REPRODUCTIVE EFFICIENCY TRAITS AND VIABILITY OF CALVES OF MPWAPWA CATTLE AND THEIR CROSSES

BY

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DECLARATION

I, SHOSHINDER SACHINDRA MANMOHAN DAS, hereby delcare that the work presented in this dissertation is original and has not been submitted for a degree in any other University.

Signature : ....

Date : ..11/6/88.....

DEDICATED

to

Soluchna, Siddu and Shivani who sacrificed their happy days during the study.

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ABSTRACT

Fifteen years data on reproductive traits and viability of calves were analysed. Data were collected from cattle records at Livestock Production Research Institute, Mpwapwa, in Central Tanzania. The reproductive traits studied were age at first calving, calving interval (CI), dry period (DP), days open and conception rate (CR).. The genetic groups in the study were Mpwapwa, F_1-crossline and Backcross having 8.0%, 54.0% and 31.0% Bos taurus genetic proportion, respectively. The objectives of the study were to evaluate the influence of genetic and environmental factors on reproductive traits and viability of calves, to estimate repeatabilities for reproductive efficiency traits (CI, DP and days open) and to evaluate the relationship between reproductive traits and milk production traits.

Overall mean age at calving of all the heifers in the study was 1251.63 $\pm$ 10.84. For Mpwapwa, F_1-crossline and Backcross heifers, mean ages at first calving were 1317.12 $\pm$ 14.21, 1137.06 $\pm$ 27.01 and 1224.31 $\pm$ 16.48 days, respectively. Year of birth and genetic group significantly ($P < 0.001$) influenced age at first calving. Age at first calving significant ($P < 0.01$) influenced lactation milk yield and lactation length pooled over the first five parities. Correlation coefficients between age at first calving and CI, DP and days open pooled over for first five parities were 0.09, 0.08 and 0.08, respectively.

Overall mean CI, DP and days open for Mpwapwa cattle and their crosses was 427.92 $\pm$ 4.38, 148.35 $\pm$ 4.76 and 153.39 $\pm$ 4.78 days,

respectively. Mean CI, DP and days open were for 371 Mpwapwa cows 446.45 $\pm$ 6.77, 172.46 $\pm$ 7.18 and 167.33 $\pm$ 7.59 days, respectively; for 191 F_1-crossline cows, 413.09 $\pm$ 7.05, 117.08 $\pm$ 7.28 and 132.88 $\pm$ 7.06 days, respectively; for 142 Backcross cows, 399.41 $\pm$ 7.57, 127.42 $\pm$ 9.38 and 118.43 $\pm$ 7.51 days, respectively. Overall mean CR was 53.89%. For 3907 Mpwapwa, 975 F_1-crossline and 845 Backcross heifers and cows, mean CRs were 52.83%, 56.21% and 56.0% respectively. Year of calving and genetic group significantly ($P < 0.001$) influenced CI, DP and days open, while season of calving age of cow and parity did not significantly ($P > 0.05$) influence CI, DP and days open. Conception rate was significantly influenced by year of mating ($P < 0.01$)m type of mating ($P < 0.01$), age ($P < 0.05$) and weight ($P < 0.001$) at mating, while the influences of genetic group and season of mating were not significant ($P > 0.05$).

Pooled data for first five parities showed that CI significantly ($P < 0.05$) influenced subsequent lactation milk yield ($b = 0.42 \pm 0.16$) subsequent lactation length ($b = 0.45 \pm 0.07$) and concurrent lactation milk yield ($b = 0.46 \pm 0.08$), while the influence on concurrent lactation length ($b = 0.22 \pm 0.01$) was not significant ($P > 0.05$). Dry period did not influenced subsequent lactation milk yield ($b = - 0.26 \pm 0.08$) and lactation length ($b = - 0.22 \pm 0.06$). Days open significantly ($P < 0.05$) influenced subsequent lactation milk yield ($b = 0.32 \pm 0.14$) and lactation length ($b = 0.34 \pm 0.02$), while the influences on cocurrent lactation milk yield ($b = 0.15 \pm 0.02$) and lactation length ($b = 0.03 \pm 0.01$) were not significant ($P > 0.05$).

Overall mean viability of calves at one month old.at weaning and at one year of age was 97.14%, 93.77% and 87.28%, respectively. Year and season of birth, genetic group, sex and birth weight of calves had no significant (P > 0.05) influence on viability of calves. High standards of management practiced at the institute was attibuted to the high viability of calves.

It is recommended that further studies on other factors affecting reproductive traits and resulting in infertility of dairy cattle at Mpwapwa be conducted.

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ABBREVIATIONS

^{o}C	degrees centigrade
CI	calving interval
CR	conception rate
DP	dry period
E	East
G_1	Mpwapwa breed
G_2	F_1-crosslines
G_3	Backcrosses
kg	kilogram (s)
L.B.3	Livestock Breeding Project.Number 3
LPRI	Livestock Production Research Institute (Mpwapwa)
mm	millimetres
NO.	Number
NSC	Number of services per conception
S	South

STATISTICAL NOTATIONS

a	constant (linear regression equation)
b	regression coefficient
df	degrees of freedom
h^2	heritability
n	sample size
m	number of observations within the sample (in repeatability)
r	simple correlation coefficient
R	repeatability
R^2	coefficient of determination
S.E.	standard error
$<$	less than
$>$	more than
Significance levels:	
*	significant at $P < 0.05$
**	significant at $P<0.01$
***	significant at $P < 0.001$
NS	not significant, $P > 0.05$
X	independent variable
Y	dependent variable

INTRODUCTION

Meat, milk and other dairy products obtained from Tanzanian cattle are of great importance in the nutritional habits of the rural people. However, milk production is generally low and in order to meet the demand for milk the country imports milk and milk by-products which results in spending substantial amounts of foreign exchange.

Low productivity of milk could be attributed to a combination of several factors. Apart from low genetic potential for milk production, productivity is also affected by non genetic factors such as, year and season of calving, nutrition and management of cattle. Tanzania Shorthorn Zebu (TSZ), constituting about 98% of the cattle population in Tanzania, have frequently been described as small and late maturing with low genetic potential for milk production (Galukande et al., 1962). Selection efforts to increase milk in TSZ have resulted in little or no improvement (Getz, 1974).

Improvement of dairy cattle by breeding methods is a long time and expensive undertaking. The climate, feeding and health practices in any given environment dictate the choice of cattle types suitable for milk production. Introduction of exotic dairy cattle in some tropical areas, where heat stress, disease and poor management prevail, have not sufficiently led to increased milk production. Crossbreeding between European dairy cattle and Zebu had some advantages over purebreeding of exotic cattle in the tropics due to the relatively better adaptability of the crossbreds. Thus the crossbreds in Tanzania were observed to have increased lactation milk yield (1854.0 kg for crossbreds versus 1039.5 kg for TSZ) and reduced age at first calving (37.4 mths for crossbreds versus 39.9 mths for TSZ) compared to TSZ (Mahadaven and Hutchison, 1964).

Crossbreeding commenced at Mpwapwa as early as 1920s and a deliberate effort to form a breed was initiated in 1958 when the "composite" breed was essentially already formed (LPRI, 1985). Mpwapwa breed is a composite of breeds Sahiwal, Red Sindhi, Tanzania Shorthorn Zebu, Boran, Ankole and Ayrshire. The formation of Mpwapwa cattle was aimed at producing heat tolerant dairy cattle capable of producing high milk yields in areas where it was difficult to maintain pure Bos taurus dairy cattle (Mahadevan, 1965). In recent years, high demand of milk and other dairy products in Tanzania has necessitated the development of high milk producing crossbreds between Bos taurus dairy breeds and TSZ. This type of crossbreeding along with upgrading to Bos taurus and purebreeding of European dairy cattle are mostly practiced in state farms.

Improvement of dairy production is frequently tackled through improvement of both the genetic material and the husbandry practice. Close association between milk production and reproduction exists due to the fact that regular calving is necessary to maintain efficient milk production. High reproductive efficiency and milk production are necessary for a cow to maintain a long economically productive life. Defining adaptation as a function of survival and reproductive ability (Kiwuwa,1968) associated animal improvement with reproductive efficiency. Economic returns from milk which depend on milk yield per cow are maximised with a dry period of approximately 40 - 50 days, a calving interval of 12 - 13 months and number of days open of 80 - 100 days (Salisbury et al., 1978). Furthermore, the rate of reproduction sets an upper limit to selection intensity and thus influences the rate of genetic progress from selection (Syrstad, 1983). Genetic and phenotypic correlations between reproductive and milk production traits for Bos taurus dairy cattle have been reviewed by Phillipsson (1981). Perinatal and postnatal survival of calves in a dairy industry is as important as milk production because female calves would serve as replacement stock, whereas male calves after selection could be used as sires in the dairy herd.

Most studies on Mpwapwa cattle have so far been on evaluation of dairy performance (Kiwuwa and Kyomo, 1971; Kiwuwa, 1973; Mkonyi,1982; Msechu and Mkonyi, 1984) and growth (Msanga, 1984). Little information is available on reproductive performance and viability of calves among Mpwapwa cattle and their crosses. In view of the importance of reproductive traits and viability of calves in dairy farming, the objectives of the present study are to :

- evaluate the effects of genetic group, year, season, age at calving and parity on reproductive traits of Mpwapwa cattle and their crosses;

- estimate the effects of genetic group, year, season of birth, sex and birth weight on the viability of calves;

- estimate repeatabilities for reproductive traits; and

- evaluate the relationship between reproductive traits and milk production traits.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

Milk production, reproductive performance, survival of calves and growth rate to maturity are characters of economic importance in dairy farming (Kiwuwa, 1968). The heritability estimates of milk production traits are medium to high, ranging from 0.4 to 0.8 (Pirchner, 1969; Ahaamd *et al.*, 1974; Gur'yanova and Sokolova, 1975; Patel and Parekh, 1982). For most reproductive traits, heritability estimates are low and normally range between 0.05 and 0.2 (Davenport *et al.*, 1965; Everett *et al.*,1966; Pirchner, 1969; Dearborn *et al.*, 1973; Jonmundsson, 1981; Philipsson, 1981; Rao and Patro, 1984). The relationship between milk production traits and reproductive traits has been reported by many workers as reviewed by Philipsson (1981). The significance of these relationships, especially genetic correlations are appreciated when selection programmes are planned.

Vaccaro (1974), reviewing reports on calf mortality, observed that 40 percent or more of the temperate bred heifers born in hot climates do not survive up to first calving. The fact that the superior survival rate of native and crossbred (especially first cross) cattle in the tropics has been consistent in many reports illustrates the importance of breed choice for crossbreeding in the tropics (Ulaganathan, 1984).

The need for replacement of dairy cows which are culled from the dairy herd with young stock, demands that high survival rates of calves should be achieved. Relating calf mortality with milk production, Ngere *et al*. (1973) found that loss of the calf during lactation of Hariana cows resulted in 16.4 percent drop in milk production. In the same study the average daily yield was observed to be associated with the maternal attachment of cows to their calves since most cows dried up quickly following death of their calves.

2.1.1 Importance of reproduction in dairy production

The value of a dairy cow is more appropriately expressed on the basis of life-time production than on single lactation record (Gopal and Bhatnagar, 1969). Life time milk production is very much dependent on the reproductive performance of the cow. This is facilitated by high conception rate resulting in regular calvings. Salisbury *et al*.(1978) and Alberro (1983) observed that although economic returns from milk production depend on high milk yield per cow per day, these are maximized by high conception rate, fewer services per conception, fewer days open and shorter calving intervals. The reproductive traits are considered secondary in importance to milk production traits due to the low heritability and repeatability estimates of reproductive traits and also due to the negative relationship (Syrstad, 1983) between reproductive and milk production traits.

Selection of highly productive cows without conscious emphasis on fertility would not lead to a population with a markedly increase in ability to reproduce (Shanks *et al.*, 1978). The results from the selection study for high lactation milk yield by Shanks *et al.* (1978) showed a decline in conception rate and an increase in disease problems. Syrstad (1983) indicated that, although correlations between individual production and reproductive traits are mostly undersirable, it however, did not mean that the two groups of traits could not be improved simultaneously. Philipsson (1981) concluded that, when a population is under selection for production traits, like milk yield and growth rate, some attention to fertility is needed in order to prevent deterioration in this trait.

2.1.2 Reproductive traits

Evaluation of reproductive performance of dairy cattle has been done by many workers (for example : Danasoury and Bayoumi, 1963; Ødegard, 1965; Kiwuwa, 1968; Kidner, 1981; El-Keraby and Aboul-Ela, 1982). Wilcox *et al.* (1957) used the term "breeding efficiency" to evaluate the female reproductive performance. Breeding efficiency of a cow (Wilcox *et al.*, 1957) is obtained by using the formula :

$$\text{Breeding efficiency } \% = \frac{365 \times (N-1)}{D} \times 100$$

where N = total number of parturitions ; and

D = number of days from first parturition to last parturition. From this formula, cows with long calving intervals will tend to have lower breeding efficiency compared to cows with short calving intervals.

Everett et al. (1966) indicated that calving interval, number of services per conception and percentage of non-returns after first service were poor measures of differences in fertility levels between females. They found that these traits were mainly influenced by non-genetic factors and had low estimates of heritabilities and repeatabilities.

Heritability estimates of reproductive traits such as length of calving interval, non-return rate, conception rate to first service and number of inseminations per conceptions have been reported to be low. This has led to the conclusion that, the genetic variability of fertility is small such that selection to improve fertility is less effective (Dunbar and Henderson,1953; Legates, 1954; Collins et al., 1962; Everett et al., 1966). Wilcox et al. (1957) reported that the heritability of breeding efficiency based on length of calving interval was 0.32.

Infertility can be defined as an inability to reproduce. Deterioration of one or more reproductive traits leads to infertility. Spears et al. (1965) observed that infertility was probably second only to mastitis as a source of economic loss in dairy herds. High culling rates in dairy herds due to reproductive problems ranging from 28% to 50% have been reported by Darre and Senechal (1975), Brannen et al.(1977), Lipinski (1982), Vaccaro et al.(1983) and Arsnabarreta and Echenique (1984).

2.2 Age at first calving

Age at first calving is influenced by both genetic and non genetic factors (Bhatnagar and Sharma, 1976; Kaushik *et al.*, 1979; Landais, 1983). The mean ages at first calving of *Bos taurus* x *Bos indicus* crosses range from 31.4 to 35.5 months (Reaves *et al.*, 1985), while that of purebred Holstein Friesian averaged 31.2 months (Duc and Taneja, 1984) and for Sahiwal averaged 44.5 months (Chaudhary *et al.*, 1984)

2.2.1 Genetic influence

Heritability estimate of 0.24 ± 0.02 for age at first calving in Hariana heifers was reported by Jegam and Tomar (1983). Comparable estimate of 0.24 ± 0.18 was obtained in Sahiwals (Tomar *et al.*, 1974). Ahaamd *et al.* (1974) using half sib analysis and instrasire regression of daughters on dams techniques reported heritability estimates of 0.08 ± 0.19 and 0.08 ± 0.10, respectively, for age at first calving in Sahiwals. Early ages at first calving below 30 months in some *Bos taurus* breeds in Indian and Columbia were reported by Lemka *et al.* (1973). In the same study, none of the Indian cattle breeds calved earlier than 36 months of age even though breeding was commenced at first observed oestrus. The late age at first calving of the *Bos indicus* cattle is one of the reasons which render them uneconomic for dairy purposes. Studies on *Bos taurus* and *Bos indicus* cattle in East Africa showed that, irrespective of breeds, the mean age at first calving ranged from 3 to 4 years (Mahadevan, 1965; Mahadevan and Hutchison, 1964).

Time of puberty is a function of several factors. Age and weight of heifers seem to be the most important factors and the influence of these two phenomena varies between breeds (Wiltbank *et al.*, 1966; Short and Bellows, 1971; Laster *et al.*, 1972; Varner *et al.*, 1977). Madsen and Vinther (1975) found the effect of breed to be highly significant for age at first calving. In the same study, they indicated that for Red Sindhi and Sahiwal cattle, the mean age at first calving of 34.8 months was higher compared to 29.0 months of Red Danish cattle. Ages at first calving for Brown Swiss, Holstein Friesian and Jerseys reared in the tropics, ranged from 24.53 to 30.0 months and were significantly different from that of Red Sindhis, Sahiwals and Tharparkars which ranged from 37.36 to 39.36 months (Govindaiah *et al.*, 1984). Aziz and Siddu (1985) reported significant lower mean ages at first calving of Sahiwals compared to Friesians. Trail and Gregory (1981), indicated that for both Boran and Sahiwal breeds of cattle reared in Kenya,the mean age at first calving was 1209 days. Similar mean age at first calving for Zebu heifers in Cuba of 1152 $\pm$ 204.6 days was reported by Martinez *et al.* (1982). Tuah and Danso (1985) reported fairly low mean age at first calving of 962 days for N"Dama cattle in Ghana.

In a study of crossbreds from Holstein Friesian and Sahiwal, breed of sire accounted for 3.74% of the total variation in age at first calving (Basu and Ghai, 1977). Duc and Taneja (1984) estimated heterosis in Holstein Friesian and Jersey crossbreds of - 5.27% and - 13.96%, respectively, for age at first calving.

2.2.2 Non-genetic influence

Little and Kay (1979) indicated that body weight influenced age at puberty, thus with proper management of heifers, the age at first conception and calving can be reduced. Kiwuwa (1969) reported effect of season of birth on age at first calving of Nganda X Jersey crosses was not significant. Pereira *et al*. (1979) observed a significant effect of month of birth on age at first calving. In their study, females born in August - December were younger at first calving than those born in January - July (1271.92 - 1289.97 days versus 1302.9 - 1336.8 days,respectively). Similar results were obtained by Chawla and Mishra (1982).

Effect of year of birth on age at first calving has invariably been found to be significant (Jegam and Tomar, 1983; Valente, 1983; Roy *et al*., 1985). Nutrition varies from season to season and year to year, depending on availability of pastures and supplementary feeds. This variation has a significant role in growth of heifers which in turn determines age at mating (Blaho,1979; Little and Kay, 1979). Growth rate and location(district) were identified as main factors affecting age at first calving in Baole and N'Dama cattle (Landais, 1983).

2.2.3 Influence of age at first calving on milk production traits

Many reports have shown varying effects of age at first calving on lactation yield (Kiwuwa, 1968; Kimenye, 1978; Little and Kay, 1979; Berger and Juhls, 1982; Singh et al., 1982). Age at first calving was reported to influence the milk yield in fifth lactation only by Nagpaul and Bhatnagar (1971). The predicted milk yield in the same study was given by the regression equation : $\hat{y} = 2983.1 - 22.43x$, where, $\hat{y}$ = estimated 5th lactation yield, and x = age at first calving. Choudhary and Choudhary (1985) reported a significant influence of age at first calving on life - time milk production of Rathi and Rathi x Red - Danish cows. In addition they observed that any decrease in age at first calving significantly increased life - time milk production measured up to fixed age basis. This was attributed to the fact that most cows in the study remained in milk through the fixed-age chosen. Similar results were reported by Gopal and Bhatnagar (1969), Hargrove et al. (1969), Chandra (1977) and Lin and Allaire (1978) in different breeds of *Bos taurus* and *Bos indicus* cattle.

After reporting a highly significant effect of age at first calving on lactation yield and length in a Kenyan study, Kiwuwa (1974a), suggested that it was necessary to develop age adjustment factors for *Bos taurus* cattle in Kenya. In a study of Friesian cows, Kuhn (1983) observed that age at first calving was a less important source of variation in fat percentage than in other milk production traits.

Ahaamd et al. (1971), studying the records of Sahiwal cows, reported that there was no significant correlation between age at first calving and first lactation yield. In the same study, they indicated that total life-time milk yield and number of lactations completed in life tended to decrease with increase in age at first calving. Similar observations were reported by Tretyak and Betina (1974). A correlation coefficient of 0.172, between age at first calving and 305 - day milk yield was observed to be significant when data from 136 Holstein Friesian X Sahiwal cows were analysed (Gill et al., 1982): In their study, it was observed that age at first calving had no significant rank correlation with any measure of production, other than first 305 - day milk yield. Chaudhary et al. (1984) studying first lactations of Sahiwal cattle and their crosses with Friesian, Jersey and Swedish Red and White, reported significant and negative correlation between age at first calving and first lactation milk yield (r = - 0.31). Patro and Rao (1983), in a report based on 20 years data of Red Sindhi, observed that age at first calving and first lactation length had no significant genetic correlation, while phenotypic correlation with daily milk yield was significant (r = - 0.24).

2.2.4 Influence of age at first calving on reproductive traits

Dutt et al. (1974), studying the first lactation records of Tharparkar cows, indicated that calving interval was significantly influenced by age at first calving. From the same study it was inferred that the 54% of cows maturing and calving early were superior with respect to production traits and breeding efficiency, whereas the remaining 46% of cows maturing and calving at later ages had shorter calving intervals and service periods. In India, Bharat and Chowdhary (1980) observed in Nagauri that the effect of age at first calving on the first service period and subsequent service periods was significant. Dominguez et al. (1982) reported that age at first calving of Criollo cows in Cuba had significant influence on calving interval.

