A COMPARATIVE STUDY OF LACTATION CURVES IN CATTLE

By

MATHEW SEBASTIAN

THESIS

submitted in partial fulfilment of
the requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
Mannuthy - Trichur

1985

DECLARATION

I hereby declare that this thesis entitled "A COMPARATIVE STUDY OF LACTATION CURVES IN CATTLE" is a bonafide record of research work done by me during the course of research and that the thesis had not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

Mannuthy,
15-5-1985.

MATHEW SEBASTIAN

CERTIFICATE

Certified that this thesis entitled "A COMPARATIVE STUDY OF LACTATION CURVES IN CATTLE" is a record of research work done independently by Sri.Mathew Sebastian under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

K. C. George

DR. K.C.GEORGE
(CHAIRMAN, ADVISORY BOARD)
PROFESSOR & HEAD
DEPARTMENT OF STATISTICS

Mannuthy,
15-5-1985

DEDICATED TO THE
LOVING MEMORY OF
MY BELOVED FATHER

ACKNOWLEDGEMENTS

I am deeply indebted to Dr.K.C.George, Professor and Head, Department of Statistics, for the keen interest and unflagging enthusiasm shown in guiding me as the Chairman of the Advisory Committee.

I am extremely grateful to Sri.K.L.Sunny, Assistant Professor, Department of Statistics; Dr.K.Pavithran, Professor and Head, Department of Dairy Science and Dr.P.A.Devasia, Associate Professor in charge of University Livestock Farm, Mannuthy, for critically going through the entire manuscript and suggesting modifications as Members of the Advisory Committee.

I wish to place on record my sincere thanks to the late Dr.P.U.Surendran, former Professor of Statistics, who had been a source of inspiration and encouragement in all my endeavours.

I am privileged to acknowledge the valuable suggestions rendered by Sri.B.P.Nair, Dr.A.G.Anilkumar, Dr. Jayaram and Sri. Myint Swe. Thanks are also due to Dr.S.Talukdar, Sri.K. Murali and Sri.K.M.Suresh for all the necessary help extended for the preperation of this thesis.

I will be failing my duty if I do not express my extreme gratitude to the staff members of the Department of Statistics, my fellow students and friends for their co-operation and sincere interest in my work.

I would like to express my sincere thanks to the Dean, College of Veterinary and Animal Sciences and the staff of the University Livestock Farm, Mannuthy, for providing necessary facilities for the study.

I am grateful to the Kerala Agricultural University for the fellowship awarded to me during the course of research work.

I am thankful to Sri.T.K.Prabhakaran for his meticulous typing.

Lastly, but not least, the author expresses his indebtness to his family members especially to his brother Sri.Joseph Sebastian for encouraging to undertake the study in spite of all the odds that passed.

MATHEW SEBASTIAN

CONTENTS

INTRODUCTION

INTRODUCTION

1.1 General introduction

Rural economy of India is closely tied up with cattle. Amongst the various milch animals, the cow is the animal of choice, as the environmental conditions are generally favourable for its upkeep. Also, cow's milk is almost a perfect natural food. Furthermore, through judicious crossbreeding with exotic animals, it is possible to introduce into Indian cattle the genes for high production, earlier sexual maturity and regular breeding resulting is substantial increase in milk production of the country.

India has 243.8 million cattle and buffaloes (Singh and Singh, 1984), and the level of milk production is one of the world's lowest. With the present level of annual milk production of about 30.93 million tonnes, the per capita availability of 125 g is far below the minimum nutritional requirement of an adult human being. The present situation in respect of availability of milk in Kerala is much more alarming.

According to 1982 census, the cattle population of Kerala (including buffaloes) was estimated to be about 3.5 million, 2.6 million of which being females. The total milk production in the state during 1982-83 was estimated to be 1.08 million tonnes with an average per capita availability of 116 g being one of the lowest in the country and enough to cater to the needs of only 40 per cent of the people of Kerala. To raise the nutritional standards of about 25 million human population of Kerala to a minimum desirable level of 280 g per capita per day, the present level of milk production has to be increased by two to three times at least.

Although the level of production to an extent can be enhanced through better feeding and managemental practices, the inherent low productivity of the indigenous cattle of Kerala can be substantially improved only by selective breeding, grading up, and crossbreeding. It has been found that selective breeding and grading up would take many years for increasing the milk production considerably. On the other hand, crossbreeding using exotic dairy breeds would raise the level of production within a short period of time. On the basis of experiences gained so far, it may be said that adoption of crossbreeding is the only way by which a substantial increase in milk production can be achieved rapidly.

In view of the fact that crossbred cattle did well in heavy rainfall areas, crossbreeding using Jersey bulls was introduced in Kerala in 1955 as part of the ICAR scheme. The Hill Cattle Development Scheme introduced during the third five year plan envisaged the improvement of the cattle in high ranges. The Indo-Swiss Project started in 1963 is another scheme where extensive investigations on crossbreeding using Brown Swiss bulls are being undertaken. By this project it is contemplated to evolve a new multi-purpose breed suitable for the agro-climatic conditions prevailing in Kerala.

As Jersey and Brown Swiss crossbreds are the two main exotic breeds used for crossbreeding in Kerala, a knowledge on the performance of their crossbred group will help to formulate the future breeding policy of the state.

1.2 Present investigation

The milk produced by animals does not follow a consistent trend throughout the lactation. The biometrical properties of lactation are different in different genetic groups even if the environmental and managerial factors are identical. The graph of the trend of milk production across various stages of lactation gives lactation curve. According to Yadav *et al.* (1977a) the term lactation curve refers to the graphical representation of secretion of milk, measured in units such as days, weeks and months as the independent variates and the corresponding yield in units of weight as the dependent variates. Studies on the components of lactation curve are important in formulating effective breeding programmes for improving milk production. It would enable the breeder to have an early sire selection. Various linear and non-linear mathematical functions have been reported for describing shape of the lactation curve.

In the present study six expressions of the lactation curve viz., exponential (Brody et al., 1923), parabolic exponential (Sikka, 1950), quadratic, inverse polynomial (Nelder, 1966), gamma (Wood, 1967) and quadratic-cum-log (Malhotra et al., 1980) will be compared to find out the best fitted function to describe the lactation curve in Jersey and Brown Swiss crossbred cows. Comparison of the two breeds based on order of lactation and season of calving is another objective.

In dairy cattle, the rate of genetic improvement can be hastened through early culling of low yielders and early selection of suitable sires on the basis of their progeny performance. This can be done by selecting bulls and cows on the basis of their part records, provided that full lactation yield can be predicted from part lactation yields accurately. No such study has been reported on Jersey and Brown Swiss crossbred cattle. The present study also aims at investigating the possibilities of predicting 310 days lactation yield from various part records in Jersey and Brown Swiss crossbred cows.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

An accurate estimate of production is required for efficient planning. Lactation curves in cows computed after taking into account of season of calving, genetic make up order of lactation etc., would be quite useful for predicting the milk production of a farm. They may help to estimate the total production from incomplete records. The literature available, relevant to lactation curve is reviewed under the following heads.

