FACTORS AFFECTING REPRODUCTIVE PERFORMANCE OF RANGE-FED BEEF COWS AT ATHI RIVER RANCH, KENYA

by

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University. All sources of information have been specifically acknowledged by reference.

This thesis has been submitted for examination with my approval as University Supervisor.

Dr. A.B. Carles, M.B.E.

October, 1986

DEDICATION

For their continuous encouragement, patience and love, this thesis is dedicated to my wife Edith and my son Eria.

ABSTRACT

A study of breed and environmental factors, both internal and external, affecting calving interval of range-fed beef cattle was conducted at Athi River ranch in Kenya. Breeding females comprised the Boran, the small East African Shorthorn Zebu (EASZ) and their F_1 progeny from Hereford bulls.

Fertility was highly seasonal ($P < 0.005$) and the shortest mean calving intervals were recorded from animals that conceived between November and January followed by the period from May to July. When mating was confined between May and July, fertility became significantly influenced ($P < 0.005$) by the calving month preceeding conception, with heifers being the most affected. Under such conditions animals that calved down during March-April had a higher fertility during the subsequent breeding period. Increased rainfall during the month prior to conception was associated with a highly significant ($P < 0.01$) linear improvement in fertility depending on conception period. Year effects were highly significant ($P < 0.005$).

The target joining weight was around 318 kg. Above the target weight, up to about 410 kg, fertility became a function of the absolute body weight such that heavier cows at joining were more fertile ($P < 0.01$) than lighter ones. There was evidence to suggest that the depressing effect of suckling could dominate influence of body weight unless joining weight

was well above 318 kg. Below the target weight, relatively higher fertility was associated with females that gained weight or suffered less body weight loss during the month prior to conception. Previously dry cows tended to gain weight prior to conception to the detriment of fertility ($P<0.005$). Monitoring of proportionate body weight changes during the month prior to conception was a better method of assessing fertility than weight changes far-removed from conception.

Influence of dry season supplementation was significant but was modified by a number of factors such as age, year and previous parity. There was no significant difference in fertility of cows that were supplemented before calving with energy or energy plus urea. Generally, cows that were supplemented after calving had a higher fertility.

Fertility improved as the dam's age increased from three years onwards but declined after about nine to ten years. Young females were more vulnerable to adverse post-partum nutritional conditions but they benefitted by calving down one month earlier than the older cows.

Effects of weaning period, weaning month,previous parity and weaning year were marginally significant ($P<0.05$).

The mean calving interval of the EASZ was shorter ($P<0.05$) than that of the Borans by only 17 days. However, there was evidence that when mating occurred between November and January or when supplementation was provided, the Boran and Boran crosses had a higher fertility compared to the small zebus and their crosses.

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LIST OF ABBREVIATIONS

cal	= calorie
cm	= centimetre
C.F.	= Crude Fibre
C.P.	= Crude Protein
EASZ	= East African Shorthorn Zebu
g	= gramme
KARI	= Kenya Agricultural Research Institute
kg	= kilogramme
km	= kilometre
m	= metre
mg	= milligramme
SMI1	= soil moisture index during the month before "second" conception
WCP	= weight at "second" conception
WCV	= weight at "earlier" calving
W1ACV	= weight one month after "earlier" calving
W1CP	= weight at one month before "second" conception
W2CP	= weight at two months before "second" conception

CHAPTER I

INTRODUCTION

1.1. BACKGROUND

The National Livestock Development Policy for Kenya (1980) estimated domestic demand for beef to be around 135,000 metric tonnes per year. The projected demand by 1990 was estimated at 228,000 metric tonnes mainly due to population growth, improved purchasing power and a general rise in the standard of living. During 1982, beef supply was estimated at approximately 166,000 metric tonnes (Livestock Development Division, 1983) with no prospect for expansion over the next ten years due to the continued transfer of land in the high rainfall areas from grazing to crop production. The Development Policy also projected a deficit of some 80 million litres of milk per year and similar, or even worse, trends were expected in pig meat, poultry, sheep and goat production sub-sectors. The inevitable result of these deficits will be a general decline in the consumption of animal protein (meat and milk) which is a basic requirement in the balanced nutrition of man. The projected proportion of mild-to-moderate malnutrition cases by the year 2000 is estimated at 20% and 14% of the rural and urban population respectively (MacCarthy and Mwangi, 1982). In order to attain self-sufficiency in beef production, it is necessary to attain an estimated annual production growth rate of 8.8% between 1980 and 1989 (National Food Policy,1981). It is against this background that the livestock industry has been given the mandate to explore, examine and adopt innovative strategies aimed at producing adequate livestock products to meet the domestic demand and to generate a surplus for export to earn foreign exchange.

1.2 PRESENT STATUS OF BEEF PRODUCTION

During 1983, the total cattle population in Kenya was estimated at 10.9 million head of which 8.67 million were beef cattle (Livestock Development Division, 1983). More than 50% of beef cattle are reared in semi-arid to very arid areas of ecological zones IV, V and VI (Pratt, Greenway and Gwynne, 1966). These areas make up approximately 46.5 million hectares or more than 81% of the total land mass. The region, commonly referred to as rangelands, also accommodates about one fifth of the human population (Central Bureau of Statistics, 1984).

Rangelands are characterised by rainfall whose amount, distribution and reliability combine to create a very fragile environment. Total annual rainfall rarely exceeds 800 millimetres (Griffiths and Gwynne, 1962). Arable cropping may be carried out in the better watered pockets but is very hazardous at best and a total calamity in bad years. In its natural state, the region is eminently suited for extensive livestock production which constitutes the most reliable economic activity as a source of subsistence and income given the present state of knowledge.

Presently, two beef production systems can be distinguished: firstly, commercial ranching in which considerable capital has been invested in the acquisition of productive stock, fencing, watering points, dips, crushes, mineral supplementation e.t.c. These ranches contribute significantly to the supply of slaughter cattle in the country especially to the Kenya Meat Commission factory, Athi River. During 1983, the off-take rate from commercial ranches was estimated at 33% from approximately 400,000 crossbred beef cattle (Livestock Development Division, 1983). Originally, owners of commercial ranch properties were mostly Europeans who were sufficiently knowledgeable in animal and ranch management practices. However, after Independence in 1963, a number of commercial ranches have changed hands and are now owned by indigenous Kenyans either individually or in partnership.

The transfer of land ownership seems to have worked out reasonably well in the high potential (rainfall) areas but results in the arid zones have been disappointing. The new owners have proceeded to split the ranches into smaller and smaller units and, whereas in the earlier situation, the large-scale rancher depended on sales of cattle for revenue, the small or medium-scale farmer undertakes production of food crops, milk and beef for both subsistence and sale. Whether sub-divided or not, the new ranch owners have tended to be unfamiliar with the practices of good livestock and ranch management with deleterious effects not only on animal productivity but, even worse, on the environment.

The second production system is represented by traditional pastoralists who keep beef cattle primarily for subsistence. Their husbandry practices are, by and large, those dictated by a subsistence economy. For instance, little or no capital has been invested in acquiring better animals or in improving management practices so that herds have to depend on the whims of the natural environment. In the past, the system presented no real problem as the indigenous cattle owners were able to roam over large expanses of country and they, apparently, maintained an equilibrium with their habitat (Glover, Walker and Gwynne, 1962). This is no longer the case as there has been a strong tendency towards settled livestock keeping. As the indigenous communities still depend on milk for subsistence, there is a tendency to maintain a high proportion of milking cows at all times, often in direct conflict with the largely seasonal availability of pasture. This practice causes huge losses of animals during prolonged droughts. For instance, it has been estimated that Kajiado district alone (eco-zone lV and V) lost as much as 76% of its beef cattle population during the recent 1983/84 drought (Mukhebi, Gitumu, Kavoi and Iroha, 1985). All in all, the off-take rate from pastoral areas is very low, estimated at 12% from approximately 3.8 million zebu cattle (Livestock Development Division, 1983). It is the considered policy of the Kenya Government to draw the communities in these areas into the mainstream of national economic developement through the provision of packages of appropriate technology based on scientifically generated information. This objective was clearly underscored in the National Livestock Development Policy (1980) which, among other things, sought "to promote the development of the less favoured areas." In this regard, efforts are being taken to encourage the pastoralists to change their eating habits and accept alternative sources of diet so as to reduce their over-dependence on livestock products.

1.3 CONSTRAINTS IN BEEF PRODUCTION AND STRATEGIES FOR IMPROVEMENT

The beef industry in Kenya is characterised by a low level of productivity which has been attributed to a combination of factors ranging from inferior stock genotypes, rugged climatic conditions, undernutrition, prevalence of diseases and parasites, to sheer lack of managerial competence. Increased human population has led to extended cultivation, and hence reduced grazing land especially in high and medium-potential areas.Furthermore, change in property ownership including sub-division of land and the tendency towards settled livestock keeping in the vicinity of permanent watering points have precipitated conditions of very severe overgrazing and soil erosion. This has been aggravated by periodic burning of bush, ostensibly to maintain grassland for grazing purposes, which has stripped vast areas of their vegetative cover. The problem has also been compounded by the part played by game animals in competing with cattle for the available grazing. Taken together, these factors have crystallized to make rangelands particularly vulnerable to environmental degradation which may often be irreversible.

Whereas dairy cattle are shielded from the ravages of the environment by provision of shade, improved leys, supplementary feeding and veterinary care, beef cows are more exposed to the total impact of heat, parasites, infectious diseases, periodic undernutrition and shortage of water. Under these conditions, the important traits required are the ability to survive and reproduce. But mere survival and ability to reproduce are not enough. The beef industry is expected to play a bigger role in the overall economic and social development of this country instead of being relegated to a function secondary to crop production. The cattle production in Kenya has now reached a stage where any further increase in beef production per animal must be associated with improvement in production technology especially nutrition. However, efficiency of production *per se* is not likely to make a major impact on the overall beef production required to meet the demand. A substantial proportion of the additional meat requirements will be expected to come from increased numbers of better quality cattle. Needless to say, direct importation of improved beef cattle to satisfy current and future demand is completely out of question. For the moment, the beef industry must primarily depend upon the maximum utilisation of the adapted indigenous breeds as a basis for increased beef production. In order to multiply the beef population quickly, it is vital to ensure a high level of reproductive performance by the breeding herd. A low reproductive efficiency not only reduces productivity but also limits attempts to improve the herd genetically. For instance, when calving rate is low, nearly all replacement heifers must be used to maintain the herd number and this curtails selection intensity thereby lowering the rate of genetic improvement. Besides, a decline in fertility would result in a compensatory increase in the number of unproductive and aged cows that are retained with adverse consequences of overstocking and soil erosion. Although several factors may influence fertility, there is overwhelming evidence that inadequate nutrition is the most important single factor mitigating against reproductive efficiency of beef cattle (Topps, 1977). This is particularly relevant in tropical rangelands where pronounced seasonal changes contribute to a very precarious feed supply. It is now widely recognised that seasonal changes in feed supply are often reflected in the liveweight of grazing cattle with adverse consequences on reproductive performance. Hence, body weight and weight changes could be used to monitor the fertility status of a grazing beef cow with a view to formulating nutritional and management strategies such as supplementation, planned matings and strategic weaning in order to improve fertility. Furthermore, since nutrition, lactation, genotype and management all interplay to bring about changes in liveweight, a study of the variation in body weight in relation to these factors would provide a practical method of assessing their relative magnitude in the overall fertility complex. Lastly, evaluation of genotypes is necessitated by the diversity of exotic beef breeds already in the country and the need to assess reproductive performance of crossbreds vis-a-vis the adapted indigenous breed types. Exotic beef bulls were introduced into Kenya for crossing with indigenous cows primarily to improve growth rate, milk yield and carcass grade (Meyn, 1970). However, under arid conditions, it would be better to identify genotypes which can maintain a high level of fertility during prolonged droughts than to breed for improved growth rate and milk yield.

Some of the problems and constraints mentioned above lend themselves to easier solutions than others but, all the same, constitute a big challenge to animal production scientists in their endeavour to increase beef production from rangelands. In this context, Trail and Fisher (1971) have suggested setting up minimum standards of management as a pre-requisite before formulating improvement strategies for rangelands. Such management practices are necessary especially where there are improved stock genotypes and where husbandry practices are likely to respond to economic forces. The suggested "reasonably acceptable management levels" entail a certain degree of fencing to control ticks and grazing, regular dipping of all the animals, routine control of helminthiasis, regular prophylactic vaccinations, supplementation with salt licks and provision of adequate clean water. While it was realised that diseases played an important role in the control of fertility (Donaldson, Ritson and Copeman, 1967), this study addressed itself, primarily, to the influence of age, body weight, nutrition with its related seasonal effects, lactation, genotype and management.

1.4 OBJECTIVES

Given the various limitations that characterise the beef industry in Kenya and the concern that has been expressed about the low reproductive levels of beef cattle under range conditions, a programme was initiated by the Animal Production Research Department with the following objectives:

(i) To evaluate breed and environmental factors - both internal and external - affecting calving interval of beef cattle at Athi River ranch.

(ii) To investigate the variation in the cow's liveweight and to characterise its influence on calving interval with particular reference to the effects of strategic supplementation of the breeding cow, weaning age and weaning month.

(iii) To formulate a general policy for improving reproductive efficiency in beef cattle.

CHAPTER 2

REVIEW OF LITERATURE

2.1 THE COMPONENTS OF REPRODUCTIVE PERFORMANCE

The major traits that critically influence the production efficiency of any beef enterprise are:- mothering or nursing ability which determines survival and pre-weaning growth rate of the calf, post-weaning growth rate, reproductive performance or fertility, efficiency of gain, longevity and carcass merit (Gregory, 1968; Daly, 1971). Of these traits, reproductive performance is often the most important and complex one (Topps. 1977) and its full assessment entails measurement of:-

(i) Calving rate, i.e. the number of calves born in relation to the number of breeding females exposed to the bulls per annum and

(ii) Calving interval which is the period between two consecutive parturitions.

The two measurements are interdependent. However, in practice, calving rate is used for survey studies as it relates to the entire herd but is not adequate for management purposes since it does not reveal the extent of fertility disorders until actual calvings occur (Mason and Buvanendran, 1982). For selection purposes, individual cow data are required for which the parameter usually evaluated is the calving interval. The interval consists of the period between calving and conception, known as the service period and the period of gestation. In view of the relative constancy of the gestation period (Hutchison and Macfarlane, 1958; Mahadevan, 1966), the principal factor influencing variation in calving interval is the service period. The length of the service period can be affected by environmental, genetic, infectious reproductive diseases and management factors operating in concert with different severities (Andrews, 1972). Furthermore, these factors may intervene in the reproductive process at ovulation, fertilisation, implantation or parturition.

2.2 EFFECT OF AGE OF BREEDING FEMALES

Working on Africander ranch cows, Christie (1962) obtained a 15-20% calf crop from two year-old heifers in contrast to a calving percentage of over 90 from three year-old heifers. Comparable observations were reported in Australia by Donaldson (1968) and in Botswana by Buck, Light, Rutherford, Miller, Rennie, Pratchett, Capper and Trail (1976) who also reported a decline in fertility in cows older than seven years.

Two factors might be responsible for reduced fertility in young cattle. Firstly, Joubert (1963) observed delayed puberty in Africander cattle which was associated with low body weight. As an illustration of this point, Sparke and Lammond (1968) reported a 100% conception rate from supplemented three year-old Shorthorn heifers weighing at least 285 kg compared to a conception rate of 69% from similar but unsupplemented heifers weighing between 216 and 254 kg. Thus ranch heifers require special attention and adequate nutrition so as to attain not only the age but, more importantly, the target weight needed to reach puberty. Even after attaining the body weight required for sexual maturity, Andrews (1972), Wiltbank and Spitzer (1978) and Milles (1984) observed that heifers should continue gaining in weight to ensure that they can be mated, conceive and bear the burden of pregnancy to full term. Secondly, heifers nursing their first calves suffer from a lactational stress caused by partitioning of nutrients for their continuing body growth and milk production (Christie, 1962; Carroll and Hoerlein, 1966; Sparke and Lammond, 1968; Sacker, Trail and Fisher, 1971a). As a result, they lose body weight much faster and take longer to reconceive. Therefore, in order to synchronise reconception by first-calf heifers with that of the main herd, Daly (1971) and Spitzer, Wiltbank and LeFevre (1975) suggested mating of heifers at least one month before the breeding herd to allow them sufficient time for uterine regression and resumption of cycling after their first calving. Furthermore, a two-paddock system was recommended - one for mating heifers with replacement bulls of a similar age and the other for the main herd, the idea being to segregate heifers so that objective selection on fertility can be made (Daly, 1971). In older cows, reduced fertility has been attributed to teeth wear which affects the animal's ability to forage and obtain sufficient nutrients to maintain body weight and, possibly, due to a lower metabolic efficiency (Andrews, 1972). They, too, are vulnerable to climatic and nutritional stresses and need special treatment.

2.3 EFFECT OF BODY WEIGHT

Correlation between body weight or weight changes with reproductive performance in beef cattle was reported by Elliot (1964), Kidner (1966), Donaldson *et al.* (1967), Ward (1968) and Sparke and Lammond (1968). Subsequently, Lammond (1970) proposed the concept of a target body weight. He suggested that for each cow there was an optimum weight or range in body weight for successful conception. Thus, as the animal's body weight decreased below the target weight so did its reproductive efficiency. Conversely, as body weight increased above the target weight, animals tended to become infertile due to excess fat. Later, this concept was confirmed by Buck *et al.* (1976) and in Zambia by Thorpe, Cruickshank and Thompson (1981). Consequently, the absence of any effect on calving rate of body weight *per se* (Thorpe, Cruickshank and Thompson, 1980) or liveweight change (Capper, Pratchett, Rennie, Light, Rutherford, Miller, Buck and Trail, 1977) suggested that the level of nutrition provided to those animals was sufficient to maintain them at a liveweight above the target weight required for conception. This was particularly true of non-lactating cows (Morley, Axelsen and Cunningham, 1976).

The relationship between fertility and body weight is, basically, one of correlation, not of causation because both factors are functions of nutritional status. Consequently, the evaluation models that have been developed have been based either on liveweight, reflecting the nutritional reserves in the body or liveweight change during the mating season indicating the nutritional reserves being stored after meeting the needs of maintenance and lactation (Morley *et al.*, 1976).

A study by Richardson, Oliver anf Clarke (1976) produced data which quantified the relationship between weight change and subsequent calving percentage. They found the relationship to be curvilinear but non-significant and concluded that the animal's ability to conceive was a function of body weight per se and not the rate of gain. Further evidence in support of this concept was reported by Steenkamp, van der Horst and Andrew (1976) from a study involving Africander cattle. Under extensive conditions in South Africa, Grosskopf (1980) also intimated that for satisfactory reconception rates, it did not matter whether cows lost or gained weight during the breeding season provided their weights were maintained above a certain minimum which would be expected to vary from breed to breed. All these reports reinforce Lammond's (1970) original concept of a target body weight for early conception especially where undernutrition is prevalent.

Work by Hale (1975) helped to clarify the effect of body weight on fertility. He undernourished dry cows and observed that sexual activity ceased when the animals lost 70 kg. When the animals were fed liberally to regain weight, sexual activity did not return until a certain body weight was achieved which was significantly greater than that at which the animals stopped cycling. This implies that it is better, physiologically, to maintain beef cows in reasonable condition than to allow them lose weight and attempt to regain it immediately before the mating season. The practical significance of this finding remains one of the greatest challenges facing beef ranchers in this country.

The mechanism by which body weight loss adversely affects reproductive performance in the beef cow is still largely speculative. However, there is strong evidence to indicate that body weight loss following under-nutrition or deficient nutrition reduces the production and/or release of two gonadotropic hormones namely: the follicular stimulating hormone (FSH) and the luteinizing hormone (LH) from the anterior pituitary gland (Amoroso, 1963; Gubarevic and Teresenkov, 1965). Both FSH and LH are carbohydrate-containing proteins (Turner, 1962) and are responsible for the growth and maturation of the graafian follicles in the ovary and ovulation respectively. These effects are influenced by action of ovarian oestrogen and progesterone hormones, all working in concert to bring about ovulation. Hypothalamic release factors may be implicated in the production of FSH and LH (Hansel, 1959) but the exact mode of action caused by under-nutrition has not been fully elucidated. Certain advances have been reported in hormonal therapy to alleviate infertility (Topps, 1977) but it is generally accepted that their administration should not be regarded as a panacea for infertility nor a substitute for good management especially at this point when the endocrine mechanisms involved in infertility are still far from clear.

2.4 EFFECT OF NUTRITION

Christie (1962) observed that, in general terms, the fertility of a grazing beef animal was an expression of the nutritional level of its environment. This is a matter of great concern especially in the tropics because of the characteristic seasonality of rainfall (French, 1957) which affects the quality and quantity of dry matter intake from range grasses (Bredon and Horrell, 1962; Marshall and Bredon, 1966; Karue, 1972, 1974). Topps (1977) has associated seasonal changes in feed supply with corresponding changes in body weight of grazing beef cattle with adverse consequences on reproductive performance. From what has been reviewed above, it is evident that there exists a relationship between age, body weight, hormonal control with nutrition of the grazing animal and, as such, it is almost impossible to draw a clear-cut distinction between the influence of these factors on fertility individually. However, it will suffice, perhaps, to focus on those factors that affect nutrition in a more direct manner.

2.4.1 Pastures: nutritive value and seasonal effects

One of the climatic characteristics of rangelands is the strong seasonality of rainfall with consequent prolonged dry periods (French, 1957). During droughts, pasture growth virtually ceases and grazing animals have to contend with what is essentially "standing hay". Karue (1972,1974,1975) carried out chemical analyses of the range grasses at the ranch where this study was conducted and he observed that crude protein declined rapidly from 9-13% during rainy seasons to 3-4% in dry periods. Crude fibre content increased dramatically after a rainy season to 38% which reduced herbage digestibility and, hence, intake of energy. There were also deficiencies in phosphorus and sodium. Deficiencies in chlorine, cobalt and copper were also reported in other Kenyan range areas by Anderson (1936), French (1952), Marshall and Bredon (1966) and Slagsvold (1969). The main consequence is that beef cattle in rangelands suffer from a periodic deficiency of both energy and protein which is often compounded with shortages of several mineral elements. Seasonal deficiencies in quantity (undernutrition) and quality (malnutrition) of pasture bring about body weight changes which have been associated with a low reproductive efficiency (Topps, 1977).

Several reports have indicated that peak conception period coincided with the onset of rains (Wilson, 1963; Kidner, 1966; Stobbs, 1967; Swensson, Schaar, Brannang and Meskel, 1981; Ambrose, Oyedipe and Buvanendran, 1984). This implied two things: firstly, there was no particular advantage to be gained by all-year-round mating other than the possibility of getting breeding females into calf with a minimum of managerial skills. Secondly, mating would have to be organised when nutritional conditions were most favourable, i.e. during the period of vigorous pasture growth. As a practical guide, Daly (1971) has recommended a breeding programme such that calves are dropped approximately one month before the expected rains so that cows can enjoy the benefit of a rising plane of nutrition during the breeding period. He also suggested flushing of cows at mating time to attain the body weight required for conception.

The role of nutrition during the breeding season is influenced by both rainfall and temperature. For instance, Donaldson (1962) observed high conception rates following flush of good pasture during summer rains which confirmed ealier reports by Anderson (1944) and Wilson (1946) that conception was favoured during hot months. Therefore, the low fertility levels observed during cold periods by Plasse, Warnick and Koger (1970) could have been due to a supply of nutrients from pasture which was sufficient to bring about ovulation but inadequate to trigger off oestrus activity. These reports have been collaborated more recently by Grosskopf (1980) who also observed that cows which reconceived during summer were heavier at calving and gained more weight during the breeding season. However, it should be realised that the seasonal effects of pasture would vary in various environments and the resulting effects on fertility would also be expected to vary.

2.4.2 Supplementary feeding

Inhibition of gonadotropic hormones caused by underfeeding can be reversed by feeding an adequate diet (Amoroso, 1963). Such a diet ought to be balanced in energy, protein, vitamins and minerals to be able to maintain body weight or reduce weight loss. The debate still continues as to whether, under tropical ranch conditions, supply of energy is more critical in reducing weight loss than provision of protein. In their classic work, Wiltbank, Rowden, Ingalls, Gregory and Koch (1962) demonstrated that feeding of low levels of energy to lactating Hereford cows, regardless of protein levels, reduced their fertility. Conception rates increased to 95% by feeding high levels of energy after calving. These observations also elucidated the vital role of the demands of lactation, rather than pregnancy, in the control of fertility. The importance of supplemented energy has also been reported by Blaxter (1957), Wiltbank, Rowden, Ingalls and Zimmerman (1964), Dunn, Ingalls, Zimmerman and Wiltbank (1969) and Bond (1974). On the other hand, use of non-protein nitrogen (NPN) supplements has been reported by Elliot (1961), Ward (1968), Slagsvold (1969), Topps (1972), Winks (1974), Siebert, Playne and Edye (1976), Holroyd, Allan and O'Rourke (1977), Capper et al. (1977) and Holroyd, O'Rourke, Clarke and Loxton (1983) but results on fertility in beef cattle have been inconsistent. Where improved fertility has been observed, this has been attributed to increased NPN in its own right or to increased intake of total nutrients (Andrews, 1972). Lack of consistency in response to NPN supplementation has been attributed to a number of factors. Firstly, Christie (1962) observed that NPN merely maintained the animal and that to be successful, it should be given at the beginning of a dry season. This was confirmed by Holroyd et al. (1977) who reported shorter calving intervals when beef cattle were fed 57 g of urea during a dry season. Even when fed during a dry season, response would be affected by the severity of the dry season (Holroyd et al., 1983). Secondly, there is evidence to show that the effect of NPN feeding is partly dependent on the amount of readily available carbohydrate in the supplement or basal ration to supply energy required by rumen micro-organisms (Weston, 1967; Ernst, Limpus and O'Rourke, 1975). Apart from the need to include readily degradable carbohydrate, Karue (1971) observed an optimum total energy to nitrogen ratio of 64:1 which was later supported by Bond (1974) and Winks (1974). Furthermore, Yilala (1985, personal communication) has suggested a feeding regime which ensures synchronisation in the peak production of ammonia from NPN sources with availability of energy in the rumen. Thirdly, the need for sulphur for efficient NPN utilisation by the rumen micro-organisms has been implicated (Moir, Somers and Bray, 1967). As a practical guide, Topps (1977) suggested giving animals a supplement which offsets the nutritional deficiencies in pasture including vitamins and minerals rather than attempting to draw a dividing line between energy or protein deficiency. Besides, in providing dry season supplements to maintain body weight or alleviate weight loss, Thorpe et al. (1981) cautioned against exclusive reliance on liveweight for determining feeding levels especially with dams of average or above-average body weight or weight change. Furthermore, it is generally accepted that overfatness leads to low fertility (Amoroso, 1963; Lammond, 1970) and this observation would underline the significance of judicious feeding. What is worrying, though, is the revelation by Hammond (1963) that in dairy cattle receiving adequate feeding, the main cause of infertility was the early death of the fertilised egg which he attributed to possible hormonal insufficiency. If this is also true with beef cattle, then it becomes obvious that more detailed study is still required to characterise the response of, and interrelationship between, nutrition and hormonal control in the fertility complex.

2.4.3 Stocking rate and grazing hours

Lammond (1969) and Andrews (1972) observed differences in reproductive performance between years and paddocks which they attributed to differences in stocking rates and hence amount of dry matter available for each animal. Every property has an optimum stocking rate which varies depending on quantity and quality of pasture available. The carrying capacity is usually based on the capability of the property to maintain body weight in what is considered to be an average year (Tropical Pastures, 1975). Allen (1973) produced evidence to indicate that providing beef cattle longer grazing hours each day had a beneficial effect on liveweight performance which could be exploited to improve reproductive efficiency.

2.5 EFFECT OF LACTATION

Lactation is a complex physiological process involving the interplay of ovarian steroids, the growth hormone, adreno-corticotropic hormone and prolactin from the anterior pituitary (Amoroso, 1963). Work by Christie (1962) and the evidence reviewed by Symington (1969) indicated that post-partum infertility was induced by lactation and undernutrition, the two factors probably being inter-related. Influence of these factors is triggered through absolute body weight of the animals or liveweight change. Numerous reports have associated prologed post-partum anoestrus with lactation and in most cases, dry cows have been found to be more fertile than lactating cows (Lampkin and Lampkin, 1960; Christie, 1962; Donaldson, 1962; Elliot, 1964; Stobbs, 1967; Donaldson et al., 1967; Ward, 1968; Lammond, 1969; Symington, 1969; Andrews, 1972; Thorpe et al., 1981). The difference in fertility has, almost invariably, been attributed to changes in body weight, with dry cows being relatively better in maintaining their liveweight after calving. Although the observed low fertility in lactating cows has been associated with body weight loss, there is evidence to indicate that the depressant effect on conception is hormonal and unconnected with milk yield as such. For instance, Wiltbank and Cook (1958) reported only 57% of the nursed (suckled) cows settled at first service compared to 71% in the milked (unsuckled) group. Furthermore, there was a greater number of quiet ovulations in nursed cows which was attributed to a decreased level of oestrogen adequate to stimulate the luteinizing hormone and, hence, ovulation but insufficient to bring about oestrus. While confirming the depressant effect of suckling, Hutchison (1963) observed that the effect was more severe during dry season matings but negligible if mating was done after the cows had recovered from the previous dry season weight loss. This was confirmed later by Ward (1968) who associated reconception among nursing cows with their absolute body weight. These results imply that lactation per se may not have a significant influence on fertility when body weight is adequate and this would underline the relevance of judicious feeding to lactating cows.

That lactation imposes a heavy nutritional demand on the breeding cow has long been recognised and one way to reduce this stress is by early weaning (Christie, 1962). Early weaning is particularly relevant to beef cattle which depend largely on natural grazing to meet all their nutritional demands. Rose, Christie and Conradie (1963) reported a conception rate of 93% in first-calf Africander heifers whose calves were weaned early in contrast to 40% conception for animals with calves at foot. Corresponding figures in mature cows were 100% and 55% respectively. Apart from increasing conception rate, early weaning also resulted in an increase in body weight of the cows. Hence, it would appear as if improved fertility was associated with increased liveweight. However, considering the rapid return to heat following weaning, these workers were of the opinion that it would be most unlikely for improvement in conception rates to be dependent on weight increase. They postulated the presence of hormonal control, probably through the release of a blocking factor. In support of this proposition, they mentioned a comparable reaction in the mare and the sow where cessation of suckling brought about a rapid return to ovarian cycling. Later work in Zambia by Rakha, Igboeli and King (1971) and in Southern Rhodesia (Zimbabwe) by Richardson et al. (1976) showed that early weaning had little or no consistent benefit on subsquent calving rate possibly due to the timing of breeding in relation to weaning. However, since the extra weight carried by the cow throughout the dry season following weaning appeared to be cumulative (Rose et al., 1963), early weaning would still be advocated to reduce dry season feeding required to maintain body weight. This observation is collaborated by the evidence of Andrews (1972) who attributed the desirable effects of early weaning to the animal's ability to walk farther thereby utilising dry season pasture more fully. According to Trail, Sacker and Fisher (1971) and Schottler and Williams (1975), early weaning may have adverse effects on calf growth but such effects are usually of minor consideration compared to the grave problem of maintaining the cow's body weight for regular calving.

2.6 EFFECT OF BREED TYPE

According to Mason and Maule (1960), the indigenous beef cattle in Kenya belong to two basic breed types that have developed through natural selection namely:-

(i) The improved Boran of the large East African Shorthorn Zebu and

(ii) The small East African Shorthorn Zebu (EASZ).

