A COMPARISON OF THE PRODUCTIVITY OF KENYA SAHIWAL CATTLE AND THEIR CROSSBREDS IN LARGE SCALE DAIRY - DUAL PURPOSE AND BEEF PRODUCTION SYSTEMS

BY

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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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ABSTRACT

A study was conducted to characterise production systems which utilised the Kenya Sahiwal and its crossbreds and to evaluate productivity of the breed types in agro - ecological zones III and IV. Production systems in which the Kenya Sahiwal and its crossbreds were used were in beef production systems, dual - purpose production systems and large scale dairy production systems. Beef production systems included the Sahiwal herds at Elkarama ranch in Laikipia and Ilkerin - Loita ranch in Narok. Cattle were extensively grazed on natural pastures and supplemented with minerals for meat production in agro-ecological zone IV. The offtake rate was 27% and accounted for over 90% of the total income. Dual - purpose production systems included the Sahiwal herds at Deloraine Estate and Oljorai, the Sahiwal and Friesian - Sahiwal herds at the National Animal Husbandry Research Centre in Naivasha, and the Sahiwal crossbred herd at Mariakani Research Centre. Cattle were extensively grazed on natural pastures and supplemented with minerals for milk and meat production. Milk offtake accounted for 69% of the total income, whereas cattle offtake earned 31% of the total income. Large scale dairy production systems included the Ayrshire - Sahiwal herd at Deloraine Estate, Friesian - Sahiwal herd at Loldia Estate and the Ayrshire- Brown Swiss - Sahiwal herd at Kilifi Plantations. Cattle were rotationally grazed on natural and improved pastures and were supplemented with dairy meal and minerals for milk and meat production. The contribution to the total income from milk sales was 73%. Cattle offtake accounted for 27% of the total income.

Data were collected from the ten herds on the economically - important performance traits which included survival rate by sex and age, age at first calving, calving interval, progeny growth and milk yield. Data from each herd were subjected to least squares analysis of variance (Harvey, 1990) to obtain unbiased estimates for assessment of overall herd productivity of the breed types.

Pre-weaning survival rates among Sahiwal herds ranged from 73.60 - 97.42 percent for males and 78.00 - 97.00 for females. Post-weaning survival rates were from 91.34 - 99.5 percent. Pre-weaning survival rates of Friesian - Sahiwal crossbreds were from 78-96 percent for males and 93.95 - 99.32 percent for females, whereas post-weaning survival rates were 88-98 percent for males and 93.00 - 98.00 percent for females. For the Ayrshire - Sahiwal crossbreds, pre-weaning survival rate was 83.00 percent for males and 87.00 percent for females and survival rate post-weaning were 96 percent. Pre-weaning and post weaning survival rates of the Ayrshire - Brown Swiss - Sahiwal crossbreds ranged from 92-99 percent.

Age at first calving of Sahiwal heifers ranged from 36-47 months, Friesian - Sahiwal 34 - 35 months, the average age at first calving of the Ayrshire -Sahiwal was 37 months and for the Ayrshire - Brown Swiss - Sahiwal, the average age at first calving was 35.3 months.

Calving interval of the Sahiwal ranged from 14-17 months, Friesian - Sahiwal 13-14 months, the average calving interval of the Ayrshire - Sahiwal was 17.07 months and for the Ayrshire - Brown Swiss - Sahiwal was 13.52 months.

Milk yield varied with breed type and production system. The milk yield of Sahiwal herds ranged from 949 to 1,544 kg, Friesian - Sahiwal 2,213- 2,785 kg, Ayrshire - Sahiwal 2,480.61 kg and for the Ayrshire - Brown Swiss - Sahiwal the average milk yield was 3,649.38 kg.

For productivity evaluation, two modelling approaches were applied and these were PRY and gross margin analysis.

PRY assesses productivity at the stationary state in terms of gross monetary return per unit dry matter intake. Modelling components were survival rate by sex and age, age at first calving, calving interval, mature age and size, litter size, selective culling rate per parity (SCRAP) for heifers and cows, milk yield and unit product values.

Optimal culling ages for breeding females, surplus female and male young stock were determined and used to calculate the productivity index. The cull - for - age threshold of breeding females of different herds ranged from 166 to 180 months. To maintain herds viable and in a stationary state, the set minimum culling age of breeding females varied from 50 to 87 months. The disposal age for surplus females and male youngstock were from 20-31 months.

Productivity indices for the herds ranged from 3,170 to 9,520 Kenya shillings per ton of dry matter intake. Crossbred herds were more profitable than Sahiwal herds. Among Sahiwal herds, Sahiwal dual - purpose herds were more profitable than Sahiwal beef herds. The three- breed crossbred, the Ayrshire - Brown Swiss-Sahiwal at Kilifi plantations had the highest overall herd productivity (167%), followed by Friesian- Sahiwal crossbreds - supplemented (136%), Ayrshire - Sahiwal (118%), Friesian - Sahiwal unsupplemented (113%), Sahiwal dual-purpose herds (66 - 100%) and Sahiwal beef herds (55-61%) based on total output value per unit dry matter intake of the Sahiwal herd at Naivasha as a reference herd.

For gross margin analysis , modelling components were liveweight offtake from culled breeding females, surplus female and male young stock, milk yield, unit product values and input costs which included feeds, veterinary, labour, running and overhead costs. From these data, gross margin per year and gross margin per livestock unit per year were computed.

On the basis of gross margin per year, profitability varied with breed and herd size.
Gross margin was higher for large production units and lower for the small production units.
Ranking of the herds on gross margin per year was influenced by herd size.

Gross margin per livestock unit per year ranged from 3,029 to 9,539 Kenya Shillings.
The ranking of herds on gross margin per livestock unit per year was different compared to gross margin per year. However, it was found that gross margin per livestock unit per year and gross return per unit dry matter intake were strongly related ($r = .85$, $P < .01$) and herds were similarly ranked ($r_s = .92$, $P < .01$).

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DEDICATION

To My wife Milcher and my children Deborah, Rebecca, Philip and Job and all people who may benefit from this thesis.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

The Sahiwal is a well adapted dual-purpose breed and is efficient in utilizing the limited feed resources to produce milk and meat in marginal areas of Kenya, forming 80% of the country. The Sahiwal breed was imported from Pakistan and India in the 1930s and 1940s and since then, it has been used in cattle improvement programs in the country. The Sahiwal has been used in pure breeding programme as is the case in the nucleus herd of the National Sahiwal Stud at Naivasha to produce breeding stock and to generate genetic progress through selection. The Sahiwal has been used to upgrade the indigenous Zebu cattle for milk and meat production in the ranches. In crossbreeding systems, the Sahiwal has been crossbred with exotic dairy breeds of ***Bos taurus*** cattle to produce adapted and productive animals for marginal areas (Kimenye and Russell, 1975).

The major cattle production systems where the Sahiwal breed is a potential competitor of dairy crossbreds are mixed smallholder farming, dairy ranching and beef ranching in agro-ecological zones III and IV. In harsh environments, the Sahiwal breed seems to be preferred over dairy crossbreds because it is well adapted, although its milk yield and growth performance are lower. In high potential production systems the Sahiwal breed does not seem to be competitive in terms of overall productivity (Trail and Gregory,1982). Since the Sahiwal is used as a genetic resource in different production systems, it is important to evaluate the overall productivity of the Sahiwal in the production systems in which it is used alongside with other dairy crossbreds. This will provide the basis for policies of utilizing this breed resource and for further development through selective breeding.

For productivity modelling, the herd components are survival rate, reproductive performance, body growth and milk yield (Baptist 1988a). The inherent levels of these components can be increased by selection, crossbreeding and formation of composite breed (Gregory ***et al.***, 1982). This should be accompanied by improved nutrition, better feed resources and health management to realize the genetic potential.

Productivity is the ratio of the value of output to the value of input (Upton, 1989) and the method of valuation and aggregation depends on the nature of the problem and the model used. Productivity indices are constructed to compare the influence on overall productivity of different parameters. ILCA productivity indices (Trail and Gregory, 1981) combine parturition rate and weaning weight and these are related to dam metabolic weight. The problem with these indices is that not all the stages of the life cycle of the animal are taken into account.

Bio-economic simulation models have been developed and applied for analysis of production systems and productivity indices derived from technical and economic data are either net revenue or rate of return. Net revenue is the difference between total product value and total variable cost. Adynamic and stochastic cattle simulation model (Konandreas and Anderson, 1982) has been applied to generate data which has been used to compute the net revenue of Tswana and Simmental -Tswana genotypes under alternative production systems in Botswana (Konandreas ***et al.***, 1983). A deterministic model has been used to derive steady - state flock structure and annual offtakes which have been used to determine rate of return to goat production in Nigeria (Upton, 1985). However, the validity of a productivity model and its policy advice depends on the accuracy with which it reflects the real production environment. This in turn will depend on the model specification, the quality of data from which its parameters are estimated and the accuracy of the estimation method used. The modelling approach should give a good perception of the production systems so that with the information provided, it is possible to design technology to increase cattle productivity.

Objectives

1. To characterize the major production systems which use, or could use the Sahiwal as a breed resource and to compile estimates of survival rates, reproductive performance, milk yield and body growth of the Kenya Sahiwal and its crossbreds.
2. To analyse the relative superiority of the Kenya - Sahiwal breed and the crossbreds in different production systems in terms of overall productivity.

Hypotheses

1. The crossbreds are superior to the Kenya Sahiwal in marginal areas.
2. The Kenya Sahiwal breed has a higher overall productivity than crossbreds in specific natural, economic and managerial environments.

2. LITERATURE REVIEW

2.1. Breeds and Production Systems

Genetic diversity in cattle breeds can be utilized to increase efficiency of production in the different production systems. Evaluation of breeds utilized in tropical areas has shown that there are significant breed differences in economically important performance traits (Nagarcenkar, 1982). The choice of breeds for the production systems depends on the breeding objectives (Dickerson, 1970; Harris, 1970; Ponzoni and Newman, 1989). For studies on dairy cattle improvement in tropical areas, the breeding objectives have been improved milk yield, hardiness, tick and disease resistance and heat tolerance (Bondoc ***et al.,*** 1989).

In production systems with limited feed resources in harsh environment, adapted and improved Zebu breeds such as Kenana cattle in Sudan (Alim, 1960), Kenya Sahiwal (Wakhungu ***et al.,*** 1991), and Hariana cattle in India (Acharya and Lush, 1968) which have been shown to give steady genetic progress on selection for milk yield and other traits can be maintained and improved for milk production. For ***Bos taurus*** breeding stock which are improved in developed countries, it is necessary to rely on that improvement and continuously import semen to breed bulls for use in crossbreeding systems. Since for a broad range of production systems in the marginal areas of the tropics, a suitable animal is one with a proportion of genes from local adapted breeds and a proportion from the highly productive developed dairy breeds. Breed differences can be utilized to maximize production efficiency through grading - up, crossbreeding and formation of synthetic breeds (Gregory ***et al.,*** 1982). The optimum genetic composition in the crossbreds between the ***Bos taurus*** cattle and ***Bos indicus*** cattle was when the ***Bos taurus*** inheritance was 50 - 62.5 per cent (Osman and Russell, 1974; Bhat ***et al.,*** 1978) and this can be maintained by rotational crossbreeding or by formation of a composite breed (Cunningham and Syrstad, 1987). Crossbreeding aims to benefit from heterosis, while a composite breed may show an increase in variability and thus provide significant genetic gains on selection in future generations.

In tropical and sub-tropical areas, dairy cattle populations have been developed from stabilized crossbred foundations. These include the Australian milking Zebu, Australian Friesian Sahiwal (Hayman, 1974), Kenya Sahiwal (Mason, 1974, Meyn and Wilkins, 1974), Jamaica Hope (Wellington and Mahadevan, 1975). Genetic improvement of the adapted breeds can be accomplished in nucleus breeding schemes through selection.

2.2. Productivity Components

Productivity of grazing animals is a function of reproduction, growth and survival rates and the quantity and quality of the marketable products. Constraints are imposed by genetic and climatic factors, diseases and the plane of nutrition. Improvement of productivity can be achieved by minimizing the effects of these constraints in the production environment and at the same time increasing the inherent levels of the components.

2.2.1 Reproductive Performance.

2.2.1.1 Genetic Effects.

Additive genetic variation for reproductive performance within breeds is low. Studies of measures of breeding efficiency of cows such as conception rate at first service, services per conception, interval from calving to conception and calving interval have shown that the heritability estimates are low in the range of 0 to 0.30 (Shah and Shah, 1983; Choudhuri ***et al.***, 1984; Nobre ***et al.,*** 1984; Badinga ***et al.,*** 1985; El - Amin ***et al.,*** 1986). This shows that measures of breeding efficiency are mainly influenced by environmental factors and non-additive genetic effects (Janson, 1980). However, significant genetic variation in breeding efficiency has been shown among cattle breeds (Buck and Light, 1982). It was reported that the Africander had lower reproductive performance than the Tswana and Tuli cows. There are differences among breeds in the optimum temperature range in which breeding efficiency is maximum. Studies conducted on dairy herds consisting of Ayrshire, Brown Swiss, Guernsey, Holsteins and Jersey in Florida and Holsteins in Virginia, USA have shown that the favourable environmental temperature range for conception was between 10°C - 23°C (Gwazdauskas ***et al.,*** 1975, 1981). To the contrary, work in tropical areas by Anderson (1944) showed that Zebu cows at Naivasha in Kenya increased sexual activity with increase in temperature from 20° - 25° C. These findings were confirmed by Wilson (1946) in Malawi, Perez - Beato (1984) in Cuba and Saeed ***et al.*** (1987) in Sudan who reported that the highest conception rates for the Zebu cows were in the hottest months of the year. Furthermore, studies in Florida (Plasse ***et al.,*** 1970) showed that the highest frequency of oestrus in Brahmn heifers was in the months when the ambient temperature was within the range of 16 - 27°C, and when the temperature fell below 16°C, oestrus activity decreased.

These studies in tropical and sub - tropical areas further demonstrate that ***Bos taurus*** and ***Bos indicus*** cattle have different thermal neutral zones for normal reproductive activity and can therefore be efficiently utilised in production environments where there are favourable climatic conditions.

2.2.1.2 Age Effects

Dairy cows increase in fertility with age (Spalding ***et al.,*** 1974). This increase in fertility continues upto 4 years of age, levels until 6 years of age and then declines as cows grow old (Badinga ***et al.,*** 1985; Macmillan, 1985). It was found that primiparous cows had longer duration of oestrus than multiparous cows. On the other hand, primiparous cows have shorter oestrus cycle length than multiparous cows (Hall ***et al.,*** 1959). Advanced age has the tendency to increase interval of calving to conception resulting in long calving intervals (Saeed ***et al.***, 1987). Gwazdauskas ***et al.*** (1981) attributed the decline in fertility with increasing age to the lactation stress.

2.2.1.3 Seasonal Effects

Seasonal changes in temperature, solar radiation ,humidity and precipitation affect reproductive efficiency. Foote ***et al.*** (1984) have reported low fertility associated with heat stress in summer months in Florida. Ingraham ***et al.*** (1974) reported a negative relationship between fertility and temperature - humidity index. Hall ***et al.*** (1959) showed that high ambient temperature and humidity in summer resulted in reduced intensity and duration of oestrus, irregular oestrus cycles and more silent oestrus in a dairy herd consisting of Holsteins, Jerseys and Red Sindhi crossbreds in Louisiana. Similarly, work with beef cattle by Bond and McDowell (1972) has shown that under heat stress, cows exhibit anestrus. Increased incidence of anovulatory oestrus periods have been reported in Brahman cows in summer in Gulf coast area of USA (Plasse ***et al.,*** 1970). Research work with Holstein cows in Arizona by Stott and Williams (1962) in summer months showed that oestrus cycle length increased and was in the range of 39 to 50 days . The lowest breeding efficiency in the dairy herd was in the month of August in which high ambient temperature (34.9^{0}C) and relative humidity (78%) had adverse effects.

The effect of heat stress on fertility can be attributed to increase in rectal temperature and respiration rate of dairy cows which causes disturbance to the reproductive process (Dunlap and Vincent, 1971; Roman - Ponce ***et al.,*** 1977; Turner, 1982).This has been shown by the significant negative correlation ($P<.01$) between conception rates and rectal temperature ($r= -.51$) and respiration rate ($r = - .50$). Heat stress causes hormonal imbalance resulting in high blood levels of progesterone and cortisol (Stott and Robinson, 1970; Gwazdauskas ***et al.,*** 1973). These hormones inhibit the release of luteinizing hormone secretion essential for ovulation. Moreover, failure to conceive may be caused by the direct effect of heat on spermatozoa and ova (Stott and Williams, 1962). Stott and Robinson (1970) reported that the first 10 days of gestation are critical for embryo implantation and development, and the high embryonic mortality that occurs when dairy cows are subjected to heat stress is due to activation of the adrenal cortex and a sudden increase in levels of cortisol which create conditions unfavourable for embryo development.

Pastures form a major source of nutrients for grazing animals. In a tropical environment characterized by wet and dry seasons, there is a corresponding seasonal variation in the pasture quantity and quality and these changes are reflected in animal performance (Richardson ***et al.,*** 1975). The seasonal availability of pastures implies that cows calving in the wet season with good quality pastures will tend to have better performance than cows calving in the dry season with poor pastures. For high reproductive performance, dairy cattle should be adequately fed prior to and after calving so that they are in good condition to conceive in a short period of time post - calving (Holness ***et al.,*** 1984).

2.2.1.4 Year Effects

Year effects on animal performance are mainly related to the level of management, stocking rates and climatic variations (Saeed ***et al.,*** 1987). Year of previous calving influences subsequent reproductive performance of a cow (Nobre ***et al.,*** 1984; Badinga ***et al.,*** 1985; Rudder ***et al.,*** 1985). It was shown that cows calving in a year with adverse climatic conditions and poor pastures tended to exhibit low subsequent fertility as indicated by increased number of services per conception , low conception rate, increased service period and calving intervals. Kimenye and Russell (1975) reported that year effects explained 9% of the total variation of calving interval of Ayrshire - Sahiwal crossbreds in Kenya.

2.3 Milk Production

2.3.1 Genetic Effects

A review of studies on milk production of cattle breeds in the tropics has shown that there is adequate genetic variation for milk yield within breeds (Nagarcenkar, 1982). Heritability estimates for milk yield range from 0.19 - 0.59. Shah and Zafar (1986) have reported heritability estimate of 0.28 for milk yield of the Sahiwal in Pakistan. For the Kenya Sahiwal, Wakhungu ***et al.,*** (1991) reported heritability estimate of 0.27. For the Kenana cattle the heritability estimate was 0.11 (Wilson ***et al.,*** 1987).

Under similar management system, significant genetic variation among breeds for milk yield has been observed. Mahadevan and Hutchison (1964) showed that crossbred cows with 50 - 62.5 per cent of ***Bos taurus*** inheritance produced high milk yield than the purebred Zebu cows at Tanga in Tanzania. A comparative study of two dairy breeds, the Friesian and Jersey in Florida , USA showed that the milk yield of the Jersey was less sensitive to heat stress than were the Friesian (Sharma ***et al.,*** 1983).

2.3.2 Age Effects

Kimenye (1978) reviewed work on the effect of age on milk yield of the ***Bos Indicus*** cattle and it was shown that milk yield increased with age and the peak lactation yield was obtained in the fourth lactation and thereafter, milk yield decreased. A similar trend was observed for the milk yield of the Kenana cattle (Saeed ***et al.,*** 1987). This implies that for profitable dairy production, ***Bos indicus*** cows should be culled after the fourth lactation. However,cows may be retained after the fourth lactation, if their lactation yield exceed the herd average.

2.3.3 Seasonal Effects.

Seasonal variation in milk yield of dairy cattle in East Africa has been reported (Kiwuwa, 1974; Mwandotto, 1985). Seasonal differences were caused by changes in climatic factors, namely, temperature, humidity, rainfall amount and distribution. Milk production was directly related to the availability of good quality pastures during the wet season in the production environment where supplementary feed was not provided. Onset of rainy season also decreases solar radiation per day on the animals and minimises heat stress (Roman-Ponce ***et al.,*** 1977). In the dry season poor pasture quality caused decline in milk production and the situation was aggravated by increased solar radiation and high temperature (Johnson ***et al.,*** 1970). It was shown that dairy cows were more sensitive to heat stress in the early stage of lactation than in the late stage of lactation.

2.4 Growth Characters

When calves are fed and managed properly, they grow at a rate characteristic of their breed. There are growth rate differences among breeds (Thorpe and Cruickshank, 1980a; Light *et al.*, 1982). During early life the heifer's body is being developed for milk or beef production and reproduction. Casida *et al.* (1935) have shown that in young heifers the development of the reproductive organs depends on body growth. Underfeeding retards growth rate. On the other hand, overfeeding is undesirable as it can lead to excessive fatness and may result in infertility. A high growth rate is important for dairy and beef production. For beef production, animals that grow faster reach slaughter weight earlier (Thorpe and Cruickshank, 1980b). In dairy animals, Hansson (1941) has shown that heifers with high growth rates can calve at a young age and increase their lifetime productivity in terms of calves and milk. Measures of growth are birth weight, weaning weight and mature weight.

2.4.1 Birth weight

Birth weight varies among breeds (Light *et al.*, 1982; Abassa *et al.*, 1993) and was related to calving difficulty and vigour of the calf (Cartwright, 1973). Additive genetic variation for birth weight was low. Heritability estimate for birth weight of Zebu cattle was between 0.18 - 0.44 (Alim, 1964; Ton, 1974). Birth weight was influenced by sire effect, season of birth, year of birth, sex and parity (Mwandotto, 1985).

2.4.2 Weaning Weight

The weight of a calf at weaning depends largely on the amount of milk and other nutrition available and the growth ability of the calf. There are breed differences in weaning weight (Light *et al.*, 1982). Weaning weight was influenced by breed of sire, breed of dam, age and weight of dam, sex of calf, season and year of birth (Cartwright, 1973). The breed of sire influences both the additive genotype for growth rate and heterosis (Kang'ethe *et al.*,1990).

2.4.3 Mature Weight

Mature size is an indicator of the genetic growth potential which the cow will contribute to her calf. Also the nutritional maintenance requirement is proportional to the metabolic body weight (Cartwright, 1973). Mature weight was influenced by sire and parturition year (Mwandotto, 1985).

2.5 Survival

Survival is a component of fitness and has low additive genetic variation within breed. However, there was significant additive genetic variation among breeds for survival to tropical environmental factors (Light ***et al.,*** 1982; Cundiff, 1987). It has been shown that specific components of survival such as packed cell volume, resistance to ticks, mastitis and bloat are moderate to highly heritable. Since survival has low heritability, it is influenced by non - additive genetic variation (Cartwright, 1973). Effects of heterosis obtained from crossbreeding were significant. The percentage of calves weaned were increased by 3.4% by effects of individual heterosis on survival and by an additional 1.3% by effects of maternal heterosis on survival of calves raised by crossbred dams (Long, 1980). Survival varied with age, season and year of birth, parity and sex (Saeed ***et al.,*** 1987). The mortality rate from birth to one year of age was 16.6 per cent and after one year old the mortality rate was reduced. Mortality in calves increased as birth weight decreased (El - Barbary ***et al.,*** 1987).

2.6 Productivity Modelling

In a dual - purpose cattle production systems, total output is composed of liveweight offtake (culled breeding females, surplus female and male young stock), and milk offtake (Baptist, 1988a). Other offtakes such as manure production or animal traction are not taken into account in most cattle studies. Total output level at the stationary state of herd dynamics is determined by inherent fitness traits (survival and reproduction) and yield levels (growth performance, lactation yield). Total output value depends on output levels and also on quality mostly composition of milk and carcass quality.

Productivity relates total output value to the level of necessary inputs. Feed energy is a major input in most production systems. Feed energy requirement is determined by inherent fitness traits, yield levels and the composition of milk and liveweight gain. Thus some of the productivity components of a dual - purpose production systems include the following parameters: Survival rates by sex and age, rate of involuntary culls of breeding females, age at first calving, calving interval, litter size, body weight development, milk yield and composition and unit product values. Other parameters that could be different between breeds or production systems refer to maintenance requirements of feed energy, energy contents of products and energetic efficiencies of lactation and growth.

