PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS IN KENYA SAHIWAL CATTLE

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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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This thesis has been submitted for examination with our approval as University Supervisors.

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To my mum and dad, my wife Mary and my children Simiyu, Wafula, Nekesa and Wamanga; and to all people who may gain from this thesis.

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ABSTRACT

Records covering a 20 year period (1964-1983) on Sahiwal cows at the National Sahiwal Stud, Naivasha were used to estimate phenotypic, genetic and environmental trends of 305- day milk yield, calving interval, birth weight and age at 55 kg liveweight (AGE55) by best linear unbiased prediction (BLUP) procedures while genetic parameters were estimated by the maximum likelihood procedure. All the traits studied were regarded as the traits of the dam. The number of records analysed were 4837, 4272, 4837 and 3544 for milk yield, calving interval, birth weight and age at 55 kg liveweight, respectively.

The means of 305-day milk yield, calving interval, birth weight and AGE55 were 1662±8.3 kg, 426.2±1.5 d, 22.7±0.04 kg and 97.8±0.7 d, respectively. Year of calving or birth affected all the four traits studied. Season of birth affected AGE55 only. Parity affected all the traits except calving interval while sex of calf affected birth weight, calving interval and AGE55. The respective repeatability and heritability estimates were 0.46±0.02 and 0.27±0.06 for milk yield; 0.39±0.20 and 0.15±0.10 for calving interval; 0.48±0.05 and 0.40±0.07 for birth weight; and 0.46±0.03 and 0.35±0.05 for AGE55.

The respective annual phenotypic, genetic and environmental changes were: -11.56±5.3, 3.87±0.64 and -15.42±5.0 kg for 305-day milk yield; 2.43±0.63, -0.23±0.03 and 2.65±0.64 d for calving interval;

-0.02 ± 0.02, 0.004 ± 0.003 and -0.03 ± 0.02 kg for birth weight; and 5.26 ± 0.25, -0.05 ± 0.04 and 5.31 ± 0.26 d for AGE55. All the environmental trends were highly significant ($p<0.01$).All phenotypic trends were highly significant ($p<0.01$) except for birth weight. Genetic trends were highly significant ($p<0.01$) except for birth weight and AGE55. In all the four traits the correlations between environmental and phenotypic trends were highly significant ($p<0.01$). Although the annual genetic changes were in the direction of the breeding objectives, the annual genetic change in milk yield was lower than expected.

1.0 INTRODUCTION

In 1962 good high grade Sahiwal cattle from all the Livestock Improvement Centres of Kenya were pooled at Naivasha to form the National Sahiwal Stud (NSS). A breeding plan was drawn in 1965 (Mason, 1965) and was fully implemented by 1968 (Meyn and Wilkins, 1974). This breeding plan has been followed since then. However, declining phenotypic trends in milk yield and maternally controlled growth and reproductive traits have been reported (Kimenye, 1978; Mwandotto, 1985; 1986) over the period 1964-1983. It has been suspected that either the selection programme is inefficient or the frequent environmental changes are responsible for the declining performance in the NSS.

Genetic improvement accruing from the breeding programme at the NSS is the basic question relevant to the Sahiwal breed improvement scheme. Yet, up to now, no assessment has been done. Monitoring the effectiveness of the genetic improvement strategies, through estimation of genetic trends, ensures that selection pressure is directed to traits of economic importance and assists in deciding the future emphasis of the breeding programme. Assessment of the effects of environmental changes, through estimation of environmental trends, may make it possible to associate environmental change to various sources such as feed consumed, and yearly changes in the general environment. If the environmental trend falls far from expectation, a critical appraisal can be made and remedial action taken.

In view of the above, there was need to partition phenotypic trends into their genetic and environmental components at the NSS. The specific objectives of this study were:

a) to estimate phenotypic, genetic and environmental trends of 305-day milk yield, birth weight, calving interval and age at 55 kg liveweight,

b) to estimate genetic parameters of these traits, and

c) to identify non-genetic factors that affect these traits in Sahiwal cattle at the NSS, Naivasha.

2.0 LITERATURE REVIEW

2.1 Milk Yield

2.1.1 Means and Variations

The means and coefficients of variation of lactation milk yield reported in tropical cattle are summarised in Table 1. The comparison of these means is complicated by differences in the management of the herds and in the lactation lengths included in the analyses of the milk yield. However, they serve as a rough guide to the milk production potentials of different breeds of tropical cattle.

From the reported means, Indian cattle have generally higher milk yield than the other tropical cattle. Although the Sahiwal is a premier dairy breed among tropical cattle, its milk yield is not close to those of European dairy breeds raised in East Africa (Kiwuwa, 1974; Lindstrøm and Sølbu, 1978).

The coefficients of variation reflect the within-herd variation of milk yield. Those reported in tropical cattle are generally above 22%, a level usually reported in the well managed temperate dairy cattle (Mahadevan, 1966). However, these coefficients of variation do not appear to be directly related to the corresponding levels of milk yield reported in the individual tropical cattle herds. If these variations are largely of genetic origin, selection for high milk yield in tropical cattle would lead to genetic improvement in milk production.

2.1.2 Factors Influencing Milk Yield

2.1.2.1 Year of Calving

Many authors (Osman, 1972; Kimenye and Russel, 1975; Kimenye, 1978; Odendra *et al.*, 1978; Biswas *et al.*, 1982; Parmar and Johar, 1982; Mwandotto, 1986, Patil and Kale, 1986) have reported that year of calving has significant influence on milk yield of cattle raised in the tropics. These results are possible in herds where management has changed over the years. Change in climatic conditions can also bring about a similar situation through its effects on quality and availability of pasture .

2.1.2.2 Season of Calving

Some studies (Singh and Pandey, 1970; Parmar and Johar, 1982) have shown that season of calving has significant effect on milk yield of cattle in the tropics. However, these observations are not in agreement with those reported by Tomar and Mittal (1960); Batra and Desai (1964); Odendra *et al.* (1978) and Mwandotto (1986). These contradictory findings may be explained by the differences in breeds, herd management, definition of seasons and the number of years and records included in the analyses. Most important source of variation is the difference in weather conditions between seasons-marked in some

Table 1: Means and Coefficients of Variation (CV.) of Lactation Milk Yield of Tropical Cattle.

Breed	Milk Yield (Kg)	CV (%)	Source
Kenana	1537	-	Alim (1960)
Butana	1419	55	" (1962)
Nganda	1032	42	Mahadevan and Marples (1961)
E.A.Zebu	832	40	Galukande *et al.*(1962)
Jiddu	1050	39	Mahadevan (1966)
Ankole	813	53	Sacker and Trail (1966)
Hariana	760	-	Gill and Balaine (1971)
Red Sindhi	1534	28	D'Souza *et al* (1979)
Red Sindhi	1048	-	Singh *et al.* (1982)
Gir	1804	37	Odendra *et al.* (1978)
Gir	1191	37	Malik and Ghai (1978)
Tharparkar	2283	29	Basu *et al.* (1982)
Tharparkar	1051	40	Parmar and Johar (1982)
Sahiwal	1515	36	Mahadevan *et al.* (1962)
Sahiwal	1674	29	Singh and Desai (1966)
Sahiwal	972	30	Malik and Sindhu (1968)
Sahiwal	1928	32	Acharya and Nagpal (1971)
Sahiwal	1595	29	Singh *et al.* (1973)
Sahiwal	1386	41	Kimenye (1978)
Sahiwal	2115	-	Bhatnagar *et al.*(1982)
White Fulani	1069	-	Johnson *et al.* (1984)
Bokoloji	1143	-	" (1984)

climates.not marked in others.

2.1.2.3 Parity or Age of Cow

The influence of parity of the cow on milk production has been confirmed by different workers (Alim. 1960b: Mahadevan and Marples. 1961: Johar and Taylor. 1967; Kimenye, 1978: Lindstrom and Solbu. 1978: Odendra *et al.*, 1978: Parmar and Johar, 1982: Johnson *et al.*. 1984) in the tropics. Khanna and Bhat (1971): Nagpal and Acharya (1971): Kimenye (1978) and Mwandotto (1986) have all found that peak milk production of the Sahiwal occurs in the 4th lactation. This is within the range. 3rd-5th lactation. reported in the other tropical cattle (Mahadevan. 1966) which occurs at almost the same chronological age at which the peak milk production occurs (5th-6th lactations) in the temperate cattle. (Johansson and Rendel. 1968). The difference between temperate and tropical cattle is attributable to the fact that tropical cattle generally have higher age at puberty and hence late at age first calving.

Previous studies (Mahadevan. 1953; Galukande *et al.*, 1962: Andersen, 1970: Odendra *et al.*. 1978: Bhat *et al.*. 1980) have shown that age at first calving significantly influence milk yields of cattle. Milk yield of the Sahiwal was observed to increase with age at first calving (Batra and Desai. 1964: Kavitkar *et al.*. 1968: Kimenye. 1978) while this was not observed in the Hariana breed (Singh and Desai, 1961; Balaine, 1971). This difference may be due to differences in management and selection objectives in the individual herds. However the evidence is in favour of correction of the effect of age at first calving in the analyses of milk yield.

From the information discussed above it would be desirable to include parity or age effect in the models of analyses of milk yield data that include multiple parities.

2.1.2.4 Lactation Length

Lactation lengths have been reported to account for 45-75 percent of the total variance of milk yields in tropical cattle (Alim, 1960; Galukande *et al.*, 1962; Ngere, 1970). High correlations between lactation length and milk yield have been reported in the Sudanese cattle (Alim, 1960; 1962; Danasoury and Bayoumi, 1963). Similar correlations have been reported for Sahiwal by Batra and Desai (1964) and by Kimenye (1978); for Hariana cattle by Ngere (1970) and for the East African Zebu by Galukande *et al.*, (1962).

The above is not a general occurrence in the temperate cattle where lactation length is much less variable (Mahadevan, 1966). The degree to which the lactation length is related to milk yield depends on the breed, management, and whether the calves have been allowed to suckle or not .

2.1.2.5 Dry Period

Significant effects of the preceding dry periods on current lactation milk yields of Nganda, East African Zebu and Hariana cattle have been reported by Mahadevan and Marples (1961), Galukande *et al.*, (1962), and Dadlani and Prabhu (1968), respectively.

This was not observed in the Sahiwal breed (Batra and Desai 1964; Kavitkar *et al.*, 1968; Kimenye, 1978). It appears that the influence depends not only on breed but also on whether the length of the dry periods examined were within the range in which the influence on milk yield could be detected (Bayoumi and Danasoury, 1963; Batra and Desai, 1964). However, the inability to know whether a cow dried off naturally or due to a management decision makes the correction of milk yield for the preceding dry period difficult.

2.1.2.6 Calving Interval

Some studies (Alim, 1962; Galukande *et al.*, 1962; Bhat and Chandramohan, 1982; Mwandotto, 1986) have shown that the preceding calving interval is significantly correlated with the current milk yield in tropical cattle. Others (Singh and Desai, 1962; Dadlani and Prabhu, 1968; Kimenye, 1978; Biswas *et al.*, 1982) have not found any significant correlation between the preceding calving interval and the current milk yield. Preceding calving intervals seem to influence milk yield only when they are short. When they are very long their effect is minimized as each cow has more than a sufficient rest (Mahadevan, 1966). It appears that the influence depends on the breed and the management system adopted in the herd. However, the dry period and the lactation length which are the components of the calving interval have to be considered when correction factors are being devised.

2.1.2.7 Body Weight at Calving

Different workers (Mason *et al.*, 1972; Tomar and Arora, 1972; Kimenye, 1978; Mwandotto, 1986) have not found any significant correlation between milk yield and body weight. However body weight at calving has been reported to have significant influence on milk yields of cows in some studies (Farthing and Legates, 1958; Clark and Touchberry, 1962; Singh and Desai 1966; Chabra *et al*, 1970; Kimenye, 1978). In all cases the heavy cows at calving produced higher amounts of milk. Heavier cows are able to produce more milk because of their ability to ingest and metabolize large amounts of feed despite their higher maintenance requirements. The extra nutrients are turned into milk. Brody (1945) suggested that cows be compared on the basis, of fat corrected milk yield, per metabolic body weight ($W^{0.7}$) since the requirement of energy for body maintenance is proportional to $W^{0.7}$.

2.1.3 Repeatability and Heritability

The repeatability and heritability estimates reported in tropical cattle for milk yield are set out in Table 2. All the repeatability and heritability estimates reported in the Sahiwal breed fall within the range of 0.3 to 0.73 and 0.2 to 0.5, respectively, reported for the other tropical cattle. The magnitudes of these estimates suggest that selection for high milk yield based on the first lactation records should be expected to result in genetic progress.

2.2 Calving Interval

2.2.1 Means And Variations

The means and coefficients of variation of calving interval reported in tropical cattle are presented in Table 3. The means reported in African cattle are within the range (365 - 396 days) acceptable in the well managed temperate cattle herds (Johansson and Rendel, 1968). However, those reported in Indian cattle - the Sahiwal included - as well as those in the Kenana and the Native Egyptian breeds, fall within the range 396 - 605 days. Most of the coefficients of variation vary directly with corresponding means of the calving intervals reported in the individual herds and are generally low. Mahadevan *et al.*, (1962) and Kimenye (1978) have indicated that calving interval is largely affected by environmental factors and the management system adopted in the herds, for instance AI

Table 2: Repeatability and Heritability Estimates of Lactation Milk Yield in Tropical Cattle

Breed	Repeatability	Heritability	Source
Kenana	0.43	0.24	Alim (1960)
Fulani	-	0.20	Foster (1961)
Nganda	0.73	0.20	Mahadevan and Marples (1961)
Butana	0.41	0.28	Alim (1962)
E.A.Zebu	0.55	0.50	Galukande *et al* (1962)
Sahiwal	0.65	0.59	Mahadevan *et al.* (1962)
Sahiwal	0.49	-	Johar and Taylor (1967)
Sahiwal	0.35	0.15	Acharya and Nagpal (1971)
Sahiwal	0.37	0.36	Gopal and Bhatnagar (1972)
Sahiwal	0.57	-	Dharmendra *et al.* (1978)
Sahiwal	0.43	0.23	Kimenye (1978)
Sahiwal	-	0.41	Taneja *et al.* (1978)
Hariana	0.50	-	Gill and Balaine (1971)
Tharparkar	0.37	0.35	Basu *et al.* (1982)
Tharparkar	0.30	0.28	Parmar and Johar (1982)
Red Sindhi	0.32	0.30	Singh *et al.*(1982)

or natural service of cows, hence the low heritabilities associated with the trait.