The Borans are up to 35% faster growing than the EASZ (Ledger,1966 and Stobbs, 1966) and have been selected on commercial ranches for improved fertility among other things (The Boran Cattle Breeders' Society, 1951; Mason and Maule, 1960). Results from Ruhengere Field Station in Uganda by Sacker et al. (1971a) indicated the superiority of Boran cows in respect of calving rate. However, the review report by Meyn (1970) showed that even under unfavourable conditions, the EASZ also had a reasonable fertility probably due to their ability to remain in a better condition during drought periods when feed supply is scarce (Mason and Buvanendran, 1982). Consequently, the low conception rates in herds of indigenous zebu cattle previously reported by Hutchison (1962), Christie (1962), Wiltbank *et al.* (1962), Lammond (1969) and Plasse *et al.* (1970) were the result of environmental, particularly nutrition, rather than genetic factors. This observation has been confirmed by various workers who have reported very low heritability and repeatability estimates on calving interval (Lindley, Easley, Whatley and Chambers, 1958; Mahadevan and Marples, 1961; Galukande, Mahadevan and Black, 1962; Stobbs, 1965). It should be noted, however, that the concept of heritability - that portion of the total variation within a population which is attributable to genetic influence - is, by definition, the balance of variation after that attributed to environmental influences has been accounted for. Thus, as the variation attributable to such major environmental factors as nutrition and disease is accounted for, the proportion of genetic variance can be expected to increase.

Although fertility traits possess low heritabilities, they are particularly responsive to cross-breeding and improvement has been achieved as a result of crossing exotic beef bulls with indigenous zebu cows (Donaldson, 1962; Mahadevan and Hutchison, 1964; Mason 1966; Andrews, 1972; Koger, Cunha and Warnick, 1973; Seebeck, 1973; Rudder, Seifert and Maynard, 1976; Baharin and Beilharz, 1977). From a genetic viewpoint, improvement in fertility from cross-breeding arises from:

(i) Complementarity, i.e. the combination of the adaptation of the tropical indigenous breed with the productivity of the improved exotic breed and

(ii) Heterosis or hybrid vigour which is a non-additive effect arising from a heterozygous genotype. It is measured as the percentage advantage of the mean of the crossbreds over the mean of the purebreds. In practice, especially under tropical conditions, the superiority of the offspring over the indigenous female would be of more interest (Mahadevan, 1966).

Improvement in fertility of crossbreds has been attributed to a higher rate of body weight gain (Lampkin, 1969; Sacker, Trail and Fisher,1971b; Thorpe et al., 1981; Milles, 1984). Although Andrews (1972) also observed the significance of body weight gain, he reported similar reproductive performance from the indigenous zebu cattle and the crossbreds in northern Australia which he attributed to better grazing ability and higher digestive efficiency of the animals on poor pasture. It is not surprising, therefore, that more recently, Swensson et al. (1981) did not observe any superiority of the crossbreds over the indigenous zebu cows in Ethiopia although they recorded some improvement in age at first calving and manifestation of oestrus. While these reports may seem conflicting, Andrews (1972) contended that cross-breeding might play a significant role only if the adaptive features, i.e grazing ability, resistance to parasites and heat tolerance of the resulting genotypes permit them to more easily combat adverse nutritional conditions. Besides, the genotype X environmental interaction reported by Mahadevan (1966), Meyn (1972) and Koger, Burns, Pahnish and Butts (1979) would make it absolutely necessary to breed and evaluate beef cattle in the environments in which they will perform subsequently.

2.7 MATING PRACTICES

2.7.1 Length of breeding season

Reports by Donaldson et al. (1967), Plasse, Koger and Warnick (1968) and Spitzer et al. (1975) indicated that more than 85% of the total number of beef cows conceived within the first 100 days after calving and, in the light of an observation made earlier that peak conception occurred during wet and hot seasons, it would be advantageous to have a closed mating season. Shortening of the breeding season has since been advocated so as to gain effective control over the animals and grazing (Wiltbank and Spitzer, 1978). Daly (1971) and Allen (1973) recommended a three-month mating period to facilitate easy management and overall supervision of the herd particularly with regard to culling, flushing of breeding females during the mating period and grazing control. However, it was evident from the various reports that seasonal mating could be successfully followed only where nutritional conditions were adequate and sound management practices followed especially in regard to strategic weaning (i.e weaning calves according to seasonal conditions and condition of breeding cows), special care of first-calf heifers and bulls and use of pregnancy diagonosis to indentify low fertility cows for culling.

2.7.2 Bull-to-cow ratio

Rollinson (1962), Amoroso (1953) and Plasse et al. (1970) reported psychological interactions which inhibited libido in some males. Consequently, they suggested use of several bulls. The correct ratio of bulls to cows would depend on size of the paddocks, terrain, number of watering points, age and breed of bulls. Daly (1971) suggested a mating intensity of 2.5 to 3% in the closer and more settled areas and 6% in the more extensive ranches. Younger bulls would be used at a slightly higher rate. Whatever the ratio, beef bulls experience considerable activity following cows which are in oestrus but are not prepared to stand for service (Topps, 1977) such that by the end of the breeding season, they may have lost sufficient body weight and condition to depress their fertility. Therefore, it is imperative that bulls should be in a well-fed vigorous condition at the start of the mating season.

CHAPTER 3

MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

3.1.1 Location - The study was conducted at the Kenya Agricultural Research Institute (K.A.R.I.) field station near Athi River, some 24 km South-East of Nairobi. The ranch encompasses some 1600 hectares at Latitude $1^{o}20'$ South and Longitude $37^{o}05'$ East and stands at an elevation of 1500 $\pm$ 50 m above sea-level in the Upper Midland Ranching Zone (Jaetzold and Schmidt, 1983).

3.1.2 Climate - The site lies in a semi-arid area with a bimodally distributed annual rainfall averaging about 565 mm (1956-1980). The "long rains" come in April and May while the "short rains" occur during November and December. Rainfall is highly variable both annually and seasonally and prolonged drought periods are a common feature (Griffiths, 1962). Incoming radiation is quite high, averaging 515 cal/cm^2/day (1972-1980) which, coupled with high mean air temperatures and a relatively important aerodynamic (wind and humidity) term, result in high evaporative rates. The pattern of rainfall and evapo-transpiration at the ranch is summarised in Figure 1.

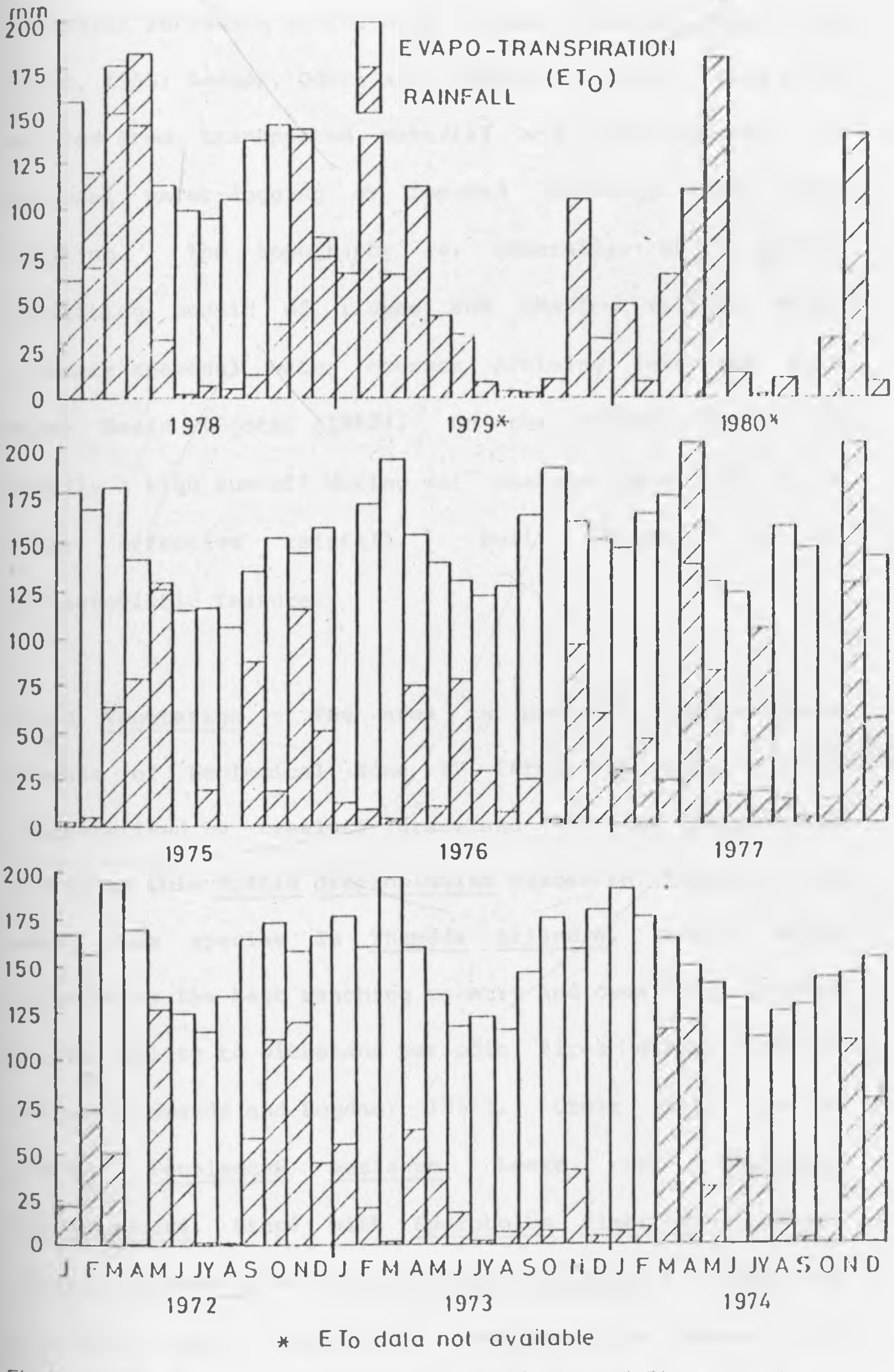

Fig.1 Rainfall and evapo-transpiration (mm) at Athi River ranch

3.1.3 Soils and topography - Generally, the soils are shallow, calcareous black clay or clay loam with some colluvial influence on the hill slopes (Gethin Jones and Scott, 1955; Ledger, Odero and Ndugire, 1969). They are derived from transported material and are subjected to seasonal water-logging or impeded drainage and deep cracking. The topography is, generally, of a gently undulating mosaic of ridges and shallow valleys which indicate seasonal water courses draining into the Athi River Basin (Scott, 1962). On the slopes, there is usually a high run-off during wet seasons resulting in a lower effective rainfall. Soil erosion is a characteristic feature.

3.1.4 Vegetation - The area is part of the northern reaches of Ecological Zone IV (Pratt et al., 1966) characterised by treeless grassland in some places and scattered thin Acacia drepanolobium bushes in others. The main grass species is Themeda triandra, Forsk, which constitutes the best ranching country and owes its success to its ability to withstand periodic fires during drought periods (Edwards and Bogdan, 1951). Other grass species include Pennisetum mezianum, Leeke and Digitaria macroblephara, Stapf with Sporobolus fimbriatus, Nees, Setaria incrassata and Bothriochloa insculpta, A. Cumus as important minor components. These grasses mature very quickly during wet seasons which results in a sharp decline in their nutritive value (Karue, 1972, 1974). Legumes are relatively scarce and are chiefly represented by species of Indigofera and Crotalaria. For at least eight months of the year, the vegetation is, essentially, "standing hay".

3.2 EXPERIMENTAL ANIMALS

3.2.1 Cows - The breeding females used in this study consisted of four breed types namely: Boran, small East African Shorthorn Zebu (EASZ), Boran X Hereford and EASZ X Hereford F_1 crossbreds. Some of the Boran females were bought from commercial ranches in Laikipia district during 1967/68. These were used for comparative nutrition studies involving *Bos indicus*, *Bos taurus* and crossbred cattle at the Institute's main station, Muguga (Ledger, Rogerson and Freeman, 1970) and for producing steers used for beef feeding and appetite trials (Ledger and McQueen, 1967) before they were transferred to Athi River ranch in 1969. Other Boran cows were born at Kedong field station near Naivasha from dams that were used for growth rate studies at low and high-planes of nutrition (McQueen, 1965). The remaining Borans were born either at Muguga or at the ranch itself. The small East African Shorthorn Zebus were purchased from markets in South Nyanza province in 1969 and 1970 and were moved straight to the ranch. A few EASZ were born at the ranch. It was impossible to establish accurately the ages of females that were purchased from outside the station.

3.2.2 Mating programme - All animals were run as one herd. A random mating programme to deliberately avoid selection was followed using Hereford bulls. The bulls used to be taken from K.A.R.I., Muguga to the ranch for the mating season after which they were returned to Muguga. Heifers joined the breeding herd at approximately two years of age and having attained 250 kg live-weight. Mating of under-weight heifers was deferred by a month or so until they achieved the stipulated body weight. The majority of heifers during 1975 breeding season fell in this category. Table 1 highlights the main features of the breeding programme.

3.2.3 General herd management - Animals were grazed during daylight hours but were enclosed at night to minimize losses from predators and theft. They were kept entirely on natural pasture without any supplementation except for "Maclik"* mineral licks given *ad libitum* at

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*Obtained from Wellcome (K) Limited, Nairobi.

Composition:

Elemental (%) - Ca(18.75), P(3.51), Na(12.24), Cl(18.89), Mg(0.10), Cu(0.12), Co(0.015), Fe(0.20), I(0.005), Zn(0.10), Mn(0.08), S(0.12).

Compound (%) - CaO(26.25), P_2O_5(8.04), NaCl(31.13).

Table 1 - The main aspects of the mating programme at Athi River ranch.

Year	Mating season	Bulling %	Mean age of bulls(years)	Range in Age of bulls
1973	All-year-round	1.9	5.9	5.8 - 6.2
1974	June-August	2.3	4.2	2.5 - 6.2
1975	" "	2.1	4.4	2.9 - 7.2
1976	" "	1.6	3.5	2.1 - 4.9
1977	May-July	1.5	3.8	2.8 - 4.8

night twice a week. Water was provided both in the paddocks and night enclosures. Spraying against ticks was twice a week using "Bacdip"[1] or "Delnav"[2]. Vaccination against foot-and-mouth was done twice a year or whenever there was an outbreak of the disease in neighbouring areas. The animals were also vaccinated against contagious abortion, rinderpest, blackquarter and anthrax. Weaning was done in batches approximately eight months after calving. Cows that failed to get in-calf or wean calves for at least three consecutive years were culled otherwise animals stayed on regardless of their age. By 1980, some cows were sixteen years of age or more. All animals were weighed once a week and their weights twenty-four hours post-calving were also recorded.

3.3 EXPERIMENTAL DETAILS

3.3.1 Experiment 1 Evaluation of breed type and environmental factors affecting calving interval of beef cattle.

3.3.1.1 Objective - It was intended to ascertain and evaluate breed and, perhaps more importantly, environmental factors that influence calving interval and the overall reproductive status of beef cattle on range.

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1. Obtained from Bayers Limited, Nairobi.

2. Obtained from Wellcome (K) Limited, Nairobi.

3.3.1.2 Data - Each breeding female was regarded as an entity during every breeding season and the following data were collected for each animal:

Breed type: Boran; small East African Shorthorn Zebu and Boran/EASZ X Hereford (F_1) crossbred.

Date of birth: year of birth was estimated from information available on arrival at the ranch for those females that were bought from outside the station.

Previous parous state: heifer; dry or suckled female at conception prior to calving interval in question.

Date of calving.

Body weight (kg): twenty-four hours after earlier calving (WCV); at subsequent (i.e. "second") conception (WCP); one and two months before "second" conception (W1BC and W2BC respectively).

From this information, the following values were calculated:

Date of conception: estimated from date of calving and assuming a mean gestation period of 283 days (Hutchison and Macfarlane, 1958).

Age at earlier calving: i.e at beginning of calving interval in question.

Calving interval: computed as the period (days) between two successive parturitions.

Weight change (kg): during the month before "second" conception (W1BC-WCP) and between two to one month before "second" conception (W2BC-W1BC). These weight changes were included for evaluation in order to pinpoint the exact period when changes associated with fertility occurred so that corrective measures in feeding and management of animals could be instituted at the right time with least cost.

Conception period: since climatic variation was expected to have a major influence on pasture productivity and, hence, animal performance, it was decided to divide the year into six conception periods to coincide, as much as possible, with the seasonal pattern of rainfall and temperature (Fig. 1) as follows:

Period	General Description
1. Mid-Jan. to Mid-March	Hot and dry
2. Mid-March to Mid-May	Hot, moderate/wet
3. Mid-May to Mid-July	Warm/cold, moderate/dry
4. Mid-July to Mid-Sept.	Cold and dry
5. Mid-Sept. to Mid-Nov.	Warm, moderate/wet
6. Mid-Nov. to Mid-Jan.	Hot, moderate/wet

On the basis of the above classification and after establishing the date of conception, it was possible to assign an appropriate conception period with respect to each animal.

Soil moisture index: In order to explore more precisely the magnitude of climatic influence on calving interval, it was decided to include a factor which would integrate agricultural meteorological parameters to give an estimate of water adequacy in the soil. Thus, the Penman's (1948) estimate of evaporative losses from an open water surface (E_o) for each day at the ranch from 1972 to 1977 was calculated using McCulloch's (1965) tables modified for altitude. Raw data for calculation of E_o were available from the meteorological station at the ranch. The E_o values were multiplied by a crop coefficient of 0.86 derived by Pereira and McCulloch (1962) for Kikuyu grass (Pennisetum clandestinum) to predict evapo-transpiration (ET_o) for range grasses at the ranch. The coefficient for a fully established grass cover tends to remain practically the same from the report by Doorenbos and Pruitt (1977) who used a crop coefficient of 0.8 to predict evapo-transpiration of grasses not only in humid areas of England but also in very hot and semi-arid regions. As indicated by these workers, the slight difference between 0.8 and 0.86 coefficients could be due to differences in the aerodynamic term. A possible source of error would be the presence of patches of bare ground during certain periods of the year. However, the magnitude of such an error would be expected to be minimal as to be disregarded. Soil moisture index was calculated from the equation:

$$\text{Soil Moisture Index (SMI)} = \frac{\text{Total Monthly Rainfall (mm)}}{\text{Estimated } ET_o \text{ (mm/month)}}$$

which, for the purposes of this study, would give an indication of soil water adequacy for pasture growth after taking into account the biggest water loss from a vegetative cover namely, evapo-transpiration. Application of this Index would facilitate comparison of the various climatic regimes during which animals performed. Soil moisture indices were calculated for each animal for the periods one month (SMI1) and one to two months (SMI2) prior to "second" conception.

3.3.1.3 <u>Grouping of breeding females</u> - Arising from variation in the breeding season (Table 1), females were initially classified into five groups depending on the period taken after calving before joing with the bulls. The following groups were obtained:

Group 1 - regarded as the normal group with bulls present within 60 days post-calving. This period was selected purely for biological reasons because most range cows show first oestrus following calving at 30-108 days

Table 2 - Data structure and number of calving intervals in Experiment 1

Class	Levels	Groups 1	Groups 2	Groups 4	Total
1. Breed type	Boran	44(39)	29(22)	58(51)	131
	EASZ	42(29)	47(36)	33(31)	122
	Crosses*	28(19)	20(17)	7(7)	55
2. Dam's age at earlier calving (years)	3 or below	18	16	22	56
	4 - 8	65	38	71	174
	9 and above	31	42	5	78
3. "Second" conception period	Mid Jan.-Mid March	1	7	33	41
	Mid March-Mid May	2	-	8	10
	Mid May-Mid July	52	59	19	130
	Mid July-Mid Sept.	37	26	1	64
	Mid Sept.-Mid Nov.	6	-	-	6
	Mid Nov.-Mi Jan.	16	4	37	57
4. Year of "second" conception	1973 (early)	2	11	70	83
	1973 (late)	26	-	3	29
	1974	2	3	-	5
	1975	28	59	19	106
	1976	23	23	-	46
	1977	33	-	6	39
5. Dam's previous parity	Heifer	17	17	31	65
	Dry	39	14	49	102
	Suckled	58	65	18	141
Total		114	96	98	308

*Crosses were F_1 from Boran and EASZ cows X Hereford bulls.

Figures in parentheses are individual animal numbers.

with a mean of around 60 days (Lasley and Bogart, 1943; Warnick, 1955; Lindley et al., 1958; Wiltbank and Cook, 1958; Mahadevan and Marples, 1961; Marples, 1963; Wiltbank and Spitzer, 1978) although mean values as low as 26 days have also been reported (Plasse et al. 1970).

Group 2 - cows were introduced to the bulls at varying periods from 61-150 days after calving.

Group 3 - joining with bulls from 151 to 230 days.

Group 4 - joining occurred from 231 days or more.

Group 5 - cows did not conceive during the first breeding season but did so in the subsequent mating period.

Groups 2,3 and 4 described above were formed on the basis of distribution among females such that animals that clustered together formed a group of their own. For resons explained in section 4.1.1, only groups 1,2 and 4 were retained for the final analysis. The data structure for these three groups is summarised in Table 2.

3.3.2 Experiment 2: Effect of supplementation on calving interval of beef cattle.

3.3.2.1 Objective - To characterise the response of calving interval and body weight changes to dry season energy supplementation with or without nitrogen sources to beef cows prior to or immediately after calving.

3.3.2.2 Animals - In-calf Boran, EASZ and their F_1 crosses with Hereford bulls were used for this study. A pregnancy diagnosis (PD) was undertaken by a veterinarian to establish their stage of pregnancy. A total of 185 cows that were due to calve down within two months or earlier were finally selected.

3.3.2.3 Rations and feeding treatments - Three experimental rations were prepared for supplementing the selected cows during the January - March dry period in 1978, 1979 and 1980 as follows:

Ration 1 - 2 kg chopped fresh grass from the paddocks.

2 - 2 kg ground sorghum grain (*Sorghum vulgare*) mixed with 500 g of cane molasses (Energy).

3 - 2 kg ground sorghum grain mixed with 75 g of "feed quality" urea and 500 g of molasses (Energy + Nitrogen).

Seventy-five grams of "Super Lick"* mineral powder[1] were

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*From Pfizer Laboratories, Nairobi.

[1]Elemental Composition(%): P(12.0), Ca(7.4), Mg(4.5), Na(7.37), Cl(13.63), S(4.5).

mg/kg: Co(14), Cu(845), I(105), Mn(1290), Zn(2520), Fe(1775).

Compound (%): NaCl(21.0), CaO(10.35), P_2O_5(27.5).

mixed with the supplements (rations 2 and 3) or water and sprinkled on chopped grass (ration 1). All the cows grazed together during the day between 0700 and 1600 hours. In the evening, they were confined in individual feeding stalls where they received the various experimental rations. The supplemental regimes were:

(i) Chopped grass (Control) - Ration 1.

(ii) Pre-parturient supplementation

(a) Energy alone - Ration 2

(b) Energy + Nitrogen - Ration 3

(iii) Post-parturient supplemetation - Ration 3

Cows on feeding regimes (i) and (ii) were supplemented for varying periods until they calved down while those on regime (iii) were fed immediately after calving also for varying periods as indicated in Table 3. Animals were allowed to feed each day for approximately one hour. The range in the period of supplementation before calving was quite large due to inaccuracies in estimating stage of pregnancy. Animals were selected in such a manner that all groups were supplemented at the same time. By implication, the majority of cows on feeding regime (iii) were early calvers.

Table 3 - Mean supplemental feeding periods (days).

Year	Supplemental diets			
	Chopped grass	Pre-parturient energy	Pre-parturient energy + N	Post-parturient energy + N
1978	35(19-49)	40 (24-58)	42 (8-59)	39 (35-40)
1979	30(5-54)	37 (14-66)	31 (4-57)	47 (36-49)
1980	44(18-67)	48 (31-65)	44 (18-66)	62 (53-68)
Mean	36(5-67)	42 (14-66)	39 (4-66)	49 (35-68)

Numbers in parentheses are ranges.

3.3.2.4 Mating Period - Supplementation was discontinued during March and all the experimental animals joined the main herd for mating with Hereford bulls beginning on 1st May each year. During the three-month mating season, there were two field assistants who recorded dates and identification numbers of cows in oestrus. Bulling percentages during 1978, 1979 and 1980 were 3.0, 3.6 and 2.6 respectively. During the 1980 breeding season, three year-old Friesian and Ayrshire bulls were used for mating in addition to the Hereford bulls which were comparatively much older. Each year during September, a pregnancy diagnosis was done to estimate stage of pregnancy to facilitate the distribution of animals to the various supplemental regimes. Dates of calvings were used to establish date of conception for each cow.

3.3.2.5 Data - Records were collected as described in experiment 1 except for conception period, soil moisture index and weight changes. Additional data were on supplemental regime, period of supplementation and dam's weight one month after earlier calving (W1ACV). Weight change between one month post-calving and "second" conception (W1ACV-WCP) was computed. The rest of the data structure is summarised in Table 4.

Table 4 - Data structure and number of calving intervals in Experiment 2.

Class	Levels	No. of Observations
1. Breed type	Boran	34 (19)
	Boran X Hereford (F_1)	52 (31)
	EASZ	48 (27)
	EASZ X Hereford (F_1)	51 (28)
2. Dam's age at earlier calving (yrs)	4	22
	5 - 9	100
	10 and above	63
3. Dam's previous parous state	Dry	72
	Suckled	113
4. Feeding regime	Chopped fresh grass	40
	Pre-parturient supplementation	88
	(a) Energy	43
	(b) Energy + Nitrogen	45
	Post-parturient supplementation	57
5. Month of earlier calving	February	83
	March	58
	April/May	44
6. Year of earlier calving	1978	58
	1979	53
	1980	74
Total		185

Figures in parentheses are individual animal numbers.

3.3.3 Experiment 3: Effect of weaning age and weaning period on calving interval.

3.3.3.1 Objective - It was intended to identify and evaluate the most suitable age and month after calving for weaning, to ensure the continued reproductive potential of the breeding cow without detriment to the vigour of the calf.

3.3.3.2 Animals - The breed types and mating programme were the same as those described in experiment 2. All the cows were suckling their calves during 1977, 1978 and 1979. A pregnancy diagnosis was performed to establish whether the animals were in-calf. The animals were divided into three groups and their calves were weaned in three batches at the end of October, November and December each year. It was intended to wean calves in each group at ages ranging from five to nine months. However, due to the small number of cows available each year for this particular experiment, it was not possible to have the same age range from group to group. For instance, the group that was weaned at the end of December 1977 had, on average, older calves than the first two groups. Weaning was brought forward by one month during 1978 and 1979 but the same problem prevailed. What was done, therefore, was to take as wide a range in weaning age as was practicable for each group as shown in Table 5.

Table 5 - Range (days) in weaning age.

Year	Weaning month	Age of calves at weaning
1977	End October	167 - 229
	" November	179 - 253
	" December	204 - 259
1978	" September	154 - 268
	" October	202 - 269
	" November	207 - 289
1979	" September	164 - 251
	" October	195 - 272
	" November	193 - 287

Table 6 - Data structure and number of calving intervals in Experiment 3.

Class	Levels	No. of. Observations
1. Breed type	Boran	21 (12)
	Boran X Hereford (F_1)	42 (22)
	EASZ	29 (14)
	EASZ X Hereford (F_1)	30 (22)
2. Dam's age at weaning(years)	4	14
	5 - 9	70
	10 and above	38
3. Weaning month	End of September	35
	End of October	38
	End of Nov./December	49
4. Weaning year	1977	28
	1978	43
	1979	51
5. Calving month*	Jan./February	46
	March	36
	April/May	40
Total		122

* Month of calving following weaning in question.

Figures in parentheses are individual animal numbers.

3.3.3.3 Records - The data were compiled as before. Additional data were dam's weight at weaning (WWN), weight change between weaning and calving (WWN-WCV) and the period (days) from calving to weaning. Other details of the data structure are presented in Table 6.

3.4 STATISTICAL ANALYSIS

The sources of variance and covariance for calving interval were analysed using the generalised least-squares regression methods for multiple classifications and non-orthogonal data as described by Harvey (1960) and adapted by Seebeck (1976) in his computer programme SYSNOVA (Version 8). By simultaneous consideration of the various factors such as breed, age of dam, period of conception, weight of dam etc that may have some influence on, in this case, calving interval, the method of least-squares analysis allows determination of the magnitude of the separate effects of such factors by fitting constants for each one of them. Classification of the sources of variation for experiments 1, 2 and 3 has been presented in Tables 2,4 and 5 respectively. In experiment 2, the type of nutrient i.e energy or energy plus nitrogen was evaluated as a hierarchical (nested) effect within the pre-parturient supplemental regime only. The covariables evaluated have been described in sections 3.3.1.2, 3.3.2.5 and 3.3.3.3.

All effects were considered fixed. The estimate of the mean squares attributable to any effect was computed after all other effects in the model had been fitted and was tested against that of the residual. In addition to the estimate of the coefficients and the mean squares for effects, the SYSNOVA programme obtained estimates of the following: -

- standard error (S.E) of the difference between coefficients for the levels within each class which permitted the testing of the significance of the differences.
- homogeneity of the residual within-cell variances (χ^2)
- variation in calving interval accounted for by the model used (R^2).
- remaining interaction mean square and its significance.
- the residuals which were subsequently mapped out to get some idea of their distribution.

The generalised model used for analysis was:

$$y_{ijkl} = \mu + a_i + b_j + c_{jk} + (ab)_{ij} + (ad)_i + d(D_{ijkl} - D) + e_{ijkl}.$$

$i = 1,2,.......,p$

$j = 1,2,.......,q$

$k = 1,2,.......,r$

$l = 1,2,.......,n_{ijk}$

s = no. of AB sub-classes

where,

y_{ijkl} = calving interval of an individual cow.

μ = effect common to all cows

a_i = effect of the ith A class after removal of μ

b_j = effect of the jth B class after removal of μ

c_{jk} = effect of the kth C class within the jth B class, after removal of the jth B class.

$(ab)_{ij}$ = effect of the ijth AB subclass after the average effects of A and B have been removed.

$(ad)_i$ = effect of an interaction between A and the continuous variate D_{ijkl}. This interaction between a treatment and a covariate enables particular slopes to be fitted.

d = partial regression coefficient of calving interval y_{ijkl} on D_{ijkl} averaged over the p levels of a.

D_{ijkl} = an independent continuous variate.

e_{ijkl} = random effects which are assumed to be normally and independently distributed with a mean of zero and a common variance of σ^2.

Various models were tested for each experiment. However, the choice of the most appropriate model was based upon a combination of the following criteria:

- minimising the residual mean square.
- ensuring that the residual within-cell variances did not depart significantly from homogeneity.
- omitting terms that contributed little to the total variation.
- maximising R^2.
- the distribution of the residuals did not indicate any trend departing from random.

CHAPTER 4

RESULTS

4.1 EXPERIMENT 1 - EVALUATION OF BREED TYPE AND ENVIRONMENTAL FACTORS AFFECTING CALVING INTERVAL.

4.1.1 Selection of data set and general features

A preliminary analysis was done on data from all the animals classified according to the period taken before joining with the bulls. The results indicated an extremely high and significant ($P<0.005$) chi-square of the order of 240 for 71 degrees of freedom which indicated a lack of homogeneity of residual within-cell variances. This meant that sampling of the animals used was most unlikely to be from the same population. Besides, the mean squares for the remaining interactions were highly significant ($P<0.005$) which indicated that some of the important interactions between the main effects included in the model were not tested. Unfortunately, when such interactions were included for evaluation, fitting of constants could not be done succesfully as some of the variables fell below the 0.000001 tolerance level set for

Sysnova. Consequently, at the risk of having to evaluate many models, the analysis proceeded with each group of animals separately. When this was done, the chi-squares and mean squares for remaining interaction dropped to non-significant levels. However, on scrutinising the results of the various groups, it was evident that there was no important additional information lost by excluding groups 3 and 5. This was not surprising, with group 3 being intermediate between groups 2 and 4. Although group 5 consisted of animals which, for various reasons, were difficult to bring into calf, the fact that they conceived subsequently made them behave in a manner similar to that of group 4. Consequently, only groups 1,2 and 4 were retained for final analysis.