The economic models use technical data generated by statistical models with economic data to measure the monetary impacts and evaluate possible interventions.

Trail and Gregory (1981) have developed the ILCA cow productivity index in order to aggregate some of these components, namely, weaner liveweight and milk offtake.

The index relates output to dam metabolic weight. This type of index has been widely used in productivity assessments because of its methodical ease. However, it does not take into account all stages of the life cycle. In an effort to handle complex interactions that exist among productivity components, interactive computer - based livestock productivity packages have been developed (McNeil and Harris, 1988; Korver and Arendonk, 1988). The Texas A & M Model (Blackburn ***et al.***, 1987) sets seasonal feed availability, feed quality and health status and determines how these factors can be expected to affect survival, yields and reproductive performance of a genotype defined in terms of its potential feed intake, body growth, conception rate, lactation yield and fibre production.

Konandreas ***et al.***, (1982) refined one of the early versions of the Texas A & M model to make it applicable to modelling extensive livestock production systems in tropical environments. However, this ILCA model is not interactive and it is no longer in use as it requires a main frame computer and is not documented. Kahn and Spedding (1983; 1984) and Kahn and Lehrer (1984) developed a microcomputer application which is a modified version of the Texas A & M Model.

Other cattle production models have been applied to smallholder dairy development (Chudleigh, 1977; Brockington ***et al.***, 1983, 1986). The models have been used to simulate physical and financial flows and for the economic assessment of various production systems and technological innovations. The Herd - Econ Model (Stafford-Smith ***et al.***, 1988) is used for modelling productivity of beef cattle and wool sheep in a ranch. Annual input and output flows are discounted over ten years and a complete financial assessment of the ranch is given. However, the model does not deal with stationary - state population dynamics and energy flow. Furthermore, there is no optimisation of the culling strategy.

The ILCA Bio- Economic Herd model was developed by von Kaufmann ***et al.***, (1990) for cost- benefit analyses adapted to cattle herds. The model calculates net present value for a fixed project duration of ten years. However, it can neither handle stationary - state dynamics nor optimise culling strategy.

The Livestock Production Efficiency Calculator, LPEC (PAN Livestock Services, 1991) aggregates live weight and milk offtake for a stationary - state herd or flock and herd or flock productivity is expressed in economic units per unit of metabolisable energy. LPEC takes into account input costs. PRY (Baptist, 1988b) consists of a determistic model of stationary state demography and Stochastic model of herd or flock dynamics over time. It is species independent and is flexible with regard to culling strategies. The static component automatically varies culling options in order to identify an optimum culling strategy. It calculates gross return in monetary units per unit dry matter intake but unlike Livestock Production Efficiency Calculator input costs are not considered.

PRY was used because it has provision for entry of a range of products and it can simulate physical and financial functions to generate data over the lifetime of the herd taking into account changes in herd structure and size and production parameters to assess overall herd productivity. PRY productivity modelling was compared with gross margin analysis because the latter approach is used by farm managers to evaluate herd productivity.

3. MATERIALS AND METHODS

A survey was conducted to obtain data on the Sahiwal and the Sahiwal - exotic dairy cattle crosses and to characterise the production systems in which they were raised. The Sahiwal is an improved Zebu breed developed for milk and meat production in marginal areas.

The exotic dairy breeds that were used in the crossbreeding were mainly Friesian, Ayrshire and Brown Swiss.

3.1 Study Areas

Data were collected from eight large scale farms keeping these type of cattle. The farms which provided data were Loldia Estate at Naivasha, Agricultural Development Corporation Ranch Oljorai, Deloraine Estate at Rongai, Elkarama ranch in Laikipia, National Sahiwal Stud at Naivasha, Kilifi plantations at Kilifi, Mariakani Research Centre at Mariakani, Ilkerin - Loita Ranch in Narok. The farms were in agro-ecological zones III and IV and altitudes ranging from 10 - 2,200 metres above sea level. Average annual rainfall varied from 620 - 1,200 mm with a bimodal distribution more pronounced in the low rainfall areas (Table 1). Based on the rainfall distribution pattern of each farm in the period covered by the data collected, the months of the year were grouped into two seasons which consisted of the wet and dry seasons. A month was dry when the monthly total rainfall was less than 50 mm. This was because with an average annual potential evaporation of 1600mm , the rainfall to annual potential evaporation ratio (r/Eo) is over 35% when average monthly rainfall is 50mm and over and therefore in a semi-arid environment this amount of rainfall is adequate for pasture growth. The Natural vegetation consists of evergreen and semi-evergreen bushland, combretum woodland and savanna.

3.2 Distribution of Breed Types

Few farms kept both the Sahiwal and crossbreds. Most farms had either Sahiwal or crossbreds. In cases where the Sahiwal and crossbreds were kept, it was noted that they were managed differently. It was a common practice to find crossbreds supplemented with dairy meal during milking, while the Sahiwal cows were not supplemented.

At the National Animal Husbandry Research Centre, Naivasha, the Sahiwal and crossbreds were managed together as one herd. However, the tendency to sell pregnant Friesian-Sahiwal crossbred heifers meant that for some years there was no data on the crossbreds and therefore a comparison of the Sahiwal and Friesian-Sahiwal crossbreds was not possible. The Sahiwal and Friesian-Sahiwal crossbred data were analysed separately.

The Sahiwal and crossbreds cattle at Mariakani Research sub-centre were kept and managed together as one herd. Analysis of data was done for the herd with the different breed types taken into account. Deloraine estate had Sahiwal and Ayrshire-Sahiwal crossbred herds kept separately and managed differently. Data from the two breed types were analyzed separately. Kilifi Plantations had Ayrshire-Brown-Swiss-Sahiwal crossbreds managed as one herd. Loldia estate kept Friesian-Sahiwal crossbreds as one herd. Agricultural Development Corporation farm at Oljorai, Elkarama ranch and Ilkerin-Loita kept Sahiwals only.

3.3 Data Collection

Information was obtained by means of questionnaires and the respondents were either the owners or the farm managers. Other information on cattle productivity came from livestock records and Literature review. Four categories of structured questionnaires were used (Appendix 1.)

Questionnaire 1. Farm survey data

Information collected included:

(a) Natural Environment - Altitude, agro-ecological zone and rainfall etc.

(b) The Livestock production system - Land use pattern, breed type, herd size and structure and management practices.

(c) Health management - Animal diseases and control.

(d) Socio-economic factors - farm inputs, farm produce, markets and prices etc

Questionnaire 2. Herd productivity data

milk yield , lactation length, calving interval and age at first calving ,

birth weight and weaning weight.

Questionnaire 3. Animal disposal.

The information included culling dates, reason for culling, age at culling and sex of the animal.

TABLE 1. Rainfall (mm) in the Ranches

Month	NAHRC Naivasha	Loldia Estate	ADC Oljorai	Deloraine Estate	Elkarama Ranch	Ilkerin Loita	Mariakani Res.Centre	Kilifi Plantations
Jan	38.94	26.16	38.82	37.94	12.70	49.90	79.40	20.57
Feb.	48.63	48.26	67.40	44.76	35.56	66.60	42.00	23.37
Mar	57.83	53.60	87.00	98.55	52.07	94.30	96.70	65.53
Apr.	116.0	113.03	103.00	174.12	146.05	119.30	145.00	169.20
May	87.70	73.66	86.00	167.34	76.42	103.90	95.60	310.13
June	53.25	68.58	75.00	101.84	68.83	44.40	58.90	123.20
July	39.46	33.02	69.80	98.05	61.98	24.75	42.80	124.21
Augu.	36.56	48.51	50.50	86.07	83.82	13.70	49.40	78.74
Sep.	40.26	30.48	49.30	57.15	50.29	33.20	39.20	42.74
Oct.	57.28	35.56	55.10	50.86	96.52	25.60	76.40	102.87
Nov.	58.66	46.00	43.50	66.95	61.21	87.40	60.20	57.40
Dec.	45.65	58.42	44.40	28.21	33.02	70.90	84.80	39.62
Total	**680**	**635.28**	**769.82**	**1014.04**	**778.97**	**733.95**	**870.80**	**1,157.51**
Period (Years)	20	6	8	7	10	16	10	12

Source: Farm rainfall data

Table 2. Characteristics of the Agro-ecological zones (AEZ)

AEZ		Rainfall (mm)	Mean Annual Temperature(°C)
III	i) Highlands Sub-Humid	800-1200	15 - 25
	ii) Coast Sub- Humid Lowlands	800-1200	20 - 30
IV	i) Highlands Semi-Arid	600-800	10-25
	ii) Coast Semi-Arid Lowlands	600-900	24 - 30

Source: Farm Management Handbook of Kenya Vol.IIA

3.4 Variables Studied

The performance traits studied were:

1. Age at First Calving

This is the age of a cow in months when reproduction first occurs. It is derived from the date of birth of the animal and date of first calving. Reproduction serves to initiate milk flow and produces replacements. To increase the productive life of cattle, heifers should be raised properly so that they can maintain steady growth rate to reach puberty and safe calving size at an early age.

2. Calving Interval

Calving interval is the period in days between two consecutive parturitions and is derived from the previous date of calving and the current date of calving. Calving interval is thus closely matched to a yearly production cycle and influences the amount of milk a cow is likely to produce in a given period.

3. Milk Production

Milk production parameters studied were total lactation milk yield and lactation length. Total lactation milk yield measured in killogrammes is the amount of milk produced by a cow from the date of calving to the date dried off. Lactation length in days is the interval from the date of calving to the date a cow is dried off.

4. Survival Rate.

Is a measure of viability of the animals of a particular age and sex group in the herd. The Surviving animals are expressed as a percentage of the total animals in a sex and age group.

3.5 Analysis Models and Parameter Estimation.

3.5.1 Introduction

The purpose of analysis of variance is the decomposition of the total sum of squares according to the sources of variation to determine whether all the observed sums of squares are due to the factors fitted in the model.

For analysis of variance there must be a dependent variable and independent variables. The factors of the independent variables can be considered either fixed or random.

In the case of fixed effects, the effects of several factors on a dependent variable are investigated and the inferences pertain to just those factors included in the study.

For random effects, the inferences refer to the population from which the factor levels are obtained.

Analysis of variance is done to identify and quantify genetic and environmental factors affecting the performance traits so that appropriate interventions can be made in the production system to increase productivity.

3.5.2 Fixed Effect Model

Fixed effect model (Harvey 1990) was used for analysis of variance of the performance traits. The fitting of interaction in the model required that all cells in cross classification had at least one observation. This was determined by the 2-way table observation frequency distribution. However, the appropriate analysis of variance model fitted varied with the data set.

The following model was fitted for lactation milk yield, and calving interval

$Y_{ijkl} = U+P_i+S_j+Y_k+PS_{ij}+PY_{ik}+SY_{jk}+E_{ijkl}$

Where

Y_{ijkl} = Performance record

U = is a constant common to all observations.

P_i = Effect of Parity of the cow (number of pregnancies plus one).

S_j = Season of calving

Y_k = Year of calving

PS_{ij} , PY_{ik}, SY_{jk} = Interaction effects

E_{ijkl}= Residual error

For milk yield linear regression of lactation length was fitted in the model

The model for age at first calving included fixed effects of season, year of birth and the interaction effects of Season and year of birth.

$Y_{ijk} = U+S_i+Y_j+ SY_{ij}+E_{ijk}$

Where

Y_{ijk} = Performance record

U = is a constant common to all observations

S_i = Season of birth

Y_j = Year of birth

SY_{ij} = Interaction effect

E_{ijk} = Residual error

3.6 Productivity Modelling

For productivity evaluation of the breeds and production systems, two modelling approaches were applied to aggregate outputs and inputs:-

1. PRY
2. Gross Margin Analysis.

3.6.1 PRY

Pry package developed by Baptist (1990) was used to assess herd productivity. The measure of productivity was the aggregate offtake value per unit of dry matter intake

The physical consumption of a single input was considered and this was dry matter intake as determined by feed energy requirements. This was because for most production systems feed energy was the most limiting input and one which accounted for the greatest proportion of the production cost.

Pry consists of a set of interactive routines for the assessment of herd productivity:

1. Demographic Program Input Constants (DIC)
2. Stationary-State Animal Demographic Model (SAM)
3. Produce-Related Program Input Constants (PIC)
4. Find Optimal Culling Practice (FOC)
5. Breakdown of Offtakes and Intake (BOI)

3.6.2 Demographic Program Input Constants

Is an interactive inputting routine for entering demographic parameters which include the inherent fitness traits of Survival rates, selective culling rate per parity (SCRAP) of breeding females, age at first calving, calving interval and litter size. After entering, the parameters are formatted and saved to a work file from where they can be retrieved by the simulation and derivation routines.

3.6.3 Stationary -State Animal Demographic Model

The Stationary - state Animal Demographic Model calculates population structure, numeric offtake, length of life expectancies and potential rate of increase of population size for an infinitely large population of equilibrium structure. The program automatically varies disposal ages for surplus female and male youngstock in increments of one-quarter of the age of first parturition. Similarly, the cull-for-age threshold of breeding females is varied in increments of the parturition interval.

3.6.4 Produce-Related Program Input Constants

The Produce-Related Program Input Constants is a routine for entering produce - related parameters which include growth traits,yield levels, metabolic constants and unit produce values. At every step of the entering process, checks are carried out to ensure consistency of values. When PIC is run, demographic input constants are retrieved from the work file saved earlier with DIC.

The retrieved DIC- constants are used for consistency checks of the entered PIC - constants. At the end of the run, both the demographic and produce - related parameters are formatted and saved to a work file from where they can be retrieved for analysing productivity.

3.6.5 Find Optimal Culling Practice

The Find Optimal Culling Practice varies the cull-for-age threshold of breeding females and the two disposal ages of male and female youngstock. Stationary-state feed energy efficiency is calculated for each set of three culling ages. The productivity of the very first set of culling ages is taken to be 100 and the productivity of all other sets is expressed in percent of this base level. The best culling strategy can be identified by the set of culling ages for which relative productivity is maximised.

3.6.6 Breakdown of Offtakes And Intake

Breakdown of Offtakes and Intakes is used for detailed analysis of feed energy efficiency after the best culling strategy has been identified and the resulting optimal culling ages have been inputted using PIC. Life expectancies per kind of offtake and animal category are given separately. The weighted mean constitutes total offtake value (TOV) per animal-year. Feed energy requirement converted into dry matter intake (DMI) is assessed per animal - year.

The ratio of TOV and DMI is feed energy efficiency. This represents gross return on dry matter intake which can be expected at the stationary -state.

3.6.7 Input Data

(i) Survival rate by sex and age

(ii) Age at first calving (months)

(iii) Calving interval (Months)

(iv) Milk yield

(v) Mature age

(vi) Mature size

(vii) Scrap rate for heifers

(vii) Scrap rate for cows

(ix) Litter size

(a) The demographic input constants which included survival rates by sex and age, age at first calving, calving interval, scrap rates for heifers and scrap rates for cows and litter size were used by PRY to establish a stationary state population structure which was broken down into monthly cohorts of :-

(i) Breeding females

(ii) Surplus female

(iii) Male youngstock

(b) The produce - related input constants which included mature age, mature weight, milk yield and monetary values in Kenya shillings per production unit were used to derive the overall herd productivity index. Parameters describing growth and energy metabolism of liveweight gain are specified for each one of four growth periods between birth and maturity. The breakdown of the growth period is a practical alternative to the mathematical equations of the growth curve requiring about as many parameter estimates.

The Stationary - State implies that the breeding female replacements were adjusted to keep population size constant. Equilibrium population structure depends on the culling pattern characterised by (a) the rate per parity of involuntary culls, including failure - to - conceive, yield and conformation (b) a cull -for-age threshold of breeding females and disposal age of c) Surplus female and of (d) Male youngstock. The culling pattern influences overall productivity. The program identifies the optimum culling strategy for a breed which maximises feed energy efficiency.

Energy requirements as determined by population structure and expected offtakes were assessed according to the factorial method (Close and Menke, 1986). Offtakes and dry matter intakes were derived as life expectancies per newborn in each of the three animal categories (i) to (iii) above. Weighted averages per animal - year were then obtained, the weights being the life expectancies with which newborns were assigned to the three classes (i) to (iii). Overall Productivity expressed as total output value per unit dry matter intake or gross return on feed was determined.

Table 3. Fitness Traits.

a,	Survival without culling - Birth to weaning (%)
	- Post - Weaning (%)
b,	Involuntary culls (% breeding female per parity)
c,	Age at first parturition (Months)
d,	Parturition interval (Months)
e,	Litter size (No. of young)

Table 4. Liveweight Development

a, Adult bodyweight (kg) - Females
(Weight at maturity) - Males

b, Age at adult bodyweight (AA) in months
bodyweight by age- at birth
- at ¼ AA[1]
- at ½ AA
- at ¾ AA

c, Weight gain from dam's
milk (%) of adult bodyweight
(estimated from growth curve)

[1]AA - Age when adult bodyweight is attained

Table 5. Energy Requirements

a, Exponent of bodyweight giving
metabolic bodyweight - MB $^{0.75}$

b, Maintenance requirement - birth ¼ AA [1]
MJ ME per kg MB 0.25 per day - ¼ AA to ½ AA
- ½ AA to ¾ AA
- ¾ AA to $^{1}/_{1}$ AA
- at maturity

[1] AA - Age when adult bodyweight

Table 6. Energy Contents

Energy content (MJ/kg) gain	- birth to ¼ AA [1]
	- ¼ AA to ½ AA
	- ½ AA to ¾ AA
	- ¾ AA to $^{1}/_{1}$ AA
- gestation products	
- milk	
Metabolisable energy (MJ) per kg dry matter (DM) intake	

[1] AA - Age when adult bodyweight is attained.

Table 7. Energetic Efficiencies (MJ product/MJ ME intake

a,	Liveweight gain:	- birth to ¼ AA[1]
		- ¼ AA to ½ AA
		- ½ AA to ¾ AA
		- ¾ AA to $^{1}/_{1}$ AA
b,	Gestation	
c,	Lactation	

[1] AA - Age when adult bodyweight is attained

Table 8. Yield Levels

Yield (kg)	- Liveweight per culled breeding female
	- Liveweight per culled female youngstock
	- Liveweight per culled male youngstock
	- Milk yield per lactation
	- Gestation products per gestation

Table 9. Unit Product Values (Kenya Shillings)

a,	kg of culled breeding female liveweight
b,	kg of culled female youngstock liveweight
c,	kg of culled male youngstock liveweight
d,	kg of lactation milk yield
e,	kg of salvaged liveweight

Table 10. Stationary-state Offtakes, Intakes and Feed Energy Efficiency Offtake/Intake

Value in Kenya shillings (Ksh) per lifetime	
- Liveweight offtake	- BF 1)
	- SF 2)
	- M 3)
- Fallen meat	- BF
	- SF
	- M
- Lactation milk yield	- BF
- Dry matter intake	-BF
(kg per lifetime)	- SF
	- M
Life expectancy	
(years of age per newborn)	- BF
	- SF
	- M
Frequency	- BF
(% of newborns)	- SF
	- M
Total output value (TOV) per animal year (Ksh).	
Dry matter intake (DMI) per animal - year (kg)	
Stationary - state feed energy efficiency	
(TOV/DMI) in Kenya shilling per ton of dry matter intake	

1) Breeding female
2) Surplus female
3) Male

3.7 Gross Margin Analysis

The profitability of a livestock enterprise depends on the efficiency of livestock production which is influenced by female production, reproduction and growth of youngstock. Overall productivity depends on the total value of animal products and the total cost per animal per year. In commercial herds, identification of sources of income and expense makes it possible to compute gross margin.

Gross margins are used to provide information on the relative importance of a particular breeding and management system.

In computing gross margin, income and expense are combined as a difference.

$$Gm = I - E$$

Where

Gm is Gross margin

I is Income

E is Variable Costs

3.7.1 Sources of Income

i, Surplus heifers

ii, Male youngstock

iii, Culled breeding female

iv, Milk

3.7.2 Variable Costs

i, Feed cost per livestock unit.

ii, Veterinary cost (drugs, vaccine and treatment) per livestock unit.

iii, Labour cost per livestock unit.

iv, Running cost (fuel, oil, repairs and servicing of vehicles and tractors used in farm operations).

v, Overhead cost per livestock unit (water, electricity and machinery).

Variable costs vary with the level of herd production and they are therefore taken into account when computing gross margin.

3.7.3 Data

Data used in the calculation of gross margins were obtained from the farm survey covering 10 herds keeping Sahiwal and Sahiwal crossbreds in agro-ecological zones III and IV. Inputs and Outputs of a particular production system were identified, quantified and valued at the market prices.

3.7.3.1 Milk

Annual milk production per cow was calculated from the total milk produced per lactation and the calving interval.

$$\text{Annual Milk yield} = \frac{\text{Lactation Milk Yield x 365 days}}{\text{Calving interval}}$$

Income/year = Annual Milk Yield per cow(Kg) x Number of lactating cows x Price per kg of milk.

3.7.3.2 Surplus Females

i, Sterile Heifers:

Heifers which were sterile were sold for slaughter on liveweight basis . The average weight was 350 kg.

ii, Heifers for breeding:

Most ranches preferred to sell surplus heifers for breeding when they were pregnant at a uniform price.

3.7.3.3 Male youngstock

i, **Steers**

In some ranches male youngstock not suitable for breeding were castrated and sold for fattening. However, for most of the ranches the steers were reared and fed to attain slaughter weight of 450 kg at $2^1/_2$ years of age and they were sold on liveweight basis for beef.

ii, **Breeding bulls**

In Sahiwal production units, good young males were reared and sold for breeding when they were 2 - 3 years old at a uniform price which was higher than that of a mature steer.

3.7.3.4 Culled Cows

Breeding cows were culled because of low milk yield and if they failed to conceive and calve within 2 years and were in poor health. Culled cows were sold for beef on liveweight basis.

3.7.3.5 Prices

For parastatal Sahiwal and crossbred production units, prices for animals were determined by an Evaluation Committee and on other commercial ranches prices for animals and farm produce were determined by market forces.

3.7.4 Inputs.

The main components of the production cost included:

i, Labour

ii, Minerals

iii, Concentrates

iv, Veterinary cost (Dipping, drugs and vaccine).

v, Overhead costs

3.7.5 Calculation of Gross Margin

A spreadsheet Model was used to compute the profitability of the production systems:

Income

I = Male youngstock **x** value per animal

+ Surplus heifers **x** value per animal

+ Culled breeding female **x** value per animal

+ Annual Milk Yield less milk suckled **x** number of Lactating cows **x** value per kg of milk

Variable Costs

E = Male youngstock feed intake **x** cost per kg

+ heifers feed intake **x** cost per kg

+ Cows feed intake **x** cost per kg

+ Veterinary cost per livestock unit

+ Labour cost per livestock unit

+ Running cost per livestock unit

+ Overhead Cost per livestock unit.

Gross margin/year = Income - Variable Costs

$$\text{Gross Margin/Year} = \frac{\text{Gross margin/Livestock Unit/Year}}{\text{Livestock Units}}$$

3.8 Reference Herd

The National Sahiwal Stud at Naivasha was taken as the reference herd because it was the major source of breeding stock for all the herds. In the National Sahiwal Stud, genetic progress was generated through selection and disseminated to other Sahiwal - based production units in the country.The Sahiwals were utilised as purebreds or used in crossbreeding systems with the exotic breeds mainly the Friesian, Ayrshire and Brown Swiss for milk and meat production.

4. RESULTS

4.1 Production Systems

Production systems are influenced by factors of the natural ,economic and institutional environment. The many aspects that constitute the natural environment are best combined by objective zoning of the country into agro-ecological regions. Sahiwal and Sahiwal-crossbreds production units occur mainly in agro -ecological zones III and IV (Table 2). From the point of view of the economic environment, production systems are sub-divided into dairy and beef ranches. The institutional environment can be characterized in terms of whether a production unit is small scale, commercial, governmental or parastatal.