2.2.2 Factors Influencing Calving Interval

2.2.2.1 Year of Calving

Previous studies (Singh *et al.*, 1958; Osman, 1972; Kimenye, 1973; 1978; Kimenye and Russel, 1975) have shown that year of calving has significant influence on calving interval of tropical cattle. Although management does influence calving interval, it cannot be expected to explain annual fluctuation. Yearly fluctuations can be caused also by changes in weather and inbreeding levels over the years (Trail and Gregory, 1981).

2.2.2.2. Season of Calving

Some authors (Singh *et al.*, 1958; Osman, 1972; Kimenye, 1973; 1978; Kimenye and Russel, 1975) have shown that season of calving has a significant influence on calving interval of tropical cattle. In all these cases , animals calving during periods of food scarcity had prolonged calving intervals. However, Rao *et al.* (1969) and Aggrawal *et al.* (1972) did not observe a significant influence of season of calving on calving intervals of the Ongole and Kankrej breeds, respectively. The difference in observations may have arisen because of differences between breed, management and definition of seasons.

Table 3: The Means and Coefficients of Variation of Calving Interval of Tropical Cattle.

Breed	Mean (days)	CV.(%)	Source
Sahiwal	471	10	Amble *et al.*(1958)
Sahiwal	484	23	Singh and Choudhury (1961)
Sahiwal	388	19	Mahadevan *et al.* (1962)
Sahiwal	439	20	Gheloni and Malik (1967)
Sahiwal	498	25	Kushwana and Misra (1969)
Sahiwal	412	-	Kimenye (1978)
Red Sindhi	549	30	Amble *et al.* (1958)
Red Sindhi	436	33	D'Souza *et al.* (1979)
Native Egyptian	419	26	Asker *et al.* (1958)
Hariana	439	17	Johar and Taylor (1970)
Hariana	473	20	Ngere (1970)
Nganda	420	21	Mahadevan and Marples (1961)
Tharparkar	440	22	Basu *et al.* (1982)
Gir	603	35	Malik and Ghai (1978)
E.A. Zebu	363	19	Galukande *et al.* (1962)
E.A. Zebu	349	22	Sacker and Trail (1966)
Ankole	342	14	Sacker and Trail (1966)
Butana	416	-	Alim 1964)
White Fulani	366	-	Johnson *et al.* (1984)

2.2.2.3 Parity

A number of studies (Alim, 1960; Johar and Taylor, 1967; Singh and Prasad 1968; Dadlani *et al.*, 1969; Johnson *et al*, 1984) have reported that parity influences calving interval of tropical cattle. Some of them (Dadlani *et al.* 1969; Johar and Taylor, 1970; Johnson *et al*, 1984) have observed that the first calving interval is the longest and the third is the shortest and that calving intervals increase in subsequent parities. The longer calving intervals for the young cows may reflect a higher nutritive requirement, because they still have a requirement for growth in addition to requirements for lactation and maintenance. It is generally known that in the partitioning of nutrients among the metabolic functions in the body, priority is given to survival of the individual rather than its reproductive functions (Williamson and Payne, 1978). In older cows, longer calving intervals result from the reduced ability to conceive associated with the aging process. Vascularisation of the uterine stroma is, generally, known to be a major factor affecting conception rate in mammals. However, vascularisation of the uterine stroma diminishes with the age of the female farm animals maintained for a longer period of breeding (Hunter,1985), hence the longer service period and, therefore, longer calving interval in older cows.

2.2.2.4 Age at First Calving

Several workers (Singh and Sinha, 1960; Plasse *et al*, 1965; Kumar, 1982) have reported insigificant correlations between calving interval and age at first calving. These findings are not in agreement with those of Singh and Choudhury (1961) and Kushwana and Misra (1969) working with the Sahiwal breed, and Kumar (1982) working with Hariana breed in India. The influence of age at first calving on calving interval seem to depend on feeding and breeding management in tropical cattle herds.

2.2.2.5 Service Period

Several workers (Kholi *et al*, 1961; Bhalla *et al*, 1967; Malik and Sindhu, 1968; Tomar and Arora, 1972; Chopra *et al*, 1973) have reported service periods ranging from 120 to 219 days in Indian cattle. Service periods of tropical cattle are long and may partly be the cause of the long calving intervals observed. Service period has a very low heritability (Singh *et al*, 1968) and is, therefore, largely affected by environmental factors such as feeding and heat detection techniques used in the herd.

2.2.2.6 Lactation Length and Dry Period

Basu *et al*, (1982) reported a near-zero genetic correlation between the current calving interval and the current lactation length while Kimenye (1978) reported a low and highly significant phenotypic correlation (r_p = 0.08).

Several workers (Gheloni and Malik, 1967; Johansson and Rendel, 1968; Dutt *et al*, 1974; Kimenye, 1978) have shown that the current dry period is highly correlated with the current calving interval. This has also been reported by Brotherstone (1987) in British Holstein/Friesian herds. This relationship arises since calving interval is made up of dry period and lactation length.

2.2.2.7 Lactation Milk Yield

Basu *et al*, (1982) have reported non- significant genetic correlations between current lactation milk yields and current calving intervals. However, Dadlani *et al*, (1969) and Maijala (1978), working with Hariana cattle and temperate cattle, respectively, found significant positive phenotypic correlations between current lactation milk yield and current calving interval. These findings tend to suggest that the influence of the lactation milk yield on the current calving interval vary with the breed and the selection objectives in the herd. However, in the low producing breeds such as the Sahiwal milk production is too low to influence calving interval negatively (Mahadevan, 1966).

2.2.2.8 Sex and Birth Weight of the Calf

There is little information in the tropics on the relationship of the sex and birth weight of the calf with calving interval. It is known that long gestation periods are associated with heavy calves (Gregory *et al.*, 1978) and that male calves are usually heavier than female calves at birth (Gregory *et al.*, 1979). Although the gestation period and service period are the two components of the calving interval. The extra days contributed by the heavy calves have been shown not to significantly increase the calving interval of the dam (Prabhu *et al.*, 1961; Singh and Dutt, 1961).

2.2.3 Repeatability and Heritability

While repeatability and heritability estimates of calving interval, reported in the Sahiwal breed ranged from 0.02 to 0.23 and 0.06 to 0.20, respectively (Mahadevan *et al*, 1962; Singh and Desai, 1962; Kushwana, 1964; Dharmendra *et al*, 1978; Kimenye, 1978), the values reported in other tropical cattle for both parameters are close to zero (Mahadevan, 1966; Williamson and Payne, 1978). The low estimates of these parameters indicate that calving interval is largely influenced by temporary environmental factors.

2.3 Birth Weight

2.3.1 Means and Variations

The mean birth weight reported in tropical cattle are summarized in Table 4. Birth weights of the Sahiwal are within the range 13 to 28 kg reported in the other tropical cattle. While the between-breed differences are large within-breed differences are much smaller (Table 4).

2.3.2 Factors Influencing Birth Weight

2.3.2.1 Year of Birth

Several workers (Touchberry, 1967; Willis *et al.*, 1972; Taneja *et al.*, 1980; Gregory and Trail 1981b; Mwandotto, 1985) have shown that year of calving has significant influence on birth weights of tropical cattle. The year effects may be attributed to genetic trends and climatic factors (Trail and Gregory, 1981) and inbreeding levels (Butts *et al.*, 1984). While the effect of annual fluctuation in weather conditions are erratic, those associated with genetic trends and inbreeding are systematic and can, to a large extent, be accurately adjusted for.

Table 4: The Means of Birth Weight of Tropical Cattle.

Breed	Mean kg	Source
Hariana	24	Sharma *et al.*, (1951)
Hariana	21	Bhat *et al.*, (1982)
Nganda	19	Faulkner and Brown (1953)
East African Zebu	18	" " " (1953)
Tharparkar	24	Joshi and Phillips (1953)
Native Egyptian	24	Ahmed and Tantawy (1954)
Red Sindhi	16	Mahadevan (1966)
Red Sindhi	18	D'Souza *et al.*, (1979)
Sinhala	13	Mahadevan (1966)
Gobra Zebu	26	Denis and Valenza (1968)
Mpwapwa	23	Meyn (1970)
W. Afr. Shorthorn	15	Ngere and Cameron (1972)
Ndama	15	,, (1972)
Boran	28	Tonn (1976)
Boran	25	Thorpe *et al.*, (1980)
Sahiwal	24	Harricharan *et al.*,(1976)
Sahiwal	22	Bhat and Chandramohan(1982)
Sahiwal	23	Mwandotto (1985)
Barotse	26	Thorpe *et al.* (1980)
Red Kudhari	23	Ghafoor *et al.*, (1980)
Tabapua	22	Ledic *et al.*, (1987).

2.3.2.2 Season of Birth

Season of birth has been shown to significantly influence birth weight of calves in tropical cattle (Gregory and Trail, 1978; Bhat and Chandramohan, 1982; Mwandotto, 1985; Cardellino and Castro, 1987). Seasonal influence is caused by the effect of seasonal conditions of weather on feed quality and availability on the condition of the dam, and, hence, the maternal environment on birth weights of calves.

2.3.2.3 Parity

Previous studies (Koch and Clark, 1955; Sacker *et al.*, 1971; Tonn, 1974; Gregory *et al.*, 1978; Ledic *et al.*, 1987) have shown that parity of dam has a significant effect on birth weights of cattle mainly through the maternal environment the dam imparts on the calf (Koch and Clark, 1955). In the Sahiwal breed, Bhat and Chandramohan (1982), working in India, observed lightest calves in the first and second calvers and the heaviest calves in the eighth calvers. Mwandotto (1985), however, found a positive trend in birth weights produced from first to fourth parity followed by a gradual decline in the subsequent parities in the Kenya Sahiwal. The difference can partly be attributed to the fact that selection of dams in the study in India favoured dams whose calves had high birth weights (Bhat and Chandramohan, 1982).

2.3.2.4 Calving Interval

Willham (1972) has shown that the preceding calving interval form part of the maternal effect which is environmental to the calf. Few reports exist in the tropics on this effect. However, Bhat and Chandramohan (1982) and Mwandotto (1985) have shown that the preceding calving interval has a significant effect on birth weight of Sahiwal cattle. This concurs with the findings of Tonn (1974), working with Boran cattle. But the effect of preceding calving interval may be confounded by whether the calf suckled or not during that calving interval hence is dependent on the calf feeding and weaning system in the herd considered.

2.3.2.5 Sex of Calf

Sex of calf has been reported to influence birth weight in cattle (Sacker *et al.*,1971; Willis *et al.*, 1975; Gregory and Trail 1981a; Mwandotto, 1985). Male calves are usually heavier at birth compared to female calves. The physiological basis for this difference is found in the hormonal differences between the sexes (Bell *et al.*,1970).

2.3.2.6 Interaction of the Main Fixed Factors

Year X season interaction significantly affected birth weights of Ayrshire X Sahiwal crossbred cattle (Gregory and Trail, 1981a). This was also reported by Mwandotto (1985). These two results indicate that care should be exercised when correction factors for season of calving are applied across years in the comparison of birth weights.

2.3.3. Repeatability and Heritability

Repeatability estimates of birth weights have been reported to range from 0.16 to 0.34 in African cattle (Trail *et al.*, 1971; Thorpe *et al.*, 1980) and most of these estimates fall within the range of estimates 0.2 to 0.3 reported in temperate beef cattle (Dalton, 1980). Heritability estimates of birth weight, as trait of the dam, have been reported to range from 0.14 to 0.25 in Holstein cattle (Everret and Magee, 1965), 0.27 in Aberdeen Angus and 0.26 in Hereford (Brown and Galvez, 1969). Heritability estimates of birth weight as trait of the dam in zebu cattle are sparse. However, Arnason and Kassa-Mersha (1987) have reported a value of 0.12 in Ethiopian Boran cattle.

It can be concluded that the range of values reported for repeatability and heritability estimates are low to moderate in magnitude depending on the model of analysis used, breed of cattle and locality of the herd.

2.4 Age of Calf at 55 kg Liveweight

Few workers have reported on this trait as the definition is not conventional in the management systems adopted in most range cattle herds. The ages of calves at 55 kg at the NSS on average range from 60 to 120 days (Mwandotto, 1986). Therefore, the following review will be confined to herds where liveweight within this range of ages have been studied.

2.4.1 Means and Variations

Mwandotto (1985) has reported an average age of 106 days at 55 kg liveweight of calves in the NSS herd. Msanga *et al.*, (1986) reported an average liveweight of 59.3 kg at 75 days in Mpwapwa calves and Ledic *et al.* (1987) reported average weight of 92.8 kg at 90 days in Tabapua calves. These two cattle breeds have birth weights close to those of the Sahiwal (Table 4). The above results appear to show that the Mpwapwa and the Tabapua cattle have higher average daily gains than the Sahiwal cattle.

2.4.2. Factors Influencing Ages of Calves at 55 kg Liveweight

2.4.2.1 Year of Birth

Mwandotto (1985) has reported that year of birth has significant influence on the age of the calf at 55 kg liveweight. A number of other workers (Touchberry, 1967; Willis *et al.*, 1972; Taneja *et al.*, 1980, Ledic *et al.*, 1987) have reported significant effect of year of birth on liveweight of calves at ages ranging from 60 to 120 days. These results are attributable to the selection goals in the different herds, resulting in different genetic trends, and to the effect of yearly fluctuations in general environmental conditions on the maternal environments during the pre-weaning period.

