HETEROGENEITY OF VARIANCE OF MILK YIELD AMONG HERDS AND APPLICATION OF ADJUSTMENT FACTORS FOR SIRE AND COW EVALUATION IN KENYAN FRIESIAN CATTLE.

BY

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF
MASTER OF SCIENCE IN ANIMAL SCIENCE , UNIVERSITY OF NAIROBI,
1994.

DECLARATION:

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

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

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DEDICATION

To Elijah, Mathews, Antony and Gay Atichi,
my late brothers and above all, GOD
for His Glory and Grace.

ACKNOWLEDGEMENTS

I am most grateful to my University supervisors, Drs. R.O. MOSI and J.J. OTIM for their able guidance, counsel, discussions, friendliness, constructive criticism and consistent interest they displayed towards this work throughout the study period.

I owe my appreciation to the Kenya Milk Records and the Livestock Recording Centre for granting permission to use their Friesian cattle records for this work, to Mr. B.A.O. INYANGALA for initial data entry and computer work. I am indebted to Mr. A.M. OKEYO and Mr. J.W. WAKHUNGU for their tireless assistance in data analysis. Thanks are also due to all other staff of the Department of Animal Production who assisted in one way or another to make this study a success. I extend my sincere appreciation to my family and friends for their prayers and support which kept me going in difficult times.

This study was made possible through a scholarship provided by the University of Nairobi.

TABLE OF CONTENTS

TOPIC PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES.

ABSTRACT.

Production and reproduction records of Kenyan Friesian cows obtained at the Kenya Milk Records (KMR) , covering the period 1968 - 1984 , were used to study heterogeneity of variance of 305 - day milk yield and to develop parity and lactation length adjustment factors. Two different methods of multiplicative correction factors and linear regression were used to standardize milk yield to 305 day equivalent. Coefficients of variation and standard deviations across herds were used to test heterogeneity of variance. A fixed effect least squares model was used to analyse the contribution of fixed effects to heterogeneity of variance of milk yield, while lactation length and parity adjustment factors were developed by ratio method.

The least squares means for 305_M, 305_L- day and annual milk yields were 2740.3 ± 10.37 kg, 2813.2 ± 11.08 kg and 2722.8 ± 12.88 kg respectively. Significant heterogeneity of variance of milk yield was found to exist between herds. Year of calving, herd, herd class, parity, calving interval and lactation length affected milk yields significantly and contributed to heterogeneity of variance. Season of calving did not influence milk yield. Age within parity affected 305 day milk yields significantly but not annual milk yield. Average herd standard deviation and coefficient of variation after correcting for the fixed effects were 672.2 Kg and 26.7% respectively, while scaled standard deviations between herds were 180 kg and 3.4% . Use of parity adjustment factors reduced the CV of 305_M day milk yield from 24% to 20%, while the amount of variation accounted for by parity reduced from 82% to 23% .

It was concluded that heterogeneity of variance of milk yield should be accounted for in sire and cow evaluation. The scaling of observations within individual herds by sample standard deviation minimises heterogeneity of variance and increases accuracy of selection. Adjustment factors for lactation length and parity were proposed as possible means of using all lactation records in sire and cow evaluation in Kenya.

CHAPTER 1: INTRODUCTION.

The basic assumption in sire and cow evaluation in Kenya is that the variance of milk yield is homogenous among herds. However, lactations of individual cows within and between herds are affected by genetic and non-genetic factors which lead to differences in milk yields and consequently heterogeneity of variance. In order to develop appropriate lactation length and parity adjustment factors for use in sire and cow evaluations, it is necessary to account for the heterogeneity of variance. This can, to a large extent, be achieved through adjusting for most of the factors that affect milk yields.

Lactation length in the tropics is mainly dependent on the management within herds and partly the genotype. This was the basis of developing lactation length correction factors by the Kenya Milk Records. However, in developing these factors, only lactations lasting from 199 to 305 days were considered. Considering the fact that lactation lengths of less than 199 days are common in Kenya, these factors appear to be unrealistic.

The hypothesis tested in this study was that variance of milk yield between Kenyan Friesian herds is not significantly heterogenous to warrant the use of adjustment factors in sire and cow evaluation. The specific objectives of the study were:

i) To investigate the level of heterogeneity of variance of 305 - day milk yield between Kenyan Friesian herds.

ii) To identify and evaluate factors that cause heterogeneity of variance between herds.

iii) To examine the possibility of using appropriate adjustment factors to improve sire and cow evaluation.

CHAPTER 2: LITERATURE REVIEW.

Much of the genetic change in milk production is attributed to selection of progeny-tested bulls,either as sires of a new generation of bulls or of cows. The efficiency of sire selection can be increased by accurately identifying those cows with the highest genetic potential and then entering their bull calves into a well designed A.I testing programme. Sire and cow evaluations are, however, greatly hampered if variances between herds are heterogenous.

This chapter reviews literature on causes of heterogeneity of variance between herds and its influence on sire and cow evaluation. The review also covers the different methods used in adjusting for the systematic environmental effects on milk yields.

2.1 LEVEL AND VARIATION OF MILK YIELD.

Although means of milk yield serve as a rough guide to the production potentials of various cattle breeds, differences in the management of different herds complicate the comparison of these means (Wakhungu, 1988). **Table 1** presents the mean milk yields of various breeds raised in tropical and subtropical areas. Most of the herds with high milk yields were institutional herds (Marples and Trail, 1967; Kabuga and Agyemang, 1984; Mwai and Mosi, 1991). Some of the herds (Kabuga and Agyemang, 1984) had imported heifers and their records were included in the analyses as heifers or cows. High production levels in institutional herds were attributed to the genetic and overall management superiority. **Table 1** also shows

Table 1 **Mean milk yields of various breeds raised in tropical and subtropical areas.**

Location	Breed	Yield (Kg)	CV%	Reference	Remarks
Kenya	Jersey	2153	29	Kiwuwa (1974)	1st three lactations
"	Friesian	2806	-	"	1st three lactations
Kenya	Sahiwal	1662	34.4	Wakhungu (1988)	1st six lactations
Kenya	Friesian	2822 (us)	44	Mosi (1984)	1st five lactations
"	"	2885 (s)	39	"	1st five lactations
Kenya	Friesian	4062	20.26	Mwai and Mosi (1991)	1st seven lactations
Uganda	Jersey	2006	21.8	Marples and Trail (1967)	305 - day
"	Friesian	3201	18.7	"	"
"	Guernsey	2309	23.9	"	"
Ghana	Friesian	3878	-	Kabuga and Agyemang (1984)	305 - day
India	Friesian	1775	-	Arora and Sharma (1983)	1st lactation
Tanzania	Jersey	1892	34.4	Katyega (1988)	1st four lactations

Key: us : unselected; s: selected

the high coefficients of variation within and between breeds for milk yield, explicable mainly by genetic and environmental (e.g nutrition and management) differences.

Annual milk yield per cow takes into account its productive and reproductive performance. Dairy farmers are usually interested in the net annual income which is derived from total annual milk yield sales less the total annual inputs. Cunningham and Syrstad (1987) reported annual milk yields of 1842, 1612 and 1539 kg for Friesian, Brown swiss and Jersey crosses. The high annual milk yield of Friesian crosses was attributed to high lactation milk yield (2165 kg) despite long calving interval (429 days). Mwai and Mosi, (1991) estimated annual milk yield of Kenyan Friesian cattle at Naivasha to be 4122 kg. This exceptionally high production level was probably due to the high actual milk yield (4062 kg) attributed to good feeding and management coupled with genetic superiority. Njubi (1990) reported mean annual milk yield of 1692 kg for Jerseys in the sub-humid coastal zone of Kenya. The low annual milk yield relative to that of Friesian breed was attributed to low actual milk yield (1788 kg) despite the short calving interval (408 days).

It follows therefore that the Friesian and its crosses have high lactational and annual milk yields compared to other exotic breeds despite their long calving intervals. Improvement in nutrition and management is expected to lead to higher milk yields, reduced calving intervals and consequently higher annual milk yields. However, differences in nutrition and management are reflected in different herd production levels.

2.2 HETEROGENEITY OF VARIANCE OF MILK YIELD AND ITS IMPLICATION TO CATTLE EVALUATION.

Both phenotypic and genetic differences between individuals are considered by geneticists as the raw material for improvement. The differences are measured and expressed as the variance (Falconer,1989). When the variances are not alike, they are said to be heterogenous and heterogeneity of variance is then said to exist. The use of Best Linear Unbiased Prediction (BLUP) or similar procedures in predicting breeding values of sires and cows assumes that the variance of milk yield is homogenous between herds (Brotherstone and Hill,1986; Garrick and Vleck,1987). BLUP also assumes knowledge of variances of the random effects (sire, cow and error terms) and accounts for differences in genetic merit of sires between different herds (Rege and Mosi, 1989). However,published evidence suggests the presence of systematic changes in variance components associated with mean level of herd performance (Vleck et al.,1988). Many workers have reported an increase in phenotypic variance of milk yield with increasing level of herd production (Danell,1982; Veer and Vleck,1987; Weller et al.1987). Correlations between herd variability and mean production have been reported as positive and moderate, falling in the range of 0.21 to 0.49 (Meinert et al.,1988a). These findings invalidate the normal assumption that between and within-herd variance is homogenous among herds.

The impact of heterogeneity of variance on animal evaluations and selection has been examined by several workers. Everett et al.

(1982) found that among herds of equal genetic merit,herds with greater variance had a higher proportion of cows achieving elite status than herds with lower variance. Powell et al. (1983) reported similar findings. In the latter study, it was found that among herds of equal sire merit, herds with higher production level had greater variance attributed to better nutrition and management. In a simulation study on selection among herds with heterogenous variance, Hill (1984) reported the fraction of animals that would be selected from the more variable groups under differing intensities of selection. The proportion selected from the high variance group increased as both selection intensity and standard deviation increased. In his review, Vinson (1987) noted that heterogenous herd variance causes genetic evaluations for high producing cows in high variance herds to be exaggerated. Evidence presented in these studies suggests that herd phenotypic variance influences the proportions of animals selected from the different herds, with extreme animals being found in high variance herds.

In the contemporary comparison method,now routinely used in Kenya in evaluating dairy sires (Philipsson et al.,1988; Rege and Mosi,1989), the comparison is made within years.The method assumes that genetic differences between herds are not large enough to interfere with the sire's breeding value estimation and that variances of milk yield are homogenous between herds (Hickman,1977). But research with production traits has demonstrated that regressions of daughter yield on sire predicted difference can vary drastically between herds (McDaniel and

Corley,1967; Powell and Norman,1984; Meinert et al.,1988b). There are also genetic and environmental differences between herds due to use of different bulls by different herds, management factors and nutrition (Rege and Mosi,1989; Vercoe and Frisch,1990). All these factors contribute to differences in production levels between herds. Using evaluations based on progeny tests,Wilhelm and Mao (1989) showed that young bulls selected from herds with low milk yield variance were genetically superior to those selected from herds with high variance. They also observed that predicted transmitting abilities for young bulls selected from low variance herds were less biased, while those of bulls selected from high variance herds were inflated probably due to genotype - environment correlation.Similar findings have been reported by Garrick and Vleck (1987), who observed a reduction in the accuracy of sire evaluation due to heterogeneity of variance of milk yield between herds. Thus, heterogenous variances have to be accounted for in sire evaluation.

In cow evaluation, information about an individual cow and its relatives is combined into a cow index and is expressed as breeding value (Brotherstone and Hill,1987). Different methods are used worldwide in cow indexing. The use of a cow genetic index for dam selection is complicated by heterogenous variances arising from differences in levels of production between herds (Hill,1984; Brotherstone and Hill,1986; Vinson,1987; Wilhelm and Mao,1989). Yet for its efficient use , the index has to reflect the genetic merit of the cow correctly irrespective of the level of herd production.

Heterogenous phenotypic variation is mainly attributed to genetic and environmental causes (Short et al.,1990). Differences between herds in culling levels and breeding skills make it difficult to eliminate genetic inter-herd variation. However, the use of A.I sires across herds or assumption of a fixed amount of genetic variation in herds may eliminate inter-herd genetic differences. Environmental differences may be eliminated by within herd corrections (Mosi,1984). These findings suggest the need to account for heterogeneity of variance to minimize the effects of variation in herd yield level on the index values. This would overcome the bias in evaluations and remove disproportionate selection that results from heterogenous variances.

2.3 CAUSES OF HETEROGENEITY OF VARIANCE OF MILK YIELD.

Milk yield and composition are as a result of many factors within the cow and environment. Farmers can alter many factors to increase milk yield and improve its composition, while some factors are beyond the farmers' control. Factors which influence milk yield also contribute to the heterogeneity of variance of milk yield between herds. Among these factors are, herd, year and season of calving, parity, lactation length, calving interval and age at calving.

