in birth weight and weaning weight in all three breeding populations. At birth the males weighed 2.1 (6.4%), 2.4 (6.7%) and 3.2 (9.0%) kg heavier than the females in HE, SY and XB respectively. At weaning age of

Table 4.6 Least squares means and standard errors for birth weights (kg) in the populations

	BREEDING POPULATION					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	189	30.85 ± 0.30 *a*[1]	362	32.96 ± 0.25 *a*	204	33.39 ± 0.40 *a*
3	112	32.50 ± 0.36 *b*	285	35.03 ± 0.26 *b*	106	35.87 ± 0.47 *b*
4	109	33.99 ± 0.37 *c*	209	36.56 ± 0.30 *c*	76	37.68 ± 0.56 *c*
5	95	35.29 ± 0.39 *d*	184	37.55 ± 0.33 *d*	34	39.61 ± 0.78 *c*
6	84	36.37 ± 0.44 *d*	120	38.46 ± 0.40 *d*	49	39.19 ± 0.72 *c*
7-8	113	35.57 ± 0.36 *d*	183	37.72 ± 0.33 *d*	103	39.35 ± 0.52 *c*
9+	65	36.40 ± 0.50 *d*	93	38.67 ± 0.46 *d*	81	37.62 ± 0.52 *c*
SEX OF CALF						
Females	400	33.36 ± 0.21 *a*	766	35.52 ± 0.18 *a*	339	35.91 ± 0.29 *a*
Males	367	35.48 ± 0.22 *b*	670	37.89 ± 0.19 *b*	314	39.15 ± 0.44 *b*
TOTAL	767	34.42 ± 0.15	1436	36.71 ± 0.13	653	37.53 ± 0.27

[1] Subclass means followed by different letters are significantly different (p< .05)

Table 4.7 Least squares means and standard errors for weaning weights (kg) in the populations

	BREEDING POPULATION					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	189	145.17 ± 1.64 *a*[1]	362	171.05 ± 1.23 *a*	204	172.37 ± 2.47 *a*
3	112	154.97 ± 1.94 *b*	285	186.24 ± 1.27 *b*	106	188.91 ± 2.65 *b*
4	109	165.19 ± 2.00 *c*	209	195.18 ± 1.45 *c*	76	200.95 ± 3.20 *c*
5	95	170.18 ± 2.06 *c*	184	197.51 ± 1.55 *c*	34	202.68 ± 4.39 *c*
6	84	167.43 ± 2.33 *c*	120	205.19 ± 1.89 *d*	49	199.19 ± 3.92 *bc*
7-8	113	169.79 ± 1.93 *c*	183	201.83 ± 1.57 *d*	103	198.33 ± 2.90 *bc*
9+	65	165.99 ± 2.65 *c*	93	205.87 ± 2.17 *d*	81	191.91 ± 2.93 bc
SEX OF CALF						
Females	400	160.29 ± 1.13 *a*	766	187.86 ± 0.93 *a*	339	188.87 ± 2.06 *a*
Males	367	165.22 ± 1.25 *b*	670	201.53 ± 1.00 *b*	314	198.08 ± 2.47 *b*
TOTAL	767	162.75 ± 0.95	1436	194.70 ± 0.75	653	193.48 ± 1.79

[1] Subclass means followed by different letters are significantly different ($p<.05$)

Table 4.8 Least squares means and standard errors for preweaning average daily gain (

	BREEDING POPULATION					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	189	.715 ± .010 *a*[1]	362	.864 ± .007 *a*	204	.872 ± .014 *a*
3	112	.763 ± .012 *b*	285	.946 ± .007 *b*	106	.956 ± .015 *b*
4	109	.819 ± .012 *c*	209	.992 ± .008 *c*	76	1.017 ± .018 *c*
5	95	.846 ± .013 *c*	184	.999 ± .009 *c*	34	1.015 ± .025 *bc*
6	84	.823 ± .014 *c*	120	1.039 ± .011 *d*	49	.998 ± .022 *bc*
7-8	113	.841 ± .012 *c*	183	1.022 ± .009 *cd*	103	.988 ± .017 *bc*
9+	65	.810 ± .016 *c*	93	1.042 ± .012 *d*	81	.965 ± .017 *bc*
SEX OF CALF						
Females	400	.793 ± .008 *a*	766	.951 ± .005 *a*	339	.954 ± .012*a*
Males	367	.812 ± .008 *a*	670	1.022 ± .006 *b*	314	.992 ± .014*b*
TOTAL	767	.802 ± .006	1436	.986 ± .004	653	.973 ± .010

[1] subclass means followed by different letters are significantly different (p<.05

approximately 160 days, the males averaged 4.9 (3.1%), 13.7 (7.2%) and 9.21 (4.9%) kg heavier than the females in HE, SY and XB respectively.

The superiority of male calves over female calves in growth rate is well documented in the the literature (Cundiff *et al.* 1966; Tudor, 1972; Bair *et al.* 1972; Fahmy and Lalande, 1973; Seifert *et al.* 1974; Harricharan *et al.* 1976; Holland *et al.* 1977; Pell and Thayne, 1978; Knapp *et al.* 1980). The actual differences in magnitude have differed among studies depending on the size of the breeds and the level of nutrition. Generally, not only do the larger breeds exhibit larger differences between the sexes but also the differences betweeen the sexes have been observed to increase with increasing level of milk production and increasing ages of the calves at which comparisons were made (Pabst *et al.* 1977).

In this study, it was observed that the superiority of the males over the females (expressed in percentage units) declined from birth to weaning in HE and XB, while there was a slight increase in SY. This suggested a strong sex by breed interaction due to the three populations not being able to provide enough milk to satisfy the growth potential of their male calves.

4.3.4 Age of dam

The mean birth weights, weaning weights and ADG for the age of dam categories of the three breeding populations are shown in Tables 4.6, 4.7 and 4.8. Significant differences (P<.05) existed among calves from different age of dam categories in all the three traits analyzed. In general, older dams which were heavier, calved and weaned heavier calves which maintained higher ADG values than calves from younger dams. Definitions in the literature of mature and aged dams differ among studies, and this sometimes makes comparisons of results difficult. However, the general trend in this study was for the birth weight to increase significantly with the age of the dam up to about four years in the XB and up to about five years in the HE and SY. Peak birth weights were however recorded in five year old dams of the XB population and in six year old dams in the HE and SY populations. The absolute differences between birth weights of calves from two year old dams and those from peak aged dams were 5.52, 5.50 and 6.22 kg in the HE, SY and XB populations respectively.

Weaning weight significantly increased from calves of two year old dams to calves from four year old dams in HE and XB, with peak weaning weight being for calves from five year old dams. In SY however, calf weaning weights significantly increased from first calf to a peak in six year old dams. Sharma *et al.* (1982) working on data from the same herd, compared HE and SY and observed that while in HE very little increase was evident in preweaning ADG and WNWT in calves from dams five years and older, there was still a significant increase in the traits when differences were considered in calves from five and six year old dams in SY. This difference was explained as a reflection of the later maturation of the SY population with milk yield continuing to increase until the cows were six years old. The difference could also have arisen as a result of selection within the SY dams in which increasing population size allowed some culling of five year old dams on the basis of progeny performance. These findings are in general agreeement with most published results, in particular studies by Cardellino and Frahm (1971), Schaeffer and Wilton (1974a) and Harricharan *et al.* (1976).

Results from the literature indicate that once the dams are over five years, there is no consistent pattern among breeds for the effect of the age of the dam on preweaning performance of their calves. Pabst *et al.* (1977) observed that there was a tendency in Hereford, South Devon and Sussex breeds for the effect of age of dam to decline after ten years while in the Aberdeen Angus, Devon and Lincoln Red breeds such an observation was not apparent. Several other studies (Marlowe, 1962; Hamann *et al.* 1963; Thrift, 1964; Singh *et al.* 1970; Schaeffer and Wilton, 1974a) have also observed various ages when weaning weight peaked in different breeds. Nevertheless the general agreement is that weaning weight usually plateaued in mature (five to eight year old) dams and thereafter declined.

Cundiff *et al.* (1966) have reported that the earliness of decline in weaning weight with increasing age of the dam is more marked in arid regions than in areas with moderate to high rainfall. There was some evidence, especially in the HE and XB populations, that preweaning performance was beginning to decline in the 9+ age of dam category but no apparent decline was noticeable in the SY population.

4.3.5 Year by sex of calf interaction

Year by sex of calf interaction was not significant for any of the traits analyzed in the HE population. It was however significant ($p<.05$) for birth weight in SY and XB and in weaning weight and ADG for XB. The nonsignificant effect of this interaction term in HE indicates that the effect of yearly environmental and climatic fluctuations were similar in both sexes. Correlations between the least squares constants of years within population and absolute superiority of males over females are given in Table 4.9. All correlations in HE are near zero and nonsignificant. On the other hand correlations for birth weight in SY and for all traits in XB are positive and significant. The positive coefficients indicate that as yearly environmental effects became fovourable, males expressed greater superiority over females in birth weight in SY and XB and also in weaning weight and ADG in the XB population.

Table 4.9 Correlations between least square constants of years and absolute superiority of male calves relative to female calves for preweaning traits.

TRAIT	HEREFORD	BEEF SYNTHETIC	BEEF CROSSBRED
	BREEDING POPULATIONS		
Birth Weight			
	r = 0.18	0.55**	0.44**
Weaning Weight			
	r = -0.14	-0.11	0.33**
ADG			
	r = -0.03	-0.10	0.48*

* significant at ($p<.05$)
** significant at ($p<.01$)

The reason for the nonsignificant effect of this interaction in HE is not clear. However, as XB and SY are synthetic populations, it is possible that there is a greater genetic diversity in these two populations compared to HE. Thus, XB and SY have a greater genetic potential for growth than HE. Therefore XB and SY could be more responsive to environmental fluctuations with the males capitalizing on improved environmental conditions thereby expressing their superiority over the females more readily than in HE.

4.3.6 Sex of calf by age of dam interaction

The nonsignificant interaction between birth weight and age of dam in all three breeding populations indicated that the effect of age of dam was similar in both sexes. At weaning however, sex by age of dam interactions were significant (p<.05) for weaning weight and ADG in XB but not in HE or SY. This indicated that the age of dam effects were similar in the sexes at weaning in HE and SY but not necessarily so in the XB population. This observation may be related to the milking ability of the dams. Harwin *et al.* (1966) reported that the sex difference in weaning weight of calves from young cows was smaller than the sex difference in weaning weight of calves from mature cows, and that male calves, because of their greater growth potential, may have been more severely limited by the lower nutritional environment provided by the young dams.

The regression of the additive correction factors for the sexes on the age of dams within populations for ADG gave positive though not significant coefficients for the XB population (β = 0.0146 ± 0.0084) and SY populations (β = 0.000074 ± 0.0042). In the HE population, a significant negative regression coefficient was obtained (β = −0.0108 ± 0.0033). This indicated that as the Hereford dams grew older, the performance of their male calves (in terms of ADG) relative to the performance of the females declined. That is, male calves were increasingly disadvantaged with increasing age of the dam in HE; this is perhaps due to the fact that despite the increased birth weights which usually paralleled increasing age in the dams, there may not have been a commensurate improvement in the milk yields in the older dams of HE to fully satisfy their growth potential.

Butson and Berg (1984) have shown that dairy crossbreds exhibited greater persistency and yielded significantly more milk constituents, (butter fat, protein and lactose), than HE and SY. Butson *et al.* (1980) also reported SY to yield about 17% more milk than HE. The standardization of XB population was based on selecting animals which had at least 50% British beef breeding. However, the level of dairy breeding in the selected XB population was estimated to be 10.3%. The milk yields of XB individuals were not determined. However, they could have benefitted from their dairy ancestry and therefore yielded more milk than HE.

4.3.7 Effect of calving date

The mean dates of calving were 118.6, 116.9 and 119.2 days for the HE, SY and XB respectively. The least squares estimates of the regression coefficients are shown in Table 4.10. The effect of date of birth on birth weight was a highly significant source of variation in HE, and SY but not in XB. The linear regression coefficients of birth weight on birth date were 0.0294, 0.0289 and 0.0026 kg/day in HE, SY and XB respectively. The positive regressions established in all three populations indicated that birth weight increased as the calving season progressed. Thus in HE and SY populations, calves born earlier were significantly lighter at birth than those born later in the calving season while in XB, the stage of the calving season did not significantly affect the birth weights of the calves.

The positive regressions may be accounted for in two ways. Firstly, the preliminary analysis revealed that heifer dams calved significantly earlier than older dams. Hence it would be expected that as the older dams calved later in the calving season the overall trend would be one of increasing calf birth weights from an initial low. Secondly, the improved birth weights may be explained by the fact that because the dams received grain supplementation during the winter, those dams which calved late would have received grain for a longer period than those which calved early. Therefore the late calving dams might have been advantaged from a nutritional point of view. The general trends of the

Table 4.10 Least square estimates of covariates in equations

VARIABLE AND EFFECTS	BREEDING POPULATIONS		
	HEREFORD MEAN ± SE	BEEF SYNTHETIC MEAN ± SE	BEEF CROSSBRED MEAN ± SE
Birth Weight			
DATE OF BIRTH			
Linear (β_1)	0.0294 ± 0.0093	0.0289 ± 0.0079	0.0026 ± 0.0120
Weaning Weight			
AGE OF CALF (days)			
Linear (β_1)	0.769 ± 0.053**	1.002 ± 0.037**	1.035 ± 0.062**
Quadratic (β_2)	-0.00217 ± 0.00123	-0.00105 ± 0.00096	-0.00561 ± 0.00[illegible]7**
Average Daily Gain (ADG) kg/day			
AGE OF CALF (days)			
Linear (β_1)	$1.960 \times 10^{-4} \pm 3.250 \times 10^{-4}$	$4.790 \times 10^{-4} \pm 2.11 \times 10^{-4}$**	$4.650 \times 10^{-4} \pm 1.58 \times 10^{-4}$**
Quadratic (β_2)	$-1.009 \times 10^{-5} \pm 0.756 \times 10^{-5}$	$-0.104 \times 10^{-5} \pm 0.55 \times 10^{-5}$	$-2.970 \times 10^{-5} \pm 1.13 \times 10^{-5}$**

* significant at ($p<.05$)
** significant at ($p<.01$)

regression equations agree with reports in the literature. For example, Holland *et al.* (1977) reported a pooled regression estimate of 0.099 kg/day in Angus, Hereford and Polled Hereford cattle in Australia. Alexander *et al.* (1960) also reported a slightly higher coefficient of 0.044 kg/day. Other workers (Koch and Clark, 1955; Singh *et al.* 1970 and Franke and Turner, 1983) have observed positive and significant associations between calving date and birth weight.

4.3.8 Effect of age of calf

Age of calf at weaning was an obvious source of variation in weaning weight. The means of the age of calves at weaning were 157.4, 160.8 and 162.9 days for the HE, SY and XB populations respectively. The least squares estimates of regression coefficients for the breeding groups are shown in Table 4.10. The analyses showed that linear and quadratic components of age at weaning were highly significant for weaning weight and ADG in the XB population but only linear components of weaning age were highly significant in the HE and SY populations. The linear component of age was also significant in SY for ADG, while in HE neither of the regressions for ADG was significant. This means that in HE and SY, the increment in weaning weight for each increment in age seemed to be constant, whereas in the XB, this increment was not constant but significantly decreased with increasing age of the calf. The negative coefficients of the quadratic regressions even though nonsignificant in HE and SY, indicated that a curvilinear relationship might well describe the growth pattern more accurately than a straight line.