Classification of the production systems in which Sahiwal and Sahiwal crossbreds were used was based on the production method, the commodities for sale and the scale of operation. Based on these criteria three production systems (Table 11) were identified :

1. Beef production systems
2. Dual-purpose production systems
3. Large scale dairy production systems

For these production systems, three breeding systems provided cattle:

1. Pure breeding (Sahiwal herds)
2. Two - breed crossbreeding
3. Three - breed crossbreeding

4.1.1 Beef production systems

Beef production systems included the Sahiwal herds at Elkarama ranch and Ilkerin Loita ranch in agro-ecological zone IV. Cattle were extensively grazed on natural pastures and supplemented with minerals for meat production. Offtake rates were 28% and 27% for Elkarama and Ilkerin Sahiwal herds, respectively. In these herds, a greater proportion of the income of over 90% was obtained from the sale of steers, breeding bulls, culled cows and surplus heifers. Ranches are remote from the market and roads are impassable during the rainy season. Surplus milk was used for subsistence on the ranches.

Table 11. Breeds and Production Systems

Farm Name	Agro-Ecological zone	Breed	Production System	Products
1. Kilifi Plantations	III	Ayrshire-Brown Swiss-Sahiwal crossbreds	Large scale dairy production systems	Milk Surplus stock for breeding and slaughter
2. Loldia Estate	IV	Sahiwal-Friesian crossbreds	Large scale dairy production systems	Milk Surplus stock for breeding and slaughter
3. NAHRC-Naivasha	IV	a. Friesian-Sahiwal crossbreds b. Sahiwal	Dual purpose production systems	Milk Surplus stock for breeding and slaughter
4. Deloraine Estate	III	a. Ayrshire-Sahiwal crossbreds b. Sahiwal	Large scale dairy production systems Dual purpose production systems	Milk Surplus stock for breeding and slaughter
5. Mariakani Research Centre	IV	Ayrshire-Sahiwal Friesian -Sahiwal crossbreds	Dual purpose production systems	Milk Surplus stock for breeding and slaughter
6. ADC Oljorai	IV	Sahiwal	Dual purpose production systems	Milk Surplus stock for breeding and slaughter
7. Elkarama Ranch	IV	Sahiwal	Beef production systems	Surplus stock for breeding and slaughter
8 Ilkerin-Loita Ranch	IV	Sahiwal	Beef production systems	Surplus stock for breeding and slaughter

TABLE 12. Herd Structure and Size

CLASS	Sahiwal Naivasha	Friesian-Sahiwal Naivasha	Friesian-Sahiwal Loldia	Sahiwal ADC Oljorai	Sahiwal Deloraine	Ayrshire-Sahiwal Deloraine	Sahiwal Elkarama	Sahiwal Ilkerin	Sahiwal-Friesian Ayrshire Mariakani	Ayrshire-Brown Swiss Swiss -Sahiwal Kilifi
1. Calves-										
(i) Male	140	42	72	27	72	45	123	48	29	254
(ii) Female	150	26	70	27	68	43	120	48	30	203
2. Weaner stock										
(i) Male	100	8	60	26	40	30	106	40	26	240
(ii) Female	121	5	60	20	46	35	118	42	25	195
(ii) Male 1 - 3 yrs										386
(iv) Female 1 - 2 yrs										328
3. (i) Lactating cows	230	10	140	5	136	89	85	96	43	511
(ii) Dry cows	130	5	28	70	59	40	196	34	40	139
4. Bulls Steers	200	5		2			62		9	87
Total herd size	**1071**	**101**	**202**	**430**	**177**	**431**	**282**	**810**	**308**	**2343**

4.1.1.1 Elkarama Ranch

Elkarama ranch is a privately owned ranch and covers an area of 5,454.5 ha. The ranch is located on the Laikipia plateau at an altitude of 1,800 metres above sea level in Agro-ecological zone IV. The natural vegetation consists of short scattered *Acacia* species, Red oat grass (*Themeda triandra)* and *Brachiaria* species. A small area of Bana grass and lucerne has been established near the homestead. The fodders are used to feed weak and sick animals. The average rainfall is 778mm per annum. Rainfall distribution is bimodal with a peak in April and October. The wet seasons (March - August and September - November) and dry seasons (January - February and December) in Table 1. The ranch enterprises include Sahiwal breeding, Dorper Sheep breeding and a tourist campsite for eco-tourism.

4.1.1.1.1 Sahiwal Cattle

Originally the Elkarama Ranch had the Sahiwal and Boran, but the Boran cattle have been upgraded to the Sahiwal through several generations of crossbreeding. The Sahiwal herd was separated into groups according to age, sex and lactation status. Each group was herded separately in different parts of the ranch. Fencing was limited to the perimeter and around the homestead. Herd structure and size were as shown in Table 12.

4.1.1.1.2 Breeding

Sahiwal cows were bred throughout the year by natural service using bulls. Each bull was assigned 40 cows. Initially breeding bulls were obtained from the National Sahiwal Stud at Naivasha and Deloraine Estates. Presently the breeding bulls are produced on the ranch. Male calves not required for breeding were castrated when 3 - 4 months of age. Pedigree and performance records were kept.

4.1.1.1.3 Feeding

Calves were weighed and suckled. Young calves upto 1 month were kept in the homestead and thereafter they stayed with their dams and suckled at all times except at night when they were put in a separate boma. Calves were supplemented with a home - made mineral mixture and were weaned at 8 months.

4.1.1.1.4 Mature stock

Cattle were extensively grazed on natural pastures. In the dry season cattle were supplemented with Rhodes grass hay, cotton seed cake and a home made - mineral mixture. The ranch has central watering point and each herd moved an average 4 km/day to the water. At night cattle herds were kept in separate enclosed Bomas and guarded by herdsmen.

4.1.1.1.5 Health Management

The herd was served by field veterinary services. Routine vaccinations against foot and mouth diseases and blanthrax were carried out twice per year. Cattle were vaccinated against rinderpest and Rift Valley fever once in a lifetime. Young breeding animals were vaccinated against brucellosis using imported vaccine before they attained service age and weight. Tickborne - diseases mainly east coast fever and corridor disease were controlled by dipping cattle weekly. Young stock were dewormed once a year to control helminthic infection.

4.1.1.1.6 Farm Produce and Marketing

The ranch produced breeding and slaughter stock. Milk extracted was for home consumption. Surplus good heifers, cows and bulls were sold to dairy farmers and ranchers for breeding. Heifers and culled cows with fertility problems and low milk yield were sold to butchers for slaughter. Steers were sold for slaughter when they were 28 months of age and weighing an average of 450kg.

4.1.1.1.7 Elkarama Sahiwal Herd - Performance Parameters

4.1.1.1.7.1 Age at First Calving

The mean age at first calving of 173 heifers born during the period 1975 - 1987 was 36.20 ± 4.61 months (Table 13) and ranged from 26 to 52 months. Analysis of variance in Table 44 showed that month of birth had no effect on age at first calving. Year of birth greatly influenced age at first calving ($P<.01$). Heifers born in 1977 calved at a younger age of 30.04 months, while heifers born in 1979 calved late at an age of 39.47 months and this was 3.04 months above herd average. In a previous study on this herd by Trail and Gregory (1981) the average age at first calving for heifers born during 1964 - 1974 was 39.86 months and compared with the findings of the present study, age at first calving has improved by 3.43 months. Thus heifers are calving first at a younger age.

Table 13. Means and standard deviations of performance traits of Sahiwals at Elkarama.

Trait	No. Cows	(n)		CV %
Calving Interval	147	631	422.71 ± 104.90	25
Age at first calving	173	173	36.20 ± 4.61	13

4.1.1.1.7.2 Calving Interval

The mean calving interval of 631 records collected from 1978 - 1990 was 422.71 ± 104.90 days (Table 13) and ranged from 301 to 846 days. Analysis of variance in Table 44 showed that month of calving had no effect on calving interval. Year of calving and parity significantly affected calving interval (P<.01). With regard to year effects, it was observed that cows calving in 1980 had the longest calving interval of 525.90 days which was 117.19 days above herd average.

However, cows that calved in 1990 had the shortest calving interval of 341.21 days which was 67.49 days below herd average.

Parity affected calving interval. Cows in the first parity had the longest calving interval of 451.28 days and calving interval decreased in subsequent parities. In previous investigation of the same herd by Trail and Gregory (1981) the average calving interval was 390 days and this is fairly close to the average calving interval of 408.71 days in the present study.

4.1.1.1.7.3 Survival Rates

Survival rates of males from birth - weaning and mature stock were 97.42 ± 0.48 percent and 99.50 ± 0.26 percent, respectively (Table 24). Survival rates of females from pre-weaning and mature stock were 97.61 ± 0.58 percent and 99.32 ±0.21 percent, respectively.

4.1.1.2 Ilkerin - Loita Ranch

Ilkerin - Loita Ranch is an integrated pastoralist development project managed by the local community and funded by Non- Governmental Organizations. The project also generates income through sale of livestock. The ranch is located in South - West of Kenya in Narok South and covers an area of 3,100 ha at an altitude of 2,200 metres above sea level in agro-ecological zone IV. The natural vegetation consists of scattered ***Acacia*** spp and extensive natural pastures of Red Oat grass ***(Themeda triandra), Setaria*** spp and ***Hyperrhenia*** spp

The average rainfall is 733mm per annum. Rainfall is bimodal with a peak in April and November. The wet seasons (February - May and November- December) and dry seasons (January and June - October) in Table 1. The ranch enterprises were Sahiwal breeding, Sheep and Goat and a tannery. The herd structure and size were as shown in the Table 12.

4.1.1.2.1 Sahiwal Cattle

The Sahiwal breed has been developed through upgrading of the local Zebu using pedigree Sahiwal bulls from Deloraine estates at Rongai. The herd was separated into groups according to age, sex and lactation status. The different groups were grazed in paddocks which had a regulated water supply from a dam.

4.1.1.2.2 Breeding

Since the dry season tended to be severe seasonal breeding was practised. Cows were bred by natural service using bulls from the ranch and from other breeders mainly Deloraine estates. Each bull was assigned 40 cows in the breeding season which coincided with the onset of the wet season in April. Pedigree and performance records were kept. The Sahiwal herd acted as a nucleus breeding herd in which genetic progress was generated and transmitted to the pastoralist herds through sale of breeding stock.

4.1.1.2.3 Feeding

Sahiwal calves were weighed within 24 hours after birth and birth weights were recorded. Calves suckled their dams and were housed for 6 months. This was done to avoid losses through predation calves were weaned when they were 6 months of age. male calves not required for breeding were castrated when they were 3 - 4 months of age.

4.1.1.2.4 Mature stock

Cattle were extensively grazed on natural pastures. There was no concentrate supplementation. However, mineral lick was available at all times. Animals were moved to the night boma and protected from predators such as lions and hyenas.

4.1.1.2.5 Health Management

The ranch herd was served by on- farm Veterinary Staff and Field veterinary services.
Vaccinations against foot and mouth disease and blanthrax were done twice a year.
Vaccinations against Rinderpest and Rift Valley fever were carried out once in a lifetime.
Young breeding animals were vaccinated against brucellosis. Cattle were also vaccinated against Contagious Bovine Pleura - Pneumonia (CBPP) and lumpy skin disease.
Tickborne - diseases observed on the ranch cattle were east coast fever, anaplasmosis and heartwater. Ticks were controlled by weekly dipping. Other diseases which were treated on the ranch included Pneumonia and diarrhoea.
Youngstock were dewormed every 2 months. Weaners stock were dewormed at a 6 - months interval.

4.1.1.2.6 Farm Produce and Marketing

The ranch produced breeding and slaughter stock. Surplus heifers, cows and bulls were sold to farmers and ranches for breeding. Heifers and culled cows with fertility problems and low milk yield were sold to butchers for slaughter. The ranch is connected by an earth road to the main road to Narok Town. The earth road is impassable in the wet season.

4.1.1.2.7 Ilkerin Sahiwal Herd - Performance Parameters

4.1.1.2.7.1 Age at First Calving

The mean age at first calving for 172 heifers born between 1972 - 1981 was 46.64 ± 13.85 months (Table 14) and ranged from 25 to 96 days. Analysis of variance in Table 45 showed that month of birth had no effect on age at first calving. Year variation greatly influenced age at first calving (P<.01). Heifers born in 1977 calved at an older age of 57.80 months and this was 14.53 months above herd average. Heifers born in 1980 calved at a younger age of 33.09 ± 2.42 months and this was 10.18 month younger than the herd average. In a previous report by Gregory and Trail (1981a) the average age at first calving was 38.23 months and findings in the present work shows that age at first calving has increased

Table 14. Means and standard deviations of performance traits of Sahiwals at Ilkerin.

Trait	No. Cows	(n)		CV %
Calving Interval	171	361	499.76 ± 165.31	33
Age at first calving	172	172	46.64 ± 13.85	30

4.1.1.2.7.2 Calving Interval

The mean calving interval for 361 records collected between 1975 - 1984 was 499.76 ± 165.31 days (Table 14) and ranged from 310 to 959 days. Analysis of variance in Table 45 showed that month of calving had no effect on calving interval. Year effects greatly influenced calving interval (P<.01). Cows that calved in 1975 had the shortest calving interval of 383.89 days and this was 86.04 days below herd average.Cows that calved in 1976 had the longest calving interval of 580.53 days and this was 110.59 days above herd average. Parity had a significant effect on calving interval (P<.01). For the cows in the first parity, the calving interval was 536.34 and this decreased to 441.91 days in the third parity and increased in the fourth parity. In the previous study, Gregory and Trail (1981a) reported a higher average calving interval of 454 days for the same herd.

4.1.1.2.7.3 Survival Rates

Survival rates of males from birth - weaning , 7 - 12 months and mature stock were 93.75 percent, and 97.5 percent, respectively (Table 24). Survival rates of females from birth to weaning, 7 - 12 months and mature stock were 95.84 percent, 97.6 percent and 98.5 percent, respectively.

4.1.2 Dual purpose production systems

The dual purpose production systems included Sahiwal herds at Deloraine estate and Ol jorai, The Sahiwal and Friesian - Sahiwal herds at National Animal Husbandry Research Centre, Naivasha and Sahiwal Crossbred herd at Mariakani. Cattle were extensively grazed on natural pastures and supplemented with minerals. Since the herds were located in areas with good transport and reliable market, the dairy component made a significant contribution to the total income. The milk offtake accounted for 69% of the total income. Additional income was obtained from the sale of steers, breeding bulls culled cows and surplus heifers. Average cattle offtake rate was 21% and this accounted for 31% of the total income.

4.1.2.1 National Sahiwal Stud

The National Sahiwal Stud is maintained by Kenya Agricultural Research Institute at the National Animal Husbandry Research Centre, Naivasha. The Research farm has an area of 4,545.45 ha and is located to the east of Lake Naivasha in the Rift Valley at an altitude of 1,829 - 2,330 metres above sea level in agro-ecological zone IV. The National Sahiwal Stud utilises 3,600 ha. The Natural vegetation consists of Kikuyu grass (***Pennisetum clandestinum***) near Lake Naivasha and Naivasha star grass (***Cynodon plectostachyum)*** with scattered trees of ***Acacia*** species. The average rainfall is 680mm per annum. Rainfall distribution is bimodal with a peak in April and November. The wet season (March - June and October - November) and dry season (January - February and July - September and December) Table 1. The average maximum temperature is 26^0C and the average minimum temperature is 8^0C. July is the coldest month. The relative humidity varies from 60 to 75 percent. In the dry season there are strong desiccating winds.

4.1.2.1.1 The Kenya Sahiwal Cattle

The National Sahiwal Stud was established at the National Animal Husbandry Research Centre, Naivasha in 1963 because its ecological conditions and size were well suited for maintaining the Sahiwal Stud. The Kenya Sahiwal cattle was developed by systematic crossing of the improved indigenous Zebu cows with imported pure bred Sahiwal bulls at the livestock improvement centres. In 1963 the Sahiwals from these centres were transferred to Naivasha to form the National Sahiwal Stud. Mason (1965) designed the Sahiwal breeding plan for the genetic improvement of milk yield and growth rate in a nucleus closed herd.

4.1.2.1.2 Breeding

Sahiwal cows were inseminated with deep frozen semen from proven Sahiwal bulls. Heifers and first calvers form the test herd and were inseminated with semen from young bulls selected for progeny testing. Heifers were bred when they were 27 months old and weighed 270kg. Cows were observed for oestrus signs by herdsmen at grazing and milking time. Cows showing heat signs were inseminated 12 hours after onset of oestrus. Cows displaying irregular oestrus were examined by a veterinarian for presence of cystic follicles and treated. Pregnancy diagnosis was done by rectal palpation 2-3 months post-breeding to detect pregnant cows. Cows that were not pregnant were scheduled for rebreeding or disposed of if they had fertility problems. Pregnant heifers and cows were moved to the maternity paddocks in the last 3 months of pregnancy. Cows were closely observed for signs of parturition. After parturition, cows were weighed immediately within 24 hours. Rebreeding was done 70 days after parturition.

4.1.2.1.3 Friesian - Sahiwal Crossbreds

The half bred Friesian - Sahiwal crosses were produced by breeding Sahiwal cows with Friesian semen. Sahiwal cows used in the crossbreeding programme were from the second lactation and over. Friesian - Sahiwal crossbreds were managed together with the Sahiwals. Semen was collected from good half- bred bulls for ***inter se*** mating.

4.1.2.1.4 Herd Organization

The Sahiwal herd consisted of Sahiwals and Friesian - Sahiwal crossbreds.

(i) The herd was grouped according to age, sex, and lactation status.

(ii) Adult cows were divided into lactating and dry cows.

(iii) The bull herd consisted of young bulls for progeny testing and laid- off bulls awaiting progeny test results.

(vi) Young stock consisted of calves, weaners from 3-8 months of age. After 8 months, females and males were branded and separated. Heifers joined the dry cow herd while young bulls joined the bull herd . The structure and size of the Sahiwal and Friesian - Sahiwal crossbreds were shown in Table 12.

4.1.2.1.5 Calf Management

The breeding pattern was such that calving occurred in all months throughout the year but not in equal proportions. Of the total births, 70 percent occurred between March and October, 30 percent of the births occurred in January - February and November- December. Calves were separated from their dams immediately after calving, weighed and nipple fed colostrum in the first week and whole milk thereafter at a rate of 10% of the body weight. Calves upto 1 month of age were housed and thereafter moved to mobile calf pens in the grazing paddocks at Lower Farm. Calves were weaned at 3 months of age at an average of 55 kg and grazed on good quality pastures.

4.1.2.1.6 Mature Stock

Mature stock consisted of lactating cows, dry cows and bulls and these were managed as different herds. The different Sahiwal and crossbred herds were rotationally grazed on natural pastures in paddocks which were adequately supplied with water. Mineral licks were provided ***ad libitum*** when available.

Cows were not supplemented with dairy meal at milking. Lactating cows were hand milked twice a day in the morning at 4 am and in the afternoon at 3 pm Sahiwal and crossbred cows were milked in the absence of calves. Cows were milked for an average of 305 days.

4.1.2.1.7 **Health Management**

Dipping was done once a week and routine vaccinations against rinderpest were done after 1 year of age and once in lifetime, foot and mouth disease twice a year, blanthrax once a year. Young stock were dewormed regularly .

4.1.2.1.8 **Farm Produce and Marketing**

The farm sold breeding and slaughter stock. Milk was sold to Kenya Cooperative Creameries. Surplus good heifers, cows and bulls were sold for breeding. Culled animals were sold to butchers for slaughter. Steers were sold for fattening when they were between 6 - 12 months of age.

4.1.2.1.9. **Naivasha Sahiwal Herd - Performance Parameters**

4.1.2.1.9.1 **Age at First Calving**

The mean age at first calving for 2,031 Sahiwal heifers born in the National Sahiwal Stud between 1963 - 1986 was 41.20 ± 5.42 months (Table 15) and ranged from 26 to 76 months. The analysis of variance in Table 39 showed that season of birth, season x year of birth interaction had no effect on age at first calving. Year of birth significantly affected ($P<.01$) age at first calving. Heifers born in 1965 calved at a younger age of 38.22 months and heifers born in 1982 calved later at an average age of 48.34 months.

Table 15. Means and standard deviations of performance traits of the Sahiwal at Naivasha.

Trait	N0. Cows	(n)		CV %
Milk yield	1805	5779	1543.87 ± 551.70	36
Calving Interval	2064	6571	446.42 ± 105.69	24
Age at First Calving	2031	2031	41.20 ± 5.42	12

4.1.2.1.9.2 Calving Interval

The mean calving interval for 6,571 records from 1966 - 1989 was 446.42 ± 105.69 days (Table 15) and ranged from 302 to 999days. The analysis of variance in Table 39 indicated that season of calving affected calving interval (P <.05), year of calving greatly influenced calving interval (P<.01). Parity and season x year of calving interaction had no effect on calving interval.

Cows calving in the wet season had a slightly shorter calving interval than cows calving in the dry season. The mean calving interval was 445.40 ± 2.21 days in the wet season and 452.14 ± 2.21 days in the dry season. Year variation affected calving interval (P<.01). The average calving interval was 415.17 days in 1970 and longest in 1984 with an average calving interval of 485.32 days.

4.1.2.1.9.3 Lactation Milk Yield

The mean lactation milk yield for 5,779 records from 1966 - 1989 was 1,543.87 ± 551.70 (Table 15) and ranged from 101 to 3,778kg. The analysis of variance in table 39 showed that effects of year of calving (P<.01), parity (P<.01), Season x year interaction (P<.01) greatly influenced lactation milk yield. Similarly, season x parity interaction affected (P<.05) lactation milk yield. Lactation length was fitted in the analysis of variance model as a covariate.

Although season of calving had no effect on lactation milk yield, there was a tendency for lactation milk yield to be slightly high for cows calving in the wet season.

The mean lactation milk yield in the wet season was 1,599.80 kg and in the dry season the lactation milk yield was 1,585.36 kg. Animal performance was related to rainfall distribution. Year of calving significantly affected lactation milk yield. The lowest milk yield was 1,135.88 kg in 1984, a year that experienced severe drought. The highest milk yield was 1,867.79 kg in 1972. High milk yield in the early years was attributed to availability of supplementary feed.

Parity had a marked effect on milk yield. Milk yield increased from the first lactation to the fourth lactation and decreased thereafter. In the first lactation milk yield was 1,330.39kg and the highest milk yield of 1,719.81 kg was produced in the fourth lactation.

4.1.2.1.9.4 Survival Rates

Survival rates varied between sex and age groups (Table 24). Survival rates of males from birth to weaning, 4 - 12 months and mature stock was 78.09 ± 2.66 percent, 91.84 ± 1.61 percent and 91.43 percent, respectively. Survival rates of females from birth to weaning , 4 - 12 months, 13 - 36 months and mature stock were 78.43 ± 4.60 percent, 93.95 ± 1.03 percent , 96.38 ± 0.70 percent, 96.38 ± 0.70 percent, respectively. Mortality rates were high in youngstock before weaning and decreased in mature stock.

4.1.2.1.10 Naivasha Friesian - Sahiwal Herd - Performance Parameters

4.1.2.1.10.1 Age at First Calving

The mean age at first calving for 38 records from 1970 - 1988 was 35.00 ± 4.05 months (Table 16) and ranged from 25 to 42 months. The analysis of variance in Table 40 showed that season of birth had no effect on age at first calving. Year of birth affected ($P<.05$) age at first calving. Heifers born in 1980 calved at a younger age of 30.32 months, while heifers born in 1984, a drought year, calved late at an age of 38.36 months.

Table 16. Means and standard deviations of performance traits of Friesian - Sahiwal at Naivasha

Trait	No. Cows	(n)		CV %
Milk yield	36	61	2213.77 ± 808.90	36
Calving Interval	38	66	399.51 ± 61.01	15
Age at first Calving	38	38	35.00 ± 4.05	11

4.1.2.1.10.2 Calving Interval

The mean calving interval for 66 records from 1972-1991 was 399.51 ± 61.01 days (Table 16) and ranged from 332 to 667days. The analysis of variance shown in Table 40 indicated that month of calving greatly influenced calving interval ($P<.01$). Year of calving affected calving interval ($P<.05$). Parity had no effect on calving interval.