1. Comparison of various lactation curve models
2. Factors affecting the shape of lactation curves
3. Prediction of full lactation yield from part records

2.1 Comparison of various lactation curve models

The inherent definite trend of milk secretion throughout the lactation of a cow has invariably been represented mathematically in the form of a lactation curve and expressed differently by different workers. Studies on the relative efficiency of such mathematical expressions describing the lactation curve are reviewed as follows:

Brody *et al.* (1923) described the lactation curve in cattle by an exponential model. But this model could describe only the descending phase of the lactation curve with a fair degree of accuracy.

Gaines (1927) used a straight line to describe the lactation curve in cattle. But this model was valid only during the first few weeks and many authors showed that it should be divided into several sections to take into account the depressing effect of gestation.

Subsequently, parabolic exponential (Sikka, 1950), inverse polynomial (Nelder, 1966) and gamma function (Wood, 1967) were developed to explain both the ascending and descending phases of the lactation curve.

Yadav et al. (1977b) compared the relative efficiency of exponential, parabolic exponential, inverse polynomial and gamma function models of lactation curves in 249 cows belonging to 3 breeds. R^2 values for the four models were 0.95, 0.95, 0.95 and 0.99 respectively in Hariana cows; 0.95, 0.96, 0.98 and 0.99 in 1/2 HF - 1/2 Hariana, and 0.91, 0.91, 0.93 and 0.99 in 1/4 Hariana - 3/4 HF cows. Based on R^2 values gamma function was chosen as the best curve.

To establish some suitable models of lactation curves for Hariana cattle, Singh and Bhat (1978a) compared the relative efficiencies of exponential, parabolic exponential, gamma and inverse polynomial functions. They found that gamma function had the better fit for those individual lactations which were having the ideal lactation length of 44 weeks. The parabolic exponential function was better for the other individual lactations of varying duration. The inverse polynomial function was superior in abstracting the average lactation curves. The exponential function did not give better fit in any of the cases.

Lactation curves of buffaloes are better described by the inverse polynomial function than by either the gamma function or the exponential parabolic function (Basavaiah <u>et al</u>., 1978; Kumar and Bhat, 1978). On the contrary, Kumar and Bhat (1979b), Bhat and Kumar (1980) and Cheema (1982) reported that gamma function followed by inverse polynomial function explained the variability better than exponential and parabolic exponential functions for describing the average lactation curve in Indian buffaloes.

Malhotra <u>et al</u>. (1980) fitted different mathematical models to milk production records of healthy Karan-Swiss cows and found that the quadratic-cum-log curve gave better fit than the other curves. The study indicated that the fitted curves had little bias, and the estimate of total lactation yield from the curve was unbiased because of positive and negative biases at different stages of lactation.

Analysing data from normal lactation records of buffaloes maintained under village conditions Singh and Gopal (1982) observed that the quadratic-cum-log curve accounted for greater than 90 per cent of total variation. Among various models of the lactation curve examined, this model gave the best fit irrespective of parity or season of calving. They also found significant effect of parity and season of calving on constants K_2 and K_4 of the model (Peak yield and rate of decline respectively).

Mukundan and Bhat (1983) stated that lactation curves of goats were better described by the inverse polynomial function that by any other function. In all the three genetic groups studied, this model accounted for more than 99 per cent of total variability. It was concluded that none of the functions was able to describe thecomplete lactation curve, although all functions described the descending phase satisfactorily.

Rowlands et al. (1982) compared four models viz., (1) $\log_e Y(n) = \log_e a + b \log_e n - cn$ (2) $Y(n) = an^b e^{-ct}$ (3) $Y(n) = ae^{-pn} - ae^{-qn}$ (4) $Y(n) = a-P'n-ae^{-q'n}$ of the lactation curve in cattle. Model (2) fitted the data slightly better, on average, than models (3) and (4) and all were better than model (1). Compared with model (1) model (2) reduced the average residual mean square by 10 per cent in cows and 4 per cent in heifers. Model (4) described the initial rise in milk yield upto week 5 better than model (1) or (2), but reached a maximum value slightly early. Models (1), (2) and (4) slightly underestimated and model (3) slightly overestimated maximum yield, but model (2) provided the best estimate of the position of maximum yield.

According to Yadav and Sharma (1985), the linear, exponential and parabolic exponential functions explained only the decling trend in milk production of Jersey, Holstein Friesian and Brown Swiss half breds and they could not define the shape of lactation curve efficiently. Inverse polynomial and gamma functions estimated the initial ascending phase followed by peak phase and the descending phase with the advancement of lactation. They also reported that all the records had R^2 values of more than 80 per cent when inverse polynomial function was fitted on individual records.

2.2. Factors affecting the shape of lactation curves

It has been recognized for many years that the shape of the lactation curve is affected by environmental factors (Cersovsky, 1957), season of calving (Maymone and Molossini, 1959), age (Blau, 1961) and fertility (Gerdemann, 1964).

Brody (1927) observed that milk yield declined at a constant rate of 5.5 per cent per month in a straight line decline. For those cows bred 3-4 months following calving there was a straight line decline upto 9 months from freshening and then therewas a sharp decline when the cows were pregnant for 6-7 months. He also reported that the decline was about 17 per cent per month in poorly bred cattle.

In the analysis of the lactation curve into maximum yield andpersistency, Sanders (1930) noticed that the rate of decline in the average daily yield was the greatest before January for cows which had calved before the previous August and were milked through the following May.

Caukas (1939) reported thatthe shape of the lactation curve appeared to be inherited and there was significat difference in lactation curves among consecutive lactations of the same cow. But such within cow differences were not as great as between cow differences.

There were two periods in the lactation where in a decrease in production was noticed in 60-250 days and a more rapid decrease from 250-300 days (Dolage et al., 1953).

Turner (1955) noticed that as the lactation advanced milk yield declined and it was probably due to the gradual decline in the secretary activity of the individual epithelial cells. He further stated that hormones from the adenohypophysis was essential for the initiation and maintenance of lactation.

Bouma (1956) compared the lactation curves of M-R-Y breeds of cattle and Friesian breeds of cattle. He observed that the month of calving appeared to have a much greater effect on the shape of the lactation curve in the M-R-Y than in the Friesian cattle, and the difference between the two breeds in standard production was also high.

Labouche (1957) noticed that the average daily production of Zebu X European crossbred cattle varied from 3.58 litres in the 1st week of lactation to 1.02 litres in the 40th week. In most animals it declined from the 1st week, but in some a temporary increase in daily yield was observed.

Wood (1969) reported that cows with the same parity of calving at the same time of the year showed similar curves modified only by total yield and abnormal seasonality of production.