2.3.1 YEAR AND SEASON OF CALVING.

The effect of year of calving on production traits of dairy cattle raised in the tropics is well documented (Rege and

Mosi,1989; Gupta et al.,1990; Mbap and Ngere,1991; Mchau and Syrstad,1991). In some studies, year of calving has been found to account for upto 65% of the variation in milk yield (Kabuga and Agyemang, 1984). Management, climatic and genetic factors (Rege and Mosi,1989) are the major causes of yearly variation in dairy cattle performance. In the tropics, rainfall is the major climatic factor that influences pasture quality and availability. Animals that calve down during unfavourable years with reduced pasture supply perform poorly (Mbap and Ngere,1989). However, supplementation and better management improves herd performance. Due to differences in supplementation and management levels between herds, variation in herd performance still occur (Short et al.,1990). However, the effects of management and climate are usually confounded. Consequently, it is important to identify and classify the real causes of year effects.

Reports on the influence of season on production performance of cattle raised in the tropics are inconsistent. Some studies have reported significant effects of calving season on milk yield (Krishnaiah et al.,1988; Katochi et al.,1990; Mwai and Mosi,1991), while others (Murdia and Tripathi,1990; Gupta et al. 1990 and Yeotikar and Deshpande, 1990) have found non-significant season effects.Differences in herd management, breed, method of analysis, distribution of records among seasons and years included in the analyses could explain the inconsistency. Supplementation of animals during the dry season may lead to non-significance of the season effects. In Kenya, Wakhungu (1988) observed that although season of calving did not have a significant influence on milk yield, cows calving in the short rainy season had the highest milk yield while those that calved in the long rainy season had the lowest. He attributed this to the small part of lactation supported by the high quality pasture for cows which calved in the long rainy season. Those that calved during the short rains were advantaged by the long rains which coincided with their lactation period. Despite the inconsistent results, there is need to include season in analytical models so as to remove the biases in milk yields recorded in different herds in different seasons. However, it is important that in every analysis, seasons are definite such that they reflect the true climatic pattern of the environment.

2.3.2 PARITY AND AGE AT CALVING.

The significant effects of parity on milk yield are well documented (Wakhungu,1988; Rege and Mosi,1989; Mbap and Ngere,1991). **Table 2** presents a summary of the influence of parity on milk yields of various breeds in tropical and subtropical areas. Several workers have reported an increase in milk yield with increased parity upto a maximum, followed by a gradual decline in later parities (Mosi,1984; Juma and Jajo,1986; Mchau and Syrstad,1991). This could be due to differences in heifer and cow nutrient partitioning for growth, maintenance and lactation. Gyawu et al. (1988) have reported an unusual peak milk yield occurrence in the second lactation in Holstein cattle in Ghana.

In Kenya, Mwai and Mosï (1991) reported a peak yield occurrence in

Table 2 Influence of Parity on milk yields of cattle raised in tropical and sub-tropical areas.

Location	Breed	Influence	Parity of peak yield	Reference
Kenya	Sahiwal	significant	4	Kimenye (1978)
Kenya	Sahiwal	significant	4	Wakhungu (1988)
India	F X Hariana	significant	3	Biswas et al.(1982)
Kenya	Friesian	significant	5	Mosi (1984)
Kenya	Friesian	significant	5	Rege and Mosi (1989)
India	R and cross-bred cows	non-sign	-	Dhumal et al.(1989)
India	J X Hariana	significant	3	Panda and Sandhu (1983)
India	H-F XBengal	significant	4	"
Kenya	Friesian	significant	4	Mwai and Mosi (1991)
India	Karan Fries	significant	5	Singh and Tomar (1991)

Key: F : Friesian; J : Jersey; H-F : Holstein- Friesian; R : Red Kandhari; H : Holstein

the fourth parity. This contradicts earlier findings of Mosi (1984) and Rege and Mosi (1989), who reported peak yield in the 5th parity. Mwai and Mosi (1991) attributed this early attainment of peak production to fast growth and development achieved through the long term and consistent breeding for dairy characteristics in their country of origin. Besides, they used lactation records of only one herd with superior feeding and management programmes. Contrary to this, studies of Mosi (1984) and Rege and Mosi (1989) involved the National Friesian population and thus included many herds with differential feeding and management programmes. It appears that milk yield by the same cow changes with parity. Consequently, this leads to heterogeneity of variance between and within herds. Development of appropriate parity adjustment factors could minimise this heterogeneity of variance and thus increase the accuracy of sire and cow evaluation.

Milk yield of a cow is also influenced by the number of years it has lived (actual age). However, most studies emphasize specific effects of age at first calving on milk yield. It is argued that age at first calving which is closely related to generation interval, influences response to selection and determines how early in life an animal's breeding value may be estimated (Mukasa-Mugerwa,1989). The few studies on the effects of actual age on milk yield have all reported its significant influence (Kiwuwa ,1974; Mosi ,1984; Parekh and Singh ,1987 and Mwai and Mosi ,1991) . Martinez et al. (1990) observed that under practical conditions, the relationship between milk yield and age cannot be separated from the effect of selection. Milk yield from an individual cow increases with advancing age to maturity and then declines steadily (Syrstad,1965). Compared to a mature cow, a heifer's production ability is limited by the incomplete body and udder development. The rate at which milk yield increases with age is also dependent on nutrition and management. Marshall et al.(1990) observed that an earlier relative calving date was associated with increased cumulative feed energy intake. Due to the different levels of feeding and management between herds, animals born on the same date tend to have different rates of growth and consequently attain weight at first service at different times. This leads to differences in the levels of milk yields between herds with corresponding differences in variances. Age effect should be corrected for in the analytical models for milk yield. This can allow the use of all records for genetic evaluations. The correction should preferably be on within parity basis to avoid the confounding effects of actual age with those of parity.

2.3.3 LACTATION LENGTH AND CALVING INTERVAL.

The genetic correlation between milk yield and lactation length of cattle raised in the tropics is in the range of 0.32 to 0.87 (see Table 3) indicating that under tropical conditions, this correlation is highly variable. The high positive genetic correlation means that selection for lactation length may be achieved indirectly by selecting for milk yield. The corresponding high positive phenotypic correlation means that high milk yields are associated with long lactations with subsequent increase in phenotypic variance. The magnitude of the correlation depends on the breed, management and whether the calves have been allowed to suckle or not (Kimenye,1978; Wakhungu,1988). Management may reduce lactation length by not milking cows beyond a certain lactation period. In such cases, lactation milk yield is determined more by maximum daily yield than lactation length. Thus, differences in milking days for the various herds lead to different milk yields and hence heterogeneity of variance of milk yield. To minimise the

Table 3 Reported genetic (r_g) and phenotypic (r_p) correlation of milk yield with lactation length for various breeds in tropical and subtropical areas.

Breed	Location	r_g	r_p	Reference
Sahiwal	Kenya	0.72±0.10	0.62	Kimenye (1978)
Gir	India	0.16	-	Madalena (1988)
Friesian	Iraq	0.27	-	"
Friesian	Kenya	0.50 (1)	0.61 (1)	Mosi (1984)
"	"	0.32 (2)	0.14 (2)	"
"	"	0.62 (3)	0.44 (3)	"
Sudanese cattle	Sudan	0.87	-	Alim (1960)
"	"	0.86	-	Alim (1962)
Jamaica Hope	Jamaica	-	0.64	Schneeberger et al.(1982)

Key

1 : First lactation

2 : Second lactation

3 : Third lactation

heterogeneity of variance, there is need to develop appropriate lactation length adjustment factors.

Documentation on the relationship between preceding calving interval and the current milk yield of tropical cattle is inconsistent. Some studies (Galukande et al., 1962; Wakhungu ,1988) have reported a significant correlation while others (Singh and Desai, 1961; Biswas et al. 1982 and Strandberg and Danell 1989) have not. Higher milk yield per lactation is associated with longer postpartum intervals to first service (Berger et al., 1981; Wakhungu,1988), longer service period (Hansen et al.,1983) and more days open (Seykora and McDaniel,1983). Large variations in calving intervals and hence milk yields are more of managerial practices than the genotype of the animal. Consequently, these lead to heterogeneity of variance of milk yield between herds. Milk yields should therefore be adjusted for the effects of preceding calving interval especially when they are short. Otherwise when they are long, their effect is minimised because the cow has more than enough rest.

2.3.4 HERD.

Marked differences exist between herds in the level of milk production. An accurate knowledge of the underlying causes of these differences is important in dairy cow and sire evaluation (Vercoe and Frisch,1990). The magnitude of the effect of herd on milk yield is well documented. In some studies, the herd effect has been found to account for upto 30% of the total variation (Mosi, 1984).

Both genetic and several identifiable non-genetic factors contribute to differences between herds in milk yields (Agasti et al.,1988; Vercoe and Frisch,1990). The genetic component is caused mainly by the effect of additive genes. The environmental variation is mainly through nutrition, disease incidence and management practices within herds (Frisch and Vercoe,1986; Brotherstone and

Hill,1986; Wakhungu,1988). Good levels of feeding tend to stimulate milk yield while underfeeding has the opposite effect. Cows that calve in good body condition usually have enough energy reserve for increased production. Besides, the ability of different farmers to cope with fluctuating nutrient supply during adverse weather conditions is usually reflected in the mean milk yields of the different herds. The differences in milk yields consequently lead to heterogenous variances that should be accounted for in sire and cow selection by fitting herd as a factor in the analytical model.

2.4 USE OF ADDITIVE AND MULTIPLICATIVE ADJUSTMENT FACTORS .

Systematic environmental effects such as parity,age, herd, season and year of calving can be accounted for by use of appropriate adjustment factors (Chauhan et al.1990;Funk et al.,1991). The adjustments can be made either additively or multiplicatively (Emanuelson,1985). Several criteria for assessing the effectiveness of correction methods have been suggested. They include unremoved variation, bias in sire predictions, interactions of certain effects with herd-year and residual variance ignoring interactions (Searle and Henderson,1960).

For additive correction factors,the increases or decreases in milk production due to the effect of an environmental factor are assumed to be of the same magnitude for all cows (Chauhan,1988). Using records of Swedish dairy cattle, Emanuelson (1985) concluded that additive adjustments were most appropriate in the first parity, whereas multiplicative adjustments were effective in later parities. Multiplicative correction factors are appropriate when scalar effects lead to unequal subclass variances (Chauhan,1988). Fimland et al. (1972), using the criteria of herd-year-season by age and herd-year by season of calving interactions, compared additive and multiplicative factors. They reported that with multiplicative factors, the interaction variance was smaller for age effects but larger for season of calving. Dempfle and Hagger (1979) found that there were substantial differences between the estimates of age effects in low versus high producing herds but the multiplicative correction factors for any age specific class were quite similar. They concluded that a single set of multiplicative correction factors for all herds would be more useful than additive factors. Contradictory findings were reported by Funk et al. (1991) who observed that multiplicative adjustment often does not equalize variation for classes due to scaling problems. For example,for milk yield, a multiplicative factor of 1.15 adjusted 6000 kg to 6900 kg (+900 kg) and 9000 kg to 10,350 kg (+1350 kg). Thus, with multiplicative adjustment, the corrected milk yields tended to be inflated. They however concluded that for milk yield,multiplicative adjustment is preferable because variance tends to increase with the mean.

Other studies (Janson, 1980; Saxena et al. 1991) have found negligible differences in the effectiveness of the two methods of adjustment. It should, however, be realized that each of the two methods has limitations and therefore, the method to use depends among other factors, on the effects to be adjusted for.

2.4.1 ADJUSTMENT FACTORS FOR PARITY AND LACTATION LENGTH.

Since parity is known to affect milk yield substantially, it should be adjusted for when estimating genetic parameters and breeding values (Mchau and Syrstad,1991). In the contemporary comparison method of sire evaluation, although outdated, only first lactation records are used (Philipsson et al,1988). This has the disadvantage that the number of records available for evaluation is compromised. Furthermore, due to increased generation interval, sires whose daughters have a slow growth rate may be left out. This is a likely occurrence in the tropics where management standards and nutrient supply fluctuate. BLUP procedures incorporate later cow lactations in sire and cow evaluation (Meyer,1983). But because these procedures are quite demanding in terms of data structure and computer running time and therefore, difficult to implement in most developing countries (Mosi,1984), there is need to modify the contemporary comparison method to include later lactations in sire evaluation. This observation is supported by Beaudry et al. (1988) who noted that later-lactation sire evaluations were more useful than evaluations based on first lactations in the prediction of total lifetime production. The genetic basis of this is the "lactation development of a sire," that is, the performance of its daughters during the different lactations (Ron and Hillel,1983).

