PERFORMANCE OF AYRSHIRE-SAHIWAL CROSSBRED CALVES AT THE COAST.

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DECLARATION

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

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Date: 29/08/90

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

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DR. R. O. MOSI

DEDICATION

Dedicated to my parents,

Mr. & Mrs. Michael Charagu.

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ABSTRACT

Data from Mariakani Animal Production Research Sub-Centre, at the Coast Province of Kenya, was used to estimate genetic and environmental effects on birth weight, preweaning average daily gain, weaning weight (at 5 months) and preweaning survival for 8 genotypes of crossbred and straightbred calves. These genotypes are: >87.5% (high-grade) Sahiwal, 75%Sahiwal 25%exotic, 67%Sahiwal 33%exotic, F_1 Ayrshire Sahiwal, F_1 Friesian Sahiwal, 67%exotic 33%Sahiwal, 75%exotic 25%Sahiwal and >87.5% (high-grade) exotic. A total of 1135 records were analysed for birth weight, 727 for rate of gain, 745 for weaning weight and 1156 for survival. A fixed effects least squares model was used for growth traits while a logistic model was employed in the analysis for calf survival. Genotype of sire was important for weight gain and weaning weight but not for birth weight. Friesian-sired calves gained more per day and weaned heaviest, followed by Ayrshire-sired calves and last were the Sahiwal-sired calves. Dam genotype was important for birth weight and weaning weight but not for preweaning weight gain. Crossbred dams generally performed better than the straightbred Sahiwal dams. Mean performance of crossbreds was also generally higher than that of the straightbred dams in all the traits studied. Maternal heterosis in F_1 dams was, however, not important for in any of the growth traits. Genotype of calf was important for

preweaning average daily gain, weaning weight and survival but not for birth weight. Friesian cross calves performed better than Ayrshire cross calves in most traits. Generally, crossbred calves performed better than straightbred calves. The level of heterosis in the F_1 Ayrshire-Sahiwal calves was -2.1% for birth weight, 7.0% for rate of gain, 3.0% for weaning weight and -7.3% for preweaning survival. Additive genetic effects were found to be more important than heterotic effects and the calves with a higher proportion of exotic genes were generally favoured.

1. INTRODUCTION

Although Bos-taurus cattle breeds have greater potential for milk and meat production than Bos-indicus breeds, the latter have a higher level of adaptability to the environmental stress typical of most parts of sub-Saharan Africa. This adaptability is mainly manifested in fairly good fertility under harsh conditions and tolerance to the many tropical diseases and parasites that abound in these areas, leading to high survival as compared to the temperate breeds. The introduction and utilization of the highly productive Bos-taurus cattle can be made possible by the modification of the harsh environment and provision of high levels of management. However, it is not economically feasible in many African, and indeed other tropical, situations to modify the environment for the full exploitation of the Bos-taurus potential.

Regardless of these shortcomings with either of the two categories of cattle, there is still a need to make best use of the environment prevailing in sub-Saharan Africa for cattle milk and meat production. Substantial increases in meat and milk production are required in this region to feed the ever increasing human population as well as generating income for the people. The most logical approach to achieve these increases seems to be some modification of the environment in a technically and economically practical way and to make use of systematic crossbreeding programmes, or to form new breeds, using Bos-indicus and Bos-taurus parental stock to exploit the improved environments.

A crossbreeding programme involves the mating of two or more breeds. Different methods are used in the systematic crossbreeding of cattle. These include terminal sire crossing, rotational crossing and a combination of the two (Cunningham and Syrstad, 1987). The ultimate aim is to achieve the optimum additive genetic composition (complementarity) and non-additive (heterosis) effects for production by combining specific breeds of Bos-taurus and Bos-indicus cattle in the environment most favoured by economic and technological feasibility (Touchberry, 1970). This approach has been followed in Kenya using Sahiwal cattle (Bos-indicus) which were introduced into Kenya from Pakistan in the 1930's. The main utility of the breed today is seen in crossbreeding for dual purpose production in semi-arid and arid areas. The contribution of the breed to adaptability in several ecological zones in the Tropics and sub-Tropics is well documented (Mahadevan et al;1962, Kimenye; 1973, Meyn and Wilkins; 1974). The breed is considered unequalled in transmitted effects for milk production among Bos-indicus breeds. In both semi-arid and sub-humid coastal areas, a two-breed rotational crossbreeding system combining Sahiwal with European dairy breeds is considered appropriate (Meyn and Wilkins, 1974). The European breeds mostly used are the Ayrshire and Jersey. The aim is to genetically improve milk and beef production, and to supply stock to farmers for both pure-breeding and cross-breeding in coastal and inland areas. The pure-bred stock is produced by the maintenance of some pure-bred Sahiwal dams.

In line with these objectives a crossbreeding programme was initiated in the mid 1960's at the Mariakani Animal Production Research Sub-Centre of the Kenya Agricultural Research Institute (KARI) located in the hinterland of the Kenyan coast. The programme involved crossbreeding Sahiwals with Ayrshires and to a lesser extent, Friesians. Some Sahiwal purebreeding has also been carried out.

The programme also provided data for breeding research, particularly, the comparison of purebred Sahiwal with various Sahiwal x Ayrshire crosses with emphasis on the proportions of each of the breeds in the crosses. The identification of suitable breeding material was considered essential to the successful improvement of cattle production in the area.

The present study was undertaken as a contribution to the realisation of those objectives. The specific objectives of the study were to compare the performance of the various genotypes for birth weight, preweaning average daily gain and weaning weight and to compare the rates of calf survival (hence mortality) in the herd. The levels of heterosis in the crosses would also be estimated. The estimates of calf performance would then contribute to the identification of superior genotypes and the breeding systems to produce them.

2. LITERATURE REVIEW

Decisions regarding crossbreeding involve choice of breeds and the design of crossbreeding schemes. Evaluation of crossbreeding research results should include quantification of additive genetic (breed) effects, heterosis and reciprocal differences with respect to magnitude and variation.

2.1. Heterosis

In terms of performance, heterosis is the superiority of the crossbred individual over the average performance of the parental breeds. It usually occurs for complex productivity traits where adaptation plays an important role. Its estimates provide information concerning responses in various characters one may expect from crossbreeding (Long,1980).

Some characters have both individual and maternal components of heterosis. Individual heterosis is the improvement (or superiority) in performance in an individual animal relative to the mean of its parental breeds. It is not attributable to either maternal, parental or sex-linkage effects. Maternal heterosis refers to heterosis in an individual that is attributable to using crossbred instead of purebred dams. The dam's maternal heterotic effects can promote the growth and survival of the offspring. Heterosis for both individual and maternal traits has been shown to be of major economic importance for crosses among Bos-taurus breeds (McDonald and Turner, 1972; Gregory and Cundiff, 1980; McElhenney et al., 1986), for crosses of Bos indicus breeds with Bos-taurus breeds (Cartwright, et al., 1964; Sacker et al.1971; Koger et al., 1975) and for crosses among Bos-indicus breeds (Gregory et al., 1984).

Generally, crosses between Bos-taurus and Bos-indicus breeds show higher levels of heterosis than either Bos-taurus breed crosses or Bos-indicus crosses. This could be explained from the fact that heterosis arises from the heterozygosity of loci, the level of heterosis depending on the degree of heterozygosity, that is, the number of heterozygous loci. Most Bos-taurus breeds are closely related or of similar sources (origins), and so are their loci. The differences in the genes are much wider between the two groups of cattle, and this leads to high levels of heterosis in crosses between them. Averaging eight production traits for various classes of crossbreds, Koger (1973) found that the Bos-indicus x Bos-taurus crosses had larger margins of advantage over the mean of their straightbreds than crosses among Bos-taurus breeds. In studies conducted in East and Central Africa, heterosis was generally highest for Bos-taurus x Sanga (Barotse and Sanga) and Bos taurus x Bos indicus breeds (Boran and Angoni) in weight of calf weaned per cow per year (Thorpe et al., 1981; Tawonezvi, 1984; Gregory et al., 1985).

Estimates of heterosis reported in the crossbreeding of Bos-indicus and Bos-taurus cattle for birth weight vary greatly. Trail et al., (1982) reported a heterosis estimate of 3.6% in Red Poll - Boran crosses. Sacker et al. (1971)

reported a heterosis level of 9.7% in the same type of crosses in Western Uganda. These estimates fall within the range of 1 to 11% (with a mean of 4%) given by Long, (1980). Koger (1973) reported mean heterosis estimates of 9.5% in crosses of Bos-taurus and Bos-indicus breeds and 2.2% in Bos-taurus breed crosses. The low heterosis estimate reported by Trail et al.(1982) could have been due to an inferior prepartum maternal environment as most of their calves were born of Boran dams, as indicated by inferior birth weights of calves of the dams.

Preweaning average daily gain (ADG) (from birth to weaning) has exhibited a heterosis of 3 to 8% (mean approximately 4%) (Gregory et al., 1965; Gaines et al., 1966; Trail et al., 1977; Anderson et al., 1978; Dillard et al., 1980). Some reports (Nitter, 1978; Thorpe et al., 1980; Trail et al., 1982) indicate that the non-additive (heterotic) effects increase with age. Significant heterosis between the Barotse and Boran breeds was only found at the postweaning ages (Thorpe et al., 1980). Nitter (1978) found in sheep that a decreasing maternal influence on growth due to age seems to be reflected in an increase in individual heterosis and suggested that the purebreed maternal environment may be a limiting factor on the full expression of the growth potential of F_1 progeny at early ages. Immediately after birth and during the next few weeks a calf depends solely on its dam's milk. The calf's rate of liveweight gain therefore will be determined by the dam's potential for milk production and partly by the calf's genetic potential for weight gain. This calf genetic potential would never be realised as long as it does not get optimal quantities of milk from the dam. Purebred mothers especially of the Bos-indicus breeds have poor potential for milk production. When they produce F_1 calves, these calves are unable to express fully heterotic effects for growth due to lack of adequate nutrition (maternal environment). With age, however the calves depend less and less on the dam's milk and instead satisfy their nutritional requirements increasingly by increasing their intake of forage and other feedstuffs. It is at this stage therefore that the genetic potential of the calf for both intake and feed conversion becomes more important than the maternal environment.

In his review of crosses among Bos-taurus breeds, Long (1980) gave a heterosis range of 3 to 16% (mean of approximately 5%) for weaning weight, The results were similar to those reported by Koger (1973) who gave a mean heterosis for weaning weight of 3.3 lb (1.5 kg) for such crosses, lower than the mean of 10.8 lb (4.9 kg) for crosses between Bos-taurus and Bos-indicus breeds. Trail et al. (1982) reported a heterosis estimate of 5.3% for weaning weight (9 months) in Red Poll/Boran cross calves in Western Uganda. Koger et al., (1975) reported a much higher estimate of heterosis (21.3%) in crosses between Brahman (B. indicus) and Shorthorn (B. taurus). This high heterosis level may be due to the higher management levels (especially nutrition) at the Florida Agricultural Research Centre where the study was undertaken. Long and Gregory (1975) reported larger heterosis effects on liveweight gain at relatively higher rates of gain, that is, at better management levels. This is because at higher rates of gain the full genetic potential of the calf is being realised, implying that the full heterosis in the calf is expressed. The levels of heterosis observed in weaning weight are generally higher than those observed in birth weight. This is as a result of the increasing expression of the calf's genetic potential with age discussed earlier.

Like the growth traits, preweaning calf survival is also advantaged by heterosis. In his review, Koger (1973) reported a mean heterosis of 7.5% for F_1 Bos-taurus x Bos-indicus crosses and a mean of 3.6% in crosses of Bos-taurus breeds. Trail et al.(1982) reported a heterosis estimate of 2.9% for survival (birth to weaning) in Boran/Red Poll crosses. This estimate was below the mean given by Koger (1973) possibly because of lower levels of management in the ranches in Western Uganda. Gaines et al. (1966) reported losses at or within 36 hours of birth to be 7% for purebred compared to 4% for crossbred calves in a study of Angus, Hereford and Shorthorn crosses in Virginia. This represents a heterosis level of 3%, which is similar to the the mean given for crosses among Bos-taurus breeds. Cundiff (1970) reviewed various research reports and indicated a 3% advantage in preweaning survival of crossbred calves over purebred ones.

2.2 Effect of Genotype of sire

The net value of a cross is a function not only of heterosis but also the sum of additive genetic values of the breeds making up the cross. Breed of sire differences reflect differences in additive direct effects between breeds.