Dave and Patel (1971) observed that the shape of the lactation curve is influenced by environmental factors, especially the age.

Ratheiser (1972) found that the shape of the lactation curve and persistency in simmental cows were not influenced by live weight.

2.2.1. Peak yield and days to attain peak yield

Maymone and Molossini (1959) showed that maximum production was reached in the first month after calving by 66.8 per cent of cows, in the second month by 94.2 per cent and in the third month by 98.7 per cent. The average duration of the ascending phase of the lactation was 28.31 days. Age of cow, breed or level of production had no significant effect on duration of ascending phase. However, a slightly significant effect could be demonstrated in season of calving the phase varying between a minimum of 23 days in the spring and a maximum of 26 days in winter.

Pradhan (1970) stated that in Kankrej cows the period from 1 to 7 weeks represented the rapidly rising segment of the curve followed by the decline. The curve showed a high average persistency value of 98.235 per cent between 7th to 41st week. There was more or less a straight line decline in weekly milk yield from the 7th-41st week. The average rate of decline was 1.67 per cent per week.

Nair (1973) reported for the first time the performance of Jersey X Zebu crossbred cows in Kerala State. Nair (1973) reported on the first lactation yield of Brown Swiss half-bred cows maintained at the Indo-swiss Project, Madupetty, where the conditions of management were superior to those in farmer's premises.

In Brown Swiss crossbred cows, the mean period to attain peak yield were 36.2 ± 1.6 days in F_1 and 46.8 ± 4.1 days in F_2 (Chauhan <u>et al</u>., 1974)

Rajagopalan and Dave (1976) reported that Jersey cows reached maximum production by 6th week after calving and from that level the production was being maintained more or less regularly upto 9 weeks, after which that declined almost in a straight line fashion.

According to Girija (1980), the mean lactation yield upto 305 days in Jersey X Zebu crossbreds was 1411.23 ± 32.38 kg with a coefficient of variation of 39.61 per cent. The corresponding average was 1453.92 ± 77.89 kg with a coefficient of variation of 44.50 per cent in Brown Swiss X Zebu crossbred cows. The number of days to attain peak yield in the above two breeds of cows were 44.75 ± 1.23 days

(CV = 47.84 per cent) and 49.86 ± 3.06 days (CV = 51.50 per cent) respectively. She also reported that the mean peak yield in Jersey X Zebu crossbreds was 7.91 ± 0.15 kg (CV = 33.91 per cent) and that in Brown Swiss X Zebu crossbreds was 7.70 ± 0.31 kg (CV = 33.02 per cent).

Mathew (1983) observed that Brown Swiss half breds were producing significantly more milk than Jersey half-breds under Kerala conditions. The unclassified Jersey crosses had significantly higher lactation milk yield compared to Brown Swiss half breds and the difference between the unclassified animals of both Brown Swiss and Jersey was not significant. Pooled data analysis showed that the average lactation milk yield in dry and rainy season were 1500.3 ± 26.1 kg and 1472.6 ± 28.4 kg respectively. However, season did not exert any significant influence on milk yield.

2.2.2. <u>Factors affecting the shape of gamma function</u>

In Hariana and Fr-Hariana crossbred cows on three farms, Yadav <u>et al</u>. (1977a) could observe significant effect of breed type, farm, parity and season of calving, but not age at first calving on the 'a' constant of the gamma function. Lactation sequence, season and age at first calving had significant effects on the 'b' component, whioh measured the average slope of the ourve. The 'o' component, desoribing the rate of ohange in the deolining phase of the ourve, was significantly affeoted by all the genetio and non-genetio faotors. They also developed prediotion equations for average weekly milk yield in the two breeds. On the contrary, Mehto et al. (1980) found that all the non-genetio faotors significantly affeoted the 'In a' component of the gamma funotion; 'b' component was significantly only by season of calving, season and year of oalving were the only two significant sources of variame in 'o' component of the funotion in Hariana orossbreds.

Bhat and Kumar (1978) fitted the gamma funotion in buffaloes to study the effeots of various faotors on the constants of the funotion. They found that the constant 'a' was significantly affeoted by farm, parity and season of oalving. The 'b' component was significantly affeoted by farm and year of oalving. The rate of ohange for the deolining phase of the laotation ourve (o constant) was significantly affeoted by farm, parity and year. Singh et al. (1979) also reported similar results in Hariana oattle.

Madalena et al. (1979) analysed the parametes 'a', 'b' and 'o' of individual gamma typo laotation ourves of HF and

HF X Gir cows by least square technique. They could observe that cows calving during the rainy season had higher initial production than cows calving in the dry season, which, however, had more persistant lactations. Parity affected only the initial production 'a' parameter, which, was lower for first calvers, while the other parity classes had similar 'a' values.

Studies on the lactation curves of some high yielding British Friesian cows revealed that the gamma function explained 87.7 per cent of the total variability in $\log_e Y(n)$ and the mean constants were 31.8, 0.3160 and 0.0373 respectively (Wood, 1980). He found that seasonality of production was confined mainly to a peak in spring of about 10 per cent above an approximate constant level of production during the rest of the year. These high yielding lactations generally peaked latter, were more persistent, and showed less response to seasonal variation than average lactation.

In Polish Black-and White Lowland crossbred cows of 10 Friesian strains Zarnecki and Dworak (1981) noticed that the constant 'b' of the gamma function was similar (0.277-0.376) for all strains. The 'a' value showing the height of the curve was greatest (14.5-15.7) for the high yielding strains. The 'c' value defining the declining phase was highest (rapid decline) for (in ascending order) Danish, Swedish, Dutch and Polish strains, 0.063-0.057. Except for the US strain (c = 0.054) the high yielding strains showed flat curves with a slow decline (b=0.28-0.30 and c=0.050-0.051). They further showed that the quotient b/c was significantly affected by age.

Moon et al. (1982) reported that winter calving cows had a higher and later peak yield and lower persistency than cows calving in other seasons. The constants 'a','b' and 'c' in the gamma function (R^2=0.99) were 23.85, 0.2069 and 0.1150 respectively. There were differences in lactation curves among parities; peak yields in lactation 1-2, 3-4, 5-6 and 7-8 were 19.02, 24.23, 25.23 and 21.83 kg respectively and persistency showed the reverse trend. The shape of the lactation curve was similar at the four levels of milk yield compared.

Matsuo et al. (1982) observed that the shape of the lactation curve (gamma function) was modified by calving month as a result of high temperature during summer. Milk yield during early lactation was depressed in cows calving in July and August compared with that of cows calving in other months, and tended to decrease linearily as lactation proceeded, whereas the milk yield of cows calving in spring increased during the 1st week of lactation, and declined comparitively slowly as lactation proceeded. They further showed that peak yield tended to increase with increasing parity, and total milk yield was significantly correlated with persistency (-0.323).