The distribution of the 308 females selected for analysis was distinctly non-orthogonal (Table 2). Although there was some confounding associated with certain treatments such as heifers and the three year-old females or body weight changes and soil moisture index, this did not exceed the 0.000001 tolerance level set for Sysnova. Such a low tolerance level also permitted successful fitting of the various models which, invariably, included a number of covariables with quadratic effects.

4.1.2 Group 1 females

The set of regression coefficients for the various independent variates is presented in Appendix 1 while results of the variance and co-variance analysis are summarised in Table 7.

Year of "second" conception - Calving interval was significantly ($P<0.005$) influenced by the year during which animals conceived for the second time. The year effects are shown in Table 8 and Figure 2. Overall, females that conceived for a "second" time during 1976 had the longest calving interval and the effect during this period was significantly different from that of other years. Differences between effects arising from conception during 1973, 1975 and 1977 were marginal.

Breed type within conception periods - The distribution of animals and coefficients for this interaction are shown in Appendix 2 and presented graphically in Figure 3. The response in calving interval of the three breed types depended significantly ($P<0.05$) on the period during which the "second" conception occurred. The EASZ showed least variation in fertility across conception periods. Although the Borans exhibited a pattern that was similar to the EASZ during May to September conception periods,

Table 7 - Mean squares for breed and environmental factors affecting calving interval of group 1 females.

Source of variation	D.F.	Mean squares
Breed type	2	556
Dam's age at earlier calving	2	671
"Second" conception period (2nd. Conc.Pd.)	2	2194***
Year of "second" conception	3	3373***
Dam's previous parous state (Prev. Par.)	2	255
Soil moisture index (SMI1), Linear	1	4577***
W1BC-WCP, Linear	1	149
W1BC-WCP, Quadratic	1	2846**
Breed type X 2nd. Conc. Pd.	3	1216*
2nd. Conc. Pd. X Prev. Par.	4	579
2nd. Conc. Pd. X SMI1, Linear	2	1174**
2nd. Conc. Pd. X W1BC-WCP, Linear	2	71
2nd. Conc. Pd. X W1BC-WCP, Quadratic	2	1640**
Residual between cells	29	328
Residual within-cell	57	356

Homogeneity of residual within-cell variances:
χ^2 = 32.64, D.F. = 21.
Variance accounted for (R^2) = 73.7%

* $P<0.05$; ** $P<0.01$; *** $P<0.005$

W1BC-WCP = weight change from one month before conception to conception.

Table 8 - Differences (± S.E.) between coefficients for levels within year of "second" conception of group 1 females.

Year of conception	1975	1976	1977
1973(late)	25.88±11.02*	46.60±10.77***	11.71±11.21
1975		20.72± 8.32*	14.17± 7.10*
1976			34.89± 8.12***

*P<0.05; ***P<0.005

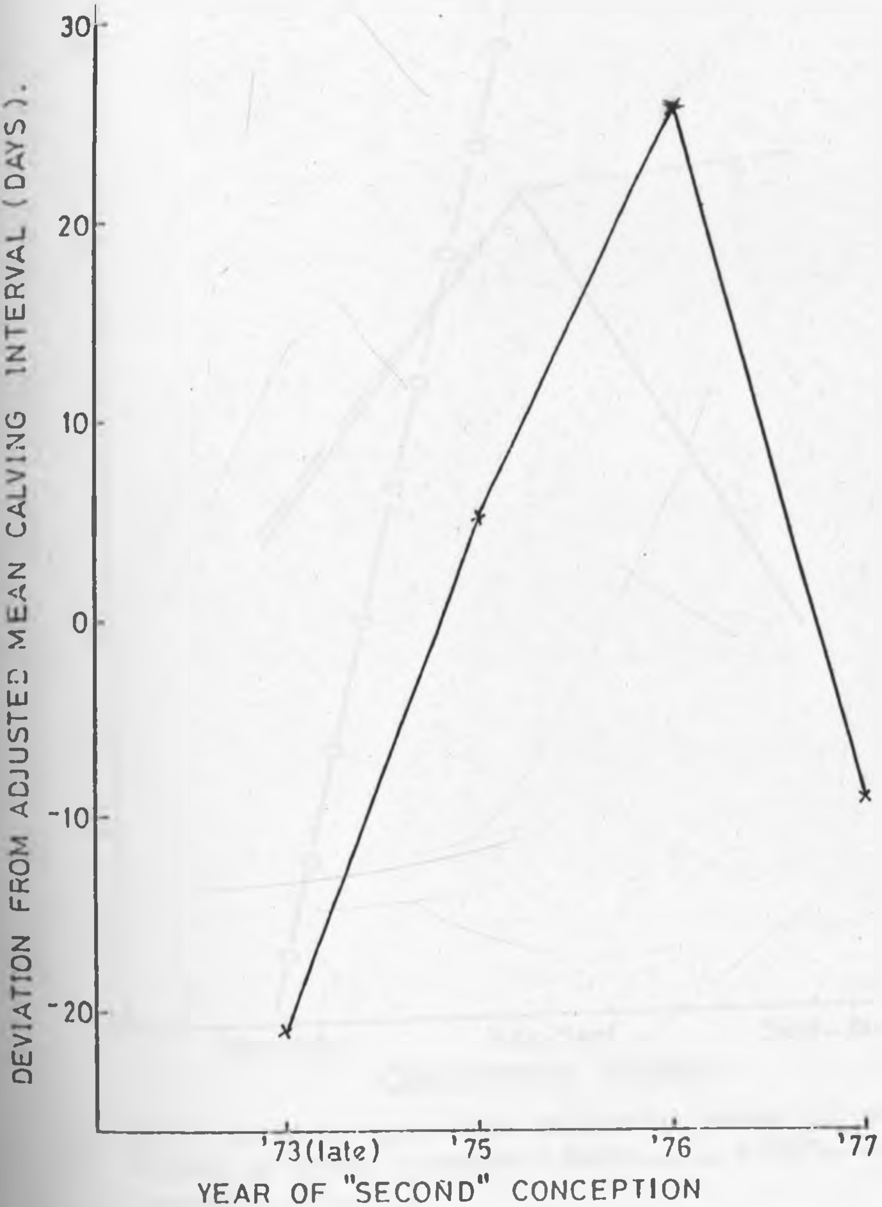

Fig. 2: Effect of year of "second" conception on calving interval of group 1 females.

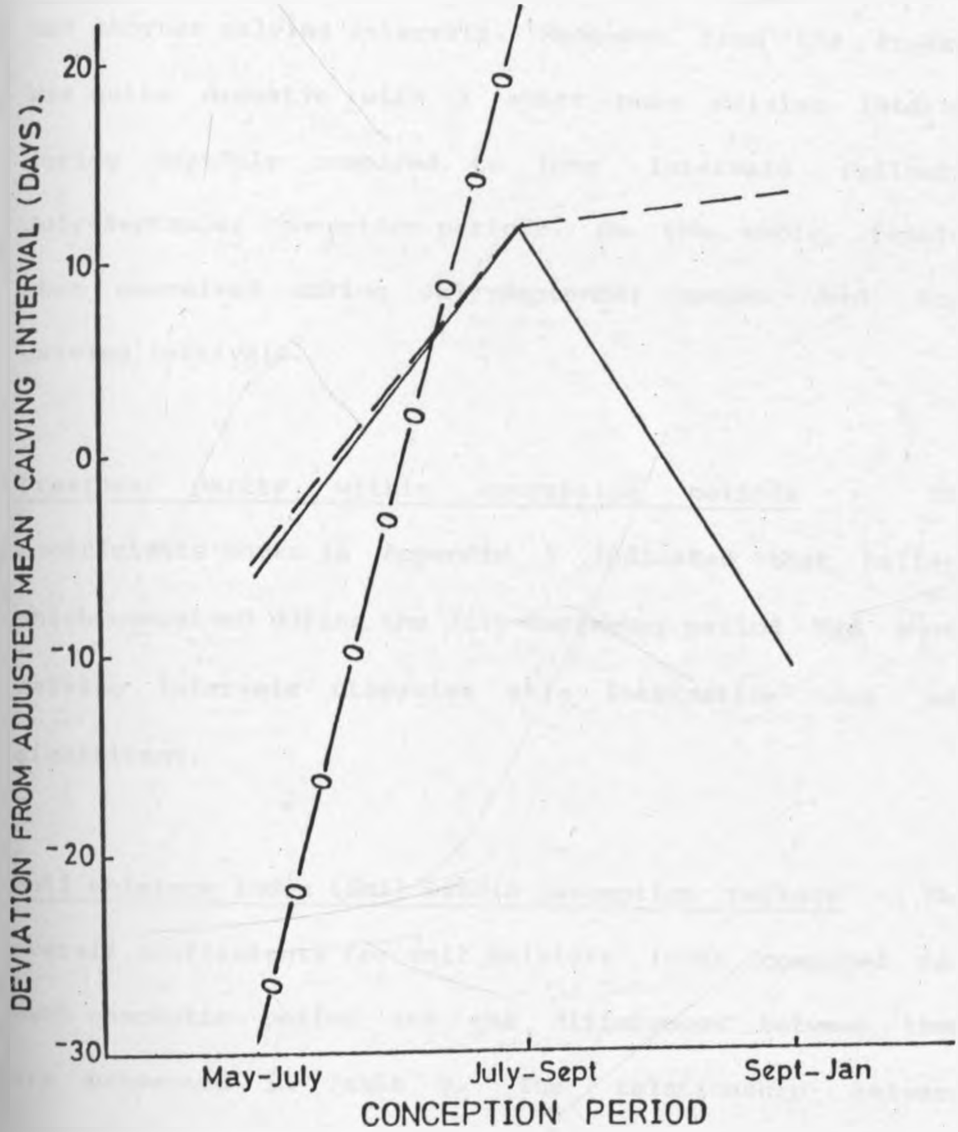

Fig 3: Effect of breed type within conception period on calving interval of group 1 females.(Boran ——, EASZ – – – –, Crosses —— 0 ——).
EASZ = small East African Shorthorn Zebu.

those that conceived during the September-January season had shorter calving intervals. Response from the crosses was quite dramatic with a short mean calving interval during May-July compared to long intervals following July-September conception periods. On the whole, females that conceived during July-September season had long calving intervals.

Previous parity within conception periods - The coefficients shown in Appendix 1 indicated that heifers which conceived during the July-September period had short calving intervals otherwise this interaction was not significant.

Soil moisture index (SMI) within conception periods - The overall coefficients for soil moisture index computed for each conception period and the differences between them are presented in Table 9. The relationship between calving interval and these two parameters is shown in Figure 4. A unit increase in SMI during the month preceeding conception resulted in a decrease in calving interval of approximately 14, 46 and 248 days for animals that conceived during May-July, July-September and September-January, respectively. The most marked effect occurred during the September-January period and this was significantly different from the other two periods.

Table 9 - Differences (± S.E.) between coefficients for soil moisture index (SMI1) within conception period of group 1 females.

Conception period	July-Sept. (-46.2)	Sept.-Jan.(-248.2)
May-July (-13.8)	32.4 ± 21.0	234.4 ± 82.3**
July-September		202.0 ± 84.4*

* $P<0.05$; ** $P<0.01$

Figures in parentheses are the overall interaction coefficients obtained by adding the coefficient for SMI1 (a covariate) to the conception period x SMI1 interaction coefficient. The same applies to subsequent tables regarding a treatment x covariate interaction.

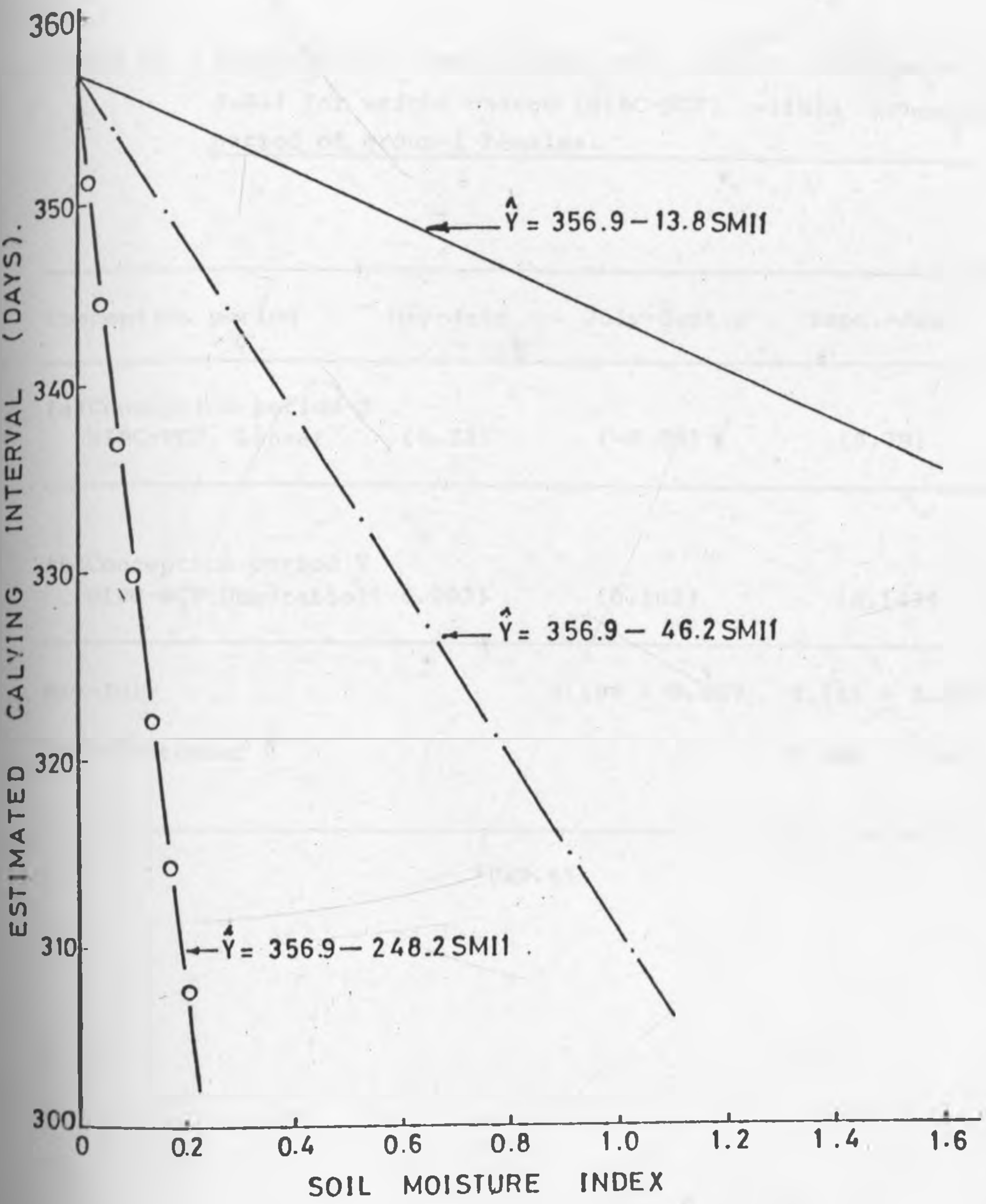

Fig. 4: Relationship between calving interval ($\hat{Y}$) and soil moisture index (SMI1) for each conception period of group 1 females (May - July ———; July-Sept —·—·—; Sept-Jan —0—).

Table 10 - Interaction coefficients and their differences (± S.E.) for weight change (W1BC-WCP) within conception period of group 1 females.

Conception period	May-July	July-Sept.	Sept.-Jan.
(a)Conception period X W1BC-WCP, Linear	(0.23)	(-0.09)	(0.79)
(b)Conception period X W1BC-WCP(Quadratic)	(-0.002)	(0.102)	(0.143)
May-July		0.104 ± 0.069	0.145 ± 0.051*
July-September			0.041 ± 0.08

*$P < 0.05$

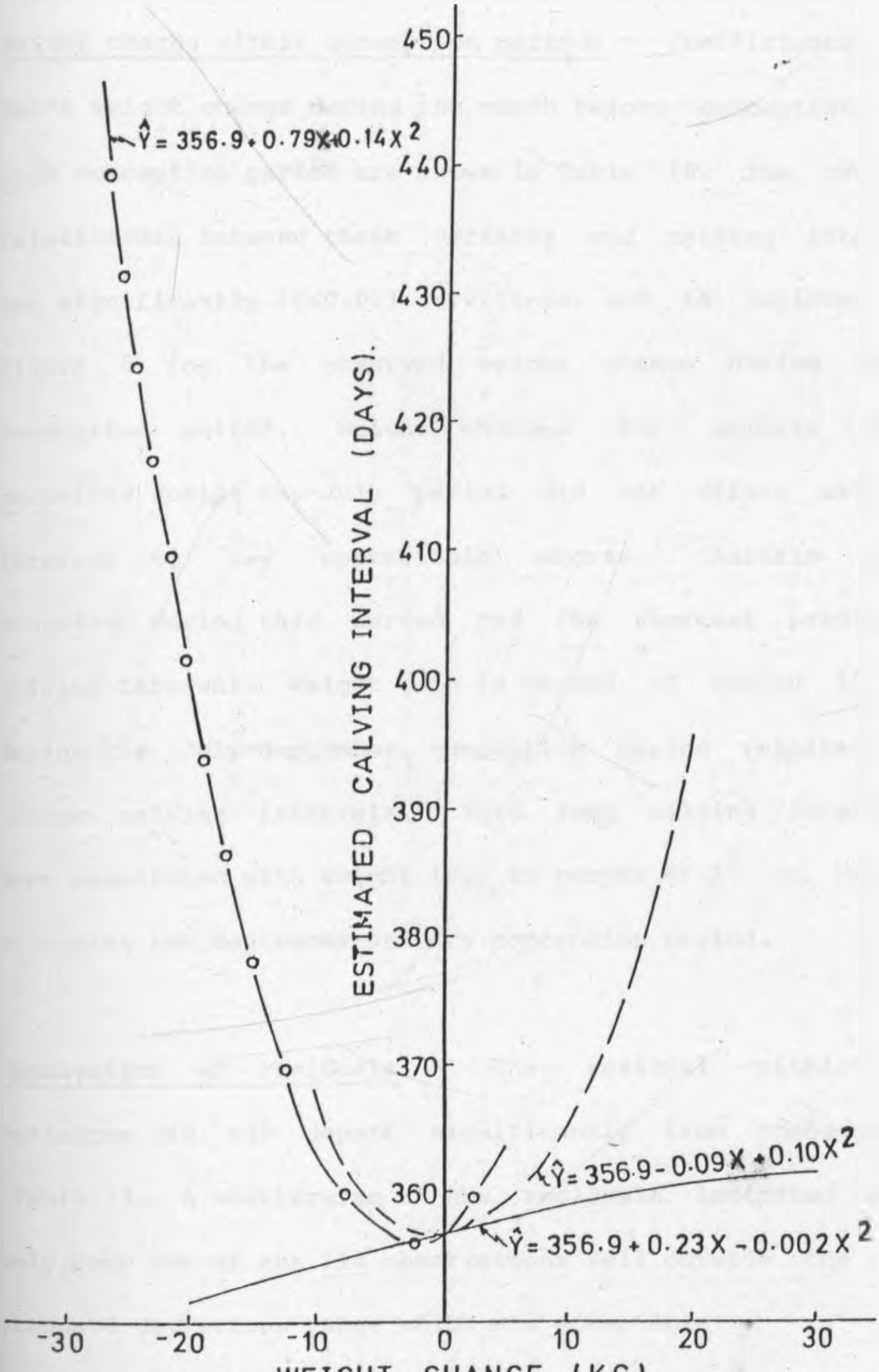

Fig.5: Relationship between calving interval ($\hat{Y}$) and dam's weight change during the month before "second" conception (W1BC - WCP) within conception periods of group 1 females.
(May to July_____, July to Sept_ _ _, Sept to Jan_o_).
X in regression equations = W1BC - WBC (kg).

Weight change within conception periods - Coefficients for dam's weight change during the month before conception for each conception period are shown in Table 10. The overall relationship between these variates and calving interval was significantly ($P<0.01$) curvilinear and is depicted in Figure 5 for the observed weight change during each conception period. Weight changes for animals that conceived during May-July period did not affect calving interval to any appreciable degree. Animals that conceived during this period had the shortest predicted calving interval. Weight gain in excess of around 10 kg during the July-September conception period resulted in longer calving intervals. Very long calving intervals were associated with weight loss in excess of 15 kg before or during the September-January conception period.

Examination of residuals - The residual within-cell variances did not depart significantly from homogeneity (Table 7). A scattergram of the residuals indicated that only four out of the 114 observations fell outside the two standard deviations range which was acceptable.

4.1.3 Group 2 females

The coefficients are given in Appendix 3 while results of the variance and co-variance analysis are summarised in Table 11.

Table 11- Mean squares for breed type and environmental factors affecting calving interval of group 2 females.

Source of variation	D.F.	Mean squares
Breed type	2	7
Dam's age at earlier calving (Age)	2	246
"Second" conception period (Conc.Pd)	3	3458***
Year of"second" conception(Yr.Conc.)	2	1043***
Dam's previos parous state	2	227
Soil moisture index, Linear	1	1753***
W2BC - W1BC, Linear	1	1826***
W1BC - WCP, Linear	1	682**
W1BC - WCP, Quadratic	1	1062***
Age X Conc. Pd.	3	590***
Conc. Pd. X W2BC - W1BC, Linear	3	1100***
Yr. Conc. X W1BC - WCP, Linear	2	1799***
Yr. Conc. X W1BC - WCP, Quadratic	2	869***
Residual between cells	15	71
Residual within-cell	55	100

Homogeneity of residual within-cell variances:

χ^2 = 27.30, D.F. = 21

Variance accounted for (R^2) = 91%

**P<0.01, ***P<0.005

W2BC - W1BC = weight change from two to one month before conception.

W1BC - WCP = weight change during the month before conception.

Soil moisture index - A unit increase in soil moisture index during the month prior to conception resulted in a highly significant ($P < 0.005$) overall reduction in calving interval of 19 days.

Dam's previous parity - The coefficients shown in Appendix 3 indicated that heifers averaged 20 days below the mean calving interval recorded for previously suckled cows. However, the overall effect of this factor was not significant.

Dam's age at calving within conception periods - The coefficients presented in Appendix 4 and Figure 6 depict the effect on calving interval of dam's age at the earlier calving, for each conception period. In general terms, the effect of dam's age depended significantly ($P < 0.005$) on the conception period. The three-year-old females that conceived during the January-March period had a mean calving interval which averaged 35 days longer than that of the 4-8-year-old animals. This trend continued into the May-July conception period although the difference in mean calving interval between the three year-olds and the other two age groups was reduced to 23 days. All the animals, irrespective of age, that conceived during the July-September period had long calving intervals averaging 62 days above the adjusted mean value.

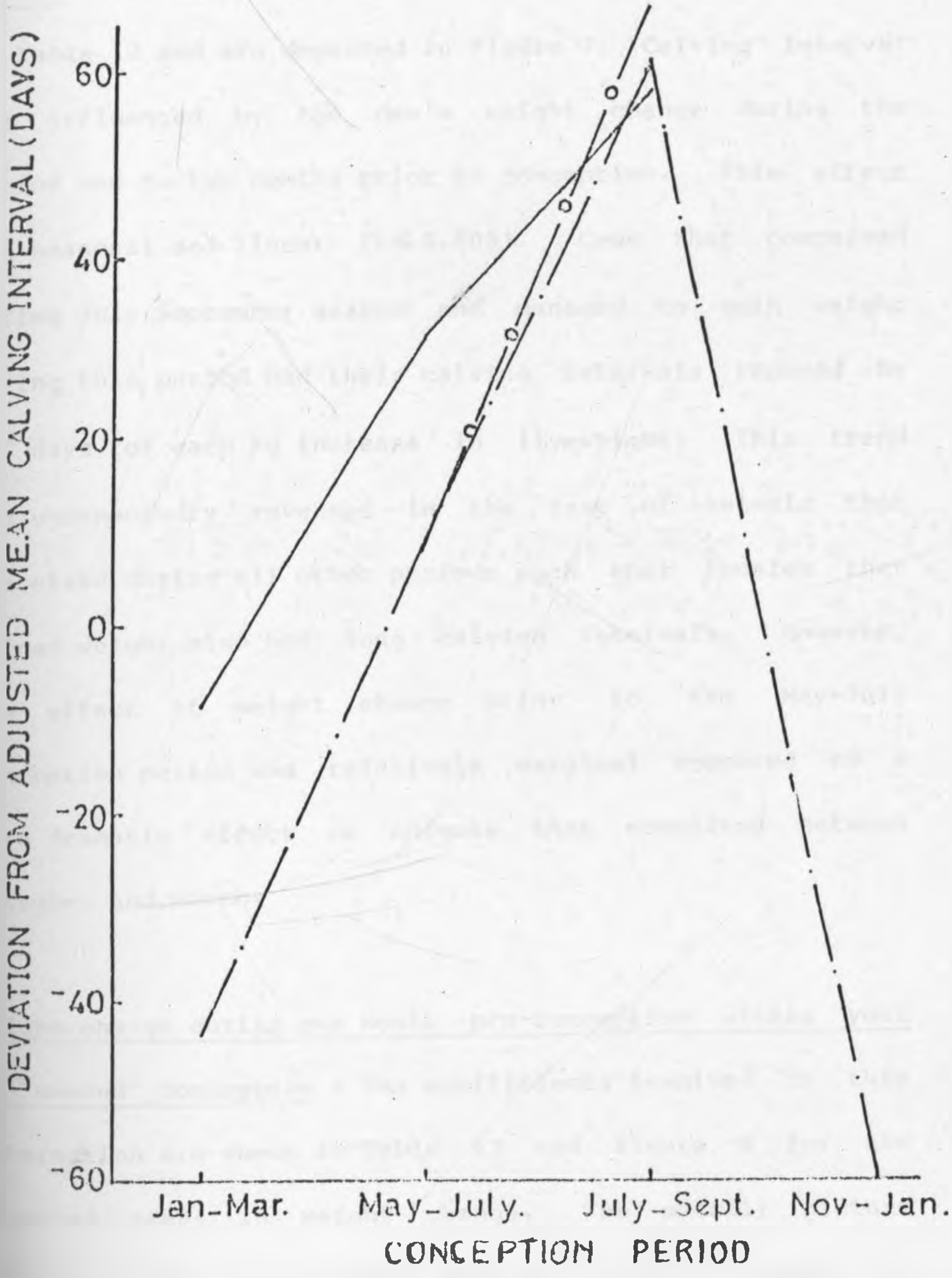

Fig.6: Effect of dam's age at calving within conception period on calving interval of group 2 females. (3 years ————, 4-8 ——·——, 9 and above —o——).

Weight change 1-2 months pre-conception within conception period - The coefficients for this interaction are given in Table 12 and are depicted in Figure 7. Calving interval was influenced by the dam's weight change during the period one to two months prior to conception. This effect was seasonal and linear ($P < 0.005$). Cows that conceived during July-September season and managed to gain weight during this period had their calving intervals reduced by 0.7 days for each kg increase in liveweight. This trend was unexpectedly reversed in the case of animals that conceived during all other periods such that females that gained weight also had long calving intervals. However, the effect of weight change prior to the May-July conception period was relatively marginal compared to a more dramatic effect on animals that conceived between November and March.

Weight change during one month pre-conception within year of "second" conception - The coefficients involved in this interaction are shown in Table 13 and Figure 8 for the observed range in weight change. The overall picture indicated that whereas weight gain during 1976 resulted in a systematic and sharp reduction in calving interval, this effect was hardly manifested during 1975. However, weight changes during 1973/74 caused considerable variation in calving interval. The overall relationship between calving

Table 12 - Differences (± S.E.) between coefficients for weight change one to two months before conception (W2BC - W1BC) for each conception period of group 2 females.

Conception period	May - July (0.43)	July - Sept. (-0.67)	Nov. - Jan. (2.30)
Jan.-March (4.66)	4.23 ± 1.17***	5.33 ± 1.20***	2.36 ± 1.26
May-July		1.10 ± 0.24***	1.87 ± 0.80*
July-Sept.			2.97 ± 0.84***

* $P<0.05$; *** $P<0.005$

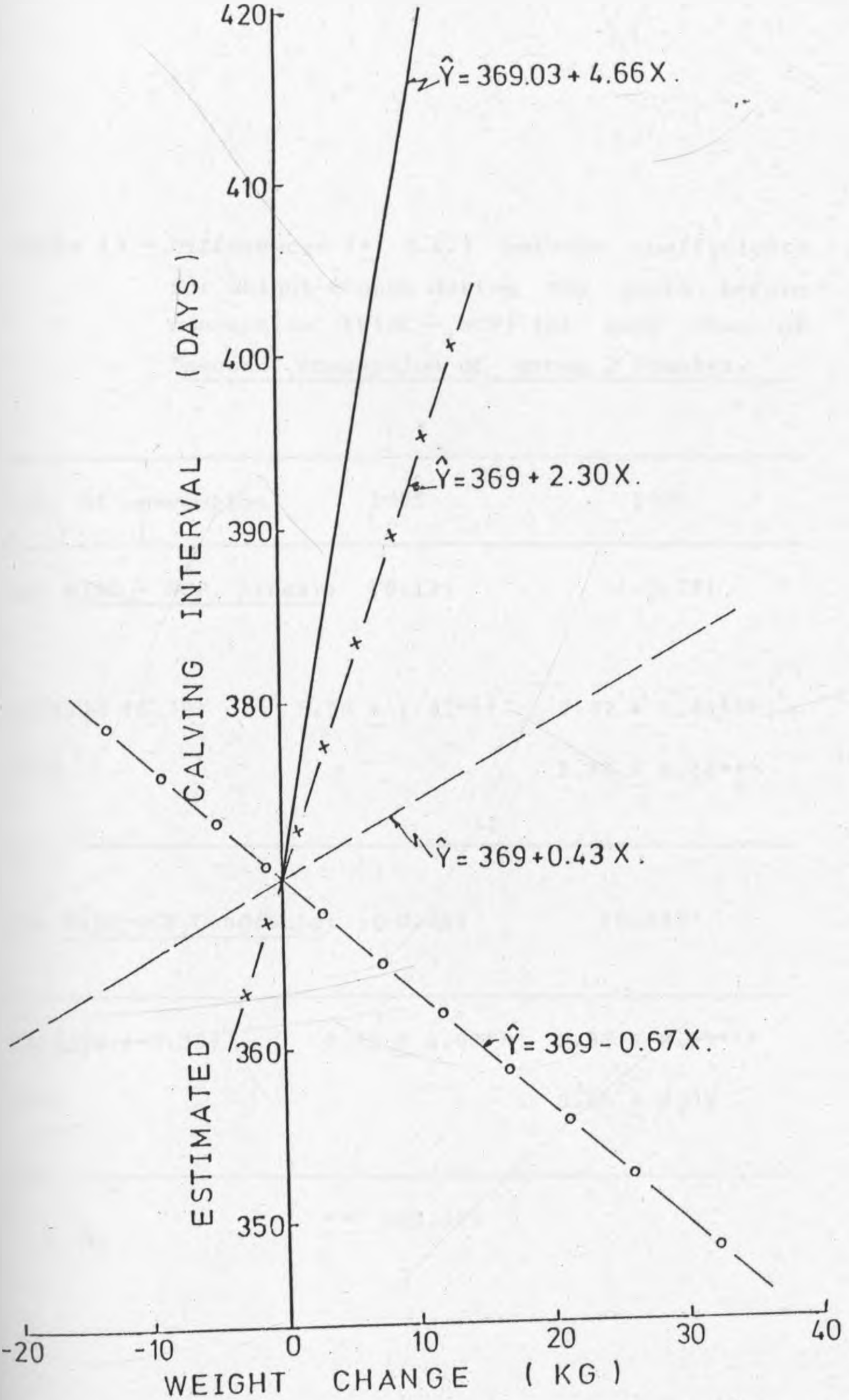

Fig. 7: Relationship between calving interval ($\hat{Y}$) and weight change from 2 to 1 month before conception (W2CP - W1CP) for each conception period of group 2 females. (Jan.-Mar. ——; May - July — —; July - Sept —o—; Nov.- Jan. —x—).

