A GENETIC STUDY OF THE KENYA SAHIWAL BREED

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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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7/8/78

Date

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

PROFESSOR R.S. MUSANGI
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7/8/78
Date

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SUMMARY

A study of the production traits of the Kenya Sahiwal cattle was conducted with a view to obtaining reliable parameters for planning breeding programmes in this breed.

Altogether, 3993 normal lactation records of 1183 Sahiwal cows completed in the period 1963-1971 at the National Sahiwal Stud were included. The data were analysed by least squares procedures (Harvey, 1966).

The results of the analyses are summarised below:

a) The LSQ means for 305 day milk yield, fat percentage and fat yield were 1455 $\pm$ 10 kg, 5.00 $\pm$ 0.02 percent and 72.26 $\pm$ 0.57 kg respectively. These means are comparable to other Bos indicus herds in the tropics although the fat percentages were somewhat lower than those reported earlier in tropical cattle.

b) Milk and fat yields were influenced to a similar extent by age, parity, calving season and calving year. In all the cases the effects of these independent variables were highly significant.

c) Fat percentages were influenced by parity and year of calving but not by season of calving. The contribution to total variance of fat percentage by the above stipulated effects was small.

d) Different ways of classifying calving period were tested and found to reduce the error mean squares to a similar extent. However, the highest R^2 value was

obtained when each month of calving in each year was regarded as a separate season. Suitability of the different classifications is discussed.

e) The mean lactation length, dry period and calving interval were 274 ± 0.8, 149 ± 1.8 and 412 ± 1.4 days, respectively. Current lactation lengths influenced milk and fat yield without affecting the fat percentage significantly. Dry periods influenced all the three traits while calving intervals did not influence fat percentage when dry period and lactation length were included in the same model.

f) The mean weight at calving was 396 ± 0.97 kg. Weight increased steadily up to the fifth lactation and then stabilised. Milk yield was influenced by weight at calving while weight at calving itself was influenced by age at first and second calving, parity, calving period and sires.

g) Heritabilities were as follows:- Milk yield 0.23 ± 0.04 fat percent 0.16 ±0.04, fat yield 0.23 ± 0.04, lactation length 0.16 ± 0.03, dry period 0.19 ± 0.03, calving interval 0.08 ± 0.03 and weight at calving 0.50 ± 0.19. Repeatabilities as well as genetic and phenotypic correlations among the traits were calculated.

h) The current breeding plan at the National Sahiwal Stud was appraised using heritabilities and repeatabilities found in this study. It was concluded that at present, too small a section of the herd was used as a test herd. Young bulls were, as a result, inaccurately tested.

i) Alternative breeding plans were calculated and evaluated. Increasing herd size resulted in larger daughter groups per tested bull and higher numbers of young bull tested. The paths, bulls to breed young bulls and cows to breed young bulls, were found to account for most of the genetic progress in these plans.

Sahiwals are quite adapted to the semi-arid conditions that exist in Naivasha. When comparing cows that calved in different periods and at different ages, it is important to correct the data for variations due to these effects. Correction of the data for variations due to lactation lengths, dry period and calving interval is not recommended although milk and fat yields are influenced significantly by these effects.

The heritabilities, repeatabilities, genetic and phenotypic correlations obtained suggested that milk and fat yields can be improved through direct selection exclusively for milk. Fat testing does not seem to be warranted in this herd. In order to maximise genetic progress it is necessary to increase the herd size and to utilise a larger part of the herd for testing young bulls.

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1. INTRODUCTION

1.1 General

Sahiwals were introduced into Kenya in 1939 through the importation of bulls from India and Pakistan (Meyn and Wilkins, 1974). Crossbreeding with the local East African Zebu started then, and this was followed by up-grading to the Sahiwal in the livestock improvement centres (LICs). Mahadevan et al., (1962), reported on the benefits of this up-grading work.

In 1965, Mason recommended that all the good Sahiwals in the LICs be transferred to the then Naivasha Government Farm (Now National Animal Husbandry Research Station, NAHRS), where selection and further breeding work could be done (Mason, 1965). Sahiwals have been bred on this farm since. Parameters necessary for selection have been measured. Individual selection as well as progeny testing has been done on this farm, the latter only after 1969 when Dr. Klaus Meyn joined the NAHRS as their geneticist.

Apart from the NAHRS annual reports, no detailed studies giving information about genetic parameters in the herd are available. Zebu herds of the size of the National Sahiwal Stud, (NSS), which have official ancestry and production records are few. The facilities in the NSS have therefore provided a basis for a study of both genetic and non-genetic factors affecting the production of Zebu cattle in the tropics. It is also one of the few large herds of Zebu cattle where selection for milking temperament (including milking without calves at foot) has been done with some success. This selection has made it possible to carry out progeny testing for lactation milk yield, and the subsequent availability of progeny tested Zebu semen has generated considerable interest in the breed in the tropical world. To date, bulls have been exported to Burundi, Somalia, Tanzania and Zambia while the semen of the progeny tested Sahiwal bulls is in great demand within the country and for export to the above mentioned countries as well as to Bangla-Desh, Nigeria and Oman.

The main objective of conducting this study was to obtain reliable parameters for planning sound breeding programmes.

1.2 THE NATIONAL SAHIWAL STUD (NSS)

Meyn and Wilkins (1974) described the development of NSS in detail. Some general information on the environment in which the Sahiwals in the NSS performed, follows.

Geographical location and environment

Naivasha lies between $0^{0}40$ 'S and $36^{0}26$ 'E (see Fig. 1). Its altitude is 1900 meters above sea level and as such the climate although tropical is very much modified by altitude. Figure 2 and 3 show rainfall, and temperature-humidity indices. The amount, time and intensity of the rainfall is so variable that prediction is virtually impossible, although in general April, May and November are the wettest months.

Naivasha is a relatively dry area. Temperature-humidity indices calculated with data from the nearby Water Development Centre, (Fig. 3) show that the fluctuations are small and that they are below the levels in which cattle would experience stress due to combinations of high temperatures and humidities.

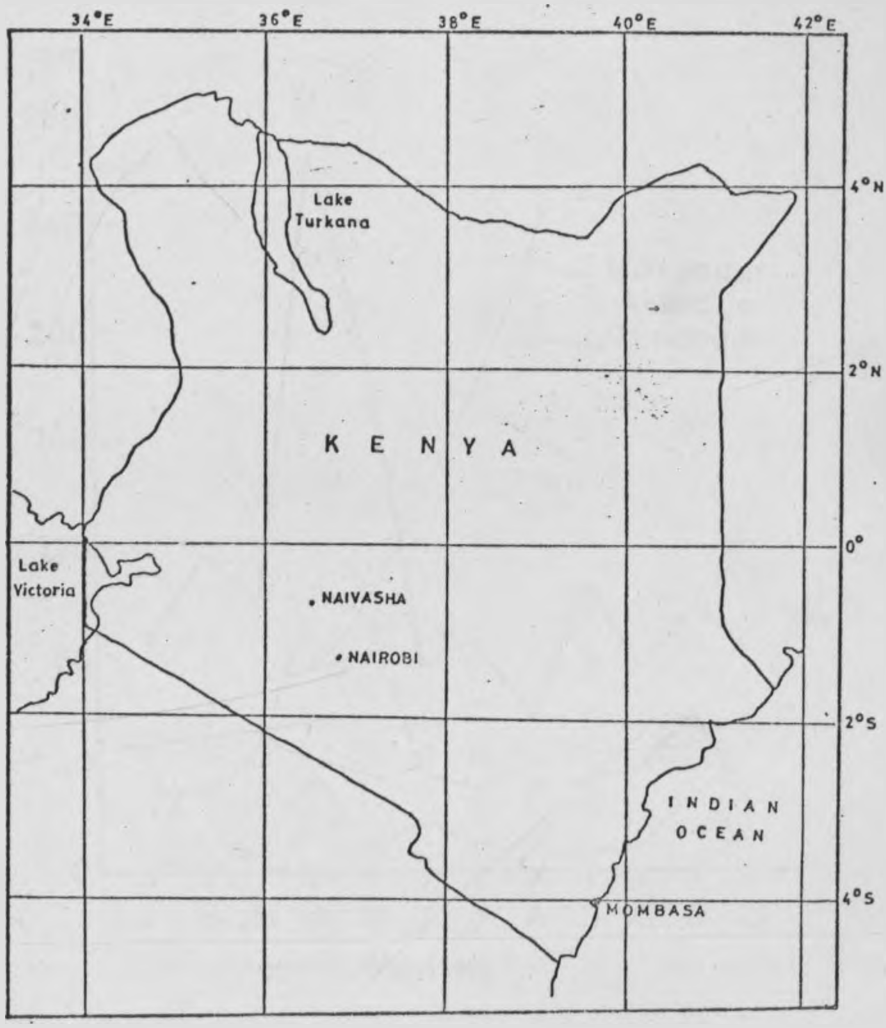

Fig. 1. Geographical location of the National Sahiwal Stud, Naivasha.

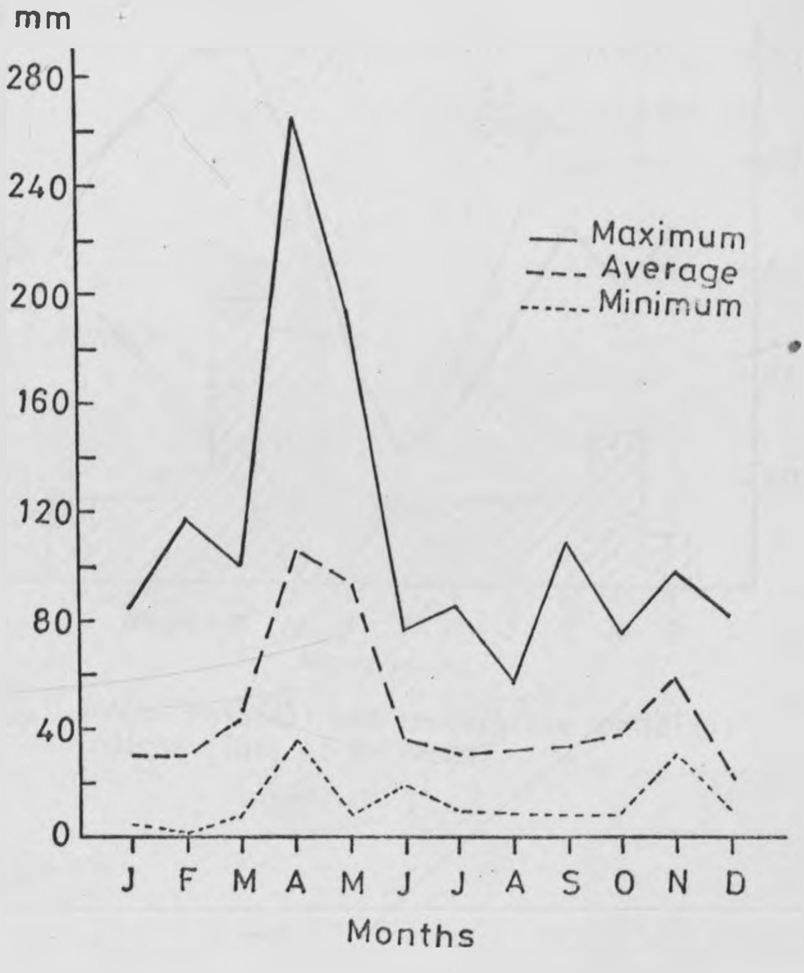

Fig. 2. Maximum, average and minimum rainfall at Naivasha.

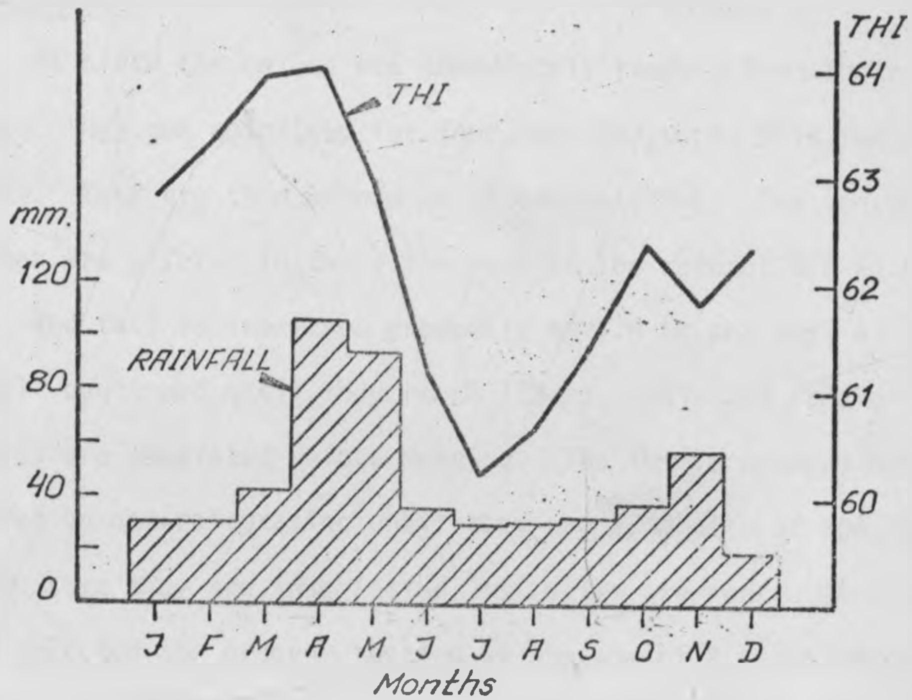

Fig. 3. Annual rainfall and temperature humidity indices (THI) at Naivasha.

The area tends to be windy and while this has a cooling influence it has the disadvantage of dessicating the soil and thereby reducing the moisture available for plant growth.

The natural vegetation is modified savanna with a few Acacia spp. trees, the grass consisting mainly of star grass, (Cynodon spp.) and Kikuyu grass P. clandestinum

Management

At birth the calves are immediately removed from their dams. They get colostrum for four days and whole milk for nine weeks. They are then weaned on to concentrates. The concentrates are offered in the fifth week at the rate of 0.5 kg per day, and this is increased gradually to 1.4 kg per day, a level continued until they reach 125 kg. Male and female calves are separated before weaning. The female weaners are reared on natural grazing until they are 27 months of age, at which time they are inseminated. The males are reared separately and selected for progeny testing at the age of 2 years. Pregnant heifers join the milking herd about 2 months before calving. Routine vaccinations, inoculations, deworming of calves and general treatment for diseases is done by the resident veterinary surgeon in the station.

Feeding

The management of the NSS over the years has been extensive. The general practice of giving the best pastures to the milking cows is followed. Cows are expected to maintain themselves and to produce 5 litres a day on the natural grass. Cows giving more than the above amount are supplemented with concentrates at the rate of 1 kg for every 2.5 kg milk produced. The composition of the concentrates depends on the type of feeds available in the market. It is the policy in this herd not to feed for very high productions (> 2500 kg milk per lactation) since the breed is supposed to be suitable for the relatively drier areas and is therefore not meant for high potential areas where Bos taurus dairy breeds are more suited.

Milking and milk recording

Cows are milked by hand twice daily, milk yield weighed and entered on the official Kenya Milk Recording Organization (KMR) sheets. These yields are checked at random intervals by the KMR officials. Butterfat tests are made each month by the KMR officials.

305 day yields as well as the average butterfat contents are calculated at the end of lactation and are used by the genetics section of NAHRS for selection.

Breeding plan

The current breeding plan at the NSS is a modification of an earlier one devised by Mason, (1965) and is shown by Meyn and Wilkins, (1974). This plan appears in Figure 4 and is discussed later under the section "Appraisal of the Current breeding plan".

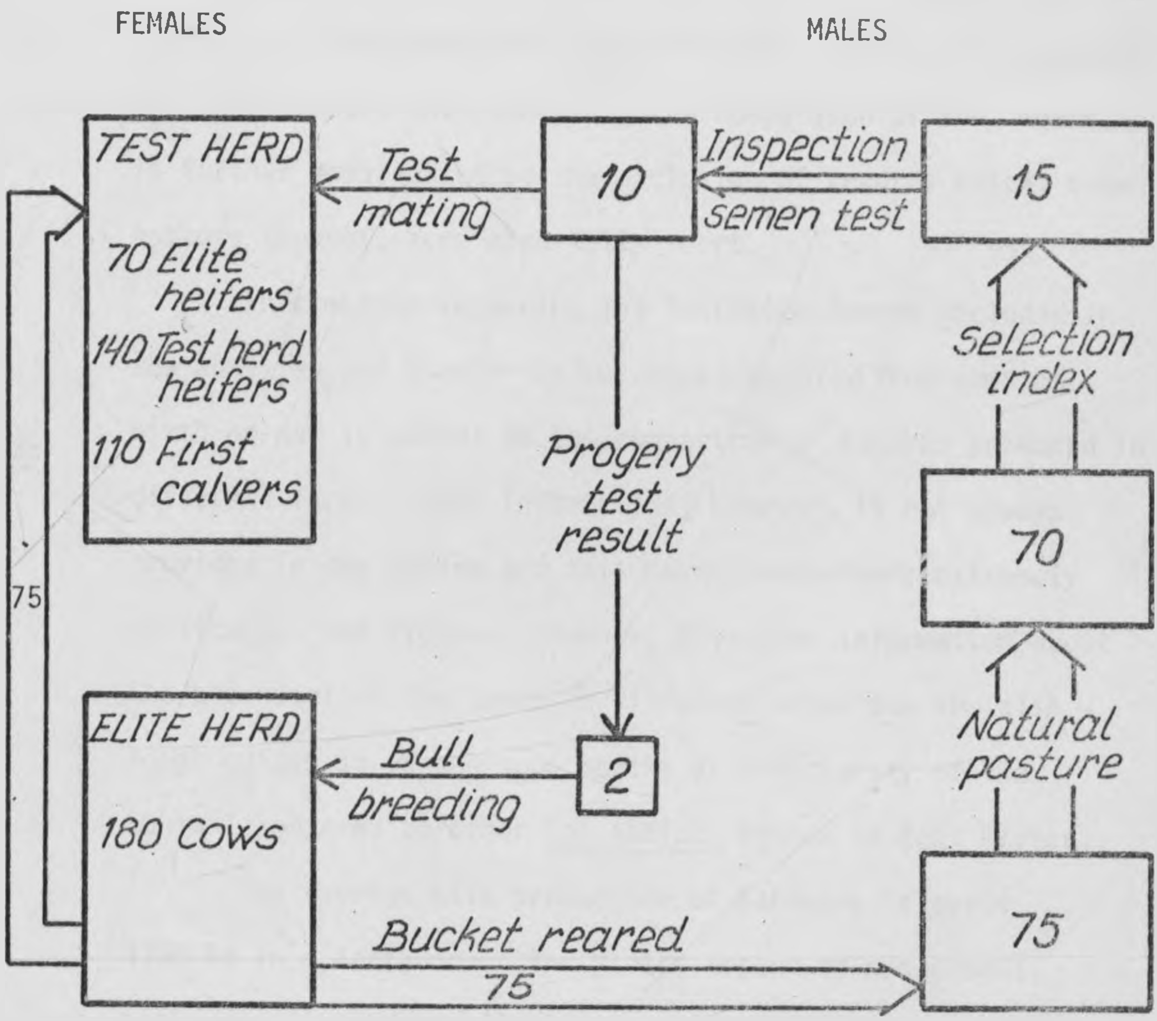

Fig. 4. Breeding plan at the National Sahiwal Stud, Naivasha, Kenya.

SECTION 2 REVIEW OF LITERATURE

2.1 Milk yields

2.1.1 Means and variations

The mean milk yields of Sahiwal cattle in different areas of the world are given in table 1. It is worth noting that these yields were produced under very different systems of management and in different environments. The comparison of the means is further complicated by the exclusion of records which, some authors thought, were abnormally short.

Information regarding the lactation length included in the analyses and whether calves were separated from dams at birth or not is useful in the comparison of figures produced in different farms. Such information, however, is not always provided in the papers and this makes comparisons extremely difficult. The figures, however, give some information about the potential of the breed in different areas and are also rough guides as to the superiority or inferiority of the Sahiwal compared to other *Bos indicus* breeds in East Africa.

The average milk production of Sahiwals is about 1700 kg in a lactation. The yields depend on management, pasture quality and availability, quality of sires and dams used in the herds and the general environmental conditions. In some Sahiwal herds where pastures were good throughout the year (e.g. Karnal in India, Sundaresan *et al.*, 1965) the yields were higher than the rest. This shows that the breed does respond to improved feeding although the yields are not comparable to those of *Bos taurus* cattle in East Africa

Table 1: Milk yields of Sahiwals

Mean yield kg	C.V. %	References	Remarks
1489	46	Singh and Choudhury (1961)	1st lactation only
1515	36	Mahadevan *et al.*, (1962)	lactations <70 day excluded
2499	-	Sundaresan *et al.*, (1965)	good pastures
1674	29	Singh and Desai (1966)	1st lactation only
972	30	Malik and Sindhu (1968)	"
1570	34	Misra and Kushwana (1970)	"
2058	-	Ahmad *et al.*, (1971)	Yields <400 kg excluded
1944	24	Khanna and Bhat (1971)	"
1928	32	Nagpal and Acharya (1971)	1st 5 lactations
2313	29	Chopra *et al.*, (1973)	lactation <100 days deleted.
1595	29	Singh *et al.*, (1973)	-

Unweighted average = 1876 kg.