Phenotypic correlation coefficients of age at first calving with length of dry period and first calving interval of 0.288 and 0.361, respectively, in Sahiwal cattle were reported by Ahmad and Ahmad (1974). Patro and Rao (1983) reported phenotypic and genetic correlations between age at first calving and breeding efficiency of 0.01 ± 0.07 and 0.60 ± 0.28, respectively. The results from the same study indicated that the genetic correlation between age at first calving and first calving interval, and the phenotypic correlation between age at first calving and first dry period ($r = 0.09 \pm 0.07$) were not significant. Earlier report on the phenotypic correlation between age at first calving and breeding efficiency was negative and significant (Bhatnagar and Sharma, 1976). Furthermore, Singh et al. (1982) observed that age at first calving was significantly correlated with first and second calving intervals, ($r = 0.77$ and $r = 0.33$, respectively). Genetic correlations between age at first calving and other production and reproductive traits such as, first calving interval, first dry period, first lactation yield and first lactation length have been reported to be significant (Solanki *et al.*, 1973).

Kiwuwa (1968) reported that age at first calving had no significant relationship with first calving interval (r = 0.08). Similar observations were reported by Busol (1972) and Tomar *et al.* (1974).

2.3 Calving interval (CI)

Olds *et al.* (1979a) described the components of CI as days open, post-partum interval and service period. The gestation period is less variable, although its significant influence on CI has been reported (Gill and Balaine, 1979). In the same study service period was found to play a major role in causing variation in CI.

The importance of CI as one of the reproductive traits is appreciated from the fact that the length of CI is often used as a measure of reproductive efficiency (Legates, 1954; Wilcox *et al.* 1957; Everett *et al.*, 1966; Hahn, 1969; Kiwuwa, 1974 b;Osman and Russell, 1974; Matsoukas and Fairchild, 1975; Olds *et al.*,1979a; Sartore and Ladetto, 1983). Calving interval is considered the most important character in production of beef cattle, and it is the best index for evaluating the reproductive efficiency of a herd under field conditions (Linares and Plasse, 1966).

2.3.1 Genetic influence

Heritability and repeatability estimates for CI have ranged from low to medium. This shows that although both genetic and non-genetic factors affect variation in CI, the non-genetic effects are more pronounced. The heritability and repeatability estimates reported in literature for CI are given in Table 1.

Valente (1983) studied genetic effects on CI in European x Zebu cattle and found that the heritability estimate of CI was much lower when effect of age of dam was included. The heterosis estimated in Holstein Friesian and Jersey crossbreds for the first CI were 0.11% and - 1.06%, respectively (Duc and Taneja 1984). While in another study, Syrstad (1985a) estimated heterosis to be - 7% (percentage deviation from mid-parent mean) in *Bos taurus* x *Bos indicus* crossbreds.

Breed differences in length of CIs have been reported previously by many workers. In some studies, the increase in length of CIs in crossbreds (*Bos taurus* x *Bos indicus*) was attributed to the increase in the "blood" of *Bos taurus* (Mahadevan and Hutchison, 1964; Vaccaro, 1973; Osman and Russell, 1974; Deshpande and Bonde, 1982; Govindaiah *et al.*, 1984). In an earlier report, Pandey and Desai (1973) observed that length of CI decreased significantly as the

Table 1 : Heritability (h^2) and repeatability (R) estimates for calving interval

Breed/type	h^2	R	Author
Bos taurus breeds	0.026	0.133	Legates (1954)
Holstein	0.08	0.12	Everett *et al.* (1966)
Hariana		0.12	Lemka *et al.* (1973)
Sahiwal	0.08		Ahaamd *et al.* (1974)
Slovakian Pied		0.18	Novy and Psenica (1977)
Nagauri		0.41	Bharat and Chowdhary (1980)
Zebu		0.22	Hinjosa *et al.* (1980)
Icelandic	0.08		Jonmundsson (1981)
Tharparkar	0.254		Gupta and Gurnam (1982)
Tharparkar	0.68	0.38	Parmar and Johar (1982)
Baoule and N'Dama		0.08	Landais (1983)
Japanese Black		0.17	Oishi *et al.* (1983)
Pitangueiras		0.145	Duarte *et al.* (1983)
Nellore	0.26		Weitze and Magalhaes (1984)
Bos taurus breeds	0.36		Toelle and Robison (1985)

proportion of Friesian "blood" increased in Friesian x Sahiwal crosses. Differences due to breed CIs were observed to be not significant in three separate studies by Voigt et al. (1974), Madelena et al. (1983) and Sadana and Basu (1983). Studies by Rao et al. (1984) on Zebu,European x Zebu and European breeds of cattle, revealed significant differences in the CIs between the genetic groups Mirza et al. (1985) compared Australian Illwara Shorthorn, Sahiwal and their crossbreds and reported that the CIs of 523, 412 and 391 days, respectively, for the three genotypes were significantly different ($P < 0.001$). Similar findings have been reported by Landais (1983), Leon and Denton (1983), Nobre et al. (1984) and Roy et al. (1985)

Improving fertility by natural selection was considered by Scholtz and Roux (1984). Nguni cattle have been reported to have the shortest CI of all beef breeds in South Africa (Scholtz and Roux, 1984). In their study males and females were reared together. This resulted in early bulls servicing the largest proportion of females. Consequently, due to natural selection on fertility, the practice led to dramatic decrease in CI and age at first calving of the Nguni cattle.

The average CIs of some tropical and European cattle breeds reared in the tropics and their crosses are given in Table 2.

Table 2 : Average calving intervals of some tropical and European cattle breeds and their crosses

Breed/type	Country	CI (days)	Author
White Fulani	Nigeria	370.8	Johnson and Buvanendran(1984)
Dauara	Somalia	486.0	Giorgetti _et_ _al_.(1983)
Pitangueiras	Brazil	431.0	Duarte _et_ _al_. (1983)
Sahiwal	India	433.7	Sharma _et_ _al_.(1982)
Criollo	Cuba	432.1	Dominguez _et_ _al_.(1982)
Sahiwal	Pakistan	412.0	Mirza _et_ _al_.(1985)
Mpwapwa	Tanzania	456.0	Mkony (1982)
N'Dama	Ghana	501.9	Tuah and Danso (1985)
Iraqui	Iraq	380.9	Barret _et_ _al_. (1973)
Ankole	Burundi	491.2	Pozy and Kagarama (1980)
Red Sindhi	Thailand	467.0	Madsen and Vinther (1975)
Brown Swiss	India	405.3	Sadana and Basu (1983)
Jersey	India	406.8	Duc and Taneja (1984)
Holstein Friesian	Brazil	410.0	Dias _et_ _al_. (1985)
Holstein Friesian	Cuba	421.6	Buxadera _et_ _al_. (1983)
Holstein Friesian x Kankrej	India	409.0	Fulsounder _et_ _al_. (1984)
Friesian x White Fulani	Nigeria	358.0	Sohael (1984)
Jersey x Tharparkar	India	389.9	Rao et al.(1984)
Brown Swiss x Zebu	Venezuala	400.5	Garcia _et_ _al_. (1975)
Holstein Friesian x Gir	Brazil	410.0	Madelena _et_ _al_. (1983)
Jersey x Red Sindhi	India	408.5	Pandey and Desai (1977)

2.3.2 Non-genetic influence

Previous studies have demonstrated significant effects of year and season of calving, age of cow and parity on CI (Garcia *et al.*, 1975; Martinez *et al.*, 1982; Madelena *et al.*, 1983; Velasco-Casarrubias, 1983; Duc and Taneja, 1984; Hernandez *et al.*, 1984; Wilson, 1985). In a study of British Friesian cows, Wood (1985) observed that CI increased on average by 3 days per month of age within parity. This indicates that CI increases with increase in age of cow, and that older cows would have longer CIs. In an early report, Tajane and Vyas (1984) observed significant declining trends over years of calving in CI on Kankrej cattle. They reported that the length of CI was reduced from 488 to 367 days as parity advanced from first to fifth. This could mainly be due to culling of cows with longer CIs as the parity advances.

Influence of season of calving on CI is related to availability and quality of adequate pastures and concentrates. In Cuba, Dominguez *et al.* (1982) observed that shortest CIs occured for Criollo cows calving in May to November. Rao *et al.* (1984) reported that the effect of management in three farms studied was significant whereas season of calving had no effect on CI. It was indicated by Nobre *et al.* (1984) that although year of calving significantly influenced the CI, season of calving and parity had no significant effect. Johnson and Buvanendran (1984) reported that CIs were not influenced by year of calving, but parity influenced both first study of calving intervals of Santa Gertrudis, Brahman and Sahiwal cattle, Mahadevan et al.(1972) reported that the Santa Gertrudis herd had shorter CI compared to the Brahman herd. They attributed this to better type of pastures for the Santa Gertrudis herd. In the same study, Sahiwal had shorter CI than both Santa Gertrudis and Brahman herds, and this was attributed to the ability of Sahiwals to perform more efficiently under range conditions. In studies where Zebu cows were treated with Iodine, Zeranol, and Vitamins A,D and E, Camacho et al. (1984) found that treated cows had significantly shorter CIs of 360 to 380 days than control cows (459 days).

Other environmental factors, such as viability of calf in previous calving (Landais, 1983) or suckling of calf during milking (Lemka et al., 1973) have been indicated to significantly influence CI. Lewczuk et al. (1974) reported a significant effect of maximum daily milk yield on length of first CI. The results from the same study indicated that, heifers with maximum yield up to 15 kg had the largest first CIs, and that CIs increased in second, third and fourth lactations when lactation yields exceeded 3500, 4000 and 4500 kg, respectively.

2.3.3 Influence of calving interval on milkproduction

Some studies on the influence of CI and its components on milk production traits have revealed little or no effect (Olds and Seath, 1953; Carrie, 1956; Smith and Legates, 1962; Everett et al., 1966; S'rtmadzhiev and Videv, 1974; Matsoukas and Fairchild, 1975; Holtz et al., 1976). After the analysis of complete 300 - day lactation records of Hariana cows, Ngere et al. (1973) found that CI was associated with an insignificant (2-4%) portion of the total variance in lactation yields. In the same study, it was observed that CIs of up to 600 days had a small, positive correlation (r = 0.12) with subsequent lactation yields, while such relationship was negative for CIs exceeding 600 days (r = - 0.17).

Influence of CI on milk yield and traits associated with it have been reported (Mahadevan, 1951; Cooper, 1966; Louca and Legates, 1968). Bhusari et al. (1985) observed that the total variation in lactation yields due to CI was 12.52 and 13-68 percent in the two herds of Sahiwal cattle. Moreover, Auran (1974) observed that the influence of CI on the concurrent milk yield during the first six months was small, but the effects of CI increased sharply from seventh month, accounting for nearly 30% of the total variation. This phenomenon of the depressive effect of new pregnancy on milk yield has been reported to commence at five months of pregnancy, but depends on parity and stage of lactation (Auran, 1974; Syrstad, 1975). Similar observation was reported by Olds et al. (1979a), when they found that the correlation between 305 - day milk yield and CI was higher than that between 120 days milk yield and CI.

The concurrent CI, compared to preceding CI, has a greater influence on current lactation, and cows with long current CIs out - yield those with short CIs (Syrstad, 1985b). This may have resulted due to long lactation lengths of about 305 days and short dry periods of 10 - 15 days in *Bos taurus* cattle. A short CI may not allow cows to store enough fat reserves for sustaining the same level of maximum daily milk yield as well as maintenance (Kitaro, 1984). Mahadevan (1951) cautioned that, although an increase of 12 to 15 kg in milk yield was observed when preceding CI increased by 10 days, it was economically not justifiable to prolong CI excessively.

Philipsson (1981) reported, that, most studies on association between reproductive or fertility traits and production traits indicate genetic antagonism. This common observation was noted by Drenyovszki (1974), Sharma *et al*. (1982) and Syrstad (1983). It was also reported by Novy and Psenica (1977) that CI was negatively and significantly correlated with milk yield (r = - 0.66 and fat yield (r = - 0.68). The conflicting results on the relationship between CI and lactation milk yield may be attributed to the type of cattle studied whether high yielding cows with long lactation lengths and short DPs or those with short lactation lengths and long DPs.

Positive correlations have nevertheless been reported, indicating non-antagonistic relationship between CI and milk production traits (Herrera-Garcia, 1976; Novy, 1981; Deshpande and Bonde, 1982: Sartore and Ladetto, 1983; Terawaki *et al*., 1985). Jonmundsson (1981), studying first lactation records of Icelandic heifers, observed that the first CI significantly influence the first lactation yield and that the lactation yield increased by

1.62 kg for each increase of 1 day in the CI. Wood (1985) reported that the lactation yields of milk, fat and protein were observed to increase by 20, 0.75 and 0.6 kg, respectively, per day increase in the preceding CI. It was also noted that lactation lengths were shortened by 3 days per week decrease in CI. In the same study it was observed that CIs exceeding 380 days had lower yields of milk, fat and protein than those less than 380 days. Otel et al. (1973) attributed the positive correlation (r = 0.374) between CI and subsequent milk yield to prolonged anoestrus caused by inadequate feeding or low feed quality that failed to meet metabolic requirements during lactation.

2.3.4 Influence of calving interval on reproductive traits

High producing cows with long lactation lengths of 305 days will have a short dry period and a short service period if they calve annually and thus shorter calving intervals are observed. The importance of the association between CI and other reproductive traits can be useful in predicting the trend of other reproductive traits, when the preceeding CI is known.

The influence of CI on other reproductive traits and their relationship has been a subject of great interest to many scientists (Dutt et al ., 1974; Olds et al., 1979a ; Parmar and Johar, 1982; Iliev, 1982). In studying reproductive performance of Criollo cows, Buxadera et al.(1983) indicated that the ranges of correlation coefficients of CI with service period, days open and number of services per conception were from 0.46 to 0.85, 0.85 to 0.94 and 0.40 to 0.66, respectively. Similar findings were observed by Olds et al. (1979a) when studying reproductive parameters in dairy cattle.

Relationship between CIs and dry periods has been reported to be positive and significant, such that higher values of CIs are due to longer dry periods. This relationship has been reported by Amble and Jain(1966), Rajgobal(1969)and Pandey and Desai (1977). Iliev (1982) reported that dry periods increased disproportionately with CIs. He reported that CI of less than 365 days had lengthened dry periods compared to those with longer CIs.

Close association between service period and CI was observed by Larionova (1975). In the same study, the data indicated that service periods longer than 90 days led to CIs greater than a year. Syrstad (1985b)indicated that reducing postpartum interval and service period would result in shorter CI.

2.4 Dry period (DP)

Length of DP has been of particular interest to many workers due to its influence and relationship with milk yield and other milk production traits (Schaeffer and Henderson, 1972; Lemka et al., 1973; Deshpande and Bonde, 1982, 1983). Cows having long DPs indicate poor milk yield, whereas short DPs are desirable not only because of high lactation milk yield but also for efficient reproduction. Several factors have been known to influence the length of DP. These factors may be grouped into two categories, genetic and non - genetic.

2.4.1 Genetic influence

The estimates of heritability (h^2) for DP in Holstein Friesian cows are medium, and are in the range of 0.25 to 0.40 (Schaeffer and Henderson, 1972). In their study of Holstein Friesian cows, these authors reported heritability estimates for DP of 0.15, 0.33 and 0.34 for second, third and later lactations. These low (0.15) and medium (0.33 and 0.34) heritability estimates imply that there is more genetic influence on length of DP, than on other reproductive traits. Wilton et al. (1967) also reported medium heritability estimates for first and second DPs. When studying reproductive performance in Red Sindhi cattle, Rao and Patro (1984) estimated h^2s for DP using two methods, paternal half sib correlation and dam daughter regression. The h^2 estimates were low, with high standard errors in all parities, except for second parity when using the paternal half-sib correlation method than when using dam - daughter regression method.

Sharma et al. (1982) reported that, although h^2 for DP was not significantly different from zero, differences between genetic groups for dry period. Their results indicated that the crossbreds and grades of Holstein Friesian x Sahiwal had lower DPs, than purebred Sahiwal. The estimated heritabilities and lengths of DP of some dairy cattle breeds and crossbreds is summarised in Table 3.

Table 3 : Heritability estimates (h^2) for dry period and lengths of dry period

Breed/Type	h^2 (Approx)	Length (days)	Author
Friesian	0.34	67.0	Schaeffer and Henderson(1972)
Hariana		203.0	Lemka _et al_.(1973)
Sahiwal		182.8	Ahaamd and Ahmad (1974)
Latvian Brown	0.32	79.0	Gur'yanova and Sokolova(1975)
Jersey X Red Sindhi		98.4	Pandey and Desai (1977)
Holstein Friesian		70.0	Medina-Cruz (1979)
Sahiwal		160.3	Sharma _et al_. (1982)
Jersey		90.0	Sadana and Basu (1983)
Friesian x Sahiwal		104.0	Alexander _et al_. (1984)
Friesian x Kankrej		50.0	Fulsounder _et al_. (1984)
Holstein Friesian		68.6	Rako and Karadjole (1984)
Tharparkar		224.4	Rao _et al_. (1984)
Red Sindhi	0.57		Rao and Patro (1984)
Estonian Black Pied	0.14		Saveli (1984)
Friesian x Sahiwal		93.2	Singh and Sharma (1984)
Sahiwal		242.0	Mirza _et al_. (1985)
British Friesians		60.0	Wood (1985)

In a study comparing DPs of three *Bos indicus* breeds of cattle, Taneja (1974) reported that genetic group significantly influenced the length of DP. In his study, Sahiwals had significantly longer DPs than Harianas and Tharparkars. Similar observations, indicating significant effect of genetic group on DP, have been reported by other workers (Pandey and Desai, 1973, Mirza *et al.*, 1985; Rao *et al.*, 1984; Roy *et al.*, 1985).

Effect of crossbreeding and upgrading *Bos indicus* with dairy breeds of *Bos taurus* on DP was reported by Pandey and Desai (1973). Length of DP was observed to decrease significantly in Friesian x Sahiwal grades and crossbreds as the proportion of Friesian"blood" increased. Similar effect of increased *Bos taurus* proportion in grades and crosses on DP has been reported(Pandey and Desai, 1977; Govindaiah *et al.*, 1984; Sharma *et al.*, 1984). Deshpande and Bonde (1983) suggested that the DP of dairy cattle was not significantly affected by the differences in the genetic grades. They observed that the DPs of various crosses and grades of Holstein Friesian x Sahiwal did not differ significantly. Several other authors have reported similar observations (Sadana and Basu, 1983; Singh and Sharma, 1984; Bhan and Prasad, 1985).

2.4.2 Non-genetic influence

Effect of year, season, age of cow and management on DP are some of the factors that have consistently been reported in literature. Ahaamd *et al.* (1974), in a study on the reproductive traits of Sahiwal cows,concluded that most of the observed variation in DP was due to environmental influences. Schaeffer and Henderson (1972) showed that cows that freshened in spring months had longer DPs than those that freshened in summer months. Seasonal influence on DP was also reported by Rako and Karadjole (1984). In their study, DPs of cows calving in spring summer, autumn and winter averaged 68.6, 60.5, 61.3 and 68.5 days, respectively. Roy et al. (1985) reported a significant effect of season on first DP in a study with dairy cattle crossbreds in India. Studying Zebu and Zebu crosses with European dairy breeds, Rao et al.(1984) revealed that the length of DP was significantly influenced by year and farm.

Spalding et al. (1975) and Roman-Ponce et al. (1978) reported that age of cow significantly influenced DP. The correlation between the two variables, DP and age of cow, was positive and significant. A report on significant influence of parity on DP by Saveli (1984) showed that second DP was 15 days longer than first DP. It was observed by Schaeffer and Henderson (1972) that, within parity, older cows tended to have significantly longer DPs than younger cows. Spalding et al. (1975) reported that the influence of milk yield and herd size on DP was not significant in Holstein Friesian. Poutous and Mocquot (1974) indicated that the influence of herd on DP was significant, and that herd accounted for 16 - 19% of total variation in the duration of DP.

Season of calving had insignificant influence on DPs of dairy cows (Deshpande and Bonde, 1983; Govindaiah et al., 1984). Ngere et al. (1973) reported that DP was not significantly influenced by parity in Hariana cows.

2.4.3 Relationship with milk production and reproductive traits

Smith and Legates (1962) considered the influence of DP on subsequent milk yield as being largely environmental. Their results indicated that short DPs were followed by significantly diminished milk production. The effect of DP on subsequent lactation milk yield was reported to be largely environmental (Smith and Legates, 1962) as the genetic correlations between the variables were very low. Later, Schaeffer and Henderson (1972) observed that phenotypic correlations of DPs with subsequent milk yields were meaningless since the relationship between the two variables was non-linear. The genetic correlations estimated by Schaeffer and Henderson (1972) were - 0.18, - 0.41 and - 0.31 at second, third and later parities between DPs and subsequent lactation milk yield. Ngere *et al*. (1973) and Tomar and Balaine (1973) reported insignificant influence of DP on subsequent lactation milk yield.