In calculating the cow genetic index, the cow's first lactation and her later lactation information should all be incorporated (Hill and Swanson,1983; Brotherstone and Hill,1987;

Martinez et al. 1990). This is mainly because selection on a multiparity cow index results in more genetic gain than selection on first parity alone (Weller et al.,1987; Banos and Shook,1990). This can be achieved by developing appropriate parity adjustment factors that would permit the use of multiple records in both sire and cow evaluation. The gain in accuracy could compensate for any disadvantageous effects such as bias of proofs for any particular group of bulls if parity is not included in the model.

The handling and interpretation of lactation length in genetic studies is rather controversial. Some authors (Ruvuna et al. 1984 ; Shrivastava and Khan, 1989) have adjusted milk yield by the phenotypic regression on lactation length. The linear regression method is based on the fact that cows are usually managed to have a yearly calving so as to raise enough replacements.To meet this objective, the cows are allowed to lactate for a maximum of 305 days with an optimal calving interval and dry period of 365 and 60 days respectively (Bar-Anan and Genizi,1981). Other workers (Lindstrom and Solbu,1978) have used all the available records while others exclude from the analysis short lactations (≤150 days) considered "abnormal" (Madalena,1988). Ngere et al., (1973) extended yield to mean lactation length for records terminated by loss of calf. They argued that such terminations were associated with identifiable environmental disturbances. Kiwuwa et al. (1983) excluded lactations shorter than 75 days as abnormal. However, the same authors concluded that lactations in which peak yields were reached generally between 21 and 60 days and cows later voluntarily dried up should be regarded as normal records, if no extraneous factors led to the cessation of milk yield.

Heritability of lactation length is low (Madalena, 1988). Njubi (1990) reported a value of 0.12± 0.056 in Kenyan Jersey cattle while Lindstrom and Solbu (1978) reported a value of 0.09 for improved dairy breeds in Kenya. Hence, exclusion of short lactations may not necessarily remove genetic variation in lactation length. On the other hand, because short lactations in the tropics are mainly managerial, there is need to include all lactations in cow performance analyses. Based on this, the Kenya Milk Records (KMR) developed correction factors for lactation length (**Appendix 1**). However, the KMR considered only lactation lengths of 199 days and above. It appears that the current KMR factors for predicting lactation yield from uncompleted lactations are not realistic. Besides, peak yields for tropical cattle have been reported to occur within the second month of lactation (Bar-Anan and Genizi, 1981). Therefore, there is need to develop more realistic extension factors for lactation length to accommodate most lactations. These would provide unbiased estimates of the production of cows at different lactation stages while at the same time aiding the farmers in making breeding and management decisions. This is more important in Kenya where the shapes of lactation curves are least understood.

CHAPTER 3: MATERIALS AND METHODS.

3.1 SOURCE AND DESCRIPTION OF THE DATA:

Data for this study were obtained from the cow files maintained at the Kenya Milk Records (KMR), the organisation responsible for official milk recording in the country. The records were made by the Kenyan Friesian cows kept in commercial herds between 1968 and 1984. The herds were mainly located in the medium and high potential zones of Kenya, receiving mean annual rainfall of about 800-1000 and 1000-1500 mm respectively.

In total 5401 lactation records from 972 cows, kept in 60 different herds and served by 49 different sires were extracted. Each record contained the following information :

- herd identification.
- individual cow identification.
- cow's date of birth (day - month - year).
- cow's date of calving (day - month - year).
- Lactation milk yield (kg).
- Lactation length (days).
- Lactation number (parity).
- Butter fat percent.
- Butter fat yield (kg) .
- Service sire.

Age at calving (months) and calving interval (days) were derived variables. The records were built up for each cow and parturition. The major limitation of this data was the unavailability of pedigree information on the cow and service sire.

3.2 HUSBANDRY PRACTICES.

Different production systems were used. For herds kept in the high potential areas, semi-intensive feeding system was practised. Fodder was grown and was either grazed by the animals themselves or cut and brought to the animals. Lactating cows were supplemented with rations such as maize meal and cotton seedcake. Calving was all-the-year round, though majority of calves were born during the relatively dry months. On the other hand, most of the herds kept in medium potential areas practised extensive grazing of natural pastures that varied considerably in both quantity and quality.

Artificial insemination (A.I) was variably available to the herds. Due to the unreliability of the service, some herds used natural service. Heifers were first bred according to age (at about 24 months). All female calves born in the herds were retained while most bull calves were either sold to other farmers for breeding purposes or castrated.

Similarly, cattle management practices varied between herds. Those in high potential areas practised better disease control than those in medium potential areas. Routine vaccinations, deworming and dipping were carried out on all the animals. Thus, animals were protected against major diseases such as foot and mouth, rinderpest, trypanosomiasis and tick borne diseases such as east coast fever. Calf management practices such as dehorning, castration and removal of extra teats were carried out.

3.3 DATA PREPARATION:

Data preparation was carried out using statistical packages and computer facilities of the Department of Animal Production, University of Nairobi. Derived variables and basic statistics were obtained by the use of Panacea data base programme (Pan Livestock services,1989).

Lactations which were less than 60 days were excluded. A record was also omitted if any of the following information was missing : herd identification, cow identification, date of birth,year of birth,date of calving,year of calving,lactation number and lactation milk yield. Of the 5401 lactation records, 4025 were available after editing, for the derivation of adjustment factors, a reduction of about 25% . Only 24 of the original 32 herds were used in the analysis of heterogeneity of variance. In this analysis, the minimum number of records per herd was set at 10. Consequently, the number of records was further reduced to 3975. The structure of the data used in the study is summarized in **Table 4.**

The lactation milk yield was adjusted to a standard lactation of 305 days using multiplicative extension factors developed from the data as detailed out in Section 3.5 and Table 15. This adjustment was to eliminate variation in lactation lengths due to management. Annual milk yield (AMY) was calculated as:

$$AMY = \frac{LMY}{CI} \times 365$$

where, CI is the calving interval and LMY is the lactation milk yield. For heifers, the second calving intervals were credited to

Table 4 **Structure of the data set for yield traits (305-day and Annual milk yields).**

EFFECT	**Number**
Total no. of records.	4025
Cow	949
Parity	6
Year of calving	17
Season of calving	3
Herd	32
Herd class	3
Calving interval	2507
Lactation length	4025

first calving and used in deriving AMY in the first lactation. The underlying assumption was that the second and subsequent calving intervals were approximately equal and very long and were also assumed to be equal to the first calving interval of heifers.

The 32 herds were grouped into three main categories as set out in **Table 5**, according to the distribution of herd means for annual milk yield (low, medium and high). Parity classes were defined as 1st to 5th with 6th and subsequent parities being grouped into one subclass because of small numbers of observations **(Table 6)**. Besides, the rate of decline in milk yields increased in parities 7 and above **(Fig. 1)**.

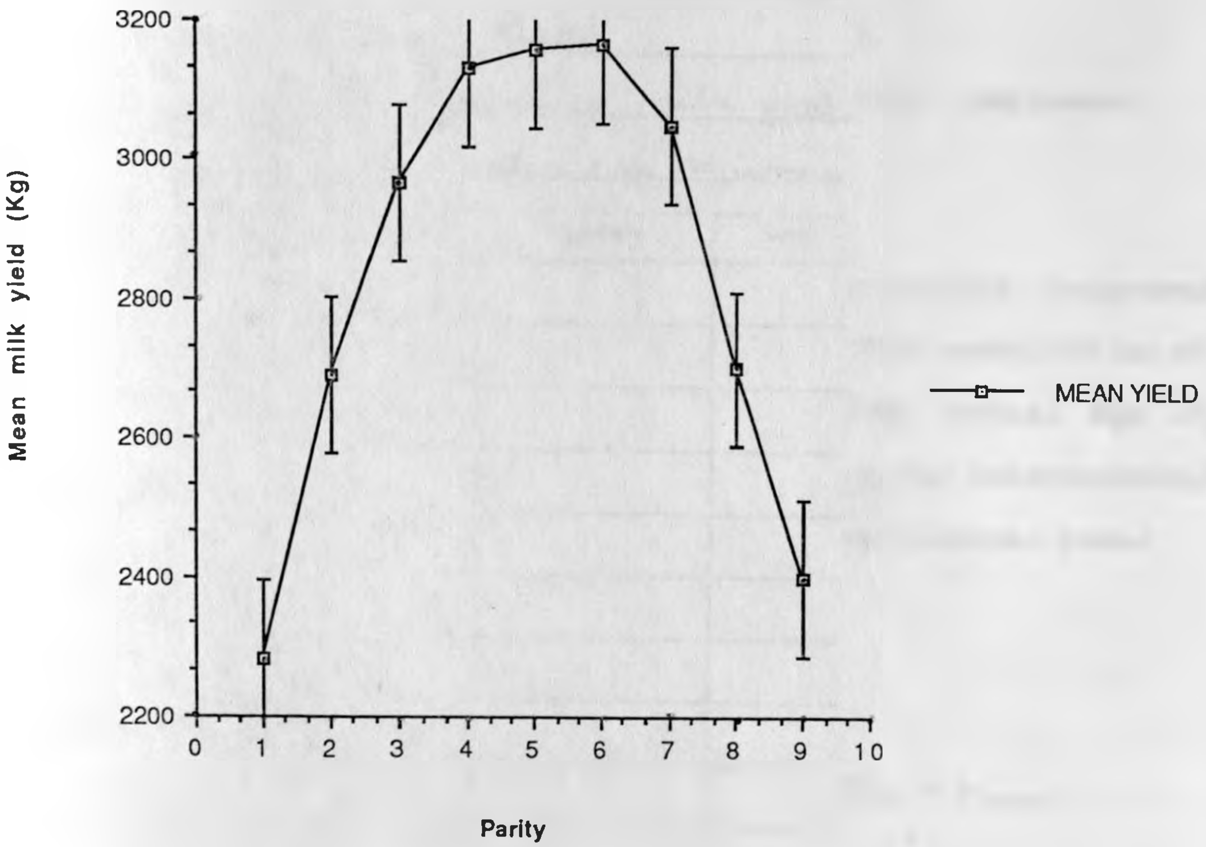
Table 5 Category of herds according to level of production.

HERD CATEGORY	MEAN AMY	NUMBER OF HERDS	NUMBER OF RECORDS
A (LOW)	< 2500	7	195
B (MEDIUM)	2500-3000	23	3405
C (HIGH)	> 3000	2	425

Table 6 Actual milk yields (±s.e) by parity.

Parity	No. of obser.	Mean yield
1	1523	2282 ± 19.48
2	921	2690 ± 27.30
3	644	2966 ± 36.28
4	431	3132 ± 46.70
5	268	3159 ± 57.00
6	136	3167 ± 78.86
7	67	3049 ±112.40
8	28	2700 ±176.23
9	7	2400 ±274.11

FIG. 1: Unadjusted mean milk yield by parity.



Rainfall was the major climatic factor that influenced pasture availability and quality in all herds which provided data for this study. The pattern of rainfall distribution in most parts of the country was bimodal. Due to this, it was considered appropriate to divide the year into three calving seasons using the procedure of Rege and Mosi (1989). These were :

Season 1 :Long rains: March - May

Season 2 :Short rains: October - November

Season 3 :Dry Period : December - Feb; June - September.

3.4 DATA ANALYSES.

Least Squares and Maximum Likelihood Statistical Programme (Harvey,1990) was used in the main data analyses. The contribution of the fixed effects of year and season of calving, actual age at calving within parity, herd, herd class and parity to heterogeneity of variance were investigated by the following statistical model (Model 1):

Model 1:

$$Y_{ijklmno} = \mu + H_i + YR_j + SN_k + P_l + bC_{ijklmno} + HC_m + AP_{nl} + e_{ijklmno}$$

Where;

$Y_{ijklmno}$ is the Annual or 305 day milk yield (Kg) of the o^{th} lactation record of a cow which calved in the i^{th} herd in the j^{th} year, k^{th} season and m^{th} herd class.

μ is an underlying constant common to all records.

H_i	is the fixed effect of the i^{th} herd (i= 1,2,3,...32).
YR_j	is the fixed effect of the j^{th} year (j = 1,2,3,...,17).
SN_k	is the fixed effect of the k^{th} season (k = 1,2,3).
P_l	is the fixed effect of the l^{th} parity (l = 1,2,3,4,5,6).
HC_m	is the fixed effect of the m^{th} herd class (m = 1,2,3).
AP_{nl}	is the interaction effect between the n^{th} age at calving, A, and the l^{th} parity.
b	is the partial regression coefficient of milk yield on a covariate, C.
$C_{ijklmno}$	are covariates of age at calving, calving interval and lactation length.
$e_{ijklmno}$	is the residual error term normally distributed with mean zero and variance σ^2_e

Actual age at calving was fitted together with other fixed effects as a linear regression within parity in a fixed model (model 1). The effects of lactation length and calving interval on milk yield were also investigated by fitting them as covariates in model 1. Least square means of milk yield for lactation length classes were fitted in model 2 to permit estimation of extension factors. The following fixed model (model 2) was used for this purpose:

Model 2:

$$Y_{ijklmnop} = \mu + H_i + YR_j + SN_k + P_l + bC_{ijklmnop} + HC_m + L_n + AP_{ol} + e_{ijklmnop}$$

Where;

$Y_{ijklmnop}$ is the lactation milk yield (Kg) of the p^{th} lactation record of the a cow which calved in the i^{th} herd in the j^{th} year, k^{th} season and m^{th} herd class.