Year variation had a significant effect on calving interval.

The longest calving interval was in 1976, a year that experienced severe drought and the shortest calving interval was 361.39 days in 1987. Month of calving influenced calving interval.

For cows calving between January - November calving interval was below herd average. However, for cows calving in December calving interval was above herd average. The shortest calving interval of 324.38 days was for cows calving in October.

4.1.2.1.10.3 Lactation Milk Yield (Kg)

The mean lactation milk yield for 61 records from 1972-1991 was 2,213.77 ± 808.90 kg (Table 16) and ranged from 1,019 to 4,187 kg. The analysis of variance in Table 40 in which lactation length was fitted as a covariate, it was shown that season of calving had no effect on lactation milk yield. Effects of year of calving and parity greatly influenced milk yield (P<.01).

Although season of calving had no effect on milk yield, it was observed that milk yield tended to be slightly high during the wet season and the milk yield was 2,001.08kg, whereas milk yield in the dry season was 1,992.65kg.

Year of calving had a marked effect on lactation milk yield and the lowest average milk yield was 995.94kg in 1977 and the highest average milk yield was 3,378.89kg in 1973.

4.1.2.1.10.4 Survival Rates

Survival rates varied with sex and age group. Survival rates of males from birth to weaning, 4 -12 months and mature stock were 88.63 ± 1.82 per cent, 88.64 ± 4.23 per cent and 96.46 ± 0.73 per cent, respectively. Survival rates for females from birth to weaning , 4 - 12 months , 13 - 36 months and mature stock were 91.39 ± 3.77 per cent, 93.38 ± 1.13 per cent, 92.94±1.45 per cent and 93.22 ± 2.01 per cent. Preweaning survival rates for males and females were low and improved with age (Table 24).

4.1.2.2 ADC Oljorai Ranch

Oljorai ranch is a leasehold state property which is managed and utilised by the Agricultural Development Corporation for livestock production. The ranch occupies a flat area at an altitude of 2,100 metres above sea level to the west of Lake Elementeita in the Rift Valley and is bordered to the south by Eburu Escarpment. The ranch is in agro-ecological zone IV. The natural vegetation is mainly scattered ***Acacia*** spp and Red oat grass (***Themeda triandra***). In some paddocks improved pastures of Boma Rhodes (***Chloris gayana)*** have been established.

The average rainfall is 769mm per annum. Rainfall is bimodal with a peak in April and October. The wet seasons (February - August and October) and dry seasons (January,September and November-December (Table 1).

The ranch enterprises include Sahiwal breeding, Boran breeding and Santa Gertrude crosses and sheep and goats. The Sahiwal herd utilises 2,272.72 ha and the remaining area is used by the other cattle breeds, sheep and goats.

4.1.2.2.1 Sahiwal Cattle

The Sahiwal herd was established on the ranch in 1987 with pedigree Sahiwals from the National Sahiwal Stud at Naivasha, the Cedarvale farm and Webb farm. There were 177 Sahiwals. The herd structure and size were shown in Table 12.

4.1.2.2.2 Breeding

Breeding of Sahiwal cows occurred throughout the year. Cows were bred by natural service using Sahiwal bulls. Heifers were bred when they were 24 - 30 months old and weighed 270 kgs. Each bull was assigned 40 cows. Breeding bulls were selected from the bull herd. Male calves not required for breeding were castrated when they were 3 - 4 months of age. Pedigree and performance records were kept in livestock cards and ledgers.

4.1.2.2.3 Feeding

Calves were weighed immediately after birth and were fed colostrum upto 7 days and thereafter they were bucket - fed whole milk at 10% of the bodyweight twice a day. They were weaned at 4 months of age.

Cattle were extensively grazed on natural pastures and Boma Rhodes. Mineral supplementation consisted of Bayer mix and Oljorai mix (contained the desired levels of phosphorus and cobalt). Animals had unrestricted access to pastures, water and mineral lick. Lactating cows were hand milked twice a day without supplementation.

4.1.2.2.4 Health Management

The cattle herds on the ranch were served by on-farm veterinary staff. Vaccinations against foot and mouth disease and blanthrax were done twice a year. Rinderpest, Rift Valley fever vaccinations were done once in the lifetime of an animal. Young breeding animals were vaccinated against brucellosis before they attained service age and weight.

Prevalent diseases on the ranch were east coast fever, pneumonia, scouring and mastitis. Tickborne - diseases were controlled by weekly dipping. Young stock were dewormed monthly . Weaner stock were dewormed once a year.

4.1.2.2.5 Farm Produce and marketing

The ranch produced breeding and slaughter stock. Milk was sold to Kenya Cooperative Creameries. Surplus good heifers, cows and bulls were sold for breeding. Heifers and culled cows with infertility problems and low milk yield were sold to the butchers for slaughter. Steers were sold for slaughter when they were 30 months of age and weighing an average of 450kg.

4.1.2.2.6. Oljorai Sahiwal Herd - Performance Parameters

4.1.2.2.6.1 Age at First Calving

The mean age at first calving for the 19 heifers born in the period 1981 - 1986 was 47.58 ± 5.28 months (Table 17) and ranged from 42 to 61 months. Analysis of variance in Table 41 has shown that month and year of birth had no effect on age at first calving. However, heifers born in 1982 calved first at a slightly younger age of 42.37 months, whereas heifers born in 1983 calved first at a later age of 53.93 months.

Table 17. Means and standard deviations of performance traits of Sahiwal at Oljorai.

Trait	No. Cows	(n)		CV %
Milk yield	44	89	1075.75 ± 533.58	49
Calving Interval	49	102	484.69 ± 158.83	33
Age at first calving	19	19	47.58 ± 5.28	11

4.1.2.2.6.2 Calving Interval

The mean calving interval of 102 records collected from 1986 - 1990 was 484.69 ± 158.83 days (Table 17) and ranged from 310 to 998 days. From the analysis of variance in Table 41, it was shown that month and year of calving had a slight effect on calving interval . Calving interval was less than herd average in January - March and May - August and November. Fertility of the herd tended to be poor in 1986.

4.1.2.2.6.3 Lactation Milk Yield

The mean lactation milk yield of 89 records from 1986 - 1991 was 1,075.75 ± 533.58 kg (Table 17) and ranged from 418 to 3,359 kg . Month and year of calving had a slight effect on lactation milk yield. The highest milk yield was obtained in May . Milk yield was below herd average in the months of April, September , October and December.

4.1.2.2.6.4 Survival Rates

Survival rates of males from birth - weaning, 5 - 12 months and mature stock were 87.04 ± 4.89 percent, 93.82 ± 2.18 percent and 96 percent, respectively. Survival rates of females from birth - weaning, 5 - 12 months and mature stock were 78.71 ± 4.11 percent, 95 percent and 98.67 percent, respectively (Table 24). Pre-weaning mortality rate for males was 13% and for females was 22%. Post-weaning mortality rates decreased with age. Mortality rates ranged from 2-6% for mature stock.

4.1.2.3 Deloraine Estate

Deloraine Estate at Rongai is a leasehold property covering an area of 2,316 ha. The farm is located in the Rift Valley at an altitude of 2,100 metres above sea level . It is bordered to the North by Molo Escarpment and beneath is a lower flat area extending to Molo river. The Estate is in Agro- ecological zone III.

The natural vegetation consists of tall ***Acacia*** species, Red oat grass (***Themeda triandra***) on the upper hilly part of the farm. Boma Rhodes (***Chloris gayana***) has been established in the paddocks on the lower flat area. Fodder maize for ensiling is grown in this part of the farm.

The average rainfall per annum is 1,014 mm. Rainfall is bimodal with a peak in April and November. The wet seasons (March - August and September - November and dry seasons (January - February and December (Table 1).

The Estate enterprises include Sahiwal , Ayrshire - Sahiwal crosses, Ayrshire, hay and fodder production, wheat and maize. The area used for livestock production was 67 percent.

4.1.2.3.1 Sahiwal Cattle

The Sahiwal herd was separated into groups according to age,sex,and lactation status. The herd size was 431 head of cattle. Cattle were grazed in paddocks which were supplied with water.

4.1.2.3.2 Breeding

In the 1970s and early 1980s cows were bred by artificial insemination using semen from the proven Sahiwal bulls. After 1985 animals were bred by natural service. The pure Sahiwal herd was served by selected Sahiwal bulls produced on the Estate. Occasionally breeding bulls were obtained from other Sahiwal breeders to maintain a broad genetic base and variation within the herd.The number of cows assigned to each bull was 40. The bulls used were between 3 - 6 yrs old. Pedigree and performance records were kept on individual animals.

4.1.2.3.3 Feeding

Sahiwal calves were weighed within 24 hrs of parturition and birth weights were recorded. Sahiwal calves suckled their dams upto weaning when they were 6 months old.

4.1.2.3.4 Mature Stock

Sahiwal cattle were extensively grazed on the natural pastures on the hilly upper part of the Estate. In the dry season lactating Sahiwals were supplemented with Rhodes grass hay and maize silage to maintain high production levels. Cattle had unrestricted access to mineral lick. Lactating cows were hand milked twice a day. At milking time Sahiwal cows were not fed dairy meal.

4.1.2.3.5 Health Management

The herd was served by both on-farm veterinary staff and field veterinary services. Vaccinations against foot and mouth disease and blanthrax were carried out twice a year. Vaccinations against rinderpest and Rift Valley fever were done once in a lifetime. Young breeding female animals were vaccinated against brucellosis.

Tickborne - diseases prevalent on the Estate were east coast fever, anaplasmosis, heartwater and redwater. Ticks were controlled by dipping cattle at a 10 - day interval. Young stock were dewormed every two months and weaner stock every six months. Mature stock were not dewormed.

4.1.2.3.6 Farm Produce and marketing

The Estate produced milk which was sold to Kenya Cooperative Creameries.Surplus good heifers, cows and bulls were sold to farmers for breeding. Heifers and cows with fertility problems and low milk yield were sold for slaughter to the butchers. Steers were sold for slaughter when they were 27 - 30 months of age and weighing an average of 450kg.

4.1.2.3.7 Deloraine Sahiwal Herd - Performance Parameters

4.1.2.3.7.1 Age at First Calving

The mean age at first calving of 157 heifers born between 1974 - 1986 was 44.33 ± 8.37 months (Table 18) and ranged from 30 to 74 months. Analysis of variance in Table 42 showed that month of birth, had no effect on age at first calving. Year of birth greatly influenced age at first calving ($P<.01$). Heifers born in 1975 calved at a younger age of 36.96 months, whereas heifers born in 1979 calved at a later age of 55.17 months. The average age at first calving recorded in this study was close to the average age at first calving reported by Trail and Gregory (1982).

Table 18. Means and standard deviations of performance traits of Sahiwal at Deloraine.

Trait	No Cows	(n)		CV %
Milk yield	158	426	949.06 ± 321.04	34
Calving Interval	156	482	488.74 ± 146.62	30
Age at first calving	157	157	44.33 ± 8.37	19

4.1.2.3.7.2 Calving Interval

The mean calving interval of 482 records collected from 1978 - 1990 was 488.74 ± 146.62 days (Table 18) and ranged from 310 to 970 days. Analysis of variance in Table 42 showed that month of calving had no effect on calving interval. Year of calving and parity significantly affected calving interval ($P<.01$).

With regard to year effects, it was observed that cows that calved in 1982 had the shortest calving interval, whereas cows that calved in 1984, a year that experienced drought, had the longest calving interval.

Parity affected calving interval. The calving interval of the first parity was 541.62 days and decreased by 11.6 percent in subsequent parities.

The average calving interval obtained in this study has increased by 52 days over the calving interval reported earlier by Trail and Gregory (1982) on the same herd.

4.1.2.3.7.3. Lactation Milk Yield

The mean lactation milk yield of 426 records collected from 1978 - 1991 was 949.06 ± 321.04 kg (Table 18) and ranged from 112 to 1,974 kg. Analysis of variance in which lactation length was fitted as a covariate in Table 42 showed that month of calving and parity had no effect on milk yield.

Year of calving greatly influenced milk yield($P<.01$).

On a yearly basis, the lowest average milk yield of 781.56 kg was obtained in 1981 and the highest average milk yield of 1,181.39 kg was recorded in 1991.

It should be noted that Sahiwal cows at Deloraine were suckled to let down milk and the milk yield reported represented only the amount of milk extracted. An earlier study from 1974 - 1977 on the same herd by Trail and Gregory (1982) reported an average milk yield of 833kg. The average milk yield in the present study has increased by 13.56 percent.

4.1.2.3.7.4 Survival Rates

Survival rates of males from birth to weaning and mature stock was 92.36 ± 0.69 percent and 96.88 percent, respectively (Table 24). Survival rates of females from birth - weaning, 7 - 12 months, 13 - 24 months and mature stock were 95.14 ± 1.34 percent, 97.35 ± 0.29 percent, 93.28 ± 1.84 percent and 97.25 ± 0.62 percent, respectively.

Preweaning calf survival rates were slightly lower than earlier reported by Trail and Gregory (1982). Mortality rates were relatively high in youngstock and decreased with age.

4.1.2.4 Mariakani Animal Production Research Centre

Mariakani Animal Production Research Centre of the Kenya Agricultural Research Institute in Kilifi District in Coast Province lies in the semi-arid lowland livestock - millet agro-ecological zone IV and is 180 - 185 metres above sea level. The research centre is on the main Mombasa Road. It covers an area of 437ha with an average annual rainfall of 870mm. Rainfall distribution is bimodal with maximum rain in April and December. The wet seasons (March - June and October - December and January) and dry seasons (February and July - September) in Table 1.

The natural vegetation consists of wooded grassland. The dominant natural pasture grasses are ***Panicum*** species, ***Cenchrus ciliaris and Cynodon dactylon,*** established pastures of ***chloris gayana***. The main farm enterprises were dual - purpose cattle and sheep and goats and pasture evaluation.

4.1.2.4.1 Sahiwal and Sahiwal Crossbreds

The Research Centre had Sahiwal - Ayrshire and Sahiwal, Friesian crosses. The herd was separated into young stock and breeding herd and herd structure were shown in Table 12.

4.1.2.4.2 Breeding

Cows were bred by artificial insemination using semen from proven Sahiwal,Ayrshire and Friesian bulls. The pure Sahiwal herd was served by Sahiwal bulls.

Some Sahiwal cows were bred by Ayrshire and Friesian bulls to produce Sahiwal - Ayrshire and Sahiwal - Friesian crosses.

The crosses were then involved in a two breed rotational crossbreeding with Ayrshire, Friesian and Sahiwal bulls to produce different genetic grades of the three breeds. The Centre relied on field artificial insemination services which were not reliable.

4.1.2.4.3 Feeding

In the first 5 days after birth calves were fed colostrum. Thereafter they were bucket - fed whole milk at 10% bodyweight twice a day. Calves were weaned at 5 months of age. Cattle were extensively grazed on the natural pastures and improved pastures. The Paddocks have regulated water supply. Occasionally they were supplemented with mineral licks. Lactating cows were hand milked twice a day without dairy meal.

4.1.2.4.4 Health Management

The Centre was served by the field veterinary staff. Vaccinations against foot and mouth disease, blanthrax and rinderpest were done once a year. Prevalent disease were trypanosomiasis and infected animals were treated with trypanosomiacid drugs.

Tickborne - diseases such as east coast fever were controlled by dipping cattle weekly with acaricide (BacDip). Young stock were dewormed every three months while mature stock were dewormed twice per year.

4.1.2.4.5 Farm Produce and Marketing

The Research Centre produced breeding and slaughter stock. Milk was sold to staff and local hotels. Surplus good heifers, cows and bulls were sold for breeding. Heifers and culled cows with infertility problems and low milk yield were sold to butchers for slaughter. Steers were sold for slaughter when they attained weight of 450kg between 27 - 30 months of age.

4.1.2.4.6 Mariakani Sahiwal and Sahiwal Crossbreds- Performance Parameters

4.1.2.4.6.1 Age at First Calving

The mean age at first calving of 194 heifers consisting of 100 Sahiwal, 57 Ayrshire - Sahiwal and 37 Friesian - Sahiwal was 34.37 ± 5.91 months (Table 19) and ranged from 24 to 67 months. Analysis of variance in Table 46 showed that month and year of birth had no effect on age at first calving. Differences between breed groups was significant ($P<.01$).

The average age at first calving of the Sahiwal heifers was 35.82 ± .65 months and this was 1.35 months higher than the herd average. Ayrshire - Sahiwal crossbreds calved at a younger age of 32.55 ± .75 months. The average age at first calving of the Friesian - Sahiwal crossbreds was 35.02 ± .98 months. Although the heifers of the three breed groups were managed together, variation in age at first calving indicated that breed groups differed in growth rates.

Table 19. Means and standard deviations of performance traits of Sahiwals and crossbreds at Mariakani

Trait	No. Cows (n)		Overall	CV %	Sahiwal	Ayrshire Sahiwal	Friesian- Sahiwal
			LS Mean				
Milk Yield (kg)	177	457	1490.52 ± 778.65	52	1360.01 ± 544.16	1796.28 ± 520.38	1818.63 ± 511.88
Calving Interval	171	482	456.98 ± 137.66	30	435.18 ± 144.66	457.49 ± 130.55	451.44 ± 127.26
Age at first calving	194	194	34.37 ± 5.91	17	35.82 ± 6.50	32.55 ± 5.66	35.02 ± 5.90

4.1.2.4.6.2 Calving Interval

The mean calving interval of 482 records from 1973 - 1990 consisting of 263 Sahiwal, 130 Ayrshire - Sahiwal and 89 for Friesian - Sahiwal crossbreds was 456.98 ± 137.66 days (Table 19) and ranged from 302 to 979 days. Analysis of variance in Table 46 showed that differences among breed groups were not significant. Month of calving and parity had no effect on calving interval. Effects of year of calving greatly influenced calving interval (P<.01). The Sahiwal were better adapted to the environment as shown by the slightly shorter calving interval. The Ayrshire - Sahiwal and Friesian - Sahiwal had similar fertility levels. Year of calving had a marked effect on calving interval. The shortest calving interval of 387.77 days was in 1974 and the longest calving interval was 505.69 days in 1983. The calving intervals of the three breed groups in the present study were slightly higher than the calving intervals for the same breed groups reported in previous work by Mwandotto ***et al.*** (1990).

4.1.2.4.6.3 Lactation Milk Yield

The mean lactation milk yield of 457 records consisting of 223 records for Sahiwal, 147 records for Ayrshire - Sahiwal and 87 records for Friesian - Sahiwal from 1973 - 1990 was 1,490.52 ± 778.65 kg (Table 19) and ranged from 118 to 4,183 kg.

From the analysis of variance model in which lactation length was fitted as a covariate in Table 46, It was observed that breed differences greatly influenced milk yield (P<.01) . The average milk of the Sahiwal was 1,360 .01 ± 36.44 kg and this was 20% less than the herd average. For the Ayrshire - Sahiwal crossbreds the average milk yield was 1,796.28 ± 42.98 kg and this was 9% higher than the herd average. The average milk yield of Friesian - Sahiwal crossbreds was 1,818.63 ± 54.88 kg and this was 11% higher than the herd average. Performance of the crossbreds in the production system with minimum supplementary feed is remarkable and the animals have high production potential which can be realised with good feeding and management.

Parity affected lactation milk yield (P<.01). Milk yield increased with parity upto the fifth lactation. Year variation influenced milk yield (P<.01). The lowest milk yield of 1,111.31 kg was recorded in 1977 and the highest milk yield of 2,080.32 kg was obtained in 1978. The average milk yield of the three breed groups in the present study were slightly higher than the average milk yield reported by Mwandotto ***et al.*** (1990).

4.1.2.4.6.4 Survival Rates

Overall herd survival rates of males from birth to weaning, 6-12 months and mature stock were 80.53± 6.24 percent, 91.34 ± 2.11 per cent, 92.20 ± 3.83 percent, respectively. Survival rates of females from birth to weaning, 6 - 12 months and mature stock were 85.04 ± 7.35 percent, 94.01 percent and 96.45 ± 5.6 7 percent, respectively. It was observed that pre weaning calf mortality was high for the three genotypes and ranged from 15-20%. Survival rate of the Sahiwal calves pre-weaning were lower than for the Friesian-Sahiwal and Ayrshire-Sahiwal crossbred calves. The pre-weaning survival rate of Sahiwal males was 6 percentage units less than the overall calf preweaning survival rate. The trend was similar for Sahiwal females, although they had higher survival rate than Sahiwal males. With regard to the crossbreds, Frisian-Sahiwal crossbred males had relatively low preweaning survival rate compared to the Ayrshire-Sahiwal male calves. The Ayrshire-Sahiwal females had a higher preweaning survival rate than the Friesian -Sahiwal females. Post weaning survival rate of the different sex and age groups of the three genotypes was over 90%.

Table 20. Survival rates of different sex and age groups of the Mariakan herd

	Sahiwal		Friesian-Sahiwal		Ayrshire-Sahiwal	
Age groups	Male	Female	Male	Female	Male	Female
0 - 4 (mo)	73.60 ± 6.24	81.40 ± 2.15	78.8 ± 2.59	85.40 ± 2.00	89.20 ± 2.59	88.30 ± 2.20
6 - 12	91.34 ± 2.11	95.0 ± 2.11	91.34 ± 2.11	95.00 ± 2.15	91.34 ± 2.11	95.10 ± 7.35
13 and Over	92.00 ± 1.92	96.67 ± 5.6	92.00 ± 1.92	96.00 ± 5.67	92.60 ± 1.92	96.67 ± 3.83

4.1.3 Large Scale Dairy Production Systems

Large scale dairy production systems included the Ayrshire-Sahiwal herd at Deloraine Estate, Friesian-Sahiwal herd at Loldia Estate and the Ayrshire-Brown Swiss-Sahiwal herd at Kilifi Plantations. Cattle were rotationally grazed on natural and improved pastures and were supplemented with dairy meal and minerals for milk and meat production. The crossbred herds were located in densely populated areas with good transport and a reliable fresh milk market. As a result, the dairy component was well developed and milk offtake accounted for 73% of the total income. Other sources of income which accounted for 27% of the total income were the sale of steers, culled cows and surplus heifers. Average cattle off-take rate was 25%.

4.1.3.1 Ayrshire-Sahiwal Crossbred Herd at Deloraine Estate

The crossbred herd was separated into groups according to age,sex,and lactation status and the herd size was 282 head of cattle(Table 1).

4.1.3.1.1 Breeding

In the 1970s and early 1980s Sahiwal cows were bred by artificial insemination using semen from Ayrshire bulls to produce Ayrshire-Sahiwal crosses. Crossbred cows were then involved in a two-breed rotational crossbreeding with the Ayrshire and Sahiwal bulls. The number of cows assigned to each bull was 40. The bulls used were between 3-6 years old.

4.1.3.1.2 Feeding

Crossbred calves were weighed within 24 hours of parturition and birth weights were recorded. Calves were bucket-fed colostrum for the first 5 days and thereafter they were fed whole milk at 10% of the body weight. Crossbred calves were supplemented with calf pencils and mineral licks. Calves were weaned when they were 6 months old.

4.1.3.1.3 Mature Stock

Ayrshire-Sahiwal crosses were grazed on improved Rhodes grass pastures on the lower part of the Estate. In the dry season lactating cows were supplemented with Rhodes grass hay and maize silage to maintain high production levels. Cattle had unrestricted access to mineral lick. Cows were hand milked twice a day and were supplemented with dairy meal.

4.1.3.1.4 Health Management

The herd was served by both on-farm veterinary staff and field veterinary services. Vaccinations against foot and mouth disease and blanthrax were carried out twice a year. Vaccinations against rinderpest and Rift Valley fever were done once in a lifetime. Young breeding female animals were vaccinated against brucellosis.