2-2.3. <u>Factors affecting the shape of inverse polynomial and parabolic exponential functions</u>

Yadav <u>et al.</u> (1977c) concluded that the constants 'b_0' (describing the rate of change in the ascending phase of the curve), 'b_1' (average slope of the curve) and 'b_2' (rate of change in the declining phase of the curve) of inverse polynomial function were significantly affected by breed type, farm and age at 1st calving, and 'b_1' by lactation number. Other effects were not significant.

Singh and Bhat (1978b) fitted the parabolic exponential function to the individual lactations of 1202 Hariana cows. They observed significant effect due to herds, order of lactation, period and month of calving on all the constants except for 'b' in which the effect of lactation order was not significant. Maximum production was observed in the lactations initiated during monsoon (August and September) and winter (December and January) seasons. The production increased from the 1st-6th lactation. On the contrary, Kumar and Bhat (1979a) reported that the constant 'a' was significantly affected by farm and parity, 'b' by farm only, and 'c' by farm, parity and year of calving. They also developed the prediction equation $\log_e Y_t = \log_e 50.20 + 0.0198t - 0.0008t^2$.

Studies on the effect of the age at 1st calving and lactation length on the 1st lactation yield revealed that lactation milk yield was significantly affected by source of import, month and year of calving, lactation length, and age at calving ($P < 0.01$)(Al-Rawi and Said, 1980). They also showed that increase of one month in age at 1st calving and one day in lactation length were associated with increase of 27.4 and 7.0 kg respectively in 1st lactation yield.

Gaskins _et_ _al_. (1980) reported that breed, cow within breed and age of cow ($P < 0.01$) affected daily milk production. The trend in daily milk production during lactation was linear for AH cows and for two year old cows. The trends in daily milk production were curvilinear for JA and SA cows and three and four year old cows, with milk production decreasing at an increasing rate with days in lactation.

Rao and Sundaresan (1981) pointed out that persistency and the shape of the lactation curve were significantly affected by genotype, parity, season of calving and age at calving. Persistency was greater for 1st than for later lactations and for lactations starting in the monsoon rather than in other seasons. They also found that the effect of service period and calving interval on lactation yield and lactation curve shape were not consistent among genotypes.

Yadav and Sharma (1982) studied the factors affecting the lactating and non-lactating period of crossbred cows belonging to three genetic groups viz., Jersey X Hariana, Brown Swiss X Hariana and HF X Hariana. They found that lactation length, dry period and the duration of the ascending phase of lactation curve did not differ significantly between genetic groups. In the three groups respectively, lactation length was 19.87, 20.16 and 4.52 days longer for the 1st than the 2nd lactation, and 21.82, 22.80 and 19.60 days longer for the 1st than for the 3rd lactation. The ascending phase of the lactation curve was longer for 1st than for 2nd and 3rd lactations (4.14 Vs 3.54 and 3.48 week). Year period of calving did not significantly affect the dry period, but had a significant effect on lactation length. Although lactation length was not affected by season of calving, the preceeding dry period was significantly longer for winter calves than for cows calving in summer or the rainy season. The number of days to reach peak yield was significantly greater in winter calvers than in cows calving in other seasons, except for Brown Swiss X Hariana cows.

Costa et al. (1982) observed that peak milk yield increased and persistency decreased as age at calving increased from less than 36 to 73-96 months. Peak yield was lowest with calving in January-June and highest with calving in July-September. Persistency was greater after April-June calving.

Singh and Raut (1982) studied the lactation curve for Rathi cows, in 1st-4th lactations, under village conditions. Lactation milk yield averaged 1109.1 ± 37.36 and 1527.7 ± 80.32 kg in thetwo breed groups respectively. Milk yield was significantly affected by lactation length, but not by parity. In both groups, peak yield occured at different stages of lactation. Lactation length had a significant effect on persistency, but not on peak yield. In both groups, lactation length was significantly correlated with lactation yield (0.43 and 0.48 respectively) and persistency (0.47 and 0.52).

Shimizv et al. (1983) reported that both the 180 day and peak milk yields of HF cows increased with parity and were highest with calving in January-June (highest in January-February and lowest in July-August). Milk yield peaked later in 1st than in later lactations and was latest with January-February calving and earliest with May-June calving. Measures of persistency were highest when peak yield was latest.

2.3. <u>Prediction of full lactation yield from part records</u>

The ability to predict the complete lactation production of a cow from its part yields will determine the success of a herd culling programme. In dairy cattle, rate of genetic improvement can be hastened by selecting cows and bulls on the basis of their part records, provided that full lactation yield can be predicted from part lactation yields accurately.

Bussert (1957) studied the part yields of heifers in relation to the shape of the lactation curve. Part yields were based on 100 and 200 day yields. It was found that the 100 day yield was not an accurate guide to later production, particularly in the case of cows with a steep rise in the curve at the beginning of lactation. But 200 day yields were suitable for estimating milk production ability in heifers and did not need to be considered in relation to the shape of the lactation curve.

Studies on 532 lactations from 101 Black-and-White, herd tested cows showed high correlations between the peak test day and the first 100 day milk production on the total lactation yield, and the first 100 day milk production (X) with the total lactation yield (Y). The prediction equation was $Y = 778 + 1.99\,X \pm 611$, $r=0.94$ (Blau, 1961).

In buffaloes, Agarwala (1962) could observe that irrespective of levels of production the correlation between actual and estimated lactation yields increased as the interval between the recordings decreased. He concluded that recording milk production every 10 days was not reliable for predicting the total lactation yields.

Highly significant correlations between full lactation and different part lactation yields in different exotic breeds of cattle was reported by Cannon et al. (1942) and Lamb and McGillard (1967a,b). Similarly high correlations between the part and full lactation yields in Hariana cattle were reported by Dutt et al. (1964), Singh et al. (1967) and Singh and Acharya (1969). In crossbred cattle similar results were reported by Kartha (1934).

Preliminary results for Brown Alpine cows in the province of Sondrio showed significant correlations ($P=0.001$)

between 50-, 70- and 120-day lactations on the one hand and 305 day lactation on the other of r=0.671, 0.705 and 0.824 respectively (Mascherpa *et al.*, 1967).

Krefft (1967) constructed the model $Y = 1.406 \cdot 10^{-5} r \; x^{1.878} \; e^{-0.0251x}$ (Y is the daily milk yield, r is the 305 day yield, x is the day of lactation, and e is the base of natural logarithms) to determine the milk yield of cows during a single lactation.

Miller and Pearson (1972) compared four methods - ratio, multiple regression, modified regression and regression of the remainder of the lactation on the last test - of extending (cow) lactations-in-progress. They concluded that multiple regression estimates and regression estimates on the last test were about equally precise. Modified regression was intermediate while errors of ratio estimates were largest. They also reported that present use of ratio extension factors results in excessively large errors in projecting short-length lactation to a 305 day basis.