Johnson and Dinkel (1951) found that growth of calves on range was linear from birth to 155 days of age and thereafter progressively decreased. Pell and Thayne (1978) working in West Virginia with Hereford and Angus calves observed significant linear and quadratic age effects on weaning weight. They reported regression coefficients of 0.85 and -0.5×10^{-4} as linear and quadratic components respectively in Hereford while the corresponding values for Angus were 0.95 and -8.3×10^{-4}

Marlowe *et al.* (1965) reported that as calves grew older, their rates of gain decreased. Swiger *et al.* (1962) reported a significant ($p<.05$) curvilinear regression of weaning weight on age from 130 to 200 days or more. Thrift (1964) and Warren *et al.* (1965) also reported a curvilinear association of weaning weight and age. These studies had considerably older weaning ages, usually 200 days, than the average weaning age (160 days) for this study. Perhaps at this younger age the rate of decline in the gains of the HE and SY calves had not become significant as evidenced by the nonsignificant negative quadratic regressions. The linear coefficients observed in this study agree with those reported by Lawson (1976), Barlow *et al.* (1978), and Butson *et al.* (1980).

In the ADG analyses, the linear β_1, and quadratic β_2, (regression of ADG on age) were 1.96×10^{-4} and -1.009×10^{-5} for HE. The corresponding coefficients for SY were $\beta_1 = 4.79 \times 10^{-4}$ and $\beta_2 = -0.104 \times 10^{-5}$, while for XB the values were $\beta_1 = 4.65 \times 10^{-4}$ and $\beta_2 = -2.97 \times 10^{-5}$. Schaeffer and Wilton (1974a) reported significant linear and quadratic regressions of ADG on age in Angus and Hereford calves. In Angus the regressions were $\beta_1 = -0.0010$ and $\beta_2 = -8.0 \times 10^{-4}$. The corresponding regressions in Hereford were $\beta_1 = -0.0006$ and $\beta_2 = -6.0 \times 10^{-4}$. However, they stated that although the coefficients were highly significant, the observed regressions were expected to have little effect on ADG considering the range of age usually encountered.

Barlow *et al.* (1978) computed 72 regressions of ADG on weaning age within sex, herd and years and found only 33 to be significant. Some of these had negative coefficients while others had positive coefficients. Singh *et al.* (1970) did not find significant effects of age of calf on preweaning ADG. In all the above studies and also in the present study, the near zero regression coefficients suggest that the age of the calf at weaning may not be an important source of variation in ADG. This is perhaps due to the fact that the computation of ADG intrinsically adjusts for age of the calf effects (Kennedy and Henderson, 1975b). Schaeffer and Wilton (1974a), therefore suggested that both the linear and quadratic terms of age at weaning as a covariate could be ignored in future analysis of preweaning ADG. The results from this study lend support to this suggestion.

4.3.9 Main effects in combined data analysis

The main effects of year of birth, sex of calf, age of dam and breeding population were highly significant sources of variation in all the three traits of the combined data. Table 4.11 shows the summary of the analyses of variance for the combined data. The overall annual linear increases in birth weight, weaning weight and average daily gain during the 14-year period were 0.28 ± 0.05, 2.56 ± 0.42 kg and 0.013 ± 0.003 kg/day respectively. The least squares means and standard errors of the traits for the combined data are shown in Table 4.12. Male calves were significantly heavier at birth than female calves and weaned significantly heavier than female calves. Male calves also recorded significantly higher preweaning average daily gain than female calves.

Overall, birth weight, weaning weight and average daily gains increased in calves from two year old dams to a peak in calves from six year old dams. The calves from two year old dams were significantly lighter at birth and weaning, and had significantly lower average daily gain compared with calves from older dams. The significant differences existing between the traits in the age of dam categories are indicated in Table 4.12.

Significant differences existed among the breeding populations in all three traits analyzed. At birth, HE was the lightest of the group with a mean birth weight of 34.48

Table 4.11 Summary of the analyses of variance tables for birth weight, weaning weight and average daily gain (A.D.G) for the combined data.

SOURCE OF VARIATION	PREWEANING TRAITS					
	BIRTH WEIGHT		WEANING WEIGHT		A.D.G	
	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	13	342.11**	13	22273.67**	13	0.6878**
Population (B)	2	1312.02**	2	206098.38**	2	6.9368**
Sex of Calf (S)	1	3511.11**	1	53188.72**	2	1.1572**
Age of Dam (A)	6	1571.60**	6	44493.64**	6	0.0925**
YB	26	43.59**	26	798.93**	26	0.0356**
YS	13	27.29	13	749.37*	13	0.0217
BS	2	31.03	2	2015.00**	2	0.0912**
BA	12	22.62	12	1245.54**	12	0.0414**
SA	6	25.55	6	420.58	6	0.1027
Regressions						
Birth Date (Linear)	1	253.60**				
Age (Linear)		-	1	505590.23**	1	0.1206**
Age (Quadratic)	-	-	1	3229.91**	1	0.0617**
Error	2773	17.22	2772	412.67	2272	0.0139

* significant at (p<.05)
** significant at (p<.01)

Table 4.12 Least squares means and standard errors of birth weight, weaning weight and average daily gain for breeding population, sex of calf and age of dam in the combined data analyses

		PREWEANING TRAITS		
		BIRTH WEIGHT (kg)	WEANING WEIGHT (kg)	A.D.G (kg/day)
	N	MEAN ± SE	MEAN ± SE	MEAN ± SE
POPULATION				
Hereford	755	34.48 ± 0.11 *a*[1]	163.38 ± 0.87 *a*	0.805 ± 0.005 *a*
Synthetic	1436	36.72 ± 0.13 *b*	195.17 ± 0.70 *c*	0.990 ± 0.004 *b*
Crossbred	653	37.43 ± 0.23 *c*	190.50 ± 1.19 *b*	0.958 ± 0.007 *b*
SEX OF CALF				
Females	1505	34.90 ± 0.13 *a*	177.92 ± 0.72 *a*	0.894 ± 0.004 *a*
Males	1351	37.52 ± 0.15 *b*	188.11 ± 0.79 *b*	0.941 ± 0.005 *b*
AGE OF DAM				
2	755	32.46 ± 0.18 *a*	161.92 ± 0.96 *a*	0.812 ± 0.006 *a*
3	503	34.44 ± 0.22 *b*	176.23 ± 1.10 *b*	0.886 ± 0.006 *b*
4	394	36.11 ± 0.24 *c*	186.52 ± 1.24 *c*	0.939 ± 0.007 *b*
5	313	37.41 ± 0.31 *d*	189.34 ± 1.54 *c*	0.949 ± 0.009 *b*
6	253	38.00 ± 0.31 *d*	190.20 ± 1.54 *c*	0.952 ± 0.009 *b*
7-8	399	37.56 ± 0.23 *d*	189.31 ± 1.19 *c*	0.947 ± 0.007 *b*
9+	239	37.49 ± 0.29 *d*	187.60 ± 1.45 *c*	0.936 ± 0.008 *b*
TOTAL	2856	36.21 ± 0.10	183.01 ± 0.61	0.917 ± 0.004

[1] subclass means followed by different letters are significantly different ($p<.05$)

± 0.11 kg. This was followed by SY with a mean birthweight of 36.72 ± 0.13 kg, while XB was the heaviest at birth with a mean birth weight of 37.43 ± 0.23 kg. Thus the largest difference in the mean birth weights was 2.95 kg between HE and XB while the smallest difference was 0.71 kg between XB and SY. These differences were determined to be statistically significant ($p<.05$).

At the time of weaning, the order of superiority in weight among the breeding groups was somewhat altered. While HE remained the lightest breed and weaned 163.38 ± 0.87 kg, SY weaned the heaviest with a mean weaning weight of 195.17 ± 0.70 kg compared with 190.50 ± 1.19 kg for the XB calves. At weaning therefore SY weighed 31.79 and 4.67 kg heavier than HE and XB respectively while XB on the average weighed 27.12 kg heavier than HE. This meant that even though at birth the absolute differences between the breeds were small, at the time of weaning these differences had translated into large differences which were due mainly to the differential average daily gains (ADG) of the breeds.

The mean ADG for SY and XB were 0.990 ± 0.004 and 0.958 ± 0.007 kg/day respectively while the mean ADG for HE was 0.805 ± 0.005 kg/day. Though the difference between XB and SY for ADG was not significant, their mean values were significantly higher ($p\leq.05$) than that of HE. However, the cumulative effects of the slightly higher growth rate of SY over XB during the preweaning period was enough to offset the initial superiority of XB over SY so that SY calves were significantly heavier at weaning than XB.

4.3.10 Interactions in combined data analysis

In the analysis of birth weight, year by breed interaction was the only significant interaction term observed. In the analysis of weaning weight and average daily gain however, the breeding population interaction with all the other main effects was observed to be significant while the year by sex of calf and age of dam by sex of calf interactions were not significant. The year by breed interaction may have arisen in part because of the distribution of the breeds among years. An examination of the data revealed that very few crossbreds were represented in the herd between 1969 and 1972. Also the interaction may be due to the differential responses of the breeding populations within years. Possibly, in the populations where numbers were limiting, culling rates were less rigorous and this may have been the case with the crossbreds.

The significant breed by age of dam and breed by sex of calf interactions in weaning weight and average daily gain meant that sex of calf effect and age of dam effect were not the same in all breeds. The within population analysis had revealed that weaning weight and average daily gain peaked in two different age of dam categories in the different populations. That is, in HE and XB populations the peak weaning weight and average daily gain were observed in calves from five year old dams while in SY the peak values were observed in six year old dams.

The significant breed by sex of calf interaction confirmed the results of the within population analysis where it was suggested that in some breeds the males may have been disadvantaged from a nutritional point of view by inadequate milk production in the dams. Butson *et al*. (1980) reported that SY produced about 17% more milk than HE; however, the milking capacity of the XB has not been determined. Sharma *et al*. (1982) observed significant breed by sex of calf interaction when working with SY and HE data. They offered the explanation that, in view of the lower milking capacity of HE compared with SY, and the fact that male calves have a greater nutritional requirement than heifer calves, HE males might not have been able to express their full growth potential.

Sharma *et al*. (1982) also determined that multiplicative correction factors were more appropriate than additive factors for correcting sex of calf effects. Multiplicative correction factors which adjust data to a male basis in effect express the superiority of male calves relative to female calves. Utilizing the least squares means for the breeding population by sex of calf interaction for comparing the sexes, HE males were found to exceed their female counterparts by 6.8, 4.6, and 3.6% in birth weight, weaning weight and average daily gain respectively. In the SY population the males were superior to the females by 6.9, 6.9 and 7.0% in birth weight, weaning weight and average daily gain respectively. The corresponding values for the XB population were 8.8, 5.5 and 5.0%. The fact that the correction factors decreased from birth weight in HE and XB populations while they were fairly constant in SY indicated that male calves in HE and XB were marginally disadvantaged. This may be due to a lower genetic potential for milk production of HE and XB compared to SY.

4.3.11 Traced Data results

The Traced Data are the calving performance of the six year old dams which have been traced back in years for at least three calvings. The analyses of variance tables for the Traced Data are summarized in Appendix Tables 2, 3 and 4. In general the results for the main effects of the Traced Data agreed with the results for the general population. A few exceptions were however apparent particularly in the ADG analysis of the Traced Data. For instance the sexes were not significantly different for ADG. Year and age of dam effects were not significant for ADG analysis in SY. None of the interactions and covariate terms were significant in the Traced Data analysis of ADG, although significant interaction terms were observed in XB in addition to significant linear effects of age of calf on ADG.

In the analysis of birth weight, the levels of significance achieved were similar for all the main effects and interaction terms fitted in all three populations. The year by sex of calf interaction term was however, significant in SY and XB for the Traced Data analyses but was not significant in the analyses of their respective general populations. In the analysis of weaning weight, all significant levels for the effects were similar except in XB where the interaction terms were not significant in the Traced Data analysis but were significant in the respective general population data.

The least squares means and standard errors for birth weight, weaning weight and ADG for the Traced Data are shown in Appendix Tables 5, 6 and 7. The least squares estimates of the covariates in the Traced Data analyses are also shown in Appendix Table 8. At both birth and weaning, male calves were significantly heavier than female calves; however, in all three populations the ADGs were not significantly different. Significant differences existed among the age of dam categories for most of the traits in each population. Birth weight was observed to increase in calves from two year old dams to a peak in six year olds in HE and SY while peak birth weights were observed in calves from five year old XB dams with a slight decline in birth weights of calves from six year old dams. Weaning weights of calves also increased in calves from two year old dams to a peak in calves from six year old dams in all three populations for the Traced Data. In the general population, peak weaning weights were observed in calves from six year old dams only in SY while HE and XB had peak weaning weights in five year old dams. In general however, trends of increases in weight in the Traced Data analyses were similar to those observed in the general populations.

Results from the ADG analysis of the Traced Data were generally the same as those from the general populations of HE and XB. In SY however, unusually high ADG values were observed for calves from two year old dams. This may basically be due to the adjustment for the age of the calf at weaning. Since the preliminary analysis revealed that heifer dams usually calved earlier than the older dams, adjusting the ADG of the calves to a common age may have biased the results of the two year old dams.

4.4 SUMMARY AND CONCLUSIONS

Differences in preweaning performance due to calving ages of dams were obvious. Calf birth weights increased from heifers to a peak in four year old dams in XB while peak birth weights were observed in five year old dams in HE and SY populations. Weaning weight and ADG however peaked in five year old dams in HE and XB and in six year old dams in the SY population. The results suggested that in the HE and SY populations, calf birth weights were positively associated with calving dates; calves born later in the calving season being heavier. Though age of dam effect was fitted in the model, the age of dam effect could not have been completely controlled because two year old dams were shown to calve significantly earlier compared with most other age of dam categories. Therefore the lower birth weights observed at the beginning of the calving season could be partially confounded with age of dams. Calf birth weights increased linearly at an average rate of about 29 g/day or 2.2 kg over the entire calving season of approximately 75 days. Birth weight, weaning weight and ADG also increased in all populations during the 14 year period of the breeding programme.

Late calving dates observed in the three and four year old dams could be explained by stress due to excessive demands of lactation and growth. On the other hand the early calving in the heifers could primarily be due to absence of the stresses associated with previous pregnancy and lactation.

The mean birth date of bull calves was significantly later than that of heifer calves in HE and SY. This delay could be attributed to the fact that bull calves have a slightly longer gestation length than heifer calves. The calving dates were not significantly different between the sexes in the XB population.

Male calves were heavier at birth and at weaning and attained higher preweaning ADG than female calves. However, significant breed x sex of calf interaction suggested that because of their greater nutritional potential, male calves might have been marginally disadvantaged by the poor nutritional environment provided by the HE and XB dams. Male size superiority in terms of multiplicative adjustment factors declined from birth to weaning in HE and XB but there was very little change in the SY population.

Linear age of calf effect was a significant source of variation in weaning weight. Quadratic effects were significant only in the XB population but the negative regression coefficients observed for quadratic effects in all populations although non significant, indicated that linear age of calf adjustments in the analyses of weaning weights could lead to a bias in mean estimates. In ADG analysis, linear age of calf effects were significant only in the XB population.