Tickborne - diseases prevalent on the Estate were east coast fever, anaplasmosis, heartwater and redwater. Ticks were controlled by dipping cattle at a 10 - day interval. Young stock were dewormed every two months and weaner stock every six months. Mature stock were not dewormed.

4.1.3.1.5 Farm Produce and marketing

The Estate produced milk which was sold to Kenya Cooperative Creameries.Surplus good heifers, cows and bulls were sold to farmers for breeding. Heifers and cows with fertility problems and low milk yield were sold for slaughter to the butchers. Steers were sold for slaughter when they were 27 - 30 months of age and weighing an average of 450kg.

4.1.3.1.6 Deloraine Ayrshire - Sahiwal Herd - Performance Parameters

4.1.3.1.6.1 Age at First Calving

The mean age at first calving of 69 heifers born from 1979 - 1987 was 38.49 ± 4.37 months (Table 21) and ranged from 26 to 51 months. Analysis of variance in Table 43 showed that month of birth had no effect on age at first calving. Year of birth affected age at first calving ($P<.05$). Heifers born in 1981 calved at a younger age of 33.05 months and heifers born in 1983 calved late at an age of 41.63 months.

The average age at first calving in this investigation was very close to the average age at first calving of 37.93 months reported by Trail and Gregory (1982) in an earlier study.

Table 21. Means and standard deviations of performance traits of Ayrshire- Sahiwal at Deloraine.

Trait	No. Cows	(n)		CV %
Milk yield	69	226	2480.61 ± 982.25	40
Calving Interval	71	215	512.09 ± 156.08	30
Age at first calving	69	69	38.49 ± 4.37	11

4.1.3.1.6.2. Calving Interval

The mean calving interval of 215 records collected from 1982 - 1990 was 512.09 ± 156.08 days (Table 21) and ranged from 301 to 989 days. Analysis of variance in Table 43 showed that month and year of calving and parity had no effect on calving interval. In an earlier study by Trail and Gregory (1982) the average calving interval for the Ayrshire - Sahiwal crossbreds was 382 days for the period from 1974 - 1977. Fertility has decreased by 34% in the herd.

4.1.3.1.6.3 Lactation Milk Yield

The mean lactation milk yield of 226 records collected from 1983 - 1990 was 2,480.61 ± 982.25 kg (Table 21) and ranged from 471 to 5,649 kg. From the analysis of variance model in which lactation length was fitted as a covariate (Table 43), it was shown that month of calving had no effect on milk yield. Year of calving and parity had a significant influence on milk yield ($P<.01$). On yearly basis, it was observed that the lowest average milk yield of 2,118.22 kg was obtained in 1984 and the highest average milk yield of 2,818.12 kg was recorded in 1988. Since 1984 experienced drought, pasture were of poor quality and inadequate to meet the animals maintenance and production requirements.

Milk yield increased with parity ($P< 01$). In the first parity, milk yield was 2,064.57 kg and increased to a peak milk yield of 2,664.59 kg in the sixth parity. The present average milk yield of 2,511.20 kg showed that there has been a remarkable increase in milk yield of the Ayrshire - Sahiwal herd over the years compared to an average milk yield of 1,017 kg reported by Trail and Gregory (1982) for the period 1974 - 1977.

4.1.3.1.6.4 Survival Rates

Survival rates of males from birth to weaning and mature stock were 83.89 ± 6.37 percent and 96 percent, respectively. Survival rates of females from birth - weaning, 7 - 12 months and mature stock were 87.79 ± 3.95 percent, 96.88 percent and 98.5 percent, respectively (Table 24). Pre-weaning mortality was 15%, whereas post-weaning mortality was 4%. The trend was similar to other herds studied where mortality rates tended to be high in the pre-weaning stage.

4.1.3.2 Loldia estate

Loldia Estate has an area of 2,727.28 hectares and is located North of Lake Naivasha in the Rift Valley at an altitude of 2,033 metres above sea level in agro - ecological zone IV. The ranch is connected by an all-weather murram road to the Nakuru-Nairobi main road and railway line. The natural vegetation consists of scattered ***Acacia*** trees, Naivasha Star grass (***Cynodon plectostachyum***), and Red oat grass (***Themeda triandra***) and Boma Rhodes (***Chloris gayana***) and lucerne have been established. The average rainfall is 635mm per annum based on the farm rainfall records. Rainfall distribution is bimodal with a peak in April and December. There are two main seasons, the wet season (March -June and December) and dry seasons (January - February and July - November) in Table 1. The main farm enterprises are dairy and beef cattle production, wheat and horticulture.

4.1.3.2.1 Herd Management

Cattle utilise 80 per cent of the farm. For this study, data recording was based on the Sahiwal - Friesian crossbreds. Other breeds on the farm included the Friesian, Boran and Friesian - Boran crossbreds.

The farm was subdivided into paddocks and had a regulated water supply. The herd was separated into young stock and breeding stock herds and these in turn were kept separate according to age, breed and lactation status.

4.1.3.2.2 Breeding

Sahiwal - Friesian crossbreds were obtained by breeding the Friesian cows with proven Sahiwal semen from the Central Artificial Insemination Station at Kabete. Heifers were served when they attained an average weight of 340kg at 22 - 24 months of age and they were bred by natural service at a ratio of 50 -75 cows per bull. Mature cows were bred by artificial insemination using Friesian semen. Breeding was carried out across the seasons. Pedigree and performance records were kept in livestock ledgers. The herd structure and size were shown in Table 12.

4.1.3.2.3 Feeding

Calves were fed colostrum during the first four days and thereafter they were fed whole milk twice a day at a rate of 10% of the body weight from 5 - 75 days. Calves were weaned after 75 days and group fed upto 6 months of age to attain an average of 154 kg. In addition calves were supplemented with calf - early weaner pellets and youngstock pencils.

Heifers, cows and steers were extensively grazed on natural pastures and supplemented with salt lick. Lactating cows were fed milled hay and wheat straw mixed with Molasses and urea during milking. Cows were milked twice a day in the morning and afternoon.

4.1.3.2.4 Health Management

The herd was served by on-farm veterinary staff and was visited monthly by a veterinary surgeon. Routine vaccinations against foot and mouth disease and blanthrax were undertaken. Cattle were vaccinated against rinderpest and Rift Valley fever once in a lifetime. Brucellosis was controlled by vaccinations of heifers before they attained breeding age. Tick-borne diseases which were prevalent on the farm were east coast fever, anaplasmosis and babesiosis. Ticks were controlled by dipping cattle with acaricide (Triatix). Young stock were dewormed every 6 weeks and mature stock were dewormed once in a year and also when it was necessary based on diagnosis.

4.1.3.2.5 Farm Produce and Marketing

Milk was sold to Kenya Cooperative Creameries at Naivasha, surplus good heifers in excess of replacement and cows were sold to dairy farmers and dairy cooperatives for breeding. Heifers and culled cows with fertility problems and low milk production were sold for slaughter to the butchers. Steers were sold for slaughter when they were 27 - 30 month of age and weighing an average of 450kg.

4.1.3.2.6 Loldia Friesian - Sahiwal Herd - Performance Parameters

4.1.3.2.6.1 Age at First Calving

The mean age at first calving was 34.19 ± 4.11 months for 59 heifers born between 1983 - 1988 (Table 22) and ranged from 24 to 48 months. From the analysis of variance in Table 48, it was shown that month of birth had no effects on age at first calving and year of birth greatly influenced age at first calving ($P<.01$). Although the month of birth had no effect on age at first calving, it was observed that heifers born in February, June, July, November and December calved at a slightly younger age than heifers born in January, March, April, May, August and October. Because of supplementary feeding , animal performance was not related to rainfall distribution in Table 1.

The effect of year of birth had a marked effect on age at first calving. Heifers born in 1988 calved at a younger age of 29.32 months and heifers born in 1985 calved at an older age of 30.88 months. Since the Friesian - Sahiwal heifers were supplemented with calf - early weaner pellets and youngstock pencils, they grew fast and reached service age and weight early and were served when they were between 20 - 23 months of age and calved when they were 30 - 33 months old.

Table 22. **Means and standard deviations of performance traits of Friesian - Sahiwal at Loldia.**

Traits	No. Cows	(n)		CV %
Milk Yield(kg)	53	216	2785.19 ± 1167.18	42
Calving Interval(Mo)	51	196	422.26 ± 102.35	24
Age at first Calving (Mo)	57	57	34.19 ± 4.11	12

4.1.3.2.6.2 Calving Interval

The mean calving interval for 196 records collected from 1986 - 1991 was 422.26 ± 102.35 days (Table 22) and ranged from 310 to 870 days. Analysis of variance in Table 48, showed that month of calving significantly affected calving interval (P<.01). Year of calving and parity had no effect on calving interval.

Cows that calved in February, March, June, August, September, November and December calving intervals were shorter than the herd average and cows calving in November had the shortest calving interval of 380.30 days. For cows calving in January, April, May, July and October, calving intervals were longer than the herd average and cows that calved in July had the longest calving interval of 545.09 days.

Although there was no clear trend with regard to the effect of parity on calving interval, it was observed that fertility was slightly high in the first to third parity and low in the fourth and fifth parity. In the later parities calving intervals were longer than the herd average.

4.1.3.2.6.3 Lactation Milk Yield

The mean lactation milk yield for 216 records collected from 1986 - 1991 was 2,785.19 ± 1,167.18 kg (Table 22) and ranged from 589 to 8,012 kg. The analysis of variance in Table 48 with lactation length fitted as a covariate showed that month of calving had no effect on milk yield. Year effects had a marked effect on milk yield (P<.01). Parity influenced milk yield (P<.05).With regard to year variation, it was observed that milk yield was above herd average from 1986 - 1989 and the highest average milk yield of 3,571.35 kg was produced in 1986. Milk yield was below herd average from 1990 to 1991 and the lowest average milk yield of 2,254.23 kg was recorded in 1991.

Milk yield increased with parity from the first lactation with milk yield of 2,433.62 kg to a maximum yield of 3,158.69 kg in the fourth lactation and decreased thereafter.

4.1.3.2.6.4 Survival Rates

Survival rates of males from birth to weaning and mature stock were 96 percent and 98 percent , respectively (Table 24). Female survival rates from birth - weaning, 7 - 12 months and mature stock were 97 percent , 98 percent and 98 percent , respectively.

4.1.3.3 Kilifi Plantations

Kilifi plantations is freehold property at 10 metres above sea level and is located in North Coast within the Coastal Strip in Kilifi District. The farm size is 2,045.45 ha. It lies in a coastal sub-humid zone in agro-ecological zone III. The natural vegetation is mainly evergreen and semi- evergreen bushland, Combretum woodland and savanna. The natural pasture grasses consists of the ***Panicum*** species. Improved pastures of ***Chloris gayana*** have been established on the farm. ***Leucaena Leucocephala*** has been established and covers an area of 22.72 ha.
The average annual rainfall is 1,157mm (1980 - 1992). Rainfall distribution is bimodal with a peak in May and October. The wet seasons (March - August and October- November) and dry seasons (January - February and September - December) in Table 1. Farm enterprises include Dual - purpose cattle, birds and sisal. Livestock enterprise utilise 1,590.91 ha.

4.1.3.3.1 Sahiwal Crossbreds

The three groups of crossbreds included the Ayrshire - Sahiwal, Ayrshire -Brown Swiss - Sahiwal and Friesian - Ayrshire- Brown Swiss- Sahiwal of different genetic composition. The Ayrshire - Sahiwal were produced in a two-breed rotational crossbreeding, the other two crossbred groups were produced in a three - breed rotational crossbreeding system and a four - breed crossbreeding system, respectively. The proportion of Ayrshire - Sahiwal crossbreds in the herd was declining, while a large proportion of the herd were Ayrshire- Brown Swiss - Sahiwal crossbreds. The Friesian - Ayrshire - Brown Swiss - Sahiwal crossbreds were still few and young as the crossbreeding programme had just been started. The herd was separated according to age, sex , lactation status and these were herded in different paddocks. The crossbred herd structure and size were shown in Table 12.

4.1.3.3.2 Breeding

The crossbred cows were mated throughout the year. Both artificial insemination and nature service were used to breed cows. For natural service each bull was assigned 31 - 35 cows. Artificial insemination was used to breed cows. However, if a cow did not conceive after 78 days then it was taken to the bull. Heifers were first bred when they approached 2 years of age at about 270kg.

4.1.3.3.3 Feeding

Calves were nipple - fed their dams colostrum from a bucket for 5 days and were transferred to a central rearing unit where they were fed whole milk at 10% of the bodyweight. Calves were provided with milk twice a day while on pasture and female calves were supplemented with a high protein diet of commercial calf pellets ***ad libitum.***

This level of feeding was required to maintain a steady growth rate of 600 - 700g/day, so that by the time calves were weaned at 12 weeks they were weighing 72kg. After weaning calves were separated into sex groups and moved away from the central rearing unit.

4.1.3.3.4 Mature stock

Cattle herds were rotationally grazed in the paddocks which were adequately supplied with water. Lactating cows were provided with supplementary feed based on their production and on the condition of the pasture they grazed. The supplementary feed consisted of a mixture of ground cotton seed cake, copra, wheat and maize bran, maize germ, sisal poles and molasses, and sea weed.

They were also provided with maclick plus and in the dry season they received Bayer mix which was rich in calcium and phosphorus and was mixed with urea. Steers were moved to a feedlot when there were 300kg and fed a high protein diet so that they could attain a slaughter weight of 450kg between 24 - 30 month of age. Cows were milked by hand twice a day in the morning and afternoon and the weight was recorded. Cows were tied to posts in the pastures and were provided with supplementary feed while they were milked.

4.1.3.3.5 Health Management

The farm herds were served by on-farm veterinary staff and a private veterinary surgeon. Vaccinations against foot and mouth disease were carried out every 6 months. Vaccination against blanthrax and rinderpest were done once a year. Animals infected with lumpy skin disease were slaughtered. The tickborne - diseases observed on the farm were east coast fever and anaplasmosis and these were controlled by dipping animals weekly with acaricide (Triatix). Calves were dewormed three times in a year at an interval of 4 months or as required. Mature stock were dewormed as required.

4.1.3.3.6 Farm Produce and Marketing

The farm produced milk which was sold to the Tourist Hotels. Surplus good heifers and cows were sold to farmers for breeding. Steers, heifers and culled cows with infertility problems and low milk yield were sold to butchers for slaughter.

4.1.3.3.7 Kilifi Plantations Ayrshire - Brown Swiss - Sahiwal crossbred herd - Performance Parameters

4.1.3.3.7.1 Age at First Calving

The mean age at first calving of 874 heifers born from 1976 - 1988 was 34.34 ± 4.33 months (Table 23) and ranged from 25 to 96 months. Analysis of variance in Table 47 showed that month of birth had no effect on age at first calving. Year of birth had a significant effect on age at first calving ($P<.01$). It was observed that heifers born in 1977 calved at a younger age of 28.67 months and heifers born in 1979 calved late at an age of 38.24 months which was 3.74 months above herd average. The average age at first calving in this study compared with previous report by Gregory and Trail (1981b) on Ayrshire - Sahiwal rotational crossbreds.

Table 23. Means and standard deviations of performance traits of Ayrshire - Brown Swiss - Sahiwal crossbreds at Kilifi.

Trait	No Cows	(n)		CV %
Milk Yield(kg)	881	2871	3649.38 ± 1092.96	30
Calving Interval	881	2871	405.72 ± 68.79	17
Age at First Calving (Mo)	874	874	35.34 ± 4.33	12

4.1.3.3.7.2 Calving Interval

The mean calving interval of 2,871 records collected from 1982 - 1991 was 405.72 ± 68.79 (Table 23) and ranged from 310 to 753 days. Analysis of variance in Table 47 showed that month and year of calving greatly influenced calving interval ($P<.01$). Parity had no effect on calving interval. For cows calving between January - July except February calving intervals were less than herd average. However, for cows calving between August - December, calving intervals were longer than herd average. It was observed that animal performance was related to rainfall distribution in Table 1. Animal performance was better in the wet season than in the dry season .

Year variation had a marked effect on calving interval. It was observed that cows that calved in 1989 had a long calving interval of 422.06 days, whereas cows calving in 1991 had the shortest calving interval and the average calving interval was 385.36 days.

The average calving interval in the present study was within the range of a previous report by Gregory and Trail in (1981b).

4.1.3.3.7.3 Lactation Milk Yield

The mean lactation milk yield of 2,871 records collected between 1982 - 1991 was 3,649.38 ± 1,092.96 kg (Table 23) and ranged from 493 to 9,196 kg. From the analysis of variance model in which lactation length was fitted as a covariate in Table 47 , It was shown that month of calving significantly influenced milk yield ($P<.01$), year of calving had a marked

effect on milk yield (P<.01), and parity significantly affected milk yield (P<.01). It was observed that milk yield was below herd average yield of cows calving between January and June, and milk yield was above - herd average for cows calving between July - December. The highest milk yield of 3,819.27 kg was recorded in October. With regard to milk production, it was found that animal performance was not related to rainfall distribution in Table 34. Animal performance was better in the dry season than in the wet season.

Lactation milk yield increased with parity.

In the first parity the milk yield was 3,046.77kg and increased to a maximum milk yield of 3,968.08 kg in the sixth parity and decreased thereafter. This milk production trend with parity implies that cows should be culled after the sixth parity. However, cows may be retained after the sixth lactation if they exceed herd average.

Year variation affected milk yield. The lowest lactation milk yield of 3,295.50 kg was obtained in 1985 and the highest milk yield of 4,293.52 kg was produced in 1991. This shows that there has been an improvement in feeding and management in the later years. Also the introduction of the Brown Swiss in the crossbreeding programme has improved the retention of heterosis and contributed to increased herd productivity by 30 percent compared to the average milk yield for the Ayrshire -Sahiwal rotational crossbreds reported by Gregory and Trail (1981b).

4.1.3.3.7.4 Survival Rates

Survival rates of males from birth - weaning, 4 - 12 months and mature stock were 92.52 ± 1.52 percent, 98.69 ± 0.30 percent and 98.88 ± 1.02 percent, respectively (Table 24). Survival rates of females from birth to Weaning, 4 - 12 months, 13 - 24 months, 25 - 36 months and mature stock were 92.43 ± 1.83 percent, 98.09 ± 0.35 percent, 97.81 ± 0.79 percent, 98.72 ±0.47 percent, respectively. Survival rates in this study were comparable to survival rates reported by Gregory and Trail (1981b). Pre-weaning and post-weaning survival rate were over 90%.

TABLE 24. Derived Parameters used in the Determination of Productivity of Breeds in the Ranches

	Naivasha		Loldia	Oljorai	Deloraine		Elkarama	Ilkerin	Mariakani	Kilifi
	Sahiwal	Friesian-Sahiwal	Friesian-Sahiwal	Sahiwal	Sahiwal	Ayrshire Sahiwal	Sahiwal	Sahiwal	Ayrshire - Friesian Sahiwal	Ayrshire -Brown Swiss - Sahiwal
Survival rate %	M* F*	M F	M F	M F	M F	M F	M F	M F	M F	M F
-Preweaning	78.09 78.43	88.63 91.39	96 97	87.04 78.71	92.36 95.14	83.89 87.79	97.42 97.61	93.75 95.84	90.42 88.33	92.52 92.43
-Post-weaning - 12 Mo	91.84 93.95	88.64 93.38	98 98	93.82 95.0	96.88 97.35	96.00 96.88	99.5 99.32	97.5 97.6	91.34 96.67	98.69 98.09
13 -24 Mo	91.43	96.38 96.46	92.94 98	96 98.7	93.28			97.5 98.5	91.99 95.01	98.88 97.81
25 -36 Mo)	96.38	93.22			97.25					98.72
Over 36 Mo)										99.20
Age at first calving (Mo)	41.50	33.85	33.29	46.98	44.43	37.69	36.43	43.27	34.46	34.51
Calving interval (Mo)	14.96	14.52	14.25	16.95	16.37	16.98	13.62	15.66	14.93	13.52
Milk yield (kg)	1592.58	1996.87	2874.57	1030.51	946.05	2511.20	600	600[1]	1658.31	3,697.47
Mature age (Mo)	86	76	76	98	94	96	77	90	98	88
Mature size (kg)										
Male	500	620	620	500	500	600	500	500	600	600
Female	425	480	480	425	425	480	425	420	430	450
Scrap rate for heifers (%)	5.0	5.0	5.0	4.0	4.0	5.0	2.0	2.0	7.0	2.0
Scrap rate for Cows (%)	20.8	19.8	28.0	18.7	17.3	18.9	23.3	23.1	21.5	24.4
Litter size	1	1	1	1	1	1	1	1	1	1

M* - Male

F* - Female

1. Gregory and Trail (1981a)

4.1.4 Cattle Offtake

Offtake rate was influenced by the herd size, calving rate, mortality rate,replacement rate and the culling criteria of the herd. Cattle offtake consisted of steers,breeding bulls,culled cows, and surplus heifers. Offtake rate was computed as the percentage of animal units put on the market and sold in relation to the animal units that were available at the beginning of the production year. The average offtake rate of the ten herds was 24% (Table 25). Offtake rates of the Sahiwal beef herds at Elkarama and Ilkerin-Loita Ranch were similar and were 3 percentage units more than the average. For the dual-purpose herds , offtake rates varied from 13.8 to 28.2 percent. The Friesian-Sahiwal herd at Naivasha had the lowest offtake rate which was 10.2 percentage units less than the average offtake rate because the herd was still being established at the period of the study.

The offtake rate of dairy crossbred herds was variable. For Kilifi herd an offtake rate of 19.88% was relatively low compared to the herd size. The Friesian-Sahiwal herd at Loldia Estate had the highest offtake rate.

TABLE 25. Herd size and offtake rate %

Ranch Name	Breed	Herd size	No. of cattle sold	Offtake rate (%)
NAHRC Naivasha	Sahiwal	1071	199	18.58
NAHRC Naivasha	Friesian -Sahiwal	101	14	13.86
Loldia	Friesian -Sahiwal	430	129	30.0
Oljorai	Sahiwal	177	42	23.74
Deloraine	Sahiwal	431	122	28.76
Deloraine	Ayrshire - Sahiwal	282	71	25.17
ElKarama	Sahiwal	810	231	28.52
Ilkerin	Sahiwal	308	85	27.60
Manakani	Ayrshire - Friesian-Sahiwal	202	51	25.25
Kilifi	Ayrshire-Brown Swiss-Sahiwal	2343	465	19.88

4.2 PRY Productivity Indices

Productivity of the herds was derived from liveweight and milk offtake. Unbiased estimates of measures of performance traits (Table 24) of the breeds in different production systems were entered into the PRY model to derive productivity indices of the herds. The Sahiwal herds at Ilkerin Loita and Elkarama which produced beef as the major product, were less efficient and generated the lowest gross returns of less than 3.5 Kenya Shillings per kg of dry matter consumed. Dual purpose herds were raised to produce milk and meat and were more efficient in utilising feed resources than beef herds and the average gross returns per kg of dry matter intake was Kenya Shillings 5.10. The production efficiency of dairy crossbred herds was higher than dual purpose herds and the average gross returns per kg dry matter intake was Kenya Shillings 8.63. The highest income on feed was obtained from the Ayrshire-Brown Swiss- Sahiwal herd at Kilifi.

4.2.1 Optimum Culling Strategy

The optimum culling strategy was different between breeds within ranches with regard to the culling age threshold for breeding females, the disposal age of young surplus female and male youngstock. The program showed that the cull - for - age threshold of breeding females of different herds ranged from 166 to 180 months. To maintain the herds viable and in a stationary state, the set minimum culling age of breeding females varied from 50 to 87 months after 2-4 parturitions. Under this regime only few surplus young females had to be maintained in the herds and their optimal disposal age ranged from 20 to 31 months. This was also the optimal disposal age of male youngstock (Table 26).