In general calves sired by breeds of heavier mature weights (eg. Charolais) are often significantly heavier at birth than those sired by lighter breeds (eg. East African Zebu) (Long and Gregory, 1974; Gregory and Trail, 1981), although the magnitude of the difference will depend on the dam genotype (Damon et al.,1961; Lasley et al., 1973; Jain et al., 1971; Plasse, 1983). The performance of the cross (calf) reflects the crossing ability (Specific Combining Ability) of the sire breed and that of dam.

The heavier sire breeds that are associated with higher birth weights are, however, also associated with higher incidences of dystocia (Laster and Gregory, 1973; Smith et al, 1976;), especially when sires of heavier breeds are crossed with dam breeds of low weight. Thus, in the quest for higher birth weights, especially in crossbreeding, we should be careful about the parental breeds that are matched to minimise the problems of dystocia which leads to both calf and dam losses.

In their study of crossbred beef cattle in Zambia, Thorpe et al.(1980) reported that calves sired by Friesian, Hereford and Boran bulls were significantly heavier at birth than those sired by Barotse or Angoni bulls. The former two breeds of sires are of heavier mature weights and their calves were therefore expected to be heavier. In a study of rotational cross Ayrshire-Sahiwal cattle at Kilifi Plantations, Gregory and Trail (1981) reported that Sahiwal sires produced calves that averaged 2.9 kg heavier at birth than calves by Ayrshire sires, but confounding of sire breed and dam genotype could have occurred. The dams were rotational crosses, either 67% Ayrshire 33% Sahiwal or the contrasting 67% Sahiwal 33% Ayrshire cross and Ayrshire sires were mated to the latter groups of dams and Sahiwal sires to the former group. Thus, the result could be attributable to differences between the two breeds of dams in additive genes for growth. It would be expected that the 67% Ayrshire 33% Sahiwal dams having an additive genetic superiority, would give birth to heavier calves than the 67% Sahiwal 33% Ayrshire dams, which was actually the case. Thus, the resulting outcome: that Sahiwal sires appeared to produce heavier calves than the Ayrshire sires was explicable by this confounding.

Breed of sire has been reported to have significant effects on the preweaning rate of gain (Anderson et al., 1978; Gregory et al., 1978a;1979). Temperate sire breeds (B. taurus) often show a higher growth rate than B. indicus sires. Gregory and Trail (1981) reported that calves by Ayrshire sires gained 45 g/day faster ($P<.05$) than calves sired by Sahiwal sires from birth to 90 kg, a weight attained at an average of 122 days. They attributed this difference to a behavioural difference between Sahiwal and

Ayrshire sired breeds resulting in more difficulty in training Sahiwal-sired calves to drink whole milk from a pail. The superiority of the Ayrshire sired calves over the Sahiwal sired ones was indeed greater at the earlier period of birth to 50 kg when they gained 53 g/day more ($P<.01$). This example of behavioural aspects of a breed is important to note with respect to management . A good genetic potential could be wasted due to such behaviour unless the behaviour is understood and handled appropriately.

A sire breed with less merit for additive direct effects (transmitted effects) for birth weight could have a greater merit in weight gain (and consequently weaning weight). This means a sire breed could have calves relatively lighter at birth but which have a superior rate of gain and weaning weight. This was demonstrated by Trail et al. (1971) who, in a study of Boran-Angus cross calves, reported that, at birth, progeny of Boran sires were significantly heavier than progeny of Angus sires, but from 3 months onwards, progeny of Angus sires were significantly heavier than progeny of Boran sires. This is attributable to the difference in genetic additive direct effects for feed conversion efficiencies between the two breeds. The Angus have been selected and bred for many years for this trait while little has been done on the Boran.

Breed of sire has been observed to affect weaning weight of calves, and especially through its influence on preweaning rate of gain, rather than birth weight (Trail et al., 1977; Tonn, 1974; Trail et al., 1982). Those sire breeds that sire calves with high rates of gain, consequently get calves of high weaning weight at a given age. Thorpe et al. (1980) reported that calves sired by Friesian and Hereford sires weaned heavier than those sired by Angoni and Barotse sires by approximately 24 kg. The Friesian and Hereford breeds are on average of superior body weights than the Angoni and Barotse breeds and could also have superior additive direct effects for weight gain.

In most cases Bos taurus sires show an advantage over sires of the Bos-indicus breeds reflecting superior effects for weight gain and /or higher degrees of selection. This is not always the case, however, as in some studies Bos-indicus sires have had advantage over Bos-taurus sires (Hernandez, 1976; Trail et al., 1982; Plasse 1983). In a study of Charolais, Zebu and Criollo crossbred cattle in Central America, Hernandez (1976) and Plasse (1983) reported that Zebu sired calves born to 1/2 Zebu 1/2 Criollo dams were 4% heavier at weaning than those sired by Criollo (a Bos-taurus breed) sires with the same breed of dams. Trail et al.(1982) reported that calves by Boran sires were 7.7 kg heavier at weaning than were calves by Red Poll sires. This could be a reflection of superiorities in direct additive effects of the Zebu used in Central America and the Boran in Uganda over the Criollo and the Red Poll respectively.

When making choices for suitable sire breeds in cross breeding therefore it is essential to consider the characteristics of such breeds with regard to the specific and general combining abilities of the breed with the dam breeds available, the risks of dystocia especially with respect to the dam breed (size) and the sire breed's direct additive genetic effects for the traits of interest.

2.3 Effect of Genotype of Dam

The effects of the sire breed are mainly manifested as direct additive effects and/or individual heterosis (of the calf). Those sire breeds with good transmitted effects for any one trait, will give rise to calves with high performance arising from a combination of additive effects and heterosis, the magnitude of the latter depending on genes transmitted by the dam. The effects of the dam genotype on these traits, on the other hand, arise from both individual heterosis and maternal heterosis. However, distinction should be made between maternal effects and maternal heterosis. The former includes both additive genetic effects and heterotic effects (where applicable) of the dam on the performance of her calves. Thus, maternal effects is a general concept used also for purebred dams while maternal heterosis is only relevant in crossbreeding where crossbred dams are used.

Significant breed of dam effects have been reported by Gregory et al.(1978a) and Anderson et al.(1978) for birth weight. Sacco et al.(1989) reported that pure Holstein dams gave birth to heavier calves than Angus dams while the latter produced heavier calves than pure Brahman dams. Trail et al. (1982) reported that Red Poll dams had a superiority of 6 kg (P<.01) in additive maternal effect over

Boran dams in calf birth weights. These two studies in two different environments show that Bos-indicus dams have a lower merit for additive maternal effects than Bos-taurus dams. It is thus of interest to find out whether the Sahiwals in Mariakani will show the same tendencies compared to high-grade Ayrshires or whether the environment will favour them. In a clear example of this difference in additive maternal effects between the two groups of cattle, Gregory and Trail (1981) reported that 67% Ayrshire 33% Sahiwal dams gave birth to significantly heavier calves than 67% Sahiwal 33% Ayrshire dams. At Kilifi Plantations and Deloraine farms in Kenya, straightbred Ayrshire dams produced calves that were significantly heavier than calves produced by Ayrshire x Sahiwal cross dams and pedigree Sahiwal cows but not heavier than those produced by Sahiwal x Ayrshire cross dams (first breed in cross represents breed of sire) (ILCA, 1981). In addition, Ayrshire x Sahiwal cross and Sahiwal x Ayrshire dams produced calves that were significantly heavier than pedigree Sahiwal cows. This shows that apart from pure Ayrshires having a higher merit for additive maternal effects than the pure Sahiwal, the crossbred cows displayed maternal heterosis in calf birth weight. If additive genetic variation was the only effect of importance, then, Ayrshire x Sahiwal dams would perform the same as Sahiwal x Ayrshire dams (in terms of maternal component). Since this is not the case, it means that either additive effects are not important or most of the Sahiwal x Ayrshire dams were mated to Ayrshire sires.

In some cases, crossbred dams have failed to show significant heterosis in birth weight. Thorpe et al (1981) in a study of the Angoni, Boran and Barotse breeds and their reciprocal crosses, reported that birth weights of calves from the crossbred dams were close to the mean of the parental purebreeds and heterosis estimates were not significantly different from zero. This is a manifestation of the low levels of heterosis that result from the crossing of Bos-indicus and Sanga breeds. In the review by Koger (1973), he reported a mean maternal heterosis of only -1.9% for birth weight in F_1 crosses of Bos-taurus breeds but a heterosis of 12.6% in Bos-taurus-Bos-indicus crosses. He did not give any estimates of maternal heterosis in Bos-indicus breed cross dams. Sacco et al. (1989), however, reported significant estimates of heterosis in dams of Bos-taurus breed crosses. Calves out of F_1 Angus-Hereford dams were 1.3 kg ($P<.05$) heavier at birth than the average of calves out of straightbred Angus and Hereford dams. Calves out of F_2 dams were 2.0 kg heavier ($P<.01$) at birth than the average of calves out of second generation Angus and Holstein dams. This estimate of maternal heterosis in F_2 dams was higher than theoretically expected. The F_2's would be expected to have a heterosis estimate half of that observed in the F_1's. Since there might be no heterotic advantage created by the crossing of indigenous breeds, it would be better to use the best performing of the pures in a particular environment, rather than incur the costs of crossing to produce less favourable genotypes as dams.

Comparisons among dam genotypes for calf growth and weaning weight give an indication of the relative milk production of the dam. This, however, is only applicable in systems such as ranching where calves run with their dams until weaning, as opposed to cases where calves are bucket-fed in the calf house. In such cases where the calves are actually fed on a fixed milk ration regardless of the dam's milk production, their performance does not reflect the dams milk production, but rather the calf's own milk conversion ability, plus a residual of the dam effect at birth.

In a study conducted in a suckler system, Long and Gregory (1974) reported that calves from Angus dams gained faster from birth to weaning than calves from Hereford dams. This indicates that the Angus dams had a superior maternal ability, a reflection of their milk production potential. Highly significant differences have been reported for maternal effects for 180-day weight, with a 58 lb (26.4 kg) difference noted between Brangus and Hereford dams (Damon et al., 1961). Since this effect is due primarily to the milking ability of the dam, it suggests that the Hereford cattle were better in this respect. Trail et al (1982) reported that Boran dams showed a superior additive maternal effect to Red Poll dams in preweaning average daily gain. Thus despite the fact that Boran dams are of lower merit in genetic effects for birth weight of calves they are better than the Red Poll in maternal ability. Koger et al (1975) reported that crossbred Brahman x Shorthorn dams showed maternal heterosis of 18.8% in 205-day calf weight. Cundiff et al.(1974), Gaines et al.(1978) and Dillard et al. (1980) reported significant effects of maternal heterosis in daily weight gain.

The effect of dam genotype on weaning follows a similar pattern as that of preweaning gain. That is, it arises from differences in additive maternal and maternal heterotic effects, especially in beef breeds where calves run with their dams till weaning. Dillard et al.(1980) reported that Charolais maternal ability exceeded that of Hereford and Angus for rate of gain preweaning and consequently weaning weight and that calves born to Angus x Hereford cross dams weaned 4 kg heavier than those born to Hereford dams. Thus, crossbred dams displayed a degree of maternal heterosis and/or had better milk production than the straightbreds. Thorpe et al (1981) reported that calf weaning weights of Angoni-Barotse and Angoni-Boran reciprocal crossbred dams were less than 2% above the mean of the parental purebreeds, and in neither case were the progeny of the crossbred dams superior to those of the better parent breed. This means that the crossbreeding among these Bos-indicus breeds for weaner production might not be of much practical importance.

It is therefore of great importance to be objective in the choice of dam breed or genotype in a breeding programme. This comes out clearly in beef and dual-purpose programmes where growth characters are important. The maternal ability of the cow is of great importance in the production of beef cattle particularly in areas where calves are sold as slaughter (veal) calves at weaning. It would be wise to opt for dam breeds that give birth to lighter calves but have high genetic merits in maternal ability since they will ensure higher rates of gain and heavier weaning weights.

2.4 Effect of Genotype of Calf

The genotype of calf influences birth weight, weaning weight and preweaning daily weight gain through individual heterotic and individual additive genetic effects. The latter applies to both crossbred and purebred calves. Thus a calf could perform better due to its superior additive genetic composition and, in the case of crossbreds, any advantage resulting from heterosis.