2.4.2.2 Season of Birth

Season of birth had significant effect on age of calf at 55 kg liveweight in Sahiwal cattle (Mwandotto, 1985). Other workers (Sacker *et al.*, 1971; Bhat *et al.*, 1982; Msanga *et al.*, 1986; Ledic *et al.*, 1987) have reported that season of birth has a significant effect on the liveweight of calves at ages ranging from 60 to 120 days. Pasture conditions, as affected by seasonal fluctuations in weather, may be the major factor contributing to seasonal influence of liveweight of calves because maternal environment is affected by feed availability to the dam.

2.4.2.3 Parity or Age of Dam

Age of dam has been shown to have a high correlation with parity (Mosi, 1980). Other workers (Kholi *et al.*, 1961; Sacker *et al.*, 1971; Ledic *et al.*, 1987; Planas, 1987) have reported a significant influence of parity of the dam on liveweight of calves at ages of 60 to 120 days. Sacker *et al.*, (1971) found that lightest calves were produced by 2-year old dams while heavier calves were produced by older dams when considered with respect to calf liveweight at 60 to 120 days of age. These results are partly due to the fact that maternal capacity to provide milk to the suckling calf increases with age or parity of dam (Planas,1987).

2.4.2.4 Sex of Calf

Sex of calf has a significant influence on calf liveweight between 60 to 120 days of age (Touchberry, 1967; Sacker *et al*., 1971; Ledic *et al*., 1987). This is attributable to the hormonal differences in the two sexes. Generally male calves grow faster than female. This has been attributed to differential rate of protein and other organic matter synthesis in the two sexes: faster for males under androgen influence than for females which are predominantly under influence of estrogens (Bell *et al*., 1970).

2.4.2.5 Calving Interval

Mwandotto (1985) reported significant influence of the preceding calving interval on calf age at 55 kg liveweight. The preceding calving interval forms part of the maternal effects on the growth of the calf. However, in beef production systems the effect of the preceding calving interval on the liveweight of current calves is confounded by whether the dam actually suckled a calf in that interval. A longer preceding calving interval without suckling a calf in that duration would, generally, confer a good body condition to the dam which would ensure better pre-natal and postnatal maternal environment to the current calf (Willham,1972). However, if the dam suckled a calf during the preceding calving interval the suckling stimulus and the concomitant removal of milk from the udder would result in a longer period of lactation and longer lactational anoestrus (Hunter,1985), and, hence a longer preceding calving interval accompanied by poor body condition of the dam caused by the severe drain on dam's body nutrient reserves for formation of milk to support that calf.

2.4.3 Repeatability and Heritability

Trail *et al.*, (1971) reported 0.42 and 0.14 as repeatability and heritability estimates, respectively, of liveweight of calves at 2 to 4 months of age. Dalton (1980) gave 0.42 as the average of repeatability estimates reported in temperate cattle for liveweight of calves in the 2 to 4 months age range. However, hardly any estimates of heritability of liveweight of cattle at the ages ranging from 60 to 120 days as trait of the dam, have been reported.

2.5 Phenotypic, Genetic and Environmental Trends

2.5.1 Lactation Milk Yield

Lack of pure dairy breeds among tropical cattle and the general lack of milk recording facilities are largely responsible for the lack of estimates of phenotypic, genetic and environmental trends of milk production in these breeds. However, several workers (Alim, 1960; Mahadevan and Marples, 1961; Galukande *et al.*, 1962; Kimenye, 1978) have reported positive phenotypic trends in milk production in tropical cattle. Positive phenotypic trends are expected as selection in these tropical herds is in favour of high milk production.

The estimates of phenotypic, genetic and environmental trends may vary from one herd to another due to differences in locality, management, breed and selection objectives as has been observed in the temperate dairy cattle raised in the tropics (Sadana and Tripathi, 1986; Rege and Mosi, 1987).

2.5.2 Calving Interval

Phenotypic trends in this trait are expected to be negative because selection is in favour of animals with short calving intervals. However, positive phenotypic trends have been reported in tropical cattle due to unfavourable factors such as low availability of pastures resulting from overstocking and/or long dry periods and poor breeding management (Osman, 1972;

Kimenye, 1978; Gregory and Trail, 1981a). Despite these, it is possible to achieve negative phenotypic and genetic trends in tropical cattle if the selection and management objective is to shorten calving intervals as has been observed in Gir cattle (Oliveira *et al.*, 1986).

2.5.3 Birth Weight

There are few reported trend estimates of birth weight in tropical cattle. However, Mwandotto (1986) has reported a very low phenotypic trend in birth weight at NSS. In temperate herds, genetic trends close to zero have been reported (Elzo *et al.*, 1987) a result of selection for low birth weights in these herds to reduce calving difficulties associated with high birth weight.

2.5.4 Age at 55 kg Liveweight

Hardly any trend estimates have been reported on this trait. Mwandotto (1985), however, observed positive phenotypic trends of age at 55 kg liveweight over the period 1964-1981 at the NSS.

3.0 MATERIALS AND METHODS

Records of cows kept at the National Sahiwal Stud(NSS),Naivasha over the period 1964-1983 were used in this study. Detailed description of the environment, herd management, feeding and breeding programme at NSS in the period 1964-1983 has been given by Mwandotto (1985).

3.1 Environment

Naivasha area is classified as ecological Zone IV (Pratt *et al.*, 1966). The natural vegetation is modified Savannah with few *Acacia sp.* trees, *Tarchonanthus comphoratus* (Leleshwa) bushes, and low-lying bushes of sodom apple (*Solanum incanum*). The dominant grass species is common star grass (*Cynodon spp*) interspersed with Kikuyu grass (*Pennisetum clandestinum*) and *Harpachne schimperi* (wire grass). The annual rainfall ranged from 430 to 950 mm and the mean annual temperature was 18°C in the study period. The long rains (March-May) and the short rains (October-November) are the two seasons which allow vegetative growth. However, the repeatability of the rainfall in the two seasons, in amount and distribution, is very low.

3.2 Herd Management and Feeding

The herd is managed extensively. At any one time there are 400-500 cows. At birth, calves are immediately separated from the dam, ear-tattooed with serial identification number and put on bucket feeding system as the policy is not to suckle them. Colostrum is fed for the first 4 days of life. All liveweight are taken at the weigh bridge weekly in the interval from birth to 55 kg liveweight and two times every month in the interval of 55 to 125 kg liveweight. At 125 kg liveweight, calves are drafted according to sex into young bull and heifer herds managed on natural pasture without feed supplementation except mineral licks. Between 125 kg liveweight to 24 months of age, bulls are weighed once every month but heifers are weighed only at 27 months of age (bulling age).

However, in the period 1970-1983, the system changed to feeding whole milk from the age of 5 days to 55 kg liveweight, followed by concentrate calf feed from 55 to 125 kg liveweight. The milking herd is usually grazed ahead of the dry herd in the rotation system. All animals, except very young calves, are allowed to graze for 24 hours. The cows are fed ground hay mixed with a commercial dairy meal during milking.

Although in the years before 1973 cows producing greater than 5 kg of milk per day were supplemented with dairy meal feed, this practice stopped in 1973. All herds are offered mineral salt licks twice monthly.

Routine vaccination, deworming of young stock and general treatment is done by a resident veterinary surgeon or his assistants. The herd is bred through AI and heat detection is done by trained AI technicians. Cows are hand-milked twice daily without calf at foot, and milk yields recorded on Kenya Milk Record (KMR) sheets. Records include milk yield, pedigree information, AI service records, health, disposal and liveweights. In-calf heifers and cows enter the milking herd two months before calving for steaming up.

3.3 Breeding Programme

Details of the development of the NSS have been described elsewhere ((Meyn and Wilkins, 1974). The breeding plan, shown in Figure 1, was drawn by Mason (1965) and implemented in 1968 (Meyn and Wilkins, 1974). The breeding programme has the main emphasis on milk production although beef characteristics were included.

The best 50% of heifers completing first lactation are selected on the basis of their first lactation records. Further, the best 50% of them are selected on the basis of the second lactation milk yield records. These cows remain in the herd as replacements of those elite cows culled on the basis of chronic mastitis problems, accidents, old age and fertility problems such as long calving intervals.

At any one time there are 180 to 200 elite cows. These cows are used as bull dams to produce 75 to 80 two year-old bulls out of which the best 15 are selected on the basis of the index:

$$I = b_1G_D + b_2G_S + b_3G_P$$

Where G_D = estimated breeding value (EBV) of dam of candidate bull for milk production estimated from own records

G_S = EBV of sire of candidate bull for milk production estimated by contemporary comparison

G_P = EBV of candidate bull for liveweight at 2 years of age,* performance tested on pasture.

b_1, b_2, b_3 = weighting factors of the index for the

3 respective sources of information.
The weighting factors (b's) of the index are estimated as follows.

$$b_1 = b_2 = W_m h^2{}_n \quad \text{and}$$

$$b_3 = W_w h^2{}_w$$

Where W_m = gross margin per additional kilogram of milk produced.

W_w = gross margin per kilogram liveweight for a bull at 2 years of age.

$h^2{}_n$ = heritability of milk yield for n lactations per animal.

$h^2{}_w$ = heritability of liveweight of bulls at 2 years of age.

The gross margins per additional unit of production estimated from NSS data are the economic parameters used in the construction of the index. The values of genetic parameters assumed in the construction of the selection index currently in use at NSS were based on values reported in literature (Mason, 1965) and are:
Repeatability of milk yield = 0.6,
Heritability of first lactation milk yield = 0.3,
Heritability of liveweight of bulls at 2 years of age = 0.3, the correlation between milk yield of cows and the liveweight of bulls at 2 years of age = 0.

The best 15 bulls selected using the selection index are further subjected to selection to on the basis of the "breed label" characteristics of the Sahiwal breed, such as trueness to color of the breed,

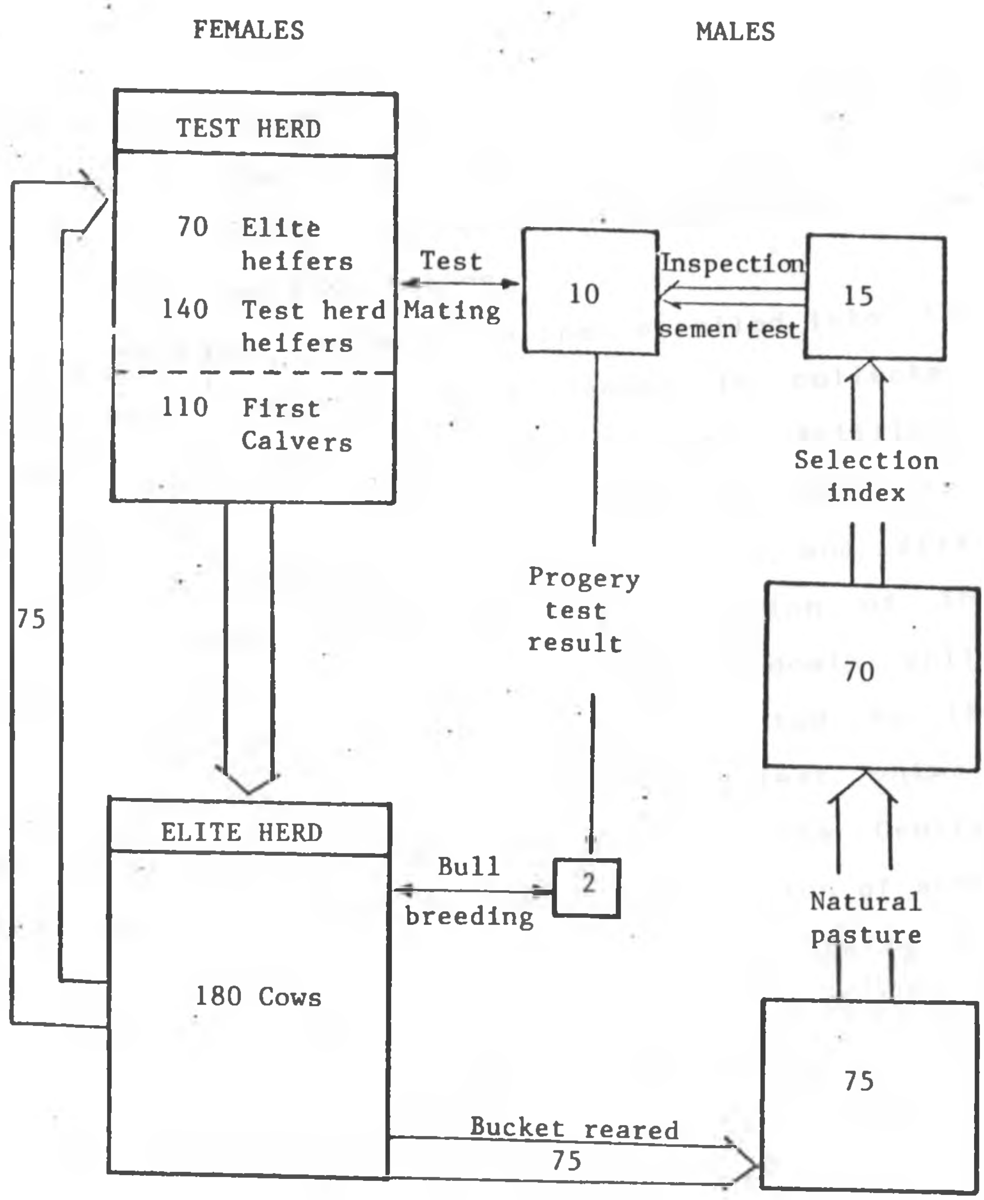


Fig. 4 Breeding plan at the National Sahiwal Stud, Naivasha, Kenya.

conformation of the bull and the dam's udder shape and teat size. At least 3 bulls are eliminated on this basis and a further 2 to 3 bulls are eliminated on the basis of semen characteristics.