(Kiwuwa 1974, Lindstrøm and Solbu 1978). The Sahiwal breed seems to fit in the medium potential areas where grass is not green for a large portion of the year and where temperatures are high (Meyn and Wilkins, 1974).

Sahiwal yields are generally higher than those of the indigenous cattle of East Africa. Mahadevan _et al._, (1962) showed that up-grading of East African Zebu to the Sahiwal was beneficial. The coefficients of variation in yield reported vary from 24 to 45 percent, for Sahiwals and from 23 to 65 percent for the indigenous cattle of Eastern Africa. Provided that a part of the phenotypic variation is heritable, there should be scope for selection.

2.1.2 Factors influencing or related to milk yields

a) Age at first calving

Age at first calving influences milk yield in the first lactation of _Bos taurus_ cattle (Mahadevan 1953, Andersen 1970). Eckless and Anthony (1950) noted that too early calving retards body development of cows. Giuliani (1953) observed that Friesians should not calve before they are two years old. However, Czako (1951) contended that they could be mated and calve at this age provided that they had attained two thirds of their mature body weight and are in good condition. Farmers in general go by both weight and age so that slow growers calve later. In addition fertility influences age at first calving.

The first lactation milk yields of tropical cattle have also been shown to be influenced by age at calving. Significant effects within the Sahiwal breed have been reported by Singh and Choudhury (1961), Batra and Desai (1964), Kushwana and Misra

(1969) and Kavitkar et al., (1968). Galukande et al.,(1962) found that age influenced the lactation yields of East African Zebu, although Alim (1960) had earlier reported the contrary in respect to Sudanese cattle. Conflicting results on the Haryana breed have been reported by Kholi et al., (1961), Singh and Desai (1961) and Balaine (1971).

Reports on the Sahiwal indicate that milk yield tends to increase with age at first calving. Late ages at calving observed among *Bos indicus* can be reduced without affecting milk yields significantly if feeding and management are improved (Mahadevan 1953, Johari and Tolapatra 1957, Chaturvedi 1972).

b) Parity

Skjervold (1949), Gravir and Hickmann (1964) and Syrstad (1965) showed that milk production capacity is influenced by both the number of previous lactations and the number of years the cow has lived.

The increase in milk yield with parity depends on the selection made, and the actual age. Selection tends to make older cows appear to have higher yields than the younger ones, if the "gross comparison method", (Sanders, 1928) is used.

Most of the reports on *Bos indicus* cattle, show signficant influences of parity on milk yields. Table 2 shows the lactation in which the maximum yields are reached. Irrespective of the method used to investigate the influence of parity, these reports show that Sahiwals give their maximum yields in the 4th lactation. The range in tropical cattle is 3-5 lactations.

Table 2: Influence of parity on milk yields

Breed/Type	Influence	Max. yield in lactation	Reference
Sahiwal	Sign.	4	Johar and Taylor (1967)
"	"	5	Misra and Kushwana (1970)
"	"	4	Khanna and Bhat (1971)
"	"	4	Nagpal and Acharya (1971)
Kenana	"	4	Alim (1960)
Sudanese	"	5	Bayoumi and Danasoury (1963)
"	"	5	Osman (1970)
"	not sign.	-	Osman (1972)
Nganda	Sign.	4	Mahadevan and Marples (1961)
East African Zebu	"	4	Galukande *et al.*, (1962)

Bos taurus cattle give their highest yields in the 6th lactation (Skjervold, 1949, Lindstrøm and Solbu, 1978). Although tropical cattle reach their peak earlier, both types of cattle are almost of the same actual age, because *Bos indicus* cattle have a late age at first calving. Older animals tend to produce more milk than the younger ones because they have larger rumen capacities and udder.

Several methods have been used to correct milk yields for parity effects. Multiplicative factors are preferred to additive factors (Syrstad, 1965). Regression techniques have also been used. Where many herds are involved, simplified herd level age correction factors (Searle 1960, Searle and Henderson, 1959) can be used.

Parity and season of calving interactions may exist in some situations and have to be allowed for in data correction. Syrstad (1965) using data for the Norwegian Red and White breed showed that there was a highly significant interaction of parity and season of calving. Kiwuwa (1973), however, using data for *Bos taurus* x *Bos indicus* cattle reported that the interactions were not significant in East Africa. It seems important to test for parity by season interaction when deriving parity correction factors.

The level of production of the cows in the herd may affect the age correction factors. Hickman (1962) showed that a highly significant relationship between age of cow and yield remained in the conventionally age corrected records at all the levels of management. The bias appeared to be less marked in the well managed herds. Where different levels of management, breeds and herds are involved, it is safer to derive correction factor on a within environment, breed and herd basis.

There is a shortage of information on the relative contribution of parity to the total variance in milk yield in the tropics. Osman (1972) found a contribution of 12 percent while Nagpal and Acharya (1971) reported a low one (1.3 percent).

c) Period of calving

Investigations on the influence of seasons have been reported from many countries. Studies in tropical and sub-tropical climates have however, been conflicting.

In India, Dutt and Singh (1961), Sundaresan et al., (1965) and Singh and Pandey (1970) reported that milk yield was significantly influenced by season of calving. Sikka (1931), Tomar and Mittal (1960) and Batra and Desai (1964) reported non-significant effects.

In East Africa, Anderson (1935) observed that the milk yield of indigenous cattle in Kenya was closely associated with the rainfall pattern in the region. Kiwuwa and Redfern (1969) noted that dry season calvers had higher milk yields than the wet season calvers. Kiwuwa (1973) found that the effect of season depended on the breed, locality and the model assumed in the analysis.

Kiwuwa (1974) also found that seasonal differences in milk yield were small and not significant for Friesians in Kenya although they were significant for Jerseys. This is the opposite of what is expected since Jerseys are supposed to be more adopted to the tropical environment. It is possible that there was a breed by season interaction with respect to these breeds under the Kenyan wet and dry season environment, but Kiwuwa (1974) did not test it. Lindstrøm and Solbu (1978) analysed data on the same breeds, but not covering the same period and found that seasons had highly significant effects on milk yield. These two works are not directly comparable because in the former only the two breeds mentioned were included and even then the analysis was done within breed Moreover, seasons were defined differently in the two studies.

The works reported on seasonal influences have given conflicting results because of the following reasons:

(i) <u>Breed</u>

Some breeds tend to adopt to particular environments better than others. Some are able to utilize the poorer grass available during the dry seasons while others are not. Kiwuwa (1974) found that seasons had no influence on Friesians although they influenced Jerseys significantly.

(ii) <u>Number of years included in the study</u>

Some studies have included only a few hundred lactations over a period of twenty years. This is bound to give estimates with large standard errors. Climatic conditions can change over a long period so that grouping a January of one decade with a January of another decade would seeem unjustified.

(iii) <u>Locality</u>

Climatic conditions differ from area to area. Some areas are wet thoughout the year while others are dry for the larger portion of the year. If the climate of an area is not very variable from month to month, then differences due to month of calving cannot be expected to be large. In some cases, what a worker terms a dry season could be termed a relatively wet period by a worker in a different area.

(iv) Method of defining seasons

Workers in temperate and sub-tropical areas group records according to the very clearly and naturally defined seasons i.e. Summer, Autumn, Winter and Spring. Tropical workers tend to group records according to the rainfall conditions (Kiwuwa and Redfern 1969; Kimenye and Russell 1975), since seasons as they are known in temperate areas do not exist in the tropics.

Rainfall is used for season definition because of its influence on forage availability. Grass is the major source of feed in the tropics and as such rainfall provides a good guide. Rainfall alone cannot tell everything about the moisture available for grass growth. To get better indicators of the moisture availability, water balance has to be calculated from the rainfall, wind speed, temperature and evaporation data.

Unfortunately, such data are not always available. Kiwuwa (1973) used a combination of mean monthly rainfall and mean monthly temperature-humidity index to define seasons. This combination gives fairly smooth curves which can be dividedinto seasons with ease. They have, however, very low repeatability and may be unreliable in an area where year to year variations in climate are large as is often the case in the tropics. The above system fails in that the conditions at the start of the lactations are different from those prevailing at the middle or the end.

It would appear that in the absence of forage availability and quality records, which are probably the best aids to season classification, each month of calving should be taken in isolation and be regarded as a "Season". This would ensure that, the same environmental factors have influenced the yields in the same way, prior to and after calving. This would create the problem of too few records but if the information is going to be used to correct the same data it would not matter very much.

(v) Feeding regimes

Scott and Wilson (1954) observed that the month of calving influenced milk yields little when nutrition was standardized. McNab (1966) also noted that seasonal influences were related to nutrition during the various seasons. Kiwuwa and Redfern (1969) made similar observations.

It would appear that seasonal influences are caused by differences in feed quality and availability. Supplementary feeding can reduce the seasonal effects.

In order to compare sire progenies accurately, seasonal influences should be investigated in an appropriate manner and corrections made accordingly.

d) Lactation length

Almost all workers have reported high correlations between lactation length and milk yield. Alim (1960), Alim (1962) and Danasoury and Bayoumi (1963) have reported significant correlations of 0.87, 0.86 and 0.89 in Sudanese cattle. Similar correlations have been reported for, Sahiwal by Batra and Desai (1964), Haryana by Ngere (1970) and for East African Zebu by Galukande et al., (1962).

Alim (1960), Galukande et al., (1962) and Ngere (1970) reported that lactation lengths account for 45, 75 and 53-65 percent of the total variance of milk yields. In general if a cow milks for many days, she can be expected to give a high yield.

The above is not the general occurrence in the temperate areas where lactation length is much less variable. The degree to which lactation length is related to milk yield depends not only on the breed but also on management, lactation length included in the study and also on whether calves have been allowed to suckle or not.

Many research workers do not correct milk yield for variation in lactation length despite the fact that lactation length is significantly correlated to milk yield. They argue that lactation length is genetically determined and that correcting yield tends to reduce genetic variance. It may be justified to correct milk yield for variation in lactation length if the heritability of lactation length was almost zero.

e) Dry period

The effects of the preceding dry periods on current lactation milk yields of Sahiwals (Batra and Desai 1964, Kavitkar et al., 1968) were not significant. Reports by Mahadevan and Marples (1961), Galukande et al., (1962) and Dadlani and Prabhu (1968) on Nganda, East African Zebu and Haryana cattle respectively showed significant effects. It appears that the influence depends on breed.

Bayoumi and Danasoury (1963) argued that the dry periods they examined were short and were therefore within the range in which the influence on milk yield could be detected. Mahadevan and Marples (1961) and Galukande et al., (1962) observed that the animals with the shortest dry periods had the highest milk yields and argued accordingly that correction for dry periods should not be done because it tends to favour the poor producers.

Tropical cattle tend to have long dry periods and they therefore get more than adequate rest periods. Galukande et al., (1962), Batra and Desai (1964) observed that the optimum dry periods for milk production purposes were 80 and 90-105 days for East African Zebu and Sahiwals respectively. These recommended dry periods are very long when compared to those of one to two months for *Bos taurus* (Berdnik 1951, Clark 1959 and Aleksiev et al., 1967).

The contribution of dry period to the total variance of milk yield has not been shown for many tropical breeds. Nagpaul and Bhatnagar (1972) found it to be very small (0.1 percent) and therefore of no practical importance. It would in general, appear that there is very little accuracy to be gained by corrections for dry period of tropical cattle.

f) Calving interval

Mahadevan and Marples (1961) reported that preceding calving intervals of Nganda cattle had significant influences on the current lactation milk yields. They found that for every ten days' increase in the preceding calving interval, there was a corresponding increase of 14-17 kg in the current total lactation milk yields. Galukande et al., (1962), and Alim (1962) reported similar relationships in East African Zebu and Butana cattle respectively. Dadlani and Prabhu (1968) and Singh and Desai (1962), however found that calving intervals of Haryana cattle were not significantly correlated with milk yield.

Calving intervals seem to influence milk yields only when they are short. When they are very long, their effect is minimised as each cow gets more than a sufficient rest.

Calving interval has a low heritability (Amble et al., 1958, Mahadevan and Marples (1961), Galukande et al., (1962). Correction factors should therefore be used before cows are selected. Dry period and lactation length which are components of calving interval have to be considered when correction factors are being devised.

g) Body weight at calving

The relationship between weight at calving and the current lactation milk yields has interested research workers for some time. The efforts have been directed to studying the actual relationship with a view to improving both characters.

While the improvement of both characteristics is of direct relevance to the improvement of dual purpose breeds (milk and beef), some workers argue that a large dairy cow is not desirable because she has high maintenance requirements. Others hold the view that comparison of efficiency of milk production, based on output per unit of input, is more important than a comparison of sizes of cows, since, in general, larger cows tend to produce higher yields than smaller ones.

Early studies of the relationship between weights and milk production in Bos taurus cattle (Gaines 1940, Gaines, Davis and Morgan 1947, Farthing and Legates 1958, Clark and Touchberry 1962) have shown that milk yield is influenced by weight at calving. In general, for each 50 kg increase in weight at calving, milk yield increased by 60-180 kg. The above relationship depended on breed, herd, age and the method of analysis. When age in months was held constant, the regression of milk yield on live weight was reduced. The correlations between body weight and milk yield were small, 0.14 within progeny groups and 0.02 between progeny groups (Mason et al., 1957).

There is a great scarcity of information regarding weight at calving and its influence on milk yield in tropical cattle. Lack of weighing facilities has contributed to this situation.

Venkayya and Anantakrishnan (1958), Singh and Desai (1966) Chhabra, Acharya and Sundaresan (1970) found that weight at calving had significant influences on milk yields of Red Sindhi, Sahiwal and Haryana cattle respectively. Tomar and Arora (1972) found only a small correlation (r = 0.08) between weight and milk yield of Haryana cattle. Singh and Desai (1966) compared the relative effects of age and body weight at first calving on first lactation and found that weight was twice as important as age although the partial regression coefficients were very small (0.16 and 0.08 respectively).

It appears that body weight does influence milk yield so that heavier cows produce more milk in general, but the actual correlation is relatively small. Heavier cows are able to produce more milk because of their ability to ingest and metabolize larger amounts of feed and despite their higher maintenance requirements, the extra energy is turned into milk. As a measure of the relative dairy merit, Brody (1945) suggested that cows be compared on $FCM/W^{0.7}$ basis, where W is the weight of the animal and FCM is the fat corrected milk yield, since the requirements of energy for body maintenance is proportional to $W^{0.7}$.

2.1.3. Genetic parameters

Data on milk yield of both *Bos indicus* and *Bos taurus* breeds have been analysed for genetic effects. In the tropics, however, the data used for parameter estimations are much fewer than in the temperate areas. Standard errors of these estimates are therefore large.

Most of the heritability estimates reported pertain to first lactations. The large reduction of the number of observations resulting form culling in the earlier lactations makes the estimates calculated on the basis of the later lactations unreliable.

A wide range (0.19-0.59) of heritability values has been reported for milk yield in Sahiwals by Mahadevan *et al.*, (1962), Acharya and Nagpal (1971) Gopal and Bhatnagar (1972) and Chopra *et al.*, (1973). The values reported for other breeds of tropical cattle are equally variable and are within the range (0.1-0.7) with fairly large standard errors attached to them.

The reported repeatability values are higher than the comparable heritability values as expected. Mahadevan *et al.*, (1962) and Johar and Taylor (1967) reported values of 0.65 and

0.49 for Sahiwals. Values reported for other tropical cattle by Mahadevan and Marples (1961), Galukande *et al*., (1962), Gill and Balaine (1971) are within the range (0.38-0.62).

From the heritability and repeatability estimates reported, it appears that milk yield of tropical cattle is moderately heritable.

2.2 Fat percentage and yields

2.2.1 Means and their variations

There is a general lack of published information on these two traits in tropical cattle. Determination of fat percentage requires equipment for analysis and such facilities were not always available.

The fat content of most Zebu cattle lies in the range 4-7 percent (see table 3). The few reports on Sahiwals are within this range. Variations in fat percentages within herds are not large, although between herds, fairly large differences exist. Some of the differences arise from variations in the number of times the cows are milked.

Kulreshtha and Razdan (1970), Kholi *et al*., (1961) and Marples (1965) have reported coefficients of variation in fat percentages of around 10 percent. The fat contents for Zebu cattle are in general higher than those reported for *Bos taurus* by Bar-Anan (1971) and Cunningham (1972).

The fat yields shown in table 3 are low. Marples (1965) and Kiwuwa (1973) have reported fat yields of Friesians in East Africa which were twice as high as those reported for *Bos indicus* cattle. Fat yield is a product of milk yield and fat percentage. The milk yield of *Bos taurus* is so much higher that

Table 3. Butterfat contents and yields of Sahiwals and other tropical cattle

Type of breed	B.F. %	B.F. yield kg	Reference
Sahiwal	4.3		Ishaq and Shah (1973)
"	3.48		Joshi and Bhatnagar (1972)
"	4.52	-	Kulreshtha and Razdan (1970)
"	5.0		Gaba and Jain (1972)
"	5.3		Singh, Yao and Singh (1961)
"	5.1		Paul and Mahan (1962)
Hariana	5.1	98	Dutt, Singh and Singh (1972)
"	4.4		Kohli, Suri, Bhatnagar and Lohia (1961)
"	4.2		Malik, Sharda and Singh (1967)
Kenana	4.7		McLaughlin (1955)
Sudanese	5.1		Khalifa (1966)
Kenana	5.7	153-213	Hattersley (1951)
Egyptian	4.5	-	Alim (1965)
White-fulani	6.0		Tasker (1955)
"	6.4		Armour *et al.* (1961)
Nganda	5.67	62	Marples (1965)
Shorthorn Zebu	5.68	57	" "
Jersey x Nganda	5.8	87	Kiwuwa and Redfern (1969)
Mpwapwa	4.6	73	Kiwuwa and Kyomo (1971)

it more than compensates for the lower (by one to two percent) fat percentage.

2.2.2. Factors influencing fat percentages and yields

a) Age and parity

Kholi et al., (1961) reported that younger Hariana cows, up to 50 months of age, had the highest fat contents. Alsafar and Ali (1970) confirmed this using Iraqi cows. Parity has been shown to influence fat content by Alim (1965), Marples (1965) and Bayoumi and Khalifa (1966). These results indicate that younger cows (1-2 lactations) have the highest fat contents. This is in agreement with studies in European cattle (Lindstrøm 1969, Lindstrøm and Solbu 1978).

Significant parity effects have been reported by Marples (1965). The lactation in which the peak production is reached was the same as for milk yield. The information available leads to the conclusion that younger cows have the richest milk but the lowest milk and fat yields.

b) Season of calving

Tasker (1955) observed that fat percentages of Fulani cattle were highest in the period of maximum available grazing. Ahuja and Gautam (1956) reported that the fat contents of Haryana cattle were lowest during the rainy season. Other works, (Alim 1965, Khalifa 1966, Kiwuwa and Redfern 1969) agrees with the above studies and show that cattle calving during the periods when grass had a high dry matter and crude fibre content had the highest butterfat contents.

Fat yields have likewise been reported to be influenced by season of calving by Khalifa (1966) and Kiwuwa and Redfern

(1969). Kiwuwa and Redfern (1969) found that seasons influenced fat and milk yield in a similar manner and that the dry matter content of the feed was directly related to yield.

From the above information it can be concluded that fat content, fat and milk yields of tropical cattle are influenced by season of calving.

2.2.3. Genetic parameters

Heritabilities of fat percentages in tropical cattle are in the range 0.3-0.7, (Alim 1965, Sharma *et al.*, 1970, Kiwuwa and Kyomo 1971). Heritabilities for this trait in *Bos taurus* has been reported to be in this range with some exceptionally low values (Abe 1959, O'Connor 1959, Christensen 1968, Bar-Anan 1971). Heritabilities for fat yields in tropical cattle are similar to those of milk yields 0.2-0.3 (Kiwuwa and Kyomo, 1971) and are similar to those for *Bos taurus* (Gravert 1958, Searle 1961).

Repeatabilities reported for fat percentages are around 0.6, (Alim 1965, Marples 1965) and are indicative of high heritabilities for the trait.

Genetic correlations between fat yield andmilk yield and between fat percentage and milk yield have been calculated mainly in *Bos taurus* populations. The results show that milk yield is positively correlated to fat yield although it is negatively correlated to fat percentage (Astullido *et al.*, 1963, U.S. State Agricultural Experimental Station Reports 1971). Kiwuwa and Kyomo (1971) observed the same relationship in Mpwapwa cattle of Tanzania.

Selection for fat percentage can be expected to bring about improvement because the heritability is high. Milk yield and fat yield are more or less equally heritable and show a high positive genetic correlation. Selection for milk yield alone then can be expected to bring about a correlated response in fat yield.

2.3 Lactation length

2.3.1 Means and their variations

The mean lactation length of Sahiwals (Table 4) are comparable to those of other tropical cattle. The comparion is not a straghtforward one, however, as in some of the studies, some records were excluded. There seems to be no agreement among the workers as to what is a normal lactation length. Galukande et al., (1962) and Mahadevan et al., (1962) included all lactations of normal animals so far as they were of more than 70 days while Mahadevan and Marples (1961), Sacker and Trail (1966) and Chopra et al., (1973) excluded those lactations which were of less than 100 days. Osman (1970) included those lactations which were upto 200 days and longer.