L_n is the fixed effect of the n^{th} lactation length. sub-class (n = 1,2,3,...35).

AP_{ol} is the interaction effect between the o^{th} age at calving, A and the l^{th} parity.

All other symbols were the same as those in Model 1, only that in this analysis, the covariate lactation length was not fitted.

3.5 COMPUTATION OF ADJUSTMENT FACTORS FOR LACTATION LENGTH AND PARITY .

Multiplicative extension factors for lactation length were computed and used to adjust the lactation yields to a standard lactation of 305 days. The actual lactation periods were grouped into 35 subclasses of seven days each (**Table 15**) . Lactation length subclasses were treated as fixed effects and the data analysed with a fixed effect model (model 2) in which lactation milk yield was a dependent variable. This gave the least squares means (LSM) for the subclasses. The least squares means were then used to derive multiplicative extension factors (MEF) using the following formula of Chauhan (1988):

$$MEF_i = LSM_b / LSM_i \quad ....(1)$$

Where ;

MEF_i is the multiplicative extension factor for the i^{th}

subclass of lactation length.

LSM_b is the least square mean of the reference subclass to which all the subclasses were adjusted (305 day subclass).

LSM_i is the least square mean of the i^{th} subclass of lactation length.

The mean 305- day milk yields, derived using multiplicative adjustment factors (305_M) were compared with the 305- day milk yields, calculated by regressing the actual milk yield on the lactation length (Shrivastava and Khan, 1989), a method commonly used (305_L).

$$305_L = \frac{LMY}{LL} \times 305 \quad \text{..........(2)}$$

where :

LMY is the lactation (actual) milk yield and LL is the lactation length. A correlation coefficient was estimated between the means of yields derived by the two different methods.

Parity adjustment factors were developed according to the method of Syrstad (1965) based on the fixed effect model (model 1). The following formula was used (equation 3):

$$a_i = \frac{X_m}{X_i} = \frac{X_t + (C_m - C)}{X_t + (C_i - C)} \quad \text{..................(3)}$$

a_i is the multiplicative adjustment factor for the i^{th} parity.

X_i is the mean yield of the i^{th} parity.

X_m is the mean yield of the reference parity class (peak parity or first parity).

X_t is the overall mean yield.

C_i is the least square constant for the i^{th} parity.

C_m is the least square constant for the reference parity class (First or peak parity).

C is the weighted mean of the constants, weighted by their numbers.

Adjustment factors based on first and peak parity production were independently used to correct for parity. Analysis of variance was carried out with adjusted data to compare the effectiveness of the factors. A correlation coefficient was also estimated between the two sets of corrected mean milk yields.

3.6 ANALYSES OF HETEROGENEITY OF VARIANCE OF MILK YIELD.

In analyzing heterogeneity of variance, the mean milk yields and the variance of yield were calculated within herd. The standard deviation and coefficient of variation (CV) were then obtained. Model 1 was used for this purpose. The grouping of herds into herd classes was used to test whether the variance of milk yield between the herds was significantly heterogenous. Milk yields were scaled according to herd mean using sample standard deviation. These ratios were further scaled to a constant coefficient of variation (Equation 6). The method of Brotherstone and Hill (1986) using the following formulae was used:

$$V(\sigma_i) = \Sigma\left[\frac{(S_i - S_m)^2 - S_m^2 / 2d_i}{K - 1}\right] \quad ....(4)$$

Where ;

$V(\sigma_i)$ is the estimator of variance among the standard deviations.

S_i is the estimate of standard deviation in the ith herd.

S_m is the unweighted mean of standard deviations over herds, for K herds.

S_m^2 is the unweighted variance over herds.

d_i is the degrees of freedom for the ith herd.

Similarly, the variance among the coefficients of variation (CV) was estimated by :

$$V(\tau_i) = \Sigma\left[\frac{(C_i - C_m)^2 - C_m^2 / (2d_i)}{K - 1}\right] \quad ....(5)$$

Where ;

$V(\tau_i)$ is the estimator of variance among the coefficients of variation.

C_i, C_m and C_m^2 are the corresponding estimates of CV and their unweighted mean and variance respectively.

The other symbols were as used in Equation 4.

The coefficients of variation of individual herds were scaled according to the herd mean using the formula:

$$CV^{*} = \frac{\dfrac{CV_{pop}}{Var_{(CV\ pop)}} + \dfrac{CV_{i}}{Var_{(CVi)}}}{\dfrac{1}{Var_{(CV\ pop)}} + \dfrac{1}{Var_{(CVi)}}} \quad ....(6)$$

Where ;

CV^{*} is the scaled coefficient of variation.

CV_{pop} is the coefficient of variation for the population (mean CV).

CV_{i} is the coefficient of variation for the i^{th} herd and $Var_{(CV\ pop)}$ and $Var_{(CVi)}$ are the corresponding variances.

When using these formulae for analyses of heterogeneity of variance, it was assumed that the heritability of milk yield was the same in all herds. When sires have been widely progeny tested, it also implies that the ratio of genetic to environmental variation within sire families is the same in all herds.

CHAPTER 4: RESULTS.

4.1 LEVEL AND VARIATION OF MILK YIELD.

Table 7 presents the unadjusted means, standard deviations and coefficients of variation of various traits in the study. The least square means and standard errors of 305_M, 305_L - day and annual milk yields were 2740.3 ± 10.37 kg , 2813.2 ± 11.08 kg and 2722.8 ± 12.88 kg respectively. The corresponding coefficients of variation were 24, 25 and 30 %, while standard deviations were 658, 703 and 817. Adjusted milk yields had higher means than unadjusted milk yields given in **Table 7**. Also, 305_M day mean milk yields were lower than the 305_L -day mean milk yields.

Table 7 Unadjusted means, standard deviations (SD) and coefficients of variation (CV) of various traits.

TRAIT	NO. OF RECORDS	MEAN	SD	CV %
Lactation milk yield	4025	2528 kg	961	38
Lactation length	4025	277 days	50	18
Calving interval	2507	431 days	105	24
Annual milk yield	4025	2218 Kg	938	42

4.2 HETEROGENEITY OF VARIANCE OF MILK YIELD.

Tables 8 and **9** and **figures 2** and **3** show within-herd variances, standard deviations and coefficients of variation of 305_M - day milk yield. Generally, herds with higher average milk yields had greater intra-herd variances and standard deviations. Similarly, **Table 9** shows that differences existed between herds in coefficients of variation (CVs) with the CVs increasing with herd production level. The herd average standard deviation and coefficient of variation of milk yield after correcting for the fixed effects were 672.2 kg and 26.7% respectively. The scaled standard deviations between herds were 180 kg and 3.4 % respectively. **Table 9** also presents the scaled coefficients of variation (CV^*). Compared to the within herd coefficient of variation (CV_i), the scaled coefficient of variation (CV^*) showed little variation as indicated by the low standard deviation of 3.4% .

Table 8 Within-herd variances and standard deviations (SD) of 305_M - day milk yield.

Herd	Mean	S.d(S_i)	Variance	d_i	$(S_i-S_m)^2$ (A)	$S_m^2/2d_i$ (B)	(A-B)·/K-1
50	1512.51	382.37	146206.82	80	84001.43	2824.08	3529.45
48	1571.75	351.23	123362.51	23	103021.74	9822.89	4052.12
15	1693.86	480.10	230496.01	27	36902.41	8367.65	1240.64
25	2005.29	575.55	331257.80	40	9341.22	5648.16	160.57
34	2046.47	462.17	213601.11	18	44112.60	12551.47	1372.22
58	2085.85	567.55	322113.00	233	10951.62	969.64	434.00
1	2112.82	641.02	410906.64	90	972.19	2510.29	-66.87
6	2138.97	750.28	562920.08	38	6096.49	5945.43	6.57
29	2156.85	456.22	208136.69	12	46647.36	18827.20	1209.57
7	2305.05	641.15	411073.32	243	964.10	929.74	1.49
10	2386.60	599.86	359832.02	488	5233.08	462.96	207.40
49	2454.00	487.35	237510.02	43	34169.52	5254.10	1257.19
4	2484.90	722.48	521977.35	332	2528.08	680.50	80.33
2	2548.92	757.38	573624.46	223	7255.63	1013.12	271.41
13	2616.68	624.78	390350.05	292	2248.66	773.72	64.13
18	2728.38	649.34	421642.44	20	522.58	11296.32	-468.42
44	2760.83	1028.23	1057256.90	35	126757.36	6455.04	5230.54
37	2790.26	695.50	483720.25	84	542.89	2689.60	-93.34
9	2822.14	887.89	788348.65	957	46522.18	236.08	2012.44
53	2850.17	762.79	581848.58	35	8206.55	6455.04	76.15
23	3515.40	867.07	751810.38	56	37974.32	4034.40	1475.65
59	3618.17	836.36	699498.05	143	26948.51	1579.91	1102.98
30	3668.69	1122.89	1260882.00	159	203121.48	1420.92	8769.59
21	3736.31	781.59	610882.93	280	11966.17	806.88	485.19

Σ [(A-B)/K-1] = 32411.00

Key:
S_m is the population standard deviation.
K is the number of herds.
d_i is the degrees of freedom for number of records.
32411.00 is the estimator of variance among the standard deviations.

Table 9 **Within-herd variances of coefficients of variation (CV).**

....

Herd	Mean	CV_i	$(CV_i)^2$	d_i	$(CV_i-CV_m)^2$ (A)	$CV_m^2/2d_i$ (B)	(A-B)/K-1	CV^*
50	1512.51	0.2528	0.0639	80	0.0002	0.0004	-0.000009	0.2595
48	1571.75	0.2235	0.0500	23	0.0019	0.0015	0.000017	0.2414
15	1693.86	0.2834	0.0803	27	0.0003	0.0013	-0.000043	0.2747
25	2005.29	0.2870	0.0824	40	0.0004	0.0009	-0.000022	0.2763
34	2046.47	0.2258	0.0510	18	0.0017	0.0020	-0.000013	0.2430
58	2085.85	0.2721	0.0740	233	0.0000	0.0002	-0.000009	0.2695
1	2112.82	0.3034	0.0921	90	0.0013	0.0004	0.000040	0.2829
6	2138.97	0.3508	0.1231	38	0.0070	0.0009	0.000265	0.2977
29	2156.85	0.2115	0.0447	12	0.0031	0.0030	0.000004	0.2326
7	2305.05	0.2782	0.0774	243	0.0001	0.0001	0.000000	0.2724
10	2386.60	0.2513	0.0632	488	0.0002	0.0000	0.000009	0.2587
49	2454.00	0.1986	0.0394	43	0.0047	0.0008	0.000170	0.2229
4	2484.90	0.2907	0.0845	332	0.0006	0.0001	0.000022	0.2778
2	2548.92	0.2971	0.0883	223	0.0009	0.0002	0.000030	0.2804
13	2616.68	0.2388	0.0570	292	0.0008	0.0001	0.000030	0.2513
18	2728.38	0.2380	0.0566	20	0.0008	0.0018	-0.000043	0.2508
44	2760.83	0.3724	0.1387	35	0.0111	0.0010	0.000439	0.3028
37	2790.26	0.2493	0.0622	84	0.0003	0.0004	-0.000004	0.2575
9	2822.14	0.3146	0.0990	957	0.0023	0.0000	0.000100	0.2869
53	2850.17	0.2676	0.0716	35	0.0000	0.0010	-0.000043	0.2673
23	3515.40	0.2472	0.0611	56	0.0004	0.0006	-0.000009	0.2563
59	3618.17	0.2312	0.0535	143	0.0013	0.0002	0.000048	0.2465
30	3668.69	0.3061	0.0937	159	0.0015	0.0002	0.000057	0.2839
21	3736.31	0.2092	0.0438	280	0.0033	0.0001	0.000139	0.2312

$\Sigma[(A-B)/K-1] = 0.001175$

....

Key: 0.001175 is the estimator of variance among the coefficients of variation.

$CV_m = CV_{pop}$ is the population coefficient of variation.

CV_i is the coefficient of variation for the i^{th} herd.

d_i is the degrees of freedom for number of records for the i^{th} herd.