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5. ANALYSIS OF PREWEANING PATTERNS OF GROWTH

5.1 INTRODUCTION

Patterns of growth, body composition and efficiency of growth can all be described with simplicity in terms of age. For example, the growth pattern of beef cattle is usually characterized by a rapid [illegible] growth followed by a progressive deceleration in the rate of gain from puberty to maturity at six to eight years of age. If, however, as Taylor (1982) has indicated, physiological age is not the same for different breeds, genetic comparisons made at the same age may be complicated by other growth variables which affect growth rate (e.g. body fat) and thus require complex biological interpretation.

Singh and Bhat (1979) have noted that differences in the amount of development or growth between fixed ages varies from breed to breed and is primarily due to the genetic differences among breeds. For any estimate of weight-age curve parameters to be useful in selection programmes, McLaren *et al.* (1982) have remarked that they must be derived from young animals and must be indicative of the genetic potential of the animals. As beef calves are not usually weighed at frequent or regular intervals, especially during the preweaning period, patterns of variation in growth of calves have not been accurately described.

5.1.1 Objectives of the study

It is the purpose of this study to evaluate the season of calving and breeding group effects on the preweaning growth patterns of beef calves maintained at the University of Alberta cattle ranch at Kinsella. It is hoped that any differences in the early growth patterns may aid in developing management practices to enhance calfhood productivity.

5.2 EXPERIMENTAL

The data used in this study were the same as those used in the previous section. However, some modifications in the analyses were made; all the data for the three breeding populations were pooled. In the combined data, the earliest date of calving was found to be March 16 (day 75) while the last date of calving was June 15 (day 166) thus giving a range in calving date of 92 days. The plot of the dates of calving at daily intervals over all years was found to be positively skewed indicating fewer and distant calvings toward the end of the calving season.

Based on the dates of calving, an attempt was made to classify the calves into three groups; early, mid and late born calves. This grouping was necessary to facilitate the analysis of the data with seasonal classification even though all calvings actually occurred in the spring season. The three groups of calves were therefore defined as follows;

early born: calves born before April 20 (day 110)

mid season: calves born between April 21 and May 12 (days 110 to 132)

late born: calves born after May 12 (day 132)

The preweaning weight records which were taken approximately at the end of the third week or early parts of the fourth week in the months of June, July and August were denoted as PW1, PW2, and PW3 respectively with the final (weaning) weight (WNWT) being recorded in October.

Since all the calves in a given year were weighed on approximately the same day at each weighing time, age differences among calves at each period corresponded to differences in their birth dates. The average ages of the calves at the three preweaning periods were denoted AGE1, AGE2, AGE3 with the final age being denoted as WEAN. Average daily gain (ADG) between two consecutive weighings was calculated by dividing the weight gain by the number of days in that period. Relative Growth Rate (RGR) at each interval was calculated by dividing the corresponding ADG by the average of the initial and final weights, that is, the average weight (AVGWT) during that period. RGR considers the daily gain relative to the average body weight (AVGWT) during a given period and can therefore be considered as a measure of the efficiency of gain. However, ADG, RGR and AVGWT were not computed for ages less than 58 days since all preweaning weighings were done after the calving season when the early born calves were already older than 58 days.

By classifying the preweaning ages of the calves at the time of weighing in two week intervals, seven age classes were defined as follows;

Age class 1: 59 to 72 days

Age class 2: 73 to 86 days

Age class 3: 87 to 100 days

Age class 4: 101 to 114 days

Age class 5: 115 to 128 days

Age class 6: 129 to 144 days

Age class 7: greater than 144 days.

The computed ADG ,RGR, AVGWT and the mean age for AGE1, AGE2, AGE3 and WEAN were analyzed across the breeding groups, sex of calf, season of birth, year of birth, age class, and age of dam categories by the least squares method as outlined by Harvey (1976). The following fixed model was assumed to describe the particular observation under consideration:

$$Y_{ijklmn} = \mu + W_i + B_j + X_k + A_l + S_m + C_n + BA_{jl} + BS_{jm} + BC_{jn} + XC_{kn} + AS_{lm} + SC_{mn} + \epsilon_{ijklmn}$$

where

Y_{ijklmn} = the particular trait under observation

μ = the overall mean for the trait

W_i = the effect of the *ith* year of calving

B_j = the effect of the *j*th breeeding population

X_k = the effect of the *k*th sex of the calf

A_l = the effect of the *l*th age of the dam

S_m = the effect of the *m*th season of birth

C_n = the effect of the nth age class

BA_{jl}, BS_{jm}, BC_{jn}, XC_{kn}, AS_{lm}, SC_{mn} are the respective 2-way interactions

ϵ_{ijklmn} = the random error term

Using the procedure for mean separation as outlined by Harvey (1979), the Student-Newman-Keuls test was used to separate the means when significant differences were established by the analysis of variance.

Individual regresssions were fitted in a stepwise manner to the least squares means of the 2-way interaction terms when these were found to be significant. These interaction means were then plotted against the average ages of the age classes to determine the pattern of ADG and RGR change with the age of the calf.

5.3 RESULTS AND DISCUSSION

The analyses of variance tables for the traits analyzed are presented in Table 5.1. In general, except for the nonsignificant effect of sex of calf in RGR, all the main effects fitted in the model were highly significant sources of variation. All the interaction terms in AVGWT were significant. Breed by age class and season by age class interactions were also significant for all three parameters. Breed by sex interaction was also significant for ADG. Table 5.2 shows the least squares means and standard errors of ADG, RGR, and AVGWT for the three breeding populations, sex of calf, season of birth, age of dam and age class

Table 5.1 Summary of the analyses of variance tables for ADG, RGR and AVGWT

SOURCE OF VARIATION	df	ADG	RGR ($\times 10^{-5}$)	AVWGT
		MEAN SQUARES OF TRAITS		
Years (Y)	14	.0419**	42.21**	39604.94**
Breeding Pop. (B)	2	.1691**	114.54**	207422.86**
Sex of Calf (X)	1	.0575**	.17	100236.99**
Age of Dam (A)	6	.0234**	17.06**	67716.08**
Seasons (S)	2	.0311**	693.03**	8918.63**
Age Class (C)	6	.0548**	4522.94**	721153.71**
BA	12	.0008	3.06	1002.11**
BS	4	.0014*	3.00	2224.54**
BC	12	.0019*	8.60**	3678.77**
XC	6	.0008	3.58	676.73*
AS	12	.0005	.91	1335.17**
SC	12	.0216**	88.12**	1925.82**
Error	8263	.0005	2.93	253.48
Total	8353			

* significant at (p<.05)
** significant at (p<.01)

Table 5.2 Least squares means and standard errors of ADG, RGR and AVGWT for the main effects in the analysis of variance

EFFECT	N. OF OBS.	ADG (kg/day) Mean ± s.e	RGR (k/day/kg body wt) Mean ± s.e	AVGWT (kg) Mean ± s.e.
POPULATION				
HE.	2310	.840 ± .005 *a*	8.674 ± .041 *a*	120.37 ± .38 *a*
SY	4202	1.019 ± .004 *c*	9.131 ± .036 *c*	139.71 ± .34 *c*
XB	1841	.969 ± .006 *b*	8.822 ± .049 *b*	136.74 ± .46 *b*
SEX OF CALF				
Females	4337	.915 ± .004 *a*	8.880 ± .031 *a*	128.63 ± .29 *a*
Males	4016	.970 ± .004 *b*	8.871 ± .032 *a*	135.92 ± .30 *b*
SEASON				
Early	3214	.988 ± .005 *c*	9.632 ± .042 *c*	132.35 ± .39 b
Middle	3629	.951 ± .004 *b*	8.770 ± .035 *b*	134.61 ± .33 c
Late	1510	.889 ± .007 *a*	8.225 ± .052 *a*	129.87 ± .48 d
AGE OF DAM				
2	2178	.844 ± .006 *a*	9.077 ± .048 *c*	116.17 ± .45 *a*
3	1452	.915 ± .007 *b*	9.022 ± .052 *bc*	126.66 ± .49 *b*
4	1131	.951 ± .007 *b*	8.915 ± .059 *abc*	133.18 ± .55 *c*
5	1010	.964 ± .009 *b*	8.701 ± .071 *a*	137.72 ± .66 *d*
6	803	.981 ± .009 *b*	8.769 ± .073 *ab*	138.63 ± .68 *d*
7-8	1117	.972 ± .007 *b*	8.764 ± .058 *ab*	137.31 ± .54 *d*
9+	663	.971 ± .009 *b*	8.880 ± .072 *abc*	136.26 ± .67 *d*
AGE CLASS				
1	1397	.826 ± .006 *a*	12.429 ± .050 *g*	89.75 ± .47 *a*
2	1033	.874 ± .008 *b*	10.698 ± .063 *f*	104.70 ± .58 *b*
3	1485	.980 ± .006 *d*	9.800 ± .051 *e*	120.41 ± .48 *c*
4	1191	1.030 ± .008 *e*	8.906 ± .061 *d*	133.32 ± .57 *d*
5	1263	1.008 ± .009 *e*	7.721 ± .067 *c*	146.74 ± .63 *e*
6	1244	.981 ± .008 *d*	6.816 ± .060 *b*	159.80 ± .55 *f*
7	740	.900 ± .009 *c*	5.759 ± .075 *a*	171.22 ± .69 *g*
TOTAL	8535	.942 ± .003	8.876 ± .025	132.27 ± .23

[1] Means within an effect followed by different letters are significantly different ($p<.05$)

categories.

5.3.1 Effect of breeding population

The analysis of the average weights (Table 5.2), shows that SY was the heaviest with an average weight of 139.71 kg. This was significantly higher than that of XB which weighed 136.74 kg. The XB was in turn significantly heavier than HE whose average weight was 120.37 kg. The same sequence of significant differences was observed in the analyses of ADG and RGR. That is SY had the highest mean ADG and RGR followed by XB and then HE. These results show that not only did the heavier breeds (SY and XB) gain more weight per unit time as measured by ADG, but also in terms of accelerated growth rates, the heavier breeds exhibited better performance as measured by the relative increment of tissue deposition.

5.3.2 Sex of calf

Males were significantly heavier and had higher ADG than females. However there was no difference in RGR between the sexes. This means that despite the higher absolute growth rates shown by the males, they were not more efficient than the females in term of percentage increment of body weight over the same period.

5.3.3 Season

At the same average age of approximately 107 days, the early born calves were significantly lighter than the mid season calves by about 2.26 kg while the mid season calves were on the average heavier than the late born calves by [illegible] 4.74 kg. ADG and RGR in the early and mid season [illegible] did not show the same trend as that in the AVGWT. The mid season calves (with higher average weights than the early season calves) actually recorded an overall lower ADG and RGR than the early season calves. The reason for this apparent discrepancy can be realized from Fig 5.2 where the relationships between ADG and ages of the calves for the three seasons of birth have been depicted. The sudden drop in ADG in the mid season calves contributed greatly to the lowering of the overall mean ADG and RGR of this group. Fig 5.2 is further discussed under season by age class interactions.

5.3.4 Age of dam

Significant differences were noted for AVGWT which was observed to increase in calves from two year old dams through six year old dams with a tendency for AVGWT to decline thereafter. Even though the average weights analyzed do not represent a weight recording at a particular age, AVGWT is envisaged as the weight at the average age of approximately 107 days.

It is a common observation that the weights of calves increase with age of dam, i.e. calves from two year old dams are smaller than calves from mature (five or six year old) dams (Minyard and Dinkel, 1965; Jeffery and Berg, 1971; Cardellino and Frahm, 1971; Schaeffer and Wilton, 1974a; Barlow *et al*. 1978). Results from this study therefore are in agreement with those reported in the literature.

Except for a significant difference in ADG between calves from two year old dams versus all other age of dam categories, no other comparisons showed significant differences. Nonetheless, there were observable increases in ADG in calves from two year old dams to a peak in calves from six year old dams before a decline was noticed. There did not appear to be any noticeable pattern in which the age of the dam influenced RGR.

5.3.5 Age class

Older calves were necessarily heavier and had a lower RGR. However, ADG was seen to increase from younger ages to a peak around 107 days before declining in higher age levels. From Table 5.1 both breed and age class interaction and season by age class interaction were significant for ADG and RGR. In addition breed by season interaction was significant ($p<.05$) for ADG. No other interaction was significant. In Table 5.2 it can be seen that ADG progressively declined from early born calves through late born calves. The least squares means for the breeds within populations were 0.90, 0.84 and 0.78 kg/day for early, mid-season and the late born calves respectively in the HE population. The corresponding values for the SY population were 1.06, 1.02 and 0.98 kg/day whereas in the XB population, the means were 1.00, 1.00 and 0.91 kg/day for the early, mid-season and late born calves respectively.

The significant interactions arose from the fact that while the rate of decline was linear in HE and SY, mid-season calves of XB appeared to perform equally as well as their early born counterparts. This may have been due to a sufficient persistency of milk production in XB to have avoided adverse effects on their calves' growth rate. Butson and Berg (1984) have reported Hereford milk production to exhibit the greatest decline over 87 days when compared to the Beef Synthetic (SY), Dairy Beef (50% beef and 50% dairy), and Dairy Synthetic (aproximately 67% dairy and 33% beef).

The level of dairy breeding in the Beef Crossbreds in this study was estimated to be 10.3%. The general trend based on published reports is that average daily milk yield increased as the level of dairy breeding increased (Notter, 1976; and Gaskins and Anderson, 1980). The decline in growth rate of late born calves could be explained by deterioration of the nutritional value of forage on the range resulting in reduced milk yields in the dams. Hence the late born calves of XB were in no special advantageous position compared to SY and HE contemporary calves.

5.3.6 Breed by age class interaction in ADG

It can be seen from Fig. 5.1 that in all the populations, ADG increased to a peak between 100 and 120 days of age and then declined thereafter. Individual regresssion equations fitted to the pattern of ADG changes along with the R^2 value of each equation are presented in Table 5.3. The equations indicated significant linear and quadratic components of ADG on age of calf at weaning. By taking the first derivative of each equation and setting it to zero, the average ages at which maximum ADG occurred were derived to be 119.3, 112.5 and 110.8 days for HE, SY and XB respectively with an overall peak average age of 113.4 days for the pooled data. The estimated maximum ADG values were derived to be 0.940, 1.071 and 1.036 kg/day for HE, SY and XB respectively. The combined derived maximum ADG for all three breeds was 1.011 kg/day from the pooled data. The only available report in the literature depicting a similar kind of study was by Ridler *et al.* (1963) who indicated that the rate of gain in calves from birth to three or four months of age in Shorthorn and Friesians followed a pattern similar to that described in this study.