It is therefore necessary to know if any lactations have been excluded before comparisons can be made. In general, means calculated from selected data are greater and have less variance than those calculated from the data where no records have been deleted.

There is a controversy as to whether lactations, where suckling has been allowed, should be included in analyses or not, Mahadevan (1966) and Osman (1972). For those breeds where milk let down is stimulated only if in the presence of the calf and its

Table 4 Mean lactation lengths of some tropical cattle

Breed	Mean (days)	C.V. %	Reference
Sahiwal	265	19	Singh and Choudhury (1961)
"	283	18	Mahadevan et al. (1962)
"	274	22	Malik and Sindhu (1968)
"	296	33	Batra and Desai (1964)
"	270	25	Gehlon and Malik (1967)
"	322	32	Chopra et al. (1973)
"	298	33	Kushwana and Misra (1969)
N. Sudan Zebu	288	32	Osman (1970)
Sudan (indigenous)	232	30	Osman (1972)
Kenana	224	39	Alim (1960)
Butana	253	41	Alim (1962)
E.A. Zebu	239	24	Galukande et al. (1962)
"	230	26	Sacker and Trail (1966)
Nganda	267	18	Mahadevan and Marples (1961)
Ankole	239	26	Sacker and Trail (1966)
White Fulani	246	-	Knudsen and Sohael (1970)
Haryana	291	28	Singh and Desai, (1961, 1962)
"	284	-	Misra and Kushwana (1970)
"	286	-	Soof and Singh (1970)
Red Sindhi	317	-	Amble et al. (1967)
"	264	-	" " " "
"	240	-	Pires et al. (1971)

suckling, then the lactation length also depends on the suckling. It is therefore incorrect to compare such breeds or cows with those where calves were removed at birth. Sacker and Trail (1966) and Osman (1972) have given results where calves had been allowed to suckle their dams.

The mean lactation lengths of Sahiwals are generally comparable to those of Sudanese and East African cattle although those of Sahiwals tend to be longer. The coefficients of variation are in the same range. The lactation periods of Sahiwals are however, shorter than those of Bos-taurus cattle in the temperate regions.

2.3.2 Factors influencing lactation length

a) Age at first calving

Venkayya and Anantakrishnan (1956) observed that age at first calving influenced the first lactation length in the Red Sindhi breed. They reported a significant correlation ($r = 0.49$) between these two variables. Singh and Choudhury (1961) reported a low but significant correlation ($r = 0.19$) in Sahiwals. Kushwana and Misra (1969) observed a high correlation ($r = 0.7$) in Sahiwals. Age at first calving of tropical cattle seems to affect the length of lactation.

b) Parity

Relatively little evidence is available on the influence of parity on lactation length. Sandhu et al., (1973) reported significant effects in Sahiwal cattle while Osman (1972) observed that parity did not influence the lactation length of indigenous North Sudanese cattle. Significant parity effects on lactation length of European cattle in

East Africa were recently reported by Kiwuwa (1974) and Lindstrøm and Solbu (1978).

c) Season of calving

Dutt and Singh (1961), Desai and Kumar (1964), Tomar and Mittal (1961) showed that season of calving had a significant influence on the lactation length in Haryana cattle. Rao and Taylor (1971) and Sandhu *et al.*, (1973) gave confirmatory results in respect to Sahiwals. Danasoury (1962), however, reported that the opposite was true for Sudanese cattle.

In the absence of a clearly defined minimum level of daily production, it is possible, that cows milking in the dry season are allowed to milk for longer periods if milk is scarce. In those areas where dry season milk fetches a premium, farmers will tend to milk them for longer periods even if the actual daily yields are low. Supplementary feeding and the cost of it may influence the length of lactation in such a way that low yielding cows will be dried off earlier. In the above case, analysis of the lactation periods on the basis of the season of drying off may be appropriate.

d) Year of calving

Alim (1962) observed that lactation length in Butana cattle varied significantly between the years. Similar observations were made later by Singh and Pandey (1970), Osman (1972) and Kimenye (1973) for Hariana, indigenous Sudanese and Ayrshire x Sahiwal cattle respectively. In some cases year was found to have a significant influence while season did not. This points to the possibility of improving the accuracy of the correction of data by including years as independent variables in the analyses.

2.3.3 Genetic parameters

Heritability values reported for lactation length in tropical cattle are in the range (0-0.1). Mahadevan and Marples (1961), Mahadevan *et al.*, (1962), Shukla and Prasad (1970) and Soof and Singh (1970) reported heritabilities within the above range for Nganda, Sahiwal, Gir and Haryana cattle respectively. Singh and Desai (1962) and Galukande *et al.* (1962) reported higher values for Haryana and East African Zebu.

The repeatabilities reported by Singh and Desai (1962) Alim (1962) and Galukande *et al.*, (1962) were in the range (0.2-0.4). These repeatabilities were in general high enough to permit selection of cows on the basis of the early lactations.

Direct selection for lactation length may not bring about a quick response because of its low heritability. It may be better to select directly for milk yield and obtain correlated response in lactation length, since the genetic correlation between the two is highly positive.

2.4 Dry periods

2.4.1 Means and variations

Table 5 shows the mean dry periods for some Sahiwals and other tropical cattle breeds. The average dry period of the Sahiwal is around 140 days. There are large differences within breeds between the values reported showing that management differences were the cause of these variations in the means. Sahiwals tend to have longer dry periods than

Table 5 Mean dry periods of Sahiwals and other tropical cattle

Breed	Mean	C.V. %	Reference
Sahiwal	105	70	Mahadevan *et al.* (1962)
"	121	47	Batra and Desai (1964)
"	183	43	Gehlon and Malik (1967)
"	196	50	Kushwana and Misra (1969)
"	105	33	Kavitkar *et al.* (1968)
E.A. Zebu	123	65	Galukande *et al.* (1962)
"	106	65	Sacker and Trail (1966)
Nganda	153	61	Mahadevan and Marples (1961)
Ankole	97	69	Sacker and Trail (1966)
Butana	159	65	Alim (1960)
Kenana	164	57	Alim (1962)
Sudanese	97	60	Bayoumi and Donasoury (1963)
Egyptian	153	57	Asker *et al.* (1958)
Tharparkar	147	68	Nagpaul and Bhatnagar (1972)
Haryana	256	50	Tomar and Balaine (1973)
"	152	-	Soof and Singh (1970)
"	342	-	Singh (1969)

the indigenous East African Zebu although they have shorter dry periods than most Indian breeds of cattle.

The dry periods are certainly long when they are compared to those recommended for Bos taurus by Berdnik (1951) and Clark (1959). If dry period is expressed as a proportion of calving interval, Bos indicus cattle are out of milk production for 35 percent of their time.

2.4.2 Factors influencing dry periods

2.4.3 Age and period of calving

Most workers regard dry period as an independent variable in their analyses and as a consequence reports on the non-genetic factors influencing dry periods are very few. Some studies (Galukande et al., 1962, Jhas and Biswas, 1964, Kavitkar et al., 1968 and Tomar and Balaine, 1973) have been reported on the changes associated with parity. There is general agreement that older animals have significantly shorter dry periods than the younger ones.

Gehlon and Sekhon (1966) and Kuswhana and Misra (1969) reported correlations between age at first calving and length of first dry period of 0.65 and 0.06 for Haryana and Sahiwals respectively. These correlation coefficients are extremely different. They are based on small bodies of data (200 and 150 observations respectively) and without any more information it is not possible to say if age at first calving has any effect on the length of dry period.

Rao and Taylor (1971) is the only report on seasonal influences on dry period in tropical cattle. Season in their study did not have a significant effect on dry period. It is possible to imagine how unfavourable climatic and management effects at the beginning of a lactation might lead to a long dry period but information to this effect is lacking.

2.4.4 Genetic parameters

As for other traits associated with milk production in tropical cattle, heritabilities for dry period have been calculated using mostly small bodies of data and consequently high standard errors are attached to the estimates. Mahadevan and Marples (1961), Galukande *et al.*, (1962), Mahadevan *et al.*, (1962, Dadlani and Prabhu (1968) and Osman and El-Amin (1971) reported heritabilities of 0.53±0.02 for Nganda, 0.29±0.22 for East African Zebu, 0.19±0.23 for Sahiwal, 0.32±0.33 for Haryana and 0.06±0.09 for the indigenous Sudanese cattle. Repeatabilities reported by most authors are in the range (0-0.26).

The heritability of the dry period is moderate and as such, selection can be expected to improve it. Dry periods can be reduced by breeding for longer lactation lengths in tropical cattle. Animals with long dry periods and lactation lengths can be culled on the basis of their long calving intervals. As such, dry period is unlikely to be used as a criterion for selection by itself, and more often than not, it will have been taken into account in the selection for milk yield.

2.5 Calving intervals

2.5.1 Means and variations

The mean calving intervals of Sahiwals (see table 6) are longer than 14 months which is considered as the upper limit in well managed herds in the temperate countries. The lengths seem to depend on the farm and locality. The means reported are

Table 6 Mean calving intervals of Sahiwals and other tropical cattle

Breed	Mean	C.V. %	Reference
Sahiwal	484	23	Singh and Choudhury (1961)
"	471	10	Amble *et al.* (1958)
"	416	23	Johar and Taylor (1967)
"	439	20	Gehlon and Malik (1967)
"	388	19	Mahadevan *et al.* (1962)
"	498	25	Kushwana and Misra (1969)
Haryana	439	17	Johar and Taylor (1970)
"	454	28	Bhasin (1967)
"	473	20	Ngere (1970)
Red Sindhi	549	30	Amble *et al.* (1958)
"	448	26	" " " "
Butana	416	22	Alim (1962)
N. Sudan zebu	428	20	Osman and El Amin (1971)
Egyptian	419	26	Asker *et al.* (1958)
E.A. zebu	363	19	Galukande et al. (1962)
"	347	14	Sacker and Trail (1966)
"	393	15	Marples (1964)
Ankole	342	14	Sacker and Trail (1966)
Nganda	420	21	Mahadevan and Marples (1961)
Boran and Jiddu	382	23	Mahadevan and Hutchison (1964)

comparable to those of other Indian breeds. They are, however, in general longer than those reported tor East African Zebu, Ankole and Nganda cattle in East Africa.

2.5.2 Factors influencing calving intervals

a) Age at first calving

This effect was investigated in Sahiwals by Singh and Choudhury (1961) and Kushwana and Misra (1969) who found low and not significant correlations. Other works in other *Bos indicus* breeds, Singh and Sinha (1960), Gehlon and Sekhon (1966), Kholi *et al*., (1961) and Plasse *et al*., (1965) are in agreement with the studies in Sahiwals. Most workers observed that age at first calving does not affect calving intervals significantly.

b) Parity

Alim (1960) found that the calving intervals of Kenana cattle were significantly influenced by parity. The first calving interval was found to be the longest. Similar results were reported by Singh and Prasad (1968), Dadlani *et al*., (1969) Johar and Taylor (1970) and Ngere (1970) for Haryana. According to Dadlani *et al*., (1969) and Johar and Taylor (1970), calving interval tends to decrease steadily up to the 3rd lactation and then starts to increase in the later lactations.

Parity has been shown to have a significant effect on calving interval and this information should be used when comparing dams of different ages in the tropics.

c) Season

Singh *et al*., (1958) and Osman (1972) observed that seasons had significant effects on the calving intervals of Haryana and Sudanese cattle respectively. They found that animals calving during the periods of food scarcity had lower conception rates and prolonged calving intervals. Rao et al., (1969) and Aggrawal et al., (1972) observed that the above situation did not pertain in Ongole and Kankrej cattle. The difference in observations may have arisen because of the diversity in the environments and breeds.

d) Years

Alim (1960) and Osman (1972) reported significant effects of year on the calving interval of Sudanese cattle. Osman (1972) asserted that the cause of the lengthnened calving interval in the later years was the deterioration in the management standards. Kimenye and Russell (1975) showed that years accounted for up to 9 percent of the total variance of calving intervals of Ayrshires x Sahiwal crossbreds in Kenya. The above situation is possible in farms where management has changed over the years. A gradual worsening of the climatic conditions can also bring about a similar situation.

e) Service Period

Calving interval can be expressed as service period + gestation period and if it can be accepted that the latter does not vary much from breed to breed or between farms, then the variance of calving interval can be explained by the variations in service period.

Service period has been investigated in Sahiwal cattle. Bhalla, Sengar and Soni (1967), Malik and Sindhu (1968) and Chopra et al., (1973) reported mean service periods of 120, 195 and 188 days respectively. Kholi et al., (1961) and Tomar et al., (1972) reported service periods of Haryana of 230 and 219 days respectively.

From these reports, it can be established that service periods of these tropical cattle are long and are partly the cause of the long calving intervals, observed.

Service period like calving interval has a low heritability (Singh et al., 1968) and does not therefore provide an alternative character for selection to improve breeding efficiency. It can be reduced by better feeding especially with feeds containing phosphorus and energy and by improving heat detection (Higwett and Higwett, 1951; Snook, 1952, Bozworth et al., 1972).

f) Dry periods and lactation lengths

Gehlon and Malik (1967) reported a highly significant correlation (r = 0.6) between the length of the preceding dry period and the current calving interval in Sahiwals. Dadlani et al., (1969) and Dutt, et al., (1974) confirmed that calving intervals were influenced by dry periods significantly using data from Haryana and Tharparkar herds respectively. Dadlani et al., (1969) reported a significant correlation (r = 0.74) between the current lactation length and the current calving interval.

From the above information, it appears that both lactation period and dry period do influence calving interval and that as they get longer the calving intervals follow suit.

2.5.3. Genetic parameters

Heritabilities reported for calving interval in tropical cattle are low. Most workers including Amble et al., (1958), Mahadevan and Marples (1961), Osman and El-Amin (1971) and Johar and Taylor (1970) have reported values that are close to zero.

Heritabilities reported for Sahiwals by Mahadevan et al., (1962), Kushwana (1964) and Johar and Taylor (1967) were 0.06, 0.20 and 0.28 respectively. The standard erros were large in all the three studies.

Repeatabilities reported were also close to zero (Amble et al., 1958; Alim 1960; Singh and Desai 1962). Some were around 0.2 (Mahadevan and Marples, 1961; Galukande et al., 1962; Osman and El-Amin, 1971).

From the heritabilities and repeatabilities reported, it can be observed that calving interval has hardly any genetic variance. Other effects like management feeding, and heat observation are more important cause of variation (Bozworth et al., 1972) and should be improved if reduction in the length of the calving interval is to be expected.

2.6 Weight at calving

There is relatively little work published on body weights at calving and the factors influencing them in the tropics. Lack of weighing facilities has contributed to this situation. Table 7 shows the weight at calving of Sahiwals and other tropical cattle.

The weight at calving of Sahiwals tends to be in the range 340-380 kg and is slightly higher than that of Haryana cattle and much higher than those reported for East African cattle (Joshi, Mclaughlin and Phillips, 1957).

Table 7: Weights at calving of some tropical cattle

Breed	Mean weight kg.	Reference	Remarks
Sahiwal	380	Mudgal and Ray (1966)	1st lactn.
"	381	Singh and Desai (1967)	"
"	362	Taneja and Bhat (1971)	"
"	343	Tomar *et al.*, (1971)	"
Haryana	294	Tomar and Arora (1972)	"
"	285-341	Chhabra *et al.*, (1970)	1-8th lactn.
Red Sindhi	322	Venkayya and Anatakrishnan (1958)	1-6th lactn.
"	348	Mudgal and Ray (1966)	1st lactn.

Weights are affected by age at first calving, parity, breed and management. This makes direct comparison of weights of limited value unless details of management and feeding are given.

Only parity effects on weight at calving have been investigated in tropical milk cattle. Singh and Desai (1966) showed that weight at calving of Sahiwals increased with age in lactations up to the sixth calving. Venkayya and Anantakrishnan (1958) and Chhabra *et al.*, (1970) reported similar findings in Red Sindhi and Haryana respectively. If these weights are taken as a measure of maturity, then the tropical cattle are very late maturing since they are late first calvers.

More details on weight at calving and the factors influencing it are required urgently to fill this gap in the information available on *Bos indicus* cattle.

2.7 Prediction and estimation of genetic change

The principles of estimating the rate of genetic improvement were first formulated by Dickerson and Hazel (1944), who emphasized that expected or observed genetic changes should be expressed as the gain per unit of time. Rendel and Robertson in their two papers (Rendel and Robertson (1950) and Robertson and Rendel (1950) developed a method of predicting genetic change in a closed herd of dairy cattle and in AI populations, based on the principles proposed by Dickerson and Hazel (1944).

The above procedures have been used extensively by Mahadevan and Marples (1961), Syrstad (1966) and Lindstrøm (1969) to cite a few. These procedures are clearly documented by Syrstad (1966) and Lindstrøm (1969) and are shown in the MATERIALS AND METHODS section of the present study.

Genetic gains in milk yield are expressed either as the gain in kilograms of milk per year or as a percentage of the herd or population average. Lindstrøm (1969) reviewed the published results at that time. The results showed that the genetic gains depend on the selection pressures exerted. In dairy cattle, gains of 0-3-2.0 percent of the herd averages were reported (Rendel et al., 1951; Asker et al., 1955; Alim 1962; Syrstad 1966; Acharya and Lush 1968; Lindstrøm 1969). In Eastern Africa the gains were so low that Mahadevan (1965) was convinced that selection within the indigenous cattle populations would not give the desired progress. He, however, overlooked the fact that the selection pressures exerted were too low to effect the desired changes.

In AI schemes, bulls have a greater number of daughters than under natural mating and in this way AI facilitates a more accurate progeny testing. Since progeny testing makes it possible to select superior bulls for further breeding, AI is a way of effecting improvement in the herds. Different systems of organization of AI exist and this has made researchers work out ways of optimalising genetic gain under the various systems.

Specht and McGilliard (1960) showed that in herds of less than 100 cows, progeny testing was less efficient in improving the expected rate of genetic gain than the use of young sires selected on the basis of their dam's production. In herds of 100 and 200 cows progeny testing had a slight advantage over the latter method. Progeny testing is most efficient in large herds.

Skjervold (1963) and Skjervold and Langholz (1964) discussed the major factors influencing the accuracy of a progeny test with special emphasis on the factors affecting the optimum progeny group size of AI bulls and the factors affecting the optimum utilization of young bulls in AI breeding of dairy cattle. They showed that the optimum size of the progeny group depends on the testing capacity, the selection intensity among the bull sires, the selection intensity among the progeny tested cow-sires the proportion of cows which are inseminated with proven bulls' semen and the proportion of cows which are inseminated by young bulls. The optimum utilisation of young AI bulls was achieved when 50 percent or more of all inseminations are made with semen of young bulls. In small populations, not less than 90 percent of the cows should be inseminated with semen of young bulls.

Hinks (1974) reports further factors influencing testing capacity and emphasized that it is necessary to get daughters of young bulls and their contemporaries balanced if maximisation of testing resources is to be realised. Using results of progeny tests in different breeds, he showed that due to the time lag between inseminations and completion of milk records, heifers get transferred and unless the cattle identification is good, bulls' daughters ended up being born in herds where contemporaries were not available.

Progeny testing like other services in any government or breed society competes for scarce resources. For this reason, genetic gains have been expressed as marginal returns to the investments made. As progeny testing programmes are long term projects cost-benefit analyses have to be done using discounted cash flow technique similar to those used in industry. The method is described in detail by Hill (1971) and has been used by Soller, Bar-Anan and Pasternak (1966) and Lindhé (1968).

McClintock and Cunningham (1974) have developed the "Discounted gene flow technique" and used it to evaluate selection in dual purpose cattle populations. They showed that in order to maximise returns to investment in dairy bull testing, more emphasis should be given to dairy traits. Brascamp (1973 a) using similar techniques showed that the contribution of the path, sire to breed young bulls, to total genetic improvement proves to be of less importance from an economic than from a genetic point of view in dual purpose breeds.

Hinks (1974) using ordinary discounting procedures and interest rates of 5, 7½, 10 and 20 percent, concluded that dairy sire testing programmes in Britain are likely to prove unprofitable only under extremely adverse economic conditions. Hill (1971) using similar techniques showed that performance testing for meat could be expected to yield up to 15 percent return in the U.K.

Discounted gene flow techniques or similar methods are likely to be tested in different situations in future. In developing countries where recorded and expanding testing facilities is scarce, these methods will prove necessary since they are based on the old cost-benefit analysis of projects. Different cost and benefits of storage of semen, "laying off" bulls, feeds and prices of commodities vary from country to country and each case requires its own analysis.

SECTION 3 MATERIALS AND METHODS

The data used in this study were obtained from the records of Sahiwal cattle kept at the National Sahiwal Stud in Naivasha, Kenya, and includes the following details:

a) Cow number, dam and sire.

b) Dates of birth, first and subsequent calvings.

c) Lactation periods, calving intervals and dry periods in days.

d) Milk yields, fat percent and fat yields.

e) Weights at calving.

All Sahiwal cattle that completed at least one lactation at Naivasha in the years 1963-1971 were included. Lactation records up to 305 days were included irrespective of length.

The table 8 below shows the distribution of records by parity.

Table 8 Distribution of records by parity

Parity	n
1	1183
2	879
3	634
4	460
5	345
6	218
7	137
8	73
>8	64

The data were copied, checked, punched and transferred to a magnetic disc to facilitate quick access and fast computations. Least squares procedures (Harvey, 1966) were used in estimating the influence of genetic and non-genetic effects on the various traits. All the computations were done using a least squares program on an IBM Model 360 computer at NLH, Ås, Norway.