CV^* is the scaled coefficient of variation.

FIG. 2: Standard deviation of 305 -day milk yield of herds.

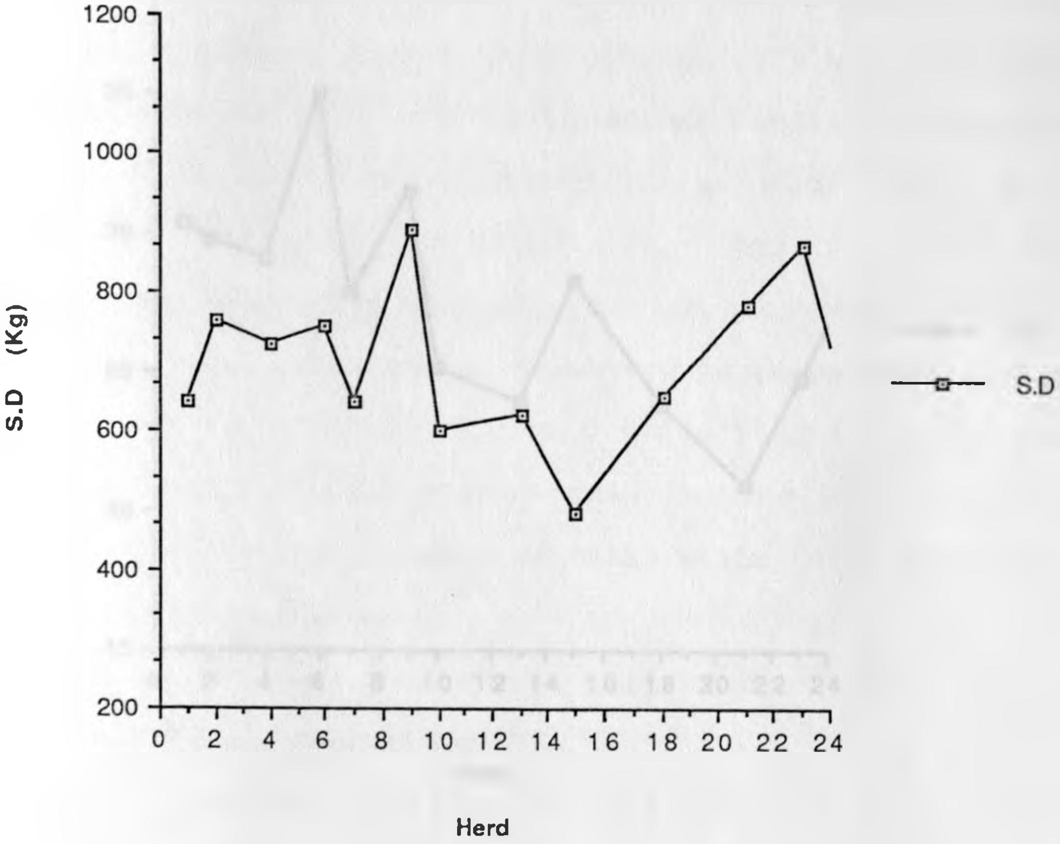
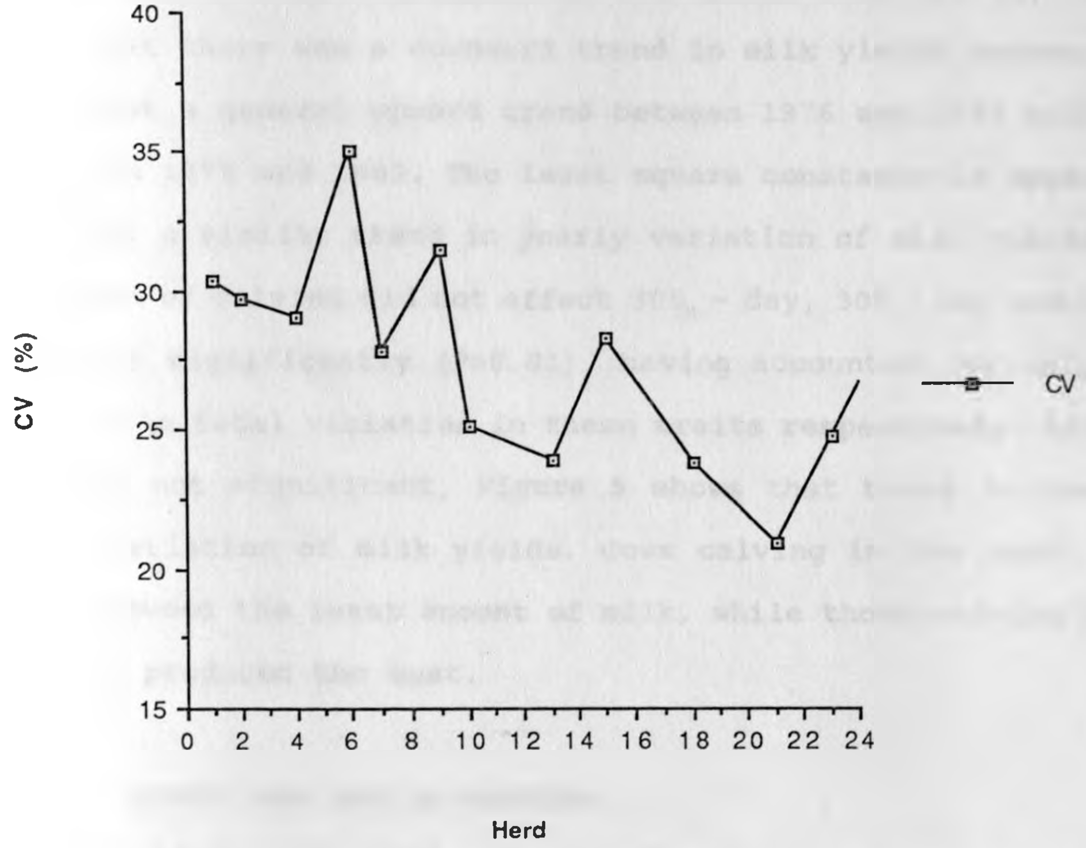


FIG. 3: Coefficient of variation of 305-day milk yield of herds.



4.3 CAUSES OF HETEROGENEITY OF VARIANCE OF MILK YIELD BETWEEN HERDS.

YEAR AND SEASON OF CALVING .

Effects of year and season of calving , which are environmental, are shown in **Table 10**. Year of calving influenced 305_M-day, 305_L - day and annual milk yields significantly ($P<0.01$) and accounted for 10, 12 and 8% of the total variation in the traits respectively. **Figure 4** shows that there was a downward trend in milk yields between 1969 and 1976 but a general upward trend between 1976 and 1985 with some decrease in 1979 and 1982. The least square constants in **Appendix 5** also depict a similar trend in yearly variation of milk yields.

Season of calving did not affect 305_M - day, 305_L- day and annual milk yields significantly ($P>0.01$), having accounted for only 2, 1 and 1% of the total variation in these traits respectively. Although season was not significant, **Figure 5** shows that there is trend in seasonal variation of milk yields. Cows calving in the short rainy season produced the least amount of milk, while those calving in the dry season produced the most.

PARITY AND AGE AT CALVING.

Table 10 presents the effects of parity and age at calving, which are both genetic and environmental, on 305_M -day, 305_L - day and annual milk yields. Parity significantly affected 305_M, 305_L and annual milk yields ($P<0.01$) and accounted for 82, 64 and 27% of the total variation in the traits respectively. The least squares means and constants for parity displayed consistent trends (**Tables 11 and**

12). Milk yields increased at a decreasing rate upto the peak in the 5th parity **(Fig.6)** after which they dropped drastically in the 6th parity, in which the yields roughly equalled those in the 1st parity.

Table 10. Influence of fixed effects on milk yield (Model 1).

TRAIT	SOURCE OF VARIATION							
	YR	SN	PAR	H	HC	AP	CI	LL
Actual milk yield (KG)	**	ns	**	**	**	**	**	**
305M-day milk yield (KG)	**	ns	**	**	**	**	**	**
Annual milk yield (KG)	**	ns	**	**	**	ns	**	**
305_L-day milk yield (KG)	**	ns	**	**	**	*	**	**

KEY

** : P<0.01

* : P<0.05

ns : not significant (P>0.05)

YR : Year; SN:Season; PAR:Parity; H:Herd; HC:Herd class according to production level; AP:Actual age within parity; CI:Calving interval and LL:Lactation length.

The highest and lowest rates of increase occurred between the second and third and the fourth and fifth parities respectively. In the case of annual milk yield,the highest rate of increase occurred between the first and second parities.

Age at calving within parity significantly influenced 305_M - day milk yield ($P<0.01$) and 305_L - day milk yield ($P<0.01$) but not annual milk yield ($P>0.01$). Age within parity effect accounted for 4, 3 and 1% of the total variation in the three respective traits.

Table 11 Least square means (LSM) for milk yields by parity and rates of change (in brackets) between parities.

	305_M-day milk yield	305_L-day milk yield	Annual milk yield
Parity	LSM	LSM	LSM
1	2682 ±24	2760 ±27	2290 ±19
2	2708 ±31 (26)	2827 ±35 (67)	2670 ±24(380)
3	2851 ±37 (142)	2976 ±43 (148)	2827 ±29(157)
4	2954 ±45 (103)	3009 ±52 (33)	2897 ±35 (71)
5	3013 ±57 (60)	3037 ±65 (28)	2915 ±44 (17)
≥6	2635 ±61 (-398)	2762 ±69 (-276)	2257 ±47 (-658)

Table 12 Parity least square constants for 305_M, 305_L and annual milk yields .

	305_M-day milk yield	305_L-day milk yield	Annual milk yield
Parity	Constant estimate	Constant estimate	Constant estimate
1	-6.89	-135.24	-432.55
2	19.27	67.87	50.44
3	161.58	80.74	103.82
4	264.65	113.09	174.46
5	324.31	142.78	191.74
≥6	-87.92	-133.50	-556.25

FIG. 4: Yearly trends in milk yields.

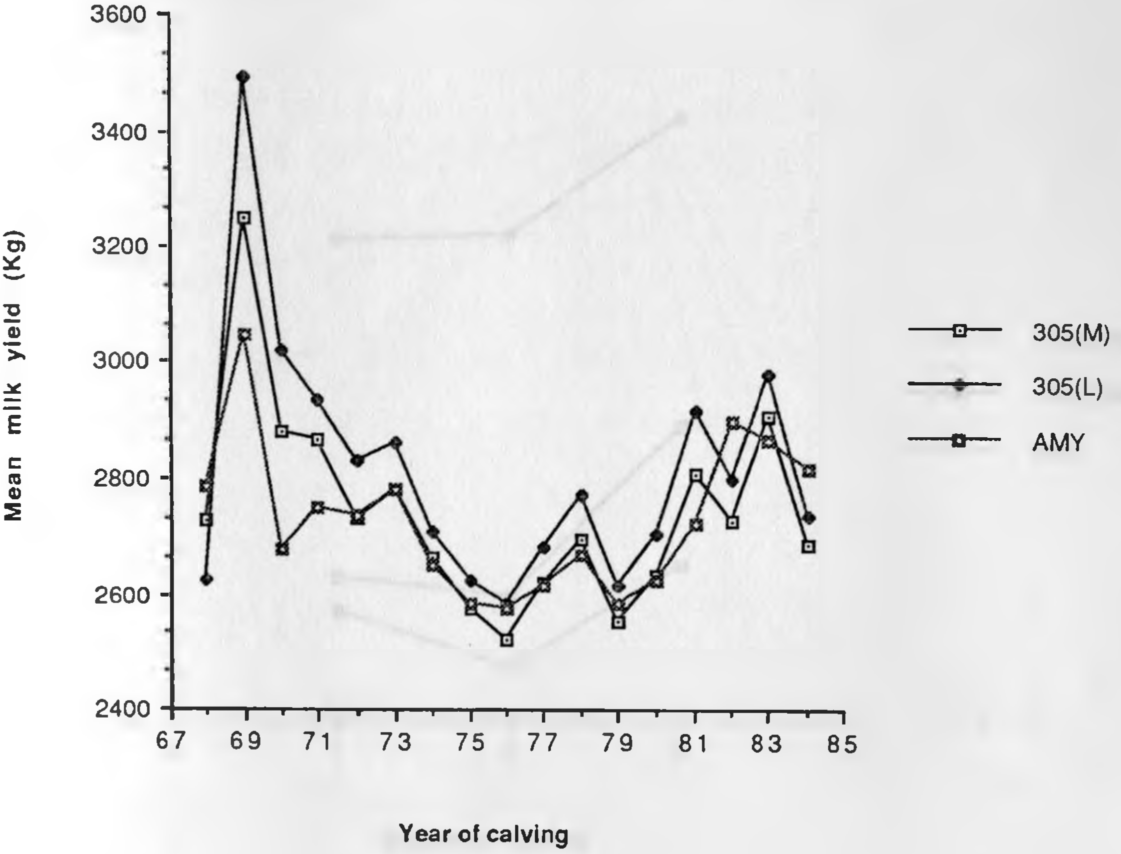


FIGURE 5: Seasonal trends in milk yields.