If all three populations reached the same maximum ADG but at different ages, then the population which would have attained its maximum ADG earlier would be expected to be more productive in terms of total liveweight at any given age. If that is true, then SY is a superior population to either XB or HE in view of the fact that SY attained its

Table 5.3 Regression equations for significant interaction terms in the analysis of AVGWT, ADG and RGR

PARAMETER		R^2 VALUE Linear	R^2 VALUE Quadratic[1]
AVGWT			
	BREED x AGE OF DAM(a)		
HE	$80.762 + 14.299a - 1.080a^2$	.52	.97
SY	$101.726 + 12.596a - .848a^2$	.74	.97
XB	$102.944 + 12.372a - .949a^2$	.45	.95
	SEASON x AGE OF DAM(a)		
Early Season	$91.630 + 14.312a - 1.047a^2$	.59	.97
Mid Season	$96.907 + 11.415a - .966a^2$	.56	.97
Late Season	$96.991 + 11.458a - .829a^2$	.55	.87
Pooled age of Dam	$95.138 + 13.083a - .959a^2$	.59	.97
ADG			
	BREED x AGE OF CALF(a)		
HE	$-0.0562 + 0.0167a - 0.00007a^2$	.28	.91
SY	$-0.0195 + 0.0225a - 0.00010a^2$	.33	.94
XB	$-0.0440 + 0.0195a - 0.000088a^2$	.09	.87
	SEASON x AGE OF CALF(a)		
Early Season	$-0.3375 + 0.0223a - 0.000086a^2$	.73	.94
Mid Season	$-0.5449 + 0.0252a - 0.000114a^2$	.04	.71
Late Season	$-0.2902 - 0.00007a + 0.01305a^2$	.15	.59
Pooled age of dam	$-0.0949 + 0.0195a - 0.000086a^2$	.23	.93
RGR			
	BREED x AGE OF CALF(a)		
HE	$1.7276 - 0.009036a + 8.77\times10a^2$	.99	.99
SY	$1.8464 - 0.009919a + 1.00\times10a^2$	.90	1.00
XB	$1.9303 - 0.0118a + 0.000000a^2$	.99	.99
	SEASON x AGE OF CALF(a)		
Early Season	$1.8623 - 0.009057a + 6.05\times10^{-}$[illegible]$a^2$	.99	.99
Mid Season	$1.9500 - 0.01234a + 0.00002a^2$	.94	.95
Late Season	$1.6158 - 0.0774a + 2.62\times10^{-}$[illegible]$a^2$	.98	.98
Pooled age of dam	$1.9421 - 0.0124a + 2.19\times10a^2$	.98	.99

[1] values indicated are for both linear and quadratic effects in equation

maximum ADG on the average 6.8 and 8.5 days earlier than XB and HE respectively. Furthermore since SY did in fact attain a higher maximum ADG than the other two populations, it is a clear demonstration of the superiority of this population over XB and HE.

The superiority of SY lay largely in its ability to maintain superior ADG. It can be observed from Fig 5.1 that during the very early stages XB did in fact exhibit slightly higher ADG than SY though the differences were not significant. On the other hand the XB population which started with a birth weight advantage would have been expected to maintain higher ADG than SY. However, the SY calves eventually outperformed the XB calves. This may be explained in part by a superior growth potential in SY compared to XB.

5.3.7 Season by age class interaction in ADG

Fig. 5.2 depicts the interactions of season of calving and age class. Except for the early stage of preweaning, growth rate of early born and mid season calves appeared to be higher than that of the late born calves. There was a sharp decline in gain among the mid season and late born calves after they reached 135 and 105 days of age respectively. This was probably due to the nutritional value of pasture on the range generally deteriorating in late fall. Therefore at similar ages, the dams of the early born calves enjoyed better pasture conditions and could therefore

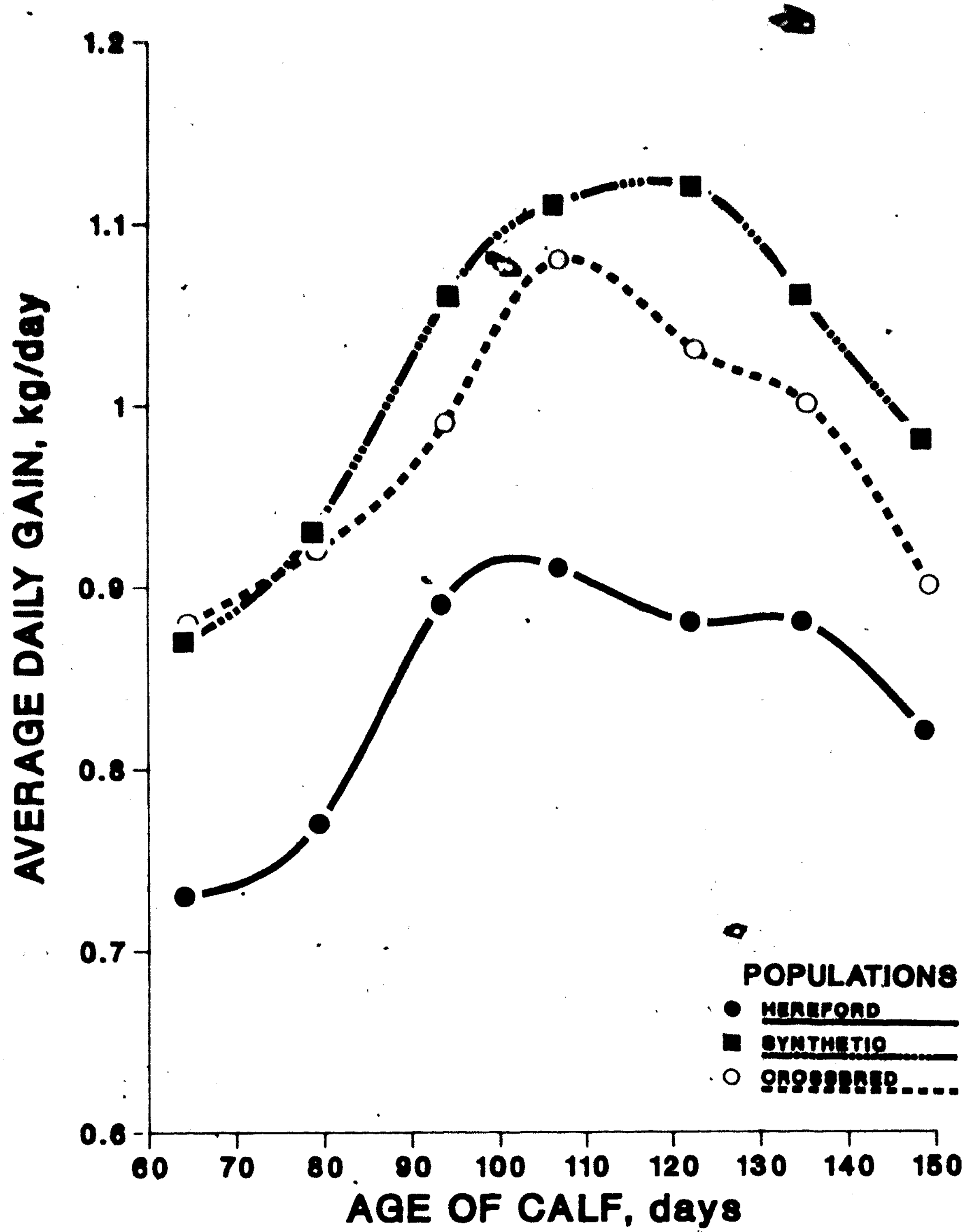

Fig. 5.1. Relationship between Age of Calf and Average Daily Gain for Populations

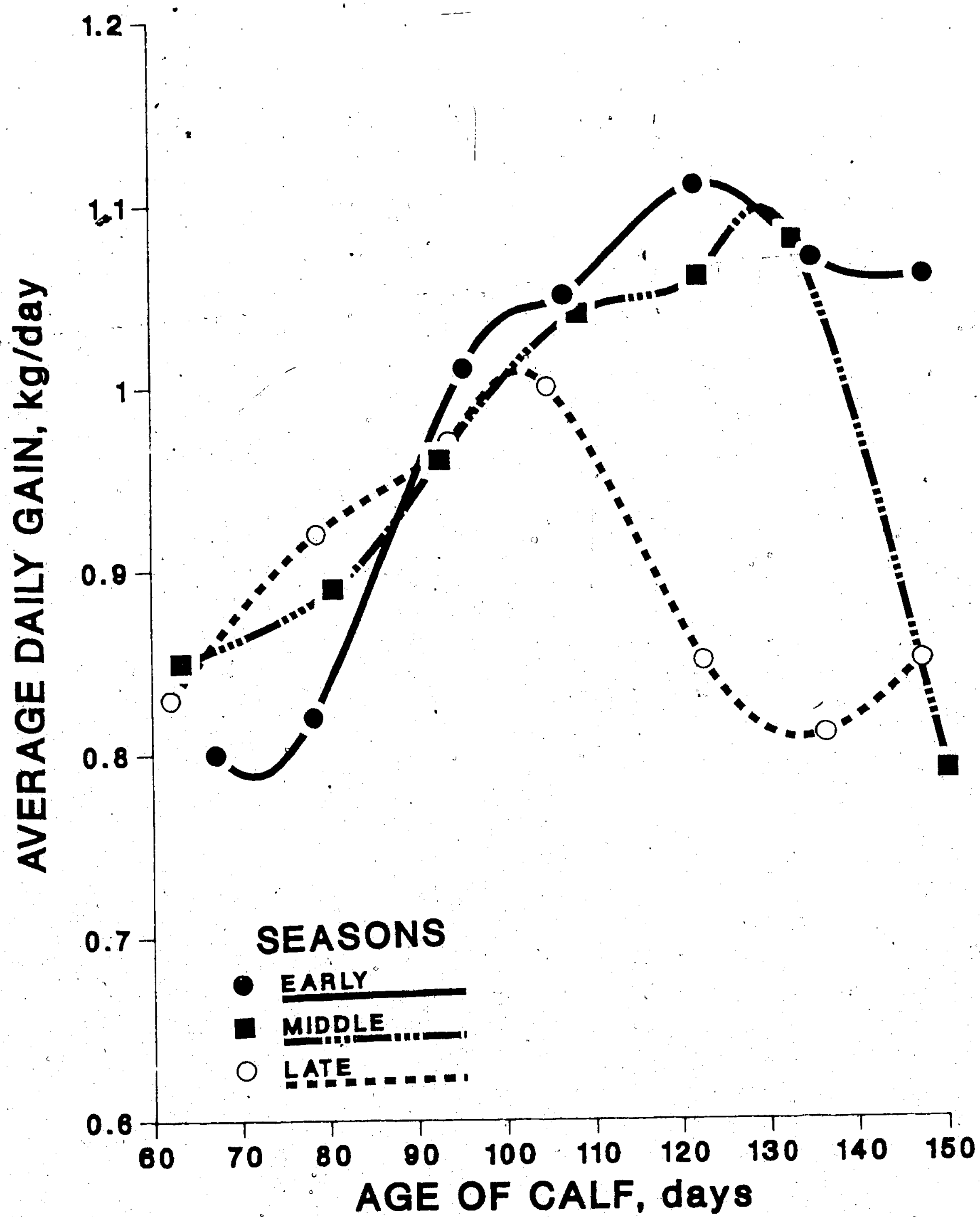

Fig. 5.2. Relationship between Age of Calf and Average Daily Gain for Seasons

be expected to better provide milk for their calves' requirements.

5.3.8 Breed by age class interaction in RGR

The preweaning relative growth rates of the calves in the three populations are illustrated in Fig. 5.3. The SY calves were generally superior in relative growth rate compared with the other two breed groups. The XB calves gained slightly faster than the HE calves, but as the calves grew older the difference disappeared and then reversed in favour of HE calves.

5.3.9 Season by age class interaction in RGR

The preweaning relative growth rates of the calves born early, mid season and late during the calving season are depicted in Fig. 5.4. Calves born early maintained a higher RGR compared with those born later. The relationship between RGR and age was linear in all three breed groups.

5.4 SUMMARY AND CONCLUSIONS

The analysis of bodyweights and preweaning patterns of growth has served to reach the following conclusions:
The influence of date of calving on preweaning gain supports the widely held belief that early born calves do better than late born calves in a given season (Seifert *et al*. 1974; Winks *et al*. 1978; Low and Wood, 1979). That is, calves born early in the calving season grew faster and achieved

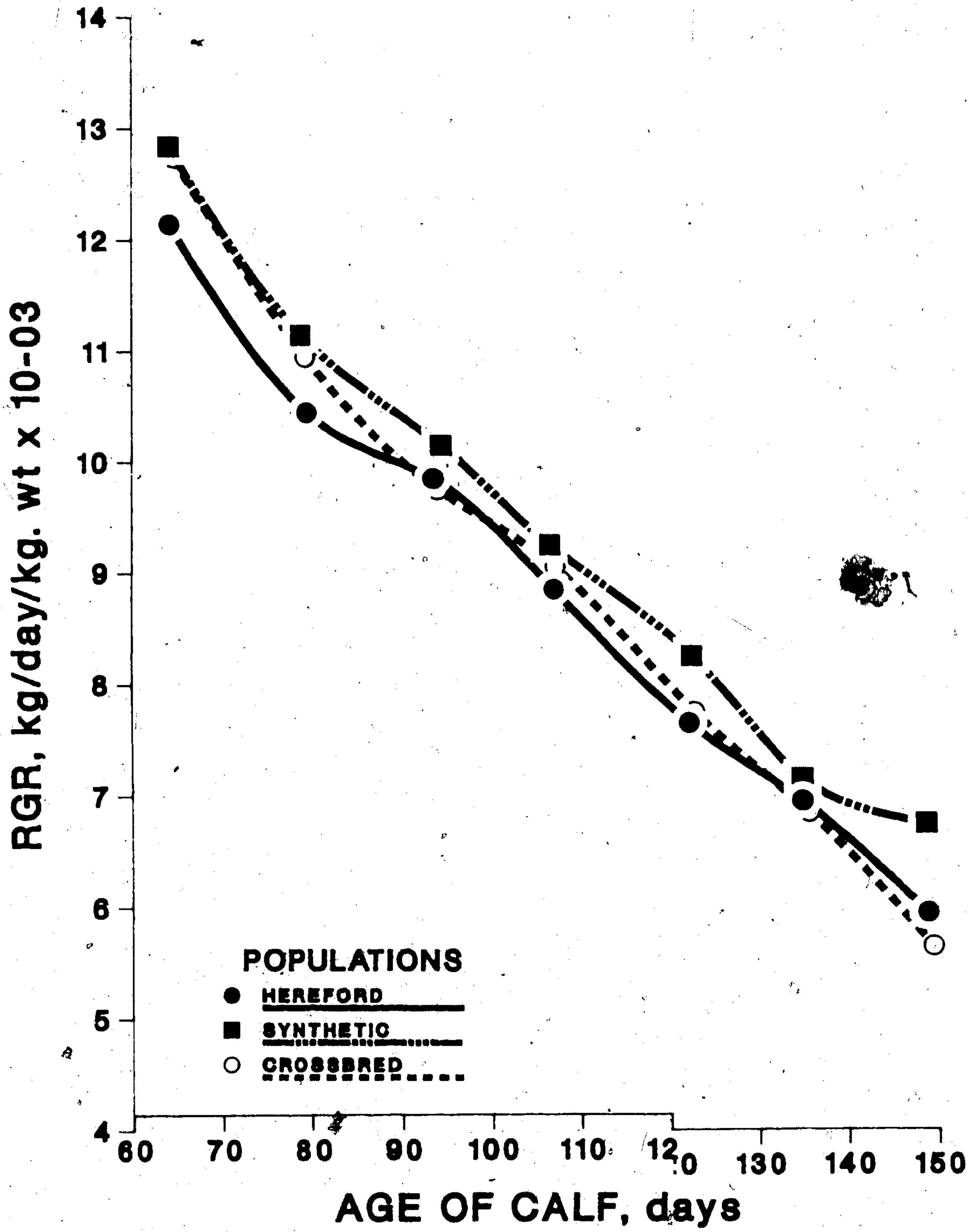

Fig. 5.3. Relationship between Age of Calf and Relative Growth Rate for Populations