Velea *et al.* (1977) reported that the correlations of milk yields at the first six recordings in the 1st lactation with 1st lactation milk yield were 0.44, 0.67, 0.75, 0.84, 0.75 and 0.71 respectively. Correlations between yields at these 1st lactation recordings and 2nd lactation milk yield were 0.15, 0.30. 0.33, 0.32, 0.30 and 0.37 respectively and corresponding correlations for the 3rd lactation milk yield were 0.18, 0.21, 0.22, 0.34, 0.24 and 0.23. When the total milk production for any 2,3,4 or 5 recordings from the first six was considered, the correlations with the 1st lactation milk yield were 0.47-0.76, 0.59-0.82, 0.65-0.84 and 0.70-0.71 respectively. The correlations of the total milk production for six recordings with that for the 1st lactation was 0.67.

Schaeffer et al. (1977) developed the technique of non-linear model to predict 305 day milk and fat yields of Canadian Holstein and Jersey cattle and compared this procedure with themultiplicative and linear regression methods of extending records in progress. They found that the method of non-linear model was at least as accurate as either the multiplicative or regression methods and it requires less computer storage for parameter estimates than for multiplicative factors and could be implemented easily into a milk recording programme.

Adeneye and Adebanjo (1978) reported that both 100- and 200-day yields were significantly correlated with the 305 day yields of Friesian cows. In the first five lactations, the value of the correlation coefficient, r, varied from 0.74 to 0.99. The 200 day yields were more closely correlated with the 305 day yields than the 100 day yields. They also reported that peak yields were attained during the first month of lactation; the 3rd lactation peak was the highest; daily milk yields decreased gradually as the 2nd, 3rd and 5th lactations advanced.

Powell et al. (1978) observed that correlations between projected milk yield from records in progress and 305 day records in Holstein cows increased from 0.80 for 40 to 69 days in milk to 0.99 for 280 to 304 days in milk. Corresponding average absolute differences decreased from 777 to 68 kg. Correlations involving cow index for milk increased from 0.91 to 0.99.

With a view to extend in-progress and terminated lactation records, Wiggans and Van Vleck (1979) developed a function involving last sample production which accounts for systematic influences in estimating remaining yields. The function is estimated 305 day yield = yield in first n days + $\left[(b_1+b_2n)\text{ last production} + (b_3+b_4\sqrt{n})/\text{last production}\right](305-n)$. The coefficients b's were estimated within three stages (<65, 65 to 245, >245 days in milk), four age at freshening grous (<34, 34 to 48, 49 to 60 and >60 months, 34 to 36 months cows were placed in the first group if freshening for the 1st time), three herd yields (5900, 5900 to 7000 and 7000 kg), and six two month season of freshening groups by least squares for milk and fat yield.

In Limonero cows, the correlations of total lactation milk yield with yields in the first two and four months of lactation were 0.77 and 0.88 respectively (Contreras and Rincon, 1979).

Rao et al. (1980) stated that the best months for predicting the succeeding complete lactation record were the 4th, 5th, 6th and 7th cumulative monthly records, the accuracy of predicting the subsequent total record ranging between 0.53 and 0.58. Prediction equations involving multiple regression factors for monthly production (5, 6 and 7 sequential months) were slightly better than the preceding total record in predicting succedding complete record.

Utilizing the milk yield data adjusted for the significant effects due to farm, season of calving and age at first calving Chillar et al.(1980) showed thatthe correlation of total lactation milk yield on part lactation yield increased with each added successive part lactation yield. 150 day record was most appropriate for predicting the full lactation yield with reliable accuracy. The 150 day part record had significant correlation coefficients of 0.82 to 0.93, 0.76 to 0.89 and 0.79 to 0.90 with different full lactation yields in Hariana, 1/2 HF and 3/4 HF respectively.

Taking into account the effects of age of cow, calving interval, feeding and disease, standard curves for 305 day lactations of cows yielding 3000-8000 kg milk were estimated (Huth et al., 1981). It was concluded that for cows with lactation yields of 3000, 5000 and 8000 kg respectively yields during the 2nd-4th week, during the 7th week, and during the 14th week respectively gave the best indication of total lactation yield.

Saigaonkar et al. (1981) could find significant correlations for total lactation yield (52 week) with yields at 4,8,12 and 16 weeks and peak yield of Sahiwal cows. Efficiency of predicting 52 week milk yield from 12-and 16-weekrecords was $>$ 60 per cent, whereas it was $<$ 50 per cent when peak yield records were used.

Batro and Lee (1981) reported that the USDA extension factors consistently predict lower production from records in progress. They modified those extension factors for use in Canada and both the actual and modified versions of the USDA extension factors were compared on a new set of data. They observed that the modified extension factors were better than the 1965 USDA extension factors and were able to eliminate the systematic bias.

Dhanoa and Du (1982) proposed a model to describe the lactation curve of a dairy cow. The model is $Y_t = \lambda(m_0 - m_1 t) + (1-\lambda)Y_{t-1}$; $t \geq 1$, $0 \leq \lambda \leq 1$, where Y_t and Y_{t-1} are the current and preceeding milk yields in kg/week, and the constant λ estimates the fraction by which milk yield adjusts to the level at the next stage. The fraction $(1-\lambda)$ by which the milk yield persists at the preceeding level is used to define a measure of persistency, $p = (1-\lambda)m_0/m_1$, where m_1 is the rate of decline in kg/week and m_0 is a constant.

Pathak et al. (1982) observed significant correlation ($r=0.726$) between 300 day lactation yield (Y) and 100 day yield (X). They also suggested the equation $Y = 249.59 + 2.0035\ X$ for prediction of 300 day yield in Gir cows.

Comparison of three methods - ratio, simple regression and modified regression- of predicting total lactation milk yield from part lactation yields in 742 lactations of HF, HF x Gir and HF x (HF x Gir) cows in Brazil indicated that the simple regression method gave the most accurate prediction of total milk yield (Teixeiran et al., 1982).

In Simmental cows, Reiser and Haussmann (1982) noticed that factors for extending part lactations were significantly affected by herd average milk yield but not by season or age at 1st calving. Linear regression on average test day performance applied within five classes for herd average yield gave the most accurate extension of part lactations. Correlations between test day results and 305 day fat yield were 0.88-0.99.

Arendonk and Fimland (1983) while comparing two methods viz., factor analysis and linear regression method to extend partial records observed that correlations between actual and predicted total lactation yields were equal for the two methods, they were 0.85, 0.93 and 0.98 when prediction was based on actual recording for 2-, 4- and 7-month periods respectively. They also found that both methods overestimated production. The longer the part records were, the lower was the overestimation. Correlation factors introduced to remove this bias were effective with the factor analysis method, but not completely effective with the linear regression method. They further suggested that to get unbiased predictions, extension factors should be recalculated in respect of each data set.