X = W2CP - W1CP (kg)

Table 13 - Differences (± S.E.) between coefficients for weight change during the month before conception (W1BC - WCP) for each year of "second" conception of group 2 females.

Year of conception	1975	1976
(a) W1BC - WCP, Linear:	(0.12)	(-1.77)
1973/74 (5.70)	5.58 ± 1.42***	7.47 ± 1.44***
1975		1.89 ± 0.44***
(b) W1BC-WCP, Quadratic:	(-0.01)	(0.04)
1973/74 (-0.33)	0.32 ± 0.08***	0.37 ± 0.09***
1975		0.05 ± 0.03

*** $P<0.005$

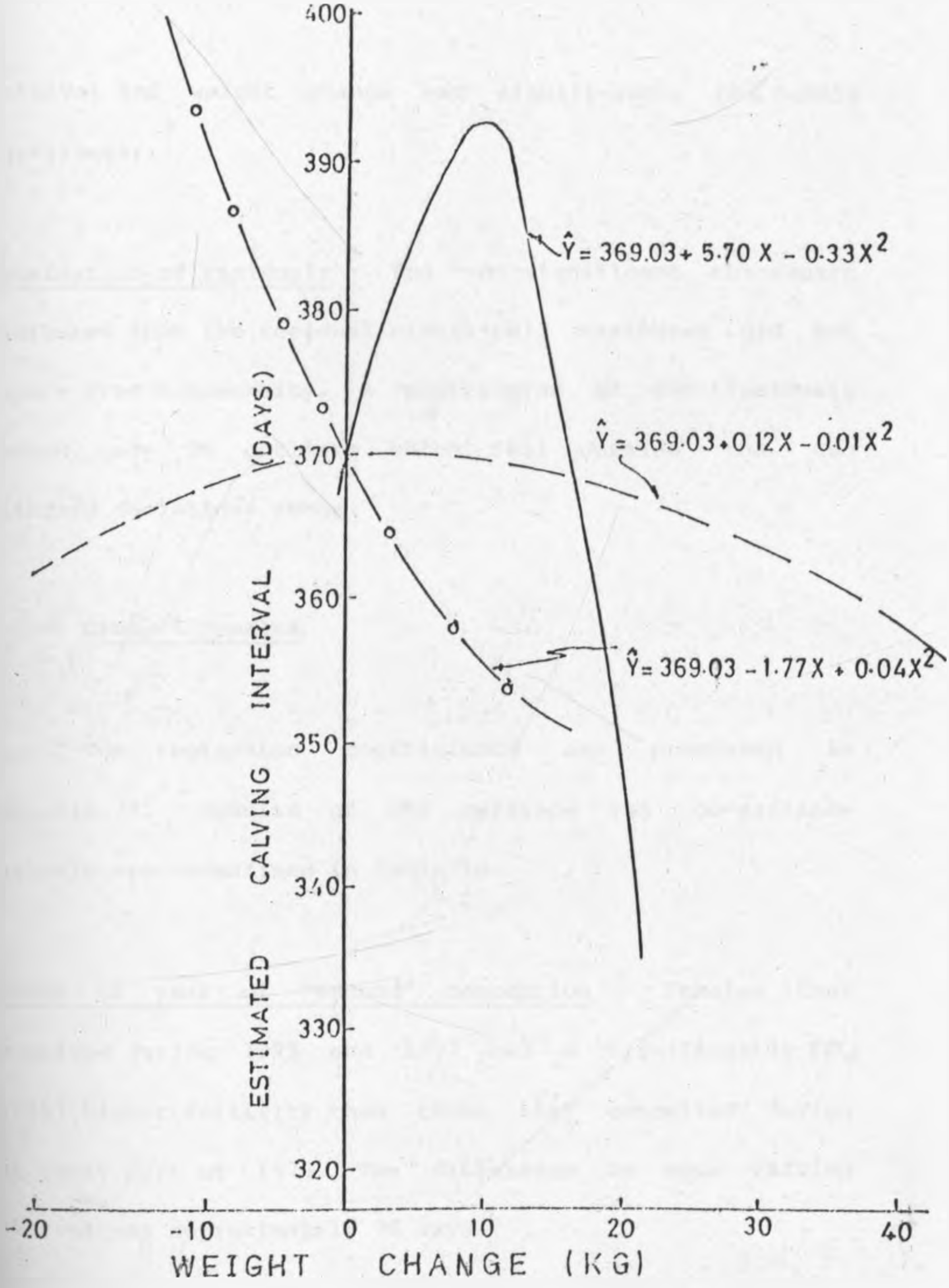

Fig. 8: Relationship between calving interval ($\hat{Y}$) and weight change during the month before conception (W1BC - WCP) within year of conception of group 2 females. (1973/74 ———, 1975 — — —, 1976 —— o ——)

$X = W1BC - WCP$ (kg).

interval and weight change was significantly ($P < 0.005$) curvilinear.

Examination of residuals - The non-significant chi-square indicated that the residual within-cell variances did not depart from homogeneity. A scattergram of the residuals showed only 3% outliers which fell outside the two standard deviations range.

4.1.4 Group 4 females

The regression coefficients are presented in Appendix 5. Results of the variance and co-variance analysis are summarised in Table 14.

Effect of year of "second" conception - Females that conceived during 1975 and 1977 had a significantly ($P <$ 0.005) higher fertility than those that conceived during the early part of 1973. The difference in mean calving interval was approximately 76 days.

Weight change 1-2 months prior to second conception - In general, an increase of one kg liveweight between one and two months before conception resulted in a highly significant ($P < 0.005$) increase in calving interval of 0.65 days.

Table 14 - Mean squares for environmental factors affecting calving interval of group 4 females.

Source of variation	D.F.	Mean squares
Dam's age at earlier calving	2	586
"Second" conception period (Conc. Pd.)	2	1547**
Year of "second" conception	1	2620***
Dam's previous parous state (Prev. Par.)	2	430
Soil moisture index (SMI1), Linear	1	8
Soil moisture index ($SMI1^2$)	1	78
W2BC - W1BC, Linear	1	2521***
W1BC - WCP, Linear	1	476
W1BC - WCP, Quadratic	1	596
Dam's weight at second conception	1	1936*
Conc. Pd. X Prev. Par.	4	821*
Conc. Pd. X SMI1	2	3729***
Conc. Pd. X $SMI1^2$	2	2943***
Conc. Pd. X W1BC - WCP, Linear	2	2559***
Conc. Pd. X W1BC - WCP, Quadratic	2	1865***
Residual	72	286

Homogeneity of residual within-cell variances:

χ^2 = 14.14; D.F. = 10

Variance accounted for (R^2) = 79%

* P<0.05; *** P<0.005

** P<0.01

Dam's weight at "second" conception - A unit increase in dam's weight at the "second" conception significantly ($P < 0.05$) reduced calving interval by 0.1 days. This parameter was evaluated in the earlier models of groups 1 and 2 described above but was found to be non-siginificant.

Previous parity within conception periods - The coefficients for this interaction are presented in Appendix 6 and are depicted graphically in Figure 9. The effect of the dam's previous parity on calving interval depended significantly ($P < 0.05$) on conception period. Previously suckled cows that conceived during the January-March period had calving intervals which were, on average, 20 days longer than those of dry cows. Heifers that conceived during March-July had a longer mean calving interval than dry cows or cows that reared calves during the previous year but they had the largest reduction in the interval following conception during November-January.

Soil moisture index within conception periods - The overall coefficients of this interaction are shown in Table 15. Once again, soil moisture index during the month prior to conception (SMI1) had a highly significant ($P < 0.005$) influence on calving interval depending on the conception period (Fig. 10). The overall relationship between these two parameters was significantly ($P < 0.005$) curvilinear. An increase in SMI1 during the January-March

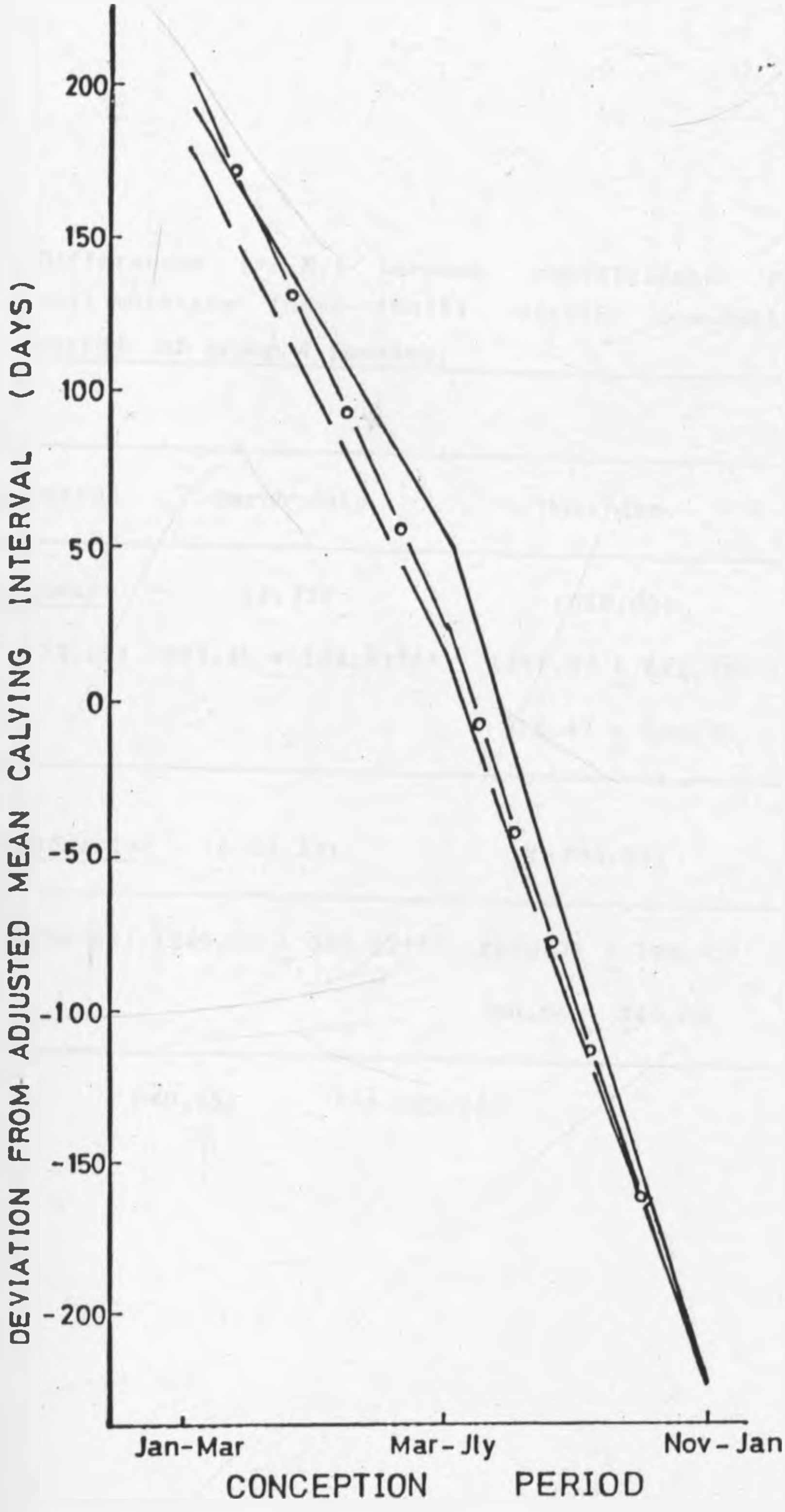

Fig.9: Effect of previous parity within conception period on calving interval of group 4 females (Heifer_____, Dry cow ___ ___ ___, Suckled ____ o ____).

Table 15 - Differences (+S.E.) between coefficients for soil moisture index (SMI1) within conception period of group 4 females.

Conception period	March-July	Nov.-Jan.
(a) SMI1, Linear:	(1.33)	(619.80)
Jan-March(-722.17)	723.35 ± 144.83***	1341.97 ± 621.70*
March - July		618.47 ± 606.35
(b) SMI1, Quadratic:	(-14.23)	(-794.09)
Jan-March (1226.42)	1240.65 ± 280.82***	2020.71 ± 799.72*
March-July		780.06 ± 749.00

* P<0.05; *** P<0.005

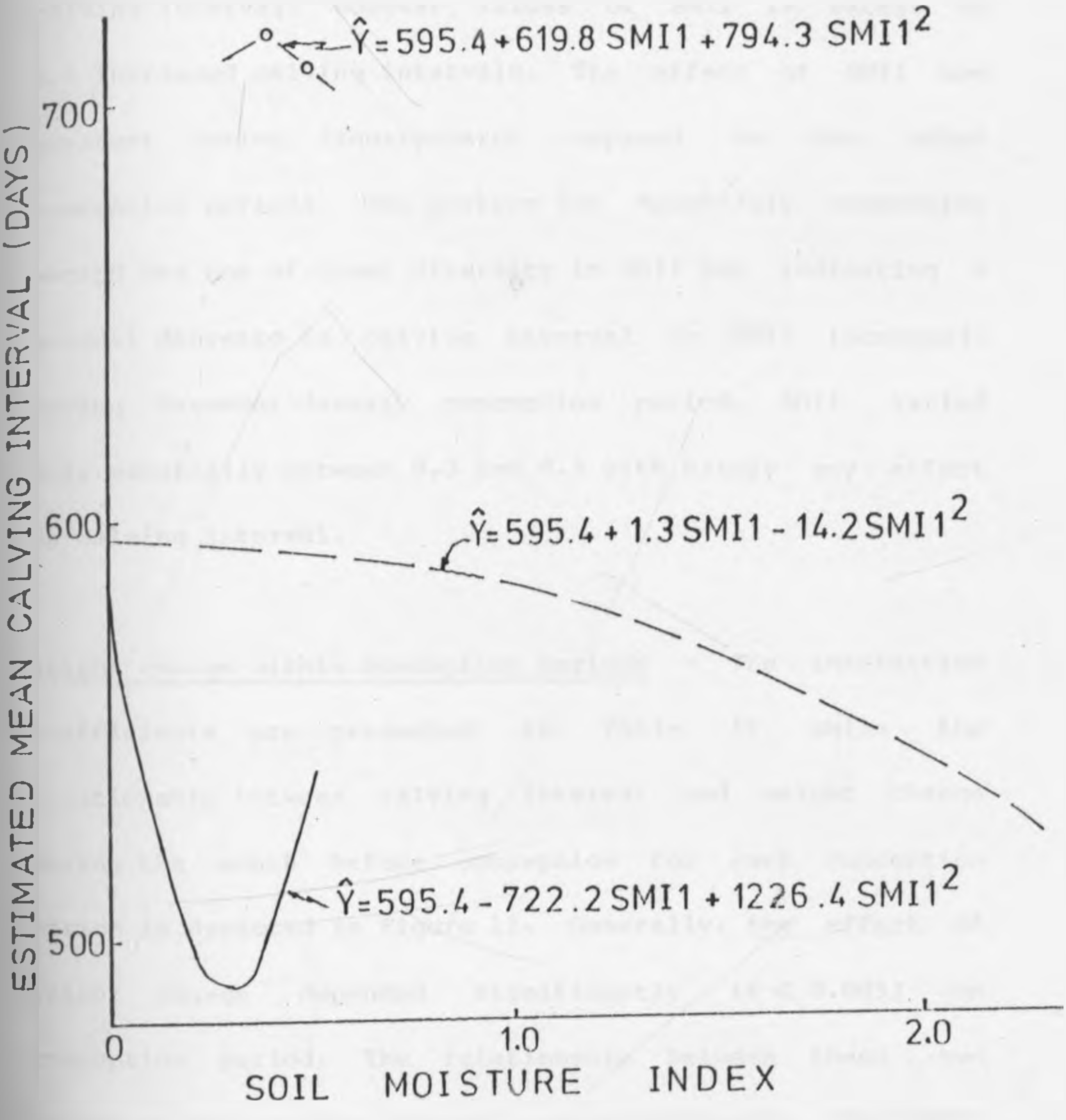

Fig.10: Relationship between calving interval ($\hat{Y}$) & soil moisture index (SMI1) within conception period of group 4 females. (Jan-Mar. ——, Mar-July — — — ; Nov-Jan. — o —).

conception period was associated with a reduction in calving interval. However, values of SMI1 in excess of 0.3 increased calving intervals. The effect of SMI1 was greatest during January-March compared to the other conception periods. The picture for March-July conception period was one of great diversity in SMI1 but indicating a gradual decrease in calving interval as SMI1 increased. During November-January conception period, SMI1 varied only marginally between 0.3 and 0.5 with hardly any effect on calving interval.

Weight change within conception periods - The interaction coefficients are presented in Table 16 while the relationship between calving interval and weight change during the month before conception for each conception period is depicted in Figure 11. Generally, the effect of weight change depended significantly ($P < 0.005$) on conception period. The relationship between these two variables and calving interval was significantly ($P < 0.005$) curvilinear. During January-March season, animals needed to gain weight in excess of 16 kg in order to reduce their calving intervals. The picture for March-July period was almost a complete reversal of the one just described such that while weight gains up to 25 kg resulted in shorter calving intervals, gains in excess of 25 kg caused longer

Table 16 - Differences (± S.E.) between coefficients for weight change during the month before conception (W1BC - WCP) within conception period of group 4 females.

Conception period	March-July	Nov.-Jan.
(a) W1BC-WCP, Linear:	(-4.23)	(1.59)
Jan.-March (6.61)	10.84 ± 2.69***	5.02 ± 2.53*
March - July		5.82 ± 1.98**
(b) W1BC-WCP, Quadratic:	(0.09)	(-0.02)
Jan.-March (-0.22)	0.31 ± 0.09***	0.20 ± 0.09*
March - July		0.11 ± 0.04**

* $P<0.05$; ** $P<0.01$; *** $P<0.005$

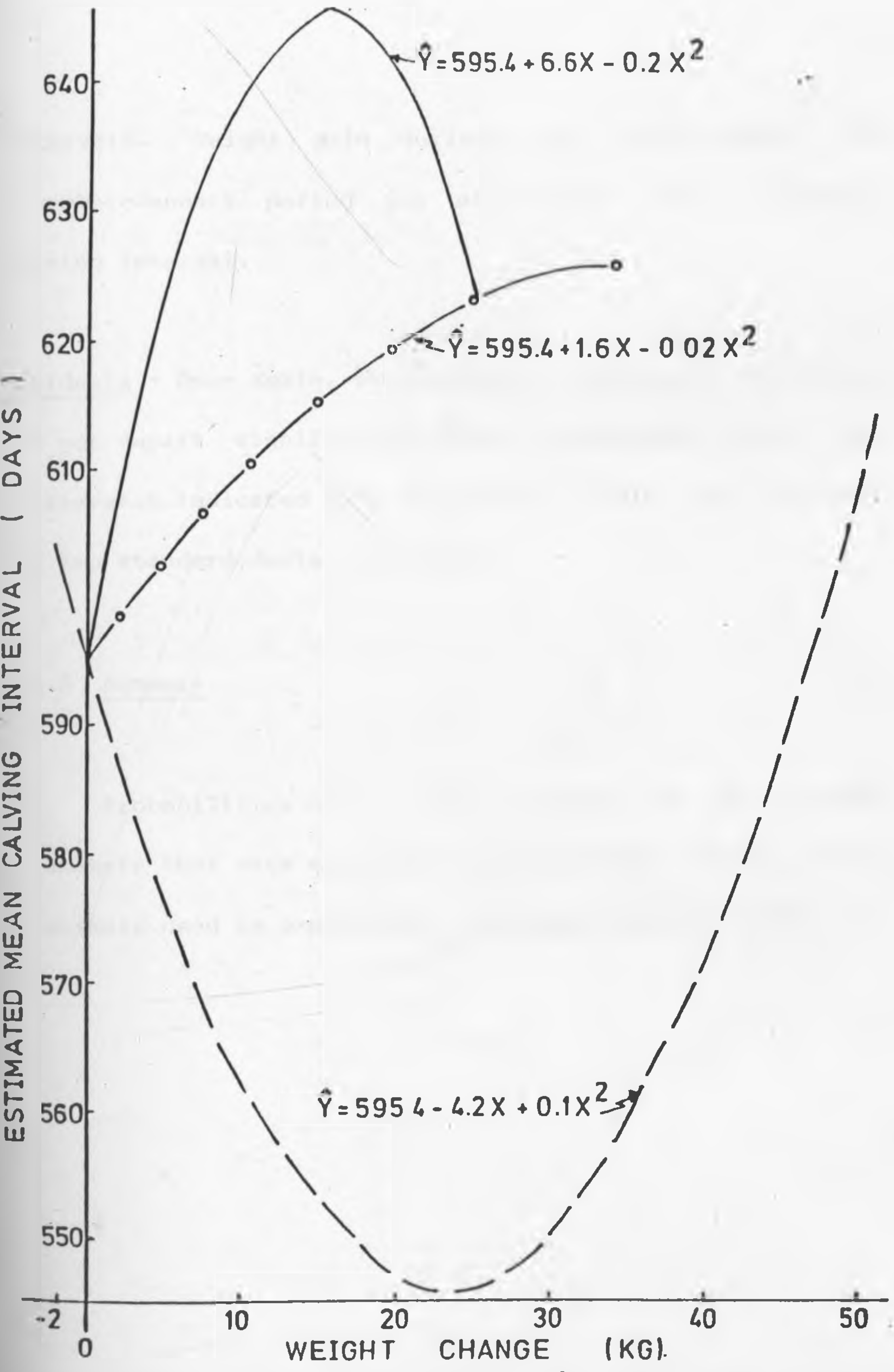

Fig. 11: Relation between calving interval ($\hat{Y}$) and weight change during the month before conception (W1BC - WCP) within conception period of group 4 females (Jan-Mar ——, Mar - July — —, Nov - Jan — o —).

X = W1BC - WCP (kg)

intervals. Weight gain during the month prior to November-January period was associated with increased calving interval.

Residuals - Once again, the residual within-cell variances did not depart significantly from homogeneity while the scattergram indicated only 3% outliers which fell outside the two standard deviations range.

4.1.5 Summary

Probabilities of the mean squares of the various parameters that were evaluated in each of the three groups of animals used in experiment 1 are summarised in Table 17.

Table 17 - A summary of the probabilities of mean squares for breed type and environmental factors affecting calving interval in experiment 1.

Source of variation	Groups 1	Groups 2	Groups 4
Breed type	NS	NS	
Dam's age at earlier calving (Age)	NS	NS	NS
"Second" conception period (Conc. Pd.)	***	***	*
Year of "second" conception (Year Conc.)	***	***	***
Dam's previous parous state (Prev. Par.)	NS	NS	NS
Soil moisture index (SMI1)	***	***	NS
Soil moisture index ($SMI1^2$)			NS
W2BC - W1BC, Linear		***	***
W1BC - WCP, Linear	NS	**	NS
W1BC - WCP, Quadratic	**	***	NS
Dam's weight at second conception			*
Breed type X Conc. Pd.	*		
Age X Conc. Pd.		***	
Conc. Pd. X Prev. Par.	NS		*
Conc. Pd. X SMI1	**		***
Conc. Pd. X $SMI1^2$			***
Conc. Pd. X W2BC - W1BC, Linear		***	
Conc. Pd. X W1BC - WCP, Linear	NS		***
Conc. Pd. X W1BC - WCP, Quadratic	**		***
Year Conc.X W1BC - WCP, Linear		***	
Year Conc.X W1BC - WCP, Quadratic		***	
R^2 (%)	74	91	79

* P<0.05, ** P<0.01, *** P<0.005

NS = non-significant.

4.2 EXPERIMENT 2 - EFFECT OF DRY SEASON SUPPLEMENTATION ON CALVING INTERVAL.

4.2.1 Overall results

The coefficients for the various variables are given in Appendix 7. Results of the variance and co-variance analysis are summarised in Table 18. Overall, the effect of breed type was relatively minor compared to the variation arising from environmental factors.

4.2.2 Sources of variation.

Duration of supplementation - For each day increase in the duration of supplementary feeding which ranged between 5 and 68 days, there was a significant ($P<0.05$) reduction in calving interval of 0.4 days.

Breed type - The results indicated a significant ($P< 0.01$) variation in calving interval due to breed type. Contrasts between the coefficients for the four breed types evaluated are given in Table 19. Of the two indigenous breed types, the EASZ had significantly ($P< 0.05$) shorter calving intervals than the Borans, a difference of about 17 days. The mean calving interval of the Boran crosses was approximately 19 days shorter

Table 18 - Mean squares for breed type and environmental factors affecting calving interval of supplemented beef cattle.

Source of variation	D.F.	Mean squares
Breed type	3	1661**
Dam's age at earlier calving (Age)	2	214
Dam's previous parous state (Prev.Par.)	1	55
Feeding regime	2	945
Nutrients (energy or energy + nitrogen)	1	449
Month of "earlier" calving	2	3321***
Year of "earlier" calving (Calving Year)	2	28
Duration of supplementation	1	1567*
Dam's weight at "earlier" calving, Linear	1	1449
Dam's weight at "earlier" calving, Quadr.	1	1127
W1ACV - WCP, Linear	1	3
W1ACV - WCP, Quadratic	1	2549*
Age X Feeding regime	4	1596***
Age X Month of "earlier" calving	4	1567***
Prev. Par. X Feeding regime	2	1296*
Feeding regime X Calving Year	4	1426**
Calving Year X W1ACV - WCP, Linear	2	1622*
Calving Year X W1ACV - WCP, Quadratic	2	312
Residual between cells	86	359
Residual within-cell	62	424

Homogeneity of residual within-cell variances:

χ^2 = 22.79; D.F. = 45

Variance accounted for (R^2) = 57%

Proportion of residuals exceeding two standard deviations of the regression = 2.2%

* $P<0.05$; ** $P<0.01$; *** $P<0.005$

W1ACV - WCP = dam's weight change (kg) between one month after earlier calving and subsequent conception.

Table 19 - Differences (± S.E.) between coefficients for breed type of supplemented beef cattle.

Breed type	EASZ	Boran crosses	EASZ crosses
Boran	17.32±6.76*	18.59 ± 6.75**	12.93 ± 7.00
EASZ		1.27 ± 8.77	4.39 ± 8.66
Boran crosses			5.66 ± 4.49

* $P<0.05$; ** $P<0.01$

(P<0.01) than that of pure Borans. However, differences between the indigenous EASZ and their crosses were not significant.

<u>Dam's age at "earlier" calving within calving month</u> - Coefficients for this interaction are shown in Appendix 8 and Figure 12. The effect of dam's age on calving interval was significantly ($P < 0.01$) influenced by the month of earlier calving. The four year-old animals that calved during February had calving intervals which averaged 42 days more than those of the older cows. Although there was a general reduction in calving intervals for all the animals that calved down during March, the decline with respect to the youngest animals was the most dramatic. There was a further reduction in calving interval of the 5-9-year-old cows which calved during April/May. The 10-year-old cows that calved during April/May had a longer mean calving interval than the other two age groups.

<u>Dam's age within feeding regime</u> - The distribution of animals and coefficients are given in Appendix 9. The effect of dam's age on calving interval depended significantly ($P < 0.005$) on the feeding regime (Figure 13). Under a purely grazing situation without any supplementation, the 5-9-year-old cows performed better

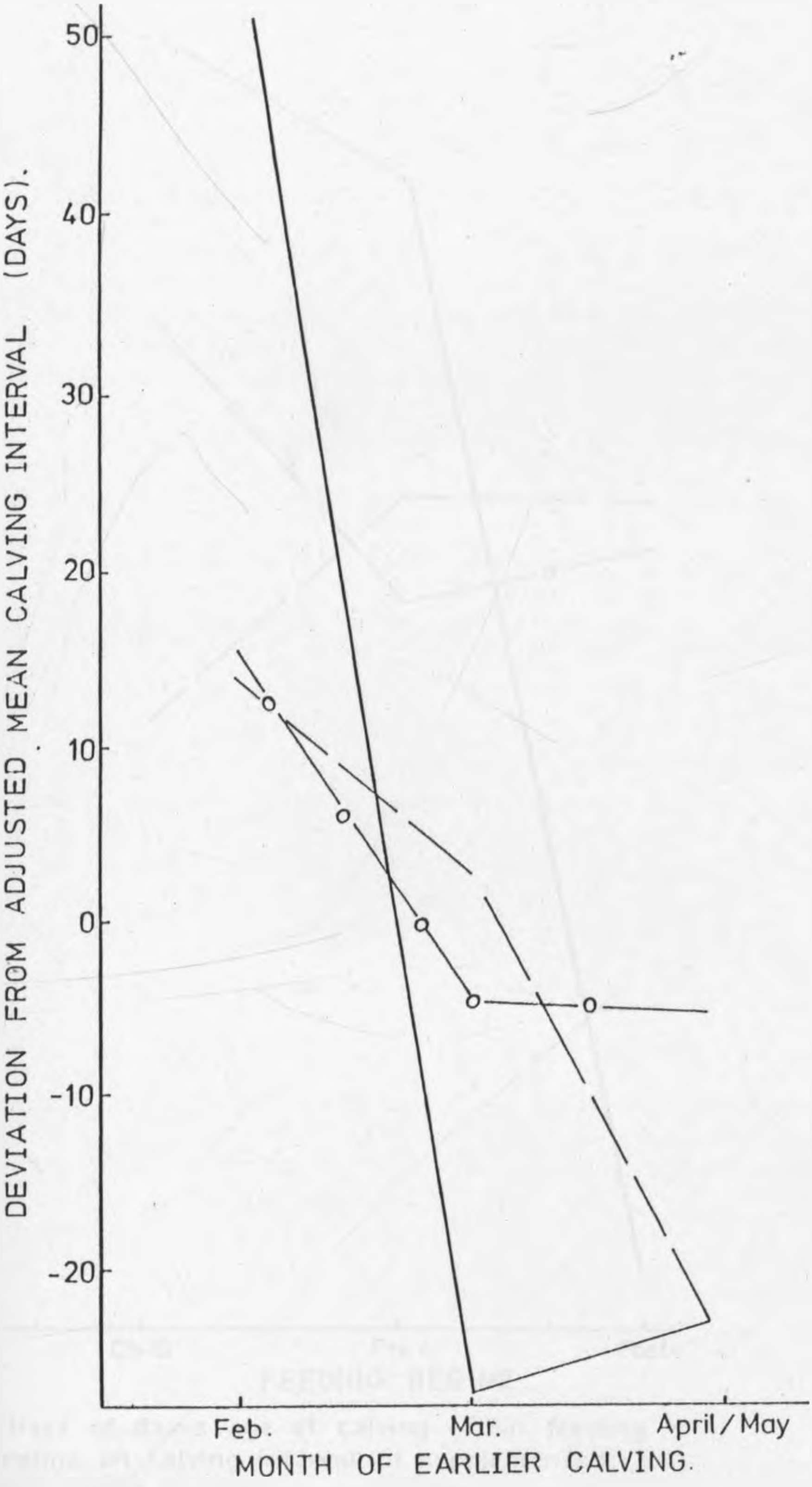

Fig.12: Effect of dam's age (years) within month of "earlier" calving on calving interval of supplemented beef cattle. (4, ———, 5 to 9, — — —, ≥10 —o—).