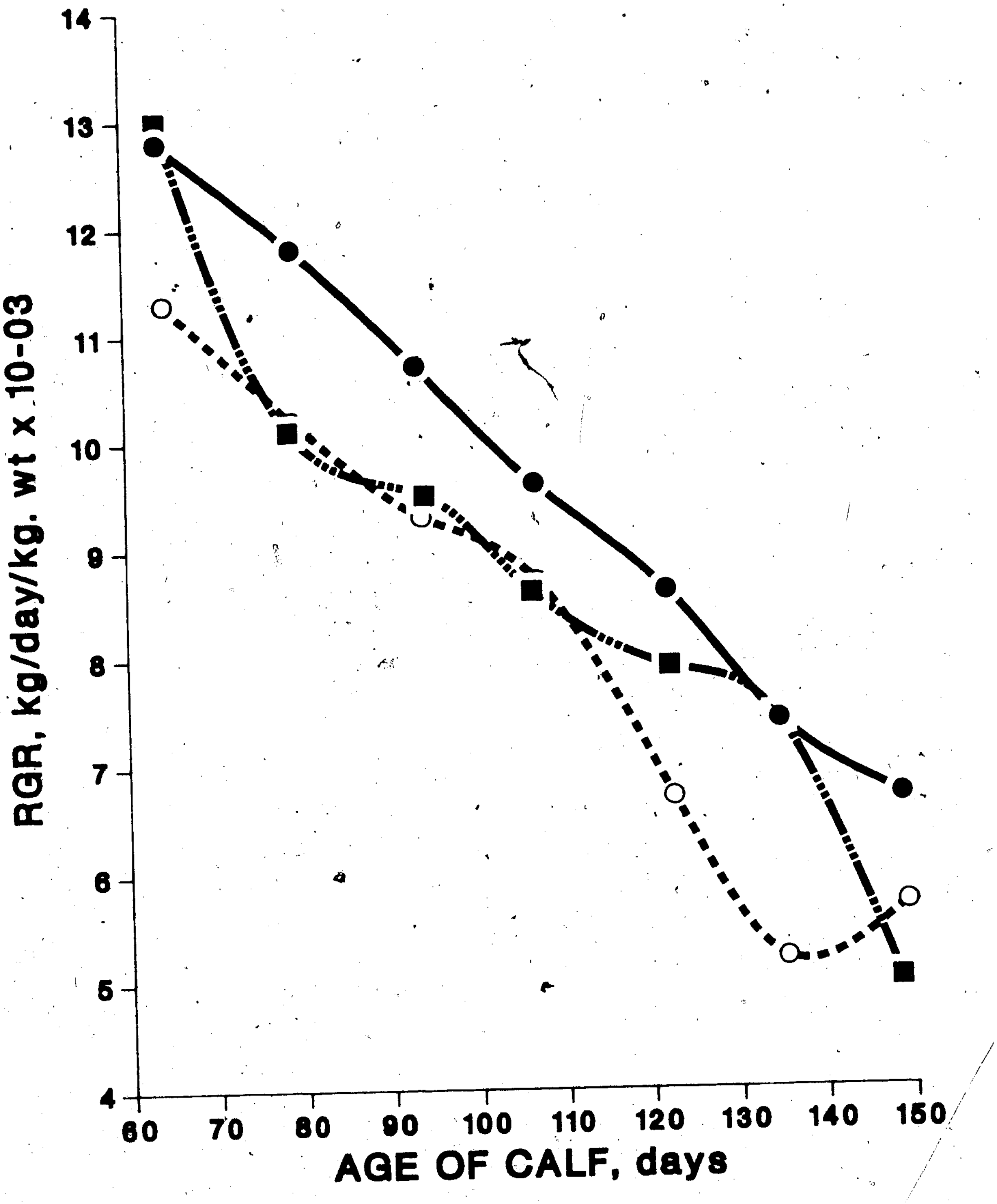

Fig 5.4. Relationship between Age of Calf and Relative Growth Rate for Seasons

steadier gains than calves born later in the calving season. The effect of season would however appear to parallel forage conditions and indeed this may indicate that forage conditions are of greater importance in controlling growth rates than are the climatic influences associated with seasons (Low and Wood, 1979).

Perhaps the early born calves were more advanced and better able to utilize the improved milk yields from their dams which coincided with the flush of pasture growth with the break in the season. Deterioration of pasture quality in the fall and early winter period before weaning would limit milk yield during that period in range beef cows. Older calves would therefore be better equipped to supplement their diets directly from available pasture. The pronounced decline in the weight gains of calves in early fall under range conditions suggested the need for supplementation at this stage in all three populations. This would be particularly important in the late born calves which were young at the time of weaning. However, there is need to determine the level of supplementation and the profitability of it.

Absolute differences between the sexes were small though these differences were statistically significant with the males showing greater gains than the females. However there was no difference in relative growth rate between the sexes thus indicating no tendency of one sex to mature earlier than the other.

Smith *et al.* (1976a) stated that the alteration of growth patterns to increase early growth and efficiency, more than subsequent size, tends to improve the efficiency of a beef production system. In an ensuing study Smith *et al.* (1976b) indicated declining correlations between weight and degree of maturity as age increased. Negative genetic correlations of age-constant weights with degree of maturity at puberty suggested that heifers with high absolute growth rates (or ADG) tended to reach maturity sooner but they do so at lighter weights than heifers growing to the same mature weight at a slower rate. Smith *et al.* (1976b) also indicated that animals which reach heavy mature weights tend to grow slower and because of their slow growth rates, they are relatively smaller at earlier ages.

Absolute maturing rate (AMR) has been shown to be equal to RGR (Fitzhugh and Taylor, 1971) and that RGR decreases with increasing approach to maturity, when evaluated over similar age intervals. Brown *et al.* (1972) have reported that it is only when two animals are growing to similar mature weights can relative growth rate (RGR) be interpreted as a measure of differences in growth rate. Otherwise RGR measures differences in growth rate relative to mature size. It has also been established by Smith *et al.* (1976b) that correlations between preweaning gains and mature weight are negative, thereby indicating that animals growing most rapidly during the preweaning period would be expected to grow more slowly at later stages. There is evidence however

(Arthur, 1982) that SY maintain their superior liveweights thoughout their lifetime. One should however be aware of the phenomenon of compensatory growth whereby individual animals which express low growth rates at one time may achieve higher liveweight gains than others which had a high growth rate throughout life. This is particulary important when breed x season interactions are significant as they were in this study.

Fitzhugh and Taylor (1971) and Smith *et al.* (1976b) have noted that in general, selection for increased growth or maturing rate would tend to increase growth in the interval of selection more than it would increase mature weight. Also such selection would tend to decrease growth and maturing rates in subsequent age intervals. Fitzhugh and Taylor (1971) also found that absolute and relative growth rates in the same age interval were genetically highly correlated. However the genetic correlations with weight were much lower for RGR than for AGR. Hence an increase in AGR, with little concomittant increase in weight to be maintained, could be accomplished by selection for RGR. Preweaning RGR is therefore envisaged as an effective selection criterion for altering the maturing patterns in beef cattle.

6. FACTORS AFFECTING THE BREEDING CONDITION OF DAMS

6.1 INTRODUCTION

The effect of factors such as age of dam, weight of the dam, sex of calf, year of birth and breed effects on calf birth weight have been studied extensively. However, factors influencing the birth date of the calf have received little attention. In cattle operations, profitability is largely determined by the cow's ability to conceive within a limited breeding season so as to enable her to produce a calf each year. Even though calves born earlier in a calving season are often lighter at birth, they are usually heavier at weaning because they are older than those born later in the calving season. Moreover if a cow calves very late during the calving season, she runs a greater risk of being culled from the breeding herd than the early calving cow. This is because the late calving dam may not have adequate time to return to an appropriate breeding condition, thereby failing to produce an offspring.

Logically, clues to the potential breeding condition of the cows at the time they are introduced to the sires in pasture mating are entwined in and delimited by both the prevailing environmental circumstances and the immediate reproductive or physiological status of the cow. Brown *et al.* (1973) remarked that visual appraisal of the cow at the time of breeding may be too subjective and categorical. Objective definitions of the differences in body condition are therefore necessary. However the problem becomes that of defining the most useful parameters to measure during the calving interval to enable objective definition of breeding condition score.

Weight and reference time measures on both the dam and the calf can be identified as variables exerting an influence on the breeding condition of the dam. Although these variables are related, their attendant multicollinearity can be handled by the technique of principal components analysis which reduces the dimensionality in the variables' structure. Thus a different angle of viewing the original data may disclose the nature of their variation and hence aid in defining objective components of the breeding condition of the dam. Moreover, when the defined variables are biologically related such as in this study, the likelihood of estimating principal components with biological significance is high.

Hitherto, principal components analysis in livestock research has mainly been employed in quantifying breed differences in physique and size. Of late however, the technique has found useful application in other areas of livestock research; for example, recently it has been used by Young *et al.* (1977) as a means of evaluating the relationship of prebreeding traits with reproductive traits in swine.

6.1.1 Objectives of the study

The purpose of this study was to employ principal components analysis as a means of evaluating the relationships of some defined prebreeding variables with some reproductive traits of the dam. This was to be achieved by combining weight, time and production variables of the dam into indexes for defining and/or contrasting productivity and breeding condition of the dam.

6.2 MATERIALS AND METHODS

The source of the data is the University of Alberta cattle ranch, Kinsella. Twelve variables were defined for the principal component analysis (Table 6.1). These variables were mainly weight and weight changes of the dam at different periods of the calving interval. Calving date and time of introduction of the dams to the sires were also considered. In addition to these, birth weight and weaning weight of the calf, age of the calf at weaning and preweaning growth rate of the calf were considered. In defining these variables, sire differences were not considered important because the main purpose of the study was to investigate the relationship between cow and calf variables.

6.2.1 Statistical procedure

Principal components analysis (PCA) with varimax rotation as outlined by Kim (1975) was performed on the correlation matrix of the variables. The analysis was carried out separately for each of the three populations and then on the pooled data of all three populations. The number of components to retain in the analysis was based on the 'eigenvalue 1.0 criterion' whereby only principal components with eigenvalues exceeding unity were considered significant (Kaiser, 1959). The rationale was that principal components being a measure of common variance should account for more variance than any single variable in the standardized score space.

6.3 RESULTS AND DISCUSSION

A listing of the defined variables, their means and standard errors is shown in Table 6.1. The correlations between the variables in each of the different populations are also shown in Appendix Tables 9, 10, 11 and 12 for the HE, SY and XB populations and for the Pooled Data respectively.

Four principal components were extracted in the analyses of the Hereford data while the analyses of the Beef Synthetic, Beef Crossbred and the Pooled Data, yielded five principal components in each analysis according to the set criterion of eigenvalue greater than one. The coefficients of the varimax rotated factor matrix, which are the correlation coefficients between each principal component and the original variable, are presented in Tables 6.2, 6.3, 6.4 and 6.5. The transformation matrices for the varimax

Table 6.1 **Means and standard deviations of variables involved in the principal components analysis**

VARIABLES	BREEDING POPULATIONS			
	HE (N = 251) MEAN ± S.E.	SY (N = 467) MEAN ± S.E.	XB (N = 157) MEAN ± S.E.	POOLED (N = 875) MEAN ± S.E.
DATE1 (previous calving date)[1]	117.01 ± 1.08	117.31 ± 0.70	122.59 ± 1.24	118.17 ± 0.53
AGE1 (age of the dam at breeding, Years)	5.56 ± 0.09	5.20 ± 0.11	6.50 ± 0.18	5.54 ± 0.07
DAMWTB (wt. of dam at breeding, kg)	445.15 ± 3.46	452.78 ± 2.11	461.67 ± 3.65	452.19 ± 1.60
CW1 (dam wt. gain; calving to breeding, kg)	14.35 ± 2.86	14.67 ± 1.88	16.90 ± 3.49	14.96 ± 1.40
DADG1 (pre-breeding rate of gain in dam, kg/day)	0.27 ± 0.06	0.29 ± 0.06	0.37 ± 0.10	0.30 ± 0.04
DADG2 (rate of dam gain, weaning to calving, kg/day)	-0.27 ± 0.02	-0.26 ± 0.02	-0.24 ± 0.03	-0.26 ± 0.01
DADG5 (breeding-weaning rate of gain in dam, kg/day)	0.42 ± 0.02	0.45 ± 0.02	0.37 ± 0.03	0.43 ± 0.01
BRWT1 (birth weight of previous calf, kg)	34.84 ± 0.28	37.05 ± 0.23	38.69 ± 0.37	36.71 ± 0.16
WNWT1 (weaning weight of previous calf, kg)	165.83 ± 1.82	198.36 ± 1.41	192.05 ± 2.41	187.90 ± 1.10
CLFDG1 (preweaning growth rate; previous calf, kg/day)	0.80 ± 0.01	0.99 ± 0.01	0.97 ± 0.01	0.93 ± 0.01
DPREG (breeding-calving interval, days)	309.87 ± 1.15	308.81 ± 0.79	316.19 ± 1.38	310.44 ± 0.60
BRWT2 (birth weight of next calf, kg)	35.64 ± 0.28	38.45 ± 0.23	39.43 ± 0.38	37.82 ± 0.19

[1] day 1 = January 1

rotations are also shown in Appendix Table 13. The resulting communalities of the variables, for each set of analyses, have also been indicated in Tables 6.2, 6.3, 6.4 and 6.5. The communality for each variable indicates the proportion of variance that is accounted for by the principal components that have been extracted.

In interpreting the derived components, the magnitude of the coefficient within a given component determined the importance of the variable. Also in the description of the principal components, effort was directed to seek out a profile of responses as a realistic appraisal of the strength of the vector rather than to assign the names of dominant variables to the vectors.

6.3.1 Principal components analysis of Hereford data

The coefficients of the varimax rotated matrix for the Hereford data are presented in Table 6.2. The first principal component accounted for 23.2% of the variation in the dependency structure and loaded heavily on CW1, DADG1, DADG5 and DAMWTB. This principal component described dams which gained weight in the interval between calving and breeding and which were therefore heavy at the time of breeding. Since the mean DADG2 is negative (Table 6.1) it means that most dams weighed less after calving than at the time of weaning their calves. The negative coefficient observed for DADG2 therefore would seem to describe dams which did not lose much weight or possibly recorded a net

Table 6.2 Results of PCA varimax rotated factor matrix for Hereford population

Principal Component No.		1	2	3	4
Eigenvalue		2.781	2.298	1.957	1.442
% Total variance explained		23.2	19.1	16.3	12.1
Variables	Communality	Eigenvectors			
CW1	0.890	0.941	0.028	-0.049	-0.026
DADG1	0.827	0.898	-0.045	-0.116	0.075
DADG2	0.759	-0.823	0.200	-0.087	0.158
DADG5	0.613	0.173	-0.740	0.176	0.067
DAMWTB	0.809	0.512	0.735	0.055	-0.047
AGE1	0.562	-0.003	0.734	0.122	-0.093
BRWT1	0.624	-0.144	0.532	0.332	0.459
WNWT1	0.971	-0.045	0.100	0.957	-0.206
CLFDG1	0.896	-0.012	-0.050	0.942	0.081
DATE1	0.562	-0.006	-0.059	-0.181	0.754
DPREG	0.445	0.052	-0.270	0.070	0.604
BRWT2	0.488	-0.182	0.393	-0.027	0.548

weight gain during the interval between weaning of the calves and the next calving date. The first principal component can therefore be described as an "index of the weight gain of the dam".