For any type of investigation, unbiased estimation of the effects involved depends on the appropriateness of the model assumed in the analysis of variance. Several models were used in this study, the choice of elements depending on:-

a) Information available in the literature on the factors influencing the trait in question.

b) The limitation of the least squares program which was 95 equations.

Several runs were made using the same trait and changing the independent variables. This was made possible by setting up matrices with all the desired independent variables and changing them as required after running the analyses with the highest number of equations. The contribution of a particular independent variable to the variance of a particular trait was calculated as the difference between the R^2 value in the models which included and excluded it in alternative runs. Where different runs (ignoring and including the independent variable) were not made, the variance components (given by the program) were used in calculation of the contributions to variance. The models shown in table 9 are the ones that included the largest number of equations.

Table 9 Analysis models

Model	Dependent	Independent	Independent variables of interest
1	T	A,B,P,F,G,H	F,G,H,
2	T	A,B,P,I	I
3	T	A,B,P,J	J
4	T	C,P,F,G,H	C
5	T,U,V	C,F,G,H,S	C,S
6	T,U,V	P,F,G,H,S	P,S
7	T,U,V	P,W,X,Y,F,G,H,S	W,X,Y,S
8	Z	B,C,P,I,S	B,C,P,I,S
9	T	B,C,P,I,Z,S	Z,S
10	W,X,Y	P,J	P,J

KEY

Code	Variable	Code	Variable
A	*Age (1st parity)*	J	*Month-season*
B	*Age (2nd parity)*	S	*Sires*
C	*Age all parities*	T	*Milking yield*
P	*Parity*	U	*Butterfat percentage*
F	*Year*	V	*Butterfat yield*
G	*Season*	W	*Lactation length*
H	*Year x season*	X	*Dry period*
I	*Year-season*	Y	*Calving interval*
		Z	*Weight at calving*

The relative contribution of each effect to total variance (σ^2_t) was shown by the expression

$$\frac{\sigma^2_i}{\sigma^2_t} \times 100 \%.$$

where σ^2_i = the variance component for that effect

Independent variables were classified into a number of groups and their effects analysed using the models. The classification depended on the purpose of the study. Before any of the analyses were done, the data were classified arbitrarily according to age at calving in months, parity, year and month of calving and sire of the cow. This preliminary grouping showed the frequencies of the records in the different periods and were used as guides to the classification. An attempt was made to balance the numbers in the different classes where possible in order to get better comparisons. Classes with relatively few observations were generally merged to form bigger ones. Representation of sires in the different periods (seasons and years) was examined. It was found that in each year up to 20 sires had daughters of different ages milking in the herd. Some sires had daughters milking in each of the years included. Selection of sires and dams was not intense at the early period. When the progeny test results were known the good sires were mated to many dams thus explaining why some sires had daughters milking in all the years covered by this study.

VARIABLES USED

a) Age at calving

Age was considered as either lactation number (parity) or actual age (chronological) in months since birth. A trial run using milk yield data was made classifying age as follows:

Parity: 9 groups i.e. 1,2,3,4,5,6,7,8, $\geq$ 9

Actual age: 15 groups i.e. 27-30; 31-32; 33; 34; 35; 36; 37; 38; 39; 40; 41-45; 46-51; 52-60; 61-72; >72 months

These two ways of age classification were obviously correlated. The results from this analysis were expected to give some guide lines to an accurate classification of age. Calving period effects were corrected for, using the description in model 1, table 9. This trial run showed that when the effects of parity and calving period are corrected for, actual age as classified above had a significant influence on milk yields in all lactations. An examination of the pattern of the constants fitted showed irregular sharp increases of milk yields. These increases corresponded to the higher frequencies of animals which were younger than the average for the parity groups, and thereby indicated that within lactations, variations in age were important. The sharpest increases were in the first two lactations. It was therefore decided to include age groups within these two calvings in the models.

Keeping the parity groups as they were in the trial run, age in months at the first two calvings were grouped as follows:

Age at 1st calving: < 35; 35-36; 37-39; > 39

Age at 2nd calving: ≤ 45; 46-48; 49-51; > 51

In defining these groups, the number of observations falling into the groups were balanced to some extent. Groups were limited so as to get higher numbers of observations falling into each of the defined sub-classes. Larger numbers were desired because the constants fitted would have smaller standard errors. The above classification was used in the preliminary study of the calving period classification.

After selection of the model for estimating the effects of calving period on production traits, age at calving was reclassified to reflect situations where the actual ages of the animals at which calving were known. In this classifiction, parity was dropped from the model and age classified into the following 27 groups:

≤34; 35-37; 38-40; 41-43; 44-46; 47-49; 50-52; 53-55; 56-58; 59-61; 62-64; 65-68; 69-72; 73-76; 77-80; 81-84; 85-90; 91-95; 96-100; 101-105; 106-110; 111-115; 116-120; 121-125; 126-130; 131-140; 141-150; 151-180 months.

This classification was tested on milk yield, fat percentage and fat yields and was shown to be more efficient than those based on parity alone. However, in the tropics, age of the animal is rarely known accurately and therefore parity was used in most of the analyses.

b) Calving period

One of the aims of the present study was to devise a suitable system for classification of "season of calving" under Naivasha conditions and then use it to correct data for the effects of calving period in the subsequent analyses. Milk yield was considered the most important trait and therefore only the data on it were used in the selection of a suitable classification.

A climatic index, Temperature Humidity Index (THI) developed by the United States Weather Bureau (1959) and the mean monthly rainfall were used in defining seasons. The index is derived as follows:

Using degrees Fahrenheit (^{o}F) and RH percent

$$THI = td - (0.55 - 0.55\ RH) \times (td - 58)$$

where THI = Temperature Humidity Index

td = The dry bulb temperature in ^{o}F

RH = Relative humidity

Using degrees centigrade (^{o}C) and dew point

$$THI = 0.99TD_b + 0.36Td_p + 41.5$$

where Td_b = The dry bulb temperature (^{o}C)

Td_p = The dew point at a given (^{o}C)

Meteorological data (consisting of monthly rainfall in the period 1963-1971) were assembled for this study. Mean monthly, maximum and minimum rainfall figures were plotted (see fig. 2). Data for THI calculations were not available at NAHRS. However, the Ministry of Water Development has a weather Station at Naivasha Town, a few kilometers from NAHRS. The data recorded there are routinely forwarded to the Meteorological Department Headquarters at Dagoretti, Nairobi, from where they were obtained for this study.

THI calculations were then made and plotted month by month. Examination of these THI showed that they were below the critical level of 70 (Kiwuwa, 1973). This was due to the low night temperature at Naivasha. The monthly mean THI for the period 1963-1971 were plotted (see Fig. 3). They showed that January-May is hotter and more humid than July-December. June, July and August are mainly cool while September is a hot month. The short rains occur in the last three months.

Average rainfall and THI values (see fig. 3) were used in identifying "seasons". It was considered unnecessary and expensive to look into all possible combinations of months to a calving period and the following three systems were tested:

(i) Four periods (seasons) were defined using figure 3. These were:

January-March; April-June; July-September; October-December.

These periods corresponded to either high or low THI values. Calving period in this model (ref. Model 1 table 9) was represented by year of calving and season as defined above. Because of the large yearly variation, interaction of year and season were also fitted into the model.

(ii) Results of (i) above showed that significant year x season interaction existed. The appropriate model was taken as one that included these interactions in some form.

A classification was made where each of the periods (seasons) as defined in (i) in different years was considered a separate period. There were 9 years and 4 seasons/year giving a total of 36 sub-classes. These subclasses were termed year-seasons as they included both year and season effects. The rationale behind this classification was that a particular period, e.g. January to March, in 1963 had a different effect on production than that of the same period in 1970.

(iii) Since the observed year to year and month to month variations in climate were large, it was decided that each month in each year should be considered as a completely different period from any other period coming before or after it. The number of sub-classes in this case was 9 x 12 = 108 and these were termed "month-seasons". This number of sub-classes was higher than the maximum allowed by the program in any single run. The effect of this classification was obtained by absorbing the equations of this class. However, it was not possible to get a print out of the monthly constants. This was not considered serious because the objective was to estimate the effect of the classification. The contribution of calving period was calculated from the difference between the R^2 values in the models that included and ignored the classification in alternate runs.

All the three classifications included age at 1st calving and parity (Models 1-3; table 9). They were compared to one another and to the model where no coding for calving period was done, on the basis of the total reduction in sum of squares, and error mean squares.

After investigating the age and calving period, the analyses, Model 1 (table 9) was used. In the case of lactation length, dry period, calving intervals and weight at calving Model 2 (table 9) was used in trial runs. Since Model 1 and 2 were equivalent, it was considered unnecessary to run the analyses with Model 1.

c) Current lactation lengths, previous dry periods and previous calving intervals

These were considered as continuous variables and were fitted into the models as regression variables. Lactation lengths were limited to a maximum of 305 days.

d) Weight at calving

This was taken as a continuous variable in the analyses involving milk yields in all lactations. In the analyses involving only first lactations, weight (in kg) was classified into 6 sub-classes i.e. ≤ 320; 321-340; 341-360; 361-380; 381-400 and >400 kg.

e) Sires

The number of sires varied between 60 and 94. As such a coefficient matrix of equations including a sires' classification would have been too large to be inverted using the program. The sum of squares due to sires were calculated indirectly by absorbing the sire classification. Fitting of sires into the models required two runs, one for the analysis where sires were ignored and the other for the absorption of sires. The sum of squares due to fitting sires were calculated as the difference in the error sum of squares in the two runs. The contribution of sires to the total variance was calculated as the difference in the R^2 value of the two runs. Because of the large number of sires, it was not possible to include any interaction terms involving sires.

Estimation of genetic parameters:

Production and reproduction records were used in the estimation of different genetic parameters, the number of observations depending on the trait and the parameter being estimated. The data were sorted and analysed in the following ways before the estimates were calculated.

a) For the estimation of heritabilities of the traits in any of the first three parities, all the animals with records of the trait in question were considered. The estimates in the first lactations were expected to be more reliable because the number of observations was higher than in the later ones. The number of records differed from lactation to lactation and as such no pooling of the data was done since the intention was to estimate the parameter from all the available and relevant records.

b) Estimates of genetic and phenotypic correlations among the traits in the first three lactations (milk yield; fat percentage and fat yield) were calculated from pooled data where each animal included had records of the three traits in each of the three lactations.

c) All the records of the different traits in all sections were later pooled and from these heritabilities, repeatabilities, genetic and phenotypic correlations were calculated.

The data were corrected for calving period and parity effects before the computations of the variance and co-variance components were done. Hierachical models were used. Heritability, repeatability, genetic and phenotypic correlations were calculated from the respective variance and covariance components according to Becker (1967). Approximate standard errors for heritabilities and genetic correlations were calculated according to Robertson's (1959 b) formulae while those of repeatabilities were calculated following Becker (1967).

Prediction of genetic changes:

The parameters obtained from the genetic analyses were utilised in models for predicting genetic changes in the herd.

The predicted genetic gain per year, ΔG was estimated following Rendel and Robertson, (1950):

$$\Delta G = \frac{I_{BB} + I_{BC} + I_{CB} + I_{CC}}{L_{BB} + L_{BC} + L_{CB} + L_{CC}} = \frac{\Sigma I}{\Sigma L}$$

where I = Genetic superiority of parents above the mean of contemporary animals of the same sex.

L = Mean generation interval.

BB = Bulls to breed bulls.

BC = Bulls to breed cows.

CB = Cows to breed bulls.

CC = Cows to breed cows.

BB, BC, CB, CC being the paths in which genes are transmitted from one generation to another.

$$I_{BB} = i_{BB}\sigma_G\sqrt{b}$$

where i_{BB} = selection intensity among the tested bulls

σ_G = genetic standard deviation of the character.

and $$\sqrt{b} = \sqrt{\frac{0.25nh^2}{1 + (n-1)\ 0.25h^2}}$$

where n = number of progeny per young bull tested

and h^2 = heritability of the character

$$I_{BC} = I_{BB} \times p$$

where p = Elite herd/Total herd.

$$I_{CB} = i_{CB}\sigma_G h$$

where i_{CB} = intensity of selection of cows to breed bulls.

$$I_{CC} = i_{CC}\sigma_G h$$

where i_{CC} = Intensity of selection of cows to breed cows. This depended on the culling rate.

Average generation interval depended on the models used.

4. RESULTS AND DISCUSSION

Age expressed either in years and months ("actual") or as parity was considered an important factor influencing milk yield and its associated characteristics. In the tropics records of actual age are available only in the research institutions and as such although an investigation of the effects of actual age was made, parity was used as the measure for age.

4.1 Preliminary investigations on classification of calving period

In the investigations of calving period (see materials and methods) three ways of grouping months and years were looked into. The results (see table 10) show that:

a) Whichever classification was adopted (of those investigated) calving period had a highly significant influence on milk yield.

b) Taking Model 1 as the reference, calving period as expressed in this study reduced the error mean square in a very similar manner in all the three models. The cause of this similarity was in the definition of calving period. All the three models included year of calving in one way or another. Years were included in the study because previous works (see literature review) had shown that years are an important source of variation in milk yield and its associated traits.

Table 10. Models used in estimating the effects of calving period on lactation milk yield

M O D E L S

Source	I				II				III				IV			
	df	MS	F	$\frac{\sigma^2_i}{\sigma^2_T}$ %	df	MS	F	$\frac{\sigma^2_i}{\sigma^2_T}$ %	df	MS	F	$\frac{\sigma^2_i}{\sigma^2_T}$ %	df	MS	F	$\frac{\sigma^2_i}{\sigma^2_T}$ %
Age 1	3	2688441	5.65**	1.21	3	1425013	3.19*	0.42	3	1657911	3.71**	0.69	3	1657617	3.71**	0.69
Age 2	3	1467940	3.09*	0.82	3	916974	2.05 ns	0.30	3	932963	2.09 ns	0.42	3	933417	2.09 ns	0.41
Parity	8	17054572	35.9**	5.53	8	16520431	36.9*	5.63	8	16571488	37.1**	7.57	8	16566511	37.1**	7.52
Years													8	11079382	24.8**	4.08
Seasons													3	9892823	22.2**	1.67
Year x Season													24	1453956	3.26**	0.58
Year - Season									35	4363616	9.73	5.78				
Month - Season					107	1711100	3.83**	7.95								
Residual	4689	475507		90.43	4582	446762			4654	446417		85.54	4654	446345		85.05
R^2 %	7.56				14.30				12.73				12.75			

ns = not significant * = significant at P < 0.05 ** = significant at P < 0.01

c) The highest reduction in error sums of squares was in Model II where each single month in the period was considered as a season by iteself. This gave as expected the highest R^2 value. Going by R^2 values, this is the model which should be used. The error mean square in model II was the highest due to the greater reduction in error degrees of freedom. This coupled with difficulties in fitting so many equations (actually beyond the capacity of the present computer program where the maximum was 95 equations, made Model II least applicable.

d) Model III and IV are basically the same. Model III can be said to have "built-in" year, season and year x season interactions. Each of these models has its own advantage. If the interest is just to correct for the calving period effects without caring about the actual year, and season constants, Model III is more appropriate than model IV. If, however, year and season constants are required then Model IV is the one of choice. In this study both year and season constants were required and Model IV gave them directly although they were of course calculable from Model II through averaging.

e) Although the objective in this preliminary part of the investigation was not to study the effects of parity, it was found that the sum of squares and the constants in the different models were basically similar.

f) The contribution of calving period to the total variance of milk yield, calculated as the respective differences between the Model's R^2 value and that in Model I were 8, 6 and 6 percent respectively. This contribution was high enough to warrant data correction for calving period.

From the results of this preliminary study, Model IV was selected and used in all the subsequent analyses where calving period effects' correction and/or estimation was done.

4.2 Lactation milk yields, fat percent and fat yields.

The above trait were analysed using the same models first because of saving computer time and secondly because the effects influencing them were the same. Discussion of the means and factors influencing them will be done for all the three at the same time to avoid unnecessary repetition.

4.2.1 Means and their variations.

The least square means of the traits depended on the effects included in the model. They were calculated and are shown in table 11, but not much emphasis was laid on them. The ordinary corrected means are presented with their variations.

Table 11: Means[1] and their variations

Trait	LSQ Mean ± S.E.	Average ± S.E.	S.D.	C.V. %
305 day milk yield (kg)	1455±10.40	1386±9.10	575	41
Fat percent	5.00± 0.02	5.04±0.02	1.25	25
Fat yield (kg)	72.26± 0.57	69.29±0.49	30.90	45

[1] *3993 Records of 1183 cows.*

The mean milk yields of cows in NSS herd are in general comparable to the reported Sahiwal herds see table 1. The average observed here is high when compared to those reported in India where lactations of less than 100 days are excluded and is also much higher than those reported for indigenous East African Zebu cattle.

Sahiwals in NSS have adapted themselves to the fairly arid climate of Naivasha and are able to produce around 5 kg a day without supplementation. The yields of individual cows can be as high as 2500 kg, but since Sahiwals should be developed for the dry areas, this yield is difficult to sustain under the conditions of extensive type of husbandry prevalent in the dry areas of East Africa.

The fat percentages and fat yields are also very comparable to the few published (see table 3). The fat percentages are, however, lower than those reported for indigenous East African cattle. Since fat kg is more important than the fat percent (as there is no premium paid for higher fat percent in East Africa) and since the fat yields of Sahiwals in NSS are higher than those reported for Nganda and short-horn zebu (Marples, 1965), then Sahiwals can be regarded as the more desirable breed for this area. The fat yields are, however, lower than those of Bos taurus cattle in East Africa (Marples, 1965 and Kiwuwa, 1973). Fat yields reflect milk yields more than fat percent and this explains why the Sahiwal fat yields are lower than those reported for Friesians by Marples, (1965) and Kiwuwa, (1973), although the Friesians have up to 1-2 percent lower fat percent in their milk.

The coefficient of variation of milk yield (see table 11) is as large as those reported before in East Africa by Galukande et al., (1962) and Meyn and Wilkins, (1974). These variations are larger than those observed in European cattle in East Africa by Kiwuwa (1973) and Lindstrøm and Solbu (1978). Variation in the milk yield of Sahiwals at the NSS is large because of the large variation in lactation length which is highly correlated to milk yield.

The effects included in Model IV accounted for 13 percent of the total variance. Lindstrøm and Solbu (1978) observed that 50 percent of the total variation was classifiable. The model they used included, breed and the previous calving interval effects which were not considered in Model IV.

The coefficient of variation observed in fat percent is twice as large as that observed by Kiwuwa and Kyomo (1971) in Mpwapwa cattle and is about three times as large as those reported by Marples (1965) and Lindstrøm and Solbu (1978). The reason why the coefficient variation is so high is not clearly known. Marples (1965) obtained a coefficient of variation which was low. He explained in his paper than the sampling of milk and the fat testing were very closely supervised, and if the figures of any two consecutive months differed by 0.5 percent units, the test was repeated. At Naivasha, the records were not checked so carefully and this possibly explains why the coefficient of variation was so large.

The effects included in Model IV accounted for about 7 percent of the total variance of fat percentages. This is much less than what Hinks (1970), Cunningham (1972) and Lindstrom and Solbu (1978) observed in Bos taurus cattle. It is possible that errors in sampling, testing and recording are the causes of this high unexplained variance. The checking of the fat records has never been very strict. Laboratory technicians in the fat testing laboratory at Naivasha have not been penalised for inaccurate sampling or recording. Some farmers in the milk recording scheme have complained about the accuracy of fat testing without getting adequate explanations. These technicians can also adjust their data to compensate for their inaccurate testing. All these increase the error component in the analysis, leading to a large part of unexplained variance.

Fat yields are calculated from milk yield and fat percentages. Cows that produce high milk yields also produce high fat yields. Fat yields are correlated more to milk yields than they are to fat percentages, in this study ($r_p = 0.94$). The coefficient of variation in fat yields were similar to that observed in milk yields and the models used accounted for similar amounts of total variation in both traits. The coefficient of variation is larger than those observed by Hinks (1968) and Cunningham (1972) and the models used in this study accounted for much less variance. Errors in fat sampling and testing and the large variation in milk yields are possibly the causes of such a large unexplained part of total variance.

4.2.2 Factors influencing milk yields, fat percent and yields.

a) Age

Age (see Materials and Methods) was coded as either actual age in months or parity. Because of their obvious correlation no attempt was made to include them in the same model. The results obtained for milk yield, fat percent and fat yields are shown in tables App. 1, App. 2 and App. 3. The results pertaining to each factor were abstracted and placed in smaller tables for convenience of discussion.

Actual age effects

Actual age influenced all the traits significantly. The relative contribution to total variance, however, depended on the trait. The contribution was highest in the milk yield and lowest in fat percent (see table 12).

TABLE 12 Actual age effects

Trait	MS	F	σ^2_i / σ^2_t %
Milk yield	3,903,207	13.80**	7.49
Fat percent	3.04	1.98**	1.26
Fat yield	7,084	8.27**	4.83

df age groups = 26 ** = Significant at $P < 0.01$

df error = 3845

Although age influenced fat percent least, it was interesting to note that in the model without sires, age accounted for 30 percent of the total explained variance.