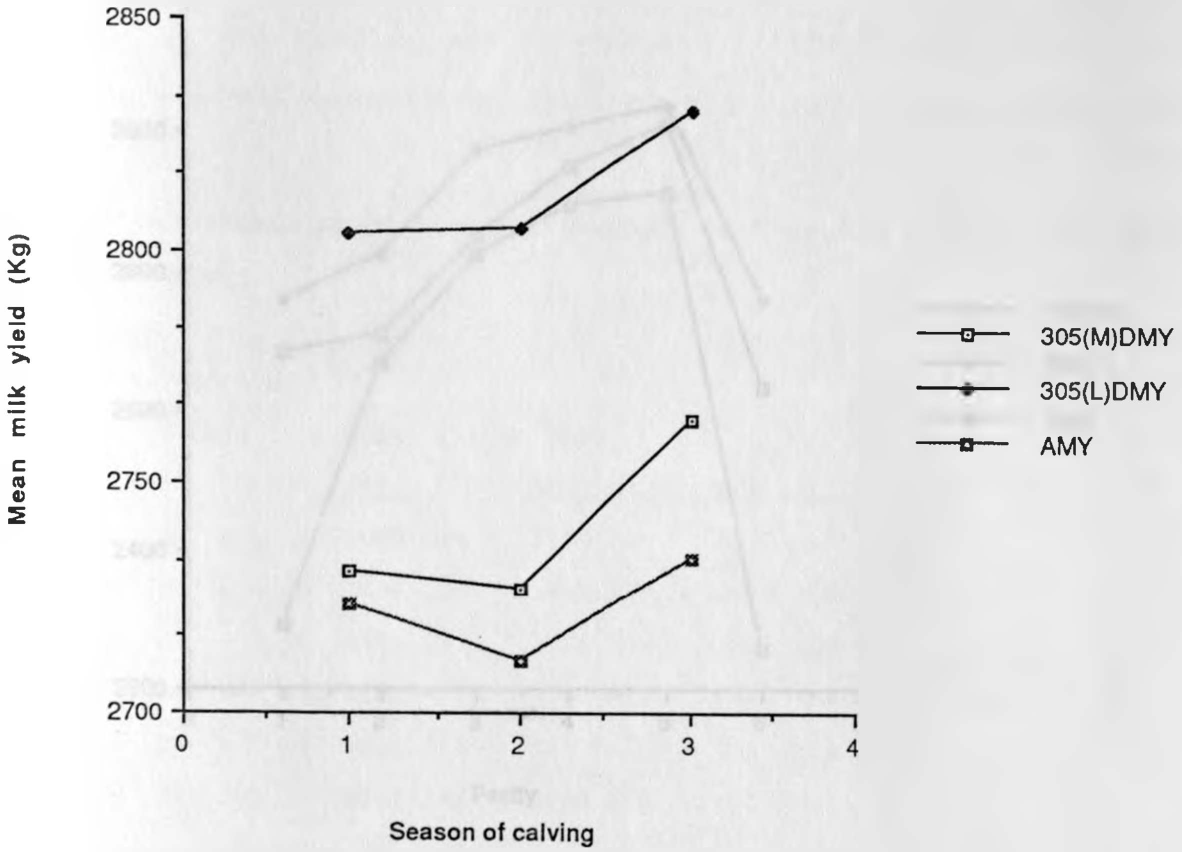
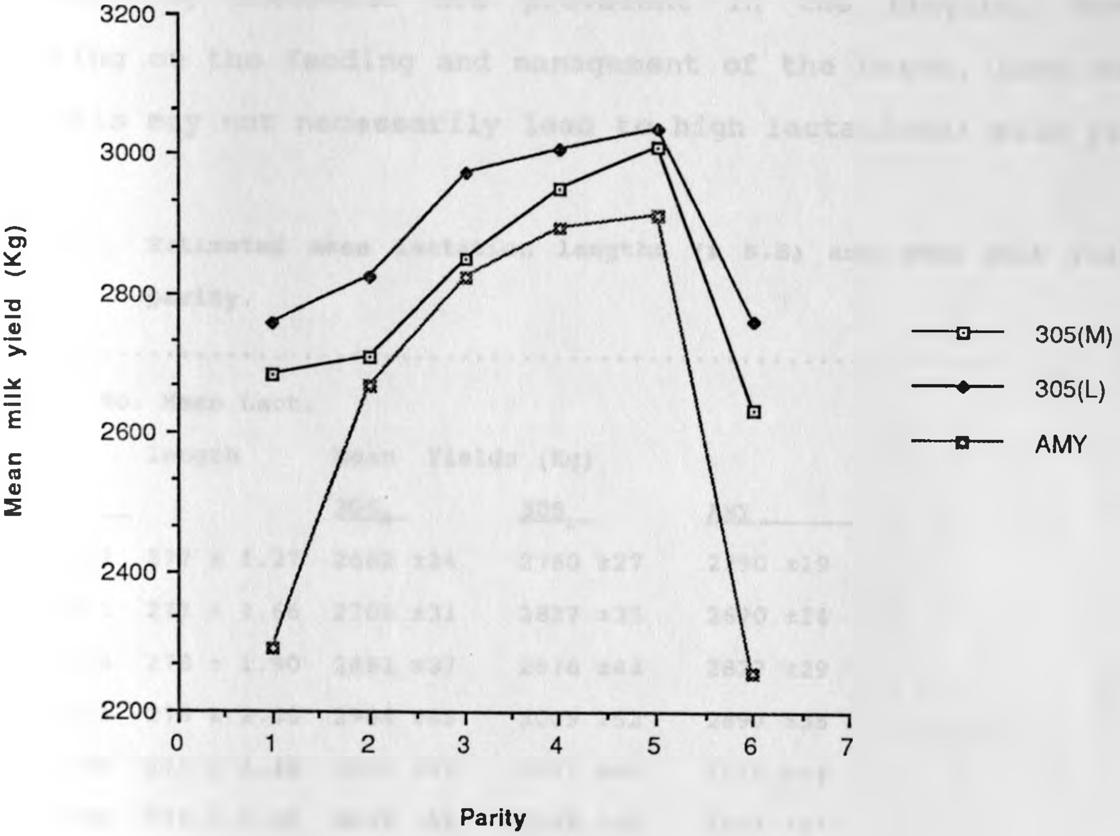


FIG. 6: Trends in 305-day and AMY with parity.



LACTATION LENGTH AND CALVING INTERVAL.

Length of lactation, which is largely environmental and partly genetic, significantly influenced milk yields ($P<0.01$). The trend in **Table 13** confirms the general expectation where milk yields increased with lactation length. The effect of preceding calving interval on milk yield was also significant ($P<0.01$). This trend was expected as long calving intervals are prevalent in the tropics. However, depending on the feeding and management of the herds, long calving intervals may not necessarily lead to high lactational milk yield.

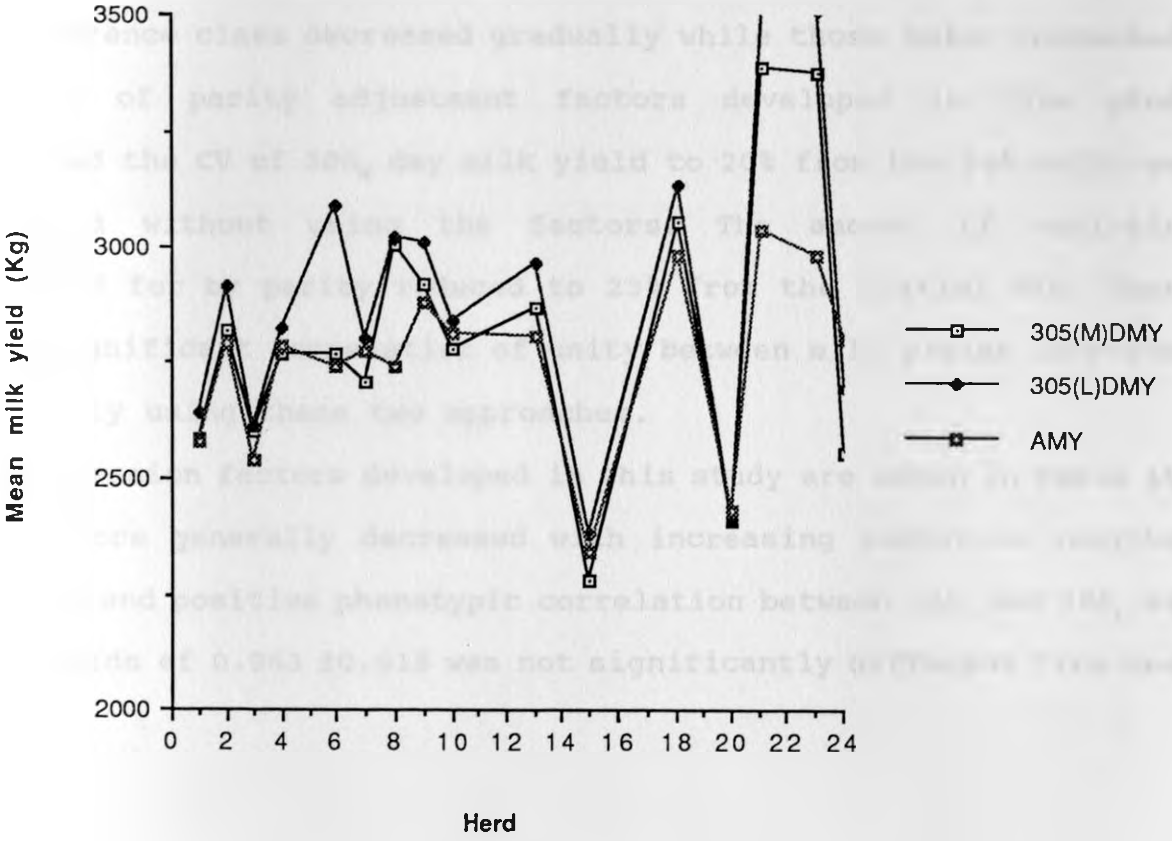
Table 13 Estimated mean lactation lengths (± S.E) and mean milk yields by parity.

Parity	No.	Mean Lact. length	Mean Yields (Kg) 305_M	305_L	AMY
1	1523	277 ± 1.27	2682 ±24	2760 ±27	2290 ±19
2	921	277 ± 1.66	2708 ±31	2827 ±35	2670 ±24
3	644	278 ± 1.90	2851 ±37	2976 ±43	2827 ±29
4	431	278 ± 2.50	2954 ±45	3009 ±52	2897 ±35
5	268	275 ± 3.46	3013 ±57	3037 ±65	2915 ±44
≥6	238	275 ± 3.36	2635 ±61	2762 ±69	2257 ±47

HERD.

Herd and herd class, which are purely environmental, significantly affected ($P<0.01$) 305_M - day, 305_L - day and annual milk yields (**Figure 7**). Herd accounted for 32, 28 and 23% of the total variation in these traits respectively. Least square means and constants for herd and herd class are given in **Appendices 4** and **5** respectively. Herds in the high producing class, presumably with high levels of feeding and management had the highest mean milk yields.

FIG. 7: Trends in mean milk yields of herds.



4.4 ADJUSTMENT FACTORS FOR PARITY AND LACTATION LENGTH.

Table 14 shows the parity adjustment factors developed in the study using first parity and peak yield parity (5th parity) as reference classes respectively. With first parity as the reference class, the parity adjustment factors decreased gradually upto the peak lactation, after which, they increased. On the other hand, using mature lactation equivalent as the reference class, the factors above the reference class decreased gradually while those below increased. The use of parity adjustment factors developed in this study decreased the CV of 305_M day milk yield to 20% from the 24% which was estimated without using the factors. The amount of variation accounted for by parity reduced to 23% from the initial 82%. There was a significant correlation of unity between milk yields corrected for parity using these two approaches.

Extension factors developed in this study are shown in **Table 15**. The factors generally decreased with increasing lactation lengths. The high and positive phenotypic correlation between 305_M and 305_L day milk yields of 0.963 ±0.015 was not significantly different from one.

Table 14 **Parity adjustment factors developed in the study.**

Parity	Reference class	
	First parity	Peak parity
1	1.0000	1.1214
2	0.9905	1.1108
3	0.9418	1.0562
4	0.9095	1.0200
5	0.8917	1.0000
≥6	1.0306	1.1557

Table 15 The developed extension factors for Lactation length.