The second principal component loaded heavily on DADG5, DAMWTB, AGE1 and BRWT1 with a moderate loading on BRWT2 and accounted for an additional 19.1% of the total variation. The component indicated that dams which were heavy at the time of breeding were usually old dams which also produced large calves at birth. The high negative coefficient for DADG5 however indicated that there was a tendency for these old dams to lose weight in the interval between breeding and the weaning of their calves. This was because the calves were getting bigger in the interval between breeding and weaning and placing great demands on the cow in terms of milk removed. This period also coincided with early fall when the nutritional value of vegetation on the range usually deteriorated. The component is seen as an index of the age of the dam and may therefore be called the "maturity component".

The third principal component centred on the calf variables, namely; WNWT1 and CLFDG1 but only moderately on BRWT1. This component accounted for an additional 16.3% of the total variation in the covariance structure and can be interpreted as the "weaning index of the calf". The fourth component extracted in the Hereford data loaded heavily on DATE1, DPREG, and BRWT2 with a moderate loading on BRWT1.

This component accounted for an extra 12.1% of the total variation and showed that dams which calved late usually experienced a long interval between breeding and the next calving date. This meant that such dams would probably calve late again in the next calving season. The positive coefficients for BRWT1 and BRWT2 indicated that the late calving dams produced calves with high birth weights. However, because the late born calves would be young at the time of weaning, the slightly negative coefficient observed for WNWT1 indicated that the late born calves were lighter at weaning than the average of the population. The component is therefore an "index of calving date".

6.3.2 Principal components analysis of Beef Synthetic data

The analysis of the Synthetic data produced five principal components which had an eigenvalue greater than 1.0. The total variance explained by these five components was 73.4%. The coefficients of the varimax rotated matrix are presented in Table 6.3 along with the communalities for each of the variables involved in the analysis. Except for BRWT2 and DPREG, moderate to high communalities were attained in all the variables which indicated that most of the variation in each of the variables was accounted for by the five principal components.

The first principal component accounted for 22.7% of the variation in the dependency structure and loaded heavily on CW1, DADG1, DADG2 and DAMWTB and moderately on AGE1. The

Table 6.3 Results of PCA varimax rotated factor matrix for the Beef Synthetic population

Principal Component No.		1	2	3	4	5
Eigenvalue		2.721	2.084	1.648	1.295	1.059
% Total variance explained		22.7	17.3	13.8	10.8	8.8
Variables	Communality	Eigenvectors				
CW1	0.865	0.921	-0.093	-0.019	0.064	-0.053
DADG1	0.701	0.827	-0.072	0.031	0.042	-0.094
WNWT1	0.974	-0.065	0.950	-0.246	-0.024	0.080
CLFDG1	0.823	-0.051	0.900	0.065	0.013	0.070
DATE1	0.662	0.032	-0.243	0.775	0.015	-0.013
DPREG	0.440	0.100	-0.106	0.623	0.129	-0.117
BRWT2	0.368	-0.058	0.203	0.560	-0.072	0.072
BRWT1	0.563	-0.105	0.510	0.517	-0.020	0.155
DADG5	0.922	0.053	0.033	0.066	0.952	-0.085
DADG2	0.874	-0.582	0.084	0.024	-0.715	-0.129
AGE1	0.820	-0.304	0.078	-0.072	0.024	0.846
DAMWTB	0.798	0.524	0.182	0.107	-0.094	0.686

component described dams which gained weight in the immediate post-calving period and were therefore heavy at the time of breeding. The negative coefficients for AGE1 suggested that these were mostly young dams which did not lose much weight during the winter period. The first principal component in the Synthetic data is also seen as an "index of the weight gain of the dam".

While accounting for an additional 17.3% of the variability in the covariance structure, the second principal component centred mainly on the calf variables, namely; WNWT1, CLFDG1 and BRWT1 with only slight loadings on DATE1 and BRWT2. This component showed that calves with heavy weaning weights were slightly older than the average of the population. The component also indicated that calves which were heavy at weaning were also heavy at birth. This is indicated by the high loading of the component on BRWT1. Therefore it can be inferred that the large calves at birth also attained high weaning weights. The component can therefore be described as "weaning index of the calf".

The third principal component accounted for an additional 13.8% of the total variation and loaded heavily on DATE1, DPREG, BRWT2 and BRWT1 with only a slight loading on WNWT1. Specifically this component showed that late born calves were usually heavy at birth but slightly light at weaning. The component showed further that the interval between the breeding season and the next calving date was considerably longer in the late calving dams. This was because these late calving dams could not have become pregnant earlier in the breeding season due to the fact that they would not have had sufficient time to return to appropriate breeding condition at the start of the breeding season. The third principal component is therefore an "index of calving date" of the dams.

The fourth principal component reflected mainly on the post-breeding rate of gain in the dam (DADG2 and DADG5) and explained 10.8% of the total variation. This component showed that dams which had high rate of gain in the interval between breeding and weaning of their calves were low on net weight loss over the winter period. The component is therefore an index of the post-breeding rate of gain of the dam during the winter season. This component can therefore be seen as an "index of the winter body condition of the pregnant dams". The fifth and final component in the Synthetic data explained only 8.8% of the total variation with high loadings on AGE1 and DAMWTB indicating that the old dams were necessarily heavy at the time of breeding. The component is therefore an "index of the age or maturity of the dam".

6.3.3 Principal components analysis of Beef Crossbred data

The analysis of the crossbred data also resulted in the extraction of five principal components which accounted for 74.0% of the total variation in the dependency structure. These five principal components are shown in Table 6.4. The first principal component accounted for 23.0% of the total variation and loaded heavily on CW1, DADG1, DAMWTB and DADG2. Similar to the analyses of the Hereford and the Beef Synthetic data, the component is an "index of the dams' weight gain" and it described cows which gained weight in the immediate post-calving period and were therefore heavy at the time of breeding. The negative coefficient for DADG2 indicated that the winter loss of weight in these dams was minimal.

While accounting for 16.9% of the variation, the second principal component centred heavily on preweaning calf gain and growth rate, namely; WNWT1 and CLFDG1. The component also reflected moderately on DATE1 and BRWT1 and showed that heavy weaning weights usually resulted from two primary reasons. Firstly, the heavy calves at weaning were older than the average of the population as indicated by the negative coefficient for birth date (DATE1). The second reason is that calves which were heavy at weaning were also heavy at birth. However this did not imply that the early born or older calves were necessarily heavy at birth. Similar to the SY population, the second principal component is regarded as a "weaning index of the calf".

About 13.7% of the total variation was explained by the third principal component which loaded heavily on DATE1 and BRWT1 and moderately on BRWT2 and only slightly on DPREG, CLFDG1 and AGE1. The component indicated that calves born late in the calving season were usually heavy at birth. This

Table 6.4 Results of PCA varimax rotated factor matrix for Beef Crossbred population

Principal Component No.		1	2	3	4	5
Eigenvalue		2.757	2.030	1.648	1.322	1.124
% Total variance explained		23.0	16.9	13.7	11.0	9.4
Variables	Communality	Eigenvectors				
CW1	0.910	0.927	-0.093	-0.178	-0.080	-0.061
DADG1	0.797	0.877	-0.022	0.035	-0.146	-0.068
DAMWTB	0.774	0.717	0.061	0.077	0.501	-0.007
WNWT1	0.988	-0.064	0.988	-0.062	0.052	-0.019
CLFDG1	0.881	-0.017	0.900	0.244	0.013	0.101
DATE1	0.753	0.045	-0.330	0.775	-0.148	0.138
BRWT1	0.598	-0.062	0.216	0.727	0.059	-0.120
BRWT2	0.232	-0.065	0.148	0.420	0.015	-0.172
AGE1	0.688	-0.056	0.088	0.206	0.761	0.235
DPREG	0.561	-0.015	0.027	0.342	-0.646	0.162
DADG5	0.869	-0.193	0.117	-0.116	-0.007	0.897
DADG2	0.831	-0.591	0.121	0.116	-0.229	-0.622

is indicated by the positive coefficients for BRWT1 and BRWT2. Also the late calving dams showed a prolonged period between the onset of the breeding season and their next calving date. The third coefficient is thus an "index of calving date".

The fourth component is a maturity component and accounted for an additional 11.0% of the total variation. This component emphasized the age of the dam (AGE1), the weight of the dam at breeding (DAMWTB) and the interval between the breeding season and the next calving date (DPREG). The implication is that the old dams were heavy at the time of breeding and became pregnant earlier in the breeding season. This resulted in a short interval from the weaning of their calves to the next calving date.

The fifth component centred on the post breeding weight changes in the dam (DADG2 and DADG5) and accounted for an additional 9.4% of the total variation. This component showed that dams which gained between the breeding season and the weaning of their calves did not lose much weight over the winter season. This component shows a profile of weight changes in the dam during the winter period. It is therefore a measure of "winter body condition of the dam".

6.3.4 Principal components analysis of Pooled Data

The five components extracted in the analysis of the Pooled Data accounted for 74.8% of the total variation. Relatively high communalities were obtained for all of the variables except BRWT2 and DPREG which yielded moderate communalities (Table 6.5). Since the Beef Synthetic population contributed more observations (N=467) than the Hereford (N=251) and Beef Crossbred (N=157) populations, the results of the Pooled Data analyses were heavily biased toward that of the Beef Synthetic. In fact, the grouping of the variables in defining the principal components in the Beef Synthetic and Pooled Data analyses were the same. To discuss the results of the Pooled Data analysis would be to repeat all that has already been said for the Beef Synthetic population. The difference between the SY and Pooled Data results was that corresponding principal components accounted for different amounts of variations (Table 6.3 vs. Table 6.5).

6.4 SUMMARY AND CONCLUSIONS

This study has employed principal components analysis to explain the variability existing in some cow and calf variables which influence the breeding performance of the dam. Moderate to high communalities were observed in most of the variables indicating that the defined variables were important in contributing to the observed variations in the derived components. The proportions of variance explained by the derived components in the different populations and the Pooled Data ranged from 70.7 to 74.8%. Thus, in all the analyses a few orthogonal variables (principal components) contained over 70% of the information provided by all of the

Table 8.5 Results of PCA varimax rotated factor matrix for the Pooled data

Principal Component No.		1	2	3	4	5
Eigenvalue		2.628	2.223	1.611	1.433	1.081
% Total variance explained		21.9	18.5	13.5	11.9	9.0
Variables	Communality	Eigenvectors				
CW1	0.884	0.945	-0.072	-0.039	0.048	-0.039
DADG1	0.764	0.866	-0.054	0.064	-0.003	-0.087
WNWT1	0.976	0.050	0.965	-0.201	0.002	0.049
CLFDG1	0.856	0.031	0.921	0.079	0.055	0.019
DATE1	0.664	0.023	-0.198	0.790	0.000	0.003
DPREG	0.448	0.048	-0.060	0.631	0.134	-0.161
BRWT2	0.408	-0.047	0.306	0.527	-0.145	0.116
BRWT1	0.593	-0.094	0.481	0.505	-0.111	0.292
DADG5	0.911	-0.074	0.056	0.049	0.941	-0.121
DADG2	0.870	-0.611	0.079	0.081	-0.677	-0.159
AGE1	0.804	-0.192	0.029	-0.038	0.003	0.875
DAMWTB	0.795	0.548	0.153	0.022	-0.123	0.675

original 12 variables. The advantage of parsimony is therefore obvious and would become increasingly so as the number of the original independent variables increased.

The defined components for the different sets of analyses are shown in Figs. 6.1 and 6.2. The study showed that the major components of variation existing in the covariance structure of the variables were similar for the three populations. Dam growth was the most important component in all cases accounting for over 20% of the total variability. The calf weaning index component was observed to precede the calving date component in order of importance in population analysis.

In all four sets of analyses, corresponding components explained similar magnitudes of variation with differences ranging from 0.6% in the fifth component to 2.8% in the third component. A comparison of corresponding components is depicted in Fig. 6.3. Differences among the proportions of variation explained by identically named components were greater than differences among corresponding numerical components. These differences ranged from 1.3% in the dam growth component to as large as 10.3% in the maturity component (Figs. 6.1 and 6.2).

The almost identical sets of principal components extracted in the SY and XB populations emphasized that the two populations were similar in factors underlying their breeding and production characteristics. The close similarity of all three populations was indicated by the

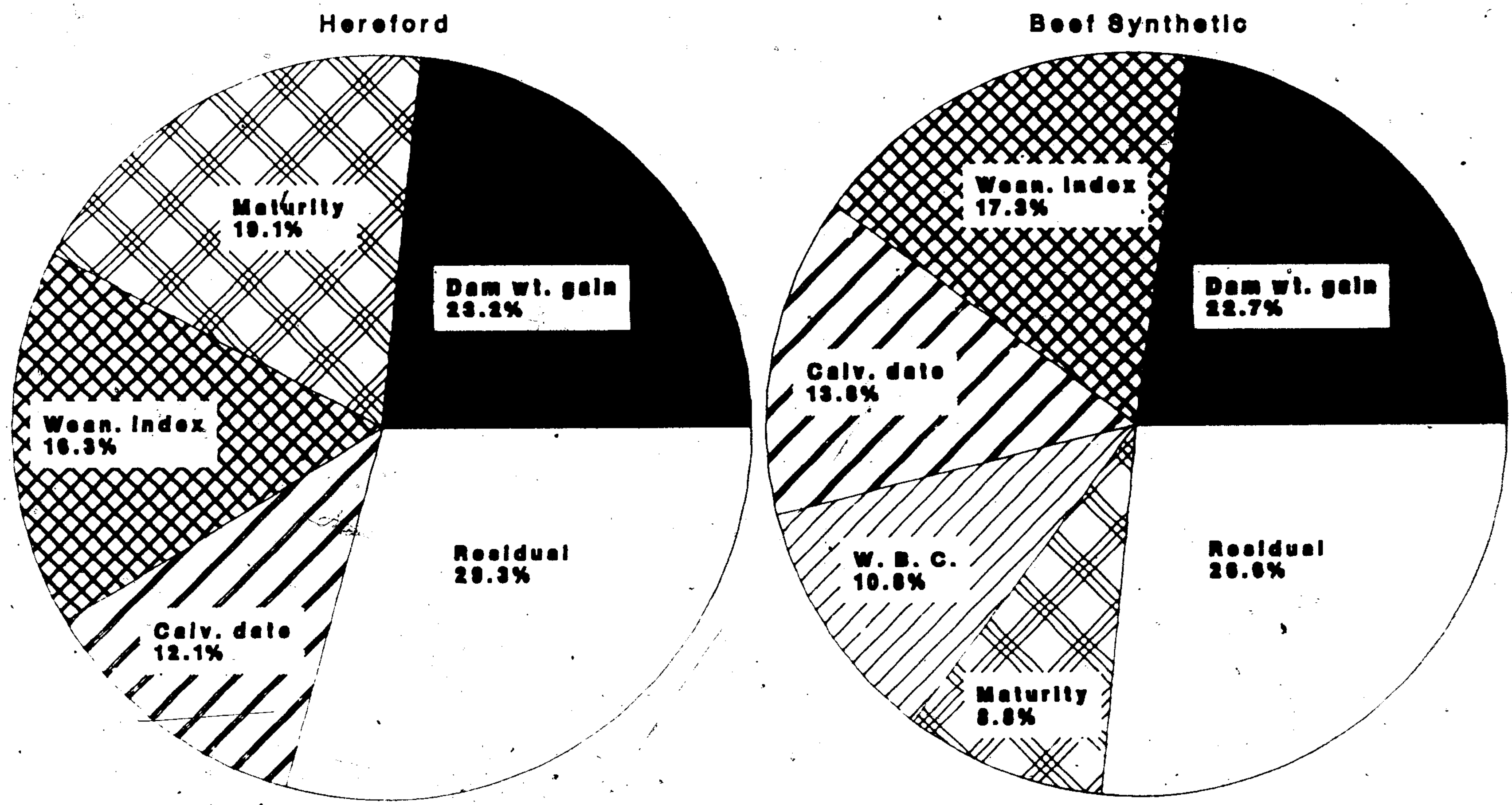

Fig 6.1. Nomenclature of Principal Components indicating the proportions of total variance explained by each in the covariance structure of the Hereford and Beef Synthetic Populations (W.B.C. = winter body condition of the dam)