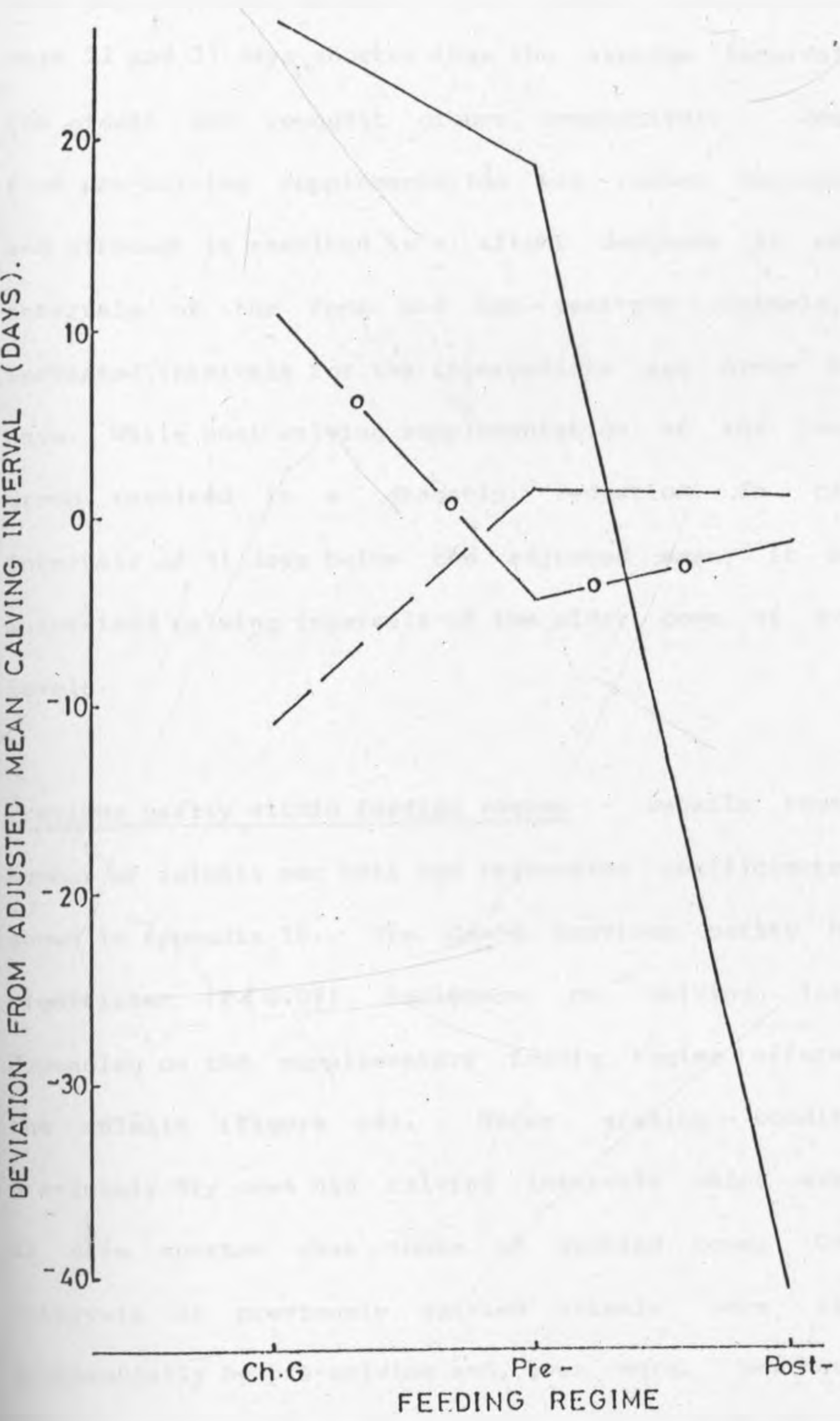

Fig.13: Effect of dam's age at calving within feeding regime on calving interval of supplemented beef cattle (4 years ———, 5 to 9 — — —, ≥10 —— o ——).

Ch.G= Chopped grass; Pre- and Post-parturient supplementation.

than the other age groups. Their mean calving intervals were 22 and 37 days shorter than the average interval for the oldest and youngest groups, respectively. Response from pre-calving supplementation was rather inconsistent and although it resulted in a slight decrease in calving intervals of the four- and ten-year-old animals, it increased intervals for the intermediate age group by 12 days. While post-calving supplementation of the youngest group resulted in a dramatic reduction in calving intervals of 41 days below the adjusted mean, it merely maintained calving intervals of the older cows at average levels.

Previous parity within feeding regime - Details regarding number of animals per cell and regression coefficients are shown in Appendix 10. The dam's previous parity had a significant ($P < 0.05$) influence on calving interval depending on the supplementary feedig regime offered to the animals (Figure 14). Under grazing conditions, previously dry cows had calving intervals which averaged 21 days shorter than those of suckled cows. Calving intervals of previously suckled animals were reduced substantially by pre-calving and, even more, post-calving supplementation. There was a tendency towards increased calving intervals when dry cows were supplemented before calving. However, their intervals were reduced following post-calving supplementation.

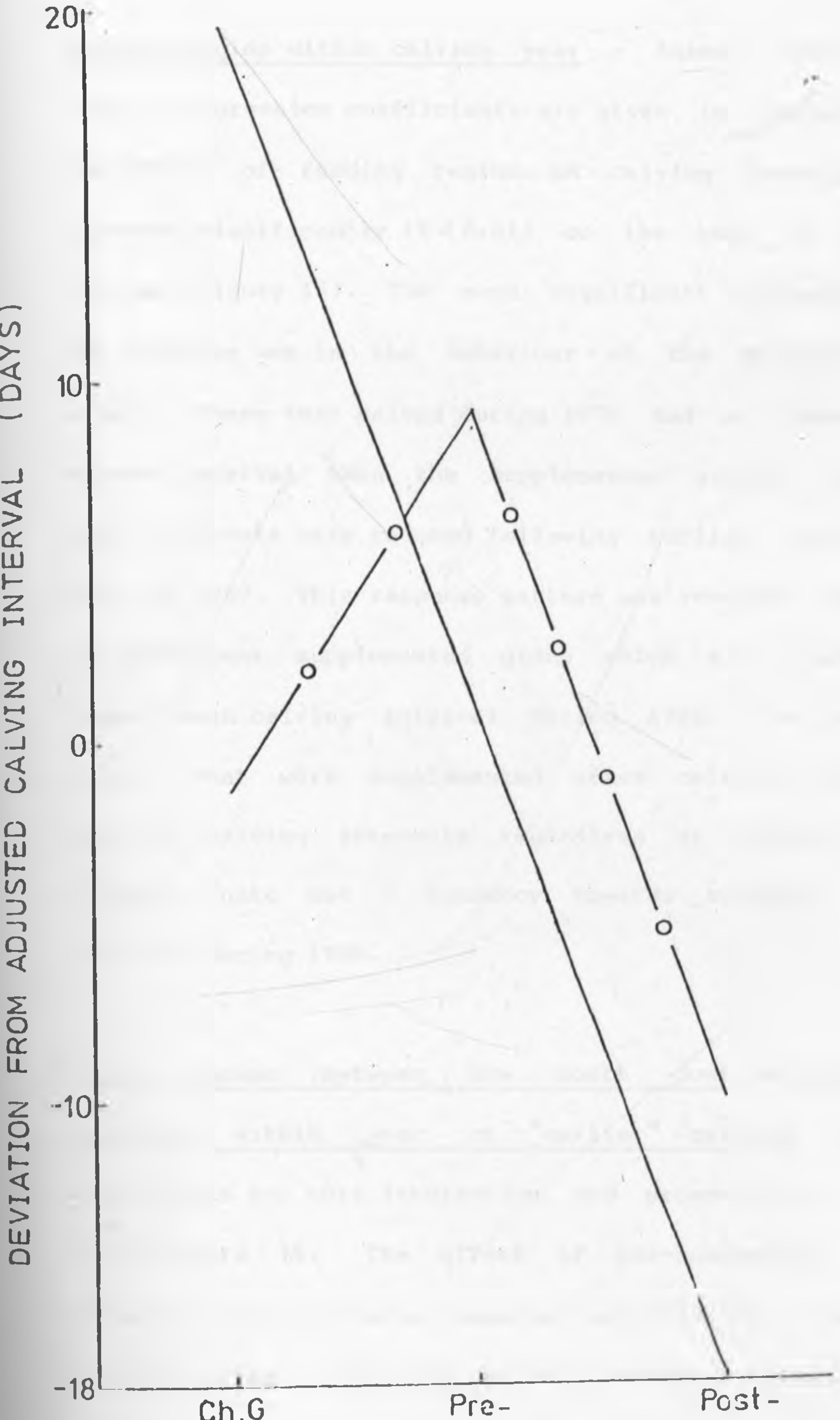

Fig.14: Effect of dam's previous parity within feeding regime on calving interval (Suckled ————, Dry cow —— o ——).
Ch.G = chopped grass; Pre- and Post-parturient supplementation.

Feeding regime within calving year - Animal distribution and the regression coefficients are given in Appendix 11. The effect of feeding regime on calving interval also depended significantly ($P < 0.01$) on the year of earlier calving (Figure 15). The most significant difference in the response was in the behaviour of the unsupplemented animals. Those that calved during 1978 had a longer mean calving interval than the supplemented groups. However, their intervals were reduced following earlier calving in 1979 and 1980. This response pattern was reversed for the pre-parturient supplemented group which also had the longest mean calving interval during 1980. In general, animals that were supplemented after calving had the shortest calving intervals regardless of calving year although there was a tendency towards slightly longer intervals during 1980.

Weight change between one month post-calving and conception within year of "earlier" calving - The coefficients for this interaction are presented in Table 20 and Figure 16. The effect of pre-conception weight change on calving interval depended significantly ($P < 0.05$) on calving year. Following the 1978 calving, animals that gained weight had their calving intervals reduced by 0.7 days for each kg weight increase up to about 25 kg. However, gains in excess of 40 kg were associated with

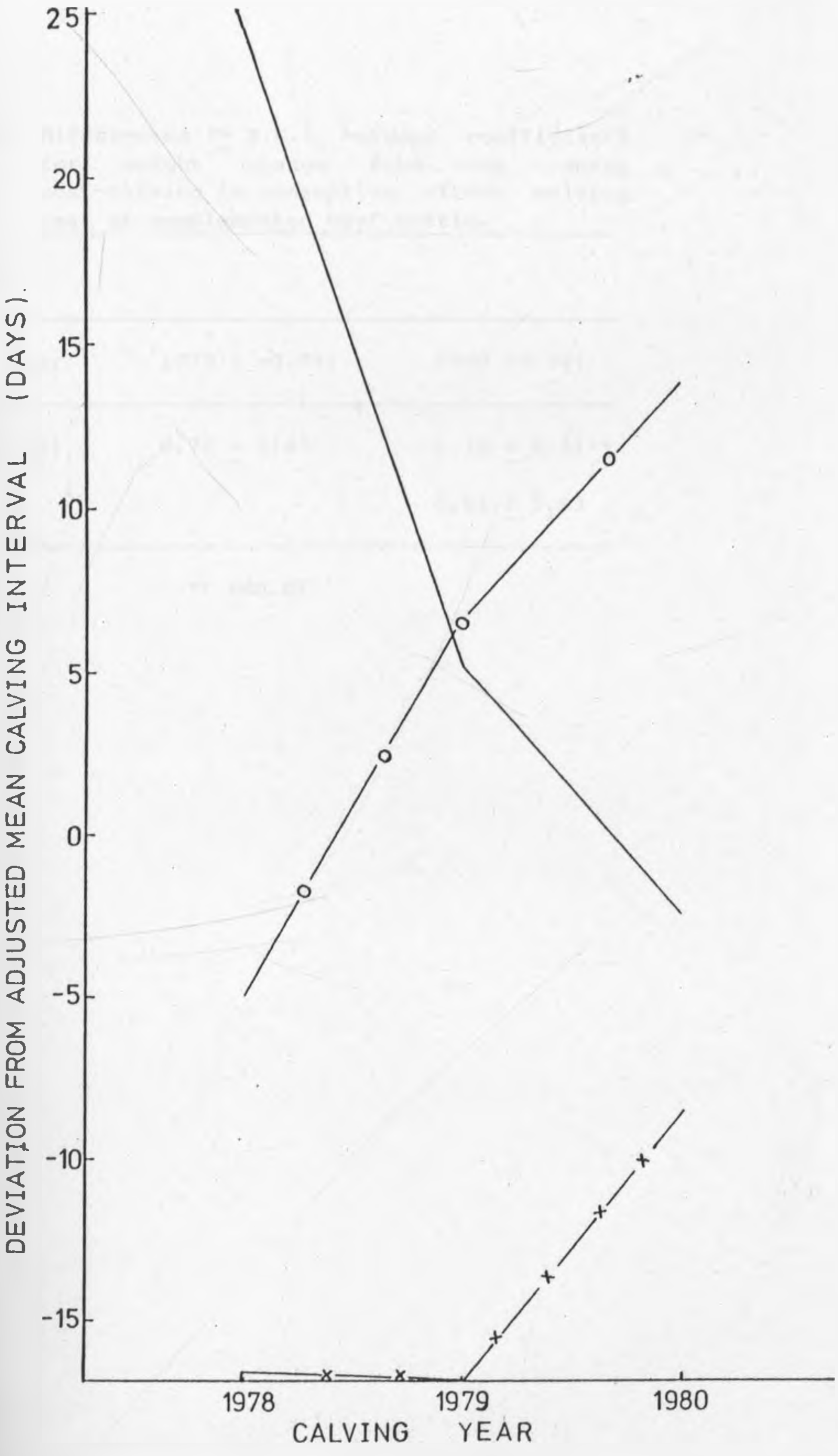

Fig. 15: Effect of feeding regime within calving year on calving interval (Chopped grass ———, Pre-parturient —o—, Post-parturient —x—).

Table 20 - Differences (± S.E.) between coefficients for weight change from one month post-calving to conception within calving year of supplemented beef cattle.

Calving year	1979 (-0.04)	1980 (0.74)
1978 (-0.65)	0.78 ± 0.49	1.39 ± 0.51**
1979		0.61 ± 0.63

** P<0.01

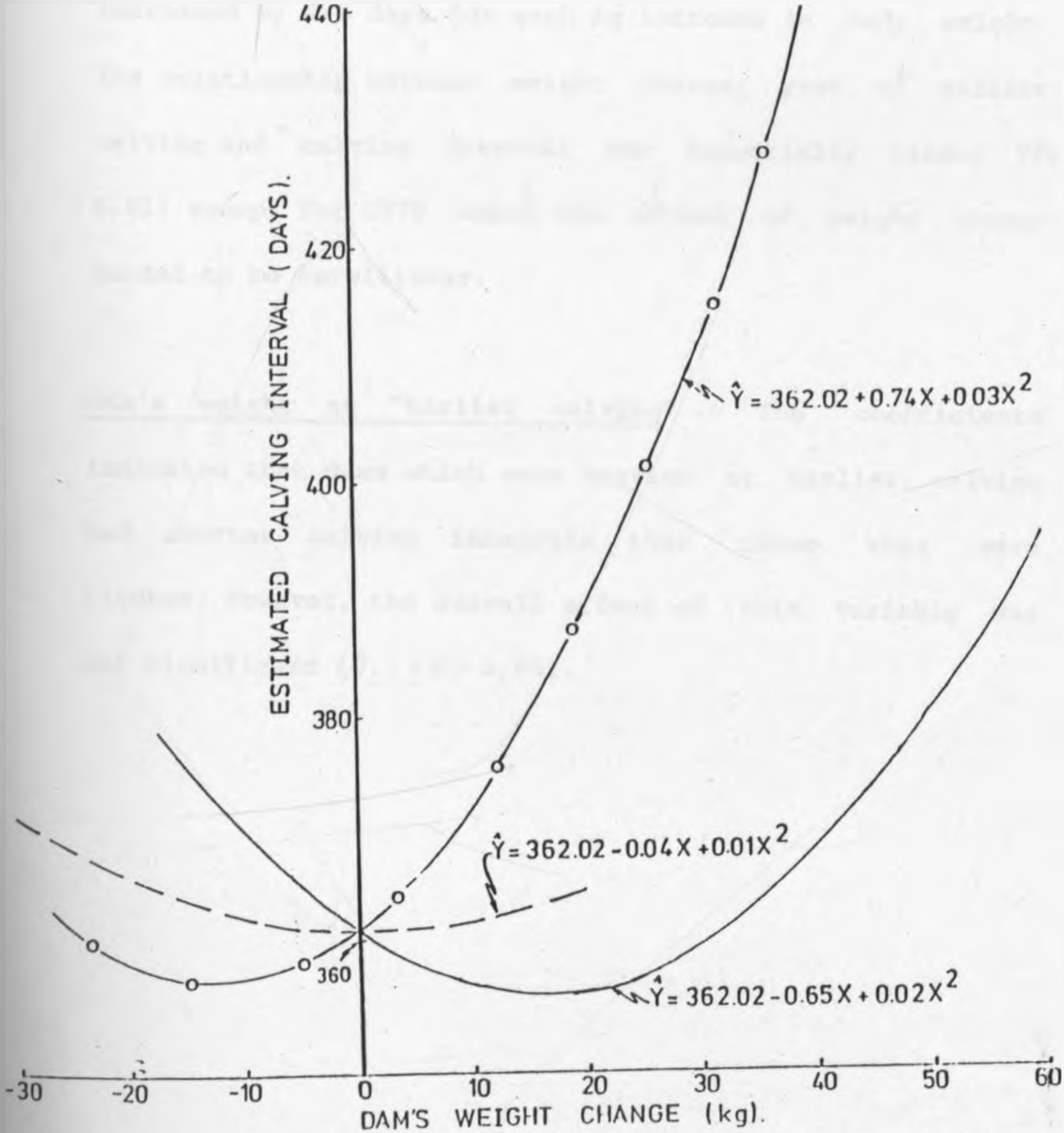

Fig. 16 : Relationship between calving interval ($\hat{Y}$) and weight change from one month post-calving to conception (W1ACV-WCP) within year of earlier calving of supplemented beef cattle. (1978 ———, 1979 —— —— ——, 1980 —— o ——).
X = W1ACV-WCP (kg).

increased calving intervals. Weight changes during 1979 hardly affected calving intervals. The trend following 1980 calving season was such that calving intervals increased by 0.7 days for each kg increase in body weight. The relationship between weight change, year of earlier calving and calving interval was essentially linear ($P < 0.01$) except for 1978 when the effect of weight change tended to be curvilinear.

Dam's weight at "earlier calving" - The coefficients indicated that dams which were heavier at earlier calving had shorter calving intervals than those that were lighter. However, the overall effect of this variable was not significant ($0.1 > P > 0.05$).

4.3 EXPERIMENT 3 - EFFECT OF WEANING MONTH AND WEANING PERIOD ON CALVING INTERVAL.

4.3.1 Overall results

The regression coefficients are presented in Appendix 12 while results of the analysis of variance and co-variance are summarised in Table 21. Variation in calving interval attributed to breed type was so small as to be excluded altogether.

4.3.2 Sources of variation

Weaning month - Variation in calving interval arising from weaning month *per se* was barely significant ($P < 0.05$). Whereas animals that had their calves weaned at the end of October had longer calving intervals, those whose calves were weaned at the end of November/December had a shorter mean calving interval (Table 22). There was a tendency for the four-year-old females which weaned their calves at the end of September to have shorter calving intervals than those which weaned at the end of October, otherwise the overall effect of weaning month was practically the same for the three age groups.

Table 21 - Mean squares for environmental factors affecting calving interval in the weaning trial.

Source of variation	D.F.	Mean squares
Weaning month	2	1573*
Weaning year	2	117
Dam's age at weaning (Age)	2	123
Month of "earlier" calving	2	2237*
Weaning period	1	2307*
Dam's weight at "2nd." conception, Linear	1	3733**
Dam's weight at "2nd." conception, Quadratic	1	3533**
WlACV - WCP, Linear	1	5
WlACV - WCP, Quadratic	1	1684
Age X Weaning month	4	716
Age X Weaning year	4	1334*
Age X Month of "earlier" calving	4	1256*
Weaning year X Month of "earlier" calving	4	860
Weaning year X Weaning month	3	798
Month of "earlier" calving X WlACV-WCP, Lin.	2	1226
Residual between cells	39	244
Residual within-cell	48	669

Homogeneity of residual within-cell variances:

X^2 = 26.72, D.F. = 29

Variance accounted for (R^2) = 59%

Proportion of residuals exceeding two standard deviations of the regression = 2.5%

* $P < 0.05$; ** $P < 0.01$

Table 22 - Differences (± S.E.) between coefficients for levels within weaning month.

Weaning month	End of October	End of Nov./December
End of September	14.28 ± 12.58	6.78 ± 9.99
End of October		21.06 ± 8.37*

* $P < 0.05$

Weaning period - Results suggested that for every day increase in the period before weaning was effected, there was a significant ($P<0.05$) increase in calving interval of 0.2 days over a weaning period between 154 to 289 days.

Dam's weight at "second" conception - The mean weight at conception was 351 kg with a range from 216 to 492 kg. The coefficients shown in Appendix 12 indicated that for each kg increase in weight at conception above the overall mean, there was a corresponding decrease in calving interval of 1.1 days. Although the quadratic term was significant, it was so small that, for all intents and purposes, the relationship between calving interval and dam's weight at second conception could be regarded as a linear one. This relationship is depicted in Figure 17. Extreme values of dam's weight at conception have been excluded.

Dam's age at weaning within weaning year - The coefficients are given in Appendix 13. The effect of dam's age on calving interval varied significantly ($P<0.05$) from year to year as indicated in Figure 18. Following the 1977 and 1979 weaning seasons, response was quite divergent with the four-year-old animals having shorter calving intervals than those of the older cows. Variation in calving interval was greatest with the ten-

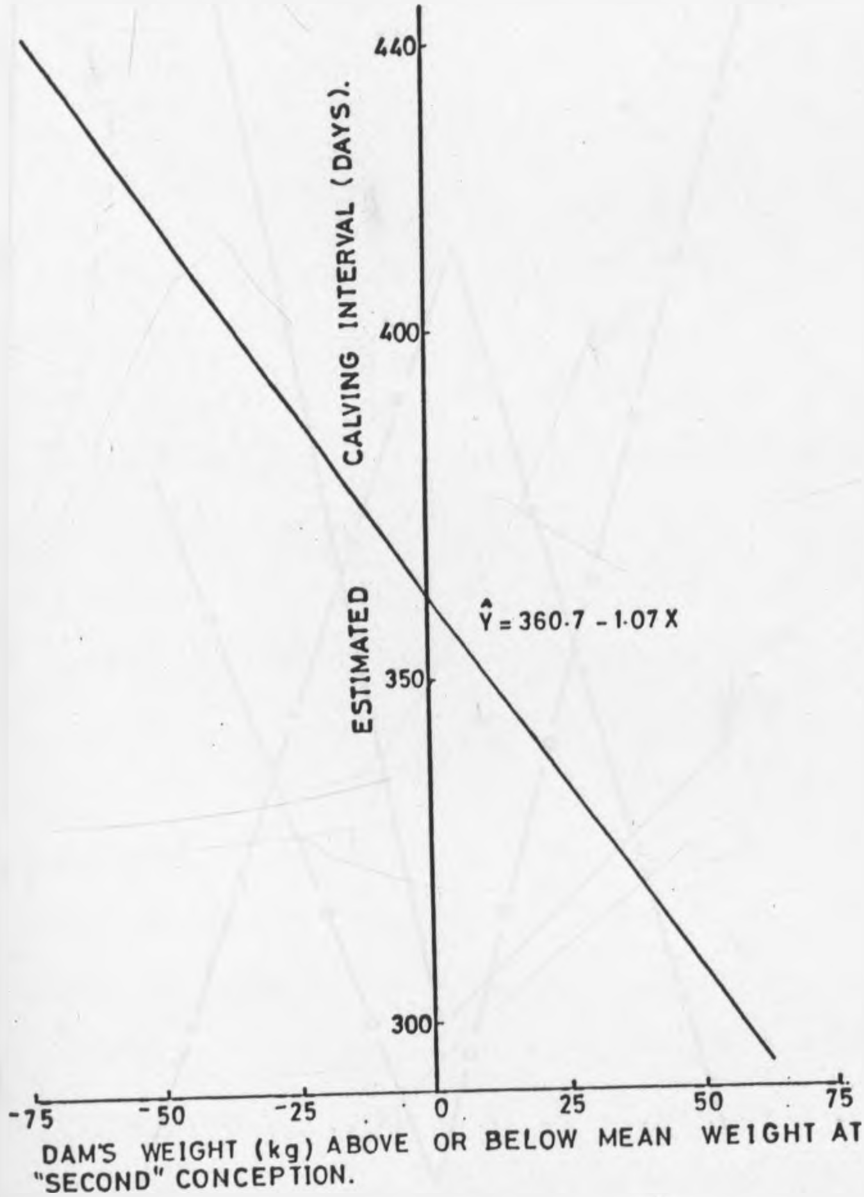

Fig.17: Relationship between calving interval ($\hat{Y}$) and dam's weight at "second" conception (X).

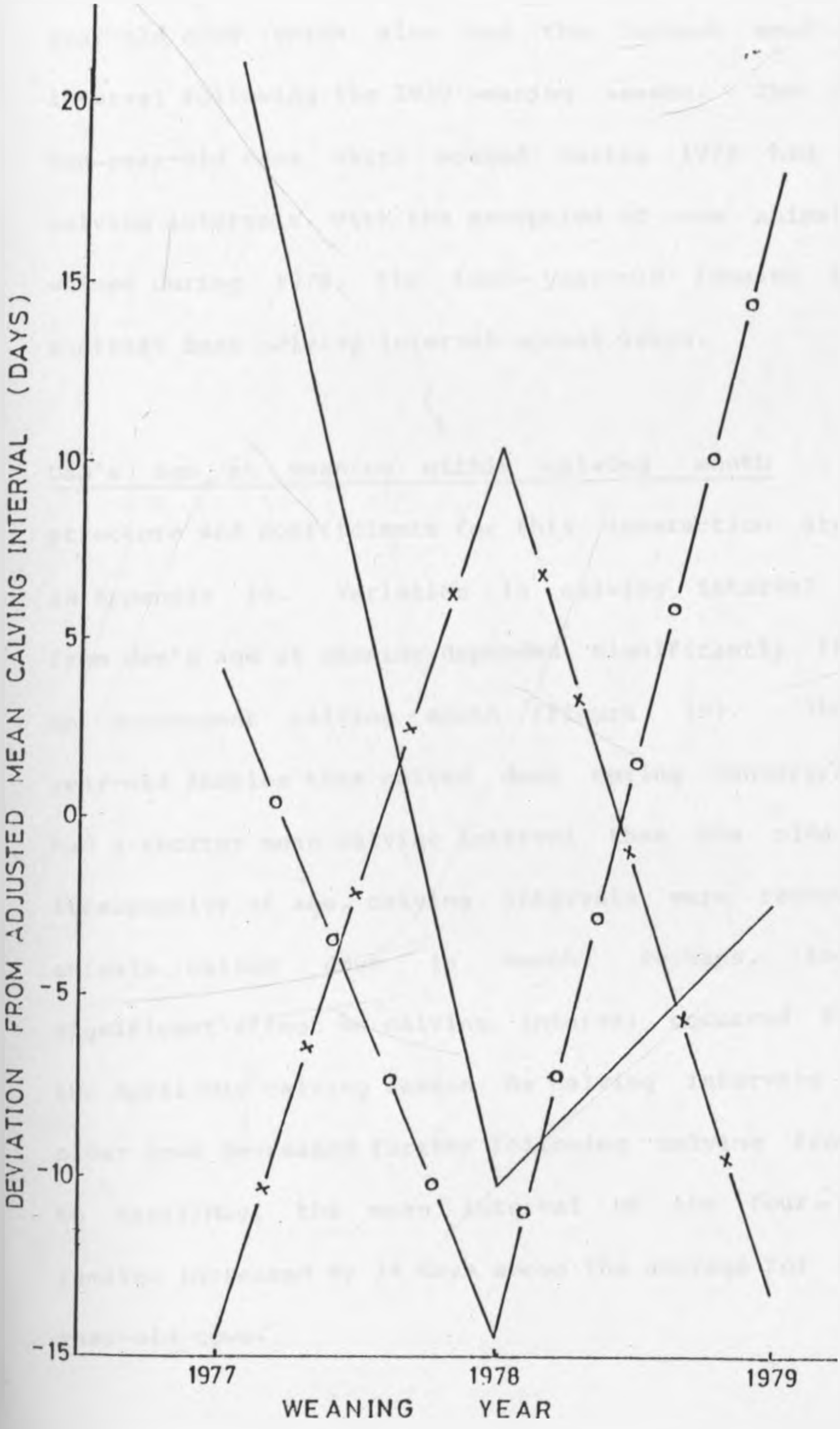

Fig. 18: Effect of dam's age (years) within weaning year on calving interval (4, —— x ——; 5 - 9, ————; ≥ 10, —— o ——).

year-old cows which also had the longest mean calving interval following the 1979 weaning season. The 5-9- and ten-year-old cows which weaned during 1978 had shorter calving intervals. With the exception of one animal which weaned during 1978, the four- year-old females had the shortest mean calving interval across years.

Dam's age at weaning within calving month - Data structure and coefficients for this interaction are shown in Appendix 14. Variation in calving interval arising from dam's age at weaning depended significantly ($P < 0.05$) on subsequent calving month (Figure 19). The four-year-old females that calved down during January/February had a shorter mean calving interval than the older cows. Irrespective of age, calving intervals were reduced when animals calved down in March. Perhaps, the most significant effect on calving interval occurred following the April/May calving season. As calving intervals of the older cows decreased further following calving from March to April/May, the mean interval of the four - year-old females increased by 34 days above the average for the 5-9- year-old cows.

Weight change from one month after calving to conception within calving month - The coefficiencts shown in Appendix 12 indicated that increase in body weight of animals that

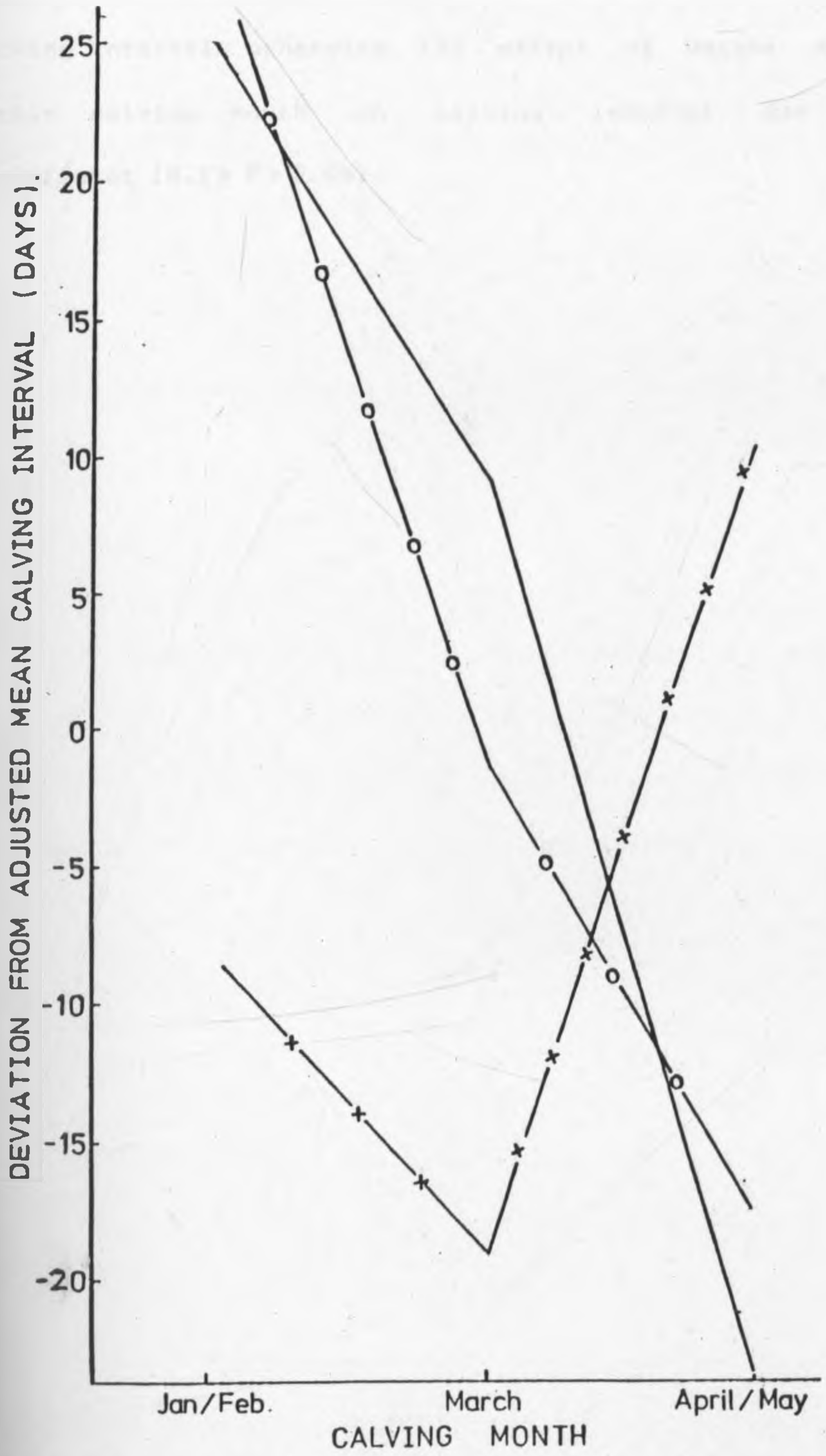

Fig. 19: Effect of dam's agé at weaning within subsequent calving month on calving interval (4years —— x ——, 5-9 years ————, ≥10 years —— o ——).

calved down during March was associated with shorter calving intervals otherwise the effect of weight change within calving month on calving interval was not significant ($0.1 > P > 0.05$).