The remaining 10 bulls are then enrolled into the progeny test programme. Their semen is collected, processed and stored at the Central Artificial Insemination Centre, Kabete. This semen is used in a test herd at NSS, consisting of heifers and first calvers of about 400 females. The allocation of the females to the bull on test is done randomly while ensuring that the bull is not closely related to the female mates. At the end of the progeny test only 2 best bulls are selected and sent to the Central Artificial Insemination Service for production of semen for use in the elite herd or for sale locally and abroad. The bulls are 6 to 8 years of age at the end of the test. Male calves born in the test herd are always sold or slaughtered at birth but the female calves are kept up to the end of their first lactation when they are selected on the basis of their milk yields.

3.4 Data Preparation

The data for the study period (1964-1983) were extracted from the NSS data into specially prepared record sheets. The information coded directly were animal's pedigree, date of birth or calving, birth weight, sex, and parity of cow at calving, age of animal at 55 kg liveweight, lactation milk yield, lactation length and calving interval. The coded data were verified and punched into computer by use of the data capturing machines at the Livestock Recording

Centre (LRC), Naivasha. The data were further edited at the Government Computer Services Centre (Nairobi) from where they were copied onto 5.25" diskettes in readiness for analysis on IBM pc at the Department of Animal Production, University of Nairobi.

Season of calving or birth was a derived variable from date of birth or date of calving. There were three calving seasons defined as: long rains (March-May), short rains (October-November) and dry period (the rest of the year). For lactation milk yield, birth weight and age at 55 kg liveweight (AGE55), parity subclasses were defined as 1st to 5th lactation numbers and the 6th lactation number and above were lumped into one subclass. For calving interval parity subclasses were 2nd to 7th lactation numbers and the 8th lactation number and above were lumped into one subclass.

Birth weight and AGE55 were regarded as traits of the dam. The earliest records were in 1964 and the latest in 1983. The structure of the data analyzed for the four traits in this study is set out in Table 5.

3.5 Statistical Analyses

Data were sorted according to known sources of variation affecting the respective dependent variables (traits) of the study. The general mixed model used in the analyses, in matrix notation was

$$\underline{y} = X\underline{b} + Z\underline{u} + \underline{e}$$

with daughters (cows) nested within sires.

Where X = incidence matrix for fixed effects

Z = incidence matrix for random effects due to cows (dams) and sires

$\underline{b}$ = unknown vector of fixed effects

$\underline{u}$ = unknown vector of random effects due to cows(dams) and sires

$\underline{y}$ = vector of known dependent variables

$\underline{e}$ = vector of the random error effects

with

$$E\begin{bmatrix} \underline{y} \\ \underline{u} \\ \underline{e} \end{bmatrix} = \begin{bmatrix} X\underline{b} \\ \underline{o} \\ \underline{o} \end{bmatrix} \text{ and } Var\begin{bmatrix} \underline{y} \\ \underline{u} \\ \underline{e} \end{bmatrix} = \begin{bmatrix} ZGZ' + R & ZG & R \\ GZ' & G & 0 \\ R & 0 & R \end{bmatrix}$$

Where G = Var ($\underline{u}$) = variance - covariance matrix of random effects (sire and cow)

R = Var ($\underline{e}$) = variance-covariance matrix of the residual effects.

With the two random effects in a nested design Z and $\underline{u}$ can be partitioned as:

$$Z = (Z_1,\ Z_2);\quad \underline{u}' = (\underline{u}'_1,\ \underline{u}'_2)$$

Where $\underline{u}_1$ = unknown vector of random sire effects

$\underline{u}_2$ = unknown vector of random daughter(cow) effects

Table 5: Data structure for the 305-day Milk Yield (MY), Calving Interval (CI), Birth Weight (BW) and Age at 55 kg Liveweight (AGE55) studies.

Item	MY	BW	CI	AGE55
Total observations	4837	4272	4837	3544
Number of cows(C)	1963	1694	1963	1676
Number of sires(S)	175	154	175	161
Years (1964-1983)	20	20	20	20
Seasons	1,2,3	1,2,3	1,2,3	1,2,3
Parities	1,..,≥6	2,..,≥8	1,..,≥6	1,..,≥6
Sex of calf	-	1,2	1,2	1,2

Sex: 1 = Male, 2 = Female; Seasons: 1 = Long Rains 2 = Short rains, 3= Rest of the year

Z_1 = incidence matrix of random sire effects

Z_2 = incidence matrix of random cow effects.

Under the assumptions of the model the variance - covariance matrices for the random effects were defined as:

$$G = \begin{bmatrix} I\sigma_s^2 & 0 \\ 0 & I\sigma_c^2 \end{bmatrix} \quad \text{and} \quad R = I\sigma_e^2$$

Where σ_s^2 = sire variance component

σ_c^2 = cow variance component

σ_e^2 = error variance component

Initial examination of the fixed effects influencing each of the four traits in this study was done by fitting completely fixed models. The mixed model equations which were solved for the Best Linear Unbiased Estimates (BLUEs) and the Best Linear Unbiased Predictions (BLUPs) which are solutions of the fixed and random effects, respectively ,are presented in general matrix notation as follows:-

$$\begin{bmatrix} X'X & X'Z_1 & X'Z_2 \\ Z_1'X & Z_1'Z_1+Ik_2 & Z_1'Z_2 \\ Z_2'X & Z_2'Z_1 & Z_2'Z_2+Ik_2 \end{bmatrix} \begin{bmatrix} \underline{b} \\ \underline{u}_1 \\ \underline{u}_2 \end{bmatrix} = \begin{bmatrix} X'\underline{y} \\ Z_1'\underline{y} \\ Z_2'\underline{y} \end{bmatrix}$$

Where $k_1 = \sigma_e^2/\sigma_s^2$ and $k_2 = \sigma_e^2/\sigma_c^2$

The assumed values of k_1 and k_2 and the heritability and repeatability values used in their calculation are set out in Table 6.

Due to the large sizes of Z_1 and Z_2 ,it was not possible to store the Left Hand Side (LHS) matrices nor was it possible to invert these matrices. To solve this problem, sire and cow effects were absorbed into the fixed effects while the required information for back solutions was stored in separate files. The storage and back solution procedures were performed according to Szkotnicki *et al.* (1978).

The repeatability of milk yield was assumed to be 0.45 since it is the mean of those generally reported in the other tropical cattle (Table 2). The maximum likelihood (ML) estimation of variance components was performed according to Schaeffer (1976) as described below.

$$\sigma_e^2 = [\ \underline{y}'\underline{y} - \underline{b}X'\underline{y} - \underline{u}_1 Z_1'\underline{y} - \underline{u}_2 Z_2'\underline{y}]/n$$

$$\sigma_s^2 = [\ \underline{u}_1'\underline{u}_1 + \sigma_e^2 \text{ trace } (T_{11})]/P_S$$

$$\sigma_c^2 = [\ \underline{u}_1'\underline{u}_2 + \sigma_e^2 \text{ trace } (T_{22})]/P_C$$

where
$$\begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} = \begin{bmatrix} Z_1'Z_1 + Ik_1 & Z_1'Z_2 \\ Z_2'Z_1 & Z_2'Z_2 + Ik_2 \end{bmatrix}^{-1}$$

When cows are nested within sires the expectations of the variance component estimates are as follows.

$$E(\sigma_s^2) = 0.25\,\sigma_A^2$$

$$E(\sigma_c^2) = (\sigma_G^2 + \sigma_{PE}^2) - \sigma_s^2$$

$$E(\sigma_e^2) = \sigma_{TE}^2$$

where the subscripts are:-

A = Additive genetic

G = Total genetic

PE = Permanent environmental

TE = Temporary environmental

Hence the estimation of heritability and repeatability were done as follows:

$$h^2 = 4\,\sigma_s^2 / \sigma_p^2$$

$$r = (\sigma_s^2 + \sigma_c^2) / \sigma_p^2$$

and $\sigma_p^2 = \sigma_s^2 + \sigma_c^2 + \sigma_e^2$

The estimated breeding value (EBV) of a cow was calculated as the sum of her sire's estimated transmitting ability (ETA), which equals the sire's solution, and the fraction of the cow solution that is genetic. The fraction of the cow variance that is genetic is $0.75h^2/[r - 0.25h^2]$ (Henderson, 1973). Where r = repeatability and h^2 = heritability.

Table 6: The Values of k_1, k_2, heritability (h^2), and repeatability (r) used in the Mixed Model Analyses

Character	r	h^2	k_1	k_2
305-day Milk Yield	0.45	0.25	6.29	1
Calving Interval	0.18	0.05	13.39	1
Birth Weight	0.37	0.30	3.65	1
AGE55	0.31	0.23	4.40	1

This formula was simplified to $3k_2/k_1$ and used in this study. Thus the cow EBVs were calculated as:

$$EBV_{cow} = ETA_{sire} + [3k_2/k_1 \times \text{Cow solution}]$$

The annual change in phenotypic and genetic components were estimated respectively by averaging the records and cows' EBVs within year of calving or birth (depending on the traits) and regressing the averages on year. The annual change in environmental component was calculated by difference between the averages of records and the cows' EBVs within year and regressing on year. The standard errors(S.E.) of the genetic parameters were calculated according to Becker (1967) as:-

$$S.E.\ (h^2) = 4\sqrt{\frac{2\ (n.-1)(1-t)^2\ [1+(k-1)t]^2}{k^2\ (n.-S)(S-1)}}$$

Where

$n.$ = total number of daughters (cows)

n_i = number of daughters of ith sire

$t = 0.25\ h^2$

S = total number of sires

$k = [S - (\Sigma n_i^2)/n_i]/[S-1]$

and

$$S.E.\ (r) = \sqrt{\frac{2(m.-1)(1-r)^2[1+(k_1-1)r]^2}{k_1^2\ (m.-C)(C-1)}}$$

Where C = total number of cows

m_i = number of observations on ith cow

$m.$ = total number of observations

$k_1 = [m. - (\Sigma m_i^2)/m_i]/[C-1]$

Mean squares of the fixed effects in the analysis of variance were tested against that of the residual. Tests of significance of estimates of trends were based upon the standard errors of the corresponding regression coefficients.

4.0 RESULTS AND DISCUSSION

Means, standard errors, standard deviations and coefficients of variation of the traits studied are presented in Table 7. The results of the analyses of variance and least squares constant estimates of factors affecting these traits are presented in Tables 8 and 9, respectively.

4.1 Milk Yield

4.1.1 Means and Variations

The estimated mean milk yield (1662 ± 8.3 kg) is comparable to those reported in other Sahiwal herds but, as expected, is much higher than those reported in most of the indigenous African Zebu cattle. However, the milk yields at NSS can be increased considerably through improved feeding because, during periods of high quality pastures, some cows achieved milk yields higher than the mean found in this study (Table 7). In addition, if the variation is largely genetic then it would provide scope for selection.

The 34.4% coefficient of variation of milk yield is comparable to those reported in Sahiwal in India and the other tropical cattle breeds (Table 1) but larger than those reported in European dairy cattle raised in East Africa (Kiwuwa, 1973; Lindstrom and Solbu, 1978). The high variation in milk yield found in this study is attributable to the erratic changes in

Table 7: Means (± S E), Standard Deviations (SD) and Coefficients of Variation (CV) of Milk Yield, Calving Interval, Birth Weight and AGE55.

Traits	Means ± SE	SD	CV(%)
305-day Milk Yield (kg)	1662±8.3	572.2	34.4
Calving Interval (d)	426.2±1.5	99.27	23.3
Birth Weight (kg)	22.7±0.04	2.76	12.2
AGE55 (d)	97.8±0.7	39.9	40.8

d = day kg = kilogramme

changes in herd managers over the years.

4.1.2.2 Parity

Parity of cow at calving had a highly significant ($p<.01$) effect on milk yield. Milk yield increased steadily up to 4th lactation and declined drastically in subsequent lactations. In general, the capacity of young cows to produce milk is limited because udder development is incomplete compared to mature cows. In addition, while young cows have to provide for nutritive requirements for their own growth, maintenance and lactation from the feed available, mature cows have only to provide for the nutritive requirements for maintenance and lactation. These explain the positive increase in milk yield from 1st to 4th parity. Cows in parities beyond 4th had lower milk yield. It is possible that selection against long calving interval, and chronic mastitis cases, rather than for milk yield, among older cows (beyond 4th parity) may be responsible for the low milk yields. Sacker *et al.*(1971) have reported that the older cows, due to their reduced ability to move over a wider area to graze under extensive grazing management, experience a breakdown in body constitution. Extensive grazing management is practised at NSS. Therefore the explanation advanced by Sacker *et al.*(1971) may also apply to the cause of decrease in milk production of older cows in this study.

Table 8:Analysis of Variance for Milk Yield, Calving Interval, Birth Weight and AGE55.

Source	Milk Yield		Calving interval		Birth weight		AGE55	
	DF	MS x 10^4	DF	MS x 10^3	DF	MS	DF	MS x 10^2
Year	19	227.6 **	19	44.3 **	19	22.7 **	19	400 **
Season	2	3.1 NS	2	3.0 NS	2	0.9 NS	2	66 **
Parity	5	178.6 **	5	5.3 NS	5	69.2 **	5	12 *
Sex			1	51.2 **	1	3137.9 **	1	367.68 **
Residual	4810	20.3	4243	7.2	4809	404	3516	5.4

DF=Degrees of freedom; MS= Mean Square; * = Significant ($p<.05$); ** = Highly Significant ($p<.01$) and NS = Non-significant($p>.05$)

Table 9: Least Squares Constant Estimates (± S.E.) of the Fixed Effects for the Four Traits.