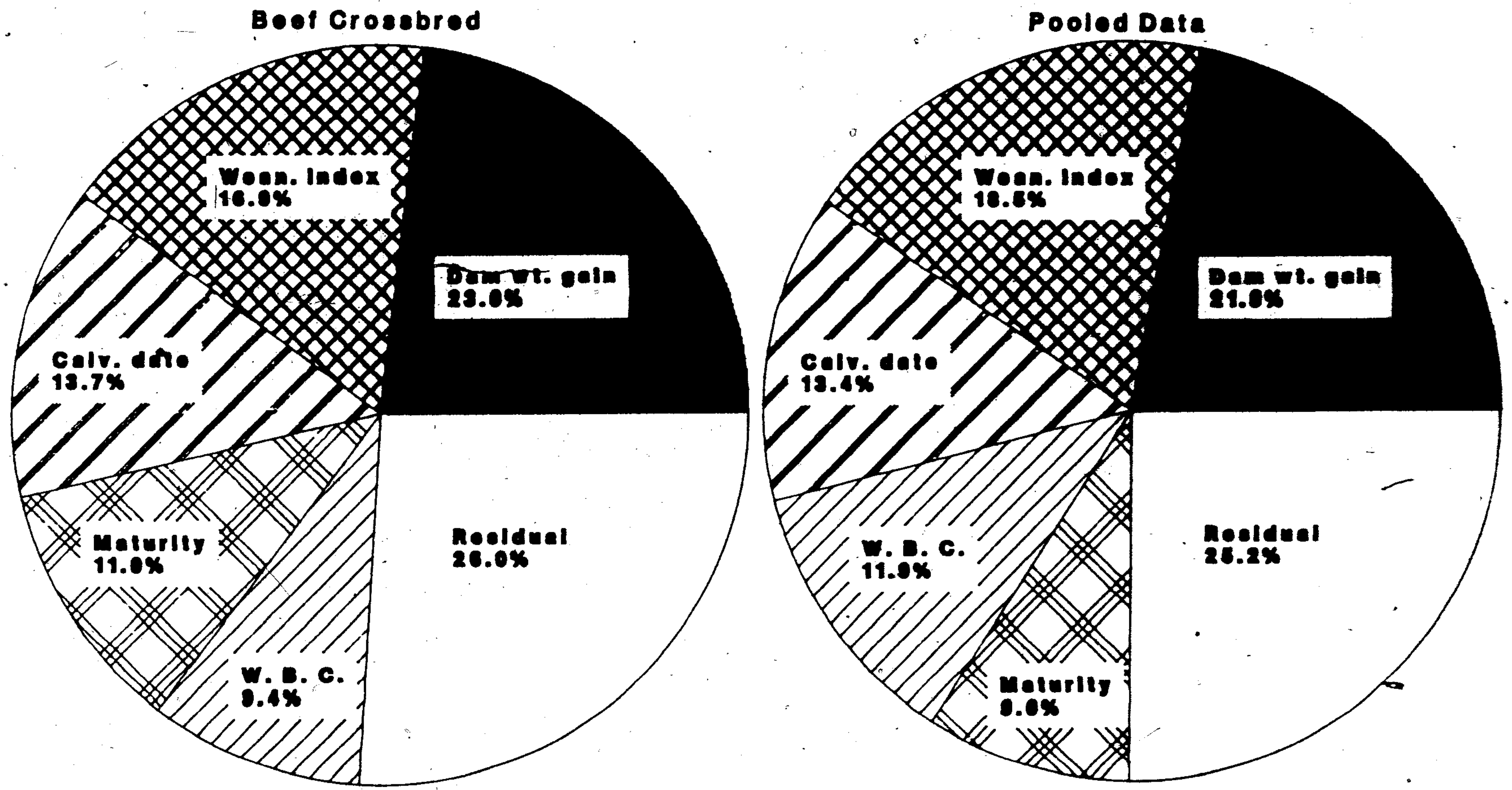

Fig 6.2. Nomenclature of Principal Components indicating the proportions of total variance explained by each in the covariance structure of the Beef Crossbred population and the Pooled Data (W.B.C. = winter body condition of the dam)

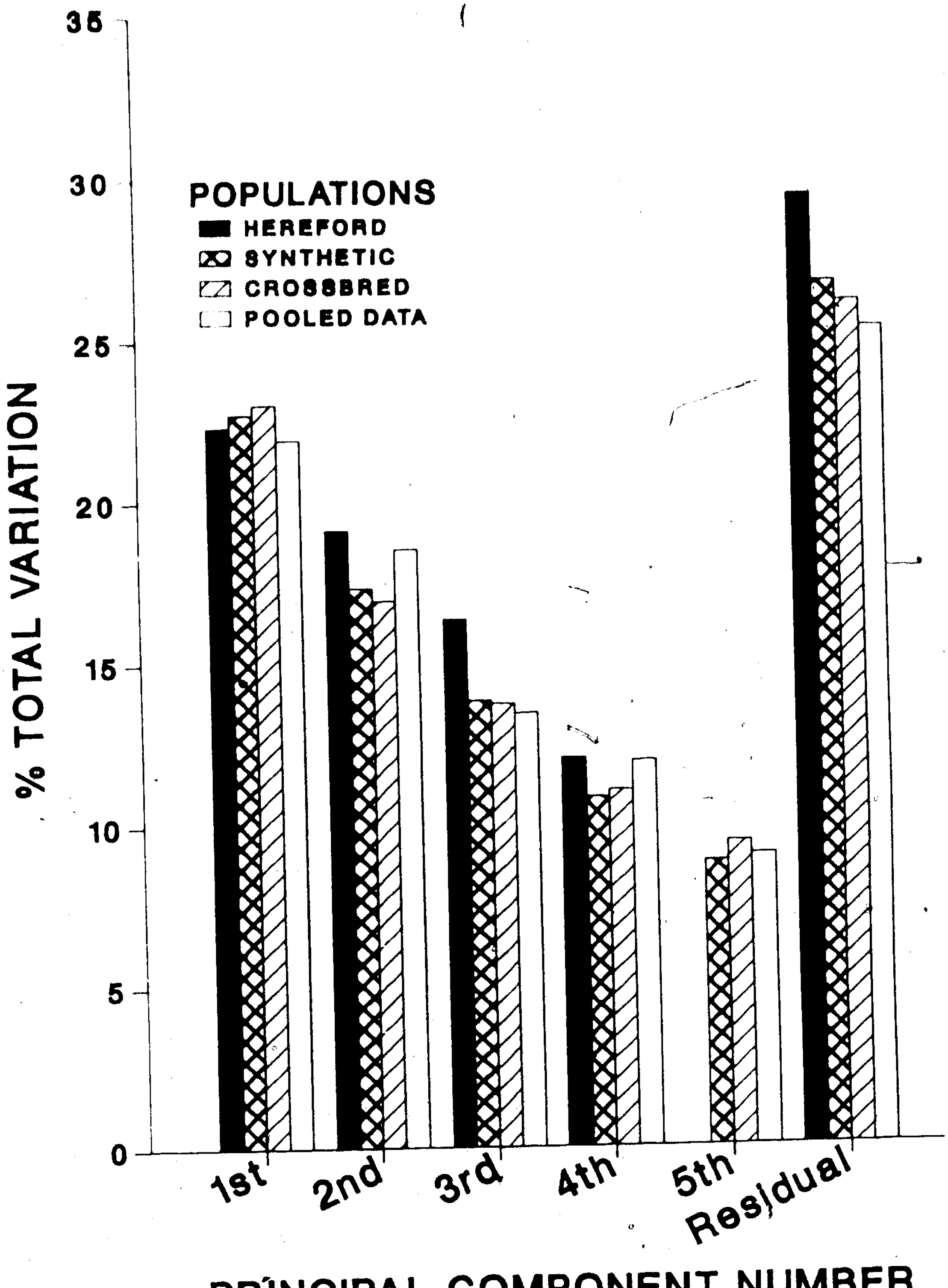

Fig. 6.3. Comparison of Proportions of Total Variance explained by the Ordered Components in each Population.

fact that in terms of the nomenclature of the components, the same set of principal components were extracted except in Hereford where there was no component for winter body condition. Differences were only evidenced in the order of importance in which particular components accounted for variabilities in the covariance structure of the different populations. For instance, age of dam or maturity component was more important in the HE population than in the SY and XB populations.

It is usual for signs and magnitudes of coefficients to differ for corresponding components in different breeds and populations. For instance, Carpenter *et al.* (1978) extracted two principal components from a set of four variables in Charolais and Hereford data and found that while the first principal axes in both breeds were characteristically similar, the second set of axes differed considerably in contrasting ectomorphic and endomorphic body types. Similar results were indicated by Brown *et al.* (1973) who derived five principal axes from an initial set of nine linear body measurements in Angus and Hereford populations and showed that the interpretation of the factors was similar for the initial sets but notably different as the number of components increased.

Two suggestions can be given for these observations. First, the ordering of the nomenclature of the principal components in the different populations means that not only will different factors have various degrees of importance in different populations but also that similar factors will have various influence in different populations. Secondly, the extraction of the same set of components may have stemmed from the fact that all three populations were beef type animals which had been exposed to the same management practices. Perhaps if populations of more divergent biological types such as beef, dairy and dual purpose breeds from different farms and locations had been utilized, the components might be more dissimilar.

Tanner and Burt (1954) have remarked that it is important that cognizance be taken of the fact that factor analysis solutions are summarizing statistics that cannot *a priori* be reified, that is, be equated with a particular physiological or genetical fact. It is probably only when definite explanations have been established and therefore successful reification achieved that factors have their greatest usefulness. Therefore the application of the present study may be enhanced by the use of different biological types from different locations. Results from such investigations could be correlated with the general findings of the present study to formulate definite and conclusive statements.

7. GENERAL SUMMARY AND CONCLUSIONS

Studies were carried out to examine the effects of certain environmental factors influencing preweaning performance and growth patterns of Hereford (HE), Beef Synthetic (SY), and Beef Crossbred (XB) calves. Factor analysis was also carried out on some cow and calf variables to ascertain the major components of variability in the breeding performance of the dam.

The first study examined the effect of age of the dam, sex of the calf, year of calving, age of calf and date of birth on the birth weight, weaning weight and preweaning average daily gain (ADG). The results indicated a trend to heavier birth and weaning weights and higher ADG in calves born in the later years of the breeding programme. However, as fresh genetic material was being introduced via the breeding programme in the course of time, yearly effects were confounded with genetic improvement.

Male calves were heavier at birth and at weaning than female calves. However, a decline in the relative superiority of male calves was noted from birth to weaning in Hereford and the Beef Crossbred populations. There was only a slight increase in male superiority from birth to weaning in the Beef Synthetic population. This observation may be a reflection on the poor milk yields in these beef populations. Therefore, because of their higher growth potential than the females, the male calves may have been disadvantaged from a nutritional point of view. This was further evidenced by a significant breeding group by sex of calf interaction in the analyses of the weaning weights and ADG.

Birth weight increased by 5.5 kg in calves from two year old dams to a peak in calves from five year old dams in the XB population. In the HE and SY populations, increases in birth weights were 5.5 and 6.2 kg respectively from first calves to a peak in calves from six year old dams. Weaning weight and ADG increased in calves from two year old dams to a peak in calves from five year old dams in the HE and XB populations, while peak weaning weights were observed in calves from six year old dams in the SY population. There was some evidence that preweaning performance was beginning to decline in calves from dams which were nine years or older in the HE and XB populations. However, there was no noticeable decline observed in the SY population.

Significant differences (p<.05) were found among the breeding groups in all three traits analysed. The Hereford population was the lightest, both at birth and weaning. At birth, the XB calves weighed heavier than the SY calves, however, superior ADG achieved by the SY calves enabled them to outperform the XB calves in weaning weight. Significant breeding population by year of calving interactions were in part attributed to differential selection pressures that may have been applied to the breeding populations within and between years.

Calf birth weights were positively associated with calving dates; calves born later being heavier. Calf birth weight increased linearly at an average rate of 29 g/day or 2.2 kg over the calving season. The mean calving date of bull calves was significantly ($p<.05$) later than that of heifer calves in the Hereford and Beef Synthetic populations but not in the Beef Crossbred population. Linear effects of age on weaning weight and ADG were significant in all three populations although quadratic effects of age were significant only in the XB population.

The second study was concerned with investigating differences in the preweaning pattern of growth in range beef calves. The calves were classified into three groups according to their birth dates. The three groups were called early, mid-season and late born. The analyses involved the use of the four preweaning weight records of the calves. ADG between two consecutive weights was calculated by dividing the weight gain by the number of days in that period. Corresponding relative growth rates (RGR) were computed by dividing the ADG by the average weight of the calf during the interval concerned. For comparison of growth rates on an equal age basis, the ages of the calves at each weighing were grouped at two week intervals resulting in seven age classes. The least squares means of ADG and RGR were plotted against the mean age of the defined age classes to obtain the pattern of ADG and RGR changes in the preweaning period.

The results showed that ADG increased to a peak between 100 and 120 days and declined thereafter. SY calves maintained higher ADG at all times in the preweaning period, while HE calves exhibited the lowest gains. Quadratic regression equations described the pattern of preweaning ADG. The RGR equations were linear.

Late born calves showed high ADG at very early stages but poorer gains as the calves grew. Both mid-season and late born calves showed decline in ADG in late summer when pasture conditions had generally deteriorated which precluded sustained milk yields in the dams. The absence of this decline in the early born calves was attributed to their advanced age in late fall. The early born calves were perhaps old enough to be able to supplement their diets directly from available pasture rather than relying completely on the dams' milk. The author suggests, therefore that the economics of supplementation of diets of young calves in late summer be investigated.

The third study involved principal component analyses of some 12 cow and calf variables which influence the breeding performance of the dam. The analyses were carried out according to the 'eigenvalue 1.0 criterion' and with varimax rotation for orthogonal contrasts. Four principal components were extracted in the HE data. The analyses of the SY and XB data and the Pooled Data for all three populations resulted in the extraction of five principal components. The derived set of components in each case accounted for over 70% of the variance in the covariance structure in each population.

The derived components were identified as dam weight gain; weaning index of the calf; calving date of the dam; age or maturity of the dam; and winter body condition of the dam. Differences were apparent in the order of the components and hence the importance of each component in each data set. The close similarity of the three populations was however demonstrated by the fact that similar components underlined the variability of the data set in all three populations.

The potential and usefulness of such analyses could be realized when the factor scores coefficient matrix for each factor and variable combination are used in formulating regression equations. This would be achieved by using the exact factor scores for each component to define the objective breeding condition of the dam. As these derivations would be empirical, it would be necessary to correlate such results with subjective condition scores for a check on accuracy.