In Ethiopia in a study of Friesian, Zebu, Jersey, Arsi crossbred cattle, Kiwuwa et al (1983) reported that, although 3/4 Friesian 1/4 Zebu and 1/2 Friesian 1/2 Zebu genotypes did not significantly differ in birth weight, the two were significantly heavier than the Zebu. This could be attributed to superior additive genetic compositions and heterosis in the two crosses. The heterotic effect could only be estimated if pure Friesian calves were also in the study. The 1/2 Friesian 1/2 Zebu, 1/2 Friesian 1/2 Arsi and 1/2 Jersey 1/2 Arsi all differed significantly in birth weight. This was attributable to the differences in the additive genetic compositions of the calves and partly to differences in additive maternal effects. The Friesian and Ayrshire breeds could have been superior in additive genetic effects as their crosses weighed the heaviest. Turner and McDonald (1969) and Crockett et al. (1978) found birth weights of Brahman calves to be similar to those of Herefords and heavier than those of Angus calves. As a straightbred therefore, Brahman has an additive genetic advantage over the Angus but not the Hereford. This means that in the study environment the Brahman and/or Hereford should be preferred to the Angus as straightbreds. Crossbred Brahman calves have also shown an advantage over straightbreds of a mean of 3.3 kg in birth weight.

The genotype of calf effect is more expressed in rate of gain than in birth weight. At birth, the expression of the maternal effects tends to obscure the effects of calf genotype. In rate of gain, the genetic potential of the calf is expressed at an increasing degree with age. Gregory and Trail (1981) reported that 2/3 Ayrshire 1/3 Sahiwal cross calves gained 45 g/day more ($P<.05$) than the contrasting 2/3 Sahiwal 1/3 Ayrshire cross calves. The former group of calves had been born lighter - a phenomenon attributable to their dams (2/3 Sahiwal 1/3 Ayrshire) having an inferior additive genetic effect. They, however, gained faster than the contrasting 2/3 Sahiwal 1/3 Ayrshire cross calves. This was conceivably due to the superior additive genetic composition of the calves with a higher proportion of Ayrshire genes. Koger et al (1975) reported that 3/4 Brahman 1/4 Shorthorn calves had a mean 205-day weight 11 kg higher than the mean of the contrasting 3/4 Shorthorn 1/4 Brahman cross calves and a mean of 2 kg higher than that of the contrasting 5/8 Brahman 3/8 Shorthorn cross calves. This indicates that calves with a higher proportion of

Brahman genes had a superior additive genetic potential for weight gain.

The calf genotype has been reported to significantly affect weaning weight (Long and Gregory, 1974; 1975; Gregory et al, 1978b; Mwandotto et al., 1988). This effect of calf genotype at weaning essentially follows the performance of the genotypes for growth rate. Generally, those genotypes that gain faster consequently wean heavier. In Kiboko and Bachuma Stations, Mwandotto et al (1988) reported that Friesian crosses with Sahiwal and Boran were consistently heavier than crosses with the East African Zebu and the purebreeds (Boran, Sahiwal and Zebu). The difference between Friesian x Boran and Friesian x Sahiwal was not significant but these crosses were on average 6.2% heavier than Sahiwal and Boran. This implies that the additive genetic potential of all crosses with Friesian genes was higher than that of all the other crosses, indicating a high genetic merit for transmitted effects for rate of gain and weaning weight for the Friesian. In an experiment in Ethiopia designed to test various crosses of cattle, crossbreds between the indigenous breeds (Boran and Zebu) and exotic beef breeds (Hereford and Angus) were 23.6% heavier at weaning than the pure Boran and Zebu, quite a high level of heterosis (Wagner et al., 1969). In another study Kennedy and Chirchir (1971), working with crosses of Brahman, Afrikander and British breeds, also found that breed of calf had a significant influence on weaning weight of calves. Differences between crosses of the three breeds ranged from 13.7 kg to 28.1 kg, Brahman crosses being heaviest and the British breed crosses (Shorthorn and Hereford) the lightest. Thus, either the Brahman breed had a higher merit for direct additive effects for weight gain and weaning weight or its inclusion in the cross resulted in higher levels of heterosis. This conforms with the observations of Koger (1973) as regards the crossing of different breeds of cattle of different origins.

Generally, the performance of a crossbred individual (calf) is influenced by the proportions of each breed in the genotype, particularly in cases where the cross is between a B. taurus and a B. indicus. The performance and suitability of a crossbreeding programme, therefore, do not depend on the genotype of calf alone but also on the level of heterosis resulting from the crossing of the sire and dam breeds. It is the choices of these two that determine the genotype of calf and their selection should be governed by their genetic merit in the environment of interest.

2.5 Other Effects

Other (fixed) effects known to affect these traits include year,season of birth, sex, parity of dam, the farm in question (management environment), disease occurrences and some first order interactions.

Calves born during, and immediately following, the season when the weather is relatively dry are usually smaller (lighter) than those born in wet seasons when temperature stress is less and there is more forage available for the pregnant dams (Gregory and Trail, 1981; Trail et al, 1982). Under extensive production systems the effect of season should be understood as the effect of the prevailing conditions on the dam during gestation and is a manifestation of feeding during this period, the latter being highly dependent on weather conditions.

Growth tends to be slower for calves whose preweaning growth occurs during the dry season, (Gregory and Trail 1981). Such calves tend to wean lighter than those that grow in the wet and/or cool season. The stressful conditions could affect calf growth either through lack of enough feed (forage) or reduced feed intake due to high ambient temperatures (heat stress) . The capacity to withstand heat stress without a greatly reduced feed intake is dependent on the calf's genetic potential.

The same general principles described for seasons applies for the year of birth. Those calves born in dry/hot years will generally be poorer in birth weight, daily gain and also weaning weight than those born in wet years (Gregory and Trail, 1981; ILCA, 1981;). Sahiwal x Ayrshire calves born in various ranches in Kenya showed important effects of year/season on birth weight, ADG and weaning weight (ILCA, 1981). In all these studies, those calves born in the unfavourable (drier than average) years or seasons performed poorer than those born in the more favourable times. It would be of interest to see what effects these factors have on the calf performance at Mariakani especially with post-natal performance since these calves were bucket fed until weaning and were only let to graze when the weather was favourable, that is, when the weather conditions were not extreme. The climatic effect would be expected to be reduced at this stage of their lives since exposure is reduced by the substantial time spent indoors.

Male calves are generally heavier at birth than female calves. They also gain faster and consequently wean heavier than females (Anderson et al., 1978; Gregory et al., 1978a; Long and Gregory, 1974; Dillard et al., 1980; Gregory and Trail, 1981). ILCA (1981) reported that male calves were about 1.3-2.1 kg heavier at birth, gained 13 g/day more and weaned 18 kg heavier (P<.01) than female calves. Mwandotto et al. (1988) reported that steer calves of Boran, Sahiwal and Friesian crosses in Bachuma and Kiboko were heavier than heifer calves at weaning. The superior performance of males in most traits is due to hormonal differences between males and females which results in differential abilities to convert feed and in the aggressiveness in feeding. This has led to the proposition to use male hormones (steroids) in beef production to enhance muscle deposition in both males and females.

Calves born to heifers (1st parity) are often significantly lighter than calves of higher parity dams (Laster et al, 1972; Anderson et al, 1978). This is attributable to the fact that a heifer, even in-calf, is still growing and has not attained mature size. Thus some of the energy and nutrients that are used for foetal growth in mature pregnant cows are used for the growth and development of the dam itself in heifers. The foetus therefore gets less nutrients for its growth and is also limited by the smaller body size of the heifer. It is expected that those calves born to the cow when it has attained its maximum size would be heavier and bigger than those born when the cow is still growing. At Deloraine farms in Nakuru, a study ILCA (1981) reported contradictory results, with calves born from first parturition averaging 1.2 kg heavier than the overall mean. Kiwuwa et al.(1983), in a study of crossbred cattle in Ethiopia reported that parity effects on birth weight were significant after the second parturition. While there was no significant difference in birth weight between the first and second parturitions, both were significantly lower than those from later parturitions. In the ILCA (1981) study of Deloraine calves, the dams had multiple lactations (including higher parities), and thus the unexpected result could have possibly been due to advanced age of dams at first parity. Willis and Wilson (1974) reported that parity of dam did not have a significant effect on calf birth weights (of Santa Gertrudis) and attributed this to the advanced age at 1st calving that averaged 40.4 months.

Parity of dam has also been reported to affect the weaning weight of the calf (Sacker et al., 1971; Tonn, 1974; Mwandotto, 1978). The effect could be attributed to the effects of parity on birth weight and preweaning weight gain. First calvers, give birth to lighter calves, and also have a poorer mothering ability because they have less milk (characteristic of lactations). Calves of these first calvers end up having a poorer maternal environment than those of later parities. Thus, heifers calving for the first time (at about 2 years of age) have calves that wean at lower weights. So do cows at an age of about 3 years (2nd parity), although their calves will most likely be heavier than those of the heifers (Minyard and Dinkel, 1965; Sacker et al, 1971; Tonn, 1974).

Other farm factors will affect calf performance for example management related factors like nutrition, disease affliction and control, and so on. These will be specific to the farm in question. It would therefore be important to study them and estimate the extent to which they are affecting production in order to judge how best to reduce them in the subject farms.

It is clear from the preceding presentation that it is important to adjust (correct) the performance of the animal in the traits of interest for all these non-genetic factors if the primary purpose is to evaluate genotypes. This can be done by including them in the analytical model(s). This way one is able to obtain more accurate estimates of the magnitudes of differences between individuals that arise from differences in genetic composition.

2.6 Preweaning Calf Survival (Viability)

Calf survival from birth to weaning is an important factor affecting net reproductive efficiency of cows. This is more crucial in ranch practice where the cow runs with its calf up to weaning as opposed to cases where the calves are reared indoors and are therefore protected from the extremes of weather, have a reduced exposure to diseases and parasites and are not prone to predation. If a calf fails to survive to weaning, it could be viewed as a failure of the dam to nurture her calf and/or lack of fitness of the calf itself, either due to a low genetic merit or an unfavourable phenotype caused by such things as deformity, weakness and so on.

Preweaning calf mortality could occur due to various causes: dystocia (difficult birth), postnatal susceptibility to diseases and parasites, general weakness or a whole range of environmental factors such as heat, cold, rain, draughts and so on. Thus, survival is influenced by both genetic and non-genetic factors.

The genotype of sire has been reported to significantly influence the rate of calf survival (Ellis et al., 1979; Cundiff, 1982; Sacco et al., 1989;). Generally, sire breeds representing biological types of large size like the Charolais and Chianina are characterized by lower calf survival from birth to weaning (Smith et al., 1976; Gregory et al., 1978b; Cundiff 1982). These same breeds are also associated with heavier birth weights. Indeed, the correlation of birth weight and early preweaning mortality has been reported to be relatively high (Laster and Gregory, 1973; Smith et al., 1976). High birth weights are directly associated with difficult births which endanger the life of the calf. Some of the calves die during birth, and others soon after, in what is called early calf mortality (within 24 hours). In a study of various crosses of breeds, Smith et al. (1976) observed that survival of Charolais and Limousin-sired calves was influenced more by dystocia than was survival of the other crosses. Sire breed was important for early mortality but not for late preweaning mortality (after 24 hours). This indicates that sire influence on calf mortality was basically through its influence on the calf's birthweight, rather than the calf's survival in later preweaning stages. In crossbreeding therefore, the compatibility of breeds with regard to the relative sizes of dam and sire are of importance if high rates of early mortality are to be avoided due to high birthweights resulting from heavy sire breeds.

In various reports, the genotype of dam has been reported to have a significant effect on the mortality rate of their progeny (Smith et al., 1976; Peacock et al., 1977 and Gregory et al., 1978b). Yet in other reports, some researchers have found genotype of dam having no statistical significance (Thorpe et al., 1981; Sacco et al., 1989). What comes out of these reports is the importance of the genotypic similarities. The comparison of Bos-taurus breed crosses and their contemporary straightbreds in calf survival shows little advantage in the crosses over the pures. Koger (1973) reported an average maternal heterosis of only 0.8% for calf survival rate in progeny of F_1 Bos-taurus breed crosses. The maternal heterosis for survival rates, on the other hand of progeny from F_1 Bos-indicus - Bos-taurus cross dams was 5.4%. There is, therefore, a substantial difference between crossbred Bos-indicus-Bos-taurus dams and the purebreds especially in the harsher environments. Among Bos-indicus breed cross dams, Thorpe et al.(1981) reported a non-significant effect of dam genotype. But the progeny from crossbred dams had marginally lower mortality rate (4.7% vs. 4%). It means that even among the Bos-indicus crosses the crossbred dams do not show any advantage over the pures.