The constants fitted (see Fig. 5) were scaled to their standard deviations to make them comparable. They show that as age increased, milk and fat yields increased up to the age of about 6 years and then stabilised (although with minor fluctuations). From this it was concluded that cows which are 6 years old and above are mature.

The trend observed in fat percent was the opposite. The youngest animals (1-2 lactations) had the highest fat percent.

Parity effects

Parity had a highly significant influence on the three traits (see table 13). Milk and fat yields increased steadily up to the 4th lactation and then dropped slightly (see fig. 6). Fat percent on the other hand, decreased with parity. The amount of variance accounted for by parity depended on the trait and was lowest in fat percent.

Table 13: Parity effects

Traits	MS	F	σ^2_i/σ^2_t %
Milk yield	11,439,798	40.24**	8.22
Fat percent	5.66	3.69**	0.72
Fat yield	20,311	23.65**	4.25

df parity = 8 ** = significant at $P < 0.01$
df error = 3851

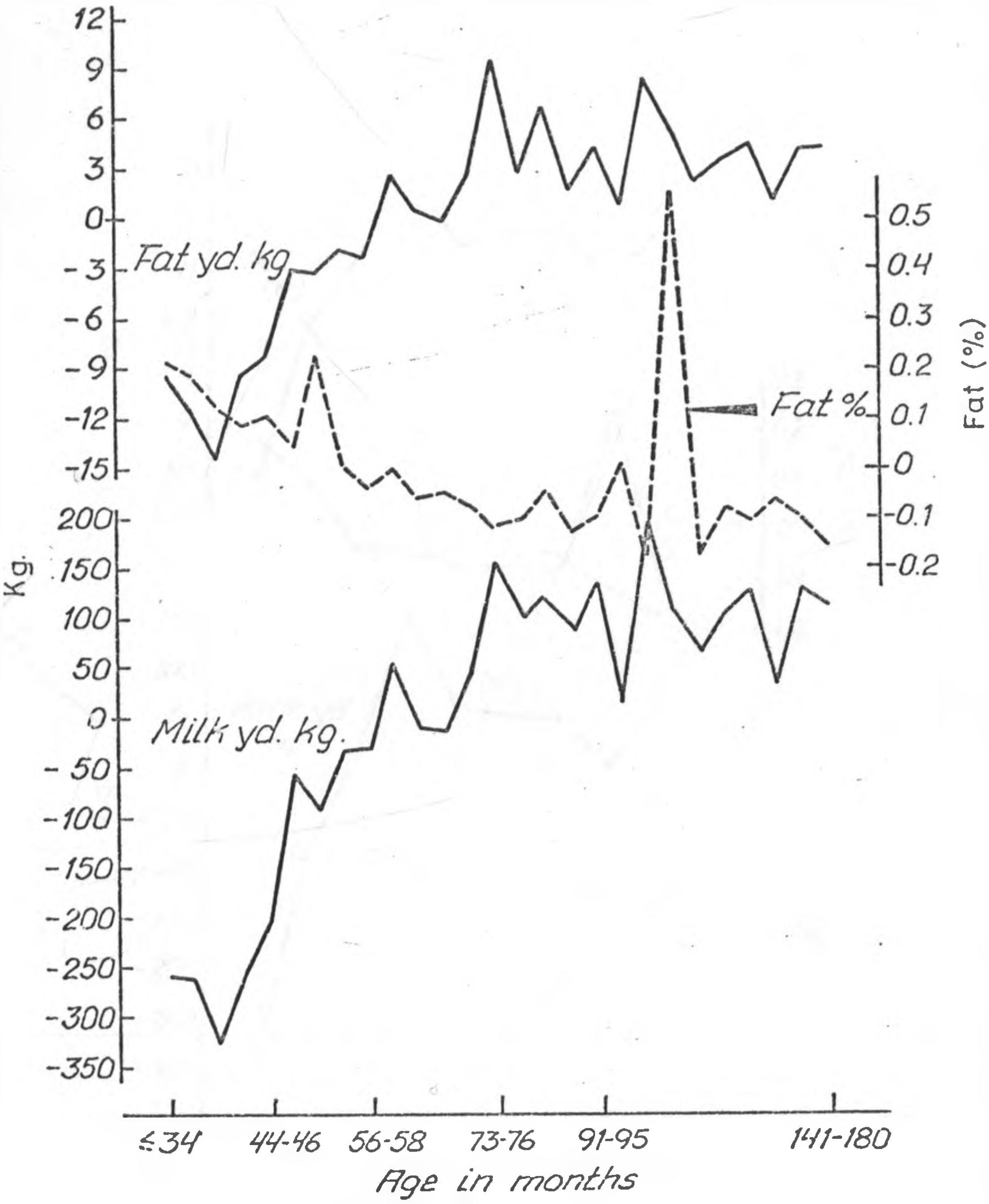

Fig. 5. Age (actual) effects on milk yields, butterfat percentages and butterfat yields.

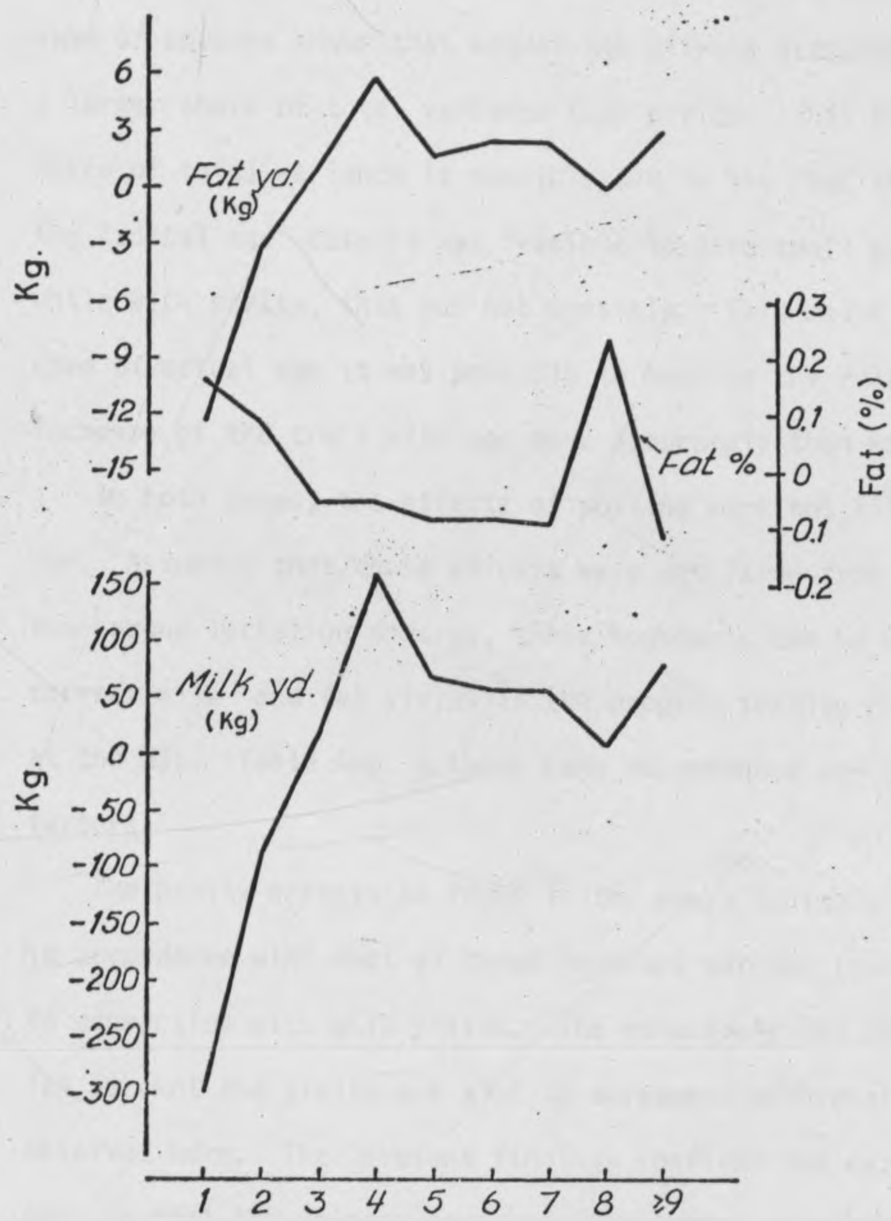

Fig. 6. Parity effects on milk yields, butterfat percentages and butterfat yields.

Comparison of actual age and parity effects

Tables 12 and 13 show the results of ANOVA obtained using the two ways of classifying age. In both cases, age had a highly significant influence. Comparison of the respective sums of squares shows that actual age effects accounted for a larger share of total variance than parity. This higher share of total variance is possibly due to the fact that in the "actual age" case it was feasible to make small groups while with parity, this was not possible. This meant that in the case of actual age it was possible to measure the relative increase of the trait with age more accurately than with parity.

In both cases, the effects of culling were not allowed for. Assuming that these effects were not large from the second lactation onwards, these constants can be used to correct milk and fat yields in the progeny testing programme at the NSS. Table App. 4 shows some recommended age correction factors.

The parity effects as found in the Kenya Sahiwal, are in accordance with most of those reported earlier (see table 2), in connection with milk yields. The relatively few reports on fat percent and yields are also in agreement with what is observed here. The present findings confirms the earlier ones in that the younger cows have the lowest fat percent.

Actual age investigations are few in the tropics. Ngere et al., (1973) showed that Hariana cattle were mature at the age of six years which is the same one in the present study. Chowdhary et al., (1974) working with Sahiwal data in India found that the mature age was 10 years, much later that what is observed here. Their method of analysis was also different as they did not consider any other environmental source of variance. Due to lack of other comparative work, it may be safe to take six years as the mature age.

The "actual age" curve shows that within the first parities, the curve is very steep. It appears therefore, that correction of data using "actual ages" is the more appropriate of the two. At Naivasha NSS where both parity and actual age records are kept, it seems a worthwhile recommendation that "actual ages" be used in the correction of data. For sometime, only the first lactating animals have been used in the bull evaluation. Now that the increase in yield with age has been studied, it is advisable to include second and third calvers in the progeny test programme and to use age correction factors shown in table App. 4. Parity correction factors are also shown for the sake of those areas where actual age is not known.

b) Calving period effects

The different ways of classifying months in the period 1963-1971 were investigated in the earlier part of this study. The effects of year, season and year x season interaction were estimated in models which included age at calving. For convenience the model which included actual age was selected for the discussion of the effects of calving period.

Calving year effects

Year of calving (see table 14) influenced all the three traits significantly. The results of the milk yield analyses agree with those reported before by Osman (1972) and Kimenye and Russell (1976). Comparative results in fat percent and yields of _Bos indicus_ cattle are not available in the tropics. Lindstrøm and Solbu (1978) showed that fat percent is also influenced by year-season of calving.

Table 14 Year of calving effects

Trait	MS	F-Value	σ^2_i / σ^2_t %
Milk yield	9,981,333	35.37**	6.75
Fat percent	6.76	4.41**	0.86
Fat yields	25,397	29.63**	5.33

Year df = 8 Error df = 3845 ** = Significant at $P < 0.01$.

The year constants (see Fig. 7) show that milk and fat yields followed a similar trend. They were fairly static in the period 1963-1967 and then started rising steadily in the later years. Fat percent showed yearly fluctuations, but did not have as clearly defined a trend as the one observed in milk and fat yields.

Yearly rainfall was plotted (see fig. 7) in an attempt to draw some connection between it and the production parameters. Fluctuations in rainfall were not always reflected in the production parameters. This was so when the yearly milk and fat yields were compared to the particular year's rainfall. If one, however, bears in mind that animals calving in the

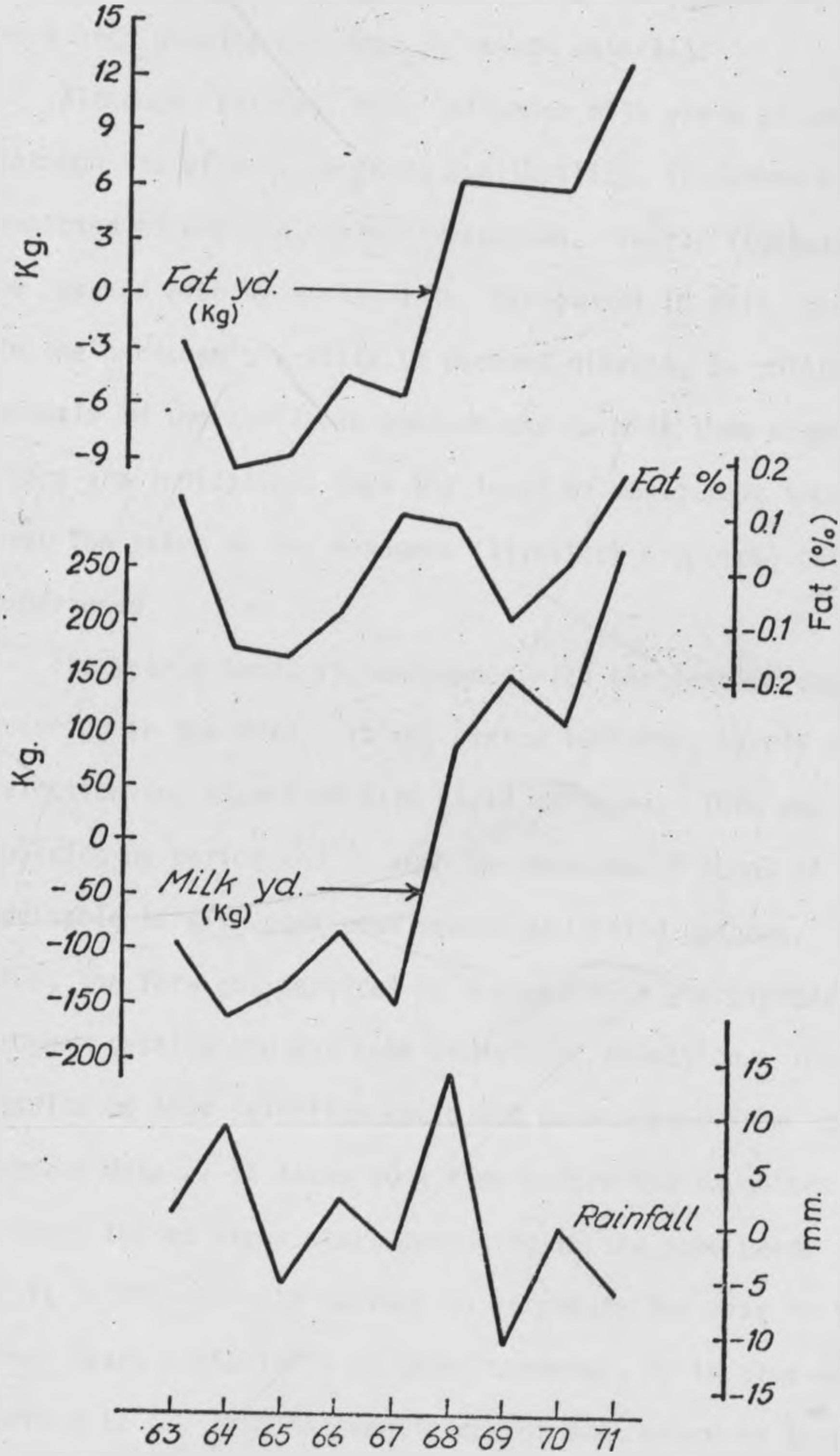

Fig. 7. Year of calving effect on milk yields, butterfat percentages and butterfat yields.

year following a good year, will have plenty of grass, then, it becomes easy to see why the milk and fat yields in 1969 were high despite the drop in annual rainfall.

Although rainfall does influence milk yield parameters through its effects on grass availability, it cannot be expected to explain every fluctuation. Yearly fluctuations can be caused also by management. Management in this case refers to the herdsman's ability to prevent disease, to rotate the animals in the available pasture and to milk them properly. There are indications that the level of management improved over the years as the managers (livestock officers) gained experience.

The yearly trend is confounded with the genetic change occuring in the herd. In the period 1962-1969 hardly any selection for increased milk yield was done. This was the building up period and as such the management found it advisable to give poor cows second and third chances. In 1969, the farm got services of a geneticist who planned progeny testing and did some individual selection. The results of this selection could not be assessed from the present data as it takes some time before the daughters of progeny tested sires start producing in the same herd. Just as it is not entirely correct to attribute the rise in the later years (1968-1971) to genetic change, it is also not correct to say that no genetic change took place in that period.

The amount of variance removed by fitting years (see table 14) depended on the trait. In the present study, the values obtained from the analyses of milk and fat yields were similar to those reported by Osman (1972). and Kimenye (1973). The contribution of the year of calving to the variations of fat percentage was small. This trait was least influenced by any of the identified effects.

Season of calving effects

Season of calving see table 15. influenced all the three traits significantly. The constants fitted (see fig. 8) showed an almost identical trend. The comparison of this seasonal trend and the actual seasonal rainfall shows that cows calving in the wettest period (April-June) had the lowest yields. The cows calving in the following two seasons benefited from the rainfall (in April-June) which supported grass growth. The grass available in the wettest period had a high moisture content and as a consequence too little dry matter. Lush grass is also associated with scouring, which also affects the yields negatively. This explanation of seasonal variations in the traits limits itself to the conditions at the start of the lactation. It appears that it is the condition at the start of the lactation rather than later that determines the yield.

The results in this study agree with previous studies in East Africa. They show that Sahiwals like other breeds are sensitive to seasonal changes as it affects feed quality and availability. Sahiwals on the whole seem to manage fairly well since the difference between the extreme constants is still less than 1/10 of the mean yield.

Table 15: Season effects

Trait	MS	F-Value	σ^2_i/σ^2_t %
Milk yield	2,418,119	8.51**	0.67
Fat percent	4.07	2.65*	0.19
Fat yield	4,666	5.43**	0.37

Season df = 3 * = significant at $P < 0.05$

error df = 3845 ** = " " $P < 0.01$

Seasonal influences on fat percent were significant at the 5 percent level. Previous studies in this field, (Tasker 1955; Alim 1965; Khalifa 1966) agree with the present one.

Seasons contributed very little to the total variance of fat percent. Reports in the tropics have not included seasons in the study of fat percent. Cunningham (1972) analysed the effect of the month of calving on fat percent of Irish dairy cows and found that month of calving contributed almost nothing to the variations of fat percentages. It can be argued that seasons can be dropped from the analysis models. without affecting the accuracy of the models much.

Year x Season interactions

Significant year x season interactions in the three traits were observed. These interactions showed that the model without interactions would not describe the effects adequately since year and season effects were not additive. The non-additivity of the year and season effects was due to the

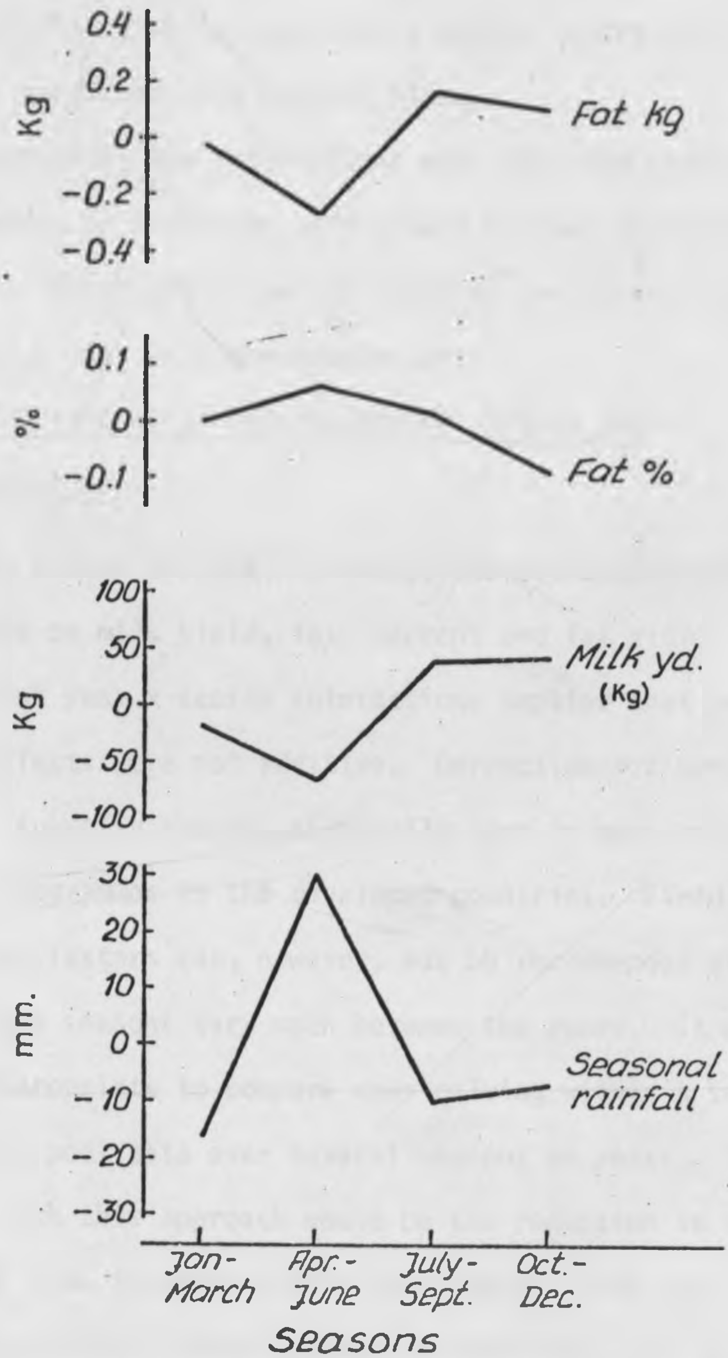

Fig. 8. Season of calving effects on milk yields, butterfat percentages and butterfat yields.

great variation in the seasonal rainfall between the years, making different seasons within a particular year more similar than the same seasons in different years. This rainfall variation also explains why year x season interactions accounted for more variation than seasons alone.