The disposal age of surplus female and male young stock was in agreement with what occurred in commercial practice. The expected offtakes and intakes per animal category of the stationary - state population of the different herds are in Table 49 and 50. It was observed that in the production systems with equal emphasis on milk and liveweight offtake, there was a tendency for breeding females to be disposed of at an older age preferably after the lactation with the maximum milk yield. However, in production systems where there was greater emphasis on liveweight offtake with minimum milk offtake such as in the Sahiwal herd at Ilkerin and Elkarama Ranch, cows were culled at a relatively younger age after two parturitions if their milk production for the suckling calves was inadequate and the culled cows were sold when they were still in good condition. The total offtake value per unit dry matter intake of the herds ranged from 3.17 to 9.52 Kenya shilling per kilogramme dry matter intake (Table 27). Thus the enhanced productivity index was 3,170 to 9,520 Kenya shilling per ton of dry matter intake. The lowest income generated on feed were obtained from Sahiwal herds and the highest income on feed were obtained from crossbred herds.

TABLE 26. Optimum Culling Strategy for Breeds in the Ranches.

Ranch Name	Breed	BF[1]	SF[2]	M[3]	BF Minimum culling Age
Naivasha	Sahiwal	176	24	23	87
Naivasha	Friesian- Sahiwal	179	22	20	63
Loldia	Friesian - Sahiwal	176	22	25	62
Oljorai	Sahiwal	166	27	27	81
Deloraine	Sahiwal	176	26	26	78
Deloraine	Ayrshire - Sahiwal	173	28	26	72
Elkarama	Sahiwal	173	25	24	50
Ilkerin	Sahiwal	168	25	24	59
Kilifi	Ayrshire-Brown Swiss -Sahiwal	180	27	24	62
Mariakani	Sahiwal- Ayrshire Sahiwal - Friesian Sahiwal	169	31	26	65

1. Breeding female
2. Surplus female youngstock
3. Male youngstock

4.2.2 Interaction of Breed and production Systems

Ranking of the breeds in the production systems within the ranches on overall productivity index (Table 27) showed that in relation to the National Sahiwal Stud which was maintained at 100 percent, the crossbred herds were superior to the Sahiwal herds. On average the crossbreds were 127.53 percentage units above the reference Sahiwal herd at Naivasha, whereas the Sahiwal herds were 70.58 percentage units below the reference Sahiwal herd. Thus the crossbreds were 56.95 percentage units above the Sahiwal herds in overall productivity. Within the crossbreds the three - breed crossbred at Kilifi plantations consisting of the Ayrshire - Brown Swiss - Sahiwal crossbred herd had the highest overall productivity index and it was 66.72 percentage units above the reference Sahiwal herd. The Friesian - Sahiwal herd at Loldia estate was 36.08 percentage units above the reference Sahiwal herd and was assigned the second rank. The Ayrshire - Sahiwal herd at Deloraine, Friesian - Sahiwal herd at Naivasha and the Mariakani herd were assigned the third, fourth and fifth ranks, respectively.

The lower ranks from 6 to 10 were assigned to the Sahiwal herds. Deviations of the Sahiwal herds from the reference Sahiwal herd were negative and ranged from -30.12 to -44.48 percentage units.

TABLE 27. Overall Comparison of Breed Productivity in the Ranches

Ranch Name	Breed	TOV/DMI[x] (Kshs/kg)	Index[a]	Rank	Deviations from Reference herd
Naivasha	Sahiwal	5.71	100	6	0
Naivasha	Friesian- Sahiwal	6.47	113.31	4	13.31
Loldia	Friesian - Sahiwal	7.77	136.08	2	36.08
Oljorai	Sahiwal	3.99	69.88	7	-30.12
Deloraine	Sahiwal	3.80	66.55	8	-33.45
Deloraine	Ayrshire - Sahiwal	6.74	118.04	3	18.04
Elkarama	Sahiwal	3.48	60.94	9	-39.06
Ilkerin	Sahiwal	3.17	55.52	10	-44.48
Kilifi	Ayrshire-Brown Swiss				
	-Sahiwal	9.52	166.72	1	66.72
Mariakani	Sahiwal- Ayrshire)				
	Sahiwal - Friesian)				
	Sahiwal)	5.91	103.50	5	3.50

a Index is percentage units relative to Sahiwal at Naivasha, which is maintained at 100

x TOV/DMI- Total offtake value in Kenya shillings per kg dry matter intake

4.3. Gross Margin Analysis

Gross margin is the difference between gross income and variable costs. Gross income is the total value of production and include produce consumed on the farm. Variable costs are the costs of items which vary with the change in the scale of operation of the enterprise.

Gross margins of the herds varied with the breed, herd size, inputs and management system. For the Sahiwal beef herds at Elkarama and Ilkerin-Loita (Table 34 and 35), gross income was obtained from cattle offtake and this generated over 90% of the total income.

Under variable costs the major items were veterinary drugs and vaccines which accounted for 32% of the total variable cost, overhead costs 28%, running costs 20%, and labour costs were 18%.

For the dual purpose herds which included parastatal Sahiwal and Friesian-Sahiwal herds at Naivasha, Sahiwal herd at Oljorai and Sahiwal and crossbreds at Mariakani and Sahiwal herd at Deloraine (Table 28,29,31,32 and 36). Gross income was obtained from milk and cattle offtake which contributed 67% and 33% to the total income, respectively. Under variable costs, the major items were labour costs which account for 35% of the total variable costs, overhead costs 32% veterinary inputs 18%, running cost 13% and mineral supplements 2%.

For the dairy crossbred herds which included the Friesian-Sahiwal herd at Loldia, Ayrshire-Sahiwal herd at Deloraine and Ayrshire-Brown-Swiss-Sahiwal herd at Kilifi (Table 30,33 and 37), gross income was obtained from milk offtake (75%) and cattle offtake (25%). Under variable costs, the main items were animals feeds which included dairy meal, calf pellets an mineral and this accounted for 43% for the Friesian -Sahiwal herd at Loldia, 34% for the Ayrshire-Sahiwal herd at Deloraine and 17% for the Kilifi herd of the total variable costs. Overhead costs 25%, labour 20% and veterinary inputs 10%.

4.3.1 National Sahiwal Stud at Naivasha.

Productivity Estimates

(i) Average Milk Yield		1543.87 ± 551.96kg
ii) Average calving interval		446.42 ± 105.69 days
iii)	Annual Milk Yield	

$\frac{1543.87}{446.42} \times 365 = 1262$ kg

(less 20% milk fed to calves)

Milk sold = 1010 kg /cow/year.

iv)	Number of cows	360
v)	Survival rate	96.38%
vi)	Calving rate	81.84%
vii)	Livestock units	566
viii)	Replacement rate (Mortality rate + Culling rate)	24.4%
ix)	Heifers (sterility)	5%
x)	Bull calves - weight	150 kg
xi)	Heifers - weight	300 kg
xii)	Culled cows- weight	400 kg
(xiii)	Heifers (Breeding)	350kg
xiv)	Breeding Bulls - weight	450 kg

TABLE 28 . Gross Margin of the National Sahiwal Stud at Naivasha

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	1010 kg	15/kg	360 Cows	5,454,000.00
Bull Calves(1 year)	150 kg	25/kg	45 Bull calves	168,750.00
Breeding bulls	1 Bull	20,000/Bull	60 Bulls	1,200,000.00
Heifers for breeding	1 heifer	14000/Heifer	5 Heifers	70,000.00
Heifers for slaughter	300 kg	35/kg	5 Heifers	52,500.00
Culled Cows	400 kg	33/kg	84 Cows	1,108,800.00
Total Revenue				**8,054,050.00**
Cost				
Minerals	15,000 kg	6.70/kg	10kg bag	100,500.00
Veterinary Cost*	566LU*	4.2/LU/day	365 days	867,678.00
Running Costs (Operation)	566 LU	3.50/LU/day	365 day	723,065.00
Labour	566 LU	9.00/LU/day	365 days	1,859,310.00
Overhead Costs	566 LU	7.00/LU/day	365 days	1,446,130.00
Total Cost				**4,996,683.00**

= Gross Margin = Ksh. 3,057,367.00

Gross Margin/Livestock Unit/Year = Kshs 5,401.71

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 425kg.**

4.3.2 Friesian - Sahiwal Herd at Naivasha

Productivity Estimates

(i)	Average milk yield	2,213.77 ± 808.90kg
(ii)	Average lactation Length	307.45 ± 16.73 days
(iii)	Calving interval	399.51 ± 61.01 days
(iv)	Annual milk yield.	
	$\frac{2213.77 \times 365}{399.51}$ =	2,023 kg
	(less 20% milk fed to calves) milk sold =	1,618 kg/cow/year.
(v)	Number of cow	15
(vi)	Survival rate	93.22%
(vii)	Calving rate	91.5%
viii)	Livestock Units	33
(ix)	Bull calves - weight	150kg
(x)	Heifers (for breeding) - weight	350kg
(xi)	Replacement rate	26.6%
(xii)	Heifers (Sterility rate)	5%.

TABLE 29. Gross Margin of the Friesian - Sahiwal herd at Naivasha

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	1,618kg	15/kg	15 cows	364,050.00
Bull calves	150 kg	25/kg	5 Bull calves	18,750.00
Heifers (2-3 years)	350kg	45/kg	5 Heifers	78,750.00
Culled Cows	400kg	33/kg	4 Cows	52,800.00
Total Revenue				**514,350.00**
Cost				
Minerals	237kg	6.70/kg	10kg bag	1,587.90
Veterinary Cost*	33LU*	3.00/LU/day	365 days	36,135.00
Running Costs	33LU	3.50/LU/day	365 days	42,157.50
Labour Cost	33LU	9.00/LU/day	365 days	108,405.00
Overhead Costs	33LU	7.00/LU/day	365 days	84,315.00
Total Cost				**272,600.00**

= Gross Margin = Kshs. 241,749.60

Gross Margin/LiveStock Unit/Year = Ksh. 7,325.75

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**
* **ILU = 450kg**

4.3.3 **Friesian - Sahiwal herd at Loldia Estate**

Productivity Estimates

(i)	Average milk yield	2785.19 ± 1167.18 kg
(ii)	Average lactation length	307.18 ± 83.82 days
(iii)	Calving interval	422.03 ± 102.61 days
(iv)	Annual milk yield	

$$\frac{2785.19 \times 365}{422.00} = 2{,}408.99 \text{ kg}$$

(Less 20% milk fed to calves)

Milk sold = 1927kg/cow/year.

(v)	Number of cows	168
(vi)	Survival rate	98 %
(vii)	Calving rate	86.5%
(viii)	Livestock Units =	254
(ix)	Steers - weight	450 kg
(x)	Heifers (breeding) - weight	350 kg
(xi)	Heifers (slaughter) - Weight	350 kg
(xii)	Cull cows - weight	400kg
(xiii)	Replacement rate	30%
(xiv)	Heifer sterility	5%

TABLE 30.Gross Margin of the Friesian - Sahiwal Herd at Loldia

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	1,927 kg	15/kg	168 Cows	4,856,040.00
Steers	450 kg	40/kg	63 Steers	1,134,000.00
Heifers for slaughter	300 kg	40/kg	3 Heifers	36,000.00
Heifers for breeding	350 kg	45/kg	15 Heifers	236,250.00
Culled Cows	400 kg	35/kg	49 Cows	686,000.00
Total Revenue				**6,948,290.00**
Cost				
Minerals	9,271 kg	6.70/kg	10kg bag	62,115.70
Dairy meal	245,280kg	7/kg	70kg bag	1,716,960.00
Calf pellets	31,200kg	13.70/kg	70 kg bag	427,440.00
Veterinary Cost*	254LU*	5/LU/day	365 days	463,550.00
Running Costs (Operation)	254 LU	5.50/LU/day	365 days	509,905.00
Labour	254 LU	8.85/LU/day	365 days	820,483.50
Overhead Costs	254 LU	11.20/LU/day	365 days	1,038,352.00
Total Cost				**5,038,806.20**

= Gross Margin = Ksh. 1,909,483.80

Gross Margin/Live Stock Unit/Year = 7,517.65

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**
* **ILU = 450kg.**

4.3.4 Sahiwal Herd at Oljorai

Productivity Estimates

(i)	Average milk yield	1075.± 533.58 kg
(ii)	Average lactation length	188.74 ± 62.79 days
(iii)	Average calving interval	484.68 ± 158.83 days
(iv)	Annual milk yield	
	1075.75 x 365 = 813.95kg	
	484	
	Less 25% (milk fed to calves) milk sold = 610kg/cow/year.	
(v)	Number of cows	75
(vi)	Survival rate	98.7%
(vii)	Calving rate	75.4%
(viii)	Livestock Units	104
(ix)	Steers - weight	450 kg
(x)	Heifers (breeding) - weight	350 kg
(xi)	Heifers (slaughter) - weight	300 kg
(xii)	Breeding bulls - weight	450kg
(xiii)	Culled cows - weight	400 kg
(xiv)	Replacement rate	20%
(xv)	Heifer sterility	4.0%

TABLE 31. Gross Margin of Sahiwal Herd at Oljorai

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	610kg	15/kg	75 cows	686,250.00
Steers	450 kg	45/kg	13 Steers	263,250.00
Breeding				
Bulls	1 Bull	24,750/Bull	10 Bulls	247,500.00
Heifers(Breeding)	350 kg	40/kg	4 Heifers	56,000.00
Heifers (Slaughter)	300 kg	35/kg	1 Heifers	10,500.00
Culled Cows	400 kg	35/g	14 Cows	196,000.00
Total Revenue				**1,459,500.00**
Cost				
Minerals	3,796kg	6.70/kg	10kg bag	25,433.20
Veterinary Cost*	104 LU*	3/LU/day	365days	113,880.00
Running Costs (Operation)	104LU	2.50/LU/day	365 days	94,900.00
Labour	104LU	8.85/LU/day	365 days	335,946.00
Overhead Costs	104 LU	10/LU/day	365 days	379,600.00
Total Cost				**949,759.00**

= Gross Margin = Ksh.509,741.00

Gross Margin/LiveStock Unit/year = Kshs 4901.35

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 425kg.**

4.3.5 Sahiwal Herd at Deloraine Estate

Productivity Estimates

(i)	Average milk yield	949.06 ± 321.04 kg
(ii)	Average lactation length	280.47 ± 71.60 days
(iii)	Average calving interval	488.72 ± 146.65 days
(iv)	Annual milk yield	

$$\frac{949 \times 365}{488} = 710 \text{ kg}$$

(v)	Number of cows	195
(vi)	Survival rate	93.28%
(vii)	Calving rate	75%
(viii)	Livestock Units	233
(ix)	Steers weight	450 kg
(x)	Heifers (breeding) - weight	350 kg
(xi)	Heifers (Slaughter) - weight	300 kg
(xii)	Culled cows - weight	400 kg
(xiii)	Breeding bulls - weight	450 kg
(xiv)	Replacement rate	20%
(xv)	Heifers (Sterility)	4%

TABLE 32. Gross Margin of Sahiwal Herd at Deloraine Estate

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	710kg	15/kg	195 cows	2,076,750.00
Steers	450 kg	40/kg	30 Steers	540,000.00
Breeding bulls	1 Bull	22,500/Bull	35 Bulls	787,500.00
Heifers(Breeding)	350 kg	35/kg	29 Heifers	355,250.00
Heifers (Slaughter)	300 kg	33/kg	2 Heifers	19,800.00
Culled Cows	400 kg	33/kg	36 Cows	475,200.00
Total Revenue				**4,254,500.00**
Cost				
Minerals	17,009 kg	6.70/kg	10kg bag	113,960.30
Veterinary Cost*	233 LU*	5/LU/day	365 days	425,225.00
Running Costs (Operation)	233LU	5/LU/day	365 days	425,225.00
Labour	233LU	8.85/LU/day	365 days	752,648.25
Overhead Costs	233 LU	11/LU/day	365 days	935,495.00
Total Cost				**2,652,553.50**

= Gross Margin = Ksh. 1,601,946.50

Gross Margin/Livestock Unit/Year = Kshs 6875.31.

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 425kg.**

4.3.6 **Ayrshire -Sahiwal Herd at Deloraine Estate**

Productivity Estimates

(i)	Average milk yields	2,480 ± 982.25kg
(ii)	Average lactation length	374.59 ± 119.31kg
(iii)	Average calving interval	512.09 ± 156.07 days
(iv)	Annual milk yield	

$$\frac{2480.60 \times 365}{512.09} = 1768.08$$

(Less 25% milk fed to calves) milk sold = 1326kg/Cow/year.)

(v)	Number of cows	129
(vi)	Survival rate	96.88%
(vii)	Calving rate	71.30%
(viii)	Livestock units	158
(ix)	Steers - weight	450kg
(x)	Heifers (Breeding) - weight	350kg
(xi)	Heifers (Slaughter) - weight	300 kg
(xii)	Culled cows - weight	400kg
(xiii)	Replacement rate	22%
(xiv)	Heifers (Sterility)	5%

TABLE 33. Gross Margin of the Ayrshire- Sahiwal Herd at Deloraine Estate

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	1326kg	15/kg	129 cows	2,565,810.00
Steers	450 kg	50/kg	37Steers	832,500.00
Heifers(Breeding)	350 kg	50/kg	9 Heifers	157,500.00
Heifers (Slaughter)	300 kg	40/kg	2 Heifers	24,000.00
Culled Cows	400 kg	40/g	25 Cows	400,000.00
Total Revenue				**3,979,810.00**
Cost				
Minerals	11,534kg	6.70/kg	10kg bag	77,277.80
Dairy Meal	70,620kg	10.20/kg	70kgbag	720,324.00
Early Weaners pellets	13,200kg	6.65/kg	70kg bag	87,780.00
Veterinary Cost*	158LU	5/LU/day	365 days	288,350.00
Running Costs (Operation)	158LU	5/LU/day	365 days	288,350.00
Labour	158LU	8.85/LU/day	365 days	510,379.50
Overhead Costs	158 LU	11/LU/day	365 days	634,370.00
Total Cost				**2,606,831.30**

= Gross Margin = Ksh. 1,372,978.70

Gross Margin/Livestock Unit/Year = Kshs 8,689.74.

Remarks

* **Veterinary costs include costs of acaricide, pygrease dewormers, drugs, vaccines and disinfectants.**

* **ILU = 450kg.**

4.3.7 **Sahiwal Herd at Elkarama Ranch**

Productivity Estimates

(i)	Average calving interval	422.71± 104.89 days
(ii)	Number of cows	281
(iii)	Survival rate	99.32%
(iv)	Calving rate	86.35%
(v)	Number of cows calving	243
(vi)	Livestock Units	469
(vii)	Steers weight	450kg
(viii)	Heifers (breeding) -Weight	350 kg
(ix)	Heifers (Slaughter) -Weight	300 kg
(x)	Culled cows - Weight	400kg
(xi)	Breeding bulls - weight	450 kg
(xii)	Replacement rate	24%
(xiii)	Heifers (Sterility)	2%

TABLE 34 . Gross Margin of the Sahiwal Herd at Elkarama

Description	Quantity	Price (Ksh.)	Units	Amount (ksh)
Revenue				
Steers	450 kg	50/kg	96 Steers	2,160,000.00
Breeding Bulls	1 Bull	25,000/Bull	20 Bulls	500,000.00
Heifers(Breeding)	350 kg	45/kg	48 Heifers	756,000.00
Heifers (Slaughter)	300 kg	35/kg	2 Heifers	21,000.00
Culled Cows	400 kg	35/kg	65 Cows	910,000.00
Total Revenue				**4,347,000.00**
Cost				
Minerals	17,119kg	6.70/kg	10kg bag	114,697.30
Veterinary Cost*	469LU*	4/LU/day	365 days	684,740.00
Running Costs (Operation)	469 LU	2.50/LU/day	365 days	427,962.50
Labour	469LU	2.30/LU/day	365 days	393,725.50
Overhead Costs	469LU	3/LU/day	365 days	513,555.00
Total Cost				**2,134,680.00**

= Gross Margin = Ksh. 2,212,319.70

Gross Margin/Live Stock Unit/Year = Kshs. 4,717.10

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 425kg.**

4.3.8. **Sahiwal Herd at Ilkerin Ranch**

Productivity Estimates

(i)	Average calving interval	483.98± 144.43 days
(ii)	Number of cows	130
(iii)	Survival rate	98. 5%
(iv)	Calving rate	75.42%
(v)	Number of cows calving	99
(vi)	Livestock Units	181
(vii)	Steers - weight	450kg
(viii)	Heifers (breeding) - weight	350 kg
(ix)	Heifers (Slaughter) - weight	350 kg
(x)	Culled cows - weight	400kg
(xi)	Breeding bulls - weight	450 kg
(xii)	Replacement rate	24.6%
(xiii)	Heifers (Sterility)	2%

TABLE 35. Gross Margin of Sahiwal Herd at Ilkerin Ranch

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Steers	450kg	50/kg	13 Steers	292,500.00
Breeding bulls	1 Bull	25,000/Bull	30 Bulls	750,000.00
Heifers(Breeding)	350 kg	40/kg	9 Heifers	126,000.00
Heifers (Slaughter)	300 kg	35/kg	3 Heifers	31,500.00
Culled Cows	400 kg	35/kg	3 Cows	420,000.00
Total Revenue				**1,620,000.00**
Cost				
Minerals	6,606kg	6.70/kg	10kg bag	44,260.20
Veterinary Cost*	181LU*	5/LU/day	365 days	330,325.00
Running Costs (Operation)	181 LU	2.50/LU/day	365 days	165,162.50
Labour	181LU	3.05/LU/day	365 days	201,498.25
Overhead Costs	181 LU	5/LU/day	365 days	330,325.00
Total Cost				**1,071,570.95**

= Gross Margin = Ksh. 548,429.05.