The influence of dam breed on calf survival is attributable mainly to its additive maternal and/or heterotic ability in milk production and overall mothering ability and transmitted effects for hardiness in the specific environment. Smith et al.(1976) reported that the effect of dam breed was not important in early calf mortality (within 24 hours) but was significant in late preweaning mortality. In ranching, where the dam runs with the calf, the mother's ability to protect its young is very important. This is especially so in the African situation where predation by wild animals like hyenas and jackals on the young is a problem. Tonn (1974) reported that the Boran breed of dam is aggressively protective over its calf from predators. Trail and Gregory (1981), however reported that the Boran had a 2% lower survival rate than the Sahiwal. This could be partly attributable to the higher milk production of the Sahiwal breed and the fact that predation was not an important factor in this study.

The genotype of calf is influenced by both additive genetic and heterotic effects. Calf genotype is important in both late preweaning mortality and early preweaning mortality. Calf genotypes associated with higher birth weights are also associated with higher rates of early mortality in situations where dystocia is important(Peacock et al., 1977). Laster and Gregory (1973) reported that breeding group (genotype) of calf influenced calf mortality in parturitions involving dystocia, but did not significantly influence calf mortality in unassisted parturitions. Mortality ranged from 5.5% for Jersey x Angus to 14.5% for Charolais x Angus. It is therefore, of importance, with respect to calf mortality, to consider the calf cross (that is in breeds of sire and dam) to reduce the level of calf mortality. The specific combining ability of breeds composing the calf's genotype would be the best mode of assessment, if not by assessment of mature body weights.

In later stages (after 24 hours) the calf's genotype is increasingly expressed and especially with resistance to both environmental stress or diseases. This will depend on genes passed from both sire and dam and the acquired immunity from the intake of the dam's colostrum. In America, Brahman cross calves have been reported to have advantages ranging from .5 to 8.6% over purebreds in preweaning survival (Turner et al., 1968; Cartwright et al., 1964; Peacock et al., 1977; Crockett et al.,1978). This advantage of the crossbred Bos-indicus x Bos-taurus calves is attributable to both heterotic and additive genetic effects on the calf's survival ability. These calves have acquired the higher degree of resistance to stress from the Brahman breed and heterosis from the crossing. Gregory et al.(1978b) reported a high preweaning calf mortality (20.1%) for purebred Brown Swiss calves in a study involving Red Poll, Brown Swiss, Hereford and Angus breeds and their crosses. This poor performance of the Brown Swiss indicate that, as purebreds, the Brown Swiss breed is not relatively well adapted to the beef production environment under which these calves were produced, but its crosses were relatively well adapted. This is a case of a poor additive effect of the Brown Swiss breed, which however leads to a high level of heterosis in its crosses.

Generally, crossbred calves tend to have higher preweaning calf survival rates than their contemporary straightbreds. In the review by Koger (1973), the mean preweaning calf survival advantage of crosses was 6.5% for the Bos-indicus-Bos-taurus crosses and 2.2% for the Bos-taurus breed crosses. This indicates the importance of individual heterosis in calf survival. Heterosis in survival rates at weaning have ranged from -2 to 15% (Cartwright et al., 1964; Klosterman et al., 1968; Peacock et al., 1977).

Other factors that influence calf survival are sex of calf, year of birth, season of birth and age of dam (Smith et al., 1976; Sacco et al., 1989). Survival to weaning of female calves was reported to be 3.0% higher (P<.05) than that of male calves (Sacco et al.,1989). Smith et al.(1976)

observed similar results in crossbred and straightbred calves of various beef breeds. The higher mortality in male calves could possibly be attributed to the higher birth weights for male calves. That is, although it is not indicated in this report whether it was tested it could be that these higher birth weights in males were associated with dystocia which may have caused higher early preweaning mortality. Gregory et al. (1978b), Gregory and Trail (1981) and Trail et al. (1982) however reported non-significant effects of sex, year and season of birth. The calves in Kilifi (Gregory and Trail, 1981), however, were bucket-reared in the calf house and this could have reduced the effects of year and season of birth. The season and year of birth essentially influence survival through stress related to seasonal and annual variations in weather conditions, and concomitant effects on disease (parasitic) incidence and availability of pasture which in turn affects the nutritional status of the dam, and hence milk production and forage availability for the calf.

Parity of dam has also been reported to influence preweaning mortality (Laster and Gregory, 1973). This was only in cases of assisted births and dystocia, with no influence on calf mortality in unassisted parturitions. Smith et al.(1976) reported an important effect of age of dam on calf mortality. Age is highly related to parturition number and higher mortalities were reported in the 1st and 2nd parturitions (2-3 years). Thus, in general, effect of parity on calf mortality seems to be related to dystocia.

3. MATERIALS AND METHODS

3.1 The Data Source

The data used in this study were extracted from cow and calf records kept at the Mariakani Animal Production Research Sub-Centre of the Kenya Agricultural Research Institute, in Kilifi District of Coast Province , situated approximately 40 km from Mombasa Island along the Mombasa-Nairobi road. The original data consisted of a total of 1172 records and covered a period of 17 years from 1969 through 1985.

The station lies in the semi-arid lowland livestock-millet agro-ecological zone (Jaetzold and Schmidt, 1983) and is 180-185 metres above sea level, with an average annual rainfall of 950 mm. The rainfall is bimodal with the first rains usually falling from April to June and the second rains from October to December. The lowest temperatures occur during the June July period, with the highest temperatures being recorded in January and August. The vegetation is mainly acacia bushland, typical of the wetter parts of the coast hinterland area, stretching from the interior of Kilifi to Kinango and further south. The soils are mainly the Mariakani sandstone with clay in the subsoil which causes poor drainage in certain sections of the station.

The station covers an area of 410 hectares divided into 3 sections: 160 hectares to the north of the Mombasa - Nairobi road used for grazing the lactating and dry herds, 200 hectares to the south of the railway line used for grazing the young stock and the beef herd, and 30 hectares between the road and the railway, the central ground, having the offices, milking parlour, stores, maternity paddocks and calf pens. The preweaning calf records were extracted from a calf book. Each record was made up of calf identity, date of birth, sire identity and breed, dam identity and breed, dam parity, calf sex, birth weight of the calf and its subsequent weekly weights up to weaning at 20 weeks. This information was extracted for all calves including those which left the herd before reaching weaning age. For the latter group, the date at which the calf exited and the reason for exit was extracted to be used in the assesment of calf survival rates from birth to weaning.

3.2 Breeding Programme

Although the herd was established in the late 1950's it remained a pure Sahiwal herd until the mid 1960's, when a rotational crossbreeding scheme with Ayrshire was started. Some crossbreeding with Friesian sires was also practised later.

One of the stipulations in the general breeding policy was that some Sahiwal cows with mean milk production of over 1237 kg per lactation would be mated to Sahiwal bulls in order to produce pure bred Sahiwal calves. It was, therefore, possible to obtain records of pure or high grade (>87.5%) Sahiwal calves over the entire period of the study. The breeding programme also made it possible to estimate the relative performances of F_1 Ayrshire-Sahiwal or Friesian-

Sahiwal calves, the contrasting backcrosses and the two-breed rotational crosses over the entire period of the study. Records were also available for high-grade exotic calves and dams which resulted mainly from upgrading to Ayrshire. However this upgrading was not a requirement of the original breeding policy.

3.3 Calf Management

At birth, calves are allowed to suckle colostrum from the dam for a few hours after which they are separated and taken to the calf house, where they are weighed. They are kept in individual pens well-littered with straw. During the first week after birth each calf is ear-tagged and the same numbers tattooed in the left ear in case the tags are lost.

Calves are fed colostrum from their own dams by bucket for the first 3 to 4 days and thereafter whole milk up to 20 weeks when weaning is done. They are fed twice daily at 8.00 a.m. and 5.00 p.m. All milk rations are given on a per-day-basis divided equally between 2 feedings following the strict ration schedule (Table 3.1). From the age of 2 - 3 days, calves have access to good quality forage. This is usually either grass hay, young napier grass, or any other suitable fresh forage. The material is supplied fresh each day on an ad libitum basis . Concentrates and minerals are fed from 2-3 days of age if and when available. All pens are supplied with a trough full of clean fresh water daily. From the age of 1 week, calves start grazing in calf

Table 3.1. Scale of milk feeding (kg) for calves up to 20 weeks of age.

Age (Weeks)	Morning	Afternoon	Total
First 5 days	Colostrum	Colostrum	
1	1.0	1.0	2.0
2	1.25	1.25	2.5
3-5	1.5	1.5	3.0
6-7	1.75	1.75	3.5
8-12	2.0	2.0	4.0
13-16	3.0	3.0	6.0
17	2.5	2.5	5.0
18	2.0	2.0	4.0
19	1.0	1.0	2.0
20	0.5	0.5	1.0

paddocks during the day and on favourable nights, that is, when it is not too wet. All calves are dehorned by a hot iron as soon as the hornbuds are prominent, normally within 2 weeks of birth. Castration of bull calves is done postweaning. Thus, comparison of males and females on preweaning performance is not influenced by castration. Routine disease and parasite control is carried out on the calves as necessary.

3.4 Classification of Effects

The sire genotypes were Friesian, Ayrshire and Sahiwal. The genotype classes of dam and calf were: >87.5% Sahiwal, 75%Sahiwal 25%exotic, 67% Sahiwal 33% exotic, 50%Ayrshire 50% Sahiwal (F_1), 50%Friesian 50%Sahiwal (F_1), 67% exotic 33% Sahiwal, 75%exotic 25%Sahiwal and >87.5% exotic. The term exotic here refers to either Ayrshire or Friesian in cases where the crosses of these were combined to make up one genetic group. Parity of dam classes consisted of the first through fourth lactation numbers which were coded 1 to 4. The 5^{th} and greater lactation numbers were combined and coded as parity class 5. The years were numbered individually from 1969 (year 1) to 1985 (year 17) and seasons as 1 - 1st wet season from May to July, 2 - 2nd wet season from November to January, 3 - 1st dry season from February to April, 4 - 2nd dry season from August to October. Sex of calf was coded as 1 = male and 2 = female. The reasons of exit for those calves that never reached weaning were coded as:1 - culling due to weakness, 2 -

culling due to sickness, 3 - culling for unknown reasons, 4 - death from disease, 5 - death from unknown reasons and 6 - death from weakness. A total of 106 calves either died or were culled before weaning due to these various reasons.

3.5. Data Editing

Data editing comprised the elimination of incomplete records: those with missing sire genotype, dam genotype, calf genotype and dam parity. Also deleted were those records with improperly recorded and/or miscoded variables for example calves whose dates of birth seemed (from various criteria) to have been wrongly entered. After editing, the number of records were reduced from the original 1172 to 1156. The remaining calves were progeny of 87 Sahiwal,25 Friesian and 56 Ayrshire sires and 456 dams.

Due to the small number of records in some of the sire genotype x dam genotype (calf genotype) subclasses, some of the classes were combined. The resultant calf and dam genetic groups (genotypes) were as follows:

Dam Genetic Group

1. >87.5% Sahiwal
2. 67% Sahiwal 33% exotic
3. F_1 Ayrshire x Sahiwal
4. F_1 Friesian x Sahiwal
5. 67% exotic 33% Sahiwal
6. >87.5% exotic

<u>Calf Genetic Group</u>

1. >87.5% Sahiwal
2. 75% Sahiwal 25% exotic
3. 67% Sahiwal 33% exotic
4. F_1 Ayrshire x Sahiwal
5. F_1 Friesian x Sahiwal
6. 67% exotic 33% Sahiwal
7. 75% Sahiwal 25% exotic
8. >87.5% exotic

All backcross dams were combined with the rotational (ie. 67% Sahiwal 33% exotic and 67% exotic 33% Sahiwal) crosses. The F_1 dams produced the backcross calves while the rotational cross dams produced high grade or rotational cross calves, depending on sire genotype.

3.6 Data Analyses

Analyses were done using the model 1 of Harvey's (1987) least squares and maximum likelihood computer programme.

3.6.1 Analytical Model

The effects of genetic group of calf, year of birth, season of birth, sex and parity of dam on the traits studied were analysed by the following fixed model (model a):

$$Y_{ijklmn} = u + a_i + b_j + s_k + r_l + d_m + (bs)_{jk} + e_{ijklmn}$$

where;

Y_{ijklmn} is the observation on the n^{th} calf, belonging to the i^{th} genetic group, born in the j^{th} year and k^{th} season, of the l^{th} sex and born in the m^{th} parity of the dam.

u is the underlying population constant common to all records.

a_i is the effect of the i^{th} genetic group of calf

b_j is the effect of the j^{th} year of birth

s_k is the effect of the k^{th} season of birth

r_l is the effect of the l^{th} sex of calf

d_m is the effect of the m^{th} parity of dam

$(bs)_{jk}$ is the interaction effect between the j^{th} year and k^{th} season of birth

e_{ijklmn} is a random effect associated with the $ijklmn^{th}$ observation.