In practice, the interactions mean that the comparison of daughters in a progeny test should be done within seasons and within years since pooling the data over years will introduce a bias into the comparisons.

Concluding remarks on calving period effects and recommendations

Year, season and their interactions had significant influences on milk yield, fat percent and fat yield. The significant year x season interactions implied that year and season effects were not additive. Correction for period of calving (usually season) is usually done in most progeny testing programmes in the developed countries. Fixed correction factors can, however, not be recommended at the NSS because seasons vary much between the years. It would appear appropriate to compare cows calving within a season and not to pool data over several seasons or years. The problem with this approach would be the reduction in the number of cows calving, within the season. With age correction factors (such as those in table App. 4), it should be possible to include animals of different parities in the comparison. Besides this, there is a case for seasonal calving, favourable period being just after the long rains

(April-June) when the grass is usually plentiful. If most of the animals were calved seasonally, progeny testing would be much easier.

Sahiwals are sensitive to environmental changes. Good management has got to include some form of fodder conservation. The mode of conservation will depend on the economic conditions and can vary between hay, silage and standing hay. Sahiwals kept on small scale farms should be supplemented according to the production milk price and severity of the seasons.

c) Current lactation length previous dry period and calving interval

The above factors were fitted into the models as independent variables although they are related to the cows' productivity in previous lactations as well as the current ones. They were included with a view to estimating the amount of variance that is removed by correcting for them.

Lactation length

The effect of correcting for lactation length in all lactations was estimated separately. The results showed that:-

a) The regression of milk yield, fat percent and fat yield on lactation length was 6.69 ± 0.13 kg, 0.003 ± 0.004 percent units and 0.340 ± 0.07 kg respectively. The regression of fat percent on lactation length was the only one that was not significant.

b) Correction for lactation length increased the R^2 value by 35, 0.01 and 32 percent in milk yield, fat percent and fat yield respectively.

Table 16 A Influence of calving interval, dry period and lactation length on milk yields corrected for parity and calving period effects (Models without sires)

Model No.	Calving interval b±SE	Dry period b±SE	Lactation length b±SE	R^2 %
1	1.43±0.15**	-0.63±0.12**	6.89±0.16**	55.63
2	3.08±0.19**	-1.99±0.16**	-	25.02
3	-	0.23±0.09**	7.27±0.16**	54.17
4	0.87±0.10**	-	7.10±0.16**	55.21
5	-	-0.18±0.11 ns	-	17.77
6	-	-	7.22±0.16**	54.04
7	1.33±0.14**	-	-	20.50
8	-	-	-	17.69

Table 16 B Models with sires fitted

Model No.	Calving interval b±SE	Dry period b±SE	Lactation length b±SE	R^2 %	R^2 due to sires
1	1.42±0.15**	-0.60±0.12**	6.83±0.16**	58.82	3.19
2	2.98±0.19**	-1.90±0.16**	-	29.87	4.85
3	-	0.25±0.09**	7.19±0.16**	57.42	3.25
4	0.89±0.10**	-	7.01±0.16**	58.45	3.24
5	-	-0.15±0.12 ns	-	23.31	5.54
6	-	-	7.14±0.16**	57.28	3.24
7	1.34±0.14**	-	-	25.96	5.46
8	-	-	-	21.75	5.67

ns = not significant
** = significant at P< 0.01

Table 17 A Influence of calving interval, dry period and lactation length on butterfat yields corrected for parity and calving period effects

(Models without sires)

Model No.	Calving Interval b±SE	Dry Period b±SE	Lactation Length b±SE	R^2 %
1	0.06±0.01**	-0.03±0.01	0.35±0.01	47.14
2	0.15±0.01**	-0.10±0.01**	-	20.02
3	-	0.01±0.00*	0.37±0.01**	46.11
4	0.04±0.01**	-	0.36±0.01**	46.87
5	-	-0.01±0.01 ns	-	14.22
6	-	-	0.36±0.01**	46.00
7	0.06±0.01**	-	-	16.37
8	-	-	-	14.15

Table 17 B Models with sires fitted

Model No.	Calving Interval b±SE	Dry Period b±SE	Lactation Length b±SE	R^2 %	R^2 due to sires
1	0.07±0.01**	-0.03±0.01**	0.35±0.01**	50.97	3.83
2	0.14±0.00**	-0.09±0.01**	-	25.31	5.30
3	-	0.01±0.00*	0.36±0.01**	49.96	5.09
4	0.04±0.01**	-	0.35±0.01**	50.71	3.84
5	-	0.01±0.01 ns	-	20.01	5.79
6	-	-	0.36±0.01	49.89	3.86
7	0.06±0.01**	-	-	22.06	5.69
8	-	-	-	19.96	5.81

ns = not significant
* = significant at $P < 0.05$
** = significant at $P < 0.01$

Table 18 A Influence of calving interval, dry period and lactation length on butterfat percentages corrected for parity and calving period effects

(Models without sires)

Model No.	Calving Interval b±SE	Dry Period b±SE	Lactation Length b±SE	R^2 %
1	0.01±0.01 ns	0.03±0.00**	0.00±0.01 ns	6.29
2	0.01±0.01 ns	0.03±0.00**	-	6.29
3	-	0.03±0.00**	0.00±0.01 ns	6.25
4	0.03±0.00**	-	0.01±0.01 ns	4.82
5	-	0.03±0.00**	-	6.24
6	-	-	0.00±0.01 ns	2.25
7	0.03±0.00**	-	-	4.76
8	-	-	-	2.25

Table 18 B Models with sires fitted

Model No.	Calving Interval b±SE	Dry Period b±SE	Lactation Length b±SE	R^2 %	R^2 due to sires
1	0.01±0.01 ns	0.03±0.01**	0.00±0.01 ns	11.09	4.80
2	0.01±0.01 ns	0.03±0.00**	-	11.09	4.80
3	-	0.03±0.00**	0.00±0.01 ns	11.05	4.80
4	0.03±0.00**	-	-0.01±0.01 ns	9.65	4.83
5	-	0.03±0.00**	-	11.05	4.81
6	-	-	0.00±0.01 ns	7.25	5.00
7	0.03±0.00**	-	-	9.57	4.82
8	-	-	-	7.24	4.99

ns = not significant
** = significant at $P < 0.01$

The regression coefficient of milk yield on lactation length obtained here is almost the same as that obtained by Ngere et al., (1973) (7.45 kg) in Hariana cattle. Alim (1960), Galukande et al., (1962) and Batra and Desai (1964) expressed the association as a correlation. They showed that there was a strong correlation of about 0.6-0.8. The correlation in the present study was 0.63 and was significant. This study confirms the earlier ones.

There are no published comparative studies on the relationship of fat percent and yields to lactation length in the tropics. The results of the present study show that fat yields are influenced by lactation length to almost the same extent as milk yield while fat percentages are not influenced at all.

Fat percentage varies during the course of a lactation. It is lowest at the start and highest towards the end, (Khalifa, 1966). One would have expected a positive regression of fat percent on lactation length. However, the regression found here, though positive, was not significant and this can be interpreted to mean that fat percent did not change with the stage of lactation. Errors in the estimation of fat percentages and deliberate erroneous recording can partly explain this observation. The latter can easily occur if the milk recording laboratory technicians do not want to be querried by farmers about sudden drops in fat percentages. They would therefore only need to give a figure that is close to the one of the previous month. This would reduce the variation within a lactation and make the regression of fat percent on lactation length smaller.

The amount of variance removed by including lactation length in the models was less than that reported by Alim (1960), Galukande et al., (1962) and Ngere (1970). The differences are due partly to the analysis models used. The methods used here compare to those applied by Ngere (1970) and the differences are possibly due to breed.

The three production traits were later analysed in the same run using different combinations of the independent variables. First lactations were excluded from these analyses because they did not have previous calving intervals or dry periods. The regression coefficients obtained are shown in table 16. There were no major changes in the regression of any of the traits on lactation length when the other effects were included. This showed that lactation length influences milk and fat yields significantly irrespective of the correction for the other effects.

Previous dry period

The magnitude and significance of the regression of traits on dry period depended on the trait and the effects corrected for in the analyses see table 17. In the milk yield analyses, the regression coefficients were generally small, negative, highly significant and dependent on whether calving intervals were included in the model or not. Calving interval seemed to be correlated to dry period in all the analyses.

The information available in the literature is conflicting. The present study considered various alternatives and the results show that good milk producers had short previous dry periods. This agrees with the reports of Mahadevan and

Marples (1961) and Kavitkar *et al.*, (1968). Correction for the previous dry period length seems inappropriate as it tends to favour the poor producers. Dry period accounted for very little variance in all the traits and in this way it seems unnecessary to correct for it.

Previous dry period influenced fat percentages significantly although the regression coefficients were small. This shows that either the cows which had long dry periods stored nutrients better and were able to produce milk at a higher fat percent than the ones with the shorter dry periods or the animals with long dry periods produced milk with high fat contents because they produced less milk. It is not possible to tell which of the two arguments applied as both are possible. The latter, however, seems more plausible.

The small negative regression of fat yield on dry period is similar to that obtained in milk yield. Although fat percentages are positively associated with dry periods, milk yields are more important in the determination of the fat yields. There is therefore no point in correcting fat yields for variation in the length of dry period.

Previous calving interval

Previous calving interval influenced milk and fat yields without affecting fat percentage. The regression coefficients (see tables 16-18) depended on the presence of dry period in the analysis models. This correlation of dry period and calving interval has been referred to already. The results, indicate that milk and fat yield data should be corrected for previous calving intervals and that in fat percentage data only dry period should be corrected for.

The milk yield analysis results agree with those reported by Mahadevan and Marples (1961) and Galukande et al., (1962) although the regression obtained in this study were lower than those reported before. Calving intervals in this herd were not too long (average 413 days). This observation was as a result expected.

Joint effects of lactation length, dry period and calving interval on milk yield, fat percentage and fat yields

Correction for the three effects simultaneously showed the relative reduction of total variance of 35, 5 and 31 percent for milk yield, fat percent and yield respectively. They represented an increase in the accuracy of the models of 150, 70 and 150 percent respectively. In milk and fat yields, lactation length accounted for most of the increase while in fat percentages previous dry periods were the most important.

A comparison of the standard partial regression coefficients (see table 19) confirms the trend observed already.

Correction of production data in the NSS for dry period and calving interval can be justified on grounds that these effects have low heritabilities.

Lactation length has as high a heritability as milk yield and as such, correcting production data for it can be expected to affect the heritabilities of the traits. Correction for lactation length in milk and fat yields reduces both the error and the sire variance. Approximate calculations showed the approximate heritability values of milk yield were 0.29 and 0.27 in the analyses where lactation length was ignored and included respectively. This change was considered small. Correction decreased the heritability of milk yield but since it is questionable and time consuming it can be omitted.

Table 19: Standard partial regression coefficients

Trait	Lactation length	Dry period	Calving interval
Milk yield	0.613	-0.096	0.192
Fat percent	0.004	0.187	0.029
Fat yield	0.574	-0.081	0.162

From the results of this study, production data at the NSS should be corrected for the effects of calving interval only. Dry periods are correlated to calving interval and as such if the data has been corrected for calving interval, they should not be corrected for dry periods.

Although lactation length influences the yield traits significantly, it should not be corrected for because it has a genetic component. Correction for it will reduce heritabilities of the traits and in this way correction will lead to erroneous conclusions. Secondly the reasons why the lactations are short must be known clearly before correction for lactation length variations is attempted. It may just be that a cow has very little milk and cannot produce a high yield however long one milks it. Alternatively milking temperament can complicate the situation. If one had reasons to believe that a cow has got milk in the udder and it is not letting it down to a hand milker, then correction for lactation length is appropriate. This can be tested once a week with a calf at foot to give a good indication of the milk production as well as the lactation length. Without knowing why the lactation length is short, it would appear unfair, to the good producers, to correct the yields of the poor producers. In many cases the reasons are not indicated. The safest approach would be to assume that milking temperament has affected such short lactation and to delete them from the analysis.

4.3 Lactation lengths, dry periods and calving intervals

4.3.1 Means

Table 20 below shows the means of the three parameters.

Table 20: Mean lactation length, dry period and calving interval

Trait	n	Mean ± SE	SD	C.V. %	LSQ MEAN
Lactation lengths	3970	274±0.8	53	19	271
Dry period	2858	149±1.8	96	64	157
Calving interval	2858	412±1.4	75	18	413

While comparing the lactation length of Sahiwals at NSS to those of similar cattle, it is worth noting that:

a) Only lactations up to 305 days were included.

b) No lactations were excluded from the analyses except for reasons of sickness.

The average lactation length was very comparable to those of Sahiwals in India, but longer than those of the East African zebu. Lactation lengths depend on the milking temperament of the cows and the degree of attachment to the calves. In this herd it has been possible to milk most of the animals without calves at foot. Cows which refuse to let down their milk to a hand milker are culled but their lactation length is recorded. The coefficient of variation in lactation length was smaller than those observed before and shows that the average lactation length was in general longer than for other zebu breeds.

The mean dry period at NSS was long, being 36 percent of the calving interval. Although it was comparable to those reported in Bos indicus cattle in East Africa, it was longer than those recommended for Bos taurus cattle by Clark, (1959). Dry periods of tropical cattle have large coefficients of variation and the Sahiwals at NSS are not an exception.

Calving intervals in the herd were in general shorter than those of Sahiwals and other Bos indicus cattle in India and Sudan. They were, however, longer than those of the East African zebu (see table 6). Sahiwals at NSS have adapted themselves to Naivasha conditions fairly well. A calving interval of 14 months is within the limits of good husbandry. These calving intervals were achieved under conditions of AI. It is possible, with natural service, that the reproductive efficiency would have been higher, but the advantages of AI more than outweigh the slightly longer calving interval.

4.3.2 Factors influencing lactation lengths, dry periods and calving intervals

a) Parity:

Parity effects (see table 21) were estimated as for milk yield and were found to be significant only for dry periods. The first dry period (see fig. 9) was the longest while the subsequent ones did not differ from each other. The above trend was observed in calving intervals also, although the effect was not significant. Parity seems to influence milk yields, fat percent and yields without influencing lactation length. The influence can be assumed to be on the daily production rather than on the ability to milk for a long period. The results in this study agree with those reported earlier in connection with calving intervals (Alim, 1960; Dadlani et al., 1969) on the trend of their change with parity but not on statistical significance. Breed and possibly the method of data analysis can explain the observed differences. Previous results in respect of lactation lengths are conflicting. The present ones agree with those of Gill and Balaine, (1971) and Osman, (1972). The results pertaining to dry periods are in agreement with previous works of Galukande et al.,(1962)and Kavitkar et al.,(1968). The observation that the youngest animals have the longest calving interval leads one to suggest that the first calvers should be watched more carefully for heat and their feeding should take into account their growth and reproductive needs for energy protein and minerals e.g. phosphorus and calcium.

Table 21: Analyses of variance of lactation length, dry period and calving intervals.

SOURCE	Lactation length				Dry period				Calving interval			
	df	SS	MS	F	df	SS	MS	F	df	SS	MS	F
Parity	8	16,068	2,009	0.76 ns	7	743,176	106,168	12.36**	7	36,114	5,159	0.99 ns
Calving period	35	1,011,975	28,914	11.05**	35	1,229.950	35,141	4.09**	35	1,271,492	36,328	6.97**
Error	3926	10,270,167	2,616	-	2814	24,167,389	8,588	-	2814	14,656,879	5,209	-
Total	3969	11,310,864	2,849	-	2856	26,194,663	9,172	-	2856	15,989,427	5,594	-

ns = not significant

** = significant at $P < 0.01$

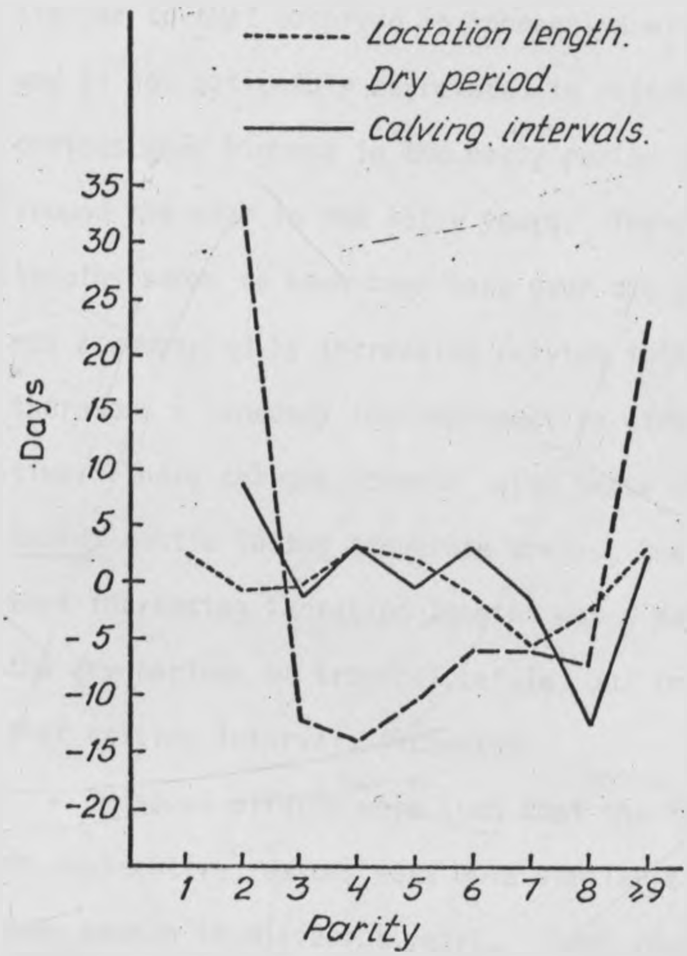

Fig. 9. Parity effects on lactation lengths, dry periods and calving intervals.

b) Calving period

The effect was found significant in all the three traits. The lactation lengths and calving intervals followed a similar trend being lower in the early part of the period (1964, 1965, 1966) and increasing in the later years. Their increase is similar to that observed in connection with milk and fat yields and is not noticeably correlated to rainfall in the period. Dry periods were highest in the early period and stabilised around the mean in the later years. Improvement in lactation lengths seems to have been made over the period, but this was accompanied by increasing calving intervals. There was therefore a tendency for reproductive efficiency to drop with time. These changes concur with those observed in *Bos taurus* cattle in the temperate areas. One would have thought that increasing lactation lengths was a matter of reducing the dry periods of tropical cattle, but in this case it meant that calving intervals increased.

Seasonal effects were such that the level of the parameters in consecutive seasons were more similar than those of the same season in different years. These results showed that, in this and similar investigations, it was important to include years and seasons in the model as both years and seasons have large effects on the parameters.

The results obtained from this study agree with the previous ones in the tropics (Alim, 1962; Osman, 1972; Kimenye, 1973; Lindstrøm and Solbu, 1968), in respect to lactation lengths and calving intervals. Hardly any information is available on the effects of calving period on dry periods. The present study

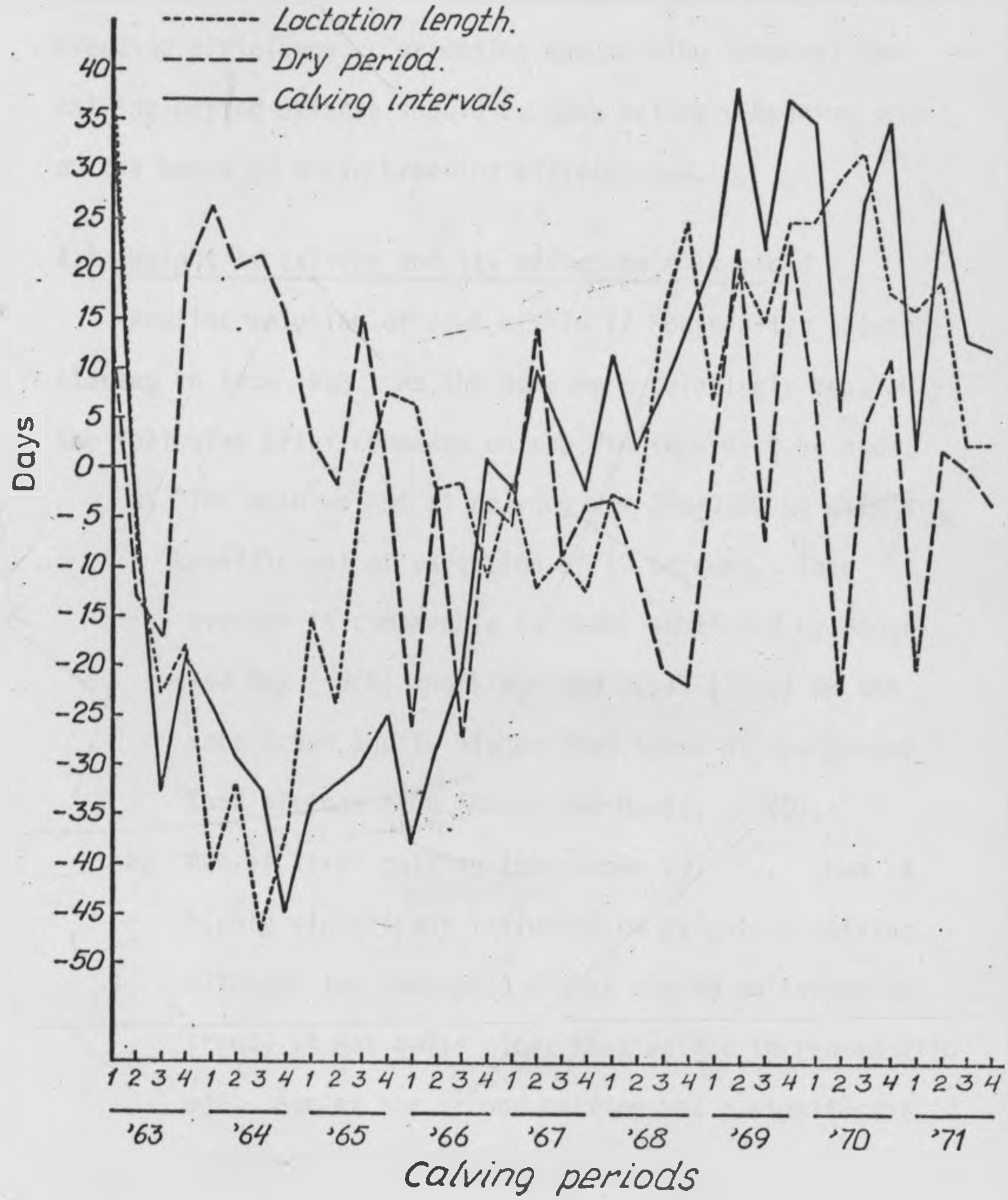

Fig. 10. Effect of calving period on lactation lengths, dry periods and calving intervals.

agrees with previous work of Kimenye (1973) while differing with that of Rao and Taylor (1971).