CHAPTER 5

DISCUSSION

5.1 EVALUATION OF ANALYSIS AND REVIEW OF RESULTS

5.1.1 General remarks

It is intended to focus attention on the results of class 1 females, considered as the normal class and to review them as a basis for further discussion. Information from class 2 and 4 will be reviewed vis-a-vis that obtained from the normal class with emphasis on the salient points of divergence and possible explanations.

5.1.2 Evaluation of the models

Non-orthogonality of the data evaluated in the three experiments is clearly indicated in Tables 2, 4 and 6. Since some of the cells had very few observations, a number of levels in the conception period and year of "second" conception treatments in experiment 1 were combined to facilitate testing of interactions which meant that interpretation of the results had to be done rather cautiously. Not all interactions were tested. However,the results indicated that the variances of remaining interactions were nonsignificant and, therefore, unimportant. Because of missing observations in some of the cells and problems that would be encountered in interpreting the results, three-factor interactions were not evaluated. However, the chi-square tests revealed that the samples of animals used in the three experiments were from homogeneous populations.

All the models evaluated included body weight changes as covariables. In order to render effects of such weight changes comparable for small as well as large animals, a reference point of body weight at "second" conception was included in each model. This enabled evaluation of weight changes after differences in weight at conception had been accounted for.

It is worth noting that class 2 was a more distinctly defined group of females as evidenced from a smaller residual standard deviation (S.D) of calving interval of 9.7 days compared to 18.6 and 16.9 days for group 1 and 4, respectively. Even before fitting the various constants, the original S.D of calving interval in group 2 was comparatively smaller. This resulted in a higher proportion of variance accounted for (R^2) of 91% in group 2 compared to R^2 values of 74 and 79% in the other two groups. Original and residual S.D's of calving interval in the supplementary feeding and weaning trials were 26.7, 19.6 and 29.0, 21.9 days, respectively which also accounted for the rather low R^2 values shown in Table 18 and 21.

Fixed models were used to evaluate the effects of the various parameters which meant that inferences could only be drawn for conditions set for these particular experiments. Consequently, while extrapolation of such treatment effects to other ranching situations should be done cautiously, information concerning significant effects would, nonetheless, provide some useful guidelines.

5.1.3 Conception period

The highly significant mean squares for the main effect and interactions with breed, age of breeding females, dam's previous parous state, body weight changes and soil moisture index made conception period one of the most wide reaching factors affecting reproductive performance of grazing beef cattle. High fertility was achieved during May-July and September-January periods (Fig.3). The observed high fertility during September-January was, in fact, attributed to the period between November and January which accounted for the majority of the conceptions (Table 2). Unfortunately, due to the nature of the breeding seasons (Table 1), it was impossible to evaluate the effect of conception between November and January during years other than 1973. With the exception of heifers, the lowest fertility was recorded during the cold and dry period between July and September (Appendix 1). During 1975, the majority of heifers were not mated until early July after attaining a liveweight of 250 kg stipulated for first mating. This meant that they calved down rather late during the calving season. By virtue of the stimulatory effect of the bulls (Rollinson, 1962) which coincided with the period immediately post-calving, these animals were more likely to conceive at their first or second oestrus. This, in effect, resulted in the apparently anomalous situation where heifers that conceived between July and September had a high fertility.

In group 2 females, high fertility was also observed between November and January (Fig.6). Because of missing data (Appendix 4), the effect of November-January conception period was tested with the 4-8- year-old females only and since a few animals were involved, one would have reservations about the high fertility associated with this period. However, the fact that the same trend was observed with a larger number of animals in group 1 and 4 (Table 2, Fig. 3 and Appendix 6, Fig. 9, respectively), it would be safe to conclude that conception between November and January was associated with high fertility. The high fertility observed between January and March could be attributed to increased sexual activity during this particular period, mainly as a result of high temperatures (Anderson, 1944; Wilson, 1946). However, in rather striking contrast with group 2, group 4 females that conceived between January and March, all of which occurred during January-March of 1973 had the lowest fertility (Fig. 9). The dry climatic conditions during January-March of 1973 (Fig. 1) would be a factor in reducing fertility through the adverse effects on pasture production. Considering that the number of females in group 4 was much greater than that in group 2, it would appear that inadequate grazing during the January-March period had a more marked adverse effect on fertility than the influence of increased temperature and sexual activity per se. The picture that emerges is that: firstly, peak conception at Rohet Ranch occurred between November and January followed by May-July periods which indicated clearly the need to follow seasonal rather than continuous breeding. Secondly, response in fertility to inadequate pasture production between January and March was greater than that due to increased temperature and sexual activity. Thirdly, it would be futile to mate beef cows during the dry and cold season between July and September.

5.1.4 Soil moisture index

Since variation in evapo-transpiration was relatively small compared to that of rainfall (Fig. 1), changes in soil moisture index would, for all intents and purposes, be assumed to arise from variation in rainfall. On that basis, increase in rainfall during the month prior to conception was associated with improved fertility. This effect was most marked during the September-January conception period but was of relatively minor significance between May and July despite the fact that variation in rainfall during the latter period was quite large (Fig.4). Low temperatures between May and September could be a major factor in depressing fertility during this period through adverse effects on pasture production.

Results of group 2 females did not indicate any seasonal trends in the effect of soil moisture index on fertility. This is because 85 out of a total number of 96 females (Table 2) conceived between May and September when the effect of increased rainfall on pasture growth was minimal. Seasonality in the effect of rainfall was also observed with group 4 females because of the diversity in conception periods. Although increased rainfall a month before or during January-March (normally dry and hot) improved fertility quite markedly, rainfall in excess of about 60 mm was associated with reduced fertility (Fig. 10). However, depressed fertility arising from increased rainfall was sufficiently minor as to be disregarded. Between March and July, rainfall varied quite considerably but the effect on fertility was marginal, an observation that concurred with the results of the normal class of females. Overall, increased rainfall during the month before conception improved fertility of beef cattle in a linear manner. The effect was seasonal which underscored the significance of conception period and seasonal mating in order to achieve high fertility. Response was greatest prior to or during dry periods with high temperatures and only marginal during most of March to September period.

5.1.5 Year effects

The highly significant effects reflected important variation in fertility from year to year (Fig. 2). Admittedly, a large proportion of year effects would be confounded with variation associated with conception periods reviewed above. But since it is possible that factors other than conception period could contribute significantly to the observed variation in fertility, inclusion of year effects in the model would be justified. Year effects could be attributed to several factors. Firstly, there were variations in total precipitation and distribution of rainfall particularly during the mating season from year to year (Table 1, Fig. 1) which would be expected to influence pasture growth and, ultimately, animal performance. However, considering that total rainfall received during the mating season of 1976 was greater than that received during late 1973, there must be other factors which contributed to a higher fertility during 1973 compared to 1976. It is likely that the relatively high rainfall during June of 1976 was ineffective in promoting pasture growth because of low temperatures (Potter, 1985). Besides, higher temperatures during the last part of 1973 could have induced greater sexual activity (Wilson, 1946). Furthermore, there were rather marked differences in the mean age of the bulls used (Table 1) such that the high fertility observed during late 1973 could have been due to the use of relatively older bulls. As a result of variation in pasture productivity especially prior to and during the mating season and management practices associated with changes in ranch managers, year effects are bound to be important sources of variation in the fertility of beef cattle, an observation which is supported by Cruz Ortiz (1979), Mariante (1979) and Rudder, Seifert and Burrow (1985).

5.1.6 The effect of body weight and weight changes

The various weight changes evaluated fell between one month after calving and conception. This period was selected because that was the time when animals were expected to regain body weight lost during the previous pregnancy and early lactation and when normal cylic activity would resume (Warnick, 1955; Plasse *et al.*, 1968; Wiltbank and Spitzer, 1978). In general, weight changes had a profound influence on fertility depending on the period of "second" conception. It was also evident that weight changes occurring near conception exerted a much greater effect on calving interval than those far - removed from conception. Effects of the various weight changes on calving interval are summarised in Table 23.

(i) Weight change during the month prior to conception

In the normal class, females reconceived at an average weight of 320 kg and a close scrutiny of the regression curves indicated that the overall threshold joining weight was around 318 kg with a range between 310 and 330 kg. Between May and July, animals reconceived at an average weight of 331 kg well above the target joining weight. Consequently, they could afford to lose up to 20 kg or gain up to 30 kg without adverse effects on fertility. The relatively minor effect of weight change between May and July was paralleled with the observation made earlier regarding the effect of an increase in rainfall during the same period. Thus variation in rainfall or body weight a month before or during May-July period did not affect fertility of grazing beef cattle. Animals reconceived between July and September at an average weight of 313 kg which was lower than the target joining weight. High fertility was indicated in those females that were able to maintain their body weight at approximately 320 kg. Although weight gains in excess of 10 kg were undesirable, such a situation would be uncommon because of low

Table 23 - Factors reducing calving interval

Season of Conception	Period of weight change: During the month before conception	1-2 months before conception	1 month after calving to conception
(a) Within year			
Jan. - March	Weight gain in excess of 16 kg	Weight loss; linear effect	-
Mar. - July	Weight gain up to 25 kg; quadratic effect thereafter	-	-
May - July	Weight gain/loss marginal effect	Weight loss; marginal; linear	-
July - Sept.	Weight gain up to 10 kg; quadratic effect thereafter	Weight gain; linear effect	-
Sept.- Jan.	Weight gain; linear effect	-	-
Nov. - Jan.	Weight loss; linear effect	Weight loss; linear effect	-
(b) Wet years			
1975	Weight gain/loss marginal effect	-	-
1979	-	-	Weight gain/loss; marginal effect
1980	-	-	Weight loss; linear effect
(c) Dry years			
1976	Weight gain; linear effect	-	-
1978	-	-	Weight gain up to 25 kg; quadratic effect thereafter

production of herbage during this period. Animals calved at an average weight of 327 kg prior to conception between September and January but they lost weight subsequently and reconceived at an average weight of 308 kg. This period covers the dry season between September and mid-November and also follows a very dry period between July and September, hence the general reduction in body weight. Under these conditions, females that suffered less body weight loss were those that reconceived earlier.

Results of group 4 females indicated that in order to reduce calving intervals, animals had to gain in excess of 16 kg prior to or during the January - March conception period (Fig.11). Since this is normally a dry period, it would be difficult to achieve such weight gains and breeding during this period would not be advocated. Weight gains up to 25 kg prior to or during March-July conception period improved fertility quite considerably. With the normal "long rains" during this period, such weight gains would be achieved on grazing alone. However, the rancher would be concerned with weight gains in excess of 25 kg. Fortunately, in normal ranching situations, the problem would not arise since animals would be lactating at the time they reconceive, unlike group 4 animals which had dried off, so that the extra nutrients would go to meet the demands of lactation, which are very high, and those of maintenance of the animal itself with minimal chances, if at all, of overweight. The same would be true of those animals that gained body weight prior to or during the November-January conception period.

Although weight change in group 2 females was not seasonal, its effect on fertility varied from year to year (Fig.8). This could be due to the fact that these animals had settled down after "first" calving before joining with the bulls so that short-term weight changes based on seasons were rendered insignificant compared to long-term effects due to years. During 1973/74, the picture was somewhat confusing probably due to the fact that fertility was evaluated over a two-year period with different breeding seasons. Besides, the sample size which consisted of 11 and 3 animals in 1973 and 1974, respectively was far too small to warrant any serious consideration of the effects during these two years. The highly significant quadratic term expressing the relationship between weight change and calving interval (Table 11) was associated with 1973/74 but was so small for 1975 and 1976 as to be discounted. This would leave comparison of the linear effects of weight change during 1975 and 1976. In 1975, regarded as a normal year with well distributed rainfall (Fig. 1), animals conceived for the "second" time at 311 kg having gained, on average, 12 kg during the month before conception. Body weight loss up to 20 kg or gain up to 45 kg did not affect fertility adversely. The picture during 1976, generally a very dry year, was quite different. Animals reconceived at an average weight of 298 kg which was below the target joining weight. Females that had gained 18 kg before conception had a higher fertility and judging from the slope of the regression line, it would be safe to extrapolate that weight gains in excess of 18 kg could have improved fertility even further. The general conclusions regarding weight change during the month prior to conception could be listed as follows:

(a) the effect on fertility was seasonal and also varied from year to year.

(b) weight change prior to or during May-July conception period did not affect fertility.

(c) to achieve high fertility, animals had to be maintained at approximately 320 kg before breeding between July and September.

(d) females that suffered less body weight loss following a dry season also reconceived earlier.

(e) dry animals tended to gain weight prior to or during March-July and November-January conception periods to the detriment of high fertility. However, in normal ranching situations, animals would be lactating at the time they reconceived and such weight gains would be minimal, if at all.

(f) during years with well distributed rainfall, weight changes did not affect fertility. However, in dry years, animals that reconceived earlier were those that gained 20 kg during the month prior to conception

(ii) <u>Weight change between one and two months before "second" conception</u>

By virtue of the fact that group 2 and 4 females took longer after "first" calving before they were reintroduced to the bulls, they were able to recoup weight loss from previous pregnancy and lactation. Consequently, weight gains between one and two months before conception would only make them overfat and hence the delay in reconceiving indicated in Fig. 7 and Appendix 5. The only exception was when group 2 animals conceived between July and September at an average of 291 kg and, therefore, needed to gain up to 36 kg so as to reduce their mean calving interval. It is noteworthy that weight changes prior to and during May-July period affected fertility only marginally similar to the effect of weight change during the month before conception in group 1 females. Judging from the slopes of the regression lines, weight gains prior to November - January and January-March conception periods caused a drastic depression in fertility. However, due to the small number of animals involved (Appendix 4), this information can only be considered with caution. Be that as it may, these weight changes are rather isolated from both calving and conception and their manipulation for the benefit of the animals would be cumbersome in practice. Perhaps one general indication is that when cows had settled down after calving before they were re-introduced to the bulls, they gained weight between one and two months before conception and this was associated with reduced fertility.

(iii) Weight change between one month after calving and conception

Because of the absence of bulls after "first" calving in experiment 1, weight changes were evaluated with reference to "second" conception. However, in the supplementary feeding and weaning trials, it was possible to measure weight change with respect to both calving and conception. While it was realised that this parameter would overlap the first two measurements, it would, nonetheless, provide some information on the effect of body weight change with respect to the two major determinants of calving interval namely: calving and conception.

While it was beneficial for animals to gain up to 30 kg to improve their fertility during 1978 which was relatively a dry year (Fig. 1 and 16), weight changes during 1979 with better distributed rainfall did not affect fertility adversely. During 1979, unsupplemented, pre- and post-calving supplemented animals conceived at an average weight of 365, 348 and 350 kg, respectively. These weights were above the target joining weight, hence the marginal response of weight change on calving interval. These observations tally with the effects of weight change during the month prior to conception in wet and dry years for the normal class of females in experiment 1. Pasture conditions were even more favourable during 1980 and all animals gained, on average, 6 kg during the period under review. It is likely that cows had reached the maximum weight needed for conception so that further weight gains only delayed reconception. Low fertility observed during 1980 could also be attributed to the use of younger Friesian and Ayrshire bulls. In the weaning trial, animals reconceived at an average weight of 351 kg, well above the threshold joining weight and this could explain why weight changes were insignificant. In both the supplementary feeding and weaning trials, the failure to register a significant seasonal response due to weight changes could well be attributed to a less variation in climatic conditions during the breeding season between May and July. However, there was a strong indication that weight gains by animals that calved during March were associated with a high fertility.

Of the three measurements of weight change, i.e. between one month after calving and conception, one to two months before conception and during the month prior to conception, the latter would be a more feasible paramenter to use in the field since it was more closely associated with a specific period immediately before or during the breeding season.

(iv) Body weight at "second" conception

There was some indication that females which were heavier at the time they conceived for a "second" time were more fertile than lighter ones depending on whether or not such animals were suckling calves at the time they reconceived. For instance, in the normal class, animals reconceived at an average weight of 320 kg which was slightly above the target weight of 318 kg. It is possible that the depressing effect of suckling (Wiltbank and Cook, 1958; Donaldson, 1962; Rose *et al*, 1963) masked any influence due to the absolute liveweight, hence the non-significant effect of body weight *per se*. In contrast, Group 4 females had dried off at the time they reconceived and with the removal of the effect of suckling, influence of body weight was able to be expressed. The effect of body weight was marginal, probably because the animals reconceived at 311 kg just below the threshold weight. Under grazing conditions without supplementation, the 5-9-

year-old and previously dry cows calved at an average weight of 362 and 348 kg and were able to maintain or gain weight until they reconceived at an average of 367 and 363 kg, respectively. In the weaning trial, the average weight at "second" conception was 351 kg, well above the target weight. Although these groups of animals were also suckling their calves at the time they reconceived, their absolute body weight at conception had a more significant influence on fertility than the depressing effect of suckling, hence the observed high fertility (Figs. 13, 14 and 17). The mean conception weights for the four, ten year-old-and- above and previously suckled cows were 339, 302 and 340 kg, respectively which, most likely, fell in the weight range within which the action of suckling exerted its adverse effect on fertility.

5.1.7 Supplementary feeding

While supplementation had a significant effect on fertility, its influence was modified by several factors. Firstly, supplementation whether before or after calving, only maintained fertility of the 5-9- year-old and older cattle at average levels (Fig. 13). However, the four-year-old females and those that reared calves during the previous year responded positively to pre-calving and, even more dramatically, post-calving supplementation (Fig. 14). Secondly, the effect of feeding regime also depended on the severity of climatic conditions, especially rainfall, during the year such that while supplementation was beneficial during dry years such as 1978, it was virtually useless during years with high and well distributed rainfall (Fig. 15). To be meaningful, therefore, supplementation has to be evaluated in the context of age of breeding females, dam's previous parity and climatic factors, particularly rainfall, obtaining during the year. It was also noted that differences in the effect of energy versus energy with nitrogen, when given before calving, were non-significant.

Improved fertility was associated with a longer period of supplementation. This was to be expected considering that the animals were supplemented during a dry period when grazing was quite sparse and of poor quality. However, the range in the period of supplementation (Table 3) was too large to evaluate the effect of this factor more precisely. For instance, post-calving supplementation was given immediately after calving and although it was most beneficial to the four-year-old and previously suckled cows in meeting their demands for body growth, lactation and general improvement in body condition in the long run, the short-term effects of getting the animals into calf might not have been realised because of post-partum anoestrus. Supplementation at some later stage after calving would ensure that animals got extra nutrients during the most critical period.

5.1.8 Calving month

Ideally, this parameter would have been confounded with conception period because of the sequential nature of their occurrence. However, as a result of the absence of bulls for varying periods after calving in experiment 1, it was not feasible to evaluate influence of calving month and conception period together. Experiment 2 and 3 were conducted following an already pre-determined three-month mating season beginning 1st May so that calving occurred between late January and early May each year. Consequently, calving month had to be evaluated for only four months which, incidentally, coincided with dry followed by wet seasons. It would appear that with the current breeding season at Rohet ranch, mating would have to be organised such that the three-year old females calve down during March while older cows drop their calves in April/May (Figs. 12 and 19). Such a breeding strategy would allow young females more time to regain body weight and condition required for earlier reconception during their second mating season. Besides, breeding in young animals would occur when pasture conditions were most favourable following the "long rains" during April/May.

5.1.9 Weaning month and weaning period

There was some indication that animals,particularly the four- year-olds, that weaned calves at the end of September following a cold and dry season had a higher fertility than those which weaned their calves at the end of October (Appendix 12) otherwise the effect of weaning month was of minor significance. This was probably due to a pre-determined period of breeding, and hence calving season, which meant that weaning had to be done over a four month period between September and November/ December. As expected, females whose calves were weaned earlier had a higher fertility than those which weaned calves later after calving. In general, the effects of weaning month and weaning period were of less importance in determining fertility status of beef cattle compared to those associated with calving month and conception period which indicated higher nutritional requirements for lactation and reconception rather than pregnancy.

5.1.10 Previous parous state

This parameter was included in the evaluation model for the normal class of females simply to draw attention to the rather strange behaviour of heifers which conceived between July and September otherwise the effect of dam's previous parity was of no particular significance on the level of fertility. Analysis of group 4 females indicated that between January and July, heifers had a slightly lower fertility than dry cows (Fig.9). However, when conception occurrred between November and January which covers the "short rains" period or when animals were supplemented either before or after calving, fertility levels of heifers, dry cows and cows that reared calves during the previous year were quite similar (Figs. 9 and 14). On the whole, the effect of dam's previous parity on fertility was marginal depending on the period of conception but disappeared when animals were supplemented or when conception was allowed to take place between November and January.

5.1.11 Age of breeding females

For reasons mentioned in section 3.2.1, only three age groups were evaluated recognising that the 4-8- and 9- and - above-year-old groups were fairly heterogeneous with respect to age. Consequently, the non-significant variances for age groups in experiment 1 were not totally surprising. Effect of age was still included in the evaluation model to provide some clue for trends in fertility, a factor that is usually of paramount importance in the ranching world. Trends obtained from the normal class and group 2 females indicated that the 4-8-year-old animals had a higher fertility than the three-year-olds (Appendix 1, Fig. 6). However, evidence from the weaning trial showed that with the exception of one odd animal during 1978, the four-year-old females had the highest fertility across years (Fig. 18). Fertility of the 5-9-year-old cows could have been relatively poor due to inclusion in this group of cows possibly older than nine years. What seemed clear was that while fertility of the three - year-old females was low, it improved appreciably when animals attained the age of four years at the time they weaned their first calves. Another striking feature was that as weaning years progressed from 1977 to 1979, the chances of including all the oldest animals in one age group were quite high, hence performance during 1979 would reflect the age effect better than in earlier years. Therefore, it could be concluded that with the passage of time, fertility of the ten-and-above-year-old animals was poor compared to animals that were nine years of age or below.

5.1.12 <u>Effect of breed type</u>

The influence of dam's genotype on fertility was, at best, only marginally significant depending on the period during which animals conceived for the "second" time, thereby emphasizing the importance of the period around conception. The EASZ had a fairly consistent response in fertility regardless of conception period

(Fig. 3). Although the Borans behaved similarly, those which conceived during the last quarter of the year had a slightly higher fertility. Performance of the crosses varied considerably depending on conception period, hence pasture production, and genotype. Thus between May and July period following the "long rains," the crosses had a higher fertility than the two indigenous breed types but they also had the poorest performance when confronted with adverse climatic conditions between July and September. When the nutritional status of the animals was further improved by dry season supplementation, the Boran crosses showed a higher fertility than the pure Borans. However, superiority in reproductive performance did not hold in the case of the EASZ crosses. In general, the effect of dam's genotype on fertility was minor compared to the overwhelming influence of environmental factors mentioned earlier. However, with better nutrition,the prospects of attaining a higher level of fertility through rearing of Boran crosses looked very promising.

5.2 GENERAL DISCUSSION

5.2.1 General aspects of calving interval

The bulk of investigative work concerning reproductive performance in cattle has revolved around dairy breeds in temperate countries. While it has long been recognised that beef cattle in the tropics are reared under harsh environments with adverse effects on reproductive capacity (Lampkin, Howard and Burdin, 1961; Christie, 1962; Lammond, 1969), there has been, generally, a paucity of information to evaluate the various factors affecting fertility of these animals particularly under range conditions.

In East Africa, the few reports available indicate that the indigenous beef cattle breeds have calving intervals ranging between 349 and 591 days with a coefficient of variation of about 20% (Mahadevan and Marples, 1961; Galukande et al., 1962; Mahadevan and Hutchison, 1964; Stobbs, 1966 and 1967; Kiwuwa, 1968; Wilkins, 1975). These intervals have been associated with very low heritability and repeatability estimates which suggested that environmental rather than genetic factors predominated in the observed fertility complex. Apart from infectious diseases, the most important environmental factors affecting fertility in general are nutrition of the grazing animal and management of the mating period (Christie, 1962; Andrews, 1972; Topps, 1977).

5.2.2 Seasonal effects

(a) Conception period - Seasonality in fertility observed in this study concurred with previous reports which correlated peak conception period with the end of the rains and increased temperatures (Anderson, 1944; Wilson, 1946; Wilson, 1963; Andrews, 1976; Grosskopf, 1980; Swensson et al., 1981). These climatic factors interplay to enhance pasture production for the benefit of grazing animals. Maximum pasture growth is required for females to recover from undernutrition associated with the dry season and the nutritional drain caused by lactation. The low fertility levels observed during the cold and dry July-Septemebr season could be due to a level of intake sufficient to bring about ovulation but insufficient for full manifestation of oestrus. These results reaffirm the need for seasonal mating to derive the maximum benefit from range vegetation. Following the suggestion by Trail and Fisher (1971) and Daly (1971) for a three-month breeding season, it would be recommended to mate cattle at Athi River ranch from 1st November until the end of January to take advantage of the "short rains" and warm/hot temperatures. Besides, such a closed breeding season would facilitate easy management and overall supervision of the herd particularly with regard to culling and grazing control.

Bishop (1978) reported high conception rates following rainfall during the previous year. However, in Kenyan rangelands with a high variability in rainfall both annually and, more importantly, seasonally, it would be desirable to correlate fertility with rainfall and its associated factors within the immediate past so that corrective measures to ensure early conception can be taken in good time. In Australia, Andrews (1976) reported a high correlation between conception rate and rainfall distribution with approximately a one-month lag. Working with Zebu x Hereford crossbred steers on the same ranch at Athi River, Potter (1985) demonstrated that liveweight gain was more highly correlated with rainfall occurring between three to six weeks than between six to nine weeks previously, although rainfall received during the latter period would have some influence on pasture growth and, ultimately, liveweight gain observed during the former period. He also observed that use of straight-foward rainfall records to assess liveweight changes was just as good as the more elaborate and often cumbersome water balance information involving evapo-transpiration data. In this study, soil moisture was evaluated during the period one month before conception which would coincide with the period evaluated by Andrews (1976) but did not quite correspond with the three to six weeks period used by Potter (1985). In some of the earlier models developed, soil moisture index during the period one to two months prior to conception was also evaluated but was found to bear no relationship with calving interval. It would, perhaps,be interesting to evaluate rainfall during the periods three to six and three to nine weeks before conception to ascertain whether the weight gains observed by Potter (1985) were also correlated with fertility. If this is so, then it will be possible to pin-point more accurately the period prior to conception when weight gain, hence supplementation, would be most useful. This would ensure not only high fertility but would also cut down feeding costs.

Although rainfall may be an important factor in pasture production, Andrews (1976) contended that a period of one month could not have been sufficient time for pastures to grow and improve body condition and thus conception rate. He postulated that increased conception rate would most likely be due to either a change in the nutritional composition of the pastures or an increase in the rate of intake or both through the action of the hypothalamus or the pituitary. While this hypothesis may well be true in the northern territory of Australia, it is important to note that range vegetation in Kenya grows very fast and matures very quickly (Karue, 1972 and 1974), so it may have a direct effect on body condition, and hence conception rate, of grazing beef cattle.

(b) <u>Calving month</u> - Poor reproductive performance with dry season calvers was reported by Kidner (1966) and was attributed to a failure to regain body weight losses but as Christie (1962) had indicated, dry season loss in body weight *per se* did not, necessarily, jeopardise fertility as long as the animal was able to recoup during the subsequent wet season. Consequently, Daly (1971) suggested dropping calves at the end of a dry season. This view was supported by the supplementary feeding and weaning trial results of this study which indicated that given the current breeding season, animals that calved from March onwards, following a dry season in January-March, had a high fertility during the subsequent mating season. The situation regarding young females was somewhat different and would warrant special examination. Whereas calving in April-May was associated with poor fertility in the four year-old females in striking contrast to the older cattle, this effect was more marked in the weaning trial where no supplementary feeding was provided and was only marginal in the supplemented group. In Nigeria, Oyedipe, Buvanendran and Eduvie (1982) also observed longer calving intervals in Zebu heifers which dropped their first calves during a wet season. The difference in response to dry and wet season calving may well be due to a nutritional difference which may have a greater effect on conception than on mere return to oestrus after calving. Thus young females that calved down during March would be ready for conception during the following rainy season in April-May when grazing conditions were favourable. The situation with heifers calving during the wet season in April-May would be a complete reversal of the one just mentioned as these animals would face an adverse nutritional environment at post-partum oestrus during June-August which is normally cold and dry. Sensitivity of heifers to calving date has also been observed in Queensland by Rudder, Seifert and Burrow (1985). The older cows that calved during the wet season seemed to get away with unfavourable pasture conditions at post-partum oestrus possibly due to their ability to draw on body reserves accumulated during the rainy period. It can be concluded, therefore, that conditions which prevail at the time of post-partum oestrus, rather than time of calving, would be the main determining factor in conception particularly in young beef cattle. It is realised, however, that given a closed three-month breeding season between May and July with a bimodal rainfall pattern as applies to Athi River ranch, there is likely to be confounding between the effects of calving month and conception period in which case, it would not matter which of the two periods was evaluated. But depending on how closely the breeding season overlaps with the rainfall pattern, it would be safer to consider conception period rather than calving month.

5.2.3 Effect of liveweight and body weight change

The relationship between body weight and weight changes with fertility of grazing beef cattle is well documented (Wiltbank *et al* , 1962; Kidner, 1966; Andrews, 1972; Buck *et al.*, 1976; Thorpe *et al.*, 1981; Milles, 1984). However, there have have been rather conflicting reports as to whether the animal's ability to conceive was a function of its absolute body weight (Lammond, 1970; Steenkamp, van der Horst and Andrew, 1976; Richardson *et al.*, 1976; Buck *et al.*, 1976; Grosskopf, 1980) or weight change prior to conception (Elliot, 1964; Ward, 1968; Andrews, 1972; Capper *et al.*, 1977; Thorpe *et al.*, 1981). While suggesting the concept of target joining weight, Lammond (1970) had intimated that for each cow, depending on genotype, age and year, there was a certain range in body weight and body condition required for conception. By implication, therefore, it did not matter whether animals lost or gained weight during the breeding season provided their liveweight were maintained above a certain minimum. The ability to maintain the required range in body weight and body condition would depend, among other things, on the lactational stress of the animal, hence the tendency for many researchers to evaluate body weight changes in heifers, lactating or dry cows (Kidner, 1966; Ward, 1968; Sacker *et al.*, 1971a; Edye, Ritson, Haydock and Griffith Davies, 1971; Morley *et al.*, 1976). In all cases, depressed fertility in lactating females was associated with lower liveweight or greater body weight loss. Fertility in dry cows was not affected by body weight changes because of their ability to maintain body weight. However, results of this study indicated that previous parous state of breeding females assumed only limited significance in influencing fertility levels when evaluated in the context of conception period. Consequently, consideration of body weight or weight changes based on parity alone and in isolation of conception period would most likely lead to discrepancies in their effects on fertility and it would be difficult to establish which of the two parameters had a greater influence on reproductive performance.