Fixed Effects	305-day Milk Yield (kg)	Calving Interval (d)	Birth Weight (kg)	AGE55 (d)
<u>Year of Calving</u>				
1964 b	0 ± 0	0 ± 0	0 ± 0	0 ± 0
1965	-66.52±2.14	6.66±0.54	-0.15±0.01	2.86±0.08
1966	-78.83±4.14	2.49±0.98	-0.09±0.02	2.48±0.13
1967	-30.05 ±5.10	20.73±1.14	-0.14±0.03	5.21±0.12
1968	95.06±3.89	21.87±0.83	0.04±0.02	10.80±0.07
1969	174.99±2.70	38.68±0.57	0.11±0.02	7.91±0.06
1970	242.74±2.53	51.54±0.44	0.01±0.01	27.87±0.02
1971	199.26±4.08	17.33±0.82	-0.00±0.02	37.41±0.01
1972	255.16±4.10	19.33±0.84	0.00±0.02	37.75±0.02
1973	147.66±5.43	6.49±1.08	-0.04±0.03	41.94±0.16
1974	85.10±6.67	15.42±1.30	-0.02±0.03	55.80±0.18
1975	24.94±7.52	26.83±1.47	-0.06±0.04	57.30±0.19
1976	-110.89±6.39	29.72±1.29	0.11±0.03	54.96±0.25
1977	56.38±7.01	60.75±1.47	0.06±0.04	64.26±1.75
1978	15.41±7.40	34.99±1.39	0.06±0.04	71.52±0.18
1979	77.76±6.42	69.26±1.18	0.15±0.03	59.45±0.13
1980	-73.14±6.53	62.82±1.30	0.10±0.04	79.23±0.06
1981	-229.06±3.83	60.44±0.84	-0.05±0.02	95.29±0.74
1982	-199.72±4.49	46.65±1.15	-0.01±0.03	83.33±0.99
1983	-265.96±83.03	25.43±16.55	-0.26±0.38	92.24±6.76
<u>Season of Birth</u>				
March-May (1)	-5.05±18.77	1.51±3.76	-0.01±0.08	2.25±1.17
October-Nov. (2)	8.90±21.97	3.92±4.41	0.06±0.10	6.84±1.40
Rest of year (3)b	0±0	0±0	0±0	0±0
<u>Sex of Calf</u>				
Male (1)	-	-8.31±3.12	1.99±0.07	-8.76±1.07
Female (2)b	-	0±0	0±0	0±0
<u>Parity of Dam</u>				
1	120.23±33.64	-	-1.02±0.15	-2.82±2.07
2	130.12±26.88	7.03±6.98	-0.30±0.12	-2.21±1.64
3	131.07±26.95	2.56±6.97	-0.16±0.12	-3.03±1.65
4	169.63±27.05	0.55±6.95	0.26±0.12	1.64±1.64
5	67.93±27.76	1.70±7.04	0.12±0.12	-1.92±1.73
≥6b	0±0	-4.18±7.22	0±0	0±0
7		-2.74±7.64		
≥8b		0±0		

b=Base (or zero level) for the subclass of Fixed Effects

4.1.2.3 Season of Calving

Although season of calving did not have a significant ($p>.05$) influence on milk yields, cows that calved in the short rainy season (October-November) had the highest milk yields (1671±21.97kg) while those that calved in the long rains season (March-May) had the lowest (1656.95±18.77kg) (Table 9).

The long rainy season covers a short time (2 months), but it represents the wettest period. This results into good pastures in the ensuing period, thereby benefiting cows calving in the subsequent dry period and the short rains rather than those calving in the long rainy season. This is because most cows which calve in the long rains have only a small part of the lactation supported by the high quality pastures. A larger component of their lactation period occur in the subsequent dry period and the short rains. On the other hand, animals which calve late in the year (during the short rains) take advantage of the subsequent long rains which will most likely come during their peak lactation. It is, therefore, advisable that cows which calve in the long rains should be supplemented with high quality fodder so as to sustain their milk yields at the levels similar to those calving in the other seasons of the year.

4.2 Calving Interval

4.2.1 Means and Variations

The mean calving interval (426.2 ± 1.5 days) is, in general, shorter than those reported in the Sahiwal herds in India but longer than those reported in the same breed in Kenya as well as those reported in the indigenous African cattle. However, it should be noted that most of the herds reported to have shorter calving intervals were bred through natural service and were raised at government institutions and research stations with herd sizes of less than 300 cows. The small herd sizes enable greater attention to individual cows and hence a higher feeding and breeding efficiency. The magnitude of the calving interval found in this study is less than 14 months and is, therefore, within the limits of those reported in herds raised under good husbandry conditions (Mahadevan, 1966).

The coefficient of variation (23.3%) of the calving interval is comparable to those reported in the Sahiwal breed but higher than those reported in the Nganda, East African Zebu and Ankole cattle (Table 3). The variation of the calving intervals found in this study is, to a large extent, attributable to environmental factors because the heritability estimates of calving intervals are generally near zero. Another cause may be the variation in the efficiency of the AI service over the period covered in this study (NAHRS-Annual Reports, 1969; 1970; 1975; 1983).

4.2.2 Factors Affecting Calving Interval

4.2.2.1 Year of Calving

Year of calving had a highly significant (p <.01) effect on calving interval. The shortest calving interval (426.2±1.5d) occurred in 1964 and the longest (495.5±1.5d) in 1979. There were changes in the AI technicians and herdsmen at end of 1978 so that a large number of new and inexperienced staff were left at the NSS in 1979. This caused deterioration in the efficiency of AI service and may have been responsible for the long calving intervals in 1979 (NAHRS-Annual Report, 1979). Although animals calving in 1964 were not selected for short calving intervals, a large number of the cows were the older high grade Sahiwal cows of the foundation herd of NSS (NAHRS-Annual Report, 1964). Other factors ,however, such as rainfall distribution and amounts which affect pasture quality and availability, together with the genetic change resulting from the culling of older cows for fertility problems could have been responsible for the yearly fluctuations of calving intervals in this study.

4.2.2.2 Season of Calving

Season of calving did not significantly (p>.05) affect calving intervals. The restricted nutrition regime at NSS probably curtailed the full expression of sexual activity and would therefore obscure, to some extent, the seasonal variation in the sexual function of the cows. Nevertheless, the longest calving intervals occurred in cows calving in the short rains and the shortest occurred in those that calved in the dry period. Generally, short oestrus cycles and long heat periods are regarded as an indication of increased sexual activity while long oestrus and short heat periods are regarded as an indication of decreased sexual activity.

Working with Zebu and high grade cattle at Naivasha, Anderson (1944) found that longer oestrus cycles and shorter heat periods were associated with decrease in both the temperature and sunshine in the short rainy season while the increase in both the temperature and sunshine in the long rainy season and the rest of the year was associated with shorter oestrus cycles and longer heat periods. Furthermore, short heat periods in Zebu cattle - Sahiwal breed included - often coupled with a show of less intensity of heat signs -may reduce the efficiency of both heat detection and AI service resulting in long service period. The cows calving in the short rainy season would on average have most of the duration of the early part of their service period occurring in the short rainy season. These may explain the longer calving intervals observed in cows calving during the short rainy season at NSS. This information indicates that closer attention should be given to cows calving in the short rainy season in order to shorten the calving intervals in the herd.

4.2.2.3 Parity

Parity did not (p>.05) affect calving interval. This result is contradictory to those reported in other studies (Alim,1960; Kimenye, 1978; Johnson *et al.*, 1984). The difference in these results may be attributed to the methods of analysis used. There was, however, a consistent increase in reproductive performance (as indicated by the shortening of calving interval) from 2nd to 5th parity. The longer calving intervals in the younger cows may be the result of the shift, at physiological level, in the use of the available nutrients away from the reproductive functions to growth, maintenance and lactation.

The deterioration in the reproductive performance of older cows, as indicated by longer calving intervals beyond 5th parity, may be due to the reduced ability of these cows to conceive. The degenerative conditions caused by the accumulation of scar tissues, fibrous connective tissue and a diminished vascularisation of the uterine stroma has been observed in the females of many farm animals maintained for a longer period of breeding (Hunter, 1985).

4.2.2.4 Sex of Calf

Sex of current calf had a highly significant ($p<.01$) influence on calving interval. Male calves were associated with shorter calving intervals in their dams. This result is contradictory to the results of other workers (Gregory *et al.*, 1978; Gregory and Trail 1981b). Generally, male calves have higher birth weights and are associated with longer gestation periods. As the gestation period and service period are the two components of the calving interval, it is expected that change in the gestation period should affect calving interval. Therefore, male calves are expected to be associated with longer calving intervals. However, when birth weight was fitted as a covariate in the analysis of variance of calving interval in this study the variance due to sex of calf changed very little. Presumably there are some physiological factors linked to sex of calf which are responsible for the shorter calving intervals observed in the dams of male calves at the NSS. A further investigation is required to explain the observations in this study.

4.3 Birth Weight

4.3.1 Means and Variation

The mean birth weight (22.7 ± 0.04 kg) is within the range reported in the other Sahiwal herds. It is, however, lower than those reported in the Boran, Barotse, Native Egyptian breeds and Gobra Zebu (Table 4). Birth weight is determined by the direct effects due to genes contributed to the calf by both the dam and sire, maternal environmental effects on the growth of the foetus in the pre-natal phase and management of the calf. The relative contribution of these three sources within each breed is what determines breed performance with regard to birth weight. Without this knowledge the comparison of Sahiwals at NSS with the other tropical cattle, on basis of birth weight, would not be accurate.

4.3.2 Factors Affecting Birth Weight

4.3.2.1 Year of Calving

Year of birth had a highly significant ($p<.01$) influence on birth weight. This result is in conformity with those reported in other studies (Touchberry, 1967; Willis *et al.*, 1972; Mwandotto, 1985). The lightest calves were born in 1983 and the heaviest in 1979. It has been established by Koch (1972) and Elzo *et al.* (1987) that the intra-uterine environment, which condition the pre-natal growth and hence birth weights, is affected by the nutrient availability to the dam. The heaviest birth weights in 1979 are attributable to the availability of good pastures throughout the year, while the poor availability of pasture in 1983 is responsible for the lowest birth weights observed (NAHRS-Annual Reports, 1979; 1981). Thus birth weights at NSS can be increased through improved feeding of dam during 3rd trimester.

4.3.2.2 Parity

Parity of dam had a highly significant ($p<.01$) effect on birth weight. This is in agreement with results reported in the Sahiwal breed (Bhat and Chandramohan 1982; Mwandotto, 1985). There was an improvement in birth weight from 1st to 4th parity followed by a decline in the parities beyond 4th parity. Effect of parity on birth weight is mediated through changes in the size of the dam, ability of the dam to provide nutrient to the developing foetus and any permanent functional development in the dam that affect the pre-natal growth of the calf (Koch and Clark, 1955; Elzo *et al*, 1987). On the basis of this explanation the maternal environment in relation to parity of dam is the limiting factor. The dams in 1st to 3rd parity have to provide for their own growth, growth of the foetus, lactation and maintenance. For cows beyond 4th parity, due to the advancing age, they are heavier and produce higher amounts of milk which causes them to have higher nutrient requirements for lactation and maintenance in competition with nutrient requirement for foetus growth. However, under extensive grazing management older cows experience breakdown in body constitution (Sacker *et al*.,1971). Thus there could be breakdown in the body constitution of older cows which curtails their ability to graze enough so as to provide a suitable nutritional prenatal environment for foetal growth.

It is known that survival rates of calves of young dams and of dams beyond 4th parity are lower during the early pre-weaning stage at NSS (NAHRS-Annual, 1983). Mortality of affected calves has been claimed to be associated with light birth weights (NAHRS-Annual Reports, 1980; 1982).In order to reduce the calf loss through mortality, the managers at NSS could have two alternative approaches. One approach would be to introduce a supplementary feeding system of calves, which increase the vigour of calves during the pre-weaning period, from the dams in the affected category. The other approach would be to introduce prophylactic treatment of calves in the affected category. To minimize possible development of drug resistance high standards of hygiene should always be observed by the personnel during feeding and handling of calves while unnecessary use of drugs should be avoided.

4.3.2.3 Season of Birth

Season of birth had no significant (p>.05) influence on birth weight. However, the calves born during the short rainy season (October-November) had heaviest birth weights while those born in the long rainy season (March-May) had the lightest birth weights. Dams calving in the short rainy season will have conceived in either February or March and their late stages of pregnancy coincide with the period when there is high availability of good quality pastures, resulting from the long rainy season. Dams calving in long rainy season have most of their pregnancy coinciding with the period when there is relatively low availability of good quality pasture. The availability of good quality pastures to pregnant dams generally result in the heavier birth weights of calves and vice-versa.

These results imply that seasonal breeding practices which ensures that all dams calve in the short rainy season would ensure heavier birth weights of calves in addition (as has been discussed in section 4.1.2.3) to higher milk yield. However, due to the low repeatability of seasonal rainfall (in amount and distribution) at Naivasha it would be risky to attempt seasonal breeding. The present practice of breeding throughout the year should be continued.

4.3.2.4 Sex of Calf

Sex of calf had a highly significant ($p<.01$) influence on birth weight. Male calves were heavier than female calves. Bell *et al* (1970) has reported that the rate of synthesis of protein and other organic matter is faster in the males under androgen influence than for females which are predominantly under the influence of oestrogen. This indicates that difference in birth weights of the two sexes is largely a reflection of hormonal differences between the sexes during pre-natal growth. Furthermore, the physiological basis of effect of sex is such that differences in birth weights could be enhanced by improved feeding of dams (Harricharan *et al*, 1976). The implication is that correction for the effect of sex should be done in any comparison of birth weights.