Shah and Singh (1983) stated that prediction of lactation yield from 60 day yield was most reliable in 1st and 2nd lactations. Milk yield was highest in the second month of lactation and then decreased. Persistency index was 92.3-93.9 per cent and rate of yield decline was 7.3-8.5 1/month.

Rungei et al. (1983) reported that root mean square error and bias in predicting 305 day milk yield of HF cows by an incomplete gamma function were 0.716 ± 0.274 kg and -0.68 kg respectively. Errors in estimating 305 day yield from actual 240 day yields in two samples embracing 60 lactations were 40.01 and 36.00 kg or less than 0.8 per cent of total yield.

Goodall and Sprevak (1984) from a study of the behaviour of the time series of the difference between the observed values of milk yield and the fitted lactation curve derived a stochastic model to improve the fit of the lactation curve, to forecast milk yield and to generate simulated values of milk yield.

MATERIALS AND METHODS

MATERIALS AND METHODS

The data pertaining to the production and reproduction performance of 148 crossbred cows maintained at the University Livestock Farm, Mannuthy during the period 1978-1983 were utilized in this study. Since the animals belonged to only one farm they were under identical conditions of management and feeding regime. Most of the animals were born and brought up in this farm but some were purchased from the field and other farms.

The cows, under study, belonged to two genetic groups viz., Jersey crossbreds (93) and Brown Swiss crossbreds (55). Records upto 4th lactation were included in the study. Those after 4th lactation were very few in number and hence were excluded. There were a total of 264 lactation records which include 174 lactation records of Jersey crossbreds and 90 lactation records of Brown Swiss crossbreds. Abnormal records such as those affected by abortion, premature birth, mastitis and death during lactation were ignored. Similarly, incomplete lactation records due to sale, culling, death and other pathological condition were also not included. Abnormal lactations of less than 150 days duration were excluded from the study.

3.1. Daily and total milk yield

Average daily milk yield (calculated from 10 days yield) upto 310th day of lactation was the main item of observation. In the present study, the term 'total yield' refers to the yield in 310 days. In the case of cows which dried before 310th day, the yield upto the date of drying was considered as total yield.

3.2. Lactation curve models

Six mathematical models viz., the exponential, the parabolic exponential, the quadratic, the quadratic-cum-log, the gamma and the inverse polynomial functions were examined to find out the best fit for a representative curve in Jersey and Brown Swiss crossbred cows.

3.2.1. Exponential function

Brody et al. (1923) used this function and represented it mathematically as $Y_t = Ae^{-kt}$ where Y_t is the yield in time 't' and A and K are constants to be estimated. In its logarithm form, this reduces to $\log_e Y_t = \log_e A - kt$.

3.2.2. Parabolic exponential function

Sikka (1950) proposed this function and represented it mathematically as $Y_t = Ae^{bt+ct^2}$. Taking logarithm on both sides we get $\log_e Y_t = \log_e A + bt + ct^2$.

3.2.3. Quadratic function

This model can be represented mathematically as $Y_t = A + bt + ct^2$ where A, b, c are constants to be estimated.

3.2.4. Quadratic-cum-log curve

Malhotra et al. (1980) represented this function mathematically as $Y_t = A + bt + ct^2 + d \log_e t$ where A, b, c and d are constats to be estimated.

3.2.5. Gamma function

Wood (1967) suggested the following expression for the lactation curve. $Y_t = A\ t^b\ e^{-ct}$ where A, b and c are constants to be estimated. In its logarithm form this can be written as $\log_e Y_t = \log_e A + b \log_e t - ct$.

3.2.6. Inverse polynomial function

Nelder (1966) described this function algebrically as $Y_t = t\ (b_0 + b_1 t + b_2 t^2)^{-1}$ where b_0, b_1 and b_2 are constants to be estimated. This can be written as $1/Y_t = A + b/t + ct$ where $A = b_1$, $b = b_0$ and $c = b_2$.

The first constant $\log_e A$ of the exponential, parabolic exponential and gamma functions and 'A' of the quadratic, quadratic-cum-log and inverse polynomial functions have been shown as 'a' constant, while k and b of the above 6 equations have been shown as 'b' constant in Tables 6, 7, 8, 9, 10 and 11. The third constant 'c' of the last five equations has been shown as 'c' constant and the constant 'd' of the quadratic-cum-log curve has been shown as 'd' constant in Tables.

3.2. Fitting lactation curves

The six functions mentioned above were fitted to the average daily milk yield (kg) seperately for each of the four lactations and also to the pooled data (Pooled over all the lactations) for each breed under study with the help of multiple linear regression analysis. Since the curves were fitted to the average daily milk yield (up to 310th day) calculated from 10 days yield, time (t) ranges from 1 to 31 in all the curves used in the present study. Also, Y_t refers to the average daily yield in time 't'.

3.2.1. Estimation of parameters

The parameters of the curves were estimated as follows (Kendall et al., 1983):

General linear model is $\underset{\sim}{Y}_{nX1} = \underset{\sim}{X}_{nXk} \underset{\sim}{B}_{kX1} + \underset{\sim}{U}_{nX1}$

where $\underset{\sim}{B}$ is a (kX1) vector of regression coefficients, $\underset{\sim}{X}$ is an (nXk) matrix of known coefficients and $\underset{\sim}{U}$ an (nX1) vector of "error" random variables with means and dispersion matrix $E(\underline{U}) = 0$, $V(\underline{U}) = \sigma^2 \underset{\sim}{I}$. The vector of LS estimaters of $\underline{B}$ is given by $\underline{B} = (\underset{\sim}{X}'\underset{\sim}{X})^{-1} \underset{\sim}{X}'\underline{Y}$ and its dispersion matrix is $V(\underline{B}) = \sigma^2(\underset{\sim}{X}'\underset{\sim}{X})^{-1}$. Unbiased estimator of σ^2 is S^2 where $(n-k)S^2 = (\underline{Y} - \underset{\sim}{X}\underline{B})' (\underline{Y} - \underset{\sim}{X}\underline{B}) = \underline{Y}'\underline{Y} - \underline{B}'\underset{\sim}{X}'\underline{Y}$.

3.3. Comparison of lactation curves

In order to compare the relative efficiency of various lactation curve models and to select the most suitable curve, two methods were used viz., (i) coefficient of multiple determination (R^2) and (ii) Furnival index (I).

3.3.1. Coefficient of multiple determination (R^2)

To test $H_0 : B_1 = B_2 = \ldots\ldots\ldots = B_k = 0$ and to compute R^2 the following Analysis of variance Table was used.