The relation between CI and milk yield in ensuing lactation was statistically attributed to the length of preceding DP (Wood, 1985). In the same study, the yields of milk, fat and protein decreased by 26, 8 and 3.5 kg, respectively, per day increase in the preceding DP. Similar negative correlations between DP and subsequent milk production traits were reported by Alim (1962), Poutous and Mocquot (1974), Garcia *et al*. (1975) and Peric (1984). Correlation coefficients between DP and subsequent milk yield and fat yield, reported by Peric (1984) when studying Danish Red cows, were -0.73 and -0.70, respecitvely.

Roman - Ponce *et al.* (1978), Iliev (1982) and Deshpande and Bonde (1982 and 1983) found that estimates of correlation between DP and subsequent lactation yield were high, positive and significant. Deshpande and Bonde (1983) reported that the correlation between lactation length and subsequent DP was negative and significant. Studying the relationship between lactation length and subsequent DP, Poutous and Mocquot (1974) reported significant correlation of - 0.39 (within herds) and - 0.81 (between herds). Peric (1984) observed that cow with short DPs had longer lactations and lighter calves in subsequent calving than cows having long DPs.

Estimated correlation coefficients between first CI and corresponding DP have been reported to be positive and significant (Ahaamd and Ahmad, 1974; Dutt *et al.*, 1974). In studying two *B. taurus* and two *B. indicus* breeds in India and Colombia, Ngere *et al.* (1973) indicated that ratio between DP and CI as a percentage was high in all breeds ranging from 36.7% to 81.0%. The influence of days open on DP was reported by Olds *et al.* (1979b) to be significant.

2.5 Days open

An optimum of 80 - 100 days interval from calving to subsequent conception (days open), along with other factors, maximise economic returns from milk production (Salisbury *et al.*, 1978; Alberro, 1983). Days open between 60 and 90 days was considered by Schaeffer and Henderson (1972) to be the ideal management practice in terms of efficiency.

Days open is largely influenced by environmental factors as estimates of its heritability and repeatability reported have been low. The non-genetic factors affecting days open include year, season of calving, age at calving, parity and managerial practice.

2.5.1 Genetic infuence

Reports of genetic influence on days open indicate little effect as the heritability and repeatability estimates have been low or near zero. Carmen (1955) reported that the estimated repeatabilities of days open ranged from 0.02 to 0.08. Studies by several other workers (Smith and Legates, 1962; Everett et al., 1966; and Schaeffer and Henderson, 1972) showed that the estimates of heritability of days open ranged from 0.01 to 0.10 in dairy cows. Recently, low to medium heritability estimates ranging from 0.108 to 0.380 of days open in Black and White cows, were reported by Lazarevic and Milojic (1984).

Comparing Bos taurus and Bos indicus dairy breeds in the tropics, Lemka et al.(1973) reported that the genetic group significantly influenced the number of days open. The author cautioned that, before the differences in breeding efficiency based on CI and days open are assumed to be genetic, comparisons would have to be made within a uniform system of heat detection and standard lactation length.

Reports comparing Bos taurus and Bos indicus dairy breeds have indicated fewer days open in Bos taurus and their crosses, compared to Bos indicus breed (Lemka et al., 1973; Alberro, 1983). In Ethiopia, Alberro (1983) indicated that differences between Friesian x Zebu crossbreds and Zebu cows were highly significant for days open. He reported that Friesian x Zebu showed a definite advantage over Zebu cows in days open (Table 4). A similar observation was reported by Chaudhary and Chaudhary (1984), whereas McElhenney et al. (1985) indicated an insignificant effect of genetic group on days open. The mean number of days open of some dairy cattle breeds are given in Table 4.

2.5.2 Non-genetic influence

There is variation in days open from one year to another because of the change in climatic factors and management practices. Schaeffer and Henderson (1972) and Buxadera et al. (1983) reported that year significantly influenced the number of days open. Coleman et al. (1985), studying reproductive performance of Holstein Friesian, Ayrshire and Guernsey cows, indicated that management practices significantly influenced days open.

Schaeffer and Henderson (1972) observed that, whereas the age at calving did not affect days open, that month of calving

Table 4 : Mean number of days open of some dairy cattle breeds

Breed/type	Days open (mean)	Authors
Holstein Friesian	101.0	Schaeffer and Henderson(1972)
Blanco Orejinegro	93.0	Lemka *et al.* (1973)
Deshi*	133.0	Lemka *et al.* (1973)
Hariana*	199.0	Ngere *et al.* (1973)
Danish Red	109.2	Anderson (1974)
Danish Black Pied	91.0	Anderson (1974)
Holstein Friesian	103.7	Olds *et al.* (1979b)
Zebu*	130.0	Alberro (1983)
Friesian x Zebu	85.0	Alberro (1983)
Rathi*	280.0	Chaudhary and Chaudhary (1984)
Holstein Friesian	173.0	Foote *et al.* (1984)
Holstein Friesian x Kankrej	171.0	Fulsounder *et al.* (1984)
Swedish Friesian	102.3	Larsson *et al.* (1984)
Black Pied	139.5	Lazarevic and Miljovic (1984)
Holstein Friesian	111.2	Terawaki *et al.* (1985)

* *Bos indicus* breed/type of cattle

significantly influenced days open in Holstein cows. Their results indicated that the period of days open was longer for cows that freshened during summer months than for those freshened in winter and spring months. Influence of season of calving on days open was also reported by Monty and Wolff (1974), Buxadera et al. (1983), Foote et al. (1984) and Coleman et al. (1985).

The effect of parity on the number of days open was reported by Ngere et al. (1973) when studying milk production and reproductive traits in Hariana cows. The results from their study indicated that there was a consistent decrease in days open with increase in parity number. The mean days open were 241, 175, 159, 156, 145, 141 and 137 for parities 1 through 7 (Ngere et al., 1973). Schaeffer and Henderson (1972) reported that age of cow did not influence the number of days open.

Occurence of postpartum oestrus, detection of heat and managerial practice of breeding at appropriate oestrus also influence the number of days open. Whitmore et al. (1974) indicated that days open was significantly influenced by postpartum interval to first breeding. In their study, the group of cows bred at the first oestrus after 74 days post partum were more fertile and had longer days open, than those bred at the first postpartum oestrus. Rounsaville et al. (1977) observed that increasing oestrus detection in cows at postpartum interval significantly decreased days open.

2.5.3 Relationship with milk production traits

Some studies have been interpreted to indicate that higher 305 - day milk production was the cause of more days open (Lewis and Horwood, 1950; Morrow *et al*., 1966; Spalding *et al*., 1975). Other tended to view more days open as a cause of higher 305 - day milk yield (Carmen, 1955; Smith and Legates, 1962; Schaeffer and Henderson, 1972).

Influence of days open on milk production were previously reported by Smith and Legates (1962), Louca and Legates (1968) and Schaeffer and Henderson (1972). Their reports indicated that the influence of days open on milk production was almost entirely environmental. Smith and Legates (1962) reported that the phenotypic correlation between days open and milk yield was about 0.12.

Olds *et al*. (1979b) reported that the correlations between days open and both 120 - day and 305 - day milk yields were 0.60 and 0.21, respectively, in Holstein Friesian. These coefficients were highly significant ($P < 0.01$). Similar estimates of the coefficient of correlation between day open and milk yield have been reported by Zaoral *et al*.(1974), Terawaki et al. (1985), and Reaves et al. (1985). In El Salvador, Reaves et al. (1985) indicated that the delay of breeding cows so as to increase days open from 90 to 305 days would result in expected gains of concurrent milk yield of 171 kg in Guernseys and 438 kg in Holsteins (Table 5). The corresponding pooled estimated gain from all cows in the same study was 341 kg. From the results, Reaves et al. (1985) concluded that gains from increasing days open would on average off-set losses expected from increased average CI.

Olds et al. (1979b) reported that the number of days open significantly influenced subsequent 305 - day milk yield. Similar observation was reported by Schaeffer and Henderson (1972) in Holstein cows. Ngere et al. (1973) reported that days open accounted for 3 - 5% and 2 - 5% of the total variation in concurrent milk yield and subsequent milk yield, respectively, in Hariana cows. The significant relationship between days open and subsequent lactation milk yield was attributed to the influence of days open on concurrent CI and subsequent DP (Ngere et al., 1973; Olds et al., 1979b).

Relationships between days open and reproductive traits strongly associated with milk production have been reported to be positive and highly significant (Ngere et al., 1973. Olds et al., 1979a; 1979b; Buxadera et al., 1983). In a study of the association of days open with production and reproductive parameters, Olds et al.(1979b) reported that days open were significantly correlated with CI, service period and postpartum interval, and the correlation coefficients estimates were 0.99, 0.80 and 0.55, respectively.

Table 5 : Effect of days open on concurrent milk yield[1]

Days open	Kg increase in lactation milk yield by breed				
	Holstein	Brown Swiss	Guernsey	Other cows	All cows
90	0	0	0	0	0
120	41	28	27	53	51
150	88	56	53	100	101
180	142	83	78	143	150
210	203	111	102	181	197
305	438	199	171	269	341

Source : Reaves *et al.* (1985)

[1]Increase in current lactation milk yield associated with increasing days open beyong 90 days, in kg.

2.6 Conception rate (CR)

Investigations conducted in different parts of world show clearly that infertility together with failure to produce live, healthy calves are some of the main causes of lowered animal production. The fundamental reasons of reduced CRs are breeding too early, delayed breeding and fertilization failure. Darre and Senechal (1975) and Gaunt (1976) reported that lowered CRs and calving rates due to repeat breeders and abortions in dairy cows accounted for 20 - 30 percent of culling rate.

Fertility in dairy cows is measured by CR and traits closely associated with CR, such as number of services per conception, and calving rate. Rowlands et al. (1977) showed that CR was an appropriate measure of fertility under field conditions. Calving rate of a herd is usually lower than the corresponding CR. Nevertheless, calving rate can be used to estimate CR when embryonic and fetal mortalities resulting in abortions are also considered. Studies on some of the phenotypic and genetic parameters of conception rate and number of services per conception have been reported by several workers (Foote, 1970; Olds et al., 1979a; Vinson, 1982; Hansen et al., 1983a, 1983b, 1983c; Freeman, 1984 ; Taylor et al., 1985).

2.6.1 Genetic influence

Low estimates of heritability and repeatability for CR and number of services per conception in cattle have been reported by Foote (1970), Maijala (1978), Winson (1982) and Freeman (1984). Dearborn (1970) reported medium to high estimates of heritability and repeatability for CR in cattle. Some estimates of heritability and repeatability for CR and number of services per conception in cattle are summarized in Table 6.

Trends in CR for a herd of Droughtmaster cows studied by Hetzel *et al*. (1985) showed that for a mean CR of 68.6% over a period of 20 years, the mean phenotypic trend in CR was 0.65 $\pm$ 0.38 percent per year, and the genetic trend in CR was 0.075 $\pm$ 0.049 percent per year. They suggested that genetic trend thus observed represented genetic improvement in fertility of 1.5%. On the other hand, Taylor *et al*. (1985) studied 14 years data of over 300,000 inseminations in a herd of dairy cows and reported no genetic trend for CR.

Differences in CRs between dairy and beef breeds were attributed to milking of dairy cows twice a day that manifest early post-partum estrus at 46 days, whereas beef cows have longer postpartum intervals (McDonald, 1975). In New Zealand Smeaton *et al*. (1983) reported a similar effect of breed on

Table 6 : Estimates of heritability (h^2) and repeatability (R) for conception rate (CR) and number of services per conception (NSC) in cattle

CR		NSC		
h^2	R	h^2	R	Author
0.08	0.06			Taylor *et al*. (1985)
0.10				Horn (1984)
0.08				Collins *et al*. (1962)
	0.15			Spears *et al*. (1965)
		0.03		Legates (1954)
		0.03	0.05	Everett *et al*. (1966)
			0.07	Oishi *et al*. (1983)
0.06				Toelle and Robison (1985)
0.22	0.55			Dearborn (1970)

post partum intervals, thereby resulting in variation in CRs. Osman and Russell (1974) compared indigenous Zebu (Butana) cows to European dairy breeds and their crosses with Butana. They reported that genetic group significantly influenced CR. Similar observations were reported by Huat (1975), Alberro (1983), Murray *et al*. (1983), Perez-Beato (1984) and Badinga *et al*. (1985)

Superiority of *Bos taurus* dairy breeds and their crosses with *Bos indicus* breeds over *Bos indicus* in CR has been reported by various workers (Osman and Russell, 1974; Alberro, 1983; Perez-Beato, 1984). In Ethiopia, Alberro (1983) reported that the CR of 55% of crossbred cows from Friesian x Zebu crossing was significantly higher than that of Zebu cows, (50% CR). Other reports by Goel (1982), Sadana and Basu (1983) and Tuah and Danso (1985) have indicated insignificant influence of breed on CR and number of services per conception.

2.6.2 Non-genetic influence

The main environmental factors known to affect CR in dairy cows include year and season of mating or inseminating, age, parity, herd, location or management and nutrition. Influences of season, year and herd on CR have been of interest to many workers (Stott and Williams, 1962; Kaushik *et al*., 1979; Laben *et al*., 1982; Murray *et al*., 1983; Senger *et al*., 1984).

Season, climate, nutritive value of pastures, availability of concentrates and managerial practices may vary from one year to another. Olson *et al*. (1985) reported that year of breeding significantly influenced the CR of Brown Swiss, Angus and their crossbreds. Spears et al. (1965) indicated that year. accounted for 1.4% of the total variation in CR of dairy cows. Significant influence of year of mating on CR has also been reported by Kaushik et al. (1979) and Dias et al. (1985).

In their review, Salisbury and VanDenmark (1961) concluded that dairy cows attain highest CR in the spring and lowest during the winter and summer months of breeding. Stott and Williams (1962) observed that reduction in fertility in dairy cows occurs during long, intensely hot summer. Penington et al. (1985)reported that in cold or mild weather, cows had more oestrus activity than cows in hot weather, thus contributing to higher CRs in colder season. Monty and Wolff (1974) considered heat stress to be an important problem to dairy industry as it resulted in reduced milk production and CR,and prolonged CIs. They reported that CRs of dairy cows decreased by 20 percent during the hot summer months, but the herd CR increased immediately with the onset of lower temperatures in October. In a similar study, Weirsma and Stott (1969) reported that fertility levels of cows were very low during hot summer months. In the United States of America, Foote et al. (1984) reported similar seasonal effects on CR of dairy cows. The results from their study showed that CR of Holstein - Friesian cows were higher (23% - 33%) during winter and spring than in summer (7% - 17%). Similar studies indicating significant seasonal influence on CR have been reported elsewhere (Espinosa and Morais , 1983; Landais, 1983; Badinga et al., 1985).

Iglesias and Morales (1977) reported that cows bred in the rainy season had higher CR than those bred in the dry season. Wilson (1985) studied fertility of cows in Mali and reported a significant and positive correlation (r = 0.56) between CR and amount of rainfall during the breeding season. In another study, a positive, significant curvilinear correlation between CR and amount of rainfall was reported by Badinga et al. (1985). The effect of season x breed interaction on CR was reported by Perez-Beato (1984). He indicated that Holstein-Friesians showed highest CR in December to January breeding than in May to June or August to September breeding, whereas Zebus had highest CR in May to June than in December to January breeding and the crossbreds showed highest CR in October and lowest in February. Feo (1982) and Dias et al. (1985) reported that seasonal influence on CR of dairy cows was insignificant.

Dawson (1960) reviewed effects of age of dam on CR of cattle and stated that the calf crop was 15 to 20 percent lower in heifers than in cows. Dawson (1960), Herman (1956), Morrison and Erb (1957) and Salisbury and VanDenmark (1961), reported that in United States of America (U.S.A.) fertility in cows increased up to 4 years of age, levelled off at 6 years of age and then gradually declined. Several other reports have also indicated that CR of dairy cows significantly decreases with advancing age (Spalding et al., 1975; Kragelund et al., 1979; Hansen et al., 1983c; Hillers et al., 1984; Ron et al., 1984). Influence of age of bulls on the CR of cows was reported by Makarechian and Farid

(1985). They found that the fertilizing ability of bulls was significantly correlated (0.92, $P < 0.01$) with age and 3 year old bulls gave higher conception rates compared to one year old bulls (88.9% versus 82.5%).

Significant influence of parity on CR of dairy cows was reported by Rowlands *et al*. (1977). They found that CR in both 1st and 2nd parities was 66% compared to 31% in 5th and 6th parities. Similar findings were reported by Osman and Russell (1974) and Badinga *et al*. (1985).

Cavalier *et al*. (1974) reported that the postpartum anoestrus in cattle and sheep was significantly influenced by the nutrition of females. El-Hassan (1985) found that CR of Holstein-Friesian cows was significantly influenced by nutrition. The results from his study showed that cows which were fed high energy diet had CR of 67% whereas the CR was 25% for cows on low energy feeding. They attributed the decrease in CR to the adrenal inactivity and low blood glucose concentration at the time of insemination. Similar observations were also reported by Selk *et al*. (1985). In a similar study, Hancock *et al*. (1985) observed that CR of cows fed a moderate protein supplement before breeding period had higher CR compared to cows that were not fed protein supplements.

Liveweight of breeding cows has been found to influence CR by Pope (1967) and Holness (1983). They suggested that cows that lost weight during postpartum period would be unlikely to conceive in the following mating season. Levine et al. (1980) reported that Zebu heifers weighing less than 220 kg at the end of breeding period did not conceive. They also indicated that the probability of conception for Zebu cows aged 4 to 8 years with liveweights less than 260 kg was zero, and that the probability of conception increased with increasing liveweight up to 380 kg. Wettemann et al. (1985) found that the CR of 59 percent for cows that maintained their liveweights from calving to the end of breeding period was significantly higher than the cows that lost weight before breeding period.

Body condition of cows rather than their liveweights at breeding has been reported to be positively and significantly correlated with CR (Elliot, 1964; Harwin et al., 1967 ; Steenkamp et al., 1975). Holness (198[illegible]) suggested that the prepartum level of feeding and thus condition of body at calving appears to have most critical effect on reconception. However, Dias et al., (1985) reported that body condition at calving did not influence the CR significantly.

Variations in CR due to differences in management practices have been reported by Shannon (1965), Kawecki and Kamienieck (1973), Ron et al. (1984)and Taylor et al. (1985). Kawecki and Kamienieck (1973) and Canedi et al . (1984) reported that CR of cows using natural mating method was significantly higher than those inseminated artificially. Variations in CR due to differences in the performance of artificial insemination technicians have been reported by Ron et al. (1984) and Taylor et al. (1985).

2.6.3 Relationship with production and reproductive traits

Reports on relationships between CR or number of services per conception and yields of milk, fat and protein in dairy cows have ranged from mild to strongly antagonistic (Maijala, 1978; Olds et al., 1979a; Vinson, 1982; Hansen et al., 1983b; Hansen et al., 1983c; Freeman, 1984). Taylor et al. (1985) suggested that the estimates of phenotypic and genotypic correlations between CR and production traits, were necessary to complement heritability estimates for optimization of selection program targeted at improving population efficiency for production.

Brauner (1975) reported significant differences in CRs, (ranging from 33.3 to 69.5 percent) among Czech Red Spotted cows in different classes of lactation milk yield . The same study the correlation coefficient between lactation milk yield and subsequent CR was found to be positive and significant. Olds et al. (1979) found that the mean CR of 70.4% of Holstein-Friesian cows was significantly correlated ($P < 0.01$) with 120 - day and 305-day milk yield.

Antagonistic relationship between CR and lactation milk yield has been reported by Gavalier et al. (1974) and Spalding et al. (1975). They reported that CR declined significantly in high milk yielding cows. Otel et al.(1973) and Rowlands et al. (1977) reported a non-significant relationship between CR and lactation milk yield.

Relationship between CR and other reproductive traits in dairy cows have not been studied extensively. Hahn (1969) and Maijala (1978) have reported small, but positive correlation coefficients. Olds *et al*. (1979a) indicated that number of services per conception was positively and significantly correlated with CI, days open and service period in Holstein-Friesian cows. Similar correlation coefficients ranging from 0.40 to 0.66 between CI and number of services per conception were reported by Buxadera *et al*. (1983). Length of postpartum interval up to breeding period and subsequent CR in dairy cows have been reported to be positively and significantly correlated (Elochevskii, 1970; Izaike *et al*., 1983). The CR of Japanese Black cows increased significantly from 31.5% to 41.0% as the insemination period at the first post-partum oestrus increased from 28 days to more than 60 days (Izaike *et al*., 1983).

2.7 Viability of calves

Prenatal and perinatal mortality of calves in the tropics have been reviewed by Vaccaro (1974) and Ulaganathan (1984). Mortality of calves at perinatal and postnatal stage has been a serious problem in dairy development in tropical lands. Factors influencing viability of calves from birth to one year of age have been studied by various workers (Rudolph, 1970; Lemka *et al*., 1973; Madsen and Vinther, 1975; Singh and Parekh, 1982; Umoh, 1982).

heifers do not survive to first calving, the herds would be unable to provide their replacements unless birth rates exceeded 72 percent annually, which is not usually the case in tropical countries. However, even if the replacements are available it will be impossible to apply high intensity of selection for production traits unless the rates of calf loss are reduced (Vaccaro and Vaccaro, 1981).