4.4 Age at 55 kg Liveweight

4.4.1 Means and Variations

The mean age at 55 kg liveweight (AGE55) was estimated at 97.8±0.7 days. This is lower than that reported by Mwandotto (1985). The difference is partly attributable to the edit criteria used in data preparation in this study (section 3.4) compared to the previous work. There is no selection for age at 55kg liveweight at NSS. The high variation (Table 7) in AGE55 is a reflection of the effect of changes in feeding and management of calves.

4.4.2 Factors Affecting Age at 55kg Liveweight

4.4.2.1 Year of Birth

Year of birth had a highly significant ($p<.01$) effect on AGE55. There was gradual decline in growth performance of calves in the period before 1970, followed by rapid decline in the years after 1970. In 1970 the old calf feeding scheme was replaced by the new scheme which is currently in operation at NSS (as discussed in section 3.2). It is at this time when the transition in the least squares constants estimates occur. This indicates that the yearly fluctuation in the growth performance of the calf in the interval between birth and 55 kg liveweight is largely a reflection of the feeding and management factors. Furthermore, the genetic changes of AGE55 may be negligible as there was no selection for growth performance of calves or dams on the basis of AGE55.

The decline in growth performance of calves with respect to AGE55 over the whole period (1964-1983) covered in this study could be interpreted to be the result of the inadequacy of the calf feed offered at the stud to meet the nutritive requirements for growth of calves in the interval from birth to 55 kg liveweight. Therefore, a re-examination of the calf feeding and its associated management system should be done with the aim of modifying it or replacing it with a better system to improve the growth performance of calves.

4.4.2.2 <u>Season of Birth</u>

Season of birth had a highly significant ($p<.01$) effect on AGE55. This is in agreement the results reported by Mwandotto (1985). The growth performance, as indicated by the high value of AGE55 (Table 9) of calves born in the short rainy season, which were heaviest at birth, was poorer than those born in the other seasons. However, heavy calves are known to be more active and sensitive to the environment and therefore need more feed per unit gain. This, therefore, may explain why lighter calves born in the long rainy season and the rest of the year reached 55 kg liveweight earlier than the heavy calves born in the short rainy season. A feeding regime which will provide adequate nutrients for growth requirements of different weight categories of calves should be developed at the NSS.

4.4.3.1 Parity

Parity had a significant ($p<.05$) influence on AGE55. This result contradict those results reported by Mwandotto (1985). The difference in results is attributable to the models of analyses used. There was a general decline in growth performance of calves from 1st to 3rd parity followed by an improvement in growth performance of calves of the dams beyond 4th parity as indicated by AGE55 (Table 9). These trends are a reflection of those of birth weights as discussed in section 4.3.2.2 because birth weight forms part of the 55kg liveweight.

4.4.2.4 Sex of Calf

Sex of calf had a highly significant ($p<.01$) effect on AGE55. Male calves had better growth performance than female calves as indicated by the AGE55. These results are similar to those reported by Mwandotto (1985). The above observations, however, can be interpreted to be the result of the high birth weights of male calves in addition to their fast growth. Therefore, correction should be made for effect of sex when comparing maternal performance of dams with respect to AGE55.

4.5 Genetic Parameters and Trends

Estimates of repeatability and heritability along with the annual changes in phenotypic, genetic and environmental components for the four traits in this study are presented in Table 10. The graphical representation of the trends in these traits are shown in Figures 2, 3, 4, and 5 ,respectively. It should be noted that there was no selection programme in operation at NSS over the period 1964-1968. This caused animals of poor genetic merit to be retained in the herd.

In a closed cattle herd (population) in which generations overlap the improvement in the genetic component, of any particular trait, in successive years resulting from a single year of selection is not constant, for the genes from a group of selected individuals may take many years to pass (or spread) through the herd (population). The initial response occurs after a duration equivalent to one generation interval and is erratic but with passage of time it eventually approaches an equilbrium (or asymptotic) value, which represents the permanent change in the genetic component resulting from selection (Hill,1971). The equilbrium value is as a result of the diminishing genetic superiority of the individual descendant which is compensated by an increase in the numbers of them exhibiting response. Using this assumption Hill(1971) proved that the estimate of annual genetic progress in the British dairy cattle was not significantly different from the estimate of annual genetic progress got by regresion of response to selection on time (generation interval in years). The method used in estimating the annual change in the genetic components in this study (section 3.5) is based on the latter assumption. Thus difference between the average phenotypic values and the genetic component (estimated from average breeding values) in a given year is assumed to represent the environmental component which is, in fact, made up of non-additive genetic effects, permanent environmental and temporary environmental effects whose relative proportions are dependent on the trait under consideration.

4.5.1 Milk Yield

4.5.1.1 Genetic Parameters

The heritability estimate (0.27 ± 0.06) for milk yield in this study is within the range reported for the other tropical cattle (Table 2) and is comparable to those reported in the temperate dairy cattle (Barker and Robertson, 1966; Cunningham, 1972). The similarity in the estimates of heritability found in this study to those reported in the other breeds of diverse origin imply that methods of selection for high milk yield proven to be highly efficient in the other breeds elsewhere could be used successfully for the genetic improvement of milk yield in the Sahiwals at NSS. The magnitude of the heritability estimate found in this study tends to suggest that selection for milk yield at NSS would result in appreciable genetic improvement.

The repeatability estimate (0.46 ± 0.02) is within the range of estimates reported in other tropical cattle (Table 2). The magnitude of the repeatability estimate is an indication that selection for milk yield in the NSS herd could be based on the first lactation records which has the advantage of reducing the generation interval in the selection programme.

On the basis of the magnitudes of heritability and repeatability estimates for milk yield , it can be deduced that the temporary environmental effects are responsible for 54% of the phenotypic variance in the milk yield of Sahiwal cattle while the non-additive genetic effects together with the permanent environmental effects are responsible for 19%. The temporary environmental effects can be altered by short-term interventions through manipulation of the feeding and management of the herd. From studies of the crossbreeding of cattle for milk production it has been established that the non-additive genetic effects on milk yield are negligible (Gregory and Trail, 1981a; Trail and Gregory, 1981). On this assumption then, 19% of the total phenotypic variance in milk yield is attributable to the permanent environmental effects.

The permanent environmental effects are caused by (permanent) differences in the anatomical, physiological and physical constitution of an animal. The permanent environmental effects in the Sahiwal cows at NSS could largely be associated with the high frequency of cows having non-functional quarters of the udder caused by mastitis and injury.

4.5.1.2 Genetic and Environmental Trends

The estimated annual changes in the phenotypic, genetic and environmental components for milk yield were - 11.56±5.3, 3.87±0.64 and - 15.42±5.0 kg per year (Table 10). The estimated annual genetic change of 3.87±0.64 kg represent a genetic progress of 0.28% per year of the base year (1964) herd average of 1396 kg, whereas Kimenye (1978) reported an expected genetic progress of 2.5% of the overall herd average in the 1963-1971 period. Because the magnitudes of the selection intensity, heritability, and phenotypic variance used by Kimenye (1978) are very similar to those in this study, it would be safe to assume that the expected genetic progress of 2.5% of the overall herd average in the base year (1964) is still valid, and that inefficient selection methods and procedures may be responsible for the very low value of 0.28%.

Six possible reasons can be advanced to explain why the estimated genetic progress was much lower than the expected progress. First the period 1964-1968, when no selection was practised so as to allow the herd to build up, was included in this study. Thus the animals with low genetic merit were retained. This caused a decrease in the genetic component values over that period. Secondly, the realized intensity of selection for milk yield was lower than the expected because of selection on many traits, for instance the selection of bulls on basis of weight at two years of age, selection against cows with fertility problems, and the breed "label" characteristics selected for in the test bulls.

Thirdly, the proportion of the cow herd used in progeny testing of bulls is small and this has often resulted in low accuracy in sire evaluation because most sires have low number of effective daughters (often less than 15). Fourthly, the level of feeding

Figure 2: The Phenotypic, Genetic and Environmental trends of 305-day Milk Yield

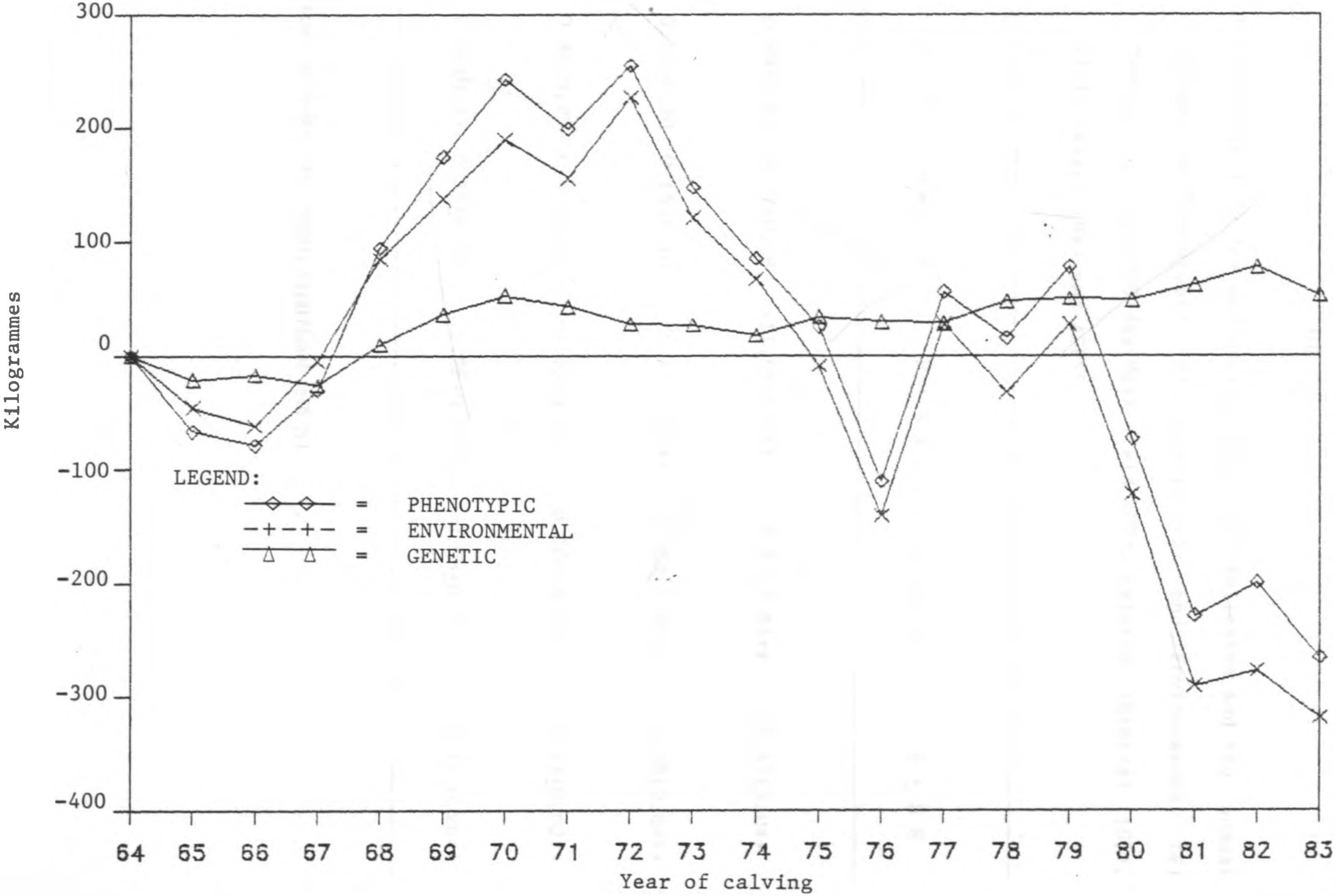


Table 10: Repeatability (r) and Heritability (h^2) Estimates and the Annual Change in Phenotypic (P), Genetic (G) and Environmental (E) Trends for the 305-day Milk Yield (MY), Calving Interval (CI), Birth Weight (BW) and AGE55.

Trait	r ± S E	h^2 ± S E	P ± S E	G ± S E	E ± S E
MY	0.46±0.02	0.27±0.06	-11.56±5.3**	3.87±0.64**	-15.42±5.0**
CI	0.39±0.20	0.15±0.10	2.43±0.63**	-0.23±0.03**	2.65±0.64**
BW	0.48±0.05	0.40±0.07	-0.02±0.02	0.004±0.003	-0.03±0.02**
AGE55	0.46±0.03	0.35±0.05	5.26±0.25**	-0.05±0.04	5.31±0.26**

* = Significant ($p < 0.05$); ** = Highly significant ($p < 0.01$)

and management of animals at various stages from calfhood to maturity has been declining over the last half of the period covered in this study causing low growth rates in animals at NSS (NAHRS-Annual Report, 1983). The low growth rates generally result in late age at puberty and hence late age at first calving. This may partly be the cause of the overall increase in generation interval at NSS from 6.5 to 9 years over the period covered in this study.

Fifthly, because of the small closed herd at NSS drift in the genetic component is expected as a result of random sampling of genes because of the small herd size. which that at NSS a rapid increase in inbreeding level would generally be expected over the first few generations. The increase in inbreeding levels is known to adversely affect traits related to reproductive efficiency and viability which result in longer generation interval and reduction of selection intensity, respectively (Williamson and Payne, 1978). Sixthly, and more importantly, although in this study the genetic progress per year is assumed to be linear the initial response is usually erratic as genes from selected individuals become distributed through the population in herd undergoing selection with overlapping generations such as the NSS (Hill, 1971). Therefore, in the breeding programme at NSS an individual bull selected at any one time from a team of candidate bulls make no effective contribution to the genetic improvement for the period spanning one generation interval (6.5 to 9 years) and a contribution thereafter whose magnitude depend on the intensity of use of that bull in the herd and the number of its descendants exhibiting response.