In this study, the effect of body weight changes was evaluated in relation to conception period. This was necessitated by the tremendous seasonal variation in the quality and quantity of grazing at the ranch (Karue, 1972 and 1974). Unfortunately, little work has been done to evaluate body weight changes based on season of conception. It is true that liveweight and body weight changes have been assessed during the mating season but depending on when such mating takes place, the effects are bound to vary, hence the inconsistence in the results reported by various workers. Besides, Andrews (1976) has indicated that variation in environmental conditions prevailing from place to place would tip the balance between the effects of body weight and weight changes either way.

Another important aspect is whether the various researchers were evaluating absolute or proportionate body weight changes. The indications are that they considered the former in which case the results would depend on the size difference between the smallest and the biggest animals even within the same breed. A proportionate weight change would be more ideal, hence the inclusion of body weight at conception as a reference point in all the evaluation models used in this study. This would make weight changes in small animals comparable with similar changes in bigger animals. Weight changes expressed as a percentage of joining body weight would have achieved the same goal. It seems as if both body weight and weight change operate either singly or simultaneously to affect fertility depending on the nutritional status of the animal. Thus, below the target joining weight, animals that had a higher fertility were those that gained weight or suffered less body weight loss during the month prior to conception. There was evidence, though, that the effect of suckling might counteract that of body weight or weight change unless the animal's liveweight was well above the target joining weight. When animals had achieved the threshold joining weight but were still subjected to fluctuations in feed supply, both joining weight and weight changes affected fertility simultaneously. Above the target joining weight, animals could lose weight without affecting fertility adversely and reproductive performance became a function of body weight at conception. This would be consistent with the original concept of a target body weight at conception proposed by Lammond (1970). Where weight change had an influence on fertility, it was a question of when the change occurrred prior to conception. For instance, while the effect of weight change during the month prior to conception was important, weight gain between one and two months before conception was of no particular significance under normal ranching conditions where animals would be lactating at the time they reconceived. However, according to the revelation by Thorpe et al. (1981), liveweight was only an approximate indicator of the nutritional status of a beef animal. These workers postulated the existence of an intricate relationship between nutrition, hormonal control, lactation and reproductive performance in which the post-partum period with its associated lactational stress was considered more important than variation due to liveweight. But since this relationship is still far from clear, monitoring of body condition as suggested by Andrews (1976) together with weight changes during the month prior to conception would give a reasonable indication of the fertility status of a grazing beef animal.

5.2.4 Supplementary feeding

Supplementation of beef cattle with energy (Wiltbank et al., 1962 and 1964; Dunn et al, 1969; Lammond, 1970; Bond, 1974) or nitrogen (Elliot, 1961; Hart and Mitchell, 1965; Siebert et al., 1976; Holryod et al., 1977) has been a normal practice to improve fertility. However, improvement has not always been achieved. For instance, in Botswana, Capper et al. (1977) reported that while stimulatory licks of molasses and urea increased pregnancy rates in cows under lactational stress by up to 20%, they had no effect on reproductive performance of dry cows or cows with calves older than five months. Results of a supplementary feeding trial conducted by the Animal Production Research Department (1981) at Athi River ranch using the same group of animals as those used in this study indicated a calving rate advantage of animals that received 2 kg/day of "dairy meal"* after calving of only 3.2% above the unsupplemented group. More recently, Holroyd et al. (1983) supplemented beef cows in northern Queensland with urea and molasses but observed no effect on fertility. Apart from improving fertility in the four year-old and previously suckled females, the results of this study support these observations. It seems imperative, therefore, that assessment of the effect of supplementary feeding must be done in the context of age and previous parity of the breeding females.

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* From Unga Feeds Ltd, Nairobi; 15% C.P and 7.5% C.F.

Under natural conditions in Botswana, Pratchett, Capper, Light, Miller, Rutherford, Rennie, Buck and Trial (1977) observed that crude protein, rather than energy, was the major limiting factor to animal performance in terms of liveweight gain. Since liveweight and liveweight change were highly correlated with fertility (Morley et al., 1976), one would expect some response to nitrogen supplementation. However, results of this study indicated that there was no difference in calving interval between animals that received ground sorghum grain with or without urea and molasses. This was probably due to less severe climatic conditions particularly during 1979 and 1980 which made it possible for the animals to derive most, if not all, their nutrient requirements from pasture alone. It is worth noting that the last trimester of pregnancies at the ranch coincided with the period immediately after or covering the "short rains" between November and December. Under such conditions, Ørskov (1982) suggested that the nitrogen requirements for pregnancy could be met by microbial protein synthesis alone with no additional dietary protein. Besides, the animal has an efficient built-in system of eating more high quality pasture and accumulating body reserves as fat which could be drawn on later (Ørskov, 1986, personal communication). This could explain why animals were heavier at calving regardless of whether they were supplemented or not or whether they were given energy alone or in combination with nitrogen.

However, the point of interest was that because of the time lag between calving and conception, and the high nutritional demands imposed by lactation and reconception (Crampton and Lloyd, 1959), the effect on fertility of weight at calving was inconsistent and of less practical significance. In lactating dairy cows, Ørskov (1982) indicated that there was a high demand for nitrogen due to the mobilisation of body fat to support milk production. Besides, the need for more dietary nitrogen was further increased by the very limited mobilisation of body protein by the animal. Since milk production in beef cattle is relatively much lower, it would be of interest to determine the influence on fertility of nitrogen and energy sources when given post-partum. Because of the intricate relationship between non-protein nitrogen (NPN) and carbohydrate metabolism and utilisation, further investigation will have to be focussed not on the relative importance of NPN and energy in the control of fertility but rather, as suggested by Ørskov (1982), on the proportion of rumen-degradable and undegradable nitrogen relative to metabolisable energy intake. This will involve replacing some of the urea, which is readily degradable in the rumen, with less degradable proteins such as groundnut or fish meal.

5.2.5 Age of breeding females

Despite the rather broad age grouping used, the results of this study are, generally, consistent with those reported on Zebu cattle in other tropical African regions (Christie, 1962; Buck *et al*, 1976) and on Herefords, Zebus and Zebu crosses in sub-tropical ranching areas of USA (Lindley *et al*., 1958; Reynolds, DeRouen, Moin and Koonce, 1979).

Two factors might be responsible for reduced fertility in the three-year-old cattle. Firstly, Joubert (1963) observed delayed puberty in indigenous Zebu cattle. Under sub-optimal nutritional conditions such as those prevailing during dry periods in range areas, this effect may be emphasized to retard onset of first oestrus (Buck *et al*., 1976). The effect of age is an indirect one through its influence on body condition to which young cattle are more sensitive (Andrews, 1976). As body condition would be related to liveweight (Andrews, 1976), Wiltbank and Spitzer (1978) have stressed the significance of allowing young cattle to attain a target weight and age before first mating - the weight and age varying according to breed. Under East African conditions, Macfarlane and Worrall (1970) had indicated that puberty in Boran heifers occurred at approximately 60% of the mature body weight. However, mere attainment of first oestrus or puberty is not enough. Young cattle should be able to conceive, carry the foetus to full term, rear the calf successfully and reconceive at the earliest opportunity. It is possible that the 250 kg liveweight stipulated for first breeding of heifers at the ranch was lower than the threshold weight required for first mating particularly in the case of crosses. This would not only delay reconception but could curtail their productive life. If anything, it would be better to breed heifers too late than too soon. Secondly, it is known that the nutrient supply available to a lactating young animal has to be partitioned to meet the demands of lactation as well as those of its own continuing body growth. Consequently, as indicated by Carroll and Hoerlain (1966) and Sacker *et al.* (1971a), young cattle nursing their first calves do experience a lactational stress which would affect their body condition, thereby depressing their fertility. But since age *per se* did not seem to cause variation in fertility of animals with the same body condition (Andrews, 1976), the method of condition scoring suggested by this worker would be a useful adjunct in assessing fertility status of female beef cattle.

The actual mechanism by which body condition affects fertility is not known. For instance, Lindsay (1976) reported an increase in the ovulation rate in ewes six days after feeding lupins. The stimulation in reproductive activity was unlikely to be the result of improvement in body condition in such a short time. Andrews (1976) was of the opinion that the mechanism could be triggered off through a change in diet or rate of intake or both. This observation would be consistent with the results obtained in this study which indicated that when heifers conceived betweeen November and January, a period when pasture production was at its peak as a result of the "short rains" and high temperatures, their fertility was as high as that of older cattle whether dry or suckled during the previous year. Also, in the supplementary feeding trial, the four year-old females that calved down during March and took advantage of the abundant pastures following the "long rains" in April-May and those that were supplemented after calving had fertility levels which were actually higher than those of older cattle.

This study was conducted under improved ranch management and it was normal practice to cull any cows with poor fertility records so that the shorter calving intervals observed with increasing age were partly an effect of selection. However, this could not be regarded as a major contributing factor because of the low herttability of fertility traits (Mahadevan and Marples, 1961; Galukande et al., 1962; Stobbs, 1965; Mariante, 1979). Besides, less than 1-2% of the cows were culled each year on account of infertility. However, it would be reasonable to assume that with increasing maturity, the animals became better adapted to their environment, hence the improvement in reproductive performance up to about nine to ten years of age.

It was noted that as the post-calving period before joining with the bulls increased from five months onwards, the three year-old females had calving intervals which, depending on the conception period, were similar to those of older cattle. This was due to a time lag after first calving that was sufficient for the young animals to recoup from both previous pregnancy and peak lactational stress and to achieve body condition and body weight required for reconception. The implication of this observation is that young beef cattle should be allowed about five months after first calving before they join the main breeding herd for their second mating season. This would mean that first breeding in heifers and that of the main herd would be out-of-phase although all indications were in favour of seasonal mating. However, earlier breeding of heifers would necessitate their separation from the main herd which would facilitate closer attention and feeding to ensure high fertility. In the supplementary feeding and weaning trials, fertility of the four year-old females was better than that of older cattle but delaying first calving to four years of age would reduce the productive period of the animals. The solution for young cattle would be a package to include:

(a) mating between November and January or, in general, immediately after a rainy season to take advantage of a high plane of nutrition following the rains

(b) separating and mating heifers approximately three months before the main herd to synchronise their second mating with the rest of the herd.

(c) providing a supplementary diet after calving.

5.2.6 Effect of weaning

Lactation is always a big burden on the breeding female (Crampton and Lloyd, 1959; Trail 1968a) and one effect of weaning is to remove lactational stress to ensure that animals attain the body weight and condition required for subsequent early conception. Results of this study confirmed earlier reports by Christie (1962) and Rose et al. (1963) that early weaning was beneficial to the animal's fertility status. Thus animals whose calves were weaned after nine months, which is the current practice on many ranches, had calving intervals averaging 24 days longer than cows which weaned calves five months after calving. For those who advocate early weaning, the story would end here. The question is: what month of the year should weaning be done? This question is relevant in view of the observed sensitivity to pasture by the early-weaned calves (Schottler and Williams, 1975) on one hand and the need to prepare the breeding female for subsequent calving and, even more important, conception on the other. Weaning at the end of September coincided with the end of a dry and cold season so that removal of lactational stress meant that animals were able to regain body weight and condition up to parturition. Weaning during November/December was done during the "short rains" period which favoured pasture production. However, weaning at the end of October meant a lot of stress on the animals, particularly so after a dry season in July - September and before the next rains in November/December.

Lammond (1970) had suggested increasing body weight and condition of cows as much as possible before calving, and attempting to hold this condition up to the breeding season. As indicated above, this could be achieved by early weaning but because of seasonality in pasture availability and quality (Karue, 1974 and 1975), it would be difficult to try and maintain body weight and body condition up to conception without supplementary feeding. In any case, results of the supplementary feeding trial showed that although there was a tendency for heavier cows at calving to have shorter calving intervals, the effect of this parameter in all the other evaluation models was not significant which meant that weight of dams at calving may be of limited importance. The other alternative, also suggested by Lammond (1970), lays less emphasis on body weight at calving. He suggested allowing cows to calve down in moderate body condition and feeding heavily before breeding. This view would be more practical and was supported by the results relating to supplementary feeding. Besides, mating could be synchronised such that cows calve down in reasonable body condition before the commencement of the rains. Thus in considering the effects of lactation, it would be more important to pay particular attention to when animals are due to calve down so that they can be prepared for early re-conception rather than when their calves should be weaned.

5.2.7 Effect of dam's previous parity

There were indications to suggest that the dam's previous parous state had an influence, albeit small, on fertility. Results from various workers reporting on this parameter are rather inconsistent (Christie, 1962; Wiltbank and Harvey, 1963; Buck *et al*; 1976; Thorpe *et al.*; 1981). It would seem that in order to make meaningful comparisons in fertility, one would have to consider previous parity in relation to the availability of feed, be it natural pasture or supplements during the breeding season. One observation that was rather striking was that during the November-January period when grazing was good and plentiful, or when animals were supplemented before or after calving,heifers and previously parous cows had a higher fertility than that of dry cows. This could be due to: firstly, a sufficient supply of nutrients to meet the requirements of lactation and, in the case of heifers, body growth. Secondly, the dry cows group consisted of what might be termed "difficult calvers" which, for various reasons, were not able to rear calves during the previous year. Fertility levels of such animals were, to some extent, compromised. Alternatively, the dry cows became too fat and this could have interfered with their reproductive performance (Amoroso, 1963; Lammond, 1970). This would re-emphasize the desirability of including a condition score as suggested by Andrews (1976). To avoid overfatness, previously dry cows could be allowed shorter grazing hours during the November - January mating season.

5.2.8 Effect of breed type

The East African Shorthorn Zebu (EASZ) exhibited fairly consistent fertility levels throughout the year, an observation that was consistent with the findings of Galukande et al. (1962). Zebu cattle are indigenous in East African (Mason and Maule, 1960) and would be expected to have adapted themselves to fluctuations in feed supply and related factors arising from out-of-season rains and prolonged droughts. Adaptability has been attributed to their ability to lay down fat on a lower plane of nutrition and to remain in a better condition even during dry seasons (Mason and Buvanendran, 1982). Reproductive efficiency of the Borans was, by and large, similar to that of the EASZ and this was consistent with the observation reported by Trail (1968b) at Ruhengere ranch in Uganda. The ability of these two indigenous breed types to maintain body weight even when nutritional conditions are poor may be due to a lower metabolic rate, slower growth rate and greater digestibility of low-nitrogen and high-fibre diets (Mason, 1968; Andrews, 1972). However, there was ample evidence to indicate that when mating took place between November and January, the Borans had a higher fertility than the EASZ possibly due to genotype X environmental interactions.

In general, results of crossbreeding to improve fertility have been inconsistent. Mahadevan and Hutchison (1964) had reported improvement in age at first calving of the crossbreds. Recently, while confirming this observation, Swensson et al. (1981) contended that apart from improved manifestation of oestrus, reproductive performance of crossbred beef cattle did not exceed the best results of the indigenous Zebu breed types in Ethiopia. In this study, it is possible that the observed improvement in calving interval of Boran crossbreds was due to heterosis but the structure of the data with no reciprocal crosses was such that this observation could not be confirmed. Improvement could well be due to complementarity (Mason and Buvanendran, 1982). What seems clear is that when nutritional conditions are improved, then there is great opportunity for improving reproductive performance by rearing Boran crossbred cows.Traditionally, crossbreeding has been done by using exotic beef breeds such as the Hereford, Aberdeen Angus etc. There is no reason to doubt why an improved Zebu from elsewhere may not form a better basis for crossbreeding with the indigenous breed types. In this regard, one is reminded of improved Zebus such as the Africander in Southern Africa, the Sindhi and Sahiwal from India, the American Brahman and, of course, the Boran in East Africa. The choice is wide.

CHAPTER 6

CONCLUSIONS

Fertility in range-fed beef cattle is a very complex physiological process involving the interplay of a number of factors. These factors are overwhelmingly environmental in origin rather than genetic which means that it is primarily the environmental conditions, particularly nutrition and management procedures, that have to be tailored for the benefit of the animal's fertility. Nutritional and management practices immediately before and during the breeding season had the most significant and far-reaching effects on fertility. Even during the conception period, influence of nutritional stress and related factors such as age and body weight changes varied from season to season with different intensities and was often modified by other factors which, all working in concert, complicated the situation even further. Generally, factors that were far-removed from conception, for instance, weaning period, weaning month, body weight at calving and previous parous state were of less significance. It was obvious that there was a need for a critical assessment of the various factors affecting fertility and by careful manipulation of the environment in range areas with such tremendous variation in the quality and, often more importantly, quantity of range vegetation available to beef cattle, it should be possible to formulate strategies for improving reproduction performance.

Due to the seasonal nature of rainfall and its profound influence on range vegetation, and hence fertility, seasonal mating would be advocated. Breeding would have to be sychronised with the rainfall pattern such that animals drop their calves at the end of a dry season to take advantage of favourable pasture conditions during the subsequent rainy period. At Athi River ranch, mating would best be done between November and January. Such a closed breeding season would demand a high level of nutrition and management and would, therefore, be recommended for large-scale properties with sufficient managerial competence. The pastoralist rancher will, for sometime, continue with the all-year-round mating to spread the risks associated with erratic pasture and water supplies but will be expected to adopt seasonal mating as he becomes more commercially oriented. Overdependence on milk and meat for his subsistence will be reduced through maximising profits from sales of surplus cattle to purchase the required food items during the year.

Considering that the target joining weight was around 320 kg for this group of animals, heifers should first be bred after attaining a liveweight close to 280 - 300 kg, the optimal weight depending on the breed. Consequently, decisions made to breed heifers based on age alone may depress their fertility. The fact that females should gain weight during the breeding season reinforces the need to mate animals when pasture conditions are most favourable. This is of primary significance because pasture is still the cheapest feed resource for ruminant animals.

Dry season supplementation with energy and nitrogen sources should be given to breeding animals post-partum and, even then, only to young females nursing their first calves and to cows that reared calves during the previous year. A reduction in calving interval of 68 days by the 4-year-old post-partum supplemented animals would mean, in economic terms, extra income from sales of one to two additional calves reared during the productive life of the dam. However, it would be uneconomic to supplement beef cattle during years with good rainfall. The need to supplement certain categories of animals would entail their separation into two groups namely, lactating heifers and previously parous cows in one group and dry cows in the other. A separate group for dry cows would facilitate their management to reduce grazing hours, and hence over-fatness, during the breeding season.

Although improvement in fertility following earlier calving in heifers compared to older cows was marginal, it would be desirable to breed heifers for the first time a month earlier than the rest of herd. This would ensure that heifers have a longer time to recoup weight loss from pregnancy and early lactation. This aspect is particularly relevant since heifers were more sensitive to post-partum nutritional conditions. Consequently, it would be recommended to have a third group consisting of heifers due for service together with young bulls of a similar age. This would also facilitate closer attention and selection of breeding heifers based on good mothering ability to replace cows which attain the age of ten years. Culling for age and other noticeable reproductive abnormalities including failure to rear calves successfully must be followed rigorously to ensure that breeding is allowed to continue from the best females. Breeding, production and treatment records must be kept to ensure efficiency and accuracy in executing culling programmes.

Ranchers would benefit through the adoption of early weaning programmes. A reduction of 24 days may not be spectacular in the short-run but the long-term cumulative effects are more than likely to reduce feeding costs involved in maintaining body weight and body condition required for reconception. It is important to ensure regular calving by the dam through early weaning even if this means temporarily compromising the growth rate of the early-weaned calf. However, due to the time lag between weaning and reconception in a ranching situation characterised by erratic and inadequate rainfall, it would be difficult to maintain body weight and body condition by early weaning alone. The recommended practice, therefore, would be a package to include seasonal breeding, dry season supplementation as well as early weaning.

The small East African Shorthorn Zebu had fairly consistent fertility levels during the year which were slightly higher than those of the Borans. However, the difference in fertility between these two indigenous breeds should not be overstressed because the small zebus were from a specific area in Nyanza Province and hardly representative of the national small zebu herd. There was ample evidence, though, that under favourable nutritional conditions between November and January or when dry season supplementation was provided, the Borans and Boran crossses had a higher fertility. Consequently, attempts to increase beef production from ranches would appear to centre around these two genotypes. However, the small zebus still form the largest proportion of adapted beef cattle in Kenya and will be expected to form the basis of the beef industry for years to come. For the time being, incorporation of the Boran, pure or cross - breeding, would be beneficial.

The significant year effects reflected mainly seasonal effects. However, the rancher would be advised to pay particular attention to stocking rates, grazing intensity, watering points, age and number of breeding bulls, mineral supplementation and other practices which may vary from year to year as a result of changes in ranch managers and climatic factors.

REFERENCES

Allen, C.J. (1973). Practical considerations in the improvement of beef cattle production. Symposium of Animal Production Society of Kenya, April. Mimeo 5pp.

Ambrose, A.V. Jr., Oyedipe, E.O. and Buvanendran, V.(1984). Influence of management and season of breeding on pregnancy rates of Zebu cattle in an artificial insemination programme. Tropical Agriculture (Trinidad), 61: 265 - 268.

Amoroso, E.C. (1963). Physiological limitations on reproductive performance. In: World Conference on Animal Production, pp 127 - 140. European Association for Animal Production, Roma 11 - Corso Trieste, 67.

Anderson, J. (1936). Studies on reproduction in cattle. 1. The periodicity and duration of oestrus. Empire Journal of Experimental Agriculture, 4: 186 - 207.

Anderson, J. (1944). The periodicity and duration of oestrus in Zebu and grade cattle. Journal of Agricultural Science, Cambridge, 34: 57 - 68.

Andrews, L.G. (1972). The major non-infectious causes of reproductive wastage in beef cattle in the northern territory. Australian Veterinary Journal, 48: 41 - 46.

Andrews, L.G. (1976). Reproductive performance of beef cattle in the Northern Territory. M.Sc. Thesis, James Cook University, Australia.

Animal Production Research Department (1981). Record of Research Annual Report, pp 20 - 23. Kenya Agricultural Reseafch Institute, Muguga.

Baharin, K. and Beilharz, R.G. (1977). A survey of reproductive performance in herds of beef cattle. Australian Journal of Experimental Agriculture and Animal Husbandry, 17: 181 - 186.

Bishop, E.J.B. (1978). The performance of a beef breeding herd subjected to continuous mating in the Valley Bushveld of the Eastern Cape. South African Journal of Animal Science, 8: 15 - 20.

Blaxter, K.L. (1957). The effects of defective nutrition during pregnancy in farm livestock. Proceedings of the Nutritional Society (England and Scotland),16: 52 - 58.

Bond, J.H. (1974). Supplementary feeding of grain and molasses. In: Beef Cattle Production and Ranch Management, p 215. Office of the Austrialian Development Assistance Agency, Canberra.

Bredon, R. M. and Horrell, C. R. (1962). The chemical composition and nutritive value of some common grasses in Uganda. Tropical Agriculture (Trinidad), 39: 13 - 17.

Buck, N.G., Light, D., Rutherford, A., Miller, M., Rennie, T.W., Pratchett, D., Capper, B.S. and Trail, J.C.M. (1976). Environmental factors affecting beef cow reproductive performance in Botswana. Animal Production, 23: 357 - 363.

Capper, B. S., Pratchett, D., Rennie, T. W., Light, D., Rutherford, A., Miller, M., Buck, N.G. and Trail, J.C.M. (1977). Effects of rumen stimulating licks on reproductive performance and live-weight gain of beef cattle in Botswana. Animal Production, 24: 49 - 55.

Carroll, E. J. and Hoerlein, A. B. (1966). Reproductive perfomance of beef cattle under drought conditions. Journal of American Veterinary Medical Association, 148: 1030 -1033.

Central Bureau of Statistics (1984). Population Census, 1979. Ministry of Finance and Planning, Nairobi.

Christie, G.J. (1962). Sterility or reduced fertility due to nutritional causes. Bulletin of Epizootic Diseases of Africa, 10: 161 - 167.

Crampton, E.W. and Llyod, L.E. (1959). General nutritional aspects of reproduction and lactation. In: Fundamentals of Nutrition, pp 386 - 393. W.H. Freeman and Co., San Francsisco and London.

Cruz Ortiz, V.(1979). Genetic and environmental parameters of production in Brahman cattle. Annotated Bibliography No. 57A, Abstract 70:1270.Commonwealth Agricultural Bureaux,The King's Building, Edinburgh 9, Scotland.

Daly, J.J. (1971). A breeding policy for beef herds. Queensland Agricultural Journal, 97: 171 - 175 and 237 - 242.

Donaldson, L.E. (1962). Some observations on fertility of beef cattle in North Queensland. Australian Veterinary Journal, 38: 447 - 454.

Donaldson, L.E. (1968). The pattern of pregnancies and life time productivity of cows in a north Queensland beef cattle herd. Australian Veterinary Journal, 44: 493 - 495.

Donaldson, L. E., Ritson, J. B. and Copeman, B. (1967). The reproductive efficiency of several north Queensland beef herds. Australian Veterinary Journal, 43: 1 - 6.

Doorenbos, J. and Pruitt, W. D. (1977). Calculation of reference crop evapotranspiration (ET_o). In: Guidelines for Predicting Crop Water Requirements, p 15. FAO Irrigation and Drainage Paper, Rome.

Dunn, T.G., Ingalls, J.E., Zimmerman, D.R. and Wiltbank, J.N. (1969). Reproductive performance of two year-old Hereford and Angus heifers as influenced by pre- and post-calving energy intake. Journal of Animal Science,29: 719 - 726.

Edwards, D.C. and Bogdan, A.V. (1951). Important grassland plants of Kenya, pp 1 - 13. Sir Isaac Pitman and Sons Limited, London.

Edye, L.A., Ritson, J.B., Haydock, K.P and Griffith Davies, J. (1971). Fertility and seasonal changes in liveweight of droughtmaster cows grazing a Townsville Stylo-Spear grass pasture. Australian Journal of Agricultural Research, 22: 963 - 977.

Elliot, R.C. (1961). Unpublished report. Cited by Christie (1962).

Elliot, R.C. (1964). Some nutritional factors affecting the productivity of beef cattle in Southern Rhodesia. Ph.D. Thesis. Cited by Topps (1977).

Ernst, A. J., Limpus, J. F. and O'Rourke, P. K. (1975). Effects of supplements of molasses and urea on intake and digestibility of native pasture. Australian Journal of Experimental Agriculture and Animal Husbandry, 15: 451 - 455.

French, M.H. (1952). Mineral deficiencies in farm livestock East African Agricultural and Forestry Journal, 18, 4 - 8.

French, M.H. (1957). Nutritional value of tropical grasses and fodders. Herbage Abstracts, 27: 1-9.

Galukande, E.B., Mahadevan, P. and Black, J.G. (1962). Milk production in East African Zebu cattle. Animal Production, 4: 329 - 336.

Gethin Jones, G. H. and Scott, R. M. (1955). A second provisional soil map of Kenya and Tanganyika. East African Agriculture and Forestry Research Organisation, Muguga, Kenya.

Glover, P. E., Walker, J. B. and Gwynne, M. D. (1962). An ecological survey of Kenya Masailand. Committee on Natural Resources, University of California, Berkley.

Gregory, K.E. (1968). Selection responses, performance and progeny testing. In: Proceedings of the Beef Cattle Breeding and Ranching Development Conference, Mbarara, pp 27 - 39. Edited by G.D.Sacker and J.C.M.Trail. Ministry of Animal Industry, Game and Fisheries, Uganda.

Griffiths, J.F. (1962). The climate of East Africa. In: The The Natural Resources of East Africa, pp 77 - 87. Edited by E.W. Russell D.A. Hawkins, Ltd., Nairobi.

Griffiths, J. F. and Gwynne, M.D. (1962). The climate of Kenya Masailand. East African Agricultural and Forestry Journal, 28: 1 - 6.

Grosskopf, J.F.W. (1980). Non-pathogenic factors associated with the reconception of beef cows under extensive conditions. In: IV World Conference on Animal Production, pp 511 - 525. The Argentina Association of Animal Production, Buenos Aires.

Gubarevic, J.G. and Teresenkov, A. S. (1965). [Increasing the conception rate in cows]. Animal Breeding Abstract, 35 : 1328

Hale, D.H. (1975). Nutrition, hormones and fertility. Cited by Topps(1977).

Hammond, J.(1963).Physiological limitations on reproductive performance. In: World conference on Animal Production, pp. 136 -138. European Association for Animal Production, Roma 11 - Corso Trieste, 67.

Hansel, W. (1959). The oestrus cycle of the cow. In: Reproduction in Domestic Animals, Vol. 1, p 255. Edited by H.H. Cole and P.T. Cupps. Academic Press, New York and London.

Hart, B. and Mitchell, G.L. (1965). Effect of phosphorus supplementation on the fertility of an open range beef cattle herd on the Barkly Tableland. Australian Veterinary Journal, 41: 305 -309.

Harvey, W.R. (1960). Least squares analysis of data with unequal subclass numbers. Agricultural Research Service, U.S.D.A.

Holroyd, R.G., Allan, P.J. and O'Rourke, P.K. (1977).Effect of pasture type and supplementary feeding on the reproductive performance of cattle in the dry tropics of North Queensland. Australian Journal of Experimental Agriculture and Animal Husbandry, 17: 197 - 206.

Holroyd, R.G., O'Rourke, P.K., Clarke, M.R.and Loxton, I.D. (1983). Influence of pasture type and supplement on fertility and liveweight of cows and progeny growth rate in the dry tropics of Northern Queensland. Australian Journal of Experimental Agriculture and Animal Husbandry, 23: 4 - 13.

Hutchison, H.G. (1962). Genetic influence on fertility of farm livestock. A discussion. Bulletin of Epizootic Diseases of Africa, 10: 173 -183.

Hutchison, H. G. (1963). Physiological limitations on reproductive performance. In: World Conference on Animal production, pp 147 - 148. European Association for Animal Production, Roma, 11 Corso Trieste, 67.

Hutchison, H.G. and Macfarlane, J.S. (1958). Variation in gestation periods of Zebu cattle under ranch conditions. East African Agricultural and Forestry Journal, 24: 148 - 152.

Jaetzold, R. and Schmidt, H. (1983). Farm Management Handbook of Kenya, Vol. 11/C, East Kenya, p 160. Ministry of Agriculture/Germany Agency for Technical Co-operation.

Joubert, D.M.(1963). Puberty in female farm animals. Animal Breeding Abstracts, 31: 295 -306.

Karue, C. N. (1971). Metabolism of nitrogen, voluntary intake, nutrient requirement and digestibility by the East African Zebu - the Boran. Ph.D. Thesis, Rutgers University, U.S.A.

Karue, C.N. (1972). Supplementary feeding of beef cattle. Paper presented to the Animal Production Society of Kenya, October. Mimeo. 10 pp.

Karue, C.N. (1974). The nutritive value of herbage in semi-arid lands of East Africa. 1. Chemical composition. East African Agricultural and Forestry Journal, 40: 89 - 95.

Karue, C.N. (1975). The nutritive value of herbage in semi-arid lands of East Africa. II.Seasonal influence on the nutritive value of Themeda triandra. East African Agricultural and Forestry Journal, 40: 372-387.

Kidner, E. H. (1966). Seasonal body weight changes in suckled Boran cows at pasture and their probable association with interval between calvings. East African Agricultural and Forestry Journal, 31:399 - 404.

Kiwuwa, G. H. (1968). Reproductive efficiency and milk production of dairy cattle. East African Agricultural and Forestry Journal, 33: 335 - 343.

Koger, M., Cunha, T. J. and Warnick, A. C. (1973). In: Crossbreeding Beef Cattle, Series 2, pp 434 - 447. University of Florida Press, Gainesville.

Koger, M., Burns, W.C., Pahnish,O.F. and Butts, W.T.(1979). Genotype by environment interactions in Hereford cattle. 1. Reproductive traits. Journal of Animal Science, 49: 396 - 402.