Besides its economic importance, calf mortality reflects the relative adaptability of various cattle breeds particularly of exotic origin, to the tropical conditions where they are reared. Brumby and Trail (1986) reported that most cattle in Africa are kept under extremely simple management conditions and received little supplementary feed and health care. They also indicated that the ability of cattle to cope with environmental stress was the prime criterion for survival, and low weaning weights in dairy calves commonly occur due to offtake of milk for human consumption. This reduction in liveweight at weaning is never made up and results in serious shortcomings in dairy production, the important one being increased calf mortality (Brumby and Trail, 1986).

2.7.1 Genetic influence

Heritability estimation of calf mortality using intra-sire half-sib correlation method was done by Singh and Parekh (1982). They reported heritability estimate of 0.0359 ± 0.0193 for calf mortality. Similar, low heritability estimates were reported by Inskep *et al.* (1961) and Parekh and Singh (1981).

Gregory et al. (1985) studied Zebu crosses with Friesian, Brown Swiss and Simmental breeds and reported that the average heterosis for preweaning viability was 7.2%, and that for overall survival rate was 7.3%. Olson et al. (1985), indicated that direct heterosis and maternal heterosis did not influence survival rate of calves.

Influence of breed of sire and breed of dam on mortality rate of calves up to 9 months age was reported by Vaccaro and Vaccaro (1981). Studies on viability of calves by Umoh (1982) reported a significant genetic influence on viability of calves. He indicated that the viability of indigenous calves in Nigeria up to 12 months of age was significantly higher than their crossebred calves with European dairy breeds. The involvement of genetic factors in the viability of calves was reviewed by Ulaganathan (1984) from the Indian reports. In the review, most of the reports indicated that Zebu calves and first cross, crossbreds had superior survival rates of about 85% and about 75%, respectively, compared to higher grades of *Bos taurus* breed (55%). In another review, Vaccaro (1974) indicated superiority of native and first cross calves over purebred and higher grades of *Bos taurus* dairy breeds. In Ghana, Tuah and Danso (1985) found significant breed differences in viability of native calves(N'Dama and West African Shorthorn cattle). Umoh (1982) and Rao (1983) reported that the genetic group had significant influence on viability of dairy calves when they observed lower postnatal viability in purebred European dairy breed compared to half breds. However, Frisch (1973) reported significantly higher perinatal mortality in purebred Zebu calves compared with Bos taurus breeds. He attributed high perinatal mortality in Zebu calves to their low birth weights and lack of vigour.

Studies on genetic influence on viability of indigenous calves in the tropics were reported by Amble et al. (1958). The results from their study indicated that the viability of calves among the Zebu breeds studied was similar but the mortality of Red Sindhi calves of 9.5% was slightly higher. Trail and Gregory (1981) reported that viability up to weaning in both Boran and Sahiwal calves amounted to 95 percent, and the survival rate of Sahiwal calves was significantly higher than that of Boran calves. Frisch (1973) indicated higher perinatal mortality in Zebu calves, but from weaning to 12 months of age Zebu calves showed a clear survival advantage over the British breed calves. In Zanzibar, Jacobsen (1983) reported that the Zebu calves up to 10 months of age had significantly higher (94.4%) survival rate than crossbred calves (80.0%). Similar findings were reported by Ibeawuchi et al. (1981) in Nigeria.

Vaccaro (1974) indicated in his review that, most reports have shown that about 40 percent or more of temperate breed heifers born in the tropics did not survive up to first calving age. In the same review he observed that calf viability in Friesians up to 18 months of age was about 84 percent, while in Guernseys it was as low as 29 percent. In another study, Vaccaro et al. (1983a) observed that mortality rate of Holstein calves in Venezuala was unusually high, the death rate being 81.3 percent up to one month of age.

In Thailand, Madsen and Vinther (1975) and in India, Rao (1983) indicated significantly higher calf mortality in purebred and higher grades of European dairy breeds compared to their crossbreds. In their studies, differences in mortality rates of calves due to genetic group was observed in the early months of life.

The rate of mortality of heifer calves of Red Danish cattle and their higher grades (5/8 to 5/16) up to 6 months of age, ranged from 7.4% to 9.2% (Madsen and Vinther, 1975). Higher calf mortaliry in high grades of European breeds of about 19.0% was reported in Cuba (Planas, 1979). Losses of 13.1% were reported in subtropical lands for high grade European crossbred calves (Sharma and Jain, 1976). Lowest mortlaity rate of 1.08% for one month old ½ Jersey x ½ Tharparkar calves and highest (6.64%) in Holstein x Tharparkar calves were reported by Rao and Nagarcenkar (1980). In their results, genetic group of calves was a significant source of variation in mortality rate of calves up to one month age (Table 7).

Vaccaro (1974) observed that Holstein-Friesian crossbreds with various zebu and Criollo breeds were superior in viability of calves, compared to Brown Swiss crossbreds with Zebu and Criollo breds. Choudhuri et al. (1984) reported that calf mortalities of Jersey x Hariana and Holstein x Hariana crosses of 5.4% and 9.4%, respectively, were significantly different. In the same study, viability of heifer calves up to conception age was significantly influenced by genetic group. Vaccaro and Vaccaro (1981) indicated that crossbreds of Holstein-Friesian were more viable at postnatal stage than the crossbreds of Brown Swiss in tropical countries. The overall losses over six months within each genetic group was 9.2% and 10.3% for crossbreds of Holstein Friesian and Brown Swiss, respectively.

Table 7 : Mortality rate (%) in two and three cattle breed crosses between Holstein (H), Jersey (J), Brown Swiss (BS) and Tharparkar (T)

Ggenetic group	Age group (months)		
	0 - 1	1.1 - 3	3.1 - 6
½H x ½T	1.80 (277)	2.76 (217)	1.42 (141)
½BS x ½T	4.60 (147)	1.64 (122)	1.33 (75)
½J x ½T	1.08 (1985)	1.32 (151)	0.00 (101)
3/4H x 1/4T	6.64 (226)	4.44 (180)	2.27 (132)
½H x 1/4BS x 1/4T	4.76 (84)	4.69 (64)	1.92 (52)
1H x 1/4J x 1/4T	5.71 (140)	2.73 (110)	0.00 (74)
Overall	3.87 (1059)	2.84 (844)	1.22 (575)
Chi-square	13.47*	4.36	3.66

Source : Rao and Nagarcenkar (1980)

Note :Figures in parentheses shows the number of calves exposed to risk.

2.7.2 Non-genetic influence

Influence of year and season of birth on viability of Jersey and Holstein crosses with Hariana was reported by Choudhuri et al. (1984). Lemka et al. (1973), Sharma et al. (1975), Srivastava and Sharma (1980), and Vaccaro and Vaccaro (1981) reported that year of birth had significant influence on viability of calves. Capriles et al.(1983) studied productivity of crossbred dairy cows and indicated that, season of calving had significant influence on viability of the calves. They reported that the crossbred calves (B. taurus breeds x Criollo) born in April to July months had higher mortality (28.1%) than those born in December to March (7.5%).

Season of birth has been reported as a significant source of variation in survival rates of calves by many workers (Vaccaro, 1974; Higgins, 1978; Ibeawuchi et al., 1981; Vaccaro and Vaccaro, 1981; Landais, 1983; Bhuyan and Mishra, 1985). Singh and Parekh (1982) reported that calves born in the rainy season had highest mortality rate (44.71%), while those born in spring had lowest mortality rate (17.07%), and the difference in mortality rates due to seasons was significant. The effects of year and season of birth, and sex of calf on mortality rate of calves reported by Singh and Parekh (1982) are summarized in Table 8.

Table 8 : Mortality rate (%) in crossbred[1] dairy calves related to year and season of birth and sex of calf

Factors	Number of calves born	Mortality rate (%) up to 12 months age	
Year of birth			NS
1976	36	19.44	
1977	35	9.38	
1978	64	11.48	
1979	77	20.0	
1980	52	11.36	
1981	14	1.44	
Season of birth			*
Spring	41	17.07	
Summer	68	26.47	
Rainy	85	44.71	
Winter	84	34.76	
Sex of calf			NS
Male	147	36.05	
Female	131	29.77	
Overall	278	33.09	

[1]Three breed crosses – ½ Jersey 1/4 Holstein – Friesian 1/4 Gir

* Significant ($P < 0.05$); NS – Not significant

Many workers have, however, reported insignificant inffluence of season of birth on viability of calves (Lemka et al., 1973 Sharma et al., 1975; Rao and Nagarcenkar, 1980; Srivastava and Sharma, 1980; Trail and Gregory, 1981). The insignificant influence of season of birth on viability of calves was probably due to the similar type of management practiced on calves born in different seasons.

Charray et al. (1977) reported that for Jersey x N'Dama crossbred calves, the mortality of male calves (9.8%) was significantly higher than that of females calves (7.1%). Lemka et al. (1973) reported that sex of calf significantly influenced viability of calves. The results from their study revealed that 18.3% of female calves born in a Hariana herd died prior to 6 months of age, while only 15.6% of male calves died. They attributed the sex difference to preferential treatment of male calves by the personnel handling calves due to the importance of bullocks for draft power in agriculture. Similar studies on mortality rate of dairy calves indicating significant influence of sex of calf have been reported (Frisch, 1973; Rao and Nagarcenkar, 1980: Bhuyan and Mishra, 1985). Although, Frisch (1973) reported that perinatal mortality up to 1st week of life was significantly higher in males (4.7%) than in females (2.9%), the effect of sex of calf on mortality rate of calves from birth to weaning was not significant. Insignificant differences in postnatal viability of calves due to sex of calf were also reported by Sharma et al. (1975), Trail and Gregory(1981) and Gotti et al.(1985).

Comparing crossbred calves of Brown Swiss x Zebu with Zebu calves(Red Sindhi and Sahiwal), Sharma et al.(1975) reported that the age of calf significantly influenced survival rates of calves. The results from their study showed that lowest viability of calves was in the first month of life, whereas less calves died with increasing age of calves. Ibeawuchi et al. (1981) reported that about 60.9% of the total calf mortality occurred in the first 3 months of life, of which 37.5% was in the first month and 25.0% in the first week of life. In the same study the percentage of deaths dropped sharply to 15.9% at the end of 6 months of age. Mortality rate in Zebu calves studied by Srivastava and Sharma (1980) varied significantly with different age groups. The results revealed that 50% of calf mortality occurred below one month of age, while 21.26% mortality occurred from 1 month to 3 months of age and 28.73% deaths occurred between 3 months and 12 months of age.

Birth weight of calf, significantly influences perinatal and early postnatal viability of calves (Singh and Parekh, 1982). Koger et al. (1967) found that the viability of calves was 49.2 percent within 24 hours of birth and the survival rate of calves from birth to weaning was significantly affected by calf's birth weight. Vaccaro (1974) suggested that birth weight may be an important factor in influencing mortality rate of calves. He attributed low birth weights of calves in the tropics to wide-spread mismanagement of dry periods and undernutrition of pregnant cows. Association between calf birth weight and calf mortality rate was reported by Singh and Parekh (1982). They estimated a correlation coefficient between mean birth weight of calves and mortality rate of calves of 0.304 and 0.204 in female and male calves, respectively. Insignificant effect of calf birth weight on either perinatal or postnatal viability of calves has been reported by Rao and Nagarcenkar (1980).

Non-genetic factors relating to maternal effects such as age and weight of dam at calving have been known to influence viability of calves. Ngere et al. (1973) reported that cows calving at 5 years of age or at younger age tended to lose significantly more calves (15.2%) than cows calving at over 5 years (13.4%). Frisch (1973) and Laster and Gregory (1973) indicated significant effect of age of dam at calving perinatal and early postnatal viability of calves. Srivastava and Agarwala (1973) reported that weight of dam at calving, significantly influenced viability of dairy calves upto one month of age.

Ngere et al. (1973) had reported that parity was a source of variation in mortality rate of dairy calves. They found that losses of calves during first parity were higher than that for later parities. Trail and Gregory (1981) reported a significant influence of parity on viability of calves, their results revealed a tendency of higher level of calf survival in later parities. Rao and Nagarcenkar (1980) reported highest mortality of dairy calves born to primiparous animals compared with cows in higher parities.

Pneumonia and gastroenteritis have been identified as major calf killer diseases in India(Sharma and Jain, 1976). Vaccaro and Vaccaro (1981) considered pneumonia and diarrhoea as principal causes of mortality in dairy calves. Similar diseases causing deaths in dairy calves have been reported by Srivastava and Agarwala (1973), Tomar (1973), and Vaccaro (1974). Srivastava and Sharma (1980) reported gastroenteritis including collibacillosis and colisepticaemia, and lastly pneumonia, in that order of importance, as common causes of death in dairy calves.

Certain managerial practices appear to be associated with variation in death rate of calves. High mortality rates in dairy calves have been recorded in herds where calves were left to suckle their dams (Vaccaro, 1974). In the same study he noted that the use of nurse cows reduced calf losses as well as rearing costs. In Nigeria, Umoh (1982) reported that bucket - fed calves had significantly higher mortality rates than suckling calves. Maltos et al. (1970) suggested that calf losses need not be excessive if calves are accustomed very gradually to the stress of hot, humid climate and to parasite load of pastures. This may be of particular importance to European dairy calves, their higher grades and crossbreds, which are reported to be more susceptible to certain tropical diseases (Maltos et al., 1970).

3.0 MATERIALS AND METHODS

3.1 Source of data

Data used in this study was extracted from cattle records kept between 1970 and 1985 at Livestock Production Research Institute, Mpwapwa.

3.1.1 Description of site

Livestock Production Research Institute is situated in Central Tanzania at latitude 6° 20'S and longitude 36° 30'E. For the period of study, 1970 to 1985, average minimum temperature was 15.5°C, the coolest month being August (13.8°C). The average maximum temperature was 27.5°C, and November with a mean monthly temperature of 30.2°C was the hottest month. The average annual rainfall is 745.5 mm with a range from 344.3 mm to 1160.2 mm. Rainfall varies greatly in distribution and amount from year to year. About 90% of it falls between the months of December and April. There are two distinct seasons, wet and dry season. Wet season commences in December and ends in April, while dry season extends from May to November.

The site of study falls under ecological zones IV and V (Pratt and Gywne, 1977). The institute's farm comprises an area of about 2000 hectares and is at an altitude of about 1000 metres above sea level. The institute is located in the semi-arid zone, but the hills surrounding the farm reduces the adverse effects of climate. The natural vegetation at the farm consists of deciduous trees of the species of *Acacia*, *Cassia*, Commiphora and Lannea. The natural pasture species are of Setaria Brachiaria, Heteropogon, Panicum, Cynodon and Hyperrhenia. The cultivated and improved pastures are mainly Chloris gayana Cenchrus ciliarias and Medicago sativa.

The main research conducted at the institute is breeding and selection of Mpwapwa cattle for milk and meat production. Research in ruminant nutrition and pastures is also conducted at the institute.

3.2 Genotypes and management of cattle

3.2.1 Livestock Breeding Project No. 3 (L.B.3)

The cattle used in this study were from a breeding project known as Livestock Breeding Project No. 3 (L.B.3). The purpose of this project was to develop a dual-purpose type of cattle for Tanzanian conditions. Formation of such cattle was aimed at having cattle genotype which could sustain semi-arid conditions of Central Tanzania where the crossbreds (Bos taurus x TSZ) and purebreds (Bos taurus) had failed to adapt. The project (L.B.3) was initiated in early 1920s and crossbreeding between Bos taurus dairy breeds and TSZ, Boran and Ankole was done. Inclusion of improved Bos indicus breeds, Sahiwal and Red Sindhi in L.B. 3 project was done to dilute the level of Bos taurus "blood". The composite breed was finally closed in 1958 and named "Mpwapwa breed" after the place of its founding. The milk production target for Mpwapwa breed was set at 2300 kg per lactation. Target for meat production was set at 230 kg carcass weight at 4 years of age on natural pastures only.

Selection for high milk production among Mpwapwa cows was done once monthly by assessing lactation records of cows that were dried during the month. Selection of sires was based on records of its dam, sire and grand parents at birth, and their own performance on growth. Cows culled from the project included those with lactation length of less than 84 days and those producing below 1000 kg of milk in one lactation. Culling was also done for cows with damaged teats, bad temperament and chronic wasting diseases.

The genetic constitution of Mpwapwa breed has varied slightly between 1958 and 1966. The 1966 breed composition has not changed to date as there has been no new germplasm incorporated into Mpwapwa breed. The breed composition of Mpwapwa is given in Table 9.

Table 9 : Mpwapwa breed composition

Breed	% in 1958	% in 1966
Sahiwal	20	30
Red Sindhi	35	32
Tanzania Shorthon Zebu	20	19
Boran	10	11
Ankole	5	-
Ayrshire	10	8

Source : LPRI (1985)

3.2.2 Mpwapwa cattle and their crosses

Genotypes of cattle used in the present study as Mpwapwa cattle and their crosses with *Bos taurus* dairy breeds. Mpwapwa cattle are mostly light brown in color, humped, and larger in size to an average TSZ cattle. Main distinguishing features of Mpwapwa cattle are large ears and pendulous udder. Mpwapwa cattle tends to resemble Sahiwal cattle due to larger proportion of Sahiwal genes (30%).

Since 1968, Mpwapwa cattle with 8% *Bos taurus* breeding have crossed with *Bos taurus* dairy breeds, Friesian, Jersey and Ayrshire. Such crossbreeding was intended to produce crossbreds with higher proportion of *Bos taurus* genetic material so as to compare with Mpwapwa cattle. Three *Bos taurus* dairy breeds used were intended for comparison among them in order to choose a suitable *Bos taurus* breed to be used for future crossbreeding. The F_1-crossbreds resulting from *Bos taurus* x Mpwapwa crossing are referred to as F_1-crosslines. They have 54% *Bos taurus* genetic proportion. The three F_1-crosslines, thus formed are ½ Friesian ½ Mpwapwa, ½ Jersey ½ Mpwapwa and ½ Ayrshire ½ Mpwapwa.

From 1975 onwards, other genotypes were produced by backcrossing F_1-crosslines to Mpwapwa breed. F_1-crossline were used as dams and Mpwapwa were sires, resulting in backcross offsprings having 31% *Bos taurus* genetic proportion. The intention for producing Backcrosses was to compare cattle having lower *Bos taurus* genetic proportion to 54% of the crosslines. The genotypes considered in the present study were grouped as follows :

Mpwapwa cattle having 8% *Bos taurus*

F_1-crosslines having 54% *Bos taurus*; and

Backcrosses having 31% *Bos taurus*

3.2.3 Management of cattle

Male and female calves born in wet and dry season were subjected to a standard management level. They received colostrum within 24 hours of birth, and identification was done using metal ear-tags and ear-tatooing. Birth weight was also recorded within 24 hours of birth. After separation from their dams at 36 hours of life, calves were reared indoors in individual calf pens. Indoor calves were bucket-fed whole milk, two litres twice a day up to weaning age at 75 days. In addition calves were given little concentrate feed and hay. Weaned calves grazed on improved pastures and were fed on one kilogram of concentrate feed per calf per day up to one year of age. Calf weights were recorded at weaning, 252, 504 and 756 days of age.

Heifers were either mated to the bull or inseminated artificially once they attained liveweight of 200 kg, which was about 756 days of age. Stud bull prospects were picked at birth on basis of their pedigree's performance in terms of milk production. Final selection was on the basis of their growth to 72 weeks of age by liveweight ranking order at the age of 72 weeks. Breeding of cattle at the institute was seasonal. The two breeding seasons, each lasting 70 days were from March to mid May and the other from September to mid - November. The resulting calvings were from December to February and from June to August for the two breeding seasons. Breeding animals were weighed before and after mating and at calving. Pregnancy was diagnosed by rectal palpation method at least 60 days after the end of breeding season.

Pregnant heifers due to calve in about two months were put through the lactation unit with milking cows to get them used to milking procedures. Most of the cows and first calvers were machine milked twice a day, while cows with poor teats were hand milked. Concentrates fed during milking time were about four kilograms per cow per day. Standard management and feeding were practiced for all milking cows irrespective of their performance. Milking animals depended on pastures mainly, mineral and vitamin supplements were provided when necessary.

Disease control measures included vaccinations against Anthrax, Blackquarter, Haemorrhagic Septicaemia and Foot and Mouth disease. Heifer calves were vaccinated against Brucellosis at the age of 6 - 8 months. Deworming to control interval parasites was done twice every year. Tick diseases and other external parasites were controlled by dipping once weekly using Toxaphene acaricide. Common cattle diseases occuring at the institute were pneumonia and gastroenteritis in calves, and mastitis, metritis and ephemeral fever in cows.