For further genetic improvement of the milk yield in the Sahiwals at NSS in future, selection criterion should be based on milk yield and liveweight of bulls at two years of age. In addition the practice of screening and treatment or culling of cows with fertility problems should followed strictly. This would result in a higher realized intensity of selection of milk yield than that currently being achieved. The mean generation interval should be reduced to less than 6 years, through improvement in the feeding and management. This would lead to attainment of puberty at early age and hence earlier breeding age in heifers and bulls. In addition, improvement of the feeding of lactating cows should be done to achieve higher postpartum fertility, which would reduce the average age of the bull dams. The contemporary comparison procedures currently used in sire evaluation at NSS should be replaced by best linear unbiased prediction (B L U P) procedures as has been recommended by Rege and Mosi (1988).

Phenotypic, genetic and environmental trends are presented graphically in Figure 2. The magnitude and direction of the phenotypic trend in milk yield are largely a reflection of the environmental trend. All the annual averages of phenotypic values over the 1964-1967 period are below those in 1964 (the base year). This is a reflection of the corresponding decrease in the genetic merit because there was no selection in the herd, as all animals were retained to form the foundation herd of NSS and in the environmental component, mostly due to low availability of pasture. Most of the pasture was not open for grazing because it was covered by bush (NAHRS-Annual Report,1967).

In the 1968-1973 period there was, generally, a positive trend in the environmental (and phenotypic) component of milk production. It is during this period that the management of the herd was of high standard. There was adequate pasture throughout the period, and the grazing in the dry months was supplemented with high quality fodder produced within the station. Besides, a programme of supplementation of cows achieving higher milk yield than average was in operation and the feed used was a high energy, protein and phosphorus ration (NAHRS-Annual Reports, 1968; 1970; 1972; 1973). Furthermore there was positive genetic trend, resulting from selection which had commenced in 1968.

Although most of the genetic component values remained at the level of those in 1973 (Figure 2), there was a drought which affected the Sahiwal herd at NSS in the 1974-1976 period (NAHRS-Annual Reports, 1974; 1976). The drought caused a reduction in the availability of pastures which led to a drastic decline in the trend of the environmental (and phenotypic) components in milk production.

In the 1977-1979 period there was a general improvement in both the genetic and environmental (and phenotypic) component over and above that in the previous period (1974-1976). A slight decrease in the environmental component is attributable to the poor distribution of rainfall which led to low availability of pastures (NAHRS-Annual Reports, 1978; 1979). Over the 1980-1983 period there was competition for pastures by sheep and goats which were introduced into the station both for experiments and for production of breeding stock for farmers. There were not enough shrubs nor bush for the goats thereby increasing the competition for grass. Sheep caused damage through their low grazing habit which reduced re-growth of pastures (NAHRS-Annual Reports, 1980; 1981; 1982; 1983). This explains why there is a drastic decline in trends of the environmental (and phenotypic) components, although the animals were of higher genetic merit having been steadily selected for milk production over the years before 1980.

On the basis of these observations, it would be advisable to improve the management and feeding system at NSS so as to match the improvement in the genetic merit so far achieved in Sahiwals at NSS. This is supported by the fact that high levels of feeding and management which were in operation in the period 1969-1973 resulted in positive trends in environmental (and phenotypic) components.

4.5.2 Calving interval

4.5.2.1 Genetic Parameters

The heritability estimate (0.15 ± 0.10) is within the range of values reported before in tropical cattle (Alim, 1960; Mahadevan 1966; Kimenye, 1978) but is not significant (P>.05). It would, therefore, be difficult to genetically improve this trait through selection in the purebred Sahiwal herd at the NSS.

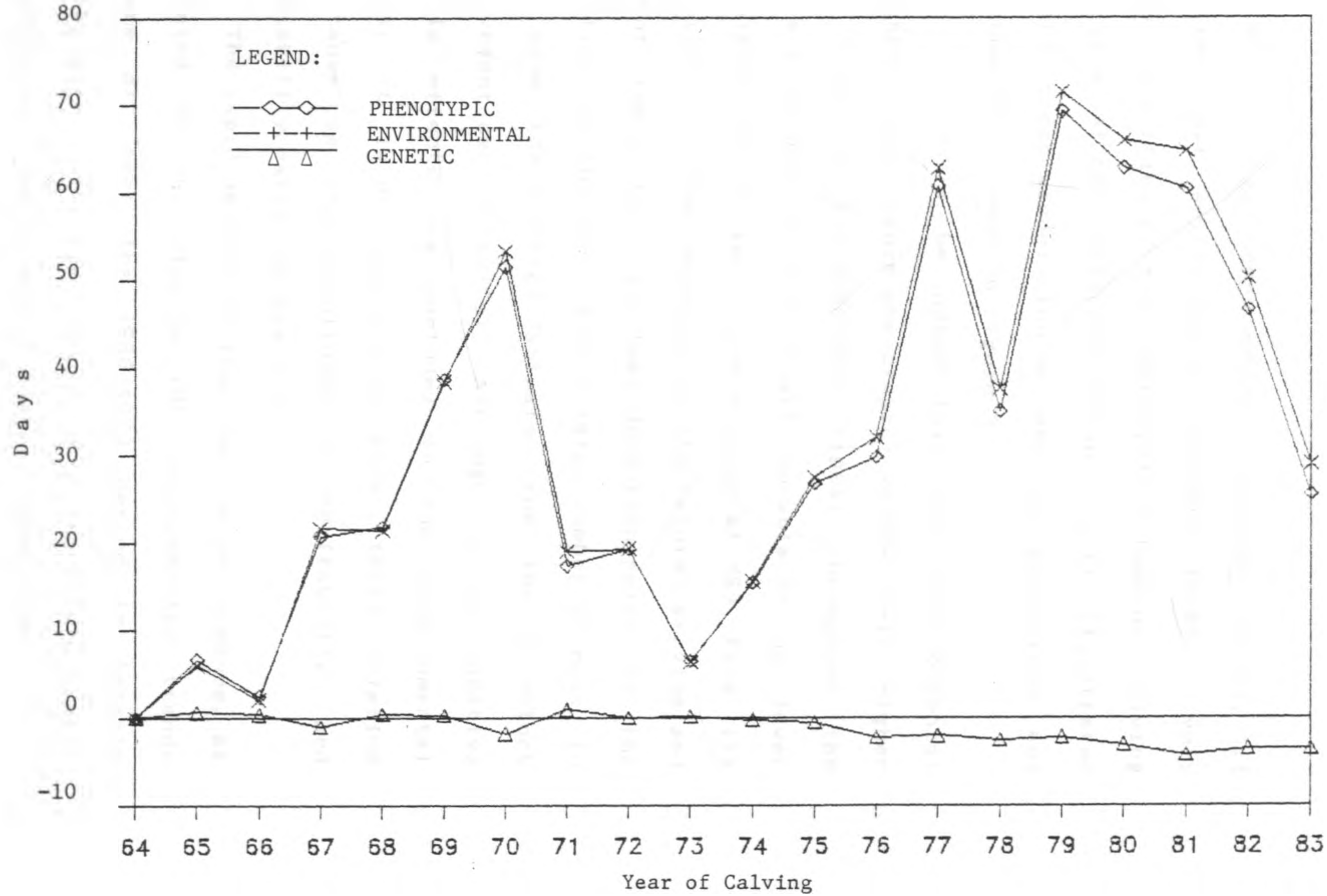
The repeatability estimate (0.39 ± 0.2) found in this study is not significantly (P>.05) different from zero. This indicates that selection for shorter calving intervals basing on the first calving intervals would be unreliable. In general, calving interval and other traits associated with reproduction, have both very low heritability and repeatability. This means that temporary environment is an important component in the variation of these traits. Thus calving interval can be shortened through improved feeding and general management.

4.5.2.2 Genetic and Environmental Trends

The estimated average annual phenotypic, genetic and environmental change in calving interval were 2.48±0.63, -0.23±0.03 and 2.65±0.64 days, respectively, and all the trends were highly significant (P<.01). Although the breeding programme indicates that intense screening and culling against long calving intervals was started in 1974 (NAHRS-Annual Reports, 1974; 1978; 1980; 1981; 1982), direct response to this selection may have contributed very little to the highly significant improvement in reproductive performance as indicated by negative genetic trend in calving interval (Figure 3). This is because all traits related to reproductive performance have, generally, very low heritability estimates (Mahadevan,1966). However, Kimenye (1978) has reported a negative genetic correlation (-0.32±0.07) between milk yield and calving interval. Therefore, the improvement in the reproductive performance as indicated by the negative genetic trends in calving interval since 1974 may be attributable to correlated response to selection for milk yield.

The positive correlation (r = 0.98±0.02) between the phenotypic values and the environmental component values over years, for the calving intervals in this study was highly significant (P<0.01). Although the magnitude of the above mentioned correlation is partly attributable to the part-whole relationship involving

Figure 3: The Genetic, Phenotypic and Environmental Trends of Calving Interval.



the environmental component and phenotypic values, it confirms that environmental component forms a very large proportion of the phenotypic values of calving intervals at NSS. This phenomenon is well illustrated by the close association between the phenotypic and environmental trends in Figure 3.

It should be noted that the environmental component (and hence phenotypic) values were higher than those in the base year (1964) throughout the entire study period. This is attributable to the lower efficiency of AI techniques adopted at NSS from its inception (in 1964) compared to the natural service and use of teaser bulls for heat detection prior to the formation of the NSS. Also a large number of cows in 1964 were the selected Sahiwals from the livestock improvement centres (LICs). Although the non-additive genetic effects are included in the environmental trends, it is not possible to know their relative importance as the magnitudes of heritability and repeatability estimates are low.

The rapid decline in reproductive performance, as indicated by the rise in the environmental trends (Figure 3), over the 1968-1970 period is largely attributable to the low efficiency of the inexperienced AI technicians (NAHRS-Annual Report, 1968; 1969, 1970). Improvement in the reproductive performance over the 1971-1973 period, as indicated by the decline in the environmental trends (Figure 3) is largely attributable to the levels of feeding and management. Availability of feed was good throughout, as there were enough pasture and fodder (lucerne hay and Napier grass). In addition, there was supplementation of cows with dairy meal concentrate high in energy, protein and mineral constituents (NAHRS-Annual Reports. 1970; 1972; 1973).

The increase in the environmental component during the 1974-1978 period may be largely a reflection of the low availability of pastures due to drought conditions as explained in section 4.3.1. However, over the 1979-1983 period managers at NSS were strict regarding the efficiency of AI technicians and heat detection was improved by training the herdsmen to assist the AI technicians. In addition, there was intense selection against long calving intervals (NAHRS-Annual Reports, 1979; 1980; 1981; 1982), hence animals of good genetic merit with respect to reproductive performance were retained as shown by the genetic trends (Figure 3).

It can, therefore, be suggested that reproductive performance in Sahiwals at NSS can be improved through increased levels of feeding and management as was done in the period 1970-1973; and that closer attention be given to AI service and heat detection.

4.5.3 Birth Weight

4.5.3.1 Genetic Parameters

The repeatability estimate 0.48 ± 0.05 is higher than those reported in temperate beef cattle (Dalton, 1980) and in African beef cattle under range conditions (Trail *et al.*, 1971; Thorpe *et al.*, 1980). These differences are probably due to differences in the methods of analysis used. However, the magnitude of the repeatability estimate in this study shows that dams can be selected for maternal performance, with respect to birth weight, on the basis of records of their first calves.

The heritability estimate 0.40 ± 0.07 is generally higher than those reported by other workers (Everret and Magee, 1965; Brown and Galvez, 1969; Koch, 1972; Arnason and Kassa-Mersha, 1987). These differences could be due to differences in the breeds, locality and the methods of analysis used. However, the heritability estimate found in this study, shows that genetic improvement in maternal performance, with respect to birth weight, could be achieved through selection of dams which calve down to heavy calves at birth.

It can also be deduced from the magnitudes of repeatability and heritability estimates that the permanent environmental and the non-additive genetic effects jointly account for 8% of the phenotypic variance of birth weights. Therefore, temporary environmental effects form the largest proportion of the total of the environmental effects in birth weights.

4.5.3.2 Genetic and Environmental Trends

The annual changes in the phenotypic, genetic and environmental components were - 0.02 ± 0.02, 0.004 ± 0.003 and - 0.03 ± 0.02 kg, respectively. Only the environmental trend was highly significant (p<.01). Although birth weight was found to be moderately heritable in this study,the annual change in the genetic component was positive and of very low magnitude. These results are as expected since there is no selection of dams on the basis of birth weights of their calves.