Lactation length subclass (days)	No. of observations	Least square mean of lactation milk yield (Kg)	Extension factor
60-66	15	1404.73 ± 148.85	2.2427
67-73	12	1657.89 ± 164.04	1.9002
74-80	11	1627.97 ± 171.05	1.9352
81-87	16	1574.26 ± 143.68	2.0012
88-94	18	1685.95 ± 136.77	1.8686
95-101	13	1702.36 ± 158.44	1.8506
102-108	17	1598.14 ± 140.42	1.9713
109-115	10	1758.89 ± 179.15	1.7911
116-122	18	1960.95 ± 136.01	1.6066
123-129	12	1708.96 ± 164.26	1.8434
130-136	16	2036.37 ± 145.26	1.5471
137-143	23	2156.96 ± 122.89	1.4606
144-150	24	1999.62 ± 120.77	1.5755
151-157	24	2139.13 ± 120.58	1.4727
158-164	18	2127.66 ± 137.66	1.4807
165-171	20	2165.44 ± 130.97	1.4548
172-178	27	2331.72 ± 115.11	1.3511
179-185	14	2182.02 ± 153.98	1.4438
186-192	26	2415.69 ± 116.52	1.3041
193-199	20	2282.25 ± 131.09	1.3804
200-206	27	2526.94 ± 115.04	1.2467
207-213	24	2635.66 ± 120.54	1.1953
214-220	23	2487.49 ± 122.59	1.2665
221-227	46	2487.12 ± 92.94	1.2667
228-234	51	2626.33 ± 89.28	1.2000
235-241	77	2694.87 ± 77.04	1.1690
242-248	75	2788.74 ± 78.20	1.1300
249-255	60	2789.52 ± 84.91	1.1294
256-262	112	2803.24 ± 67.82	1.1238
263-269	132	2891.47 ± 66.05	1.0900
270-276	122	2888.65 ± 65.30	1.0906
277-283	149	2879.13 ± 63.76	1.0942
284-290	168	2019.37 ± 62.51	1.0791
291-297	202	2971.18 ± 59.43	1.0603
298-304	785	3091.33 ± 50.09	1.0191

CHAPTER 5: DISCUSSION.

5.1 LEVEL AND VARIATION OF MILK YIELD.

The mean milk yields obtained in this study are consistent with the estimates reported from previous local studies on Kenyan Friesian population (Kiwuwa, 1974; Mosi, 1984). They are, however, lower than estimates obtained in other local investigations (Marples and Trail, 1967; Mwai and Mosi, 1991). The lower milk yields obtained in this study may be mainly due to the highly diverse management practices applied in the herds which were studied. The high production level of the better managed herds was mitigated by the low production levels obtained in the poorly managed herds. In consequence, the overall level of production was lowered.

Estimates of the coefficients of variation obtained in the study for the various traits were consistent with those reported for Friesian cattle under comparable environments (Marples and Trail, 1967; Mwai and Mosi, 1991). The estimates indicate the existence of substantial variability and, therefore, improvement opportunities through better nutrition and management programmes.

5.2 HETEROGENEITY OF VARIANCE OF MILK YIELD .

The general increase in within-herd variances, standard deviations and coefficients of variation with the level of herd production clearly shows that the variance of milk yield was not homogenous among the herds. This was confirmed by the significant effect of herd and herd class on the yield traits studied.

It should, however, be noted that CVs and SDs were derived variables and could thus be subject to errors. Nevertheless, they both showed a trend similar to that given by the within-herd variances. Similar findings were reported by Dong and Mao (1989) and Short et al. (1990), who observed that SD increased with mean milk yield. The heterogeneity of variance between herds was explained by both genetic and environmental factors. The differences in within-herd CVs observed could have been partly due to preferential treatment of cows according to production level, good conformation, high pedigree and hence monetary value, sentimental reasons or a combination of these factors. Such preferential treatment could favourably affect records of milk yield and increase within-herd variances and coefficients of variation of milk yield.

The significant differences in SDs between herds confirm that the variances were not constant over observations and therefore suggests heterogeneity of variance due to herd effect. Thus, logarithmic transformation is inadequate in minimizing the heterogeneity of variance. On the other hand, the fact that scaled within-herd coefficients of variation (CV^*) had a standard deviation of only 3.4 % imply that this approach could be effective in minimizing heterogeneity of variance and therefore, permit unbiased selection of animals. These findings are consistent with those of Brotherstone and Hill (1986) and Graham et al. (1991) who observed that when heritabilities are the same in all herds, scaling observations to a constant CV removes much of the heterogeneity of variance of milk yield. It can therefore, be concluded that, scaling by sample standard deviation reduces heterogeneity of variance among herds.

5.3 CAUSES OF HETEROGENEITY OF VARIANCE OF MILK YIELD BETWEEN HERDS.

YEAR AND SEASON OF CALVING.

The significant influence of year of calving on milk yields and hence heterogeneity of variance observed in this study concurs with results reported from previous studies in Kenya (Wakhungu, 1988; Rege and Mosi, 1989; Njubi, 1990). The differences between years in milk yields were due to corresponding fluctuations in feed supplies, herd genetic levels and management. The downward trend in milk yields between 1969 and 1976 was largely due to change in farm ownership from the more skilled pre-independence farmers to the unskilled indigenous farmers. Improvement in management by the new farmers and consistent breeding programmes in large scale herds possibly led to the increases observed from 1976. Adjustment of lactation records for year of calving was, therefore, carried out in this study to reduce heterogeneity of variance due to year effects.

Season of calving had no significant effect on milk yields and therefore contributed little to the variance. These findings agree with those of Murdia and Tripathi (1990) and Gupta et al. (1990), but contradict those of Katochi et al. (1990) and Mwai and Mosi

(1991). Supplementation of the animals masked the true between season differences in feed availability in this study. This created more uniformity in seasonal effect on milk yield. Also, the classification of seasons according to the rainfall and corresponding herbage production potential may not have been done correctly to reflect the real situation. This could have been possible if the same months in different years did have comparable climatic conditions. The highest milk yields recorded for cows calving in the dry period was obviously due to the abundance of forage in the subsequent wet season which they took advantage of.

PARITY AND AGE AT CALVING.

As in the studies of Mbap and Ngere (1991); Mchau and Syrstad (1991) and Mwai and Mosi (1991), parity significantly influenced milk yields, leading to non-homogeneity of variance. The occurrence of peak yield in the fifth parity is consistent with results reported in previous studies (Mosi, 1984; Rege and Mosi, 1989) in Kenya. The increase in milk yield from the first parity to the fifth parity was due to differential partitioning of nutrients by first calf heifers and cows. Whereas first calf heifers had to provide for nutritive requirements for growth, maintenance and lactation, cows had to provide for only maintenance and lactation. The highest increases in 305 day milk yields observed between the second and the third parities indicate the increasing physiological maturity of the cow relative to the heifer. This was probably achieved through reduction in energy allocation for growth.

The fact that age at calving was not significant for annual milk yield imply that the magnitude of age effects decrease considerably after the second parity. Similar findings have been reported by Syrstad (1965) and Mosi (1984), who observed that age effects were more pronounced in first than in later parities. It is, therefore, desirable to adjust for parity and age at calving in order to reduce heterogeneity of variance of milk yield. However, adjustment for effects of age on milk yield should be done within parities to avoid the confounding effects of actual age at calving with those of parity.

LACTATION LENGTH AND CALVING INTERVAL.

The significant effect of preceding calving interval on milk yields confirms the earlier findings of Wakhungu (1988) from Kenyan Sahiwal data. Milk yields are expected to increase with increased postpartum intervals to service because of the rest cows usually have, which enables them to recover from previous lactational stress. However, the degree of recovery can be greatly modified by the feeding and management of the animals. Variability between herds in levels of feeding and management result in heterogenous variances. Consequently, milk yields should be corrected for the effects of calving interval. When this is done, other components of calving interval such as dry period and lactation length have also to be considered.

HERD.

Herd contributed significantly to the total variation and thus confirmed the existence of differences between herds in milk production. Similar results have been reported from previous studies for breeds raised in the tropics and sub-tropics (Rege and Mosi, 1989; Katochi et al. 1990; Lusweti, 1991). The observations in this study were attributed to genetic and environmental factors. Differences in herd genetic levels arose through the differential use of bulls by herds in their breeding programmes and massive importation and use of semen by some herds. Thus, milk yields should be corrected for the herd effect.

5.4 PARITY ADJUSTMENT FACTORS.

By adjusting the records for parity effect, using the factors developed in this study, the CV of 305_M day milk yield reduced by 17% while the amount of variance decreased by 71% . The implication is that the factors could be used to adjust lactation records for parity to improve comparison of cows in different parities. This adjustment would also facilitate the use of multiple records in the evaluations.

The high phenotypic correlation of unity between milk yields corrected using the two sets of adjustment factors imply that either of the two sets of factors may be used. However, other effects such as senility that increase with advancing age (Matsoukas and Fairchild, 1975) and differences between herds in the parity of peak yields should be considered before choosing the set of adjustment factors to use. First parity yields may not vary much within and between herds as the case may be with peak parity yields. Therefore, a single set of adjustment factors based on first parity yield would appear appropriate for all herds and herd levels. Adjustments based on first parity performance would have an added advantage of reduced generation interval particularly in progeny testing of sires.

Unlike the additive correction factors, multiplicative factors take consideration of the fact that changes in milk production due to an environmental effect are not of the same magnitude. Thus, compared to additive factors, multiplicative parity adjustment factors developed in this study would appear more appropriate in minimising heterogeneity of variance due to parity effects.

5.5 EXTENSION FACTORS FOR LACTATION LENGTH.

The general decrease in the magnitude of the multiplicative factors with increasing lactation length was expected. Shorter lactations required larger factors to standardize the corresponding yields to 305 day equivalent. However, the factors exhibited some inconsistencies attributed to small sub-class numbers and the long interval (one week) between the sub-classes. Although the KMR factors (Appendix 1) appear to give a more consistent trend, they were developed only for lactations of more than 198 days. They are, therefore, considered to be unrealistic for Kenyan conditions where shorter lactation records are common. On the other hand, the extension factors developed in this study catered for shorter lactation records resulting from prevailing diverse management standards.

The choice of 60 days as the minimum lactation length was justified by the fact that peak yields for cattle raised in the tropics are known to occur within the second month (42 to 56 days) of lactation (Bar-Anan and Genizi, 1981; Dhanoa,1981). Thus, despite the inconsistencies, these factors could be more useful in minimising heterogeneity of variance associated with variable lactation lengths. However, there is need to develop more factors using large data.

Just as with linear regression, multiplicative correction factors assume a linear relationship between milk production and lactation length, while published evidence strongly indicate a curvilinear relationship (Wood, 1980). Therefore, a better understanding of the true lactation curves for the four main Kenyan dairy breeds could lead to the development of more accurate extension factors for lactation length. With the availability of accurate extension factors, it would not be necessary to discard short lactation records discriminately. At the same time, the use of extension factors for uncompleted lactations would enhance the accuracy of cattle evaluations.

The high and positive phenotypic correlation between the adjusted 305 day milk yields derived using extension factors and linear regression imply that both methods are equally effective for this purpose. As to whether the extension factors are any better than phenotypic regression of milk yield on lactation length was not considered in this study. This question should be answered by a better understanding of the rank correlations of animals under the alternative correction method.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS.

Within the limits of the data available and the procedures employed in this study, the obtained results led to the following conclusions and recommendations:

1. That significant heterogeneity of variance of milk yield exists among the Kenyan Friesian herds which cannot be attributed to chance as heterogeneity also exists in coefficients of variation. It should therefore be accounted for in sire and cow evaluation in Kenya.
2. Scaling of observations within individual herds by sample standard deviation and coefficient of variation can reduce heterogeneity of variance among herds. This standardization can enable breeders to compare animals on an equal basis.
3. In the absence of any scientific procedure for bull- dam evaluation in Kenya, the parity adjustment factors developed would be useful in comparing cows of different parities. They would also enable the use of multiple records in sire and cow evaluation.
4. That the developed extension factors could be used to project uncompleted lactations to 305-day equivalent to ensure more accurate within breed evaluations, especially where the part lactations are associated with identifiable environmental influences.
5. Development of lactation curves for the four main Kenyan dairy breeds would facilitate development of more accurate extension factors. The curves would also assist in herd management and

planning.

6. There is need for further investigation into the effectiveness of the scaled coefficients of variation for adjusting the deviations from the herd means, in relation to sire and cow evaluation in Kenya.

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CHAPTER 8: APPENDICES

Appendix 1 Factors used by Kenya Milk Records for correcting uncompleted lactations.