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APPENDICES

Appendix Table 1. Least square constants of years for birth weight (BRWT), weaning weight (WNWT) and average daily gain (ADG) in the populations

	BREEDING POPULATIONS								
	HEREFORD			BEEF SYNTHETIC			BEEF CROSSBRED		
YEARS	BRWT	WNWT	ADG	BRWT	WNWT	ADG	BRWT	WNWT	ADG
65	-1.82	-29.5	-0.166	-1.49	-30.84	-0.173	-2.63	-34.83	-0.191
66	-1.99	-4.27	-0.019	-1.76	-13.00	-0.066	-0.66	-16.54	-0.095
67	-0.81	-12.37	-0.073	-2.14	-21.06	-0.112	-2.81	-21.05	-0.108
69	-0.95	-3.45	-0.015	-1.43	-4.76	-0.021	1.23	-18.09	-0.113
70	-0.35	2.07	0.013	-2.14	3.23	0.033	2.36	90.09	-0.055
71	-1.97	-3.81	-0.012	-1.16	2.24	0.025	1.22	11.65	0.043
72	0.07	7.32	0.051	0.39	1.38	0.008	-2.54	3.27	0.038
73	1.38	10.41	0.060	0.25	12.04	0.074	1.58	8.67	0.049
74	0.20	-4.18	-0.024	0.41	4.23	0.020	1.58	1.14	-0.003
75	0.48	3.73	0.022	1.50	8.57	0.045	1.04	11.13	0.063
76	0.48	8.56	0.057	-0.48	9.14	0.059	-1.66	12.08	0.089
77	1.52	10.39	0.055	2.46	6.25	0.022	1.85	15.61	0.083
78	0.73	7.14	0.032	2.30	8.46	0.032	-0.89	10.90	0.069
79	4.01	7.92	0.019	3.29	14.12	0.057	2.26	6.97	0.021
MEAN(kg)	34.42	162 75	0.802	36.71	194.70	0.986	37.53	193.48	0.973

Appendix Table 2. Summary of the analyses of variance tables for birth weight (kg) for the Traced Data

	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
SOURCE OF VARIATION	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	16	31.29**	16	183.45**	12	45.55**
Sex of Calf (S)	1	220.65**	1	975.49**	1	361.34**
Age of Dam (A)	4	292.31**	4	571.11**	4	213.54**
YS	16	11.33	16	16.69	12	27.14
SA	4	12.97	4	22.59	4	7.75
Birth Date	1	107.98**	1	218.[illegible]**	1	32.70
Error	337	12.43	826	17.75	131	19.57

* significant at ($p<.05$)

** significant at ($p<.01$)

Appendix Table 3. Summary of the analyses of variance tables for weaning weight (kg) for the Traced Data

SOURCE OF VARIATION	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	16	2154.85**	16	6580.95**	12	2176.00**
Sex of Calf (S)	1	2013.47*	1	32498.47**	1	2517.17*
Age of Dam (A)	4	5743[illegible]	4	20824.25**	4	2055.03**
YS	16	[illegible]3.18	16	378.82	12	352.01
SA	4	631.69	4	452.29	4	269.4[illegible]
Age (Linear)	1	17377.43**	1	37476.90**	1	17342.51**
Age (Quadratic)	1	991.15	1	470.09	1	120.21
Error	336	354.47	825	408.16	130	465.13

* significant at (p<.05)

** significant at (p<.01)

Appendix Table 4. Summary of the analyses of variance tables for average daily gain (kg/day) for the traced data

SOURCE OF VARIATION	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	df	MEAN SQUARES	df	MEAN SQUARES	df	MEAN SQUARES
Years (Y)	16	0.0694**	16	9.1664	12	0.0660**
Sex of Calf (S)	1	0.0387	1	11.8561	1	0.0458
Age of Dam (A)	4	0.1496**	4	6.3104	4	0.0448
YS	16	0.0115**	16	7.9700	12	0.0106
SA	4	0.0177	4	11.9418	4	0.0134
Age (Linear)	1	0.0451	1	7.4222	1	0.0024
Age (Quadratic)	1	0.0376	1	0.0099	1	0.0019
Error	336	0.0129	825	10.5446	130	0.0151

Appendix Table 5. Least squares means and standard errors for birth weight (kg) for the Traced Data

	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	68	30.55 ± 0.48 *a*[1]	174	32.88 ± 0.35 *a*	41	32.27 ± 0.96 *a*
3	70	32.08 ± 0.47 *b*	200	34.87 ± 0.31 *b*	47	36.28 ± 0.97 *b*
4	93	34.02 ± 0.39 *c*	196	35.81 ± 0.31 *c*	51	37.63 ± 0.92 *bc*
5	81	35.10 ± 0.42 *cd*	178	37.22 ± 0.34 *d*	15	41.84 ± 1.44 *d*
6	68	36.34 ± 0.48 *d*	121	38.08 ± 0.40 *e*	12	40.61 ± 1.78 *cd*
SEX OF CALF						
Females	200	32.71 ± 0.30 [illegible]	437	34.60 ± 0.23 *a*	78	35.27 ± 0.78 *a*
Males	180	34.53 ± 0.[illegible]	432	36.95 ± 0.22 *b*	88	40.18 ± 0.84 *b*
TOTAL	380	33.62 ± 0.22	869	35.77 ± 0.16	166	37.73 ± 0.57

[1] Subclass means followed by different letters are significantly different ($p < .05$)

Appendix Table 6. Least squares means and standard errors for weaning weight (kg) for the Traced Data

	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	68	145.02 ± 2.70 *a*[1]	174	170.86 ± 1.81 *a*	41	176.15 ± 5.12 *a*
3	70	155.71 ± 2.56 *b*	184	185.55 ± 1.60 *b*	47	195.15 ± 5.19 *b*
4	93	164.04 ± 2.25 *bc*	196	192.42 ± 1.62 *c*	51	197.31 ± 5.02 *b*
5	81	168.28 ± 2.35 *cd*	178	196.25 ± 1.72 *c*	15	200.89 ± 7.38 *b*
6	84	168.87 ± 2.73 *cd*	121	203.53 ± 2.03 *d*	12	201.62 ± 8.97 *b*
SEX OF CALF						
Females	200	157.58 ± 1.75 *a*	437	182.95 ± 1.27 *a*	78	187.63 ± 4.62 *a*
Males	180	163.12 ± 1.82 *b*	432	196.50 ± 1.21 *b*	88	200.82 ± 4.47 *b*
TOTAL	380	160.39 ± 1.37	869	189.72 ± 0.87	166	194.22 ± 3.55

[1] Subclass means followed by different letters are significantly different ($p < .05$)

Appendix Table 7 **Least squares means and standard errors for average daily gain (A.D.G) kg/day for the Traced Data**

	BREEDING POPULATIONS					
	HEREFORD		BEEF SYNTHETIC		BEEF CROSSBRED	
	N	MEAN ± SE	N	MEAN ± SE	N	MEAN ± SE
AGE OF DAM						
2	60	.713 ± .016 *a*[1]	174	1.398 ± .291 *a*	41	.900 ± .029 *a*
3	70	.772 ± .015 *b*	200	.900 ± .257 *a*	47	1.001 ± .030 *b*
4	93	.812 ± .014 *bc*	196	.925 ± .261 *a*	51	1.003 ± .029 *b*
5	81	.836 ± .014 *cd*	178	.968 ± .276 *a*	15	.998 ± .042 *b*
6	68	.831 ± .017 *cd*	121	.963 ± .326 *a*	12	1.012 ± .051 *b*
SEX OF CALF						
Females	200	.781 ± .011 *a*	437	.901 ± .204 *a*	78	.955 ± .026 *a*
Males	180	.805 ± .011 *a*	432	1.160 ± .194 *a*	88	1.011 ± .025 *a*
TOTAL	380	.793 ± .008	869	1.031 ± .158	166	.983 ± .020

[1] subclass means followed by different letters are significantly different ($p < .05$)

Appendix Table 8. Least squares estimates of covariates in equation of Traced Data analysis

VARIABLE AND EFFECTS	BREEDING POPULATION		
	HEREFORD	BEEF SYNTHETIC	BEEF CROSSBRED
Birth Weight			
DATE OF BIRTH (days)			
Linear (β_1)	0.0408 ± 0.0138**	0.0370 ± 0.0105**	0.0368 ± 0.0285
Weaning Weight			
AGE OF CALF (days)			
Linear (β_1)	0.582 ± 0.083**	0.926 ± 0.050**	0.997 ± 0.163**
Quadratic (β_2)	-0.00331 ± 0.00197	-0.00171 ± 0.00159	-0.00244 ± 0.00481
Average Daily Gain (ADG)			
Linear (β_1)	$9.373 \times 10^{-4} \pm 5.018 \times 10^{-4}$	$68.067 \times 10^{-4} \pm 81.13 \times 10^{-4}$	$3.704 \times 10^{-4} \pm 9.29 \times 10^{-4}$
Quadratic (β_2)	$-2.038 \times 10^{-5} \pm 1.194 \times 10^{-5}$	$-0.786 \times 10^{-5} \pm 25.61 \times 10^{-5}$	$-0.978 \times 10^{-5} \pm 2.734 \times 10^{-5}$

Appendix Table 9. Phenotypic correlations between independent variables for principal components analysis in the Hereford population

	DATE1	AGE1	DAMWTB	CW1	DADG1	DADG5	BRWT1	WNWT1	CLFDG	DPREG	BRWT2
AGE1	-.116										
DAMWTB	-.056	.526									
CW1	-.053	-.048	.430								
DADG1	.040	-.054	.390	.882							
DADG5	-.019	-.358	-.376	.038	.011						
BRWT1	.211	.283	.249	-.163	-.112	-.215					
WNWT1	-.376	.152	.091	-.055	-.120	.016	.258				
CLFDG1	.042	.046	.014	-.042	-.097	-.091	.207	.881			
DPREG	.217	-.036	-.159	.031	.058	.178	-.025	-.065	.070		
BRWT2	.142	.122	.144	-.147	-.103	-.153	.414	-.048	-.061	-.122	
DADG2	.108	.064	-.315	-.676	-.563	-.430	.176	.012	.016	.079	.252

Appendix Table 10. Phenotypic correlations between independent variables for principal components analysis in the Beef Synthetic population

	DATE1	AGE1	DAMWTB	CW1	DADG1	DADG5	BRWT1	WNWT1	CLFDG	DPREG	BRWT2
AGE1	-.089										
DAMWTB	.025	.256									
CW1	.041	-.298	.370								
DADG1	.050	-.190	.227	.684							
DADG5	.026	-.054	-.121	.013	.043						
BRWT1	.198	.124	.166	-.111	-.126	.036					
WNWT1	-.436	.209	.155	-.157	-.123	-.027	.326				
CLFDG1	.010	.188	.175	-.143	-.115	.009	.321	.862			
DPREG	.345	-.061	-.001	.083	.146	.111	.078	-.188	-.014		
BRWT2	.155	.006	.129	-.097	-.025	.037	.287	.050	.090	.114	
DADG2	-.064	.095	-.299	-.572	-.421	-.552	.102	.119	.082	-.078	-.091

Appendix Table 11. Phenotypic correlations between independent variables for principal components analysis in the Beef Crossbred population

	DATE1	AGE1	DAMWTB	CW1	DADG1	DADG5	BRWT1	WNWT1	CLFDG	DPREG	BRWT2
AGE1	.002										
DAMWTB	-.055	.297									
CW1	-.052	-.168	.559								
DADG1	.100	-.079	.456	.771							
DADG5	-.042	.101	-.120	-.212	-.199						
BRWT1	.309	.077	.037	-.177	-.054	-.092					
WNWT1	-.383	.104	.034	-.138	-.100	-.108	.208				
CLFDG1	.060	.180	.022	-.149	-.018	.124	.216	.867			
DPREG	.194	-.117	-.185	-.065	.035	.002	.141	-.034	.041		
BRWT2	.131	-.083	.028	-.127	-.087	-.051	.199	.087	.152	.021	
DADG2	.043	-.155	-.472	-.532	-.355	-.391	.187	.134	.113	.156	.110

Appendix Table 12. Phenotypic correlations between independent variables for principal components analysis in the Pooled data

	DATE1	AGE1	DAMWTB	CW1	DADG1	DADG5	BRWT1	WNWT1	CLFDG	DPREG	BRWT2
AGE1	-.043										
DAMWTB	-.002	.346									
CW1	-.002	-.186	.370								
DADG1	.060	-.123	.303	.737							
DADG5	-.009	-.115	-.196	-.025	-.011						
BRWT1	.237	.170	.190	-.126	-.099	-.051					
WNWT1	-.353	.127	.138	-.111	-.101	.022	.347				
CLFDG1	.041	.112	.126	-.100	-.074	.060	.339	.892			
DPREG	.292	-.025	-.070	.042	.106	.095	.082	-.114	.020		
BRWT2	.161	.029	.140	-.106	-.043	-.023	.353	.144	.182	.110	
DADG2	.009	.032	-.330	-.592	-.433	-.489	.137	.087	.063	.015	.134

Appendix Table 13. Factor transformation matrices generated in the varimax rotations for each set of analyses.

Hereford population

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
FACTOR 1	.967	-.107	-.148	-.177
FACTOR 2	.170	.853	.493	.006
FACTOR 3	.013	-.473	.818	-.328
FACTOR 4	.187	-.193	.258	.928

Beef Synthetic population

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FACTOR 1	-.715	.594	-.094	-.305	.184
FACTOR 2	.557	.696	.116	.235	.370
FACTOR 3	-.178	-.038	.982	.045	.005
FACTOR 4	.329	-.132	.094	-.885	.286
FACTOR 5	.194	.380	.066	-.257	-.865

Beef Crossbred population

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FACTOR 1	-.892	.349	.238	-.141	-.083
FACTOR 2	.277	.861	.063	.383	.178
FACTOR 3	.231	.059	.790	-.296	-.427
FACTOR 4	-.087	-.303	.557	.329	.695
FACTOR 5	.135	.205	-.075	-.798	.545

Pooled data

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5
FACTOR 1	-.765	.565	.101	-.270	.113
FACTOR 2	.565	.702	.118	.084	.409
FACTOR 3	.043	-.214	.956	-.182	.069
FACTOR 4	-.110	.273	.247	.748	-.542
FACTOR 5	-.286	-.260	.011	.573	.723

VITA

NAME: Benjamin Kwadjo Ahunu

PLACE OF BIRTH Jumapo, Ghana.

YEAR OF BIRTH: 1950

POST-SECODARY EDUCATION AND DEGREES:

University of Ghana
Legon, Ghana.
1971-1975 B.Sc. (Hons) Agric.

University of British Columbia
Vancouver, British Columbia, Canada.
1976-1978 M.Sc.

HONOURS AND AWARDS:

Ghana Government Bursary
University of Ghana
1971-1975

Shell (Ghana) Ltd. Cash Prize 1975
(for the best dissertation in graduating class)

May & Baker Prize 1975
(for overall top student in graduating class)

University of Ghana/University of Guelph Exchange Program
(opted for tenure at the University of B.C.)
1976-1978

Graduate Research Assistantship
University of Alberta
1981-1984

RELATED WORK EXPERIENCE

Research Assistant
Agricultural Research Station
University of Ghana.
1975-1976

Lecturer: Animal Breeding and Biometry
University of Ghana
1978-1981

PUBLICATIONS

OPPONG, E.N.W. and AHUNU, B.K. 1976. Haematological parameters of crossbred dairy cattle at the Agricultural Research Station (Nungua). Proceedings of the Ghana Animal Science Symposium. Kumasi.

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