Lammond, D.R. (1969). Sources of variation in reproductive performance in settled herds of beef cattle in North Eastern Australia. Australian Veterinary Journal, 45: 50-58.

Lammond, D. R. (1970). The influence of undernutrition on production in the cow. Animal Breeding Abstracts, 38: 359 - 372.

Lampkin, K. (1969). Boran/Hereford cross in beef breeding. Kenya Farmer, May, pp 12,13 and 28.

Lampkin, K. and Lampkin, G. H. (1960). Studies on the production of beef from Zebu cattle in East Africa. II. Milk production in suckled cows and its effect on calf growth. Journal of Agricultural Science, Cambridge, 55: 233 - 239.

Lampkin, G.H., Howard, D.A. and Burdin, M.L (1961). Studies on the production of beef from zebu cattle in East Africa. III. The value of feeding a phosphate supplement. Journal of Agricultural Science, Cambridge, 57: 39 - 47.

Lasley, J. F.and Bogart, R.(1943). Some factors influencing reproductive efficiency of range cattle under artificial and natural breeding conditions. Cited by Warnick (1955).

Ledger, H. P. (1966). Comparison of Shorthorn Zebu and Boran Zebu on high and low nutritional planes.Cited by Meyn (1970), p 138.

Ledger, H.P. and McQueen, M. (1967). Meat research and beef cattle unit. Record of Research, Annual Report, pp 138 - 140. East African Agriculture and Forestry Research Organisation, East African Community, Kikuyu, Kenya.

Ledger, H.P., Odero, J. C . and Ndugire, N. (1969). Athi River Field Station. Record of Research Annual Report, pp 118-119. East African Agriculture and Forestry Research Organisation, Muguga, Kenya.

Ledger, H. P., Rogerson, A, and Freeman, G. H. (1970). Further studies on the voluntary food intake of Bos indicus, Bos taurus and crossbred cattle. Animal Production, 12: 425 - 451.

Lindley, C.E., Easley, G.T., Whatley, J.A. and Chambers, D. (1958). A study of the reproductive performance of a purebred Hereford herd. Journal of Animal Science, 17: 337 - 342.

Lindsay, D.R. (1976). The usefulness to the animal producer of research findings in nutrition on reproduction. Proceedings of the Australian Society of Animal Production, II: 217 - 224.

Livestock Development Division (1983). Annual Report, pp 25 - 27. Ministry of Agriculture and Livestock Development, Nairobi.

Macfarlane, J.S. and Worrall, K. (1970). Observations on the occurrence of puberty in Bos indicus heifers. East African Agricultural and Forestry Journal, 35: 409 - 410.

Mahadevan, P. (1966). In: Breeding for Milk Production in Tropical Cattle, pp 18 - 19, 94 - 95 and 112 - 122. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England.

Mahadevan, P. and Marples, H.J.S. (1961). An analysis of the Entebbe herd of Nganda cattle in Uganda. Animal Production, 3: 29 - 39.

Mahadevan, P. and Hutchison, H.G. (1964). The performance of crosses of Bos taurus and Bos indicus cattle for milk production in the coastal region of Tanganyika. Animal Production, 6: 331 - 336.

Mariante, A. da S. (1979). Growth and reproduction in Nellore cattle in Brazil. Genetic parameters and effects of environmental factors. Annotated Bibliography No. 57A. Animal Breeding Abstract 1: 1247. Commonwealth Agricultural Bureaux, The King's Building, Edinburgh 9, Scotland.

Marples, H.J G. (1963). An analysis of milk production in the Shorthorn Zebu herd at Entebbe. Tropical Agriculture (Trinidad), 41: 15 - 19.

Marshall, B. and Bredon, R.M. (1966). The nutritive value of Themeda triandra. East African Agricultural and Forestry Journal, 32: 375 - 379.

Mason, I.L. (1966). Hybrid vigour in beef cattle. Animal Breeding Abstracts, 34: 453 - 473.

Mason, I.L. (1968). Principles of beef cattle breeding in the tropics. In: Proceedings of the Beef Cattle Breeding and Ranching Development Conference, Mbarara, pp 15 - 25. Edited by G.D.Sacker and J.C.M.Trail. Ministry of Animal Industry, Game and Fisheries, Uganda.

Mason, I. L. and Maule, J. P. (1960). The indigenous livestock of Eastern and Southern Africa. Commonwealth Agricultural Bureaux, Farnham Royal, Buckinghamshire.

Mason, I.L. and Buvanendran, V. (1982). Breeding plans for ruminant livestock in the tropics, pp 43 and 77. Food and Agriculture Organisation, Rome.

McCarthy, F.D. and Mwangi, W.M.(1982). Kenyan Agriculture. Toward 2000, p 67. International Institute for Applied Systems Analysis, Laxenburg, Austria.

McCulloch, J.S.G. (1965). Tables for the rapid computation of the Penman estimate of evaporation. East African Agricultural and Forestry Journal, 30: 286 - 295.

McQueen, M. (1965). Kedong ranch. Record of Research Annual Report, pp 179 - 180. East African Agriculture and Forestry Research Organisation, Muguga, Kenya.

Meyn, K.(1970). Beef production in East Africa, pp 132 -133 and 144 - 155. IFC Institut Fur Wirtschaftsforschung 8 Munchen 19 HubertusstraBe 22.

Meyn, K. (1972). Breeding for beef and milk in tropical Africa. Mimeo. 10 pp.

Milles, A.H. (1984). Beef cattle production in the Central and Upper Burnett. Queensland Agricultural Journal, 110: 83 - 111.

Moir, R. J., Somers, M. and Bray, A. C. (1967). The utilisation of dietary sulphur and nitrogen by ruminants. The Sulphur Institute Journal, 3: 15 -18.

Morley, F.H.W., Axelsen, A and Cunningham, R. B. (1976). Liveweight at joining and fertility in beef cattle. Proceedings of the Australian Society of Animal Production, 11: 201 - 204.

Mukhebi, A.W., Gitumu, M., Kavoi, J. and Iroha, J. (1985). Impact of the 1983/84 drought on cattle and goats in Kenya. Ministry of Agriculture and Livestock Development. Kiboko National Range Research Station, Makindu, Kenya.

National Food Policy (1981). Sessional Paper No. 4. p 49. Government Printer, Nairobi.

National Livestock Development Policy (1980), pp 9 and 20. Ministry of Livestock Development, Nairobi.

Ørskov, E.R.(1982). Host animal protein requirements and protein utilisation. In: Protein Nutrition in Ruminants, pp 85 - 136 and 151. Academic Press Inc. (London) Ltd.

Oyedipe, E.O., Buvanendran, V and Eduvie, L.O. (1982). Some factors affecting the reproductive performance of White Fulani (Bunaji) cattle. Tropical Agriculture (Trinidad), 59: 231 -234.

Penman, H. L. (1948). Proc. Roy. Soc. A, 193: 120. Cited by McCulloch (1965).

Pereira, H. C. and McCulloch, J. C. G. (1962). Water requirements of East African crops. In: The Natural Resources of East Africa, pp 88 - 91. Edited by E.W. Russell. D.A. Hawkins, Ltd., Nairobi.

Plasse, D., Koger, M. and Warnick, A.C.(1968). Reproductive behaviour of Bos indicus females in a sub-tropical environment. III. Calving intervals, intervals from first exposure to conception and interval from parturition to conception. Journal of Animal Science, 27: 105 - 112.

Plasse, D., Warnick, A.C. and Koger, M.(1970). Reproductive behaviour of Bos indicus females in a sub-tropical environment. Journal of Animal Science, 30: 63 - 72.

Potter, H.L. (1985). Aspects of climate, herbage growth and animal production in a semi-arid area of Kenya. Ph.D Thesis, University of Nairobi.

Pratchett, D., Capper, B. S., Light, D., Miller, M., Rutherford, A., Rennie, T.W., Buck, N.G. and Trail, J.C.M. (1977). Factors limiting liveweight gain of beef cattle on rangeland in Botswana. Journal of Range Management, 30: 442 - 445.

Pratt, D. J., Greenway, P. J. and Gwynne, M.D. (1966). A classification of East African rangeland. Journal of Applied Ecology, 3: 369 - 382.

Rakha, A. M., Igboeli, G. and King, J.L. (1971). Calving interval, gestation and post-partum periods of indigenous central African cattle under a restricted system of breeding. Journal of Animal Science, 32:507 - 509.

Reynolds, W.L., De Rouen, T.M., Moin, S. and Koonce, K.L. (1979). Factors affecting pregnancy rate of Angus, Zebu and Zebu-cross cattle. Journal of Animal Science, 48: 1312 - 1321.

Richardson, F. D., Oliver, J. and Clarke, G.P.Y. (1976). Analysis of some factors which affect the productivity of beef cows and their calves in a marginal rainfall area of Rhodesia. 1. Factors affecting calving rate. Animal Production, 21:41- 49.

Rollinson, D.H.L. (1962). Physiology of reproduction in domestic animals with special reference to African conditions. Bulletin of Epizootic Diseases of Africa, 10: 137 - 158.

Rose, C.J., Christie, G.J. and Conradie, R.P. (1963). The effect of early weaning on the reproductive efficiency of ranch cattle in Southern Rhodesia.In: World Conference on Animal Production, pp.125 -135. European Association for Animal Production, Roma 11-Corso Trieste, 67.

Rudder, T .H., Seifert, G. W. and Maynard, P. J. (1976). Factors affecting reproductive rates in commercial Brahman crossbred herds. Australian Journal of Experimental Agriculture and Animal Husbandry, 16: 623 - 629.

Rudder, T. H., Seifert, G. W. and Burrow, H. M (1985). Environmental and genotype effects on fertility in a commercial beef herd in central Queensland. Australian Journal of Experimental Agriculture, 25: 489 - 496.

Sacker, G. D., Trail, J.C.M. and Fisher, I. L. (1971a). Crossbreeding beef cattle in Western Uganda. 4. Calving percentage and mothering ability. Animal Production, 13: 165 - 170.

Sacker, G. D., Trail, J.C.M. and Fisher, I. L. (1971b). Crossbreeding beef cattle in Western Uganda. 6. A note on hybrid vigour in Red-Poll-Boran crosses. Animal Production, 13: 181 - 184.

Schottler, J.H. and Williams, W.J. (1975). The effects of early weaning of Brahman cross calves on calf growth and reproductive performance of the dam. Australian Journal of Experimental Agriculture and Animal Husbandry, 15: 456 - 459.

Scott, R. M. (1962). The soils of East Africa. In: The Natural Resources of East Africa, pp. 67 - 76. Edited by E.W. Russell. D.A. Hawkins, Ltd., Nairobi.

Seebeck, R.M. (1973). Sources of variation in the fertility of a herd of Zebu, British and Zebu X British cattle in Northern Australia. Journal of Agricultural Science, Cambridge, 81: 253 - 262.

Seebeck, R.M. (1976). Sysnova Version 8 Reference Mannual. Tropical Research Centre, Division of Animal Production, C.S.I.R.O., Rockhampton, Queensland, 4700.

Siebert, B. D., Playne, M.J. and Edye, L. A. (1976). The effects of climate and nutrient supplementation on the fertility of heifers in North Queensland. Proceedings of the Australian Society of Animal Production, 11: 249 - 253.

Slagsvold, P. (1969). Some aspects of livestock feeding and fertility. East African Agricultural and Forestry Journal, 35: 174 - 180.

Sparke, E.J. and Lammond, D.R. (1968). The influence of supplementary feeding on growth and fertility of beef heifers grazing natural pasture. Australian Journal of Experimental Agricuture and Animal Husbandry, 8: 425 - 433.

Spitzer, J.C., Wiltbank, J.N. and LeFevre, D. G. (1975). Increase beef cow productivity by increasing reproductive performance. Cited by Wiltbank and Spitzer (1978).

Steenkamp, J. D. G., van der Horst, C. and Andrew M.J.A. (1976). Reconception in grade and pedigree Afrikander cows of different sizes. 1. Post-partum factors influencing reconception. Cited by Topps (1977).

Stobbs, T. H. (1965). Annual Report Part 11 , 1964 - 65, Serere, Uganda. Cited by Meyn (1970), p 151.

Stobbs, T.H. (1966). The introduction of Boran cattle into an E.C.F. endemic area. East African Agricultural and Forestry Journal, <u>31</u>: 298 - 304.

Stobbs, T.H.(1967). Management of the small East African Zebu in relation to milk yield, calf growth and mortality. East African Agricultural and Forestry Journal, <u>32</u>: 250 - 255.

Swensson, C., Schaar, J., Brannang, E. and Meskel, L. B. (1981). Breeding activities of the Ethio-Swedish integrated rural development project. III. Reproductive performance of Zebu and crossbred cattle. World Animal Review (F.A.O.) <u>38</u>: 31 - 36.

Symington, R. B. (1969). Factors affecting post-partum fertility in cattle with special emphasis on the hormonal aspects of the problem in ranch cows in Southern Africa. Cited by Topps (1977).

The Boran Cattle Breeders' Society (1951). Kenya Boran cattle. D.A. Hawkins Ltd., Nairobi.

Thorpe, W., Cruickshank, D. K. R. and Thompson, R. (1980). Genetic and environmental influences on beef cattle production in Zambia. 1. Factors affecting weaner production from Angoni, Barotse and Boran dams. Animal Production, 30: 217 - 234.

Thorpe, W., Cruickshank, D. K. R. and Thompson, R. (1981). Genetic and environmental influences on beef cattle production in Zambia. Animal Production, 33:165- 177.

Topps, J.H. (1972). Urea or biuret supplementation to low protein grazing in Africa. World Animal Review (F.A.O.) 3: 14 - 18.

Topps, J.H. (1977). The relationship between reproduction and undernutrition in beef cattle. World Review of Animal Production, 13: 43 - 49.

Trail, J.C.M (1968a). Some aspects of initial results from Ruhengere field station. 3. Environmental and genetic influences on cow weight. In: Proceedings of the Beef Cattle Breeding and Ranching Development Conference, Mbarara, pp 63 - 65. Edited by G.D. Sacker and J.C.M. Trail. Ministry of Animal Industry, Game and Fisheries, Uganda.

Trail, J.C.M. (1968b). Beef breeding at the Ruhengere field station. Reproductive performance. In: Proceedings of the Beef Cattle Breeding and Ranching Development Conference, Mbarara, pp 44 - 47. Edited by G.D. Sacker and J.C.M. Trail. Ministry of Animal Industry, Game and Fisheries, Uganda.

Trail, J.C.M. and Fisher, I.L. (1971). The operation of beef cattle breeding research under semi-arid extensive conditions in Botswana, pp 1- 4. Gaborone Government Printer.

Trail, J. C. M., Sacker, C. D. and Fisher, I. L. (1971). Crossbreeding of beef cattle in Western Uganda. 1. Performance of Ankole, Boran and Zebu cows. Animal Production, 13: 127 - 141.

Tropical Pastures and Fodder Crop Production and Conservation (1975). International Training Course, Queensland, Australia. Mimeo, 9p.

Turner, C.D. (1962). In: General Endocrinology, p 28. Third Edition, W.B. Saunders Company, Philadelphia and London.

Ward, H.K. (1968). Supplementation of beef cows grazing on veld. Rhodesian Journal of Agricultural Research, 6: 93 - 101.

Warnick, A.C. (1955). Factors associated with the interval from parturition to first oestrus in beef cattle. Journal of Animal Science, 14: 1003 - 1010.

Weston, R.H. (1967). Factors limiting the intake of feed. Australian Journal of Agricultural Research, 18: 983 - 1002.

Wilkins, J.V. (1975). The Kenya Beef Recording Scheme. World Review of Animal Production, 11: 52 - 57.

Wilson, S.G. (1946). The seasonal incidence of calving and sexual activity in Zebu cattle in Nyasaland. Journal of Agricultural Science, Cambridge, 36: 246 - 257.

Wilson, F. (1963). Calvings and calf mortality in Ankole long-horned cattle. East African Agricultural and Forestry Journal, 29: 178 - 181.

Wiltbank, J. N. and Cook, A. C. (1958). The comparative reproductive performance of nursed cows and milked cows. Journal of Animal Science, 17: 640 - 648.

Wiltbank, J.N., Rowden, W. W., Ingalls, J.E., Gregory, K.E. and Koch, R.M. (1962). Effect of energy level on reproductive phenomena of mature Hereford cows. Journal of Animal Science, 21 : 219 - 225.

Wiltbank, J. N. and Harvey, W. R. (1963). Reproductive performance of beef cows in Lousiana. Journal of Animal Science, 22: 823 - 824. (Abstract No.38).

Wiltbank, J. N., Rowden, W.W., Ingalls, J.E. and Zimmerman, D.R. (1964). Influence of post-partum energy level on reproductive performance of Hereford cows restricted in energy intake prior to calving. Journal of Animal Science, 23: 1049 - 1053.

Wiltbank, J. N. and Spitzer, J.C. (1978). Recent research on controlled reproduction in beef cattle. Practical Applications. World Animal Review (F.A.O.), 27: 30 - 35.

Winks, L. (1974). Protein or NPN supplements for beef cattle in Queensland. In: Beef Cattle Production and Management, pp 205. Office of Australian Development Assistance Agency, Canberra.

A P P E N D I C E S

APPENDIX 1

Regression coefficients for calving interval of group 1 females

Coeff.	S.E.	Probability	Title
356.91			General level
6.19	3.57	*	EASZ
-4.19	3.62		Crosses
19.16	14.05		3 years old
-5.51	8.10		≥ 9 " "
15.05	8.39	*	July - Sept. conception
-1.14	15.06		Sept.- Jan. "
-21.05	7.63	***	1973 "
25.56	5.39	***	1976 "
-9.34	5.00	*	1977 "
-14.13	14.39		Heifer
9.13	7.68		Dry cow
-102.72	28.27	***	Soil moisture index (SMI1)
0.31	0.48		W1BC - WCP , Linear
0.08	0.03	***	" - " , Quadratic
-9.95	4.05	**	EASZ, July - Sept. conception
11.76	4.60	**	Crossess, " - " "
8.04	3.83	*	EASZ, Sept.- Jan. "
-15.84	6.56	**	July - Sept. conception, heifer
12.09	8.73		Sept.- Jan. " , "
8.32	5.32		July - Sept. " , dry cow
-0.45	5.68		Sept.- Jan. " , " "
56.52	30.46	*	July - Sept. " X SMI1 ,Linear
-145.46	55.14	***	Sept.- Jan. " X " , "
-0.40	0.65		July - Sept. " X W1BC-WCP, "
0.48	0.83		Sept.- Jan. " X " " , "
0.02	0.05		July - Sept. " X $(W1BC-WCP)^2$
0.06	0.04		Sept.- Jan. " X "

* P<0.05; ** P<0.01 *** P<0.005

Coefficients for the first level of each class are calculated by difference from the sum of the remaining levels.

W1BC - WCP = weight change (kg) between one month before conception and conception.

These remarks apply to similar and subsequent appendices.

APPENDIX 2

Distribution of animals, mean calving interval (days) and regression coefficients of breed type within "second" conception period of group 1 females

	Conception period			
Breed type	May - July	July - Sept.	Sept.-Jan.	Totals
(a) Distribution[1]:				
Boran	16 (350)	12 (368)	16 (352)	44 (356)
EASZ	20 (353)	15 (367)	7 (377)	42 (362)
Crosses	18 (324)	10 (395)	-	28 (350)
Totals	54 (343)	37 (375)	23 (359)	114 (356)
(b) Coefficients:*				
Boran	-6.1	11.2	-11.2	
EASZ	-5.8	11.3	13.1	
Crosses	-29.8	22.7	-	

[1] Figures in parentheses are mean calving intervals.

* These are overall coefficients which are calculated from the sum of the coefficients of the levels of the individual interacting classes added to the interaction regression coefficients shown in Appendix 1.

These remarks apply to subsequent appendices relating to distribution of females per class and main factor interactions.

APPENDIX 3

Regression coefficients for calving interval of group 2 females

Coeff.	S.E.	Probability	Title
369.03			General level
-0.67	2.75		EASZ
1.58	4.22		Crosses
9.83	6.93		3 years old
-1.73	4.24		≥ 9 " "
-27.50	8.26	***	Jan. - March conception
61.96	7.61	***	July - Sept. "
-50.58	7.45	***	Nov. - Jan. "
24.32	5.20	***	1973/74 "
-18.54	5.55	***	1976 "
-11.98	6.11	*	Heifer
7.57	3.46	*	Suckled cow
-19.15	4.43	***	Soil moisture index (SMI1), Linear
1.68	0.38	***	W2BC - W1BC, Linear
1.35	0.50	***	W1BC - WCP, "
-0.10	0.03	***	W1BC - WCP, Quadratic
8.37	4.59	*	3 years old, Jan. - March conception
-13.76	3.51	***	3 " " , July - Sept. "
6.57	1.86	***	≥ 9 " " , " " "
2.98	0.86	***	Jan. - Mar. conc. X W2BC-W1BC, Linear
-2.35	0.43	***	July - Sept. " X " " , "
0.62	0.61		Nov. - Jan. " X " " , "
4.35	0.94	***	1973/74 " X W1BC-WCP , "
-3.12	0.53	***	1976 " X " " , "
-0.23	0.05	***	1973/74 " X " " , Quadr.
-0.14	0.04	***	1976 " X " " , "

* P<0.05; *** P<0.005

W2BC - W1BC = weight change (kg) between one and two months prior to "second" conception.

APPENDIX 4

Distribution of animals and coefficients of dam's age at first calving within "second" conception period of group 2 females.

	Conception period				
Age(years)	Jan.-Mar.	May-July	July-Sept.	Nov.-Jan.	Total
(a) Distribution:					
3	1 (450)	11 (383)	4 (415)	-	16 (395)
4 - 8	6 (400)	16 (383)	12 (431)	4 (376)	38 (400)
≥ 9	-	32 (375)	10 (432)	-	42 (389)
Total	7 (407)	59 (379)	26 (429)	4 (376)	96 (394)
(b) Coefficients:					
3	-9.3	31.3	58.0	-	
4 - 8	-44.0	9.2	61.1	-58.7	
≥ 9	-	7.8	66.8	-	

A P P E N D I X 5

Regression coefficients for calving interval of group 4 females.

Coeff.	S.E.	Probability	Title
595.38			General level
8.97	4.47	*	4 - 8 years old
-6.54	7.43		≥ 9 " "
192.84	61.21	***	Jan. - March conception
-223.71	96.73	*	Nov. - Jan. "
38.11	12.58	***	1973 "
-7.19	4.64		Dry cow
0.39	7.67		Suckled
-33.68	207.20		Soil Moisture Index 1, Linear (SMI1)
139.30	266.25		$SMI1^2$
0.65	0.22	***	W2BC - W1BC, Linear
1.32	1.02		W1BC - WCP, "
-0.05	0.03		W1BC - WCP, Quadratic
-0.11	0.04	**	Dam's weight at "second" conception
-2.86	6.37		Jan. - March conception, dry cow
10.91	5.94	*	Nov. - Jan. " , " "
10.04	10.37		Jan. - March " , suckled
-1.44	10.27		Nov. - Jan. " , "
-688.49	222.94	***	Jan. - March " X SMI1
653.48	406.53		Nov. - Jan. " X "
1087.12	311.95	***	Jan. - March " X $SMI1^2$
-933.59	507.96	*	Nov. - Jan. " X "
5.29	1.61	***	Jan. - March " X W1BC-WCP, Lin.
0.27	1.22		Nov. - Jan. " X " " , "
-0.17	0.06	***	Jan. - March " X " " ; Quad.
0.03	0.04		Nov. - Jan. " X " " , "

* $P<0.05$; ** $P<0.01$; *** $P<0.005$

APPENDIX 6

Distribution of animals and coefficients of dam's previous parity within "second" conception period of group 4 females.

	Dam's previous parity			
Conception period	Heifer	Dry cow	Suckled	Totals
(a) Distribution:				
Jan. - March	9 (596)	23 (594)	1 (585)	33 (594)
March - July	8 (580)	4 (636)	16 (570)	28 (582)
Nov. - January	14 (566)	22 (576)	1 (566)	37 (572)
Totals	31 (578)	49 (589)	18 (571)	98 (582)
(b) Coefficients:				
Jan. - March	192.5	182.8	203.3	
March - July	54.3	15.6	22.7	
Nov. - January	-226.4	-220.0	-224.8	

A P P E N D I X 7

Regression coefficients for calving interval of supplemented beef cattle.

Coeff.	S.E.	Probability	Title
362.02			General level
12.21	3.94	***	Boran
-5.11	5.47		EASZ
-0.72	4.06		EASZ crosses
1.36	4.54		4 years old
1.56	4.66		≥ 10 " "
-0.87	2.31		Dry cow
5.02	5.07		Pre-parturient supplementation
-14.04	7.28	*	Post-parturient "
2.36	2.19		Energy + Nitrogen
-9.86	3.76	***	Calved March
-17.31	5.15	***	" April/May
1.09	4.11		" 1978
-1.85	4.92		" 1979
-0.36	0.18	*	Duration of supplementation
-0.54	0.28	*	Dam's wt. at earlier calving, Linear
0.00	0.00	*	" " " " " , Quadr.
0.02	0.23		W1ACV - WCP, Linear
0.02	0.01	***	" " , Quadratic
12.11	7.85		4 years, pre-parturient supplement.
-11.21	4.97	*	≥ 10 " , " "
-28.76	11.20	**	4 years, post-parturient "
10.72	6.88		≥ 10 " , " "
-18.97	6.52	***	4 years, calved March
3.62	4.47		≥ 10 " , " "
-7.29	7.66		4 " , " April/May
10.31	4.36	*	≥ 10 " , " " "
4.91	2.79	*	Dry cow, pre-parturient supplement.
4.75	3.23		" " , post-parturient "
-11.22	4.41	**	Pre-parturient suppl., calved 1978
-3.40	5.87		Post-parturient " , " "
-3.34	3.52		Pre-parturient " , " 1979
-1.22	4.18		Post-parturient " , " "
-0.67	0.35	*	Calved 1978 X W1ACV - WCP, Linear
-0.06	0.33		" 1979 X " " , "
-0.00	0.01		" 1978 X " " , Quadratic
-0.01	0.01		" 1979 X " " , "

$* P<0.05$; $** P<0.01$; $*** p<0.005$

W1ACV— WCP = dam's weight change (kg) between one month after "earlier" calving and subsequent conception.

APPENDIX 8

Distribution of animals and coefficients of dam's age within calving month of supplemented beef cattle.

	Calving month			
Dam's age (years)	February	March	April/May	Total
(a) Distribution:				
4	9 (373)	9 (368)	4 (355)	22 (368)
5-9	51 (372)	31 (360)	18 (333)	100 (361)
≥ 10	23 (381)	18 (364)	22 (349)	63 (365)
Total	83 (374)	58 (363)	44 (343)	185 (363)
(b) Coefficients:				
4	54.8	-27.5	-23.2	
5-9	11.9	2.6	-23.2	
≥ 10	14.8	-4.7	-5.4	

A P P E N D I X 9

Distribution of animals and coefficients for dam's age at calving within feeding regime of supplemented beef cattle.

	Feeding regime			
Age (years)	Chopped grass	Pre-parturient	Post-parturient	Totals
(a) Distribution:				
4	7 (375)	7 (364)	8 (365)	22 (368)
5-9	24 (353)	43 (359)	33 (371)	100 (361)
≥ 10	9 (376)	38 (357)	16 (377)	63 (365)
Totals	40 (362)	88 (358)	57 (372)	185 (363)
(b) Coefficients:				
4	27.0	18.5	-41.4	
5-9	-11.0	1.2	1.1	
≥ 10	11.1	-4.6	-1.8	

APPENDIX 10

Number of animals per cell and coefficients for dam's previous parity within feeding regimes of supplemented beef cattle.

	Feeding regime			
Previous parity	Chopped grass	Pre-parturient	Post-parturient	Totals
(a) Distribution:				
Suckled	27 (364)	62 (356)	24 (367)	113 (360)
Dry cow	13 (359)	26 (363)	33 (375)	72 (368)
Totals	40 (362)	88 (358)	57 (372)	185 (363)
(b) Coefficients:				
Suckled	19.6	1.0	-17.9	
Dry cow	-1.5	9.1	-10.2	

APPENDIX 11

Animal distribution and coefficients for feeding regime within calving year of supplemented beef cattle.

	Calving year			
Feeding regime	1978	1979	1980	Totals
(a) Distribution:				
Chopped grass	13 (360)	10 (357)	17 (367)	40 (362)
Pre-parturient	23 (347)	27 (357)	38 (366)	88 (358)
Post-parturient	22 (376)	16 (368)	19 (370)	57 (372)
Totals	58 (376)	53 (361)	74 (367)	185 (363)
(b) Coefficients:				
Chopped grass	24.7	5.1	-2.7	
Pre-parturient	-5.1	6.5	13.7	
Post-parturient	-16.4	-17.1	-8.7	

A P P E N D I X 12

Regression coefficients for calving interval (days) of beef cattle used in the weaning trial.

Coeff.	S.E.	Probability	Title
360.69			General level
-2.50	7.04		Weaned September
11.78	6.30	*	" October
3.95	6.29		" 1977
-4.76	7.42		" 1978
-5.78	8.16		4 years old
2.58	4.90		≥ 10 " "
-3.79	5.29		Earlier calving in March
-10.24	5.06	*	" " " April/May
0.21	0.09	*	Weaning period
-1.07	0.38	***	Weight at "2nd" conception, Linear
0.00	0.00	***	" " " " , Quadratic
0.03	0.28		W1ACV - WCP, Linear
0.02	0.01	*	" " , Quadratic
-25.85	12.27	*	4 years old, weaned September
9.25	7.51		≥ 10 " " , " "
22.28	11.72	*	4 " " , " October
-7.58	7.05		≥ 10 " " , " "
-12.70	9.67		4 " " , " 1977
-2.47	6.57		≥ 10 " " , " "
21.00	14 16		4 " " , " 1978
-12.30	8.23		≥ 10 " " , " "
-9.50	8.90		4 " " , earlier calving March
-0.27	6.13		≥ 10 " " , " " "
26.40	9.16	***	4 " " , " " Apr./May
-9.87	5.73	*	≥ 10 " " , " " " "
-4.15	4.06		Weaned October, 1977
2.43	3.56		" September, 1978
7.87	4.31	*	" October, 1978
-14.97	6.67	*	" 1977, earlier calving March
2.67	6.09		" 1978, " " "
-2.65	6.35		" 1977, " " Apr./May
5.82	5.97		" 1978, " " " "
-0.73	0.35	*	Earlier calv. Mar. X W1ACV - WCP, Lin.
0.42	0.44		" " Apr/May X " " , "

* P<0.05; *** P<0.005

APPENDIX 13

Distribution of animals and coefficients for dam's age at weaning within weaning year.

Age (years)	Weaning year 1977	1978	1979	Totals
(a) Distribution:				
4	6 (348)	1 (346)	7 (352)	14 (350)
5-9	11 (341)	30 (357)	29 (364)	70 (357)
≥ 10	11 (348)	12 (352)	15 (386)	38 (364)
Totals	28 (345)	43 (355)	51 (369)	122 (359)
(b) Coefficients:				
4	-14.5	10.5	-13.3	
5-9	22.3	-10.3	-2.5	
≥ 10	4.1	-14.5	18.2	

APPENDIX 14

Data structure and coefficients for dam's age at weaning within subsequent calving month.

	Month of earlier calving			
Age(years)	Jan./Feb.	March	April/May	Total
(a) Distribution:				
4	3 (361)	4 (343)	7 (349)	14 (350)
5-9	31 (367)	21 (364)	18 (332)	70 (357)
≥ 10	12 (390)	11 (364)	15 (343)	38 (364)
Total	46 (373)	36 (362)	40 (339)	122 (359)
(b) Coefficients:				
4	-8.7	-19.1	10.4	
5-9	24.0	9.2	-23.6	
≥ 10	26.8	-1.5	-17.5	