3.3 Type of data collected

Information from each cow and heifer included records relating to age at first calving, calving interval, dry period, days open, lactation milk yield and lactation length. The information also included on breeding records and results of pregnancy diagnosis for each cow and heifer in the study. For each calf born, data collected included genotype, birth date and birth weight, sex, age of dam and age at death.

3.3.1 Age at first calving

The age at which a heifer calves for the first time is known as age at first calving. Age at first calving was obtained by calculating the number of days from birth to first calving date. The reproductive parameter, age at first calving considered in the present study was investigated for possible factors influencing it and its association with milk production and reproductive efficiency traits. Genetic group, year of birth and season of birth were the factors considered to affect age at first calving.

Genetic group studied as a factor influencing age at first calving consisted of cattle of three genotypes, Mpwapwa breed, F_1-crosslines and Backcrosses, having 8%, 54% and 31% *Bos taurus* proportion, respectively. Year of birth considered as a factor consisted of a period of 12 years, 1970 to 1981. Season of birth included two seasons of birth for the heifers. extending from December to February and from June to August for wet and dry seasons, respectively.

3.3.2 Reproductive efficiency traits

The reproductive efficiency traits investigated in the present study were calving interval, dry period, days open and conception rate. The study included investigation of factors influencing these traits and their relationships with milk production traits.

Calving interval is the interval between two consecutive calvings. The components of CI are days open and gestation length. Calving interval can also be divided into lactation length and dry period. For a cow calving more than once, the CI was obtained by :

CI (days) - Age at current calving - Age at previous calving

Dry period is the interval between ceasation of previous milking to the commencement of current milking. For computation of DP, the following formula was used :

DP (days) = Calving interval - lactation length

Days open is the interval from previous calving to date of conception expressed in number of days. The components of days open include postpartum interval and service period. Days open can also be stated as the period calving when the cow is ready for successful mating. Days open were computed as difference between the gestation length and the calving interval. The standard gestation length of 280 days for cattle was used in calculating days open.

Conception rate is defined as the number of heifers and cows that become pregnant from total number of females mated. Conception rate was calculated after obtaining pregnancy diagnosis results for the heifers and cows mated. Conception rate was computed for different subclasses of factors influencing it. For computation of conception rate (%), the formula used was :

$$CR\ (\%) = \frac{\text{Number of pregnant females}}{\text{Total number of females exposed to the bull or inseminated artificially}} \times 100$$

For the reproductive efficiency traits, CI, DP, days open and CR, the classification of genetic and non-genetic factors influencing these traits were as follows :

Genetic groups (G) : Three genetic groups of cattle with varying proportion *Bos taurus* genetic material were Mpwapwa, F_1-crossline and backcrosses. (3 subclasses).

Year (A) : Year of calving and mating considered in this study is for 15 years period. Year 1 denotes the period from March 1970 to February 1971; Year 2 denotes the period from March 1971 to February 1972, . . . , Year 15 denotes the period from March 1984 to February 1985. (15 subclasses).

Seasons (S) : Heifers and cows calved during both wet and dry seasons. For seasons of calving; S_1 denotes the wet season (December to February), and S_2 denotes the dry season (June to August). (2 subclasses).

Mating seasons (M) : M_1 denotes mating season from March to mid-May (wet) and M_2 denotes mating season from September to mid-November (dry). (2 subclasses).

Ages of heifers and cows (D) : Ages of heifers and cows at mating and calving ages were grouped into 4 groups where D_1, D_2, D_3 and D_4 denotes, ages below 4 years, 4 - 5, 6 - 7 and $\geq$ 8 years, respectively. (4 - subclasses).

Parities (P) : P_1 denotes first parity, P_2 denotes second parity, ... P_5 denotes fifth parity (5 subclasses).

Weights of heifers and cows at mating (W) : W_1 denotes the liveweights of females at mating of < 250 kg. W_2, W_3 and W_4 denotes liveweight of females at mating of 250 - 300 kg, 301 - 350 kg and $\geq$ 351 kg, respectively. (4 subclasses)..

Type of mating (T): T_1 denotes the use of natural service for mating and T_2 denotes the use of artificial insemination during breedin season. (2 subclasses).

Factors investigated as influencing CI, DP and days open were genetic group, year of calving, season of calving, age of heifer/cow and parity. Factors studied that influenced CR were genetic group, year of mating, season of mating, age of heifer/cow at mating, weight of females at mating and type of mating used.

Milk production records considered in the present study were lactation milk yields and lactation lengths. Milk from cattle was recorded twice a day, in the morning and in the evening.

3.3.3 Viability of calves:

Viability of calves at a designated age can be defined as the number of calves that survived out of the total number of calves born. For computation of viability at the three designated ages in this study, the following formula was used:

$$\text{Viability (\%)} = \frac{\text{Number of calves surviving up to designated age} \times 100}{\text{Total number of calves born or exposed to risk}}$$

Genetic groups: Three genetic groups of calves were Mpwapwa, F_1-crosslines and Backcrosses.

Year : Year of birth of calves, (15 years, 1970 - 1984)

Season : Season of birth of calves (2 seasons).

Sex : Sex of calf (male, female)

Birth weight : 3 groups < 20, 20 - 30 and $\geq$ 30 kg

3.4 Statistical analysis

The effects of year of birth, season of birth and genetic group on age at first calving was estimated by assuming the following linear model to represent the data :

$$Y_{ijkl} = \mu + A_i + S_j + G_k + e_{ijkl}$$

where :

Y_{ijkl} = the observation of the l^{th} heifer, born in i^{th} year j^{th} season and of k^{th} genetic group

μ = overall mean

A_i = effect of the i^{th} year of birth, i = 1, 2, . . . , 12

S_j = effect of the j^{th} season of birth, j = 1, 2

G_k = effect of the k^{th} genetic group, k = 1, 2, 3

e_{ijkl} = random error element associated with the record Y_{ijkl}

The linear model used included fixed effects of year of birth, season of birth and genetic group.

The effects of year of calving, season of calving, genetic group, age at calving and parity on the reproductive efficiency traits, (CI, DP and days open) was estimated by assuming the following linear model to represent the data :

$$Y_{ijklmn} = \mu + A_i + S_j + G_k + D_l + P_m + e_{ijklmn}$$

where :

Y_{ijklmn} = the observation of the n^{th} cow calved in the i^{th} year, j^{th} season, of k^{th} genetic group, l^{th} age at calving and m^{th} parity at calving.

μ = overall mean

A_i = effect of the i^{th} year of calving, 1, 2, . . . , 15.

S_j = effect of the j^{th} season of calving, j = 1 , 2.

G_k = effect of the k^{th} genetic group, k = 1, 2, 3,.

D_l = effect of the l^{th} age at calving, l = 1, 2, . . . 5.

P_m = effect of the m^{th} parity at calving, m = 1, 2, . . 5.

e_{ijklmn} = random error element associated with the record Y_{ijklmn}.

The linear model used included fixed effects of year of calving, season of calving, genetic group, age and parity.

The computer used was PDP - 11/23 mini-computer system at Sokoine University of Agriculture, Morogoro. The number of observations per cell are given in Appendix Table 1. Analysis of variance (ANOVA) was carried out on age at first calving, CI, DP and days open. Duncan's new multiple range test (Steele and Toorie, 1980) was used to compare subclass means where significant difference was observed in the factors with five or less level, such as season, genetic group age of cow and parity.

The influence of reproductive traits on milk production traits was estimated by fiting regression equations with lactation milk yield and lactation length being dependent variables and age at first calving, preceding reproductive efficiency traits (CI, DP and days open), and concurrent CI and days open being independent variables.

The regression model used was :

$\hat{Y} = a + bx$

where :

$\hat{Y}$ = dependent variable (lactation milk yield, lactation length)

a = constant

b = regression coefficient

x = independent variable - - (age at first calving, CI, DP, days open)

Correlation coefficients between milk production traits, lactation milk yield, lactation length and age at first calving, preceding CI, DP and days open were computed. Correlation coefficients between milk production traits and concurrent CI and days open also computed. Relationships among reproductive traits were studied by computing correlation coefficients between the traits.

The estimates of repeatability of CI, DP and days open were calculated as intraclass correlation given by the following formula (Pirchner, 1969):

$$r = \frac{V (P)}{V (P) + (T)}$$

where :

r = repeatability estimate

V (P) = variance due to permanent differences in performance between individuals

V (T) = variance due to temporary differences in performance between individuals in various periods.

The components of variance were estimated using methods described by Becker (1967) for samples of unequal size.

The effects of year and season of mating, genetic group, and weight at mating, and type of mating on CR were investigated using Chi-square test, as described by Snedecor and Cochran (1980). Chi-square test was also used to investigate influence of year and season of birth, genetic group, sex and birth weight of calves on viability of calves at one month, weaning and at one year of age.

The following asterisks represent the given levels of statistical significance:

*** - (P < 0.001) ;   ** - (P < 0.01) ;   * - (P < 0.05);

and NS - Non significant (P > 0.05).

4.0 RESULTS

4.1 Age at first calving

Mean age at first calving ranged from 1050.68 ± 22.35 to 1375.01 ± 26.17 days. The overall mean age at first calving was 1251.63 ± 10.84 days. Mean values of age at first calving under different subclasses are presented in Table 10 and in Appendix Table 2. The results of analysis of variance for age at first calving are presented in Appendix Table 3. The year of birth significantly ($P < 0.001$) affected age at first calving. There was lack of general trend in the age at first calving in relation to year of birth. Age at first calving was significantly ($P < 0.001$) influenced by the genetic group. Age at first calving tended to decrease as the *Bos taurus* genetic proportion increased in the genetic groups. F_1-crosslines with mean age at first calving of 1137.06 ± 27.01 days had significantly ($P < 0.001$) lower age at first calving than Backcross and Mpwapwa heifers. Season of birth had non significant effect on age at first calving.

4.1.1 Relationship with milk production and reproductive traits

The effects of age at first calving on milk production and reproductive traits are presented in Table 11 and in Appendix Table 4. Age at first calving significantly ($P < 0.01$) influenced lactation milk yield and lactation length, pooled over the first five parities. Age at first calving

Table 10 : Means and standard errors for age at first calving by genetic group and season

	n	Age at first calving (days)
Overall mean	336	1251.63 ± 10.84
<u>Genetic groups</u>		
Mpwapwa	164	1371.12 ± 14.21[a]
F_1 - crossline	65	1137.06 ± 27.01[b]
Backcross	107	1224.31 ± 16.48[c]
<u>Seasons</u>		
Wet	158	1269.87 ± 15.62
Dry	178	1236.56 ± 1498

Means within a column of a factor - class with different superscripts differ significantly.

n – indicates number of observations

Table 11 : Linear regression coefficients (b) showing the influence of age at first calving on the milk production and on reproductive efficiency parameters

Parameters (Y)	Age at first calving (X)	
	b $\pm$ S.E.b.	Correlation coefficient(r)
Milk production		
Lactation yield	$- 0.43 \pm 0.12^{**}$	$- 0.11^{**}$ (1093)
Lactation length	$- 0.24 \pm 0.01^{**}$	$- 0.09^{**}$ (1093)
Reproductive efficiency		
Calving interval	$0.47 \pm 0.02^{*}$	0.09^{*} (704)
Dry period	$0.46 \pm 0.02^{*}$	0.08^{*} (704)
Days open	$0.43 \pm 0.02^{*}$	0.08^{*} (704)

X Independent variable - age at first calving

Y Dependent variables - for first five lactation yields, lactation lengths, CIs, DPs and days open

S.E.b - Standard error of regression coefficient.

Figures in parentheses indicates the number of observations had non significant effect on first lactation milk yield and length. The influence of age at first calving on lactation milk yield was significant at second, third and fourth parity (Appendix Table 4). Correlation coefficient between age at first calving and lactation milk yield pooled over the first five parities was - 0.11 ($P < 0.01$). The correlation coefficients between age at first calving and lactation lengths at first and fifth parities were non significant and negative, and significant at second and fourth parities only.

Age at first calving significantly ($P < 0.05$) influenced CI, DP and days open (Table 11). For every 100 days increased in age at first calving, CI, DP and days open, pooled over for first five parities increased by 47, 46 and 43 days, respectively. The correlation coefficients between age at first calving and CI, DP and days open were 0.09, 0.08 and 0.08, respectively.

The following regression equations were obtained when lactation milk yield and lactation length,pooled over the first five parities were regressed on age at first calving :

$$Y_1 = 2214.67 - 0.43x$$

$$Y_2 = 301.91 - 0.24x$$

where :

Y_1 = lactation milk yield

Y_2 = lactation length

x = age at first calving

4.2 Calving interval

Mean values of CI under different subclasses are presented in Table 12 and in Appendix Table 5. The overall mean CI was 427.92 ± 4.38 days. The results of analysis of variance for CI are presented in Appendix Table 6. Year of calving significantly ($P < 0.001$) influenced CI. The means of CI over the years of calving ranged from 394.5 ± 19.08 to 58.92 ± 53.81 days. The trend for CI over years of calving was that it decreased as the years of calving progressed from 1970 to 1985. Genetic group of cows significantly ($P < 0.001$) influenced CI. Backcross cows had shorter ($P < 0.001$) CI than F_1-crossline and Mpwapwa cows by 13.68 and 47.04 days, respectively. Season of calving, age of cow and parity had non significant ($P > 0.05$) effect on length of CI.

The repeatability estimate for CI (overall) was 0.07 ± 0.05. Repeatability estimates for CI of Mpwapwa, F_1-crossline and Backcross cows are presented in Table 13.

4.2.1 Relationship with milk production and reproductive traits

Mean values of lactation milk yield and lactation length under the subclasses of genetic group, season of birth, age at calving, and parity are presented in Table 14.

Influences of preceding and concurrent CI on lactation milk yield and lactation length are presented in Table 15 and in Appendix Tables 8 and 9. Preceding CI significantly

Table 12 : Means and standard errors for reproductive efficiency traits by genetic group, season, age and parity

	n	Days: Calving interval	Dry period	Days open
Overall mean	704	427.92 ± 4.38	148.35 ± 4.76	153.39 ± 4.78
Genetic groups				
Mpwapwa	371	446.45 ± 6.77[a]	172.46 ± 7.18[a]	167.33 ± 7.59[a]
F_1-crossline	191	413.09 ± 7.05[b]	117.08 ± 7.28[b]	132.88 ± 7.06[b]
Backcross	142	399.41 ± 7.57[c]	127.42 ± 9.38[b]	118.43 ± 7.51[c]
Seasons				
Wet	366	426.76 ± 5.89	148.62 ± 6.48	148.24 ± 6.04
Dry	338	429.16 ± 6.54	148.06 ± 7.02	158.97 ± 7.51
Age at calving				
< 4 years	236	438.01 ± 8.12	166.71 ± 8.92	166.33 ± 9.22
4-5 years	270	425.79 ± 7.09	140.93 ± 7.43	151.61 ± 7.71
6-7 years	152	415.47 ± 7.49	132.81 ± 8.71	137.61 ± 7.57
≥ 8 years	45	429.78 ± 20.69	149.27 ± 21.19	149.78 ± 20.72
Parities				
1	278	438.41 ± 7.57	166.28 ± 8.25	165.46 ± 8.43
2	179	424.59 ± 8.77	141.15 ± 9.16	154.72 ± 9.89
3	113	420.21 ± 9.41	137.24 ± 10.68	140.76 ± 9.47
4	80	412.18 ± 9.59	124.45 ± 10.64	132.39 ± 9.63
5	54	424.32 ± 17.71	138.57 ± 18.56	144.37 ± 17.71

Means within a column of a factor - class with different superscripts differ significantly.

n - indicates the number of observations common to calving interval, dry period and days open.

Table 13 : Repeatability estimates for calving interval, dry period and days open of cattle at Mpwapwa

	n	m	Repeatability estimate $\pm$ standard error		
			Calving interval	Dry period	Days open
Overall	175	595	0.07 ± 0.05 (NS)	$0.21 \pm 0.05^{***}$	$0.12 \pm 0.04^{**}$
Genetic group					
G_1 (Mpwapwa)	97	310	0.05 ± 0.06 (NS)	$0.16 \pm 0.06^{**}$	0.06 ± 0.06 (NS)
G_2 (F_1-crossline)	42	168	0.11 ± 0.08 (NS)	0.07 ± 0.06 (NS)	0.07 ± 0.06 (NS)
G_3 (Backcross)	36	117	$0.22 \pm 0.11^{*}$	0.01 ± 0.02 (NS)	0.15 ± 0.11 (NS)

n - indicates the total number of cows

m - indicates the total number of observations

Table 14 : Means and standard errors for milk production traits by genetic group, season, age and parity

	n	Lactation milk yield (kg)	Lactation length (days)
Overall mean	1093	1659.14 ± 26.92	271.37 ± 1.75
Genetic groups			
Mpwapwa	572	1446.57 ± 37.48[a]	263.57 ± 2.65[a]
F_1-crossline	278	2209.35 ± 52.08[b]	288.24 ± 2.44[b]
Backcross	243	1530.06 ± 37.56[c]	270.41 ± 3.64[a]
Seasons			
Wet	580	1613.77 ± 31.82	266.98 ± 2.56[a]
Dry	513	1710.43 ± 44.59	276.32 ± 2.33[b]
Age at calving			
< 4 years	556	1490.12 ± 39.41[a]	268.89 ± 2.68
4-5 years	340	1716.11 ± 42.07[b]	270.28 ± 3.06
6-7 years	152	2023.03 ± 70.33[c]	279.25 ± 3.36
≥ 8 years	45	2087.82 ± 107.35[c]	283.38 ± 6.69
Parities			
1	336	1457.93 ± 47.36[a]	267.57 ± 3.43
2	280	1779.35 ± 45.11[b]	273.73 ± 3.11
3	233	1985.05 ± 55.68[c]	275.81 ± 3.34
4	190	2089.71 ± 60.61[c]	277.23 ± 3.08
5	54	2420.11 ± 115.26[d]	292.21 ± 5.06

Means within a column of a factor - class with a different superscripts differ significantly.

n - indicates the number of observations common to lactation milk yield and lactation length.

($P < 0.05$) influenced lactation milk yield, pooled over the first five parities. CI significantly ($P < 0.05$) influenced lactation milk yield and lactation length at first and second parity only (Appendix Table 8).

Concurrent CI significantly ($P<0.01$) influenced lactation milk yield pooled over first five parities. The influence of concurrent CI on lactation milk yield was significant ($P<0.01$) at parities third and fourth only (Appendix Table 9). Concurrent CI had non significant ($P>0.05$) effect on lactation length pooled over for first five parities. The regression coefficients and constants of the linear regression equation : $\hat{Y} = a + bx$, for the effects of preceding and concurrent CI on milk production traits are presented in Appendix Table 9 .

Correlation coefficients between CI and milk production traits are presented in Tables 16 and 17. CI was significantly ($P<0.05$)correlated with subsequent lactation milk yield and lactation length, the correlation coefficients were 0.12 and 0.09. The correlation coefficients between preceding CI and lactation milk yield were significant ($P < 0.05$) at first and second parity only (Appendix Table 10). Correlation coefficients between concurrent CI and lactation milk yield were significant at parities third and fourth only (Appendix Table 11).

Calving interval was positively and significantly($P < 0.001$) correlated with concurrent dry period and days open.

Table 15 : Influence of preceding and concurrent calving interval, dry period and days open on lactation milk yield and lactation length

		Regression coefficients[1]	
Preceding	n	Lactation milk yield	Lactation length
Calving interval	704	0.42 ± 0.16*	0.45 ± 0.07**
Dry period	704	- 0.26 ± 0.08 NS	- 0.22 ± 0.06 NS
Days open	704	0.32 ± 0.14*	0.34 ± 0.02*
Concurrent			
Calving interval	697	0.46 ± 0.08**	0.22 ± 0.01 NS
Days open	697	0.15 ± 0.02 NS	- 0.03 0 0.01 NS

[1]Regression coefficients computed from data pooled over first five parities

n - denotes number of pairs of observations

Table 16 : Correlation coefficients[1] between reproductive efficiency traits[2] and subsequent milk production traits[3]

	Dry period	Days open	Lactation	
			Length	Milk yield
Calving interval	0.89*** (704)	0.85*** (704)	0.12** (704)	0.09* (704)
Dry period		0.77*** (704)	- 0.06 NS (704)	- 0.07 NS (704)
Days open			0.08* (704)	0.09* (704)
Lactation length				0.51*** (1093)

[1] Correlation coefficients between traits pooled over for first five parities.

[2] Correlation between concurrent calving interval and dry period and days open; and between days open and subsequent dry period .

[3] Relationship between concurrent lactation length and lactation milk yield

Figures in parentheses indicate the number of pairs of observations

Table 17 : Correlation coefficients[1] between concurrent calving interval, days open and milk production traits

	Lactation	
	Length	Yield
Calving interval	0.06 NS	0.08*
	(697)	(697)
Days open	- 0.07 NS	0.03 NS
	(697)	(697)

[1]Correlation coefficients between traits pooled over for first five parities

Figures in parentheses indicate the number of pairs of observations

4.3 Dry period (DP)

The overall mean DP for all the cows in the study was 148.35 ± 4.76 days. Mean values of dry period under different subclasses are presented in Table 12 and in Appendix Table 5. Year of calving and genetic group significantly ($P < 0.001$) influenced length of DP (Appendix Table 6). Dry period tended to decrease as the year of calving progressed from 1970 to 1985. Mean DP ranged from 102.88 ± 17.78 to 369.43 ± 42.71 days for year 14 and 1 of calving, respectively. Length of DP tended to decrease as the *Bos taurus* genetic proportion increased in the genetic groups. F_1-crossbred cows had a shorter DP of 117.08 ± 7.28 days compared to Backcross and Mpwapwa cows.