In another analysis (model b), the effects of the genotypes of sire and that of dam and their interaction were included with the rest of the factors in model a except the genotype of calf. It was (obviously) not possible to make a single run including the genotypes of sire, dam and calf together because of inherent confounding.

The model b is shown below:

$$Y_{ijklmpn} = u + a_i + b_j + h_k + s_l + r_m + d_p + (ab)_{ij} + (hs)_{kl} + e_{ijklmpn}$$

where;

$Y_{ijklmpn}$ is the observation on the n^{th} calf, born to the i^{th} breed of sire and j^{th} genotype of dam, born in the k^{th} year and l^{th} season, of the m^{th} sex and born in the p^{th} parity of the dam.

u is the underlying population constant common to all records.

a_i is the effect of the i^{th} breed of sire

b_j is the effect of the j^{th} genotype of dam

h_k is the effect of the k^{th} year of birth

s_l is the effect of the l^{th} season of birth

r_m is the effect of the m^{th} sex of calf

d_p is the effect of the p^{th} parity of dam

$(ab)_{ij}$ is the interaction effect between the i^{th} sire breed and j^{th} genotype of dam

$(hs)_{kl}$ is the interaction effect between the k^{th} year and l^{th} season of birth

$e_{ijklmpn}$ is a random effect associated with the $ijklmpn^{th}$ observation.

3.6.2. Estimation of Heterosis

Heterosis or hybrid vigour is the difference in performance between a crossbred individual and the weighted mean of the parental breeds, the weights being the relative proportions of the component breeds in the parents. This (weighted mean) is the expected performance of the crossbred under the assumption of additive gene action. However, performance is a function of both genetic composition and non-breed specific factors. Thus, the estimation of genetic differences should take into account effects of other known factors such as year, season, parity sex and so on.

Heterosis was estimated from least squares constants of relevant breeds from a model that included the other fixed effects. Thus it was possible to effect simultaneous additive adjustment for these effects. Relevant contrasts (of the least squares constants) were constructed using the respective breed proportions. Maternal heterosis (h_M) was estimated as the difference between total heterosis (h_T) and individual heterosis (h_I) while at the the same time taking into account the proportion of heterosis (individual and maternal) expected in each cross.

3.6.3 Analysis of Pre-weaning Calf Survival

Analyses of the rates of calf survival was done using logistic models utilising multi-way tables of proportions or probability. A linear model is fitted to logits of the percentage mortality for the cells in a multi-way table. The number of animals (alive and dead) in the cells are used as weighting factors.

A logit is a transformed form of a probability or proportion, p, where p has a range of 0 to 1. The formula for this transformation is :-

$$\text{logit}(p) = \log(p/(1-p))$$

where log is the natural logarithm (to base e). The logit is a continuous variable with values ranging from minus infinity to plus infinity.

The inverse transformation from a logit, z, to a probability is :-

$$p = \exp(z)/(1 + \exp(z))$$

The model used to study the effects of calf genotype (G), year of birth(Y), season of birth (R) and sex (S) was :-

$$z_{ijkl} = m + G_i + Y_j + R_k + S_l + e_{ijkl}$$

where;

z_{ijkl} is the logit of percent mortality for the i^{th} genotype, the j^{th} year, k^{th} season and l^{th} sex.

G_i is the logit for the i^{th} genotype.

Y_j is the logit for the j^{th} year.

R_k is the logit for the k^{th} season.

S_l is the logit for the l^{th} sex.

e_{ijkl} is the residual term.

The model was fitted with an iterative maximum likelihood technique, using the SAS procedure CATMOD (SAS Institute Inc.,1986).

Three periods were defined by combining years into groups. This was necessary in order to account for effect of year. Fitting of year was itself not possible because of the large number of subclasses that resulted when using 17 year categories, with only 106 deaths/culls. Cell sizes were far too small and many cells were empty. The years were grouped according to whether a year had high mortality (> 20%), medium mortality (between 10 and 20%) and low mortality (< 10%). Grouping years according to the response variable mortality, creates a bias on the year effect which will obviously be significant. The purpose of doing this is to allow other effects such as genotype or sex to be adjusted for period differences.

In period 1 (high mortality) was the year 1975 and period 2 the years 1970, 1976, 1977, 1978, and 1985. Period 3 had the years 1969, 1971, 1972, 1973, 1974, 1979, 1980, 1981, 1982, 1983 and 1984.

Analysis for heterosis in calf survival as in the growth traits, was done by comparing the crossbred and the average of the parental genotypes. Since the estimates of rates of survival were obtained in a multiway table of genotype, sex and year, the rates were averaged across the other subclasses to obtain estimates of mortality for each genotype. Heterosis estimates were obtained from these averages.

4. RESULTS AND DISCUSSION

4.1 Means and Variations

The mean birth weight (±SD) for all calves was 25.9±4.28 kg. This mean was lower than the 30 kg that was reported by Gregory and Trail (1981) for pure Sahiwal calves in Kilima Kiu ranch in Machakos. This difference will be due partly to genotype and partly to the differences in the plane of nutrition of the dams during gestation and other times between the two herds attributable to differential management and environments. The cows in Kilima Kiu ranch received supplementation consisting of various high protein and energy feeds. The extent of supplementation in Mariakani, on the other hand, was much less, and most times none was given. The pure Sahiwal though in a different environment would have been expected to perform poorer than the crosses due to a lower genetic merit. This difference in performance however is more likely to be attributable to differences in environment than differences in genotypes.

The average preweaning daily gain (±SD) was 444±110.2 g/day while the mean for weaning weight (±SD) was 88.3±15.62 kg at 20 weeks of age (140 days).

4.2 Results of Analyses of Variance

The Analysis of variance results are summarised in Table 4.2 for model a (fitting calf genotype) and Table 4.3 for model b (fitting sire and dam genotypes). The least square means from the same models are presented in Tables

Table 4.1. Unadjusted Means, Standard Deviations, Least Square Means (LSM), Standard Errors (S.E) and Coefficients of Variation (CV) for birth weight, preweaning average daily gain (ADG) and weaning weight

Trait	No.	Mean	S.D.	C.V.(%)	LSM	S.E.
Birth wt.(kg)	1135	25.9	4.28	16.5	26.1	0.18
Preweaning ADG(g/d)	727	444	110.2	24	431	8.0
Weaning wt. (kg)	745	88.3	15.62	17.7	86.8	1.13

4.4 and 4.5 and 4.6. The least square means given for year, season, parity and sex are those obtained from model a.

4.2.1 Non-genetic Fixed Effects

Effects of year of birth were important (P<.01) for all the three traits; (birth weight, rate of gain and weaning weight). Birth weight was highest in 1979 and lowest in 1971 with a least squares difference of 4.7 kg between them, but there was no clear trend over the years (Table 4.4). The year effect could therefore be a result of annual fluctuations in weather conditions, disease incidences, sires used or changes in management. Changes in management would be important especially with respect to the feeding (supplementation) of the calves and their dams in late gestation. In this station this was governed by the availability of funds and changes in this over the years could have influenced the performances. As far as grazing conditions are concerned, weather conditions is the most crucial since it is the most important determinant of feed availability. The same kind of fluctuations were seen in preweaning weight gain and weaning weight over the years.

Season was a significant (P<.01) source of variation for all the traits. Least squares difference in birth weight between the best season (1st rainy season) and the worst (1st dry season) was 1.2 kg. Generally calves born in the two wet seasons were heavier at birth than those born in the dry seasons. In terms of rate of gain calves born in the two dry seasons gained faster than those born in the wet

Table 4.2. Results of Analysis of variance for model a

Source	df	Birth wt weight (kg)	df	Preweaning gain (g/day)	df	Weaning wt. weight(kg)
		Mean Squares				
Calf genotype	7	302.1	7	0.071*	7	1810.7**
Year (Y)	16	52.8**	16	0.142**	16	2771.6**
Season (SSN)	3	58.4*	3	0.198**	3	565.8**
Parity (P)	4	35.7	4	0.111	4	181.4
Sex	1	657.4**	1	0.002	1	806.1
Y x SSN	47	30.4**		---		---
SSN x P	12	33.4**		---		---
Residual	1044	18.3	695	0.12	713	244.1

* = P<0.05 ** = P<0.01

Table 4.3. Results of Analysis of variance for model b.

Source	df	Birth weight (kg)	df	Preweaning gain (g/day)	df	Weaning weight (kg)
		Mean Squares				
Sire gen. (S)	2	18.0	2	0.224**	2	5643.3**
Dam gen. (D)	5	215.4**	5	0.011	5	769.9**
Year (Y)	16	51.8**	16	0.143**	16	2827.7**
Season (SSN)	3	79.7**	3	0.203**	3	3722.8**
Parity	4	25.0	4	0.009	4	134.0
Sex	1	628.4**	1	0.0001	1	480.2
S x D	10	38.6**		---		---
Y x SSN	47	30.3**		---		---
Residual	1046	18.3	695	0.121	713	242.1

* = P<0.05 ** = P<0.01

Table 4.4. Least squares means of year, season, parity and sex from model a.

Variable	Birth weight No.	Birth weight LSM	Daily gain No.	Daily gain LSM	Weaning weight No.	Weaning weight LSM
Overall	1135	26.1±.81	727	431± 8.0	745	86.8±1.13
Year						
1969	58	25.7±.61	53	471±16.2	56	90.8±2.25
1970	76	25.2±.59	28	410±21.4	30	81.5±2.92
1971	61	22.9±.71	47	443±16.7	47	85.5±2.37
1972	109	25.9±.51	63	518±14.6	63	98.4±2.06
1973	110	26.8±.50	70	485±13.8	78	95.2±1.85
1974	123	26.9±.44	99	433±11.8	99	87.2±1.67
1975	102	25.5±.57	67	483±14.1	67	94.5±1.99
1976	106	26.4±.64	80	440±12.9	80	88.1±1.82
1977**	83	24.4±.73	2	224±79.0	2	59.3±11.19
1978**	27	25.6±.92	2	599±78.7	2	109.8±11.15
1979	38	27.6±.76	20	496±24.9	20	96.2±3.53
1980	39	27.5±.73	37	452±18.5	38	90.4±2.60
1981	49	26.3±.64	32	498±19.8	32	96.4±2.81
1982	50	27.3±.69	45	440±16.9	45	88.7±2.39
1983	52	26.5±.66	45	310±16.9	49	70.6±2.30
1984	21	27.1±.87	19	310±26.7	18	67.6±3.63
1985	31	26.4±.97	18	280±25.6	19	74.9±3.78
Season						
May-July	447	26.8±.30	277	431± 9.9	278	87.0±1.40
Nov.-Jan.	146	26.4±.42	112	377±12.9	116	79.5±1.79
Feb.-April	253	25.6±.34	151	476±10.9	156	92.7±1.53
Aug-Oct.	289	25.7±.31	187	439±10.9	195	87.9±1.52
Parity						
1	312	25.9±.30	194	440±10.7	198	88.0±1.51
2	257	25.5±.32	154	427±11.0	116	86.4±1.54
3	203	26.0±.37	134	435±12.0	156	86.9±1.69
4	141	26.9±.43	97	433±13.3	195	87.5±1.88
5+	222	26.3±.35	148	418±11.5	151	85.1±1.62
Sex						
Male	588	26.9±.22	349	432± 9.1	357	87.9±1.28
Female	547	25.3±.23	378	429± 9.0	388	85.7±1.27

** These two years had very few records (2) for both preweaning gain and weaning weight. Their estimates of least squares means are therefore not reliable due to the large sampling error.

seasons (476 and 439 vs. 431 and 377 g/day). Consequently, calves born in the dry season also weaned heavier than those born in the wet seasons. The effect of season on birth weight is through its influence on the dam during gestation. Those dams with their last trimester of gestation (period of fastest growth of foetus) occurring in favourable seasons, that is adequate pastures, gave birth to heavier calves. However calves born during the drier, hotter seasons spent the later part of their preweaning period in the subsequent cooler wet seasons, when forage would be more abundant and of better quality. At this time the calf would be old enough to graze outdoors when they are let out and it would be at a time when pastures are available and of higher quality. It is at this older age that the genetic potential of the calf (free of residual maternal effect) is better realised. Calves born in the wet season on the other hand, are weaned on poor pastures in the dry season when temperatures are also high. They therefore gain less and wean lighter. Gregory and Trail (1981) also found significant effects of year and season of birth on both birth and weaning weight in Kilifi. Calves born in the hotter seasons were lighter at birth than those born in the cooler seasons. Thus despite the supplementation done to the pregnant cows, the temperatures still could have had enough influence on the cows, possibly by reducing their feed intake. ILCA (1981) also reported that calves born during the drier periods in various ranches were often significantly lighter than calves born in the wetter years.