The selection index currently used at NSS incorporates the weight of the test bulls at 2 years of age. Basing on the breeding plan (Figure 1) the selection intensity of bulls is 1.3. It is expected that the genetic component for birth weights, as trait of the calf,should benefit from a correlated response to the selection index due to the genetic correlation between birth and weight at 2 years (Sacker *et al.*, 1971; Taneja *et al.*, 1980). Koch,(1972) has reported that there is negative genetic correlation between maternal additive genetic effects and the direct additive effects in birth weight . Thus the overall positive genetic trend cannot be as a result of culling calves for birth weights less than 18 kg in the period

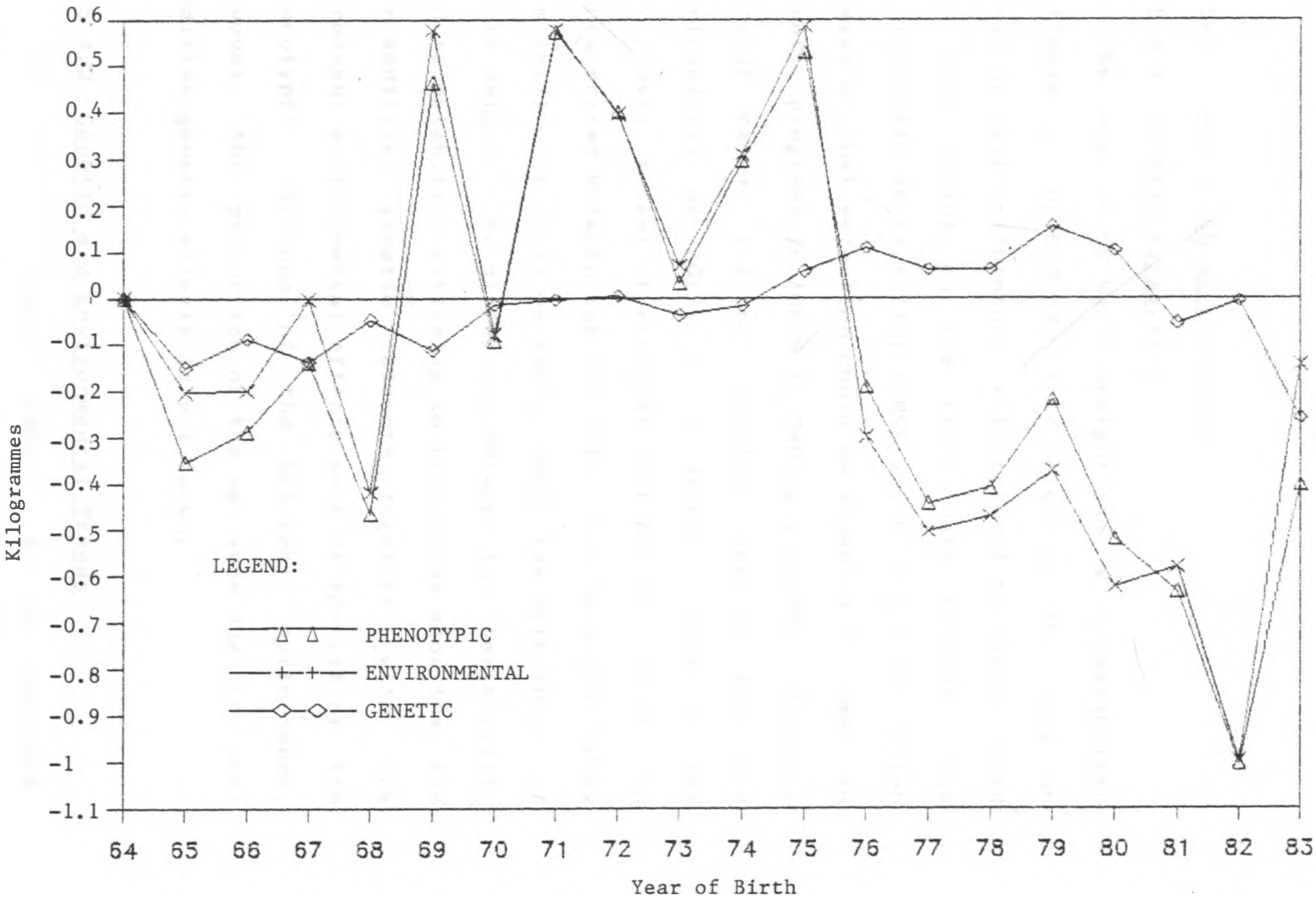
1968-1978 (NAHRS-Annual Reports, 1969; 1972; 1978). From the trends of genetic component in Figure 4, however, it appears that the relationship is positive and small. There is need, therefore, to investigate this relationship further in order to get a clear explanation of the observed trends of the genetic component of birth weights over the period covered in this study.

The annual changes for the phenotypic and environmental component values were similar in magnitude. This is confirmed by their highly significant ($p<.01$) correlation ($r=0.98\pm0.1$) also illustrated by the close association of the trends of environmental and phenotypic values (Figure 4). These observations show that the phenotypic trend is largely a reflection of the environmental trend.

In this study 60% of the phenotypic variance for birth weights was due to the temporary environmental effects. It is, therefore, possible to associate the significant environmental trend with several sources of environmental change. The four possible reasons why the environmental trend was negative and highly significant ($P<0.01$) can be identified. First, the records in the 1964-1968 period were made by a predominantly large number of cows in parities beyond 4th lactation. This group of cows have been associated with smaller calves at birth (Section 4.2.3). Secondly, the cows calving in 1970 were predominantly those in parities below 3rd lactation. This group of young cows were associated with lighter birth weight in this study (Section 4.2.3). Thirdly, the year 1973 had low availability of pastures as there was low rainfall and this may have affected the performance of the dams thus resulting in smaller calves being born in that year (NAHRS-Annual Report, 1973). Fourthly, in the period 1976-1982 the drastic drop in the environmental trend could be associated with the residual effects of the very dry years in the previous period (1974-1976). One of the possible residual effects was the shortened longevity of cows in the herd and hence most of the calves were of young dams associated with lighter calves (Section 4.2.3). In addition, there was low availability of pasture caused by the increased stocking rate on the pastures at NSS (NAHRS-Annual Reports, 1974; 1978; 1983). The low availability of feed nutrients to the pregnant dams may have depressed the birth weights.

The environmental component values can be improved through high levels of feeding and management. This is confirmed by the performance observed under good pastures, supplementation of dry season grazing with fodder and supplementation of high yielding dams as was possible in the years 1969, 1972 and 1974 (NAHRS-Annual Reports, 1969; 1972; 1974). Low stocking density and planned rotational grazing on pastures as was done in 1983 could be another way of improving the environmental component (NAHRS-Annual Reports, 1983).

Figure 4: The Phenotypic, Genetic and Environmental Trends of Birth Weight.



4.5.4 Age at 55 kg Liveweight

4.5.4.1 Genetic Parameters

The age at 55 kg liveweight had a repeatability estimate of 0.46±0.03. Thus selection for dams on basis of calf performance, with respect to AGE55, could be done basing on the first calf records. The heritability estimate for AGE55 was 0.35 ± 0.05, which suggests that selection could be expected to lead to genetic progress in AGE55 in Sahiwals at NSS. However, because calves are not suckled repeatability and heritability of AGE55 is a direct result of the carry-over effect of prenatal uterine environment and genes shared between dam and calf. This is supported by similarity of these parameter estimates with those of birth weight. The difference between the heritability and repeatability estimates in this study show that the non-additive genetic effects together with the permanent environmental effects account for 11% of the phenotypic variance of the maternal performance. However, the proportion of the variance due to non-additive genetic effects is not known.

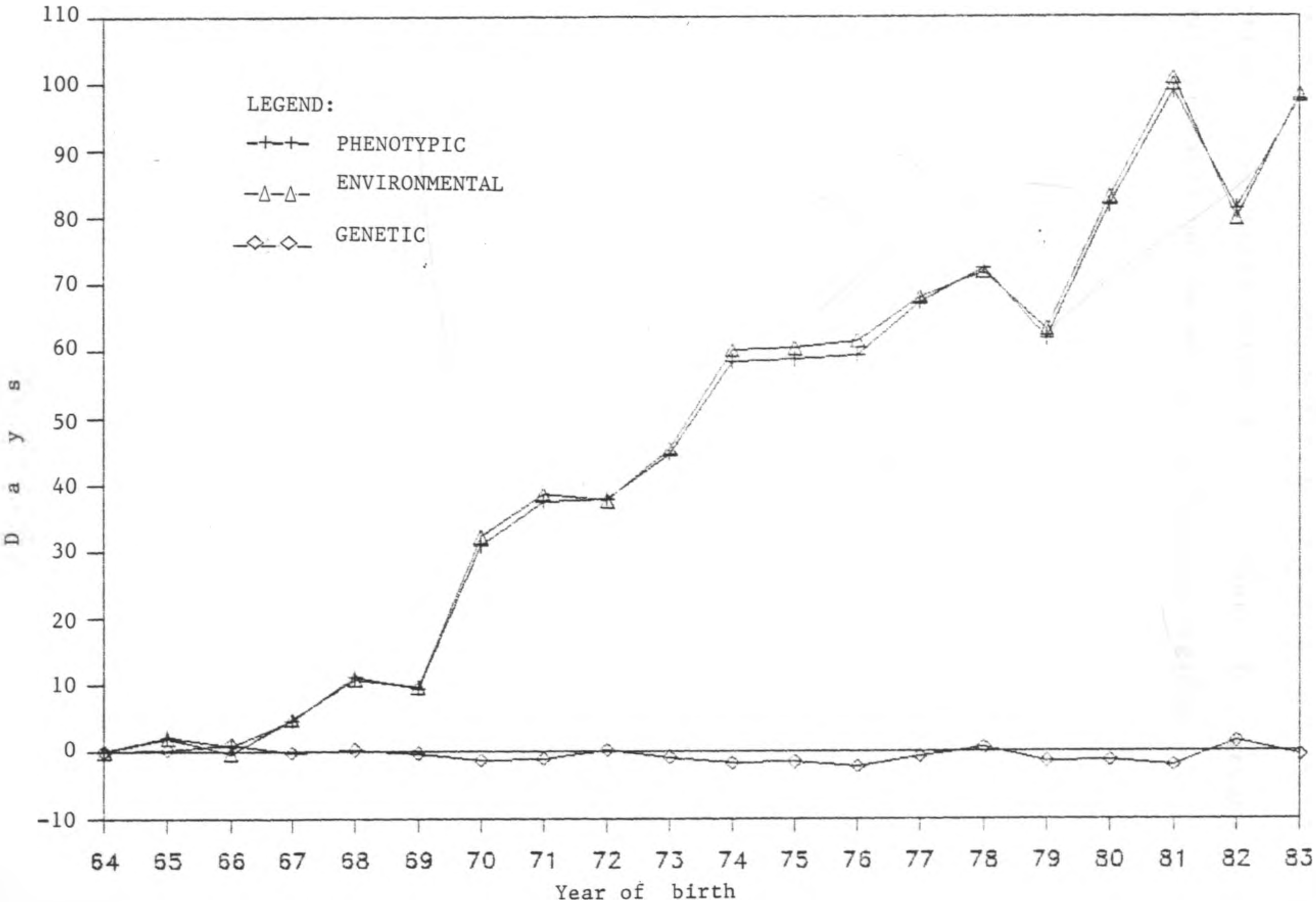
4.5.4.2 Genetic and Environmental Trends

The annual phenotypic, genetic, and environmental changes in AGE55 were 5.26±0.25, -0.05±0.04 and 5.31±0.26 days, respectively and were highly significant ($p<.01$) except the genetic component which was not significant ($p>.05$). This was expected since there was no selection for AGE55. The yearly fluctuation of the genetic component has very low amplitude about the baseline (1964). The cause of the fluctuation cannot be explained since the genetic relationships between this trait and the other traits selected for in the Sahiwal at NSS(milk yield, weight at two years of age, and calving interval) are not known.

The phenotypic values were found to have a highly significant correlation ($r=0.99\pm0.01$) with the environmental component over the years, while the genetic trend was virtually zero (Figure 5). This relationship implies that the phenotypic trend for AGE55 is mainly due to the environmental trend. Under the calf feeding system at Naivasha, where calves are not suckled throughout their pre-weaning period, the contribution of the dam to AGE55 negligible. Therefore environmental component values of AGE55 are largely affected by the diet provided at pre-weaning stage.

Over the period covered in this study the environmental component values indicate that the growth performance in the interval from birth to 55 kg liveweight deteriorated gradually before 1970 and rapidly thereafter. This shows that the two feeding regimes for calves did not meet the nutritive requirements of growth of the calves. Furthermore, the culling of smaller calves at birth left heavier and

Figure 5: The Phenptypic, Genetic and Environmental Trends in the age at 55 kg Liveweight.



active calves whose nutrient requirements for growth could probably not be met by the feeding regimes.

5.0 CONCLUSIONS

The following conclusions can be drawn from this study:-

(a) Sahiwals under extensive production systems as at NSS, Naivasha are able to produce 1662 kg of milk in a lactation of 305-day milk yield without calf at foot. Besides this production, it is able to produce a calf of about 23 kg birth weight every 426 days which attain a liveweight of 55 kg at 98 days of age.

(b) Correction of data for year of birth or calving, collected over different years, is recommended while an all-year-round calving should be encouraged at NSS. Data, collected on cows in different parities, should be corrected for parity while pre-weaning weight or growth data should be corrected for sex. The relationship between sex of calf and calving interval of dam should be investigated further especially with respect to current and previous calf.

(c) Repeatability and heritability values suggested that genetic improvement of milk yield, birth weight AGE55 and calving interval could be achieved through improvement in feeding and management.

(d) The temporary environmental effects were, as expected, largely responsible for a large proportion of the phenotypic values observed in this study. Thus the phenotypic (and environmental) trends were largely a reflection of variation in climatic conditions Therefore, the need to improve the environment through better feeding and management of the animals at NSS is imperative. In future studies emphasis should be on nutrition and feeding of the Sahiwal cattle at NSS.

(e) The low annual genetic change in milk yield, suggested low efficiency of the animal evaluation procedures used at NSS. This procedure should be replaced by more accurate procedures of such as the best linear unbiased prediction (BLUP) procedures. To increase genetic progress and maintain the Sahiwal as a dual purpose cattle breed there should be emphasis on selection for milk yield and growth. Although there were little annual genetic changes in birth weight and AGE55 there is need to investigate the correlation between these two traits and the other traits included in the selection criteria.

(f) The greater milking capacity and the general adaptability to extensive husbandry conditions makes NSS the most suitable source of the Sahiwal dam breed in crossbreeding with *Bos taurus* breeds in the arid and semi-arid lands (ASAL). For the NSS to continue to play a leading role as source of seedstock in future the herd should be, opened so that genetic resources of other Sahiwal herds not closely related to the current herd at Naivasha will be incorporated to form a wider genetic base. In addition, the NSS herd should be expanded while private breeders should be given incentives to start and/or expand their herds which will provide enough test cows for accurate evaluation of bulls as well as meeting the local and export demand. The opening and expansion of the Sahiwal herd at NSS, if done simultaneously, will ensure a lower rate of inbreeding in the future herd than what is attainable in the current herd.

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