Gross Margin/Live Stock Unit/Year = Kshs 3,029.99

Remarks

* **Veterinary costs include costs of acaricide, pygrease dewormers, drugs, vaccines and disinfectants.**

* **ILU = 425kg.**

4.3.9 **Ayrshire - Friesian - Sahiwal Herd at Mariakani**

Productivity Estimates

(i)	Average Milk yield	1490.52 ± 778.65 kg
(ii)	Average lactation length	289.86 ± 98.77 days
(iii)	Average calving interval	450.75 ± 125.74 days
(iv)	Annual milk yield	

$$\frac{1490.52 \times 365}{450.75} = 1206.97 \text{ kg}$$

(Less 25% milk fed to calves) milk sold = 905 kg/cow/Year

(v)	Number of cows	83
(vi)	Survival rate	95.01%
(vii)	Calving rate	80.98%
(viii)	Livestock Units	111
(ix)	Bull calves - weight	177 kg
(x)	Steers - weight	450 kg
(xi)	Heifers (breeding) - weight	350 kg
(xii)	Heifers (Slaughter) - weight	300 kg
(xiii)	Culled cows - weight	400 kg
(xiv)	Replacement rate	26.5%
(xv)	Heifers (Sterility)	7%

TABLE 36. Gross Margin of the Ayrshire -Friesian - Sahiwal Herd at Mariakani

Description	Quantity	Price (Ksh.)	Units	Amount (ksh)
Revenue				
Milk	905kg	15/kg	83 Cows	1,126,725.00
Bull calves	177 kg	30/kg	15 Bull calves	79,650.00
Steers	450 kg	50/kg	10 Steers	225,000.00
Heifers(Breeding)	350 kg	45/kg	4 Heifers	63,000.00
Heifers (Slaughter)	300 kg	40/kg	2 Heifers	24,000.00
Culled Cows	400 kg	35/kg	20 Cows	280,000.00
Total Revenue				**1,798,375.00**
Cost				
Minerals	4,052kg	6.70/kg	10kg bag	27,148.40
Veterinary Cost*	111LU*	5/LU/day	365 days	202,575.00
Running Costs (Operation)	111 LU	3.50/LU/day	365 days	141,802.50
Labour	111LU	9/LU/day	365 days	364,635.00
Overhead Costs	111 LU	10/LU/day	365 days	405,150.00
Total Cost				**1,141,310.90**

= Gross Margin = Ksh. 657,064.10

Gross Margin/Livestock unit/Year = Kshs 5,919.49

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 450kg**

4.3.10 Ayrshire - Brown Swiss - Sahiwal Herd at Kilifi

Productivity Estimates

(i)	Average Milk yield	3,649.38 ± 1092.95 kg
(ii)	Average lactation length	328.11 ± 67.87 days
(iii)	Average calving interval	405.52 ± 69 .17 days
(iv)	Annual milk yield	

$$\frac{3{,}649.38 \times 365}{405.52} = 3284.73 \text{ kg}$$

(Less 25% milk fed to calves) milk sold = 2464kg/cow/Year

(v)	Number of cows	650
(vi)	Survival rate	99.20%
(vii)	Calving rate	90.12%
(viii)	Livestock Units	1485
(ix)	Steers - weight	450 kg
(x)	Heifers (breeding) - weight	350 kg
(xi)	Heifers (Slaughter) - weight	350 kg
(xii)	Culled cows - weight	400 kg
(xiii)	Replacement rate	26.5%
(xiv)	Heifers (Sterility)	2%

TABLE 37. Gross Margin of the Ayrshire -Brown Swiss - Sahiwal Herd at Kilifi

Description	Quantity	Price (Ksh.)	Units	Amount (Ksh)
Revenue				
Milk	2,464kg	15/kg	650 Cows	24,024,000.00
Heifers(Breeding)	350 kg	55/kg	68 Heifers	1,309,000.00
Heifers (Slaughter)	350 kg	40/kg	5 Heifers	70,000.00
Steers	450kg	50/kg	248 Steers	5,580,000.00
Culled Cows	400 kg	40/kg	170 Cows	2,720,000.00
Total Revenue				**33,703,000.00**
Cost				
Minerals	54,202kg	6.70/kg	10kg bag	363,153.40
Dairy Meal	355,875 kg	6/kg	70 kg bag	2,135,250.00
Early weaner pellets	54,840 kg	13.70/kg	70 kg bag	751,308.00
Veterinary Cost*	1,485LU*	5/LU/day	365 days	2,710,125.00
Running Costs (Operation)	1,485 LU	5/LU/day	365 days	2,710,125.00
Labour	1,485LU	8.85/LU/day	365 days	4,796,921.20
Overhead Costs	1,485LU	11.20/LU/day	365 days	6,070,680.00
Total Cost				**19,537,662.60**

Gross Margin/Livestock Unit/Year =Kshs 9,539.00. **Gross Margin = Kshs 14,165,438.00**

Remarks

* **Veterinary costs include costs of acaricide, pygrease, dewormers, drugs, vaccines and disinfectants.**

* **ILU = 450kg.**

4.4 Differences Between Breeds According to the Different Evaluation Criteria.

Three productivity indices were used to rank the herds: These were gross margin/year, gross margin/Livestock unit/year and gross return per unit dry matter intake (PRY) (Table 38). From the gross margin analysis, it was observed that the Sahiwal and Sahiwal crossbred production units were economically viable and profitable. On the basis of gross margin/year, profitability varied with the breed and herd size.

The gross margin tended to be higher for the larger production units and was low for the smaller production units and hence the ranking of the herds on gross margin per year was influenced by herd size. The Ayrshire-Brown Swiss- Sahiwal crossbred herd was ranked first and the tenth rank was taken by the smallest Friesian-Sahiwal herd at Naivasha with 33 livestock units. It should however be noted that the Friesian - Sahiwal herd at Naivasha was still being developed and has not been fully established.

When the gross margin/livestock unit/year was used to rank the herds, it was observed that there was a change in the ranking. Although the Ayrshire-Brown Swiss- Sahiwal crossbred herd retained the first rank, the second, third, fourth and sixth ranks were taken by the crossbred herds. It was interesting to note that the Friesian - Sahiwal herd at Naivasha moved from the tenth rank when gross margin per year was used to the fourth position when ranking was based on gross margin/livestock unit/year. This implies that the crossbred herds utilise resources efficiently. Although the crossbred herds were associated with high input levels, this was justified by the high production performance of the animals. Since the Sahiwal crossbreds combine hardiness and high productivity they were preferred for dairy ranching and surplus heifers for breeding were sold when they were pregnant at a price higher than for Sahiwal heifers and this accounted for the increased returns per livestock unit in a crossbred herd. The Sahiwal herd at Deloraine Estate had a high profit margin per livestock unit because of the combined milk and meat offtake, the inputs are low and since sound breeding programme is followed , the Sahiwal breeding stock are popular with the ranchers and the Sahiwal bulls were sold at the high price based on the market situation. Steers were fattened on pastures with minimum supplementation and sold when they had reached a slaughter weight of 450 kg. The Sahiwal herd at the National Animal Husbandry Research Centre at Naivasha took the seventh position. Sahiwal herds at Elkarama ranch and Ilkerin ranch were beef enterprises with low milk offtake and this lowered overall productivity of the herds.

In comparison with the economic feed energy efficiency, the gross return per unit dry matter intake derived by PRY for each herd, it was shown that when it was used as a ranking criteria, the ranks assigned to the herds were closely similar to the ranks when gross margin per livestock unit per year was used. Thus on the basis of gross return per unit dry matter intake, the crossbred herds took the five top ranks.

Correlation analysis showed that gross margin/livestock unit per year and gross return per unit dry matter intake were strongly related ($r = .85$, $P < .01$) and herds were similarly ranked ($r_s = .92$, $P < .01$) however, the relationship between gross margin/year and gross margin/livestock unit was not significant ($r = .08$, $P > .05$) and similarly the relationship between gross margin/year and gross return per unit dry matter intake was not significant ($r = .287$, $P > .05$).

From this correlation analysis it was evident that the ranking of the herds on gross margin/livestock unit/year and gross return per unit dry matter intake was fairly close. The difference between the two measures of herd productivity was that whereas gross return per unit dry matter intake emphasises only feed energy intake, gross margin per livestock unit per year took into account the feed cost which included energy, protein, mineral and vitamin intake and other components of the production cost such as veterinary, labour, operational cost and overhead costs. Therefore in production systems, where feed energy intake accounts for a small proportion of the cost, then the gross return on the dry matter intake required by a livestock unit per year provides a basis from which other components of the production cost can be derived to obtain a correct estimate of the net return per livestock unit per year.

TABLE 38. Ranking of Breeds According to Different Evaluation Criteria

Ranch Name	Breed	Herd Size (LU)	Gross Margin/Year (Ksh)	Rank	Gross Margin/ LU/Year (Ksh)	F
NAHRC/NSA	Sahiwal	566	3,057,367	2	5,401	
NAHRC/NSA	Friesian - Sahiwal	33	241,749	10	7,326	
Loldia	Friesian - Sahiwal	254	1,909,483	4	7,517	
Oljorai	Sahiwal	104	509,741	9	4,901	
Deloraine	Sahiwal	233	1,601,946	5	6,875	
Deloraine	Ayrshire - Sahiwal	158	1,372,978	6	8,689	
Elkarama	Sahiwal	469	2,212,319	3	4,717	
Ilkerin	Sahiwal	181	548,429	8	3,029	
Kilifi	Ayrshire-Brown Swiss-Sahiwal	1485	14,165,438	1	9,539	
Mariakani	Ayrshire-Friesian-Sahiwal	111	657,064	7	5,919	

5. DISCUSSION

5.1 Survival Rates

High survival rates are important in cattle production systems in order to ensure regular supply of replacement heifers and to provide males for subsidiary beef enterprises and for sale as breeding stock. High calf mortality leads to the loss of good combination of desirable genes and reduces intensities of selection of economically important traits and by increasing the generation interval, annual genetic gain is reduced. Of the ten herds investigated, survival rates were influenced by breed, feeding and management system. Pre-weaning mortality rates were high (10-25%) in the Sahiwal herd at Naivasha and Ol Jorai. For similar sex and age group of the Sahiwal herd at Ilkerin-Loita and Elkarama Ranch, mortality rates ranged from 3-5%. Mortality rates of the Friesian-Sahiwal herd at Naivasha were 11% and were lower than mortality rates of the Sahiwal herd at the same farm. For crossbred calves under dairy production systems, mortality rates were less than 10%.

The lower mortality rates of crossbred calves was due heterosis. Crossbred calves were more vigorous and less susceptible to endemic diseases. This was in agreement with Cartwright (1973) who reported that crossbred Hereford-Brahman calves had a survival advantage of 15% over the average of the purebreds. The high pre-weaning calf mortality observed in this study was supported by an earlier study on Sahiwal and crossbreds by Trail and Gregory (1982). Studies in Egypt by Asker and El Itriby (1957) showed that 70% of the calf losses occurred before calves reached 6 months of age. The causes of calf losses were stillbirth, diarrhoea, pneumonia and accidents (NSS, 1992) and similar causes were reported for calf losses in other Sahiwal herds covered by the study.

The Sahiwal and Friesian-Sahiwal calves at Naivasha and Sahiwal calves at Ol Jorai were bucket-fed . The high calf mortality due to diarrhoea indicated that sanitary conditions of the feeding equipment were not satisfactory. It was likely that the milk fed was cold and this resulted in cases of diarrhoea. The high incidence of pneumonia in the two herds was evidence that calf houses were poorly ventilated and this combined with poor sanitation caused high mortality. It was further observed that deworming of calves was not done regularly and calves were in poor body condition as a result of helminthic infection. For similar age and sex group at Elkarama and Ilkerin-Loita, the mortality rates ranged from 3-5% and this was because calves were suckled, were regularly dewormed and housed at night.

Crossbred calves at Loldia and Deloraine were bucket-fed and at Kilifi calves were nipple-fed. Sanitary conditions were satisfactory. In addition calves were supplemented with calf early weaner pellets. Calves were also regularly dewormed. This high level of feeding and management accounted for the high survival rates of over 90%.

5.2 Reproductive Performance

Reproduction in cattle is of major importance as it produces herd replacements and also serves to initiate milk flow. Thus for high overall returns per cow, a long life, regular reproduction and a minimum of non-productive periods are essential. The traits related to reproductive performance are age at first calving and calving interval .

5.2.1 Age at First Calving

Age at first calving depends not only on the growth rate achieved by calves but is also influenced by management policies with regard to weight and age at first service. To increase the productive life of cattle, heifers should be raised properly by applying good husbandry practices so that they can reach puberty and safe calving size at an early age. In this study the main factors affecting age at first calving were breed and management system. The Sahiwal heifers at Elkarama Ranch calved first at an early age of 36 months and they were 3 months younger than in a previous report on the same herd by Trail and Gregory (1981) which covered the period from 1964- 1974. The improvement in age at first calving in later period was attributed to supplementary feeding of animals on Rhodes grass hay, cotton seed cake and home-made mineral mixture. With this feeding regime and matching of stocking rate to forage available, heifers maintained steady growth rate. This clearly demonstrated that the Sahiwal can respond to supplementary feeding. However, for most Sahiwal herds heifers were unsupplemented with concentrate and growth rate was less than 300g/day. This resulted in delayed service age and weight and heifers calved first 4-10 months later than 36 months. It was observed that the Deloraine Sahiwal herd which was provided with mineral supplementation, heifers calved first at 44 months of age. This was close to what Trail and Gregory (1982) reported in an early study on the same herd and this has shown that there has been no improvement on age at first calving. The trend as observed in other ranches has been a deterioration in the production environment with limited feed supply in later years caused by increased stocking rates as grazing land has been allocated to other farm enterprises. Similar observations were made on the Ilkerin-Sahiwal herd which in a previous report by Gregory and Trail (1981a) age at first calving was 38.23 months and in the present work the age at first calving has increased by 8 months. This was attributed to nutritional stress resulting from increased stocking rate.

For the Sahiwal heifers at Naivasha, the age at first calving has been increasing indicating a decline in growth rate in the period 1963-1986 and this has been as a result of inadequate feed. This was due to frequent occurrence of drought in 1976, 1980 and 1984, increased stocking rate and limited feed supply (Mwandotto,1985).

The Sahiwal herd at Oljorai which was unsupplemented except for mineral supplementation growth rates were low and heifers calved first at 47 months of age. This delayed age at first calving was because the heifers required time to grow to reach the service weight. The Sahiwal and crossbreds at Mariakani have maintained steady growth rates despite the lack of concentrate supplementation as shown in the present study in which the age at first calving was close to the average age at first calving in a previous report by Mwandotto ***et al.*** (1990).

For the dairy crossbreds, calves after weaning were grazed on good quality pastures and were supplemented with calf early weaner pellets to maintain a steady growth rate of 600g/day. Furthermore, calves were regularly dewormed. Crossbred heifers grew faster and attained the required service weight and age, were served and calved first at an early age 1-2 month earlier than 36 months. However the Ayrshire - Sahiwal heifers at Deloraine calved first 2 months later than 36 months due to inadequate feeding. With regard to the Kilifi crossbred herd, heifers have maintained steady growth rates as shown in the present work in which age at first calving was similar to the previous report by Gregory and Trail (1981b).

These findings demonstrated that by crossbreeding the Sahiwal with the Ayrshire, Friesian and Brown Swiss , age at first calving was improved. According to the literature, the results were in agreement with observations by Bhat ***et al.*** (1978) in India who reported that crossbreeding the Sahiwal with Friesian produced crossbreds which calved first at a younger age than the Sahiwal. Although the age at first calving of the Sahiwal was 40.3 months, the half-bred Friesian - Sahiwal heifers calved at an age of 34.78 months, a decrease of 5.52 months. A similar study by Osman and Russell (1974) in Sudan involving crossbreeding of the Butana cattle and Friesian showed that half-bred Friesian - Butana calved first at an age of 34.2 months. Furthermore, Kiwuwa ***et al.*** (1983) reported that crossbreds of the exotic breeds (Friesian and Jersey) with indigenous Zebu cattle in Ethiopia calved first between 33 - 35 months. From these studies it was evident that the ***Bos indicus*** cattle which include the Sahiwal and indigenous Zebu cattle have low inherent

growth rate and reach puberty late compared with their crossbreds with ***Bos taurus*** cattle which have high growth rates and reach puberty early to calve at a younger age.

It has been observed that when heifers are maintained on low planes of nutrition , as in the case of dry season , puberty is delayed (Day ***et al.,*** 1986). It was shown that delays in puberty on low plane of nutrition was due to restriction of dietary energy intake which retarded the prepubertal rise in secretion of luteinising hormone. The prepubertal increase in luteinising hormone is essential to stimulate increased ovarian production of estradiol to levels high enough to induce the first preovulatory secretion of gonadotropins.

5.2.2 Calving Interval

Calving interval is the period between two consecutive parturitions and the optimal calving interval is 12 months. In this study the major factors affecting calving interval were breed, feed availability and management system. It was observed that the calving interval of the Sahiwal ranged from 14 to 17 months Table 24, Ayrshire Sahiwal 15 to 17 months, Friesian Sahiwal 15 months. For the Sahiwal herd at Elkarama Ranch which was supplemented with Rhodes grass hay, cotton seed cake and home- made mineral mixture the calving interval was 408 days(13 months). In a previous study of the same herd by Trail and Gregory (1981) the average calving interval was 390 days and this was close to the average calving interval reported in the present study. Provision of concentrates and mineral supplementation greatly improved fertility of the herd. This showed that cows after parturition were able to get adequate energy, protein and minerals from supplementation and this promoted liveweight gains, involution of the uterus and resumption of oestrous activity (Hansen and Hauser, 1983). When cows are gaining weight after parturition, the postpartum oestrus period is reduced as oestrus activity resumes early and cows are served and conceive within 100 day postpartum.

The reduced postpartum breeding interval decreased the calving interval. (Holness ***et al.*** 1984) have shown that when dairy cattle are adequately fed prior and after calving they are in good condition to conceive within a short period of time.

The Ilkerin Sahiwal herd was provided with mineral supplementation without concentrates, fertility was low as indicated by the long calving interval which was 3.6 months higher than 12 months. However in a previous study, Gregory and Trail (1981a) reported shorter calving interval than in the present study. This has shown that there has been a decrease in fertility in the herd due to inadequate nutrition as a result of a decrease in quantity and quality natural pastures.This has been caused by the increase in stocking date and wildlife on the ranch.

The dual purpose herds at Deloraine, Ol jorai, Naivasha and Mariakani had long calving intervals which ranged from 14 to 17 months. The relatively low fertility in these herds was because they were grazed on natural pastures without dairy meal supplementation. Mineral licks were provided when available. Lack of concentrates supplementation adversely affected fertility of the herds. In the dry season natural pastures were of poor quality and the dry matter intake was inadequate for maintenance, production and reproduction. Cows calving in the wet season with good quality pastures had shorter calving intervals than cows calving in the dry season with poor quality pastures.

Although the Ayrshire -Sahiwal crossbred herd at Deloraine was provided with dairy meal and mineral supplement, fertility was low as indicated by the long calving interval of 512 days. This was higher than the average calving interval of 382 days reported in an early study (Trail and Gregory, 1982). The results of the present study showed that fertility has decreased in the herd due to inadequate feeding and lactation stress because over the same period there has been a corresponding increase in milk yield by 147 percent over the milk yield in the earlier period from 1974- 1977. However, the Friesian-Sahiwal herd at Loldia which was similarly provided with dairy meal and minerals, fertility was better than the Ayrshire- Sahiwal herd at Deloraine. The calving interval of the Friesian -Sahiwal herd at Loldia was 85 days shorter than the average calving interval of the Ayrshire- Sahiwal herd at Deloraine. The difference in fertility between the two herds which were supplemented and grazed on improved pastures may be due to difference in quality and quantity of the feeds.

The Ayrshire-Brown Swiss-Sahiwal herd at Kilifi plantations was supplemented with dairy meal and minerals and herd fertility was higher than the Friesian-Sahiwal herd at Loldia. The Kilifi herd grazed pastures of Panicum species and Rhodes grass which were of high nutritive quality.

With regard to crossbreeding of the ***Bos indicus*** and ***Bos taurus*** breeds , it was shown that crossbreds had shorter calving intervals than the ***Bos indicus*** breeds. These results were supported by previous research by Bhat ***et al.*** (1978) who reported that whereas the calving interval of the Sahiwal was 14.31 months, there was a remarkable improvement in the calving interval of the half-bred Friesian - Sahiwal which was 12.76 months, a decrease of 1.55 months (11 percent). In a similar study (Osman and Russell, 1974) involving the Butana cows and Friesian - Butana crossbreds in Sudan, it was observed that

the calving interval of the Butana cows was 16.20 months, whereas the calving interval of the crossbreds was between 14 - 15 months. However, among the crossbreds, calving interval tended to increase with increase in Friesian inheritance. Moreover, Kiwuwa ***et al.*** (1983) have observed a similar trend of the calving interval in a study involving indigenous Zebu cattle of Ethiopia and their crossbreds with Friesian and Jersey. In this investigation, it was shown that although the calving interval of the indigenous Zebu cattle was 15 months, the calving interval of the half-breds decreased to 13.1 months.

5.3 Milk Production

The profitability of a dairy enterprise depends on the use of adapted and productive animals that will efficiently utilise the available feed resources to produce high milk yield of satisfactory composition relative to maintenance cost. In this study factors affecting milk yield were breed, feed availability and management system. The dual purpose Sahiwal and crossbred herds had the lowest herd average milk yield which was 1300 kg because there were not provided with dairy meal and mineral supplementation was not provided regularly. Cattle depended on natural pastures as a major source of nutrients. The quantity and quality of pasture grasses was influenced by rainfall amount and distribution. The seasonal variation in pasture quality affected animal performance.

In the dry season lactating cows lost body weight and the body condition was poor and milk yield decreased. In the Friesian-Sahiwal herd at Naivasha, the average milk yield in the dry season decreased by 10% from the herd average milk yield. This decline in milk yield and poor body condition in the dry season indicated that the dry matter, energy and protein intake were inadequate to meat the animal requirements for maintenance and production. The mean annual milk yield trends showed a decline in milk production in the herds over the years except for the Sahiwal herd at Deloraine estate and the Sahiwal and its crossbreds at Mariakani which showed a relatively low but positive upward trend. The reliance of dual purpose herds on rain-fed natural pastures needs to be re-examined in view of the need to extract more products from the production systems.

The decrease in grazing land by increasing stocking rate, bush encroachment and wildlife have contributed to decreased carrying capacity of some ranches in the later years. Hence there is need to adjust stocking rate to match with the feed resources.

The dairy crossbred cows grazed on good quality improved pastures and were supplemented with dairy meal and minerals. This resulted in high yield of 2,900 kg in a lactation. Because of dairy meal supplementation, the seasonal effect had no effect on milk yield of the Friesian-Sahiwal herd at Loldia and the Ayrshire-Sahiwal herd at Deloraine. However, the season of calving significantly affected milk yield of the Ayrshire-Brown Swiss-Sahiwal herd at Kilifi. Milk yield was higher in the dry season than in the wet season. This was attributed to the low dry matter intake in the wet season when moisture content of pastures was high, whereas dry matter intake was high in the dry season as moisture content was low. Although animals were given supplementary feed rich in energy and protein, the dry matter intake did not make up for the deficit from forage in the wet season. The mean annual milk yield trends have shown an increase in milk yield over the years for the Ayrshire-Sahiwal herd at Deloraine and the Ayrshire-Brown Swiss-Sahiwal herd at Kilifi. This was attributed to the improvement in genetic composition by using genetically superior sires and matching feed resources with stocking rate. However the Friesian-Sahiwal herd at Loldia showed a decrease in milk yield over the years, this was due to the decrease in the amount of dairy meal given to the cows as a result of increased feed cost.

It was observed that crossbreeding of the Sahiwal with the Friesian, Ayrshire and Brown Swiss resulted in a remarkable increase in milk yield. Compared to the Sahiwal herd at Naivasha, the Friesian - Sahiwal crossbred herd at Naivasha without supplementation the milk yield increased by 38%, for the Ayrshire -Sahiwal herd at Deloraine milk yield increased by 56% on supplementation, the milk yield of the Friesian-Sahiwal herd at Loldia increased by 80% on supplementation. The milk yield of the Ayrshire-Brown Swiss- Sahiwal herd at Kilifi increased by 131%.

The Friesian-Sahiwal crossbreds were 24% more productive than the Ayrshire-Sahiwal Crossbreds. The three-breed crossbred at Kilifi was obtained by crossbreeding the Ayrshire - Sahiwal cows with Brown Swiss sires. The incorporation of the third breed enhanced the retention of heterosis and this resulted in increased productivity. The production of the three-breed crossbred can be sustained by an intensive feeding regime involving good quality pastures, concentrates and minerals. This crossbred is suitable for the coastal strip where there is high demand for milk and there is good transport and efficient animal health services. Increased milk production with crossbreeding has been reported by Bhat ***et al.*** (1978) who showed that whereas the Sahiwal produced an average milk yield of 1611 kg by crossbreeding with the Friesian, milk yield increased to 2,192 kg and increase of 36% for the half-bred Friesian Sahiwal.

5.4 Herd Productivity

Productivity of the herds varied with the breed and management system . The low productivity of the Sahiwal beef herds under extensive management systems was because cattle offtake was the only major product . Surplus milk was used for subsistence on the ranch. In the Sahiwal herds at Ilkerin -Loita and Elkarama ranch , a great proportion of the income was obtained from sale of steers , breeding bulls, culled cows and surplus heifers. The average cattle offtake was 27.5% and this generated over 90 per cent of the total income. For the two beef herds , average calving rate was 80% . Preweaning and post weaning survival rates were 90% more calves were raised and this accounted for the high offtake rate.

However, the limited marketable products reduced the production efficiency of the two herds. Evaluation of the herds using PRY showed that they generated an average of Kenya Shillings 3,325 for every ton of dry matter consumed. This was a low level of productivity and was 36% less than for the productivity of dual-purpose herds. Ilkerin-Loita and Elkarama Ranch are located in areas with poor infrastructure and roads are impassable in the wet season and this limits the sale of milk and dairy products. Since PRY does not account for input costs ,other than feed energy, gross margin analysis of the Sahiwal beef herds showed that veterinary inputs accounted for 32% of the total variable costs. Drugs and vaccines were required to control endemic diseases which are prevalent because in the two ranches cattle interact with wildlife. Vaccinations against foot and mouth disease, blanthrax, rinderpest, lumpy skin, brucellosis, contagious bovine pleuropneumonia(CBPP) were done regularly. Cattle were dipped weekly to control ticks. Deworming was done regularly to control helminthic infections. The high input in veterinary drugs and vaccines reduced gross margins. Dual purpose Sahiwal and crossbred herds were grazed on natural pastures and supplemented with minerals, though not regularly. Since the herds were located in areas with good transport and market, the dairy component made a significant contribution to the total income. The herd average milk yield of the dual purpose herds was 1,3000 kg per lactation. This production level was proportional to the inputs into the production systems. The seasonal availability of good quality pastures and lack of dairy meal were the causes for the low milk production. For dual purpose herds average calving rate was 80%, fertility was affected by lack of concentrate feeding, particularly in the dry season when pastures were of poor quality. Average cattle offtake rate was 22% and this was low compared to the herd size and was due to high preweaning calf mortality which ranged from 10-20%.