Sex of calf was important (P<.01) for birth weight but not for preweaning gain and weaning weight. Male calves were heavier than female calves with a least squares difference of 1.6 kg (6.3%). This superiority of males is consistent with published results (Gregory et al., 1978a,b; Gregory and Trail, 1981; Thorpe et al., 1981). Males are born heavier generally due to hormonal differences. The difference here is, however, lower than the 7.3% reported by Gregory and Trail (1981).

The lack of statistical significance of sex effects on preweaning rate of gain was not consistent with the report of Gregory et al.(1979) that male calves had an early postnatal growth rate about 10% higher (P<.01) than their female counterparts. The results in this study however conform with the findings of Gregory and Trail (1981). They reasoned that the failure of sex effects to be expressed between birth to 90 kg (attained in about 122 days) may have been the result of a lower plane of nutrition than is provided in most conventional beef programmes, which was, indeed, the case in the Mariakani herd. A heavier animal requires more feed than a lighter animal to maintain its weight and add more. Since the males in this study were born heavier on average, it follows that if feeding is on live-weight basis, they should receive more milk than the females. This was not done, meaning the males were not able to express their potential in weight gain and consequently weaning weight.

The resultant weaning weights were not statistically different between the sexes, although the males still weaned heavier by 2.2 kg (2.5%). These results were also not consistent with other published results (Dillard et al., 1980; Thorpe et al., 1981; Mwandotto et al., 1988) where males weaned significantly heavier. In all these studies, however, the herds were ranch herds where calves ran with their dams up to weaning. These calves were, therefore, able to suckle more milk, being limited more by their dam's milk production. This differs from the rearing system at Mariakani where the calves were fed on a fixed milk ration. This means some calves, especially the bigger ones at birth, were probably not able to meet their requirements.

Parity of dam had no significant effect on all the traits, neither was there any clear trend in any of the traits with parity. This differs with the reports of Laster et al. (1972) and Anderson et al.(1978) who have reported significant age of dam effects on birth weight, heifers producing significantly lighter calves. Kiwuwa et al.(1983) also reported significant parity effects on birth weight after the second parturition. Non-significant age of dam effects have been attributed to advanced age at first calving (Willis and Wilson, 1974).

The results in this study, however, could not be due to advanced age of dam at first calving since it had a mean of 1020 days (32 months or 2.8 years). Ideally a heifer should calve at around the age of 27-28 months. Thus, the age in Mariakani was not very advanced relatively, and might not fully account for the lack of significance for parity of dam on calf performance. It could be that the dams were able to achieve mature size by the age at first calving. This means that with higher parities there was no change in dam size and a consequent lack of importance of parity on the weight of calves at birth.

Breeding of heifers on the basis of weight or a combination of weight and age under low input production systems, such as the one under study, tend to produce first calvers which are undesirably older. This could also be caused by delayed first heats due to environmental stresses, climatic, nutritional or health. This advanced age at first calving has a tendency to mask age and/or parity effects on some traits. Due to the same factor ,that is, advanced age at first calving (mean of 40.4 months), Willis and Wilson (1974) obtained a non-significant effect of parity and age of dam on birth weight.

The interaction of year and season of birth and that of parity and season were both important for birth weight. This means that the effect of season can not be explained alone without its relationship with the year and dam parity. Those calves born in the second wet season (November to January) and fifth parity were the heaviest at 27.5 kg, while the lightest were born in the first dry season (February to April) and second parity with a weight of 23.9 kg.

4.2.2. Genetic Effects

4.2.2.1 Genotype of Sire

The effect of sire breed was not statistically significant (P>.05) for birth weight even though the interaction of sire and dam genotypes was important (P<.01). However, disregarding dam genotype, calves sired by Ayrshire bulls had the heaviest birth weights with a mean of 26.7 kg while Sahiwal sired calves were lightest with a mean of 26.1 kg (Table 4.5). The ranking of sire breeds in this study does not agree with the findings of Gregory and Trail (1981), who reported that Sahiwal sired calves were 2.9 kg heavier (P<.01) than Ayrshire sired calves. Although they did not report a significant interaction of sire and dam genotypes, their results could have been influenced by the fact that Sahiwal sired calves were mainly born to 2/3 Ayrshire 1/3 Sahiwal dams while Ayrshire sired calves were born to 2/3 Sahiwal 1/3 Ayrshire dams. The additive maternal effect other than sire-breed effect could therefore have been the major cause of the difference. They attributed this difference to longer gestation periods associated with calves sired by <u>Bos-indicus</u> (Sahiwal) bulls (Gregory <u>et al.</u>, 1979).

Sire genotype was significant for preweaning gain, and weaning weight. Calves born of Friesian sires had the highest rate of gain with a least squares mean of 486 g/day and those sired by Sahiwal had the lowest at 409 g/day. The Ayrshire-sired calves gained 440 g/day. These findings on

Table 4.5. Least squares means (LSM) and standard errors for sire and dam genotypes from model b.

	Birth weight (kg)		Daily gain (g/day)		Weaning weight (kg)	
Variable	No.	LSM	No.	LSM	No.	LSM
Overall	1135	26.1±.81	727	431± 8.0	745	86.1±1.13
<u>Sire Genotype</u>						
Sahiwal	549	26.1±.25	348	409± 9.3	357	83.7±1.31
Friesian	186	26.6±.84	111	486±13.4	111	96.2±1.90
Ayrshire	400	26.7±.41	268	440±10.6	277	88.0±1.48
<u>Dam Genotype</u>						
>87.5%Sahiwal	397	24.8±.26	254	428± 9.9	259	84.9±1.40
67%Sahiwal 33%exotic	176	25.3±.39	103	447±13.2	105	88.7±1.86
F_1Ayrshire-Sahiwal	241	27.1±.52	165	439±12.1	171	89.7±1.70
F_1Friesian-Sahiwal	89	28.5±.70	56	449±17.3	57	90.9±2.42
67%exotic 33%Sahiwal	173	28.1±.60	108	446±13.3	111	90.6±1.86
>87.5%exotic	59	24.8±.52	41	461±19.6	42	91.0±2.74

the Ayrshire and Sahiwal sires are consistent with those of Gregory and Trail (1981) who reported that Ayrshire-sired calves gained 45 g/day (9.5%) more than Sahiwal-sired calves. They attributed part of this difference to the behavioural difference between Sahiwal and Ayrshire breeds resulting in difficulty in training Sahiwal-sired calves to drink whole milk from a bucket. They reasoned that a low intake of colostrum resulting in low antibodies and sub-optimal nutritive environment at this period likely has important carry-over effects. These effects either directly or indirectly may affect feed consumption when supplemental feed is restricted, and thus weight gains may have been reduced for an extended period. In this study, however, there was no information to indicate whether or not there were differences in the behaviour of the calves. The differences in weight gain for the calves sired by the different breeds (Table 4.5) show that Friesian has the highest merit for direct additive genetic (transmitted) effects for weight gain, while the Ayrshire is better than the Sahiwal in the same respect. Considering the mature liveweights of the three breeds the outcome here was not surprising.

Calves sired by Friesian sires were 7.5 kg heavier at weaning than those sired by Sahiwal sires (96.2 vs. 83.7 kg) while those sired by Ayrshire sires weighed 88.0 kg. The pattern of weights at weaning was consistent with that of weight gain. The higher rates of gain in Friesian sired calves resulted in heavier weaning weights meaning that a high merit for transmitted effects of weight gain leads to consequently high weaning weights. For this environment, and considering only growth traits, it means that the Friesian would be better suited for crossing with the Sahiwal than the Ayrshire especially for weaner production. If the same trend is maintained even post weaning it implies that for growth traits the use of Friesian as sires would be more effective than Ayrshire. However, other factors such as reproduction, efficiency of gain (feed utilization), mortality rates and longevity of production in this production system must also be considered.

There was a significant interaction effect between the sire and dam genotypes on calf birth weights but not for preweaning gain and weaning weight. A significant interaction between genotypes of parents indicates the interdependence of the effects of the sire and dam genotypes and therefore the genotype of one parent of a cross cannot be discussed without making reference to the genotype of the other parent. The interaction can be manifested as a change of rank in genotypes, say of dams when a different sire genotype (breed) is used or change in rank of sires when a different dam genotype is used. It could also be manifested as change in variation or difference, without change in rank. Interaction in this study fell in both categories.

The performance of a given combination of sire and dam genotypes in their calf birth weights is a reflection of the specific combining ability (SCA) of the genotypes. Calves born of Ayrshire sires and F_1 Friesian-Sahiwal dams were born heaviest with a least squares mean of 29.9 kg while the lightest were those born to Sahiwal sires and Sahiwal dams with a mean of 23.4 kg. This indicates a superior combining ability of the crossbred dams and the Ayrshire sires which have already shown superiority over the other sire genotypes. The pure sahiwal sire and dams on the other hand combine the poorest performances on both the sire and dam sides, resulting in the lowest performing combination for calf birth weights. Generally, the crossing of any of the sire breeds to the crossbred dams gave heavier calves than crossing the sires to the high-grade dams.

4.2.2.2. Genotype of Dam

4.2.2.2.1. Performance Patterns

As has been stated, there was a significant interaction effect between sire and dam genotypes. Dam genotype was important ($P<.01$) for birth weight. F_1 Friesian-Sahiwal dams gave birth to the heaviest calves while the birth weights of calves from high-grade (>87.5%) Sahiwal and exotic dams were the lightest. Generally crossbred dams produced calves that were heavier at birth than straightbred dams (Table 4.4).

The dam genotype had non-significant effects on the preweaning gain and weaning weight. It should be noted that the coefficient of variation in the analysis of weight gain was relatively high (24.8%) compared to those of birth (16.5%) and weaning weights (17.7%) (Table 4.1). Therefore the precision of this analysis is less than that for the live weights. Moreover, statistical non-significance may not necessarily indicate lack of biological importance of an effect such as dam genotype. Calves born of high-grade exotic dams had (numerically) the highest rate of gain with a least squares mean of 461 g/day while calves born of high-grade Sahiwal dams had the lowest average daily gain (428 g/day). At weaning, calves born to high grade exotic dams were the heaviest with a least squares difference of 6.1 kg above the lightest (born to Sahiwal dams). The pattern was consistent with that in weight gain, with the progeny of crossbred dams having an advantage over the straightbreds.

4.2.2.2.2 Estimates of Heterosis and Additive Effects

The general superiority of the crossbred dams in calf birth weights indicates important heterotic and additive maternal effects. The F_1 Ayrshire-Sahiwal dams gave birth to calves with a mean birth weight of 2.3 kg heavier than the mean of the straightbred dams (a maternal heterosis estimate of 9.5%) (Table 4.6). This estimate of maternal heterosis is close to the mean heterosis of 12.6% reported by Koger (1973) for F_1 Bos-taurus x Bos-indicus cross dams and can be explained by complementarity. That is, crossbred dams had acquired additive genes for heavier birth weights from the exotic breeds and genes for withstanding stress (during gestation) from the Sahiwal enabling them to bear calves with better growth performance than either of the straightbreds.

The rotational 2/3 Ayrshire 1/3 Sahiwal dams gave birth to calves that were 2.8 kg heavier at birth than the reciprocal cross dams. The significant interaction of sire and dam genotypes notwithstanding, this could be attributed to the higher proportion of exotic genes in the 2/3 Ayrshire cross, that is, due to to additive maternal effects. The fact that high-grade exotic dams gave birth to calves of the same weight with high-grade Sahiwal dams, could imply that the high-grade exotic dams were more susceptible to environmental effects ie. less well adapted than the Sahiwals. If this were not the case, it would, on the basis of transmitted effects, be expected that calves from exotic dams would be heavier than those from Sahiwal dams.

Since calves born to high-grade (>87.5%) exotic dams (mostly Ayrshire) gained at a higher rate than those born to high-grade (87.5%) Sahiwal, it means that the exotic dams were superior to the Sahiwal in terms of transmitted effects (additive breed effects) for weight gain.

The F_1 Ayrshire-Sahiwal dams gave birth to calves that gained a mean of 439 g/day, which is equivalent to a non-significant maternal heterosis (Table 4.6) of 5.5 g/day (-1.2%). This poor maternal heterotic effect conforms with the observation that in rate of gain maternal effect was not important in this study. Calves were bucket fed so that the calf's performance in rate of gain was almost wholly dependent on its own genetic potential (genotype) and not on that of its dam's potential for milk production except possibly residual dam effect on birth weight. Had calves

Table 4.6. Maternal heterosis estimates in F_1 Ayrshire-Sahiwal dams for birth weight, preweaning daily gain (ADG) and weaning weight.