Calving interval is the only parameter of the three discussed in this section that is used in the calculation of breeding efficiency. Correcting the calving interval for calving period effects should be done before comparing cows on the basis of their breeding efficiencies.

4.4 Weight at calving and its effect on milk yield

Routine weighing of cows within 12 hours after calving started in late 1968. As the data were relatively few, only the following brief comments on the findings will be made.

a) The mean weight at calving was 396 ± 0.97 kg with a coefficient of variation of 10 percent. This average is comparable to those published by Mudgal and Ray (1966) and Singh and Desai (1966) on the same breed and is higher than those of indigenous East African zebu (Mason and Maule, 1960).

b) Age at first calving (see table 22) had a highly significant influence on weight at calving. Although the constants fitted showed an irregular trend, it was quite clear that weight increased with age. Age at the second calving had a significant influence ($P < 0.05$) also.

c) Parity effects were significant. Weight increased steadily up to the 5th lactation and then stabilised. The increase observed here agrees with the findings of Singh and Desai (1966) in Sahiwals, Venkayya and Anantakrishnan (1958) in Red Sindhi and Chhabra *et al.*, (1970).

Table 22 Analysis of variance of weight at calving

Source	df	SS	MS	F. val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %
Age at 1st calving	6	32,429	5,405	4.67**	0.17
Age at 2nd calving	4	14,682	3,671	3,17*	0.49
Parity	9	115,115	12.791	11.05**	3.80
Year-season	11	113,003	10,273	8.87**	3.73
Sires	71	259,258	3,651	3.16**	8.55
Error	1428	1,652,251	1,157		

* = significant at P < 0.05
** = " " P < 0.01

d) Calving period as in most of the earlier analyses had highly significant influences on weight at calving. Weights at calving can be taken as a measure of condition of the cows at the start of the lactation. They indicate how severe the environment was at the start or at the period 2-3 months before calving. Weight changes in cattle are expected in areas where the climatic variations are large. Good management has to make sure that cows do not lose too much weight before they start their years' production.

e) Sires were shown to influence weights significantly. The heritability of weight was 0.50 ± 0.19. This estimate was considered high enough to facilitate individual selection.

Milk yield data were analysed for the effects of weight at calving, holding age, parity and calving period constant. The regression of yield on weight was found to be 0.70$\pm$ 0.33 kg and was significant ($P < 0.05$). This increase in milk yield with weight was only a little larger than that reported by Singh and Desai (1966), who found the weight increase to have no significant influence on milk yield of Sahiwals and was almost equal to that reported by Nagpal and Acharya (1971) who observed a significant influence of weight on milk yield in the first lactation. Clark and Touchberry (1962) reported a larger regression coefficient of milk yield on weight of Holstein cattle. The small regression coefficients of milk yield on weight observed in this herd can possibly be explained by the ratio of their coefficients of variation (approx. 4:1), weight differences were too small to influence the milk yields.

First lactation milk yields were analysed for the effects of age and weight at calving. The results indicate that:-

a) There was a tendency for milk yield to increase with both weight and age.

b) Age independent of weight did not have a significant influence on milk yields.

c) Weight independent of age had a significant influence on milk yields.

The above results agree with the findings of Singh and Desai (1966) on Sahiwals in India. Weight of Sahiwal heifers at the NSS should be considered more important than age at first calving in deciding on when they should calve first time.

Decisions to adopt an earlier age at first calving than the present one of about 36 months should be based on how early heifers can attain a suitable weight without changing the present feeding and management regimes. The reason why the Sahiwal heifers at Naivasha calve so late is that they are never served earlier than 27 months of age. The same heifers have functional oestrus cycles at the age of 9-12 months. It is hereby recommended that heifers calve when they are around 360 kg (the optimum weight at calving). Progeny testing for post-weaning growth rate should be done so that bulls, whose progeny grow faster can be used as bull sires.

The development of the Sahiwal as a dual purpose (milk and beef) animal should be intensified as this breed has the potential for both traits. In order to do this, other breeding herds must be established and in them progeny testing for both milk and growth rate should be continued. Selection of dams for bull breeding should be based on the dam's post-weaning growth rate, body weight at calving and milk yield. Selection of sires for bull breeding should be based on the bull's post-weaning growth rate and its yearling weight, as well as the bull's progeny test results on both milk and post-weaning growth rate.

4.5 Genetic parameters

4.5.1 Heritabilities and repeatabilities

a) Milk yield

The heritability obtained when all the records were pooled see table 23 showed that the trait is moderately heritable. The estimate obtained in this Sahiwal herd is in general higher than those reported by Mahadevan et al., (1962) and Nagpal and Acharya (1971) in the same breed, and is within the range of the estimates reported in tropical cattle. The estimate is also equal to those reported in European cattle by Barker and Robertson (1966) and Cunningham (1972). It appears that the heritability of the trait is more or less the same in both Bos indicus and Bos taurus.

Table 23: Heritabilities (h^2) and repeatabilities (R) of traits estimated from records corrected for parity and calving period effects

Trait	$h^2 \pm$ S.E.	R ± S.E.	n_1	n_2
Milk yield	0.23±0.04	0.43±0.02	54.43	2.90
Fat percent	0.16±0.04	0.38±0.02	51.29	2.98
Fat yield	0.23±0.04	0.46±0.02	51.20	2.98
Lactation length	0.16±0.03	0.32±0.01	54.47	2.90
Dry period	0.09±0.03	0.15±0.02	17.90	3.56
Calving interval	0.08±0.03	0.05±0.02	17.19	3.58
Weight at calving	0.50±0.19	0.42±0.14	7.45	1.82

n_1 = average number of records/sire
n_2 = average number of records/cow

The heritability of the first lactation milk yield see table 24 is within the range (0.2-0.5) of the reported heritabilities in tropical cattle. It is higher than than those reported by Mahadevan et al., (1962) and Acharya and Nagpal (1971), although it is equal to that reported by Gopal and Bhatnagar (1972) in Sahiwals.

The heritability in the first lactation is higher than that calculated in the pooled material although it is not significantly so. Differences in these estimates are possibly due to selection which reduces genetic variance in the pooled material. The heritability in both cases is moderate indicating that selection can be expected to improve the trait.

Table 24 Heritabilities of traits in the first three parities

Trait	Parity	$h^2 \pm$ S.E.	Number of sires	Number of daughters/sire
Milk yield	1	0.35±0.09	66	25.91
	2	0.49±0.13	89	15.74
	3	0.31±0.12	89	15.72
Fat percent	1	0.41±0.10	58	18.93
	2	0.43±0.06	76	13.82
	3	0.42±0.06	76	13.79
Fat yield	1	0.25±0.08	42	16.69
	2	0.46±0.12	61	11.69
	3	0.29±0.11	61	11.69

The trait in the second lactation appears to be more heritable than in the first lactation. Such observations have been made before in Sahiwals by Acharya and Nagpal (1971), but not in Friesians by Barker and Robertson (1966). Examination of the variances show that the environmental variance in the second latation was less than in the first. This change in the amount of variance does not agree with the report of Barker and Robertson (1966). Selection on the basis of the second lactations can be more successful than that based on the first lactations because the heritability is higher and the phenotypic standard deviation is almost the same.

The repeatability of the trait was as expected from theory higher than that of heritability. This fairly high repeatability indicates that culling on the basis of the first records is justified. The present estimate is similar to those reported earlier by Johar and Taylor (1967) and Acharya and Nagpal (1971) in Sahiwal cattle although it is lower than that reported by Mahadevan et al., (1962).

Selection for milk yield in the Kenya Sahiwal can be expected to bring about improvement since the heritability is moderately high and the phenotypic standard deviation is large.

b) Fat percent

The heritability estimate calculated from the pooled data was low compared to those reported on tropical cattle by Alim (1965) and Kiwuwa and Kyomo (1971). It was also lower than those reported in *Bos taurus* by Hinks (1968). The estimates calculated from the individual lactations see table 24 are within the range of the reported values and show that fat percent in these early lactations was moderately heritable.

There is no clear reason to explain why the heritability of fat percent in the pooled material was so low. A possible explanation is that there may have been many errors in sampling of milk and the testing for fat percent. Such sampling errors are reflected in the residual mean squares. The residual mean square in this analysis was large compared to those in the analyses reported by Barker and Robertson (1966) and Cunningham (1972). The variance components for the other effects were also proportionately large (about 10 x). The within cow between lactations variance component was larger than the variance component for error. This also indicated that fat percent was not estimated accurately. When the variance component for within cow between lactations is not included (as in the individual lactations) the heritability estimates were comparable to those reported by Alim (1965), Barker and Robertson (1966) and Hinks (1968).

The repeatability is consistent with the heritability in all the lactations. Although it is not as high as reported in _Bos taurus_, it indicates that selection for the trait on the basis of the first lactation records is justified and can bring considerable genetic progress.

c) Fat yields

The heritability of fat yields in pooled material as well as in the individual lactations was the same as that of milk yields. The values obtained here are comparable to those reported by Kiwuwa and Kyomo (1971). It was shown earlier that milk and fat yields are influenced by the same non-genetic effects to the same extent.

The repeatability is consistent with the heritability of the trait in all lactations and is similar to that obtained in the analyses of milk yields. Selection for fat yields can be expected to be as successful as that for milk yields.

d) Lactation length, dry period and calving interval

The heritabilities and repeatabilities of these traits were estimated from the pooled data only and were shown to be low. The estimates agree with those reported by Singh and Desai (1962), Osman and El-Amin (1971) and Mahadevan *et al.*, (1962).

4.5.2 Genetic and phenotypic correlations

A few general remarks can be made on the estimates presented in table 25.

a) The correlations between milk yield and fat percent were virtually zero. This indicated that these two traits are independent and that selection for one of them cannot be expected to change the other. Reports on *Bos taurus* e.g. Barker and Robertson (1966) and on *Bos indicus* e.g. Kiwuwa and Kyomo (1971) show that the correlations are in general negative. The correlations obtained in this material are not different from those obtained by Kiwuwa and Kyomo (1971).

b) Milk and fat yields were highly correlated, indicating that selection for milk yield can be expected to improve fat yield. This improvement can occur without setting up fat testing facilities. Milk and fat yields were shown, in the early part of the study, to be affected by environmental factors to a similar extent and have also been shown to have similar heritabilities. The correlations are similar to those reported by Kiwuwa and Kyomo (1971) for Mpwapwa cattle.

Table 25: Genetic and phenotypic correlations data corrected for parity and calving period effects

r_g above diagonal
r_p below diagonal

	Milk yield 1	Butterfat % 2	Butterfat yield 3	Lactation length 4	Dry period 5	Calving interval 6
1	-	0.08±0.03	0.92±0.01	0.72±0.10	0.55±0.02	0.32±0.07
2	0.04 ns	-	0.47±0.02	-0.03±0.03	-0.25±0.03	-0.24±0.09
3	0.94**	0.18**	-	0.64±0.01	-0.44±0.02	-0.41±0.06
4	0.62**	0.09*	0.64**	-	-0.30±0.02	-0.60±0.05
5	0.02 ns	0.01 ns	0.06 ns	0.05 ns	-	1.02±0.09
6	0.01 ns	0.11**	0.60**	0.08**	0.98**	-

ns = not significant
* = significant at $P < 0.05$
** = significant at $P < 0.01$

Traits 1-4 91 sires and 51.03 records/sire used.
Traits 5 and 6 77 sires and 40.76 records/sire used.

c) Correlations of between milk yield and lactation length were high and similar to those obtained in Friesians by Barker and Robertson (1966). Selection for milk yield can be based on lactation length although the heritability of the latter is somewhat lower. Selection for lactation would not increase calving interval in this herd since the correlation between them is negative. Since milk yield records are usually available, it is advisable to select directly for it.

d) The correlations of calving interval and dry period with milk and fat yields were in the desired direction in the sense that larger yields were associated with shorter dry periods and calving intervals. It can be said that in the generally low producing breeds, of which Sahiwal is one, the level of production is too low to influence calving intervals negatively.

Within the first three parities (see table 26), a few observations can be made:-

a) The records of the traits in the first lactation were highly correlated to the records of the same traits in the other two lactations. The correlations were highest in fat percentages and least in milk yields. The results for milk yield and fat percentages agree with those of Barker and Robertson (1966) although the correlations are higher than those reported by Acharya and Nagpal (1971) in respect to milk yields of Sahiwals. The high correlations coupled with the high repeatabilities indicate that selection can be based on the first lactations alone.

Table 26 Genetic and phenotypic correlations of traits in the first three parities[1]

	Milk yield 1	Butterfat % 1	Butterfat yield 1	Milk yield 2	Butterfat % 2	Butterfat yield 2	Milk yield 3	Butterfat % 3	Butterfat yield 3
Milk yield 1	-	-0.22±0.16	0.97±0.02	0.67±0.09	0.26±0.16	0.87±0.06	1.08±0.08	-0.17±0.16	0.91±0.04
Butterfat % 1	-0.07*	-	0.08±0.16	-0.27±0.17	1.03±0.07	-0.09±0.17	-0.28±0.16	1.00±0.06	0.21±0.16
Butterfat yield 1	0.93**	0.03 ns	-	0.86±0.05	0.03±0.18	0.88±0.04	1.05±0.12	0.16±0.17	1.02±0.17
Milk yield 2	0.45**	-0.01 ns	0.45**	-	0.11±0.18	0.97±0.01	0.86±0.02	0.15±0.17	0.71±0.11
Butterfat % 2	0.03 ns	0.47	0.04 ns	-0.04 ns	-	0.17±0.18	0.01±0.22	1.03±0.08	0.53±0.12
Butterfat yield 2	0.23**	0.12**	0.45**	0.93**	0.21**	-	0.91±0.03	0.09±0.17	0.87±0.04
Milk yield 3	0.38**	-0.05 ns	0.35**	0.55**	0.02 ns	0.51**	-	0.15±0.21	0.83±0.07
Butterfat % 3	-0.06 ns	0.50**	0.06 ns	0.03 ns	0.58**	0.11**	0.14**	-	0.43±0.13
Butterfat yield 3	0.33**	0.10**	0.36**	0.48**	0.14**	0.53**	0.93**	0.38**	-

r_g above diagonal
r_p below diagonal

ns = not significant
* = significant at P < 0.05
** = significant at P < 0.01

[1] 60 sires with 2.04 daughters/sire used.

b) Correlations between milk and fat yields in all the three parities were high enough to permit improvement of fat yields through the direct selection for milk yields.

There are only a few investigations done in the tropics which have included genetic correlations. Acharya and Nagpal (1971) and Khanna and Bhat (1971) studied similar correlations of Sahiwal milk yield records. Their results agree in general with what was observed in the Kenya Sahiwal. The magnitude of the correlations, however, differed somewhat. Acharya and Nagpal (1971) found that the genetic correlation of the first and second were over 1 as did Khanna and Bhat (1971). The sample sizes in the above studies were smaller than that used here and as such only general observations can be made.

Kiwuwa and Kyomo (1971) showed that milk and fat yields are highly correlated and that fat percent is not significantly correlated with the yield traits. The present study agrees with their observations.

Before more information becomes available, it seems that selection should be directed towards milk yields in this and similar herds. Selection should be based on the first lactations since the genetic correlation between the first and the later lactation records are high.

4.6 An appraisal of the current breeding plan at the National Sahiwal Stud

A short introduction

The current breeding programme is sketched in Fig. 4. Some of the important aspects concerning genetic improvement are:-

a) Elite herd of 180 cows which comprises 60 percent of the milking herd.

b) Progeny testing for milk yield is done using approximately 14 daughters per bull.

c) Of the 10 young bulls tested per year, 2 are approved for use as bull sires.

d) All heifer calves born in the herd are reared and kept for young bulls testing and are not disposed of before they complete their first lactation records.

Evaluation

The procedures used here are as described by Robertson and Rendel (1950). The formulae are given in "Materials and Methods" section of this study and the main one is repeated here.

$$\Delta G = \frac{I_{BB} + I_{BC} + I_{CB} + I_{CC}}{L_{BB} + L_{BC} + L_{CB} + L_{CC}} = \frac{\Sigma I}{\Sigma L}$$

Where I is the genetic superiority of parents above the mean of contemporary animals of the same sex and L is the mean generation interval.

The values used in equations given in "Materials and Methods" are shown below. Milk yield is the only character selected for and the heritability (h^2), repeatability (R) and phenotypic standard deviation (σ_p) values used here are obtained from the present study.

$h^2 = 0.35$

$R = 0.43$

$\sigma_p = 550$ kg.

I_{BB} is calculated from the formula

$$I_{BB} = i_{BB}\, \sigma_p \sqrt{h^2} \times \sqrt{b}$$

Where i_{BB} = selection intensity among the tested bulls. Selection of 2 bulls out of 10 gives a selection intensity = 1.27.

$\sqrt{b}$ = accuracy of selection calculated from the formula for

$$b = \frac{0.25nh^2}{1 + (n - 1)\, 0.25h^2}$$

where n = number of progeny per young bull tested.

Genetic superiority of the selected bulls

$I_{BB} = 1.270 \times 550 \times 0.757 \times 0.592$

$= 312.8$ kg milk per generation.

L_{BB} = Age of the selected bulls when the offspring (young bulls destined for testing) are born.

L_{BB} is calculated in the following way:-

a) Young bulls are selected for semen test at 2 years of age.

b) Semen collection, insemination and pregnancy takes 1½ years.

c) Daughters of these young bulls calve at 3½ years.

d) Progeny test calculations, insemination of cows with bull sires semen and pregnancy takes 1½-2 years.

$L_{BB} \simeq 9$ years.

I_{BC} is achieved through the mating of elite cows to progeny tested sires. This mating contributes 36 percent of the heifers in the herd. There is no selection of young bulls on the basis of daughters' yields before the progeny test results are known. The heifers born in the place of the young bulls have therefore the same genetic superiority as the young bulls.

$$I_{BC} = I_{BB} \times p$$

where p = Elite herd/Total herd.

$$I_{BC} = 312.8 \times 0.36 = 112.6 \text{ kg milk.}$$

36 percent of the heifers is contributed by progeny tested bulls at the age of 9 years and 64 percent is contributed by young bulls at the age of 3-4 years.

$$L_{BC} = (0.36 \times 9) + (0.64 \times 3.5) \text{ years}$$

$$L_{BC} = 4.48 \text{ years}$$

Cows to breed bulls are selected from the Elite herd on the basis of their performance in first and second lactations. 55 over the first two lactations are retained in the herd for about three more lactations on average. The proportion of the first calvers selected to join the elite herd is

$\frac{55}{210} \approx$ 25 percent.

$$i_{BC} = 1.3$$

This selection is done after two complete lactation records. The heritability of the average of two records $h^2_{(2)}$ becomes

$$h^2_{(2)} = \frac{2h^2_{(1)}}{1 + R}$$

where $h^2_{(1)}$ = heritability of one record = 0.35

$h^2_{(2)}$ = heritability of the average of two records

R = repeatability of a single record = 0.43 as calculated from the data

$$h^2_{(2)} = 0.49$$

$$I_{CB} = i\sigma_G h$$

$$= 1.3 \times 325.4 \times 0.7$$

$$= 296.11 \text{ kg}$$

Bull dams are generally of the age of 3-6 lactations when young bulls are born. Their actual age is around 7 years.

$$L_{CB} = 7 \text{ years}$$

Selection of cows to breed replacement heifers CC is based on the retention of 110 out of 210 heifers calving each year.

$$i_{CC} = 0.8$$

and $I_{CC} = i\sigma_{ph^2}$

$= 0.8 \times 550 \times 0.35$

$= 156$ kg

L_{CC}, age of the selected cows when their second calves are born = 4 years.