Season of calving, age at calving and parity had non significant effect on DP. Dry period showed a tendency to decrease with increasing age of cow and parity up to 7 years of age and fourth parity, thereafter the length of DP increased.

Repeatability estimates for DP was 0.21 ± 0.05 ($P < 0.001$). The estimates of repeatability under genetic groups are presented in Table 13.

4.3.1 Relationship with milk production traits and days open

Dry period had no significant influence on subsequent lactation milk yield and lactation length (Table 15). The influences of DP on lactation milk yield and lactation length at first to fifth parity are presented in Appendix Table 8 .

The correlation coeffcients between preceding DP and lactation milk yield pooled over first five parities of - 0.06 was not significant (Table 16). Correlation coefficients between preceding DP and lactation milk yield and lactation length at first to fifth parities are presented in Appendix Table 10. First and second DPs had positive but non significant correlation with lactation milk yield.

4.4 Days open

The mean values of days open under different subclasses are presented in Table 12 and Appendix Table 5 . The results of analysis of variance for days open are presented in Appendix Table 6. The overall mean days open was 153.39 $\pm$ 4.78 days.

Days open was significantly ($P < 0.001$) influenced by year of calving. The range of days open over years of calving was from 114.5 $\pm$ 19.08 to 299.01 $\pm$ 54.35 days for the mean of 14^{th} and 2^{nd} years of calving, respectively. There was lack of general trend for days open and year of calving. Genetic group had significant ($P < 0.001$) effect on days open. Back-cross cows had shorter ($P < 0.001$) days open than the F_1 - crossline and Mpwapwa cows by 14.45 and 48.9 days, respectively. Days open showed a tendency to decrease with increase in age of cow.

The overall repeatability estimate for days open was 0.12 $\pm$ 0.04 ($P < 0.01$). The repeatability estimates for days open under the genetic groups of Mpwapwa, F_1 - crossbred and Backcross, are presented in Table 13.

4.4.1 Relationship with milk production traits

Influence of preceding and concurrent days open on milk production traits are presented in Table 15 and Appendix Tables 8 and 9 . Days open significantly ($P < 0.05$) influenced subsequent lactation milk yield and lactation length, pooled over first five parities. The influence of days open on subsequent lactation milk yield was significant in first and second parity only. Lactation lengths at second and third parities were significantly ($P < 0.05$) influenced by preceding days open.

The influence of concurrent days open on lactation milk yield pooled over first five parities was positive and non significant. Concurrent lactation length was not influenced significantly by days open pooled over first five parities. Lactation milk yield was significantly ($P < 0.05$) influenced by preceding days open at first parity only (Appendix Table 9): .

The correlation coefficients between days open and milk production traits are presented in Tables 16 and 17 and in Appendix Tables 10 and 11 . Overall correlation coefficient between preceding days open and lactation milk yield pooled over first five parities was significant ($P < 0.05$). Days open and subsequent lactation milk yield were significantly correlated at first and second parity only. The correlation coefficients between days open and subsequent lactation length of 0.18 and 0.18 for parities second and third, respectively, were significantly different from zero ($P < 0.05$). Concurrent days open and lactation milk yield were significantly correlated at parities first and third only. Negative and non significant correlations between concurrent days open and lactation length of - 0.08, 0.02, - 0.13 and - 0.03 were found at first, second, third and fifth parities, respectively.

4.5 Conception rate (CR)

The overall mean conception rate was 53.89%. The mean values and the results of Chi-square test of conception rate under different subclasses are presented in Table 18 and in Appendix Table 5. The year of mating significantly ($P < 0.01$) affected the CR of heifers and cows. Conception rate over years mating ranged from 43.21% to 66.67%, the means for year 10 and 4 of mating, respectively. The lack of general trend between CR and year of calving (annual rainfall) is shown in Figure 1. Genetic group had no significant effect on CR. Conception rate tended to increase with increase in *Bos taurus* blood. F_1-crossline heifers and cows with mean CR of 56.21% exceeded the CRs of Backcross and Mpwapwa females by 0.12% and 3.38%, respectively.

Type of mating significantly ($P < 0.01$) influenced CR. Natural service of cattle resulted in high CR of 55.71% than that by artificial insemination having CR of 48.53%.

Table 18 : Mean conception rates by season, genetic group, type of mating, age and weight at mating

	n	Conception rate (%)	Chi-square value
Overall mean	5727	53.89	
Season			0.57 NS
(wet)	2997	53.19	
(dry)	2730	54.65	
Genetic group			2.55 NS
(Mpwapwa)	3907	52.83	
(F_1-crossline)	975	56.21	
(Backcross)	845	56.09	
Type of mating			10.69**
(natural)	4318	55.71	
(AI)	1409	48.33	
Age at mating			9.84*
(< 4 years)	2282	52.19	
(4 - 5 years)	1552	54.57	
(6 - 7 years)	872	60.44	
(≥ 8 years)	1021	51.03	
Weight at mating			67.99***
(< 250 kg)	1245	38.88	
(250 - 300kg)	1540	58.90	
(301 - 350 kg)	1587	58.98	
(≥ 351 kg)	1355	56.01	

n - denotes number of females exposed to bull or artificially inseminated.

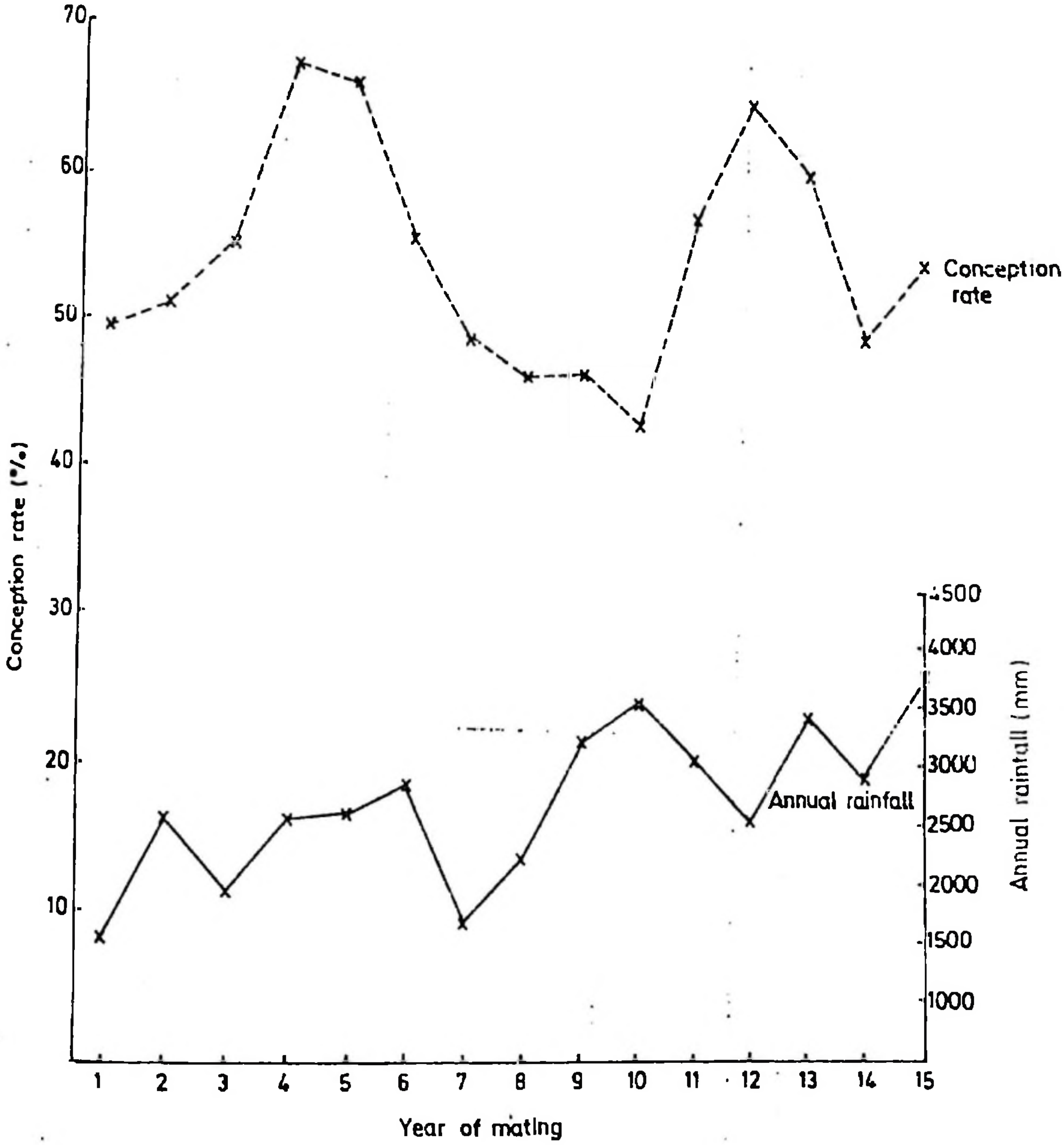

Fig. 1 : The effect of year of mating on conception rate and on annual rainfall

Conception rate was significantly ($P < 0.05$) affected by age of heifer/cow at mating. The trend of CR and age of heifer/cow was that it increased as the age of the heifer/cow increased up to 7 years of age, then declined. Weights of heifers . .. , and cows at mating with a high Chi-square value of 67.99, significantly ($P < 0.001$) affected CR. Heifers and cows with less than 250 kg weight at mating had lowest mean CR of 38.88%, and highest mean CR of 58.98% was obtained in heifers and cows with weights ranging from 301 to 350 kg. Season of mating had non significant effect on CR.

4.6 Viability of calves

The mean values of viability of calves at different ages and by various subclasses are presented in Table 19 and in Appendix Table 12. The overall mean viability of calves at 1 month age was 97.14%. Mean viability of calves at different ages over years of birth are represented in Figure 2. Year of birth with Chi-square value of 0.41 had non significant effect on viability of calves up to 1 month age. The mean viability at the age of one month ranged from 94.62% to 99.37% for years of birth. Genetic group, season of birth, sex and birth weight of calves had non significant effect on viability of calves from birth to 1 month of age. Backcross calves had lower mean mortality at one month age than F_1 - crossline and Mpwapwa calves by 1.04% and 2.47%, respectively. Viability of calves at one month age tended to increase with increase in birth weight of calves. Calves with less than 20 kg birth weight had viability of 89.52%

compared to calves with $\geq$ 31 kg having viability of 98.84%, at one month age.

The overall mean viability of calves from birth to weaning age was 93.77%. Year of birth, season, genetic group and sex had non significant effect on viability up to weaning age. Birth weight of calves significantly ($P < 0.05$) affected viability of calves from birth to weaning age. Calves with lower birth weights ($<$ 20 kg) had significantly ($P < 0.05$) lower viability of 81.19% up to weaning age than the calves with higher birth weights, ($\geq$31 kg) having viability of 96.72%.

The overall mean viability up to one year age was 87.28%. Year of birth had non significant effect on viability of calves up to one year of age. The range of mean viability of calves from birth to 1 year of age over years of birth was from 80.23% to 94.3%. Season of birth, genetic group, sex and birth weight of calves had non significant influence on viability of calves upto one year age. More F_1 - crossline calves tended to survive up to 1 year age than the Backcross and Mpwapwa calves by 1.81% and 5.41%, respectively.

For the periods, one month age to weaning age (I) and weaning age to one year age (II), the overall mean viability of calves were 96.54% and 92.08%, respectively. Year of birth, season, genetic group, sex and birth weight of calves had non significant effect on viability of calves in both periods (I and II).

Table 19 : Mean viability of calves by season, genetic group, sex and birth weight subclasses at different ages

Factor	Ages (upto)			Periods (from)	
	1 month	weaning(75 days)	1 year	(I) 1 month to weaning	(II) Weaning to 1 year
Overall mean	97.14 (2543)	93.77 (2455)	87.28 (2285)	96.54(n = 2455)	92.08 (n = 2285)
Season					
(wet)	97.33 (1312)	93.40 (1259)	86.79 (1170)	95.96(n = 1259)	92.92 (n = 1170)
(dry)	96.93 (1231)	94.17 (1196)	87.80 (1115)	97.16 (n=1196)	93.23 (n = 1115)
Chi-square value	0.01 NS	0.04 NS	0.08 NS	0.09 NS	0.01 NS
Genetic group					
(Mpwapwa)	96.24 (1483)	92.08 (1419)	85.59 (1319)	95.68 (n = 1419)	92.95 (n = 1319)
(F_1-crossline)	97.67 (293)	95.67 (287)	91.00 (273)	97.95 (n = 287)	95.12 (n = 273)
(Backcross)	98.71 (767)	96.39 (749)	89.19 (693)	97.65 (n = 749)	92.52 (n = 693)
Chi-square value	0.34 NS	1.15 NS	1.30 NS	0.27 NS	0.16 NS
Sex					
(male)	96.99 (1324)	93.48 (1276)	86.15 (1176)	96.38 (n = 1276)	92.16 (n = 1176)
(female)	97.29 (1219)	94.09 (1179)	88.51 (1109)	96.72 (n = 1179)	94.06 (n = 1109)
Chi-square value	0.01 NS	0.03 NS	0.41 NS	0.01 NS	0.24 NS
Birth weight					
(< 20 kg)	89.52 (376)	81.19 (341)	78.57 (330)	90.69 (n = 341)	96.77 (n = 330)
(20 - 30 kg)	98.51 (1655)	96.01 (1613)	89.46 (1503)	97.46 (n = 1613)	93.18 (n = 1503)
B_3 (≥ 31 kg)	98.84 (518)	96.72 (501)	87.26 (452)	97.85 (n = 501)	90.22 (n = 452)
Chi-square value	2.99 NS	8.47*	4.56 NS	1.57 NS	0.94 NS

Figures in parentheses denotes number of calves viable from the total calves born.

n - indicates the number of calves viable from these exposed to risk at periods (I) and (II).

5.0 DISCUSSION

5.1 Age at first calving

Overall mean age at first calving of 1251.63 days obtained in this study is fairly high compared to the mean ages at first calving reported for dairy cattle in tropics by Lemka et al. (1973), Martinez et al. (1982), Reaves et al. (1985) and Tuah and Danso (1985). The mean age at first calving of Mpwapwa heifers in this study is higher than that reported by Katyega (1981) at the same station. The mean values of age at first calving for the three genotypes studied are however, within the range (1095 - 1460 days) for Bos taurus x Bos indicus and Zebu cattle reported in East Africa by Mahadevan and Marples (1961), Galunkande et al. (1962), Mahadevan and Hutchison (1964), Marples (1964) and Trail and Gregory (1981). Mean ages at first calving of Mpwapwa, F_1 - crossline and Back cross heifers in the present study are close to those obtained by Mkony (1982) for the same genotypes at Mpwapwa station.

From the results of analysis of variance, year of birth of heifers was a significant source of variation for age at first calving. This is in agreement with the similar findings by Jegam and Tomar (1983), Valente, (1983) and Roy et al. (1985). The variation in age at first calving due to years of birth in the present study, could be mainly attributed to the differences in amount of annual rainfall. Little and Kay (1979) observed that year of birth influenced growth rate and age at mating of dairy heifers due to differences in availability of green fodder and supplementary feeds. The results in the present study imply that the effect of year of birth on growth rate is carried on and results in causing variation in age at first calving. This suggests that optimal feeding during early months of life to enhance growth rate will reduce age at first calving.

The significant influence of genetic group on age at first calving in this study is in agreement with the results obtained by other workers (Madsen and Vinther, 1975; Aziz and Siddu, 1985. Govindaiah et al., 1984). In the present study, F_1 - crossline heifers calved earlier for the first time than the Backcross and Mpwapwa heifers. The decrease in age at first calving was associated with increase in *Bos taurus* genetic proportion in the F_1-crossline. Similar trend was also reported by Madsen and Vinther (1975), Letenneur (1978), Mkony (1982) and Govindaiah et al. (1984). The result on significant effect of genetic group on age at first calving implies that genetic improvement in age at first calving is possible. This is supported by the medium estimates of heritability for age at first calving obtained by Jegam and Tomar (1983) and Tomar et al. (1974)

Season of birth had non significant effect on age at first calving in the present study. Similar result was reported by Kiwuwa (1969). The results in the present study indicate that heifers born in dry season had slight advantage of lower ages at first calving than the heifers born in wet season. This could be attributed to the practice of weaning calves born in dry season near the commencement of wet season, when lush green pasture is plentiful, whereas calves born in wet season are weaned at the beginning of the dry season. This does not concur with the findings by Pereira *et al*. (1979) and Chawla and Mishra (1982) who reported that age at first calving was lower for heifers born in wet season than for heifers born in dry season.

Age at first calving significantly influenced lactation milk yield and lactation length pooled over for first five parities. The lactation milk yield significantly ($P < 0.001$) decreased by 43 kg for every 100 days increase in age at first calving. This substantiated the results obtained by several others (Gopal and Bhatnagar, 1969; Hargrove *et al*., 1969; Chandra, 1977; Lin and Allaire, 1978). In the present study, age at first calving did not influence significantly first lactation milk yield. The significant influence of age at first calving was observed on second, third and fourth lactation milk yields only. Gopal and Bhatnagar (1969) and Chaudhary and Chaudhary (1985) reported similar findings of non significant effect of age at first calving on first lactation milk yield, whereas life time based lactation milk yields at 6, 8 and 10 years were significantly influenced.

The overall correlation coefficient obtained in this study between age at first calving and lactation milk yield pooled over first five parities was negative and significant. Similar correlation coefficients between the two variables were reported by Ahaamd *et al* (1971) and Tretyak and Betina (1974). Correlation coefficients between age at first calving and lactation milk yields at second, third and fourth parities were negative and significant. Similar findings were reported by Ahaamd *et al*. (1971) and Kifaro (1984).

Age at first calving and first lactation milk yield were not significantly correlated. Similar relationship between the two variables was reported by other workers (Kiwuwa, 1968; Rao and Patro, 1984; Chaudhary et al., 1984). The result on non significant relationship between age at first calving and first lactation milk yield may not necessarily mean that the variables are independent.

The results on significant influence of age at first calving on reproductive efficiency traits, CI, DP and days open are in agreement with the findings by Dominguez et al. (1982) and Patro and Rao (1983). The significant correlation coefficients between age at first calving and CI, DP and days open of 0.09, 0.08 and 0.08, respectively, are too low to give a reasonable indication concerning appreciable prediction potential.

5.2 Calving interval (CI)

The overall mean CI of all the cows in the present study of 427.92 days is fairly high than the mean CIs reported for *Bos taurus* dairy cows in the tropics by Sadana and Basu (1983), Dias et al.(1985) and Duc and Taneja (1984). Mean CIs of the Mpwapwa, F_1-crossline and Backcross cows of 446.45, 413.09 and 399.41 days, respectively, are lower than the CIs reported for most Zebu cattle. In Thailand, Madsen and Vinther(1975) reported mean CI of 467.0 days for Red Sindhi cattle. In Burundi, Pozy and Kagarama (1980) obtained mean CI of 491.2 days for Ankole cattle. The overall mean CI obtained in the present study is however, within the range of CIs of the grades and crossbreds (*Bos taurus* x *Bos taurus*) dairy cows reported by several authors (Garcia *et al*., 1975; Pandey and Desai, 1977; Mkony, 1982; Sharma *et al*., 1982; Fulsounder *et al*., 1984; Rao *et al*., 1984).

The low repeatability estimate of 0.07 ± 0.05 for CI of all the cows in the present study is close to the estimates reported by Legates (1954), Lemka *et al*.(1973). Duarte *et al*. (1983), Landais (1983) and Oishi *et al*. (1983). The overall repeatability estimate for CI obtained in this study is lower than the estimates obtained by Novy and Psenica (1977), Bharat and Chowdhary (1980), Hinjosa *et al*. (1980) and Parmar and Johar (1982). The low estimates of repeatability for CI implies that CI is, to a little extent, heritable. This is supported by low to medium heritability estimates for CI reported by several workers (Everett *et al*.,1966; Ahaamd *et al*., 1974; Johnmundsson, 1981; Weitz and Magalhaes, 1984; Toelle and Robison (1985).

The results in the present study revealed that year of calving was a significant source of variation in length of CI. Similar results were obtained by Leon and Denton (1983), Landais (1983), Hernandez *et al*. (1984) and Nobre *et al*. (1984). The mean CI in the present study tended to decrease as the year of calving progressed from 1970 to 1985. Such reduction in CI over years of calving implies that management and nutrition of dairy cows was gradually improved. This substantiates the reports by Vaccaro (1973) and Kidner (1981) that long CIs of dairy cows in developing countries are due to much reliance on pasture feeding or lack of concentrate feeding.