	Birth weight (kg)		ADG (g/day)		Weaning weight (kg)	
	Mean	SE	Mean	SE	Mean	SE
High-grade Sahiwal	24.8	0.26	428	10.0	84.9	1.41
High-grade exotic	24.8	1.52	461	39.7	91.0	5.59
F_1 exotic-Sahiwal	27.1	0.52	439	18.1	89.7	2.55
Heterosis (Kg or g/day)	2.3		-5.5		2.0	
(%)	9.2		-1.2		2.2	

been suckled as they are in ranch herds, some positive maternal heterosis would possibly have been realised since the crossbred dams have been reported to produce more milk than the straightbred Sahiwals (Thorpe et al., 1989)

Although high-grade exotic dams had the lightest calves at birth, these calves weaned heaviest due to their superior rate of gain. The F_1 Ayrshire-Sahiwal dams had a non-significant(P>.05) maternal heterosis estimate of 2.0 kg (2.2%) in weaning weight (Table 4.6). This could again be partly due to the reduced maternal effect at weaning. The maternal heterotic effect was less at weaning weight than at birth. This could be attributable to the fact that the calves did not suckle their dams up to weaning. The little maternal heterotic effect remaining is a residual of the effect at birth. In general, all crossbred dams, conforming to the pattern in the rate of gain, had calves that were heavier at weaning than those born to high-grade Sahiwal dams, but lighter than those born to high-grade exotic dams (Table 4.6). This indicates an importance of additive and heterotic maternal effects in weaning weight as was reported by Dillard et al.(1980). It is clear that the degree of expression of these effects (differences between dam genotypes) would have been greater had calves been reared by their own dams and suckled to their optimal requirements.

4.2.2.3. Genotype of Calf

4.2.2.3.1. Performance Patterns

Genotype of calf was important (P<.01) for all the three traits. The least squares means for the various genotypes are shown in Table 4.4. together with their standard errors. The high-grade Sahiwal calves had the lowest birth weights (23.7Kg) while the 3/4 Sahiwal 1/4 exotic calves were the heaviest (27.5 kg).

The F_1 Friesian-Sahiwal calves had the highest rate of gain at 480 g/day while the high grade Sahiwal calves gained the slowest, 389 g/day (Table 4.7). The F_1 Ayrshire-Sahiwal calves gained faster (436 g/day) than either of the two parental genotypes. Friesian X Sahiwal calves were the heaviest at weaning (93.9 kg) while the high-grade Sahiwal calves were the lightest at 78.8 kg. This was consistent with the pattern in preweaning gain. The F_1 Friesian-Sahiwal and F_1 Ayrshire-Sahiwal calves were not significantly different in birth weight, but at weaning the former was significantly (P<.01) heavier.

4.2.2.3.2 Estimates of Heterosis and Additive Effects

There was a general superiority of the crossbred calves in most of the traits, which means heterosis and additive genetic effects were important in performance of these calves. Only the F_1 Ayrshire-Sahiwal cross is used in the discussion of heterosis, because in the high-grade exotic group about 85% of calves had 87.5% or more Ayrshire blood.

Table 4.7. Least Squares Means (LSM) of calf genotypes from model a.

	Birth weight		Daily gain		Weaning weight	
Variable	No.	LSM	No.	LSM	No.	LSM
Overall	1135	26.1±.81	727	431± 8.0	745	86.8±1.13
Calf Genotype						
>87.5% Sahiwal	229	23.7±.31	141	389±11.7	143	78.8±1.65
75%Sahiwal 25%exotic	156	27.5±.38	107	404±12.8	110	84.8±1.80
67%Sahiwal 33%exotic	125	27.5±.41	75	413±14.5	78	85.3±2.02
F_1Ayrshire-Sahiwal	167	25.0±.36	107	436±13.0	111	85.9±1.81
F_1Friesian-Sahiwal	91	25.9±.49	59	480±16.3	59	93.9±2.30
67%exotic 33%Sahiwal	125	25.0±.42	75	446±14.7	77	88.0±2.06
75%exotic 25%Sahiwal	174	26.9±.38	114	451±13.2	118	90.5±1.84
>87.5%exotic	68	27.3±.55	49	426±17.6	49	87.0±2.49

Table 4.8. Estimates of individual heterosis for birth weight (BW) in kg, preweaning gain (ADG) in g/day and weaning weight (WW) in kg.

		Heterosis	
Genotype	Trait	Units	%
F_1 Ayrshire-Sahiwal	BW	-0.5	-2.1
	ADG	28	7.0
	WW	3.0	3.6
F_1 Friesian-Sahiwal	BW	0.41	1.6
	ADG	72	17.6
	WW	11.0	13.3
F_1 exotic-Sahiwal	BW	-0.06	-0.001
	ADG	50	12.4
	WW	7.0	8.5

Thus the group (high-grade exotic calves) was more representative of high grade Ayrshires than Friesians. The levels of heterosis in the F_1 Friesian-Sahiwal was also estimated, while the mean performance of the two crosses (F_1 Ayrshire and F_1 Friesian) was used to estimate the level of heterosis in F_1 exotic-Sahiwal. These two estimates are however, only approximate because of the very high proportion of Ayrshire crosses in the high-grade group.

The F_1 Ayrshire-Sahiwal had a birth weight of 25.0 kg. This is equivalent to an individual heterosis estimate of -0.5 ± 0.47 kg (-2.1%) (Table 4.8), which was not significantly (P>.05) different from zero. This level of heterosis is outside the range (1-11%) reported by Long (1980) and the levels reported by Trail _et al._ (1982) and Sacker _et al._(1971) of 3.6% and 9.7% respectively in Red Poll x Boran crosses in Uganda. It is also much lower than the mean heterosis of 9.5% reported by Koger (1973) for F_1 _Bos-taurus_ x _Bos-indicus_ cross calves. Majority of the F_1 calves (81%) in this study were born to Sahiwal dams and the rest to high grade exotic (mostly Ayrshire) dams. This possibly contributed to the low estimate of heterosis, because a high proportion of F_1 calves were the progeny of high-grade Sahiwal dams which on average gave birth to the lightest calves. This low genetic merit of the Sahiwals in maternal effect on birth weight may be responsible for the less-than-expected heterosis estimate. The 3/4 Sahiwal 1/4 exotic calves were 3.8 kg heavier than the high-grade (>87.5%) Sahiwal. The mean birth weight of this backcross group did not, however, significantly differ from the 27.3 kg of the high-grade exotic calves. The superiority of the 3/4 Sahiwal 1/4 exotic calves over the high-grade Sahiwals was probably due to a superior additive genetic effect, plus a higher merit of their F_1 dams in maternal effects. Though both groups had the same sire breed (Sahiwal) the backcross calves were born to F_1 dams, which, as has been seen, had a heterosis estimate of 9.2%, while the high-grade Sahiwals were born to high-grade Sahiwal dams. It is interesting that the 3/4 exotic 1/4 Sahiwal calves, despite being of a superior (additive) genotype, had a lower (though non-significant) birth weight than the contrasting 3/4 Sahiwal 1/4 exotic backcross calves. Both calf groups were born of F_1 exotic-Sahiwal dams but of either Sahiwal or exotic (Friesian/Ayrshire) sires. One would expect the 3/4 exotic 1/4 Sahiwal calves to be heavier. This expectation is based on the fact that both calf groups are expected to exploit equal maternal heterosis and thus those with a superior additive genotype (3/4 exotic 1/4 Sahiwal) ought to be born heavier. However, since the observed difference did not reach statistical significance it may have resulted from sampling variation, ie. occurred due to chance.

The 2/3 Sahiwal 1/3 exotic calves weighed 2.5 kg (10%) heavier ($P<.01$) at birth than the 2/3 exotic 1/3 Sahiwal. This is consistent with the results of Gregory and Trail (1981) where the difference between the two groups was 2.9 kg. Again, based on the calf's additive genetic composition, this result was not expected since the 2/3 exotic 1/3 Sahiwal calves have a superior additive genetic composition. The results could be attributed to the difference in maternal additive genetic effect between the dams of these calves. The 2/3 Sahiwal 1/3 exotic calves were born to 2/3 exotic 1/3 Sahiwal dams while the 2/3 exotic 1/3 Sahiwal calves were born to 2/3 Sahiwal 1/3 exotic dams. The former group of calves were therefore born to dams with a higher proportion of exotic genes and thus had a superior additive maternal effect. The 2/3 Sahiwal 1/3 exotic dams, though possessing the same degree of heterozygosity were of an inferior additive genetic composition and thus gave birth to lighter calves. This is consistent with the fact that at birth, the genotype of calf is expressed to a lesser extent than that of the dam. That is, there is a masking effect of the maternal effect on the calf's genotype. The mean birth weight of the two contrasting crosses was 1.2 kg higher than that of the F_1 Ayrshire X Sahiwal cross calves (born of high-grade dams). This indicates that the interaction of sire breed and dam genotype notwithstanding, the maternal additive genetic effect was important for birth weight. That is, the superiority of calves born to 2/3 Ayrshire 1/3 Sahiwal dams could be attributed to a superior additive genetic composition (as compared to the F_1 dams).

The F_1 Ayrshire-Sahiwal had a mean average daily gain of 436 g/day and a heterosis estimate of 28 g/day (7%) (Table 4.8). This estimate is within the range of 3 to 8% reported in the literature (Gregory _et al._, 1965; Gaines _et_ al., 1966; Trail et al., 1977; Dillard et al., 1980). The rate of gain from birth to weaning was linear, meaning weight gain was more or less uniform over the preweaning period. It was therefore not logical to examine the levels of heterosis in different stages of this period since they would be very similar. As has been alluded to (section 4.2.2.2.2), the level of heterosis would possibly have been higher in this study had these calves been reared as in ranch herds, that is, running with their dams until weaning age. In such cases the calves are able to suckle as much as their dams can produce and in so doing realise a big proportion of their genetic potential. In this study it is possible that some of the calves, especially the relatively heavier ones got less milk than their requirements. Their full genetic potential could then not have been expressed and this means that heterosis may be an underestimate. This would be in following with the observations of Long and Gregory (1975) that larger effects of heterosis are realised at better management levels or at higher rates of gain.

The 3/4 exotic 1/4 Sahiwal had a significantly higher rate of gain than the contrasting 3/4 Sahiwal 1/4 exotic backcross calves (451 vs. 404 g/day) even though both were born to the samre genotype of dams (F_1's). This is attributable to the superior additive genetic composition (potential) of the 3/4 exotic 1/4 Sahiwal since it possess a higher proportion of exotic genes. This concurs with the observation that the Friesian and Ayrshire sires were significantly better than the Sahiwal sires in their effects on weight gain. Thus, although there was a non-significant difference between the backcross in birth weight, the difference is important in weight gain, due to the increased degree of expression of the calf's genetic potential (additive), as the maternal effect of dam gradually subsides. Birth weight is more a product (trait) of the dam than of the calf genotype, while for growth in this system (bucket rearing), only the residual maternal effect is important. These results are similar to those of Koger et al.(1975) who reported that 3/4 Brahman 1/4 Shorthorn calves gained significantly faster than the contrasting 3/4 Shorthorn 1/4 Brahman calves, indicating that those calves with a higher proportion of Brahman genes had a higher additive genetic merit. The big difference between these studies is that in the current study the Bos-taurus (Ayrshire) breed shows a superior additive genetic ability than the Bos-indicus breed (Sahiwal), while in the Koger study it was the Bos-indicus (Brahman) that had the superior effect.

The 2/3 exotic 1/3 Sahiwal calves had a faster rate of gain than the contrasting cross. This was despite the fact that the latter were born heavier ($P<.01$) than the 2/3 exotic 1/3 Sahiwal calves, a phenomenon that was attributed to differential additive maternal effects. But as in the backcross, the genotype of calf with the superior additive genetic composition (2/3 exotic 1/3 Sahiwal) has the higher rate of gain although the difference did not reach statistical significance. The superiority of the 2/3 exotic cross over the contrasting cross has been reported elsewhere (Gregory and Trail, 1981) where 2/3 Ayrshire 1/3 Sahiwal calves gained 45 g/day faster (P<.05) than the 2/3 Sahiwal 1/3 Ayrshire calves. This superiority of 3/4 Ayrshire and 2/3 Ayrshire calves indicates the superiority of the Ayrshire for transmitted (direct additive) effects over the Sahiwal.