Days	Ayrshire/ Sahiwal	Friesian	Guernsey/ Brown swiss	Jersey
199-201	1.3378	1.3745	1.3564	1.3683
202-204	1.3221	1.3587	1.3417	1.3533
205-207	1.3064	1.3429	1.3270	1.3384
208-210	1.2906	1.3272	1.3122	1.3234
211-213	1.2768	1.3130	1.2994	1.3101
214-216	1.2639	1.2997	1.2876	1.2976
217-219	1.2510	1.2863	1.2758	1.2851
220-222	1.2393	1.2737	1.2619	1.2710
223-225	1.2275	1.2610	1.2480	1.2570
226-228	1.2165	1.2472	1.2345	1.2440
229-231	1.2059	1.2329	1.2210	1.2315
232-234	1.1952	1.2192	1.2084	1.2193
235-237	1.1845	1.2071	1.1971	1.2076
238-240	1.1737	1.1949	1.1859	1.1959
241-243	1.1665	1.1834	1.1749	1.1843
244-246	1.1593	1.1719	1.1639	1.1728
247-249	1.1503	1.1608	1.1532	1.1620
250-252	1.1405	1.1500	1.1427	1.1517
253-255	1.1300	1.1393	1.1324	1.1416
256-258	1.1184	1.1294	1.1225	1.1320
259-261	1.1068	1.1194	1.1126	1.1225
262-264	1.0980	1.1099	1.1032	1.1124
265-267	1.0891	1.1005	1.0937	1.1023
268-270	1.0800	1.0922	1.0839	1.0930
271-273	1.0706	1.0845	1.0739	1.0841
274-276	1.0620	1.0763	1.0648	1.0753
277-279	1.0547	1.0671	1.0577	1.0665
280-282	1.0474	1.0579	1.0506	1.0576
283-285	1.0412	1.0502	1.0430	1.0501
286-288	1.0351	1.0426	1.0355	1.0426
289-291	1.0290	1.0351	1.0290	1.0351
292-294	1.0230	1.0279	1.0230	1.0275
295-297	1.0160	1.0205	1.0168	1.0200
298-300	1.0103	1.0130	1.0103	1.0125
301-303	1.0045	1.0060	1.0045	1.0056

Appendix 2 Least squares analysis of variance for 305_M -day and annual milk yields from model 1 analysis.

		305_M - DAY MILK YIELD	ANNUAL MILK YIELD
SOURCE	D.F	MS $X10^4$	MS $X10^4$
Parity	5	1880.2718^{**}	365.6702^{**}
Year of calving	16	236.8840^{**}	108.4013^{**}
Season of calving	2	55.3988^{ns}	13.2273^{ns}
Herd	31	740.2283^{**}	307.0741^{**}
Herd class	2	32453.9076^{**}	42413.8323^{**}
REGRESSIONS			
Age linear	1	65.8665^{*}	16.3834^{ns}
Age within parity	5	97.8460^{**}	41.0429^{ns}
Age Quadratic	1	16.3702^{ns}	6.0255^{ns}
Age within parity	5	35.2205^{ns}	10.6354^{ns}
Calving interval	1	15205.7388^{**}	3177.9740^{**}
Lactation length	1	5233.6304^{**}	19318.8840^{**}
Error	3954	23.0143	13.6278
		$R^2 = 73.0$	$R^2 = 84.8$

Key

** : $P<0.01$

* : $P<0.05$

ns : not significant ($P>0.01$)

Appendix 3 **Least squares analysis of variance for 305_L - day milk and actual milk yields.**

SOURCE	D.F	305_L - DAY MILK YIELD MS X10^4	ACTUAL MILK YIELD MS X10^4
Parity	5	1914.2081^{**}	1849.7631^{**}
Year of calving	16	350.3051^{**}	195.2675^{**}
season of calving	2	32.7681^{ns}	44.2623^{ns}
Herd	31	834.7346^{**}	663.4551^{**}
Herd class	2	32880.9768^{**}	31838.4379^{**}
REGRESSIONS			
Age linear	1	65.5666^{ns}	55.4824*
Age within parity	5	89.2113^{**}	79.6267^{**}
Calving interval	1	16066.0153^{**}	15038.8095^{**}
Lactation length	1	8317.8592^{**}	36658.5425^{**}
Error	3960	29.8546	19.2052
		$R^2 = 66.0$	$R^2 = 79.6$

Key

** : P<0.01

* : P<0.05

ns : not significant (P>0.01)

Appendix 4 **Least squares means of fixed effects for milk yields.**

Class		305_M	305_L	AMY
	No.	LSM	LSM	LSM
Year of calving				
1968	67	2728.60 ±114.88	2623.77 ±130.83	2788.31± 88.40
1969	52	3249.05 ±130.40	3489.94 ±148.51	3046.04±100.33
1970	51	2882.35 ±131.67	3021.68 ±149.96	2680.85±101.31
1971	56	2866.67 ±125.66	2932.95 ±143.10	2749.32± 96.69
1972	93	2731.77 ± 97.51	2830.00 ±111.05	2735.19± 75.03
1973	187	2783.02 ± 68.76	2863.61 ± 78.32	2780.43± 52.92
1974	288	2664.59 ± 55.41	2709.00 ± 63.11	2651.69± 42.63
1975	344	2575.57 ± 50.71	2625.23 ± 57.74	2583.95± 39.00
1976	478	2522.33 ± 43.00	2583.51 ± 49.00	2574.65± 33.08
1977	609	2620.29 ± 38.10	2682.67 ± 43.39	2617.92± 29.40
1978	522	2696.13 ± 41.16	2773.87 ± 46.86	2668.03± 31.67
1979	463	2553.28 ± 43.69	2614.75 ± 49.76	2584.41± 33.63
1980	416	2635.07 ± 46.10	2706.38 ± 52.51	2624.03± 35.48
1981	222	2808.20 ± 63.11	2919.05 ± 71.87	2724.48± 48.57
1982	115	2725.95 ± 87.69	2801.95 ± 99.86	2901.06± 67.46
1983	46	2907.93 ±138.63	2981.57 ±157.90	2865.86±106.68
1984	16	2687.56 ±235.06	2738.41 ±267.74	2817.27±180.89
Season of calving				
1 (March-May)	1032	2730.88 ± 29.26	2804.04 ± 33.34	2723.51± 22.52
2 (Oct- Nov.)	658	2726.84 ± 36.65	2804.85 ± 41.75	2711.41± 28.20
3 (Dry per.)	2335	2763.27 ± 19.46	2830.56 ± 22.17	2733.53± 14.97
Herd class				
A (Low)	2488	2035.15 ± 18.86	2100.36 ± 21.46	1919.28± 67.33
B (Medium)	841	2716.96 ± 32.42	2798.99 ± 36.93	2688.21± 16.11
C (High)	696	3468.88 ± 35.63	3540.11 ± 40.59	3560.97± 45.61
Covariates				
Lactation length		2.49 ± 0.323	3.14 ± 0.368	4.78 ± 0.249
Calving interval		2.76 ± 0.212	2.84 ± 0.241	1.26 ± 0.163
Age within parity		4.78 ± 5.539	4.76 ± 6.309	2.38 ± 4.263
Herd				
15^a	28	2281.67 ±177.70	2379.40 ±202.39	2343.50±136.73
20^a	7	2408.62 ±355.39	2410.01 ±404.78	2433.31±273.48
25^a	41	2396.96 ±146.84	2537.09 ±167.25	2432.25±112.99
36^a	6	2163.08 ±383.87	1931.44 ±437.20	2411.68±295.39
45^a	8	2234.70 ±332.44	2180.57 ±378.63	2301.86±255.82
48^a	24	1989.50 ±191.92	1971.86 ±218.60	2321.32±147.69
50^a	81	1943.94 ±104.47	2047.64 ±118.99	2050.24± 80.40
1^b	91	2583.37 ± 98.57	2641.65 ±112.27	2580.37± 75.85
2^b	224	2819.17 ± 62.82	2916.99 ± 71.56	2790.50± 48.35
3^b	7	2599.00 ±355.39	2612.38 ±404.78	2538.59±273.48
4^b	333	2767.48 ± 51.53	2827.74 ± 58.68	2788.64± 39.65
6^b	39	2771.53 ±150.57	3087.73 ±171.48	2740.20±115.86
7^b	244	2710.15 ± 60.19	2802.78 ± 68.56	2774.95± 46.31
8^b	5	3007.95 ±420.50	3025.23 ±478.93	2741.34±323.58
9^b	958	2922.73 ± 30.38	3009.07 ± 34.59	2882.78± 23.38
10^b	489	2782.21 ± 42.51	2843.52 ± 48.43	2813.42± 32.71
13^b	293	2872.07 ± 54.94	2964.39 ± 62.56	2811.21± 42.28
18^b	21	3058.74 ±205.19	3133.72 ±233.69	2985.38±157.90
23^b	57	3374.78 ±124.54	3511.41 ±141.85	2983.84± 95.84
24^b	5	2556.99 ±421.50	2696.14 ±479.94	2804.85±325.60
29^b	13	2855.78 ±260.78	3100.46 ±297.02	2846.10±200.68
30^b	160	3104.20 ± 74.34	3199.41 ± 84.67	2969.62± 57.19
34^b	19	2542.67 ±215.72	2668.36 ±245.69	2738.32±165.99
37^b	85	2988.39 ±101.98	3070.99 ±116.15	2937.57± 78.48
38^b	6	2942.71 ±383.87	2937.26 ±437.20	2916.38±295.39
44^b	36	2939.50 ±156.72	2951.76 ±178.50	2830.22±120.60
49^b	44	2839.25 ±141.75	2892.48 ±161.45	2770.47±109.07
53^b	36	2932.07 ±156.72	2999.28 ±178.50	2845.67±120.60
54^b	6	2959.85 ±383.87	2959.46 ±437.20	2926.52±295.39
58^b	234	2662.94 ± 61.47	2768.33 ± 70.01	2737.10± 47.29
21^c	281	3384.98 ± 56.10	3538.24 ± 63.88	3039.91± 43.16
59^c	144	3293.56 ± 78.36	3404.09 ± 89.24	3042.13± 60.29
OVERALL	4025	2740.33 ± 10.37	2813.15 ± 11.08	2722.82± 12.88

Appendix 5 **Least square constants of fixed effects for milk yields.**

Class	No.	305_M-day milk yield Constant estimate	305_L-day milk yield Constant estimate	Annual milk yield Constant estimate
Year of calving				
1968	67	-11.73	-189.38	65.49
1969	52	508.72	676.79	323.22
1970	51	142.03	208.53	-41.98
1971	56	126.34	119.80	26.50
1972	93	-8.56	16.85	12.37
1973	187	42.69	50.45	57.61
1974	288	-75.74	-104.15	-71.13
1975	344	-164.76	-187.92	-138.87
1976	478	-218.00	-229.64	-148.17
1977	609	-120.04	-130.49	-104.90
1978	522	-44.20	-39.29	-54.79
1979	463	-187.05	-198.41	-138.41
1980	416	-105.26	-106.77	-98.79
1981	222	67.87	105.90	1.66
1982	115	-14.37	-11.21	-21.76
1983	46	167.60	168.41	143.04
1984	16	8.84	57.76	-60.32
Season of calving				
1	1032	-9.45	-9.11	0.69
2	658	-13.49	-8.30	-11.41
3	2335	22.94	17.41	10.71
Herd class				
A (Low)	2488	-705.18	-712.79	-803.54
B(Medium)	841	-23.37	-14.16	-34.61
C (High)	696	728.55	727.00	838.15
Herd				
15	28	-458.66	-433.75	-379.32
20	7	-331.71	-403.14	-289.51
25	41	-343.37	-276.07	-290.57
36	6	-577.25	-881.71	-311.15
45	8	-505.63	-632.59	-420.96
48	24	-750.83	-841.30	-401.50
50	81	-796.39	-765.51	-672.58
1	91	-156.96	-171.50	-142.45
2	224	78.84	103.84	67.68
3	7	-141.32	-200.77	-184.23
4	333	27.15	14.59	65.82
6	39	31.20	274.58	17.38
7	244	-30.18	-10.37	52.13
8	5	267.62	212.08	18.52
9	958	182.40	195.92	159.96
10	489	41.89	30.37	90.60
13	293	131.74	151.24	88.39
18	21	318.41	320.57	262.56
23	57	634.45	698.26	261.02
24	5	-183.34	-117.01	82.03
29	13	115.45	287.31	123.28
30	160	363.87	386.26	246.80
34	19	-197.66	-144.79	15.50
37	85	248.06	257.83	214.75
38	6	202.38	124.11	193.56
44	36	199.17	138.61	107.40
49	44	98.92	79.33	47.65
53	36	191.74	186.12	122.85
54	6	219.52	146.30	203.70
58	234	-77.38	-44.82	14.28
21	281	644.65	725.09	317.09
59	144	553.23	590.93	319.31