The significant influence of genetic group on length of CI obtained in this study is in agreement with similar findings by Landais (1983), Nobre et al. (1984), Mirza et al. (1985) and Roy et al. (1985). There was lack of general trend in length of CI and genetic group. However F_1-crossline cows had significantly ($P < 0.001$) shorter CIs than that of Mpwapwa cows. Similar decrease in CI due to increased B. taurus genetic proportion in crossbreds and grades have been indicated by Pandey and Desai (1973) and Alberro (1983). In the present study, genetic group accounted for 3.09% of the total variation in CI. This suggests that reduction in CI by crossbreeding and grading to Bos taurus can be achieved to a very little extent.

Season of calving did not affect the length of CI in the present study. Similar results on non significant effect of season of calving on CI were reported by Govindaiah et al. (1984) and Nobre et al. (1984). The results of non significant difference between the means of CIs of cows calving in wet and dry seasons was probably due to similar and optimal feeding of lactating cows in both seasons. This supports the observation by Montogomery et al. (1985) that effect of season on CI is less likely to be expressed in conditions of high plane of nutrition than in low plane of nutrition.

The results revealed that age of cow at calving did not influence the length of CI. Calving interval, however, showed a trend of decreasing with increase in age of cows from 4 years to 7 years of age. Similar trend was reported by Ngere et al. (1973) who attributed the decrease in CI in older cows to their performance in breeding easily or needing fever services per conception than younger cows. The older cows, aged ≥ 8 years,in the present study had longer lengths of CI compared to younger cows with ages ranging from 4 to 7 years. This is in agreement with the results obtained by Mahadevan et al. (1972) and Valente (1983). Increase in CI in the older cows may purely be attributed to the lowered physiological activity of the reproductive organs.

The non significant influence of parity on CI in this study is in agreement with the reports by Matsoukas and Fairchild (1975), Parmar and Johar (1982) and Madelena et al. (1983). Calving interval however, showed a tendency to decrease from mean CI of 438.41 days in parity one to 412.18 days in parity four. Similar trend was reported by Voigt et al. (1974) and Tajane and Vyas (1984).

Calving interval significantly influenced subsequent lactation milk yield and lactation length pooled over the first five parities. In the present study lactation milk yield and lactation length increased significantly by 42 kg and 45 days, respectively, for every 100 days increase in preceding CI. The significant influence of CI on subsequent lactation milk yield and lactation length is in agreement with the findings reported by others (Mahadevan, 1951; Cooper, 1966; Louca and Legates, 1968; Sartore and Ladetto, 1983; Wood, 1985). The correlation coefficients between CI and subsequent lactation milk yields at first two parities were positive and significant.

Similar results were obtained by Kifaro (1984). The results in the present study although indicated significant increase in subsequent lactation milk yield by increasing the CI, this would be uneconomical for the crossbred cows studied. The increase in CI of the cows in the present study would also result in increase of DP, which is already relatively long (mean 148.35 days). The increase in expenses incurred by maintaining a cow which is not lactating for a longer dry period (DP > 5 months) may not be offset by increase in subsequent lactation milk yield. Similar findings were reported by Reaves et al. (1985). Other workers have reported non significant influence of CI on subsequent lactation milk yield and length (Olds and Seath, 1953; Smith and Legates, 1962; Everett et al., 1966 Matsoukas and Fairchild, 1975; Holtz et al., 1976).

The results from the present study revealed that concurrent CI significantly (P < 0.01) influenced lactation milk yield pooled over the first five parities. The significant influence of concurrent CI on lactation milk yield was observed in third and fourth parity only. Similar result on significant influence of concurrent CI on lactation milk yield was reported by Auran (1974), Syrstad (1975) and Olds et al. (1979b). Syrstad (1975) observed that CI had more pronounced relationship with concurrent lactation milk yield than with subsequent lactation milk yield. The significant increase in lactation milk yield for increase in concurrent CI in the present study indicates that the depressive effect of new pregnancy on current lactation milk yield was not present. This was due to more days open (153.39 days) of the cows in the present study causing delayed conception. The antagonist and significant relationship between concurrent lactation milk yield has been attributed to the depressive effect of new pregnancy on lactation milk yield (Auran, 1974; Syrstad, 1975; Olds et al., 1979b). The low, positive and non significant correlation coefficients between concurrent CI and lactation length at first, third and fourth parities are similar to the results reported by Herrera-Garcia (1976) and Deshpande and Bonde (1982). Non significant relationship between concurrent CI and lactation milk yield was reported by Deshpande and Bonde (1982), Syrstad (1985b) and Terawaki et al. (1985).

The significant correlation coefficient between concurrent CI and DP of 0.89 in the present study is close to the coefficients reported by Amble and Jain (1966), Rajgobal (1969) and Pandey and Desai (1977). Concurrent CI was significantly ($P < 0.001$) correlated with days open in this study. Similar relationship between the two variables was obtained by Ngere et al. (1973), Olds et al. (1979a) and Buxadera et al. (1983). The results from the present study on the significant relationships of concurrent CI with DP and days open imply that CI can be used to predict DP and days open in concurrent lactation.

5.3 Dry period

The overall mean DP of 148.35 days is higher than the DPs reported for most *B. taurus* dairy cattle ranging from 60 - 90 days by Schaeffer and Henderson (1972), Medina-Cruz (1979), Rako and Karadjole (1984) and Wood (1985). Mean DP obtained in this study is fairly high compared to that of dairy crossbreds reported in tropics.

Fulsounder et al. (1984) reported DP of 50 $\pm$ 22 days for Holstein Friesian x Kankrej cows. Sharma et al. (1982) reported that the DP of Holstein x Sahiwal cows averaged 105.07 days. However, the mean DP in the present study is lower than DPs reported for B. indicus dairy breeds by Lemka et al. (1973) and Mirza et al. (1985). Mean DPs for the three genetic groups studied is fairly close to the mean values of DP obtained by Mahadevan (1965) for Zebu cattle in East Africa and to the mean DP obtained for Mpwapwa cows by Mpiri (1985).

The repeatability estimate of 0.21 $\pm$ 0.05 for DP obtained in the present study is higher than the estimate reported by Saveli (1984). The medium repeatability estimate for DP implies that little to moderate genetic improvement is possible in this trait. This is substantiated by reports of low to medium estimates of heritability by other workers (Wilton et al., 1967; Schaeffer and Henderson, 1972; Gur'yanova and Sokolova, 1975; Rao and Patro, 1984).

The results in the present study revealed that year of calving significantly ($P < 0.001$) influenced the length of DP. This is in agreement with the same result obtained by Rao et al. (1984). Dry period tended to decrease as the year of calving progressed from 1970 to 1985. The reduction of DP over years of calving may be attributed to the improved husbandry practices as the years progressed. The decrease in mean DP may, however, be attributed to the increase of lactation length and milk yield due to selection of dairy cows in L.B.3 project for high milk production traits over years of calving.

The significant influence of the genetic group on DP of the cows studied is in agreement with similar findings by other workers (Pandey and Desai, 1973; Taneja, 1974; Sharma *et al*., 1982; Mirza *et al*., 1985; Roy *et al*., 1985). Mean DP in the present study tended to decrease with increase in *B. taurus* genetic proportion in the genetic groups. Similar trend of DP and genetic group has been observed by Pandey and Desai (1973 and 1977), Govindaiah *et al*. (1984) and Sharma *et al*. (1984).

The result on non significant influence of season on length of DP is in agreement with the similar results obtained by Deshpande and Bonde (1983) and Govindaiah *et al*. (1984). The non significant influence of season of calving on DP suggests that management and nutrition of lactating cows was same in both wet and dry seasons.

Age of cow at calving did not influence the length of DP in the present study. Mean DP showed a tendency to decrease with increase in age of cow up to 7 years of age. Similar trend was reported by Spalding *et al*. (1975) and Roman-Ponce *et al*. (1978).

The influence of parity on DP was not significant in the present study. However, DP showed a tendency to decrease with increase in parity number up to fourth parity. Similar trend in Hariana cows was observed by Ngere *et al*. (1973) . The decrease in length of DP with increase in parity may explain longer lactation lengths at advanced parities.

The non significant influence of DP on subsequent lactation milk yield and lactation length is in agreement with the similar results obtained by Ngere et al. (1973), Tomar and Balaine (1973) and Pathak et al. (1980). The negative correlation coefficient between DP and subsequent lactation milk yield, pooled over the first five parities is in agreement with the similar result by Alim (1962), Poutous and Mocquot (1974), Garcia et al. (1975) and Peric (1984). In the present study, the correlation coefficients between DP and subsequent lactation milk yield at first and second parity were positive, while at third, fourth and fifth parities, the coefficients were negative. Similar correlations at first and second parity between the two variables, DP and subsequent lactation milk yield were obtained by Smith and Legates (1962), Roman-Ponce et al.(1978) and Deshpande and Bonde (1982). The non linear relationships between DP and subsequent lactation milk yield at parities one through five substantiate similar observations by Schaeffer and Henderson (1972). The results on relationship between DP and subsequent lactation milk yield and between DP and subsequent lactation length imply that DP and subsequent lactation milk yield and lactation length are independent characters. That is, reduction of DP would not have any untoward effect on subsequent lactation milk yield and lactation length.

The results in the present study reveal that the correlation coefficient between DP and concurrent CI, pooled over for first five parities was high, positive and significant (P < 0.001). Similar coefficient between the two variables was obtained by Ngere et al.(1973), Ahmad and Ahmad (1974) and Dutt et al. (1974). The positive and significant relationship between days open and subsequent dry period obtained in this study is in agreement with the similar findings by Olds et al.(1979b). The significant relationship between concurrent CI and DP and preceding days open and DP imply that concurrent CI and preceding days open can be accurately used to predict the DP.

5.4 Days open

The mean days open for all the cows in the present study of 153.39 days is fairly close to the mean values obtained for Bos taurus x Bos indicus crossbreds and Zebu cows reported by Lemka et al. (1973), Alberro (1983) and Reaves et al. (1985). Overall mean days open in the present study is fairly high than the range (60 - 90 days) considered ideal for management practice of dairy cows by Schaeffer and Henderson (1972). Lower mean days open for Bos taurus dairy cows have been reported by several workers (Schaeffer and Henderson, 1972; Anderson, 1974; Olds et al., 1979b; Larsson et al., 1984;Terawaki et al., 1985). However, Foote et al. (1984) reported more days open of 173.0 days for Holstein Friesian cows.

In the present study, the estimate of repeatability for days open, pooled over for all cows was 0.12 ± 0.04 ($P < 0.01$). The repeatability estimate obtained in this study for days open is within the range (0.06 - 0.14) of the estimates reported by Everett et al. (1966) and Lazarevic and Milojovic (1984). Carmen (1955) reported low repeatability estimates for days open ranging from 0.02 to 0.08. The result of low estimate of repeatability for days open in the present study implies that genetic improvement of this trait is possible to a very little extent.

The result on significant effect of year of calving on days open is in agreement with the similar findings by Schaeffer and Henderson (1972) and Buxadera *et al*. (1983). The variation in number of days open due to year of calving implies that the differences in management practices relating to breeding and feeding of dairy cows over years of calving was highly significant. This substantiates the report by Coleman *et al*. (1985) which indicated that days open in dairy cattle was significantly influenced by management practices.

Genetic group significantly ($P < 0.001$) influenced the number of days open. This is in agreement with the similar results obtained by Lemka *et al*.(1973), Alberro (1983) and Chaudhary and Chaudhary (1984). In the present study there was lack of general trend in days open and genetic group. However, F_1 - crossline cows with 54% *B. taurus* genetic proportion had lesser number of days open of 132.88 days compared to Mpwapwa cows with 8% *B. taurus* genetic proportion having days open of 167.33 days. Similar observations of lesser number of days open in crossbreds (*Bos taurus* x *Bos indicus*) cows than the *Bos indicus* cows was reported by Lemka *et al*.(1973), Alberro (1983) and Chaudhary and Chaudhary (1984).

The result of non significant effect of season of calving on days open in the present study is in agreement with the similar findings reported by Lemka et al. (1973). This implies that management practices of dairy cows during pre and post calving stage were similar in both wet and dry seasons. However, significant effect of season of calving on days open has been reported by other workers (Monty and Wolff, 1974; Buxadera et al., 1983; Foote et al., 1984; Coleman et al., 1985).

In the present study age of cow did not influence the number of days open and this is in agreement with the results obtained by Schaeffer and Henderson (1972). The coefficient of determination (R^2) between age of cow and days open was only 0.4% of the total variation in days open.

The results in the present study revealed that the influence of parity on number of days open was not significant. This does not agree with findings by Ngere et al. (1973) that parity significantly influenced days open. The mean days open in the present study showed a tendency to decrease from 165.46 days in parity one to 132.39 days in parity four. Similar result was reported by Ngere et al. (1973). However, the results on trend of days open and parity do not agree with the findings of Chaudhary and Chaudhary (1984), who reported that days open increased with increase in parity number.

Days open significantly influenced subsequent lactation milk yield and lactation length, pooled over the five parities. For every 100 days increase in days open subsequent lactation milk yield and lactation length increased significantly by 32 kg and 34 days, respectively. The result on significant influence of days open on subsequent lactation milk yield is in agreement with the similar findings by Ngere et al. (1973). The significant influence of days open on subsequent lactation milk yield and lactation length was attributed to the significant relationship between concurrent days open and CI and between days open and subsequent DP (Ngere et al., 1973). In the present study, positive correlation coefficients between days open and subsequent lactation milk yield were obtained at parity one, two four and five, while negative correlation coefficient was obtained in third parity. The non linear relationship between days open and subsequent lactation milk yield is in agreement with the similar report by Schaeffer and Henderson (1972).

The results in the present study revealed that concurrent days open did not influence lactation milk yield and lactation length. The significant influence of concurrent days open on lactation milk yield was observed at second parity only. The result on non significant influence of concurrent days open on lactation milk yield, does not agree with the findings by Ngere et al.(1973) and Olds et al.(1979b). In the present study, the regression coefficient of 0.15 was obtained when concurrent lactation milk yield was regressed on days open, pooled over the first five parities. This implies that the depressive effect of the new pregnancy on lactation milk yield was not present as reported by Auran (1974), Syrstad

(1975) and Olds et al. (1975b). In their reports, they indicated that the depressive effect of new pregnancy on lactation milk yield which occured at about fifth month of pregnancy may explain the negative relationship between concurrent days open and lactation milk yield. In the present study, the non significant positive correlation of 0.03 between concurrent days open and lactation milk yield was very low. The depressive effect of new pregnancy on lactation milk yield was not present in this study, this could be attributed to more number of days open (153 days) in the present study compared to previous reports (Auran, 1974; Syrstad, 1975) whereby the number of days open were few (60 - 70 days). This suggests that the increase of days open to 150 days would increase lactation milk yield, as the depressive of effect of new pregnancy on lactation milk yield would be avoided. Similar findings were reported by Reaves et al. (1985) who suggested that the increase of days open would result in substantial increase in concurrent lactation milk yield. The positive correlation coefficients between concurrent days open and lactation milk yield at parities one through four is similar to the positive relationship between the two variables obtained by others (Smith and Legates, 1962; Schaeffer and Handerson, 1972; Reaves et al., 1985; Terawaki et al., 1985). The negative relationship (r = - 0.7) between concurrent days open and lactation length is in agreement with the similar findings by Olds et al. (1979b).

5.5 Conception rate

The mean CR of 53.89% obtained for all the heifers and cows in the present study is lower than the CRs reported for

Bos taurus cattle and their crosses with *Bos indicus*. Dias *et al.* (1985) reported mean CR of 80.6% for Holstein Friesian and their crosses with Zebu cattle. Olson *et al.* (1985) reported mean CR for Brown Swiss cattle of 79.0%. However, Foote *et al.*(1984) obtained lower CR of 19.75% in a dairy herd of Holstein Friesian cows. The mean CRs of the genotypes in the present study of 52.83%, 56.21% and 56.09% for Mpwapwa, F_1 - crossline and Backcross, respectively, is lower than the CR (88.3%) of Nellore cows reported by Feo (1982). The mean CRs of the genotypes in the present study are however, close to the CRs reported for Bos taurus dairy cattle by Badinga *et al.* (1985) and for *Bos taurus* x *Bos indicus* cattle reported by Canedi *et al.*(1984).

The significant influence of year of mating on CR is in agreement with the similar findings by Spears *et al.*(1965), Kaushik *et al.*(1979), Dias *et al.* (1985). The difference between best and poorest years of mating in the present study of 23.4% may partly be attributed to the big annual rainfall range at the station (Fig. 1). This supports the findings by Wilson (1985) who reported that CR of dairy cattle was mainly influenced by amount of rainfall during the year of mating. The amount of annual rainfall determines the availability of fodder crops and concentrates for optimal feeding so as to have regular estrus activity in dairy cattle females.

The result on non significant infuence of the genetic group on CR in the present study substantiates the similar reports by Goel (1982), Sadana and Basu (1983) and Tuah and Danso (1985). The findings in the present study imply that genetic improvement through selection in CR is very little. This is supported by the low estimates of heritability and repeatability by other workers (Collins et al., 1962; Spears et al ., 1965; Horn, 1984; Taylor et al., 1985, Toelle and Robinson,1985). In the present study, CR showed a tendency to increase with increase in *Bos taurus* genetic proportion in the genetic groups. Similar trend was reported by Osman and Russell (1974), Alberro (1983) and Perez-Beato (1984).

Season of mating did not influence CR in the present study. This is in agreement with the similar results obtained by Feo (1982) and Dias et al. (1985). The CR of heifers and cows was slightly higher in the dry season compared to the CR in the wet season. The result in the present study implies that the availability of fodder and supplementary feeds during the two breeding seasons was same.

In the present study, type of mating significantly influenced CR of heifers and cows. Natural service of heifers and cows resulted in significantly ($P < 0.01$) higher CR than artificial insemination. This is in agreement with the similar findings by Kawecki and Kamiennieck (1973) and Canedi et al. (1984). Low CR of cattle resulting from artificial insemination may partly be attributed to the inefficient heat detection and insemination techniques along with improper storage facilities of frozen semen at the station. Ron et al. (1984) and Taylor et al.(1985) reported that the performance of technicians inseminating heifers and cows was a significant source of variation in CR.

The results revealed that age of female cattle at mating significantly ($P < 0.05$) influenced CR. Similar findings were reported by Salisbury and VanDenmark (1961), Spalding et al.(1975), Hansen et al. (1983c) and Hillers et al. (1984). The mean CR in the present study tended to increase with increase in age of heifer or cow up to 7 years of age and thereafter declined. Similar trend was reported by Spalding et al.(1975), Kragelund et al. (1979), Hillers et al.(1984) and Ron et al.(1984). Low CR in heifers (< 4 years) and in aged cows ($\geq$ 8 years) may partly be attributed to the low physiological activity of the reproductive organs.

Liveweight of female cattle in the present study significantly ($P < 0.001$) influenced CR. Similar results were reported by Pope (1967), Levine et al.(1980) and Wetteman et al.(1985). In the present study, heifers and cows with liveweights < 250 kg at mating had significantly lower CR than females weighing 250 - 350 kg at mating. Similar observations on Zebu cattle were reported by Levine et al.(1980). From the results in the present study it can be concluded that liveweight of heifers and cows at mating be considered as an important factor for CR.

5.6 Viability of calves

Mean viability of calves up to one month of age of 97.14% in the present study is higher than the viability of Zebu calves at the same age reported by Rao (1983) and Tuah and Danso (1985). The mean viability is also higher than that of *Bos taurus* calves reared in tropics (Vaccaro et al., 1983a). The perinatal viability of calves up to one month of age in the present study is fairly close to the viability (98.92%) of the crossbred dairy calves at the same age reported by Rao and Nagarcenkar (1980).

The result of mean viability of calves up to weaning age is close to the overall mean viability obtained for Boran and Sahiwal calves by Trail and Gregory (1981). Lower viability of dairy calves reared in tropics compared to that obtained in the present study has been reported by Vaccaro (1974), Srivastava and Sharma (1980), Ibeawuchi *et al.*(1981), Umoh (1982) and Rao (1983).

In the present study, mean viability of calves up to one year of age of 87.28% is within the range of viability up to one year of age reported for crossbred dairy calves in tropics by Vaccaro (1974), Planas (1979), Vaccaro and Vaccaro (1981) and Choudhuri *et al.*(1984). Mean viability of calves in the present study up to one year of age is lower than the mean viability of *Bos indicus* dairy calves of 93.1% and 94.4% reported by Rudolph (1970) and Jacobsen (1983), respectively.

Mean viability of calves for both periods (I and II) is close to the pre- and post - weaning viability of crossbred calves reported by Frisch (1973). Lower viability of *Bos indicus* dairy calves for the same periods has been reported by Srivastava and Sharma (1980) and Rao (1983).