In weaning weight the F_1 Ayrshire-Sahiwal had a heterosis (individual) estimate of 3.5 kg (3.6%). This estimate just falls within the general range of 3-16% (Gaines et al., 1966; Pahnish et al., 1969; Long and Gregory, 1974; Gregory et al., 1978b), but it is, however, much lower than the 23% reported by Koger et al.(1975) in F_1 crosses of Brahman (Bos-indicus) and Shorthorn (Bos-taurus). The big difference between these two studies could however be attributed to the different genotypes and management regimes.

Although F_1 Friesian-Sahiwal and F_1 Ayrshire-Sahiwal calves did not differ significantly in birth weight, at weaning the former were significantly heavier (P<.05). This indicates that the Friesian out-performs the Ayrshire in the transmitted effects for weight gain. This was not surprising in view of the difference in body weights of these breeds. The two contrasting rotational crosses were not significantly different in weaning weight. The 2/3 exotic 1/3 Sahiwal gained significantly more per day than the 2/3 Sahiwal 1/3 exotic cross (446 vs. 413 g/day). This was attributed to a superior additive genetic composition combined with a decreased residual dam effect. This agrees with the observation of Nitter (1978) that maternal influence on growth decreases with age of the calf. The live weight differences that existed at birth were therefore not maintained and the two no longer differed by weaning. It would be of interest to see how the two progress postweaning because from these indications it appears that the 2/3 exotic 1/3 Sahiwal calves would weigh significantly more than the contrasting cross as a result of faster post-weaning gain.

The same trend, an increase in the importance (degree of expression) of the individual additive genes of the calves with age, was observed in the backcrosses. Though similar in birth weights possibly due to similar maternal heterosis, the 3/4 exotic 1/4 Sahiwal gained significantly more per day ($P<.01$) than the 3/4 Sahiwal 1/4 exotic and therefore was significantly heavier at weaning ($P<.01$).

The mean weaning weight of the two rotational crosses (86.7 kg) was higher than the mean of the F_1 Ayrshire-Sahiwal though not significantly ($P>.05$). The two groups did not actually differ greatly for any of the traits (Table 4.9). Theoretically, the F_1 cross has 100% heterosis because all the loci are heterozygous. The rotational cross, on the other hand, retains 67%, that is, two-thirds of the heterosis in the F_1. It would therefore be expected that heterosis in the rotational crosses would be approximately two-thirds of that of the F_1's. The 2/3 exotic 1/3 Sahiwal, however, did better than the F_1, and therefore lifted the mean of the two rotational crosses to above that of the F_1. This result indicates that rotational crossbreeding involving Sahiwal and exotic breeds may be preferable in comparison to the continuous production of F_1's.

The heterosis estimates obtained here are generally low. This could be attributed to the relatively low plane of nutrition which Long and Gregory (1975) said could lead to lower heterotic effects. An optimally fed animal is able to express its full genetic potential. If however, the plane of nutrition is not optimal, this genetic potential is masked by the lack of the right environment (nutritional) and the full heterotic effect can therefore not be realised in a crossbred animal.

4.3 Viability

In the analysis of survival rates the effects of calf genotype, year and sex were important (Table 4.10). The results for year effects were, however, expected since the years were arranged according to degrees of mortality. Season of birth was not included in the model because the resultant multi-way table was too big, with many empty cells. The effect of greatest interest was that of calf genotype.

The rates of survival (mortality) were worked out using the parameter estimates given in Table 4.11. The last level of each effect eg. genotype 1 (>87.5% Sahiwal) is set to zero so that estimates of coefficients for the other

Table 4.9. Comparison of F1 Ayrshire-Sahiwal with the Rotational Crosses.

Genetic Group	NO.	Birth Wt.(Kg)	No.	ADG(g)	NO.	Weaning Wt (Kg)
2/3 Sahiwal 1/3 exotic	129	27.5	75	413	78	85.3
2/3 exotic 1/3 Sahiwal	130	25.0	75	446	77	88.0
Mean		26.2		430		86.7
F_1 Ayrshire-Sahiwal	174	25.0	107	436	111	85.9

subclasses are relative to this level. To work out the the ratio of calves that survive in Genotype 1, Year 1, Sex 1 subcell, for example, the estimates (logits) obtained in the table are used as follows:

$$\text{Intercept} + D_1 + Y_1 + S_1$$

$$z = 2.2710 - 0.8973 + 0.8011 - 0.2420$$

$$= 1.9331$$

$$\text{and } p = e^{1.9331}/1+1.9331 = 0.874$$

That is, survival rate in this cell is 87.4% (or mortality rate of 12.6%), which implies that about 67 out of 77 calves survive.

The mean mortality (due to deaths and culling) rates of the calf genotypes and sexes averaged over the three years periods (low, medium and high mortalities) are shown in Table 4.12. The overall mean mortality rate of 12.9% is fair considering that the calves do not receive any supplementation and that they are fed a fixed ration of milk which might not be enough for the heavier than average calves. Males, averaged over the years and across the genotypes had a survival rate significantly lower ($P<.05$) than that of females (85.1 vs. 89.9%). The higher survival rate in females is consistent with reports of Smith et al. (1976) and Sacco et al.(1989). The former had reported a survival rate in female calves 3% higher than in male calves. The male calves in this study were born significantly heavier than the females and this could explain the higher mortality rates in males. Heavy calves may have greater problems when feed is limiting.

Table 4.10. Maximum likelihood analysis of variance for survival from logit model.

Source	df	Chi square
Intercept	1	183.32**
Genotype of calf	7	18.73**
Period (Year groups)	2	32.39**
Sex	1	4.96*
Likelihood ratio	37	42.73

* = P<.05 ** = P<.01

Table 4.11. Maximum likelihood parameter estimates for survival from logit model

Effect	Parameter	Estimate	Standard Error	Chi square
Intercept	1	2.2710	0.1677	183.32**
Genotype	2	-0.8973	0.2369	14.34**
	3	0.0338	0.3127	0.01
	4	0.1185	0.3596	0.11
	5	0.2542	0.3412	0.56
	6	-0.2891	0.3514	0.68
	7	-0.5888	0.2764	4.54*
	8	-0.1718	0.2840	0.37
Period	9	0.8014	0.1480	29.33**
	10	0.0392	0.1511	0.07
Sex	11	-0.2420	0.1087	4.96*

The high grade exotic calves had the highest survival rates with a mean rate of 97.2% (Table 4.12). The high-grade Sahiwal calves had the lowest rate of survival with a mean of 77.5%. Most of the calves died or were culled due to either disease or weakness. Weakness could easily be associated with small size and fragility. The high mortality rates in the Sahiwals could be attributed partly to their birth weight. This is because in the earlier days of the breeding programme, there was a tendency by the management to get rid of calves that were below 18 kg, and these mostly happened to be of the high-grade (>87.5%) Sahiwal group. Due to many of them having lower than the average birth weight, it was also possible that many of them could have died due to weakness. Early deaths could also be attributedto poor nutrition i.e bucket feeding as opposed to natural suckling.

The crosses generally had survival rates that were intermediate to those of the high-grade Sahiwals and high-grade exotics, indicating important additive genetic effects. This means that additive genetic effect was important for calf survival. Among the F_1 crosses, the F_1 Ayrshire-Sahiwal had higher survival rates than the F_1 Friesian-Sahiwal. The effects of weight at birth on mortality would not appear to be important here as reported elsewhere (Laster and Gregory, 1973; Smith <u>et al.</u>,1976). They reported that calf breeds heavier at birth had higher rates of mortality, but this was mainly in situations where dystocia was important. The F_1 Friesian-Sahiwal were not

Table 4.12. Survival rates for calf genotypes

Genotype	male	female	mean
>87.5% Sahiwal	73.6	81.4	77.5
3/4 Sahiwal 1/4 Ayrshire	87.0	91.3	89.1
2/3 Sahiwal 1/3 Ayrshire	87.9	92.0	89.1
F_1 Ayrshire-Sahiwal	89.2	93.0	91.1
F_1 Friesian-Sahiwal	83.1	88.7	85.9
2/3 exotic 1/3 Sahiwal	78.8	85.4	82.1
3/4 exotic 1/4 Sahiwal	84.6	89.7	87.1
>87.5% exotic	96.6	97.9	97.2
Mean	85.1	89.9	87.5

significantly different from the F_1 Ayrshire-Sahiwals in birth weight although they were born 1.4 kg heavier. There were no dystocia cases recorded, and it would therefore be difficult to associate the higher levels of mortality of the Friesian cross with its higher mean birth weight.

In all the categories of years and sexes, the backcross and rotational cross calves with a higher proportion of Sahiwal genes (75% Sahiwal 25% exotic and 67% Sahiwal 33% exotic) had higher rates of survival than their reciprocals (Table 4.13). Thus, although the high-grade (>87.5%) Sahiwal, had lower survival rates than the high-grade exotics, the crosses with a higher proportion of Sahiwal genes had higher rates of survival than their reciprocals. If additivity were important, it would be expected that since the high-grade exotics have a higher rate of survival than the high-grade Sahiwals, the crosses with a higher proportion of exotic genes would also show superiority over their reciprocals. Since this is not the case, it means that additive genetic effects are not important in accounting for survival differences.

The estimate of heterosis for calf survival was 4.3 % for the F_1 Ayrshire-Sahiwal (Table 4.13). This estimate indicates heterosis could have been important for calf survival in the Ayrshire cross. Barlow (1981) had reported that due to a scale effect, the benefits of crossbreeding are usually greater at lower levels of performance (as is the case at Mariakani). Klosterman et al.(1968), Koger et al. (1975) and Peacock et al. (1977) had all reported significant levels of heterosis for calf preweaning survival. Crossbreeding, however still is advantageous in survival since all the crosses have higher survival than the high-grade Sahiwal. This implies that although there might be some other factors influencing survival, additive genetic effects are partly responsible for the levels of performance observed.

Table 4.13. Heterosis estimates for calf survival.

Genotype	No. born	Survival rate (%)
>87.5% Sahiwal	229	77.5
>87.5% exotic	68	97.2
F_1 Ayrshire x Sahiwal	167	91.1
Heterosis Absolute		3.8
%		4.3
F_1 Friesian-Sahiwal	91	85.9
Heterosis Absolute		-1.5
%		-1.7
F_1 exotic-Sahiwal	258	83.5
Heterosis Absolute		1.2
%		1.3

5. SUMMARY AND CONCLUSIONS

Most non-genetic fixed affects (year, season, sex) had important influences on calf performance. Birth weight was lower for those calves born during and immediately after the dry seasons than for those that were born in the wetter seasons. The same calves (born in dry season) however, gained faster and weaned heavier than those born in the wet seasons. This implies that apart from the sex factor, with improved management, especially during the harsher years and seasons, the performance of calves and consequently the cow and farm productivity could be improved by better supplementation regimes and the conservation of forage for use in the dry periods.

Crossing of Sahiwal with European breeds led to better performances, in general, than the use of either of the purebreds. This is true for the calf performances in growth rate and weaning weight and also in the birth weight of calves as a trait of the dam. In both dams and calves heterosis was not of significant importance. The differences in performance that were observed between the genotypes were evidently as a result af additive genetic effects. There was therefore little difference observed between the means of the rotational crosses and those of the F_1's, a phenomenon also observed by Thorpe et al.(1989) in their study of the lactational and reproductive traits of the dams in this herd. In general, the 2/3 exotic 1/3 Sahiwal genotype was superior to its reciprocal both as a genotype of calf and as genotype of dam. The exception was for birth weight as trait of the calf where the reciprocal was superior. This exception was however explained by additive maternal effect arising from the fact that the 2/3 Sahiwal 1/3 exotic calves were progeny of the reciprocal cross dams.

The programme for producing rotational crosses has been said to have operational advantages, including cost. Another advantage of rotational crossing is that high levels of heterosis can be sustained in a continuous rotational crossbreeding system because retention of heterosis in rotational crossbreeding systems is proportional to retention of heterozygosity. At farm level, for both large and small scale producers, it would necessitate the maintenance of purebreds if they are to continue producing F_1's. If crossbreds perform better in the subject environment, and the rotationals as well as the F_1's, then the maintenance of purebreds would be an unnecessary cost. This would be particularly so for the small scale farmer who can only maintain a few animals. It is therefore fitting that the breeding programme in Mariakani should be pursued as was originally stipulated, both for the costs and conveniences of the programme and for supply (sale) of stock to farmers in the region. The latter (supply of stock) was one of the objectives of the programme when it was started.

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