Source	DF	SS	MSS	F
Due to regression	$k-1$	$\underline{B}'\underset{\sim}{X}'\underset{\sim}{X}\underline{B} - \underline{Y}'\underset{\sim}{J}\underline{Y}/n$	MSS(Reg)	$\frac{\text{MSS(Reg)}}{\text{MSS(Res)}}$
Residual	$n-k$	$\underline{Y}'\underline{Y} - \underline{B}'\underset{\sim}{X}'\underset{\sim}{X}\underline{B}$	MSS(Res)	
Total	$n-1$	$\underline{Y}'\underline{Y} - \underline{Y}'\underset{\sim}{J}\underline{Y}/n$		

$$R^2 = \frac{\underline{B}'\underset{\sim}{X}'\underset{\sim}{X}\underline{B} - \underline{Y}'\underset{\sim}{J}\underline{Y}/n}{\underline{Y}'\underline{Y} - \underline{Y}'\underset{\sim}{J}\underline{Y}/n}$$

R^2 was tested using $F_{(k-1,\ n-k)} = \dfrac{R^2/k-1}{(1-R^2)/n-k}$

3.3.2. Furnival Index (I)

Furnival (1961) constructed an index of fit (I) as
$I = (\prod_{i=1}^{n} f'(Y_i)^{-1})^{1/n} S$ where

$f'(Y)^{-1}$ is the reciprocal of the derivative of some function $f(Y)$ of the dependent variable Y with respect to Y

n is the number of data points

S is the root mean square residual obtained from the fitted regression.

A large value of I indicates a poor fit and vice-versa.

3.4. Effect of genetic and non-genetic factors on total yield

Influence of genetic and various non-genetic factors such as lactation sequence and season of calving on total lactation yield was studied by the conventional statistical methods (Snedecor and Cocharan, 1967).

3.4.1. Effect of breed type

In order to study the effect of breed type on total lactation yield (310 days yield), the cows were classified into two genetic groups viz., Jersey crossbreds and Brown Swiss crossbreds.

3.4.2. Effect of order of lactation

To study the effect of order of lactation on total yield (310 days yield), the lactation records were classified based on the order of lactation into four classes viz., lactations 1, 2, 3 and 4.

3.4.3. Effect of season of calving

To examine the effect of season of calving on total yield, the year was delineated into three seasons as follows:

Season	Months
1. Dry season	January, February, March and April
2. Rainy season	May, June, July and August
3. Moderate season	September, October, November and December

3.4.4. Statistical analysis

The effect of breed type on total lactation yield (310 days yield) was studied by comparing the average total yields of Jersey and Brown Swiss crossbreds using Student's 't' test.

In order to study the effects of order of lactation, season of calving and order of lactation X season of calving interaction, the total yield from each of the two breeds were analysed seperately by the method of least squares. The following model was used:

$Y_{ijp} = \mu + L_i + S_j + (LS)_{ij} + e_{ijp}$ where

Y_{ijp} is the total yield from the p^{th} animal of i^{th} lactation and j^{th} season of calving

μ is the overall mean

L_i is the effect of the i^{th} lactation sequence ($i = 1, 2, \ldots, l$)

S_j is the effect of the j^{th} season of calving ($j = 1, 2, \ldots, s$)

$(LS)_{ij}$ is the two factor interaction of the i^{th} lactation sequence with the j^{th} season of calving

e_{ijp} is the random error associated with Y_{ijp} which is assumed to be normally and independently distributed with mean zero and variance σ^2.

The analysis of variance table was as follows:

Source	DF	SS	MSS
Between lactation sequences	$l-1$	S_1	$S_1/l-1$
Between seasons	$s-1$	S_2	$S_2/s-1$
Season X lactation sequence	$(l-1)(s-1)$	S_3	$S_3/(l-1)(s-1)$
Error	$n-ls$	S_R	$S_R/n-ls$
Total	$n-1$		

Where
$$S_1 = \sum_i \left\{ \left(\sum_j \sum_p Y_{ijp}\right)^2 / n_{i.} \right\} - \left(\sum_i \sum_j \sum_p Y_{ijp}\right)^2 / n$$

$$S_2 = \sum_j \left\{ \left(\sum_i \sum_p Y_{ijp}\right)^2 / n_{.j} \right\} - \left(\sum_i \sum_j \sum_p Y_{ijp}\right)^2 / n$$

$$S_3 = \sum_i \sum_j \left\{ \left(\sum_p Y_{ijp}\right)^2 / n_{ij} \right\} - \sum_i \left\{ \left(\sum_j \sum_p Y_{ijp}\right)^2 / n_{i.} \right\}$$
$$- \sum_j \left\{ \left(\sum_i \sum_p Y_{ijp}\right)^2 / n_{.j} \right\} + \left(\sum_i \sum_j \sum_p Y_{ijp}\right)^2 / n$$

$$S_R = \sum_i \sum_j \sum_p Y_{ijp}^2 - \sum_i \sum_j \left\{ \left(\sum_p Y_{ijp}\right)^2 / n_{ij} \right\}$$

3.5. Prediction of total yield using part yields

In order to predict total lactation yield (310 days yield) from part lactation yields, the total milk produced by a cow during the first 30, 60, 90, 120 and 150 days of a lactation were considered as part lactation yields. Since the effects of order of lactation and season of calving were found to be non-significant in both the genetic groups no adjustment of data was needed. The unadjusted records of the two genetic groups were analysed seperately to obtain the part-whole correlation coefficients of various part lactation records with 310 days yield. Phenotypic correlations were computed in the line of Snedecor and Cochran (1967).

3.3.1. Methods of prediction

Linear equations for predicting 310 days yield from part yields were developed by ratio and regression methods.

In ratio method, regression coefficients were estimated by dividing the 310 days yield by the cumulative yields at 30, 60, 90, 120 and 150 days of lactation, whereas, in regression method, regression coefficients were estimated by the usual method of fitting linear equations. In both the methods, coefficient of determination (R^2 values) was chosen as the criterion for measuring the accuracy of prediction.

RESULTS

RESULTS

The present study was undertaken to compare the relative efficiency of various lactation curve models and to suggest the most suitable one in cows maintained at the University Livestock Farm, Mannuthy, to compare the two genetic groups of cows based on order of lactation and season of calving and to develop equations for predicting 310 days milk yield from part yields of different types. The results obtained are presented below.

4.1. Milk production performance

4.1.1. Daily milk yield

The average daily milk yield (calculated from successive 10 day yields) upto 310th day in the first four lactations of Jersey and Brown Swiss crossbreds were presented in Table 1. It was found that, in both genetic groups, the average daily production increased during the first month of lactation, passed through a maximum between 30th and 40th day and then diminished more or less regularly upto the drying off stage (Fig.1).