In the present study, influence of year of birth on viability of calves up to designated ages and at periods I and II was not significant. Similar results were reported by Singh and Parekh

(1982). The non significant influence of year of birth on viability of calves up to one month of age and up to weaning age should be expected as all dairy calves born at the station are reared indoor till weaning age. The results from the present study imply that management of calves over years of birth did not differ.

Season of birth of calves did not influence viability of calves up to designated ages and periods. The calves born in dry season had slight advantage of higher viability than the calves born in wet season. Heavy losses of calves born in rainy season compared to those born in dry season was reported by Capriles et al. (1983), Vaccaro and Vaccaro (1981) and Singh and Parekh (1982). Lower viability of calves born in rain season than that of calves born in dry season inspite of indoor rearing during both seasons may partly be due to inability of the management to maintain hygienic standards in calf pens during the rain season. This would lead to dampness in the pens and contamination of milk, water and feeds given to calves resulting in deaths mostly due to pneumonia and diarrhoea.

In the present study, the difference in viability of calves up to designated ages and periods due to effect of sex did not reach the statistical significance. This is in agreement with the similar results obtained by Sharma et al. (1975), Rao and Nagarcenkar (1980), Trail and Gregory (1981) and Umoh (1982). Female calves were slightly more viable than the male calves up to one month, weaning and one year of age. This is probably because of the bias in handling female calves due to their importance as milking stock. Higher viability of female calves compared to male calves at one month, three months and six months of age was reported by Frisch (1973), Charray et al. (1977) and Rao (1983).

The result on significant effect of birth weight on viability of calves up to weaning age is in agreement with the similar findings by Koger et al. (1967) and Vaccaro (1974). In the present study, calves with birth weights $\geq$ 31 kg were significantly ($P < 0.05$) more viable up to weaning age than lighter calves (> 20 kg) at birth. The non significant influence of birth weight of calves on viability up to one month and one year of age agrees with the similar results obtained by Rao and Nagarcenkar (1980).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Age at first calving is influenced by both genetic and non genetic factors. Year of birth and genetic group of heifers have shown to have significant influence on age at first calving. The influence of year of birth on age at first calving might have been due to the differences in the amount of annual rainfall at the station which determined the availability of grass. Age at first calving has shown to affect life time milk production up to fifth parity.

Year of calving and genetic group have shown to have significant effect on reproductive efficiency traits (CI, DP and days open), while season, age and parity at calving did not. Differences in reproductive efficiency traits due to year of calving was attributed to the variations in amount of annual rainfall and managerial practice at the station. Repeatability estimates obtained for reproductive efficiency traits in this study ranged from low to medium with high standard errors.

Preceding and concurrent CI have shown to have significant influence on milk yield. Days open significantly influenced subsequent lactation milk yield and lactation length. The positive, but non significant influence of concurrent days open on lactation milk yield was due to the absence of depressive effect of new pregnancy on lactation milk yield.

Conception rate of heifers and cows in the present study was lower than that reported for most dairy crosses (*Bos taurus* x *Bos indicus*)and improved *Bos indicus* cattle in the tropics. Year of mating has shown to have a marked influence on CR. This was mainly due to the big differences in amount of annual rainfall over the years of mating. Female cattle bred by natural mating showed higher CR than those bred by artificial insemination. Heifers and cows with ages < 4 years and those with ages ≥ 8 years had lower CRs compared to females with ages ranging from 4 - 7 years. Lighter females (> 250 kg) at mating had significantly lower CRs than those weighing ≥ 250 kg.

Viability of calves up to designated ages of 1 month, weaning (2.5 months) and one year were higher to the values reported for most crossbred *Bos taurus* x *Bos indicus*) dairy calves reared in the tropics. Higher viability of calves in the present study was attributed to the high standards of managerial practices at the station.

It is recommended that, in order to benefit from lowered age at first calving due to increase in *Bos taurus* "blood", the farmer should improve the environmental conditions, especially the feeding aspect.

Since most of the reproductive efficiency traits are mainly influenced by environmental factors and could mainly be improved by better management and nutrition, it is suggested that efforts be geared towards this direction. Improvement of managemental factors may reduce CI which could result in more milk yield per CI and more calves per cow's life time. In order to increase the CRs of dairy cattle, the farmer should improve the nutrition of female stock and also improve the heat detection, semen storage and insemination techniques.

Finally it is recommended that further studies be conducted on other causes affecting reproductive traits and thus leading to infertility in dairy cattle. Such causes could be nutrition, climatic and diseases. Specific studies on effects of oestrus synchronisation, pregnancy induction and early calf mortality on milk production and reproductive performance of Mpwapwa cattle should be looked into.

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APPENDICES

Appendix Table 1 : Number of observations per subclass

Factor	Age at first calving	CI	DP	Days open	CR (mated)	Viability (born)
Year						
1	40	7	7	7	443	192
2	13	12	12	12	487	129
3	61	27	27	27	513	139
4	37	52	52	52	375	176
5	29	81	81	81	311	236
6	18	67	67	67	365	190
7	23	69	69	69	392	179
8	23	83	83	83	306	164
9	17	80	80	80	390	158
10	25	59	59	59	368	152
11	36	68	68	68	338	178
12	14	35	35	35	315	186
13		37	37	37	318	180
14		16	16	16	368	167
15		11	11	11	438	172
Total	336	704	704	704	5727	2618
Season (calving/birth)						
S_1	158	336	336	336		1348
S_2	178	338	338	338		1270
Season (mating)						
M_1					2997	
M_2					2730	

Appendix Table 1 continued

Factor	Age at first calving	CI	DP	Days open	CR (mated)	Viability (born)
Genetic group						
G_1	164	371	371	371	3907	1541
G_2	65	191	191	191	975	300
G_3	107	142	142	142	845	777
Age of dam						
D_1		236	236	236	2282	
D_2		270	270	270	1552	
D_3		152	152	152	872	
D_4		45	45	45	1021	
Parity						
P_1		278	278	278		
P_2		179	179	179		
P_3		113	113	113		
P_4		80	80	80		
P_5		54	54	54		
Weight of dam (mating)						
W_1					1245	
W_2					1540	
W_3					1587	
W_4					1355	
Type of mating						
T_1					4318	
T_2					1409	
Sex of calf						
C_1						1365
C_2						1253
Birth weight of calf						
B_1						420
B_2						1680
B_3						518

Appendix Table 2 : Mean ages at first calving over years

	Age in days		
	Mean	Standard error	n
Overall mean	1251.63	10.84	336
Years:	***		
1	1279.53	25.14	40
2	1099.38	45.39	13
3	1258.62	29.02	61
4	1375.01	26.17	37
5	1332.79	38.92	29
6	1269.11	39.73	18
7	1348.48	49.84	23
8	1280.96	38.16	23
9	1184.12	39.83	17
10	1050.68	22.35	25
11	1139.72	32.79	36
12	1123.43	29.79	14

n - denotes the number of observations

Appendix Table 3 : Analysis of variance for age at first calving

Source of variation	df	Sum of squares x 10^3	Mean squares x 10^3	F-ratio
Year	11	1608.85	146.25	4.48***
Season	1	68.96	68.96	2.11 NS
Genetic group	2	1062.67	531.34	16.27***
Residual	321	10478.49	32.64	
Total	335	13218.97		

Appendix Table 4 : Linear regression coefficients (b) and correlation coefficients (r) showing the effect of age at first calving on milk production at different parities

Effect of age at first calving (x) on		Lactation milk yield (y)		Lactation length (y)	
Parity	n	b	r	b	r
1	336	0.07 ± 0.01 NS	0.01	- 0.11 ± 0.02NS	0.04
2	280	- 0.26 ± 0.02**	- 0.18	- 0.31 ± 0.05**	0.22
3	233	- 0.29 ± 0.01*	- 0.16	- 0.18 ± 0.01NS	0.07
4	190	- 0.56 ± 0.11*	- 0.22	- 0.36 ± 0.03*	0.14
5	54	- 0.38 ± 0.07 NS	- 0.11	- 0.15 ± 0.06NS	0.08

n - denotes the number of pairs of observations common for lactation milk yield and lactation length

y - dependent variable

x - independent variable

r - correlation coefficient

Appendix Table 5 : Means and standard errors for calving interval, dry period, days open and mean conception rate over years.

	n^1	Days			n^2	Conception rate (%)
		Calving interval	Dry period	Days open		
Overall mean	704	427.91 ± 4.38	146.35 ± 4.76	153.39 ± 4.78	5727	53.89
		***	***	***		**
Years :						
1	7	570.29 ± 61.42	369.43 ± 42.71	290.29 ± 61.42	443	49.62
2	12	583.92 ± 53.81	364.25 ± 53.93	299.01 ± 54.35	487	51.07
3	27	473.04 ± 34.24	186.29 ± 31.93	204.11 ± 30.81	513	55.23
4	52	401.88 ± 9.36	125.15 ± 12.21	121.88 ± 9.36	375	66.67
5	81	416.99 ± 12.65	129.32 ± 13.36	134.78 ± 11.84	311	66.15
6	67	439.72 ± 13.67	147.24 ± 13.53	159.61 ± 13.68	365	55.63
7	69	419.75 ± 13.93	140.09 ± 15.64	160.77 ± 19.16	392	48.74
8	83	443.88 ± 12.82	150.22 ± 13.01	168.31 ± 13.15	306	46.31
9	80	423.58 ± 11.69	146.59 ± 13.14	144.45 ± 11.79	390	46.86
10	59	439.25 ± 16.38	159.97 ± 19.41	157.97 ± 16.28	368	43.21
11	68	402.34 ± 10.99	152.51 ± 13.89	122.06 ± 11.01	338	57.16
12	35	409.31 ± 15.49	127.01 ± 16.63	178.31 ± 36.28	315	65.28
13	37	412.32 ± 16.72	115.49 ± 17.65	131.73 ± 16.78	318	60.67
14	16	394.50 ± 19.08	102.88 ± 17.78	114.50 ± 19.08	368	49.07
15	11	407.82 ± 50.78	142.82 ± 41.97	156.45 ± 38.48	438	54.74

1 – denotes the number of observations common for CI, DP and days open

2 – denotes total number of heifers and cows mated

Appendix Table 6 : Analysis of variance for calving interval (CI), dry period (DP) and days open

Source of variation	df	Sum of squares x 10^3			Mean squares x 10^3			F - ratio		
		CI	DP	Days open	CI	DP	Days open	CI	DP	Days open
Year	14	665.87	1101.48	697.33	47.56	78.68	49.81	3.79***	5.55***	8.36***
Season	1	0.74	0.39	19.80	0.74	0.39	19.80	0.06 NS	0.03 NS	1.34 NS
Genetic group	2	294.62	450.67	475.56	147.31	225.33	237.76	11.74***	15.90***	16.05***
Age of dam	3	25.78	44.21	45.19	8.39	14.74	15.06	0.69 NS	1.04 NS	1.02 NS
Parity	4	8.40	11.38	8.17	2.10	2.84	2.04	0.17 NS	0.20 NS	0.14 NS
Residual	679	8522.32	9620.82	10062.37	12.55	14.17	14.82			
Total	703	9517.73	11228.95	11308.43						

Appendix Table 7 : Linear regression coefficients (b) showing the influence of reproductive efficiency traits on milk production traits

		Lactation milk yield (y)		Lactation length (y)	
Preceding	n	a	b	a	b
CI (x)	704	1632.26	0.42 ± 0.06*	255.69	0.45 ± 0.07**
DP (x)	704	1865.63	-0.26 ± 0.08 NS	274.46	-0.22 ± 0.06 NS
Days open (x)	704	1763.61	0.32 ± 0.14*	268.94	0.34 ± 0.02*
<u>Concurrent</u>					
CI (x)	697	1675.33	0.46 ± 0.08**	267.48	0.22 ± 0.01 NS
Days open (x)	697	1909.93	0.15 ± 0.02 NS	283.61	-0.03 ± 0.01 NS

n - denotes the number of pairs of observations common for both lactation milk yield and length, pooled over for the first five parities.

a - constant for the linear regression equation: $\hat{Y} = a + b\hat{x}$

b - regression coefficient

y - dependent variable; x-independent variable.

Appendix Table 8 : Linear regression coefficients (b) showing the influence of reproductive efficiency traits on milk production traits

		Lactation milk yield (y)		Lactation length (y)	
Parity	(x)	a	b	a	b
I	CI	1213.21	0.81 ± 0.09*	244.73	0.31 ± 0.06*
(280)	DP	1563.24	0.02 ± 0.01 NS	268.58	0.02 ± 0.01 NS
	Days open	1449.15	0.73 ± 0.11*	261.43	0.05 ± 0.02 NS
II	CI	1293.26	1.08 ± 0.23*	246.04	0.46 ± 0.06*
(178)	DP	1724.44	0.22 ± 0.02NS	271.95	-0.01 ± 0.01 NS
	Days open	1594.53	1.09 ± 0.15*	262.11	1.02 ± 0.24*
III	CI	2005.96	-0.03 ± 0.01 NS	264.69	-0.69 ± 0.09*
(112)	DP	2133.77	-0.84 ± 0.08 NS	290.71	-0.11 ± 0.04*
	Days open	2013.99	-0.08 ± 0.02 NS	288.07	-0.19 ± 0.04*
IV	CI	1980.59	0.22 ± 0.08 NS	270.19	0.02 ± 0.01 NS
(80)	DP	2178.63	-0.87 ± 0.12 NS	282.56	-0.04 ± 0.01 NS
	Days open	2061.22	0.02 ± 0.01 NS	276.69	0.01 ± 0.01 NS
V	CI	2379.58	0.03 ± 0.01 NS	279.72	0.03 ± 0.01 NS
(55)	DP	2470.54	-0.59 ± 0.11 NS	288.11	-0.02 ± 0.01 NS
	Days open	2388.61	0.04 ± 0.02 NS	284.96	0.02 ± 0.01 NS

x - independent variable (CI, DP and days open).

y - dependent variable (lactation milk yield and length).

a - constant

Figures in parentheses denote the number of pair of observations common for CI, DP and days open at a parity.

Appendix Table 9 : Linear regression coefficients (b) showing the influence of concurrent calving interval and days open on lactation milk yield and lactation length

		Lactation milk yield (y)		Lactation length (y)	
Parity	(x)	a	b	a	b
I	CI	1244.56	0.44 ± 0.12 NS	281.51	0.01 ± 0.01 NS
(276)	Days open	1630.31	0.61 ± 0.13*	283.57	-0.04 ± 0.01 NS
II	CI	1097.88	0.15 ± 0.04 NS	289.24	-0.01 ± 0.01 NS
(177)	Days open	1733.85	0.19 ± 0.05 NS	286.44	-0.01 ± 0.01 NS
III	CI	1400.13	1.22 ± 0.18*	294.59	0.05 ± 0.02 NS
(114)	Days open	1861.58	0.37 ± 0.07	290.61	-0.05 ± 0.01 NS
IV	CI	1047.02	2.76 ± 0.14**	275.11	0.34 ± 0.06*
(77)	Days open	2161.81	0.28 ± 0.07 NS	284.74	0.02 ± 0.01 NS
V	CI	2576.21	-0.57 ± 0.05 NS	286.94	-0.01 ± 0.01 NS
(53)	Days open	2433.99	-0.59 ± 0.04 NS	287.14	-0.01 ± 0.01 NS

x - independent variable (CI and days open)

y - dependent variable (lactation milk yield and length)

a - constant

Figure in parentheses denote the number of pairs of observations common for CI and days open at a parity

Appendix Table 10 : Phenotypic correlation coefficients between reproductive efficiency traits and subsequent milk production traits at first five parities

Parity		Subsequent	
		Lactation milk yield	Lactation length
I	CI	0.15*	0.12*
(280)	DP	0.01 NS	0.01 NS
	Days open	0.16**	0.12 NS
II	CI	0.18*	0.15*
(178)	DP	0.04 NS	- 0.01 NS
	Days open	0.18*	0.18*
III	CI	- 0.01 NS	- 0.18*
(112)	DP	- 0.12 NS	- 0.23*
	Days open	- 0.01 NS	- 0.18*
IV	CI	0.02 NS	0.04 NS
(80)	DP	- 0.09 NS	- 0.08 NS
	Days open	0.02 NS	0.02 NS
V	CI	0.01 NS	0.09 NS
(55)	DP	- 0.09 NS	- 0.07 NS
	Days open	0.01 NS	0.08 NS

Figures in parentheses denote number of pairs of observations common for CI, DP and days open at a parity.

Appendix Table 11 : Phenotypic correlation coefficients between milk production traits and concurrent calving interval(CI) and days open at first five parities

Parity		Concurrent	
		Lactation milk yield	Lactation length
I	CI	0.01 NS	0.01 NS
(276)	Days open	0.12*	- 0.08 NS
II	CI	0.03 NS	- 0.02 NS
(177)	Days open	0.04 NS	- 0.02 NS
III	CI	0.18*	0.07 NS
(114)	Days open	0.06 NS	- 0.13 NS
IV	CI	0.33**	0.86**
(77)	Days open	0.03 NS	0.05 NS
V	CI	- 0.09 NS	- 0.04 NS
(53)	Days open	- 0.08 NS	- 0.03 NS

Figures in parentheses denote number of pairs of observations, common for CI and days open at a parity

Appendix Table 12 : Viability (%) of calves at different ages and periods over years

	Ages (upto)				Period (from):	I		II
	n^1	1 month	Weaning	1 year	n^2	1 month to weaning	n^3	Weaning to 1 year
Overall means	2618	97.14	93.77	87.28	2543	96.54	2455	92.08
Years								
1	192	98.96	97.92	92.19	190	98.95	188	94.15
2	129	98.45	96.91	89.92	127	98.43	125	92.81
3	159	95.59	90.57	86.79	152	94.74	144	95.83
4	176	96.59	92.05	85.78	170	95.29	162	93.21
5	236	97.88	94.92	85.59	231	96.97	224	90.18
6	190	96.32	93.68	90.53	183	97.27	178	96.63
7	179	96.65	92.74	83.24	173	95.95	166	89.76
8	164	96.95	95.12	89.63	159	98.11	156	94.23
9	158	99.37	96.20	94.30	157	96.82	152	98.03
10	152	98.03	95.39	91.45	149	97.32	145	95.86
11	178	97.75	93.26	85.96	174	95.40	166	92.17
12	186	94.62	93.01	83.33	176	98.29	173	89.59
13	180	97.22	95.00	87.78	175	97.71	171	92.39
14	167	95.81	89.22	84.43	160	93.13	149	94.63
15	172	97.09	90.70	80.23	167	93.41	156	88.46
Chi-squares values:		0.41 NS	1.53 NS	4.13 NS		0.78 NS		6.62 NS

n^1 denotes total number of calves born

n^2 and n^3 denotes total number of calves exposed to risk at periods I and II, respectively.

Appendix Table 13 : Phenotypic correlation coefficients between factors and reproductive efficiency traits

Factor	Age at first calving	Calving interval	Dry period	Days open
Year	– 0.26***	0.26***	0.31***	0.25***
	(336)	(704)	(704)	(704)
Season	– 0.08 NS	0.01 NS	0.01 NS	0.04 NS
	(336)	(704)	(704)	(704)
Genetic group	– 0.26***	0.19***	0.21***	0.22***
	(336)	(704)	(704)	(704)
Age of cow		0.07 NS	0.06 NS	0.07 NS
		(704)	(704)	(704)
Parity		0.05 NS	0.04 NS	0.04 NS
		(704)	(704)	(704)

Figures in parentheses denote number of observations.

Appendix Table 14 : Total rainfall per annum at the Institute[1] (1970 - 1985)

	Total rainfall (mm) Year								
	1970	1971	1972	1973	1974	1975	1976	1977	1978
Substations[2]									
Kikombo	624.8	515.8	604.8	555.8	549.9	773.8	448.3	507.9	850.6
Vianze	344.3	1160.2	672.9	924.4	703.8	781.3	434.1	524.1	810.6
Kiboriani	556.0	850.1	645.9	832.4	845.8	754.9	406.2	772.4	898.5
Ilolo	-	-	-	-	461.3	543.6	391.8	397.6	701.9
Institute	1525.1	2526.1	1923.6	2512.6	2560.8	2853.6	1680.4	2202.0	3261.6
Mean rainfall[3]	508.4	842.0	641.2	837.5	640.2	713.4	420.1	550.5	815.4

Appendix Table 14 continued

	Total rainfall (mm) Years						
Substations[2]	1979	1980	1981	1982	1983	1984	1985
Kikombo	894.1	929.7	667.7	675.8	762.0	967.9	717.4
Vianze	825.1	697.1	730.1	834.6	698.4	1062.7	723.8
Kiboriani	1248.6	667.6	675.2	1219.3	777.4	940.2	893.8
Ilolo	534.7	750.1	498.0	674.5	598.7	738.1	674.3
Institute	3502.5	3044.5	2571.0	3404.2	2836.5	3708.9	3009.3
Mean rainfall[3]	875.6	761.1	642.8	851.1	709.1	927.2	752.3

[1] Livestock Production Research Institute, Mpwapwa, Tanzania

[2] The research institute has four substations

[3] Mean rainfall at the Institute (Total rainfall for substations ÷ Number of substations)