For herds with good health care and adequate feeding, the average offtake rate was 26%. Other than milk, additional income was obtained from sale of culled cows, steers, breeding bulls and surplus heifers. Herd productivity assessment using PRY showed that dual-purpose herds generated an average of Kenya Shillings 5,200 for every ton of dry matter consumed. Overall productivity of the dual-purpose herds was 35% less than the overall productivity of the dairy crossbred herds. This was because of the low production levels of milk and liveweight per animal and this reduced the quantity of saleable products from the herd. Gross margin analysis of the herds indicated that labour accounted for 38% of the total variable costs. It should be noted that the dual-purpose herds except for the Sahiwal herd at Deloraine were on parastatal farms where operations are labour intensive. Labour is required for milking cows, feeding calves, herding and keeping livestock records. Computerisation of data processing can reduce the number of recorders. Repair of fences of the paddocks eliminates the need for herding. Machine milking of crossbred cows could save on labour costs and increase returns.

Dairy crossbred herds were rotationally grazed on improved pastures and were supplemented with concentrate and minerals. Dipping and deworming were done regularly. Because of good health care, preweaning survival rates were high and more calves were raised. Supplementation of Young stock with calf-early weaner pellets resulted in fast growth rate and heifers attained service weight and age early and were served and calved first at a younger age of less than 36 months. Crossbred cows had better fertility as indicated by shorter calving intervals of less than 14 months. The herd average milk yield was 2,900 kg per lactation. The dairy component was well developed and milk offtake accounted for 75% of the total income. The crossbred herds were located in areas with good transport and a reliable fresh milk market. The cattle offtake rate was 25% and this was a result of high calving rate and survival rate. The increased milk and cattle offtake significantly contributed to the high overall productivity of the dairy crossbred herds. On average crossbred herds generated Kenya Shillings 8,000 per ton of dry matter consumed. This was a high production efficiency.

Gross margin analysis of these herds showed that animal feeds accounted for 40% of the total variable costs. However for the Kilifi herd the feed cost was 17%, this was because ingredients were purchased for ration formulation on the farm. Sisal poles and waste and sea weed were obtained from the farm. This reduced feed cost and increased the gross margin of the herd.

It was observed that Sahiwal herds had lower productivity than the reference Sahiwal herd. This showed that Sahiwal herds were not fully exploiting the genetic potential of the Sahiwal from the National Sahiwal Stud at Naivasha. This was due to the low systems inputs and poor accessibility to markets for the products.

6. CONCLUSION

6.1 Profitability

For accurate productivity assessment, PRY was appropriate as it has the capability to evaluate productivity responses arising from changes in fitness and production parameters in the lifetime of the herd. Gross margin analysis is static and derives gross returns for a herd in one year. Fitness components are assumed and this increases the error margin in herd productivity assessment. However, gross margin is easy to compute and is used by farm managers to identify constraints in the enterprise and for comparing farm enterprises.

On the basis of gross returns per unit dry matter intake all the herds in the different production systems were profitable and profitability varied with breed, herd size, range of products and management system. The dairy crossbred herds were more profitable than Sahiwal herds. Among the crossbreds, the three-breed crossbred, the Ayrshire-Brown Swiss-Sahiwal at Kilifi Plantations had the highest overall productivity (167%) followed by Friesian-Sahiwal crossbreds supplemented (136%), Ayrshire-Sahiwal unsupplemented (113%), Dual purpose herds (66-100%) and Sahiwal beef herds (55-61%) based on the gross returns per unit dry matter intake of the Sahiwal herd at Naivasha as a reference herd.

It was evident that management of dairy crossbreds was adequate and the high level of inputs was sufficient for increased animal performance. Hence survival rates, growth rates, calving rates and milk production were high. This resulted in increased cattle and products offtake. For dual -purpose herds, the management and level of inputs were intermediate and this accounted for the relatively low productivity of these herds which was less than for the dairy crossbreds.

With regard to Sahiwal beef herds the level of inputs except for veterinary drugs was low. Cattle were extensively grazed on natural pastures and supplemented with minerals. Cattle offtake was the major product from beef production systems.

6.2 Production systems

From the analysis and evaluation of productivity of the breed types in the different production systems and taking into consideration the constraints, it was evident that cattle were bred to be efficient in specific environmental and management situations. If the genotype of the animal is matched with systems inputs and market demand for products from the production system, then remote ranches with poor transport and with no fresh milk market, the Sahiwal is the breed of choice for the beef production system.
Dairy production systems based on crossbred cows should be located where there is a reliable market for milk and dairy products. With good transport, available animals feeds and efficient animal health services crossbred cows are recommended for potential groups of small holder farmers in peri-urban areas of Naivasha, Nairobi, Machakos, Mombasa , Kisumu and Kakamega who can keep few cows for milk production under intensive management systems.

Beef production systems were less profitable than dual-purpose production system and this was because the efficiency of conversion of feed energy to milk is much higher than to meat, furthermore, dual-purpose production systems yielded more products from the available resources than from the beef production system. The offtake of animals and products can be improved by using suitable genotypes, better feeding and health care. To improve beef production efficiency it is important that the optimal final weight for the breed types in different production systems is determined and its relationship with carcass quality.

To enhance herd productivity, it is important that manure and draft power are commercialised. Manure can be applied to crops, pastures and fodders for increased productivity. With regard to draft power, oxen can be used to pull ox-cart for transportation of milk to the dairy from the paddocks where cows are milked. Oxen can be used to pull ox-plough for land preparation for crops and fodder production. Use of oxen for transportation can greatly reduce operation costs on fuel.
It is imperative that for the efficient functioning of the production systems, it is necessary to improve rural infrastructure in terms of clean water for cattle and for milk handling and processing. Better roads and transport are required for milk and dairy products so that they can be sold in lucrative urban markets.

6.3 Management and feeding

The major constraints to increased cattle productivity in the different production systems were high calf mortality, slow growth rate, poor fertility and low milk yield levels and low animal and products offtake. The causes of these constraints were inadequate feeding, poor management and diseases. For sustainable cattle enterprises in marginal areas, available feed resources should be properly utilised. Overgrazing should be avoided by adjusting stocking rates to match the feed resources. Watering points should be evenly distributed in the grazing area to facilitate proper usage of pastures. Production efficiency of the herd can be increased by supplementary feeding of calves and cows. supplementation of calves improves growth rates and survival rates. Cows supplemented with concentrates and minerals have better fertility and increased milk production.

Calf losses can be minimised by providing adequate, well ventilated and clean housing which protects calves from rain, heat, wind, cold and draughts. Effective disease control should emphasis preventive disease control measures which include vaccination, dipping and deworming. Curative treatment should be the last option.

6.4 Crossbreeding Systems

The increased productivity of the Sahiwal crossbred herds has demonstrated that genetic effects can be fully exploited in marginal areas of Kenya under extensive grassland conditions by systematic use of crossbreeding systems to achieve a permanent improvement in growth potential and milk production.

To sustain genetic improvement of the synthetic crossbreds in marginal areas, nucleus breeding herds should be established at the Research centres, state farms and individual ranches for further genetic improvement through selection and to produce breeding stock for commercial herds. It is important that attention is given to the development of a breeding concept for increasing the total productivity of crossbreds. This breeding strategy should have the long-term effect of establishing dairy production in medium potential areas of Kenya. The high milk production potential of the crossbreds if fully exploited should make the country self - sufficient in milk and dairy products.

6.5 Future Research

Since dual-purpose production systems are increasing and there are highly variable even within the same agro-ecological zone, it is important that a methodology is developed to define productivity parameters and standardised procedures for estimating the parameters to enable comparison of different breeds used. This is important in order to identify appropriate genotypes which can efficiently utilise forage resources, crop residues to produce milk and meat at an affordable price to enhance the nutritional quality of the citizens of Kenya.

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APPENDIX 1

QUESTIONNAIRE 1. FARM SURVEY DATA

FARM NO. **OWNER NAME AND ADDRESS**

....

.....

.....

1. FARM LOCATION:

2. AGRO-ECOLOGICAL ZONE:

3. ALTITUDE:

4. FARM SIZE:

5 LAND TENURE SYSTEM:

6. FARM ENTERPRISES:

i).....
ii).....
iii).....

7. i) AREA UNDER CROPS.....Ha
ii) AREA UNDER PASTURES AND FODDER CROPS.....Ha

8. AREA FOR LIVESTOCK ENTERPRISES.....Ha

i) TYPE OF PASTURE GRASSES:

i.....
ii.....
iii.....

ii) TYPE OF FODDER CROPS:-

i.....
ii.....
iii.....

9. BREED TYPES:

i,

ii,

iii,

iv,

v,

10. CLASSES OF CATTLE:

a) Mature Stock

I) Type of Management System:-

ii) Type of Animal feeds used:-

iii) Supplementary feeding:-

b) Weaner Stock

i. Management System:-
ii. Type of Animal Feeds:
iii.Supplementary feed:-

c) Calf Rearing

i Management System:-

ii. Feeding Regime:-

iii Supplementary feeding:-

11. HEALTH MANAGEMENT

Availability of Vet. Services:

i) Field Vet Services

ii) On-farm Vet. Staff

iii) or both

11.1 Prevalent diseases on the farm:

i.).....

ii).....

III).....

iv).....

v).....

11.2 Routine Vaccinations:

i) F M D

ii) Rinderpest

iii) Blanthrax

iv) Brucellosis

11.3 Tickborne disease control:

i) Frequency of dipping.....

ii) Acaricide used:.....

11.4 Deworming:

i) Frequency of deworming

Young stock:-

Mature stock:-

ii) Dewormer used:-

11.5 Breeding:

i. Seasonal

ii. Throughout the year

Method used: i. AI

ii. Natural Service

If (ii) No. of Cows/Bull.....

12. LABOUR AVAILABILITY

i. Number of permanent workers.....

Daily wage rate.....Ksh.

ii. Number of Casual workers

Daily wage rate .....Kshs.

13. MARKET OUTLETS:

I.

ii.

iii.

iv.

14. TRANSPORT NETWORK:

I. Roads.....

ii. Railway.....

15. CREDIT INSTITUTIONS:

I.

ii.

iii.

iv.

16. **Herd Structure and Size**

	FEMALE	MALE	% OF THE TOTAL HERD
CALVES:			
0-3			
4-6			
7-12			
WEANER STOCK			
12-18			
19-24			
LACTATING COWS			
1ST CALVERS			
2ND CALVERS			
3RD AND OVER			
DRY COWS			
1ST CALVERS			
2ND CALVERS			
3RD CALVER AND OVER			
BULLS			
12-24			
25-36			
36 AND OVER			

17. Farm Inputs

TYPE OF INPUTS	SOURCE	UNIT	TOTAL PRICE	TOTAL COST
a) Animal Feeds				
i. Dairy meal				
ii.) Hay				
ii) Silage				
Iv) Mineral Licks				
b) Vet Services				
c) Drugs and Vaccines				
i. Acaricide				
ii. Antibiotics				
iii. Vaccines				
d) Fertilisers:				
i. Fodder Crops				
ii. Pasture Crops				

18. Farm Produce

TYPE OF PRODUCE	NO. OF ANIMALS	QUANTITY/ ANIMAL	TOTAL PRODUCED	UNIT PRICE	REVENUE KSHS
a) Milk					
i. Whole milk					
ii. Skimmed Milk					
iii. Butterfat					
b) Animals for Slaughter					
i. Young stock					
ii. Mature stock					
c) Animals for breeding					
i. cows					
ii. Bulls					
d) Hides and skins					
e) Manure					

19. Rainfall Data(MM)

FARM NO:

ALTITUDE:

VEGETATION:

	YEAR										
JAN											
FEB											
MAR											
APR											
MAY											
JUN											
JUL											
AUG											
SEP											
OCT											
NOV											
DEC											
TOTAL											

QUESTIONNAIRE 2 . **Herd Productivity Data**

OWNER NAME AND ADDRESS.....

.....

.....

EN

NA

FARM NO.

COW NO	SIRE NO.	DAM NO.	BREED	DATE OF BIRTH	LACT NO.	PREVIOUS CAL/DATE	CALV DATE	LACT YLD KG.	LACT LENG DAYS

QUESTIONNAIRE 3. **Liveweight Records**

OWNER NAME AND ADDRESS

.....

.....

ENUMERATOR

NAME .....

ANIMAL ID NO.	BREED	SIRE NO.	DAM NO.	SEX	BIRTH WT (KG)	DATE OF BIRTH	WEANING WT. (KG)	DATE OF WEANING	YEARLING WT.(KG)	18 MONTH WT.

QUESTIONNAIRE 4 **Animal Disposal**

OWNER NAME AND ADDRESS.....

.....

.....

ENUMERATOR

NAME:.....

ANIMAL NO.	SIRE NO.	DAM NO.	SEX	DATE OF BIRTH	DATE OF DISPOSAL	REASON	AGE OF DISPOSAL (MO)

APPENDIX 2

TABLE 39. Analysis of variance of age at first calving, calving interval and lactation milk yield of the Sahiwal herd at Naivasha

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	1	1.2294	Season of Calving	1	64036.0235**	Season of Calving	1	159384.7287
Year of birth	23	614.2163**	Year of Calving	23	94284.6043**	Year of Calving	23	8302682.7478**
Season x year	23	29.7016						
Error	1983	22.28884	Parity	7	21056.0364	Parity	7	18185596.9532**
			Season x year	23	12377.5671	Season x year	23	480277.0192**
			Error	6517	10818.9706	Season x Parity	7	38550.6052*
						Regressions		
						Lactation length (Linear)	1	269171381.0606**
						Error	5716	182466.5506
R^2 =.258	R = .508		R^2 = .039	R = .199		R^2 = .407	R = .638	

* P<.05
** P<.01

APPENDIX 2

TABLE 40. Analysis of variance of age at first calving, calving interval and lactation milk yield of the Friesian -Sahiwal herd at Naivasha

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	1	14.2045	**Month of** Calving	10	8008.0232**	**Season of** Calving	1	789.785
Year of birth	9	15.750*	Year of Calving	15	4387.6215**	Year of calving	14	1797750.9170**
Error	27	5.8905	Parity	1	182.4663	Parity	1	3042320.6797**
						Regressions Lactation Length (Linear)	1	37550.8136
			Error	39	1988.530			
						Error	43	37550.8136
R^2 =.738	R = .859		R^2 = .681	R = .825		R^2 = .681	R = .825	

* P<.05
** P<.01

APPENDIX 2

TABLE 41. Analysis of variance of age at first calving, calving interval and lactation milk yield of the Sahiwal herd at Oljorai

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	6	51.6000	Month of Calving	11	29833.7656	Season of Calving	11	165152.1493
Year of birth	5	32.7267	Year of Calving	4	37534.7022	Year of calving	5	314820.6876
Error	7	14.9286	Parity	4	25086.7692	Parity	3	5018.5706
			Error	82	23227.9423	Regressions Lactation Length (Linear)	1	7149505.1426**
						Error	43	152301.8439
R^2 =.792	R = .890		R^2 = .252	R = .502		R^2 = .587	R = .766	

** P<.01

APPENDIX 2

TABLE 42. Analysis of variance of age at first calving, calving interval and lactation milk yield of the Sahiwal herd at Deloraine Estate

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	11	63.7066	Month of Calving	11	16717.5008	Season of Calving	11	46796.3293
Year of birth	12	349.2917	Year of Calving	12	86253.2235**	Year of calving	13	305080.6685**
Error	133	44.1569	Parity	4	82678.2915**	Parity	4	85627.20615
			Error	454	17635.5169	Regressions Lactation Length (Linear)	1	21234703.8055**
						Error	396	39785.7428
R^2 =.463	R = .680		R^2 = .226	R = .475		R^2 = .640	R = .800	

** P<.01

APPENDIX 2

TABLE 43. Analysis of variance of age at first calving, calving interval and lactation milk yield of the Ayrshire -Sahiwal herd at Deloraine Estate

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	11	8.4775	Month of Calving	11	25817.3387	Season of Calving	11	241268.9817
Year of birth	8	40.6417*	Year of Calving	8	25853.5928	Year of calving	7	1112291.8636**
Error	49	16.7897	Parity	5	25559.6885	Parity	5	208.3957.8779**
			Error	190	23789.9189	Regressions Lactation Length (Linear)	1	103553060.5352**
						Error	201	355526.3002
R^2 =.368	R = .606		R^2 = .133	R = .365		R^2 = .671	R = .819	

* P<.05

** P<.01

APPENDIX 2

TABLE 44. Analysis of variance of age at first calving and calving interval of the Sahiwal herd at Elkarama Ranch

	Age at First Calving			Calving Interval	
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**
Season of birth	11	8.4028	Month of Calving	11	9817.9090
Year of birth	12	126.4316**	Year of Calving	12	105251.2447**
Error	149	14.1369	Parity	6	49431.7729**
			Error	601	8079.1986
R^2 =.448	R = .669		R^2 = .300		R = .547
**	P<.01				

APPENDIX 2

TABLE 45. Analysis of variance of age at first calving and calving interval of the Sahiwal herd at Ilkerin Ranch

Age at First Calving			Calving Interval		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**
Season of birth	11	52.2654	Month of Calving	11	13302.7653
Year of birth	9	928.3611**	Year of Calving	9	101357.4347**
Error	151	75.1154	Parity	3	91138.0731**
			Error	337	188818.4437
R^2 =.486	R = .697		R^2 = .155		R = .394

** P< 01

APPENDIX 2

TABLE 46. Analysis of variance of Age at first calving, calving interval and lactation milk yield of the Sahiwal and Crossbreds at Mariakani Research Centre.

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Breed	2	172.6865**	Breed	2	22775.3111	Breed	2	10558179.5509**
Season of birth	11	35.7641	Month of Calving	11	20677.5955	Season of Calving	11	110275.3012
Year of birth	15	31.1643	Parity	4	14820.6085	Parity	4	778547.3159**
Error	165	24.0423	Year of Calving	17	35263.5231**	Year of calving	17	1497656.4525**
			Error	447	14927.8062	Regressions Lactation Length (Linear)	1	100860489.7614**
						Error	421	229087.5258
R^2 =.236	R = .486		R^2 = .123	R = .350		R^2 = .651	R = .807	

** P<.01

APPENDIX 2

TABLE 47. Analysis of variance of Age at first calving, calving interval and lactation milk yield of Ayrshire - Brown Swiss - Sahiwal at Kilifi Plantation

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	11	26.1325	Month of Calving	11	26386.2445**	Season of Calving	11	1100550.1847**
Year of birth	12	238.8403**	Year of Calving	9	38830.4047	Year of calving	9	38870874.6059**
Error	850	15.8367	Parity	6	8081.4488	Parity	6	53379028.8618**
			Error	2844	4543.4361	Regressions Lactation Length (Linear)	1	1425059513.4869**
						Error	2843	412786.7401
R^2 = .186	R = .431		R^2 = .059	R = .243		R^2 = .658	R = .811	

** P< .01

APPENDIX 2

TABLE 48. Analysis of variance of Age at first calving, calving interval and lactation milk yield of Friesian - Sahiwal Herd at Loldia Estate.

Age at First Calving			Calving Interval			Lactation Yield		
Source	**df**	**Mean Squares**	**Source**	**df**	**Mean square**	**Source**	**df**	**Mean squares**
Season of birth	10	17.0264	*Month of* Calving	11	29641.5053**	Season of Calving	11	513445.8052
Year of birth	5	49.1418**	Year of Calving	5	13511.5739	Year of calving	5	5602686.9676**
Error	43	13.3436	Parity	4	12963.2646	Parity	4	201346.5617**
			Error	175	9188.3397	Regressions Lactation Length (Linear)	1	83566781.2364**
						Error	194	758219.9192
R^2 =.414	R = .643		R^2 = .217	R = .466		R^2 = .498	R = .706	

** P<.01

APPENDIX 3

TABLE 49. Stationary - State offtakes and feed energy efficiency of the breeds in the Ranches

Offtake/Intake Result		Sahiwal Herd at Naivasha	Friesian - Sahiwal at Naivasha	Friesian- Sahiwal Herd at Loldia	Sahiwal Herd at Oljorai	Sahiwal Herd at Ilkerin
Value in Kenya shillings (Ksh) per lifetime						
Liveweight offtake	BF1)	8572.89	11733.85	14621.41	10033.69	13090.78
	SF 2)	2612.12	3738.54	4227.08	2744.47	3431.83
	M 3)	2947.59	3929.32	6408.08	3514.94	3761.12
Dairy Milk	BF	62955.91	103354.71	135084.11	45385.91	31472.14
Dry Matter Intake (Kg per lifetime)	BF	11200.52	15462.28	16224.19	12274.75	12780.25
	SF	1219.03	1502.37	1649.61	1369.82	1570.69
	M	1308.26	1536.52	2396.18	1696.67	1675.26
Life Expectancy	BF	5.78	6.60	6.33	7.11	7.92
Years of age per	SF	1.55	1.67	1.83	1.79	2.05
New Born	M	1.48	1.44	2.05	1.95	1.93
Frequency	BF	37	28	32	33	28
(% of newborns)	SF	13	22	18	17	22
	M	50	50	50	50	50
Total Output value (TOV) per animal - Year (Ksh)		9182.62	12005.92	15376.15	5637.38	4158.96
Dry Matter intake(DMI) per animal - year (kg)		1608.83	1856.11	1980.11	1412.12	1310.34
Stationary -State feed energy efficiency (TOV/DMI) in Kshs per Kg DMI		5.71	6.47	7.77	3.99	3.17

1. Breeding 2. Surplus female 3. Male

APPENDIX 3

TABLE 50. Stationary - State offtakes and feed energy efficiency of the breeds in the Ranches

Offtake/Intake		Sahiwal Herd at Deloraine	Ayrshire - Sahiwal herd at Deloraine	Sahiwal Herd at Elkarama	Sahiwal-Crossbreds herd at Mariakani	Ayrshire - Brown Swiss-Sahiwal herd at Kilifi
Value in Kenya shillings (Ksh) per lifetime						
Liveweight offtake	BF1)	10929.59	12935.47	13579.72	10804.64	13515.08
	SF 2)	3272.86	3934.05	4499.68	3822.17	3981.24
	M 3)	3996.56	4221.52	4998.90	4024.71	4664.26
Dairy Milk	BF	53112.23	133300.23	34877.20	81159.08	188640.03
Dry Matter Intake (Kg per lifetime)	BF	14634.47	18250.61	12471.47	12757.02	17877.72
	SF	1612.79	1854.66	1807.37	1881.92	1785.63
	M	1838.56	1924.65	1940.57	1907.11	1950.99
Life Expectancy	BF	8.42	7.78	7.32	6.50	6.37
Years of age per	SF	2.08	2.14	2.11	2.31	2.10
New Born	M	2.08	1.91	2.03	1.92	1.92
Frequency	BF	26	27	26	30	30
(% of newborns)	SF	24	23	24	20	20
	M	50	50	50	50	50
Total Output value (TOV) per animal - Year (Ksh)		5210.82	12033.67	4715.29	9076.13	19383.20
Dry Matter intake(DMI) per animal - year (kg)		1370.50	1784.34	1354.56	1535.47	2035.39
Stationary -State feed energy efficiency (TOV/DMI) in Kshs per Kg DMI		3.80	6.74	3.48	5.91	9.52

1. Breeding 2. Surplus female 3. Male