Thus the genetic gain ΔG is

$$\Delta G = \frac{886.51}{24.5} = 36 \text{ kg}$$

i.e. ΔG = 2.5 percent per year (annum) of the herd average.

Table 27 Relative contribution of different paths to total genetic gain

Path	Genetic gain kg	Generation interval years	% of Total genetic gain
BB	312.8	9	35.64
BC	112.6	4.48	12.83
CB	296.11	7	33.74
CC	156	4	17.77

An annual genetic improvement of 2.5 % of the herd average, can be expected at the National Sahiwal Stud if the present plan is executed properly. This estimate is close to the one made by Meyn and Wilkins (1974) of 3.4 % herd average. Genetic gains reported in Eastern Africa, by Mahadevan and Marples (1961), Alim (1962) and Osman (1970) were low (range 0.11-0.7%). The reason for these low rates of improvement was that selection was practised in only two paths i.e. cows to breed cows and cows to breed bulls. No progeny testing was practised. High annual genetic gains are possible only through progeny testing.

In order to realise this rate of improvement fully, at the NSS it is necessary to follow the plan accurately, i.e. to make sure that the bull progeny groups are equal in size, and that enough cows are mated to young bulls each year. Without taking the proper precautions, it is not feasible to attain the projected annual improvement.

Improvement keeping the herd size constant

Judging from the phenotypic standard deviation of milk yield the heritability and repeatability in this herd, one would have expected a higher genetic gain than that calculated in 4.6. Although the projected genetic gain is higher than in most reported herds in the tropics it is possible to discuss ways of increasing it keeping the herd constant.

a) The proposed proportion of the herd used for testing the young bulls is too small. Progeny tested bulls should be mated to a small proportion of highly selected cows and the rest of the herd should be used for young bull testing.

b) Because of the intense use of progeny tested bulls in the herd at present, many of the heifers coming up for service are related to the young bulls. There is a general fear for increasing inbreeding depression and this has led to:-

   i) Un-equal progeny group sizes

   ii) Lengthening of the testing period

Mating between young bulls and heifers should be done at random to avoid the situation whereby bulls take too long to be proven.

Alternative breeding programs

The study of the means of the production traits done in the earlier part of this work has shown that the traits which must be improved and sustained at a higher levels than the present ones are milk and fat yields. The fat percentages are fairly high and as such they do not warrant further selection. The genetic correlation between milk yield and fat percentage was virtually zero. Selection for milk yield is therefore, not likely to decrease fat percentage. The genetic correlation between milk and fat yields is high and positive and their heritabilities are more or less equal. Milk yield seems a better character for selection than fat yield because it can be selected for without setting up facilities for fat testing.

Method

Using the heritability for milk yield estimated in this herd (approx. 0.35), the phenotypic standard deviation and the repeatability estimate, the possibility of increasing genetic improvement through different ways of selecting bulls was looked into. A few possible breeding plans were considered.

a) The number of breeding females (equivalent to herd size) was varied from 300-1500, see table 28. This was done to cater for situations whereby different Sahiwal breeders may co-operate in a bull testing program as well as the cases where individual breeders prefer to carry out their own breeding plans.

b) The bulls tested were varied from 3-50 keeping the number of bulls selected as bull sires constant = 2. In the larger herd sizes it was envisaged that only 2 bulls would be used to breed future bulls, the surplus being sold for either slaughter or to ranchers who are not keen to follow a pure Sahiwal breeding plan.

c) The number of a dams mated to produce one breeding bull was 6. This took into account the sex ratio of the calves, the conception rates and possible rejection of young bull calves due to genetic defects or poor growth.

d) A conception rate of 80 percent, sex ratio of 50 percent and survival rate of 90 percent were assumed for the herds. It was further assumed that all the selected bulls were mated randomly and had equal progeny group sizes.

e) All cows which were not selected for bull breeding were utilised in bull proving.

Programs and discussion

The genetic gains in milk yield per year possible in the different alternatives are shown graphically in fig. 11, while in table 29 a summary of some aspects is given. The following observations can be made:

a) Increasing herd size, keeping all the other factors constant leads to higher genetic gains and make it possible to test more bulls and with larger progeny group sizes. Fig. 12 shows that increasing the herd size and testing the optimum number of bulls results in higher genetic gains.

b) In these small herds it is apparent that a large part of the herd has to be devoted to young bull testing, if an optimum utilization of testing resources is to be achieved.

c) The paths BB and CB account for most of the progress in these systems. If one chose a system where CC was emphasized the progress would be much less than trying to maximize the bull testing resources.

d) Increasing progeny size keeping the herd size constant leads to more accurate evaluation of the young bulls. However, progeny size and the number of bulls to be tested must be balanced in order to maximise genetic gains.

e) In general for these systems, the optimum number of daughters per young bull is approximately two times the optimum number of young bulls tested in order to select two for future bull breeding.

f) When the herd size is large, the number of surplus bulls is higher. The extra bulls which are not below average can be sold to ranches and in this way improvement benefits can be distributed to areas where AI has not been made fully operational. For areas where AI is operational, semen can be obtained from the two proven bulls.

Table 28: Bull progeny sizes attainable in herds of different sizes

Bulls tested	Bull dams	Number of breeding females					
		300	400	500	800	1000	1500
3	18	32.90	44.57	56.23	91.23	114.57	172.90
4	24	24.15	32.90	41.65	67.90	85.40	129.15
5	30	18.90	25.90	32.90	53.90	67.90	102.90
6	36	15.40	21.23	27.07	44.57	56.23	85.40
7	42	12.90	17.90	12.90	37.90	47.90	92.90
8	48	11.03	15.40	19.78	32.90	41.65	63.53
9	54	9.57	13.46	17.34	29.01	36.75	56.23
10	60	8.40	11.90	15.40	25.90	32.90	50.40
11	66	7.45	10.63	13.81	33.35	29.72	45.63
12	72	6.65	9.57	12.48	21.23	27.07	41.65
13	78	5.98	8.6	11.36	19.14	24.82	38.28
14	84	5.40	7.90	10.40	17.90	22.90	35.40
15	90	4.90	7.23	9.57	16.57	21.23	32.90
16	96	-	6.65	8.84	15.40	19.78	30.71
17	102	-	6.14	8.19	14.37	18.49	28.78
18	108	-	5.68	7.62	13.46	17.34	27.07
19	114	-	5.27	7.11	12.64	16.32	25.53
20	120	-	4.90	6.65	11.90	15.40	24.15
25	150	-	-	4.90	9.10	11.90	18.90
30	180	-	-	-	7.23	9.57	15.40
40	240	-	-	-	4.90	6.65	11.03
50	300	-	-	-	-	4.90	8.40

Table 29: Alternative breeding plans

Herd	Largest genetic gain kg.	Number of bulls tested		Daughters per young bull tested	Proportionate contribution of different paths				Test herd %
		Range	Optimal		BB	BC	CB	CC	
100	23	3-4	4	7	23	6	55	16	76
200	28	4-7	5	12	28	4	54	14	85
300	30	4-8	6	15	31	4	53	12	88
500	36	7-9	8	20	35	3	51	11	90
700	38	9-12	9	25	36	3	50	11	92
1000	40	11-14	12	27	40	3	47	10	92
1500	43	13-19	15	33	41	2	47	10	94

$h^2 = 0.35$ $\sigma_p = 550$ kg $R = 0.43$

Selection of cows to breed cows 70 percent after the 1st lactation.

Bull dams selected after 3rd lactation.

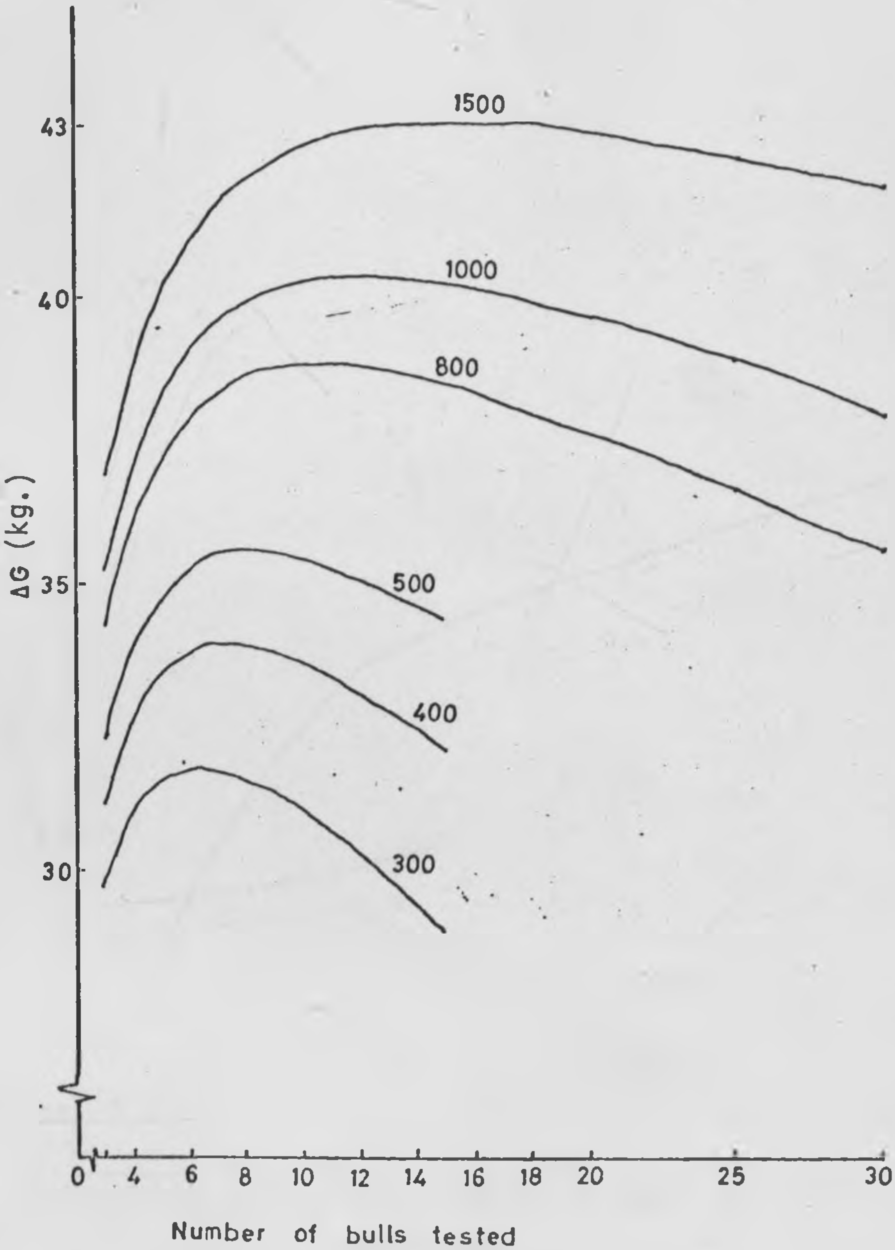

Fig. 11. Genetic gain per year ΔG in milk yield kg attainable. (Number on the curve refer to herd size).

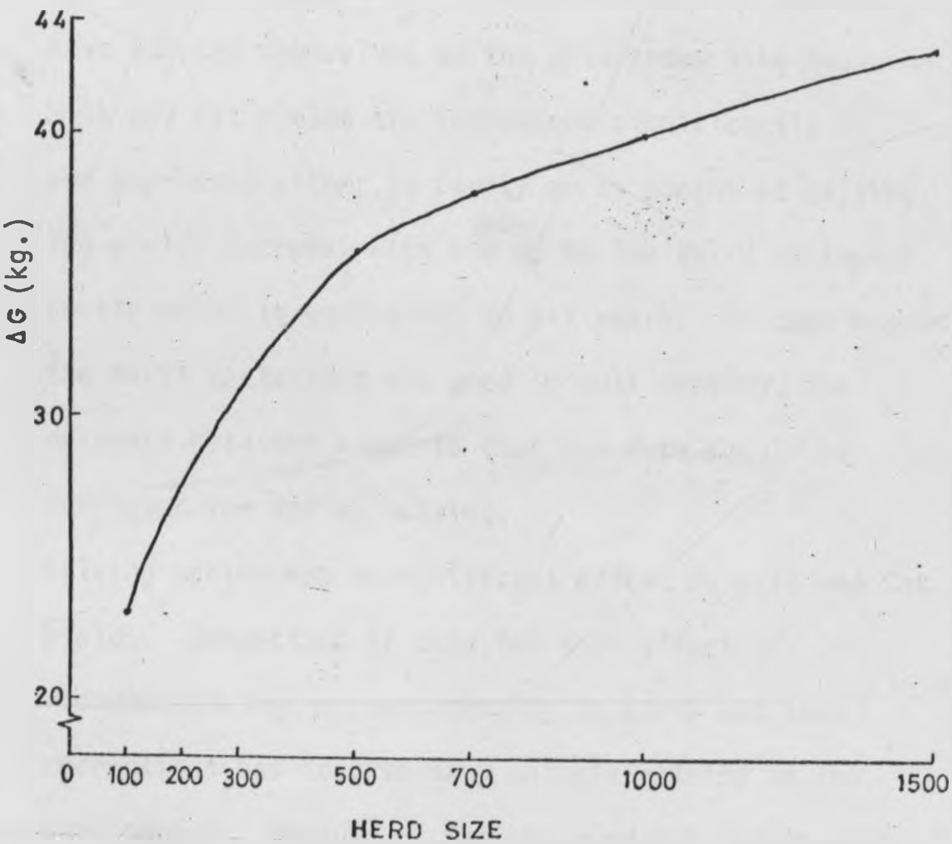

Fig. 12. Relationship of herd size to genetic gain (ΔG) in milk yield kg.

5. CONCLUSION

The following conclusions can be drawn from this study of production traits and the factors influencing them:-

5.1 Sahiwals, given an extensive system of production as that existing at Naivasha are able to produce about 1500 kg milk with 5 percent fat percent in a lactation of about 275 days without a calf at foot. This can be regarded as a sufficient level for the system. Besides this production, Sahiwals are able to give a calf every 14 months. It appears fair to conclude that Sahiwals have adapted themselves to the arid areas like Naivasha.

5.2 Milk and fat yields are influenced significantly by age expressed either as parity or as months at calving. The yields increase with age up to the third or fourth parity which is equivalent to 6-7 years. If cows beyond the first lactations are used in bull testing, the evidence obtained suggests that the data should be corrected for age at calving.

5.3 Calving period has a significant effect on milk and fat yields. Correction of data for this effect is recommended. Any system intending to carry out such corrections has to have many animals calving at the same period. Because of the observed lack of repeatability of the environmental conditions, corrections will have to be based on the production data in the particular calving period.

5.4 Correction of milk yield data for the effects of lactation length, dry period and calving interval is not justifiable.

5.5. Heritabilities, repeatabilities, genetic and phenotypic correlations calculated suggested that milk and butterfat yields can be improved through direct selection for milk a lone, and therefore butterfat testing does not seem necessary in improvement of the butterfat yields.

5.6. With a small herd as that existing at Naivasha, it is going to be difficult to carry out the proper selection procedures for the important characteristics. The solution will lie in expanding the herd either at Naivasha or incorporating other government stations. Before this recommended expansion takes place, a large part of the herd should be devoted to young bull testing. Semen of progeny tested bulls should be used mostly out-side the herd. Private Sahiwal Breeders are urged to co-operate in testing the Sahiwal bulls as so far, they have benefited a lot from the testing scheme without participating.

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Table App 1 Analyses of variance of milk yield

Source	df	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %
Age	26	101,483,370	3,903,207	13.80**	7.49	61,539,790	2,366,915	8.81**	4.88
Years	8	79,850,667	9,981,333	35.37**	6.75	31,633,048	3,954,131	14.72**	3.12
Seasons	3	7,507,520	2,502,507	8.84**	0.71	5,494,329	1,831,443	6.82**	0.56
Y x S	24	33,898,786	1,412,449	4.99**	1.18	29,546,237	1,231,093	4.58**	1.11
Sires	88	-	-	-		80,457,200	914,286	3.40	6.09
Error	3,933/3,845	1,113,207,700	282,971	-	83.86	1,032,750,500	268,596	-	84.24;
Total	3,994	1,320,926,700	-		R^2=15.73	1,320,926,700			R^2=21.82
Parity	8	91,518,380	11,439,798	40.24**	8.22	49,984,017	6,248,002	23.11**	5.36
Years	8	85,960,533	10,745,067	37.80**	7.08	38,493,330	4,811,666	17.80**	3.73
Seasons	3	7,254,356	2,418,119	8.51**	0.67	5,656,482	1,885,494	6.97**	0.56
Y x S	24	33,802,226	1,408,426	4.95**	1.15	29,666,126	1,236,089	4.57**	1.09
Sires	88	-	-	-	-	78,866,500	896,210	3.32	5.97
Error	3,951/3,863	1,123,172,700	284,276	-	82.86	1,044,306,200	270,336	-	83.29
Total	3,994	1,320,926,700	-	-	R^2=14.97	1,320,926,700	-	-	R^2=20.94

** = significant at ($P < 0.01$)

Table App. 2 Analyses of variance of butterfat percentage

Source	df	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %
Age	26	78.91	3.04	1.98**	1.26	73.89	2.84	1.89**	1.18
Years	8	54.07	6.76	4.41**	0.86	63.88	7.99	5.32**	1.02
Seasons	3	11.81	3.94	2.57 ns	0.19	9.46	3.15	2.10 ns	0.15
Y x S	24	51.71	2.15	1.40 ns	0.83	45.37	1.89	1.26 ns	0.72
Sires	88	-	-	-	-	262.45	2.98	1.98	4.21
Error	3,933/3,845	6034.66	1.53	-	-	5772.21	1.50	-	-
Total	3994				R^2 = 3.16				R^2 = 7.37
Parity	8	43.31	5.66	3.69**	0.72	41.22	5.15	3.43**	0.66
Years	8	52.84	6.61	4.30**	0.84	59.24	7.41	4.93**	0.95
Seasons	3	12.21	4.07	2.65*	0.19	9.91	3.30	2.20 ns	0.16
Y x S	24	50.55	2.11	1.37 ns	0.81	43.49	1.81	1.21 ns	0.70
Sires	88	-	-	-		263.39	2.99	1.99**	4.23
Error	3,951/3,863	6068.26	1.54	-		5804.87	1.50	-	-
Total	3994	6231.78	-	-	R^2 = 2.62	6231.78	-	-	R^2 = 6.85

ns = not significant
* = significant at ($P < 0.05$)
** = significant at ($P < 0.01$)

Table App. 3 Analyses of variance of butterfat yield

Source	df	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %	SS	MS	F-Val.	$\frac{\sigma^2_i}{\sigma^2_T}$ %
Age	26	184,190	7,084	8.27**	4.83	119,810	4,608	5.65**	3.14
Years	8	203,179	25,397	29.63**	5.33	80,496	10,062	12.33**	2.11
Seasons	3	14,752	4,917	5.74**	0.39	9,546	3,187	3.90**	0.25
Y x S	24	71,139	2,964	3.46**	1.87	59,307	2,471	3.03**	1.55
Sires	88	-	-	-	-	234,743	2,668	3.27	6.15
Error	3,933/3,845	3,371,517	857	-	-	3,136,774	816	-	-
Total	3,994	3,814,201	-	-	R^2 = 11.61	3,814,201	-	-	R^2 = 17.76
Parity	8	162,491	20,311	23.65**	4.26	92,603	11,575	14.13**	2.43
Years	8	216,182	27,022	31.46**	5.67	97,996	12,249	14.96**	2.59
Seasons	3	13,997	4,666	5.43**	0.37	9,615	3,205	3.91**	0.25
Y x S	24	70,391	2,933	3.42**	1.85	59,085	2,462	3.01**	1.55
Sires	88	-	-	-	-	229,236	2,605	3.18	6.01
Error	3,951/3,863	3,393,217	859	-	-	3,163,981	819	-	-
Total	3,994	3,814,201	-	-	R^2 = 11.04	3,814,201	-	-	R^2 = 17.05

** = significant at ($P < 0.01$)

Table App.4 Recommended age correction factors

a) Actual age: mature age ≅ 72 months

AGE GROUP MONTHS	MILK YIELD KG.	BUTTERFAT PERCENT	BUTTERFAT YIELD KG.
Up to 40 months	+ 309	- 0.3	+ 11.8
41-43	+ 304	- 0.2	+ 9.4
44-46	+ 251	- 0.2	+ 8.4
47-49	+ 139	- 0.2	+ 3.0
50-52	+ 104	- 0.1	+ 3.0
53-55	80	- 0.1	+ 2.3
56-58	78	- 0.1	+ 1.8
59-61	69	- 0.1	0
62-64	62	0	0
65-68	60	0	0
69-72	0	0	0

b) Parity: mature age ≃ 4th parity

PARITY	MILK YIELD KG.	BUTTERFAT PERCENT	BUTTERFAT YIELD KG.
1	+ 406	- 0.3	+ 18.0
2	+ 195	- 0.2	+ 9.1
3	+ 89	0	+ 4.5
4	0	0	0