4.1.2. Peak yield and days to attain peak yield

Peak yield and days to attain peak yield are two major factors determining the shape of the lactation curve. The

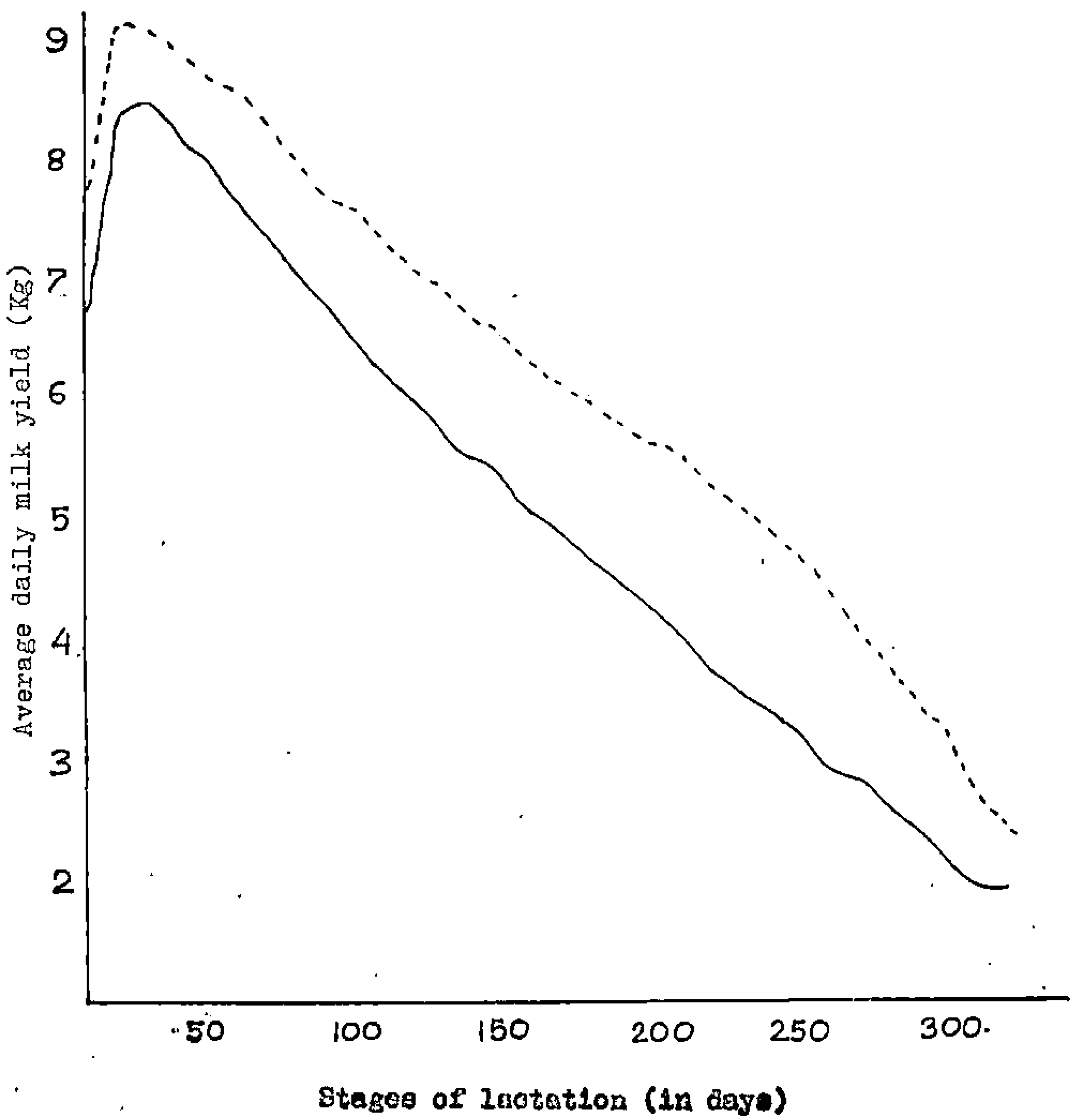

Fig.1. Observed lactation curves in crossbred cows

(———— Jersey crossbreds
.........Brown Swiss crossbreds

values of these parameters with their S.E. and coefficient of variation in Jersey and Brown Swiss crossbreds were presented in Table 2.

The mean peak yield (kg) in the first four lactations of Jersey crossbreds were 8.43 ± 0.19 (CV = 19.45 per cent), 8.38 ± 0.28 (CV = 23.09 per cent), 8.81 ± 0.42 (CV = 29.12 per cent) and 9.28 ± 0.69 (CV = 28.88 per cent) respectively with an overall mean peak yield of 8.57 ± 0.21 (CV = 32.32 per cent). In Brown Swiss crossbreds, the corresponding values in the first four lactations were 9.06 ± 0.45 (CV = 27.20 per cent), 9.08 ± 0.41 (CV = 26.81 per cent), 9.78 ± 0.56 (CV = 24.39 per cent) and 9.29 ± 1.00 (CV = 28.58 per cent) with an overall mean peak yield of 9.23 ± 0.42 (CV = 43.17 per cent).

From Table 2 it can be seen that in Jersey crossbreds, the number of days to attain peak yield were 37.70 ± 1.75 (CV = 39.89 per cent) for 1st lactation, 38.58 ± 2.13 (CV = 37.88 per cent) for 2nd lactation, 35.85 ± 2.09 (CV = 35.95 per cent) for 3rd lactation and 33.26 ± 1.97 (CV = 22.94 per cent) for 4th lactation. In Brown Swiss crossbreds the corresponding values were 43.90 ± 2.47 (CV = 30.83 per cent) for lactation 1, 40.97 ± 2.20 (CV = 31.77 per cent) for lactation 2, 38.68 ± 3.31 (CV = 36.27 per cent) for lactation 3 and 34.75 ± 3.66 (CV = 27.87 per cent) for lactation 4.

The overall mean number of days to attain peak yield in Jersey crossbreds was 37.15 ± 1.15 days (CV = 40.83 per cent) and that in Brown Swiss crossbreds was 41.00 ± 2.63 days (CV = 57.73 per cent).

4.1.3. Total milk yield

When the four lactations were pooled, the average total milk yield (yield upto 310th day) of Jersey and Brown Swiss crossbreds were 1652.83 ± 30.56 kg (CV = 24.39 per cent) and 1897.43 ± 43.81 kg (CV = 21.90 per cent) respectively (Table 3). These breed means were compared using 't' values. The result showed that Brown Swiss cows were producing significantly ($P < 0.01$) more milk than Jersey cows.

4.1.4. Total milk yield in different lactation and seasons

The average total milk yield (yield upto 310th day) in different lactations were presented in Table 3 and that in different seasons were shown in Table 4.

From Table 3, it could be seen that the average total yield in the first four lactations of Jersey crossbreds were 1659.46 ± 44.87 (CV = 23.26 per cent), 1601.04 ± 49.61 (CV = 21.24 per cent), 1699.45 ± 79.42 (CV = 28.81 per cent) and 1664.26 ± 116.20 (CV = 27.04 per cent) kg respectively. In Brown Swiss Crossbreds the corresponding values were found to be 1856.96 ± 75.78 (CV = 22.35 per cent), 1870.11 ± 65.64 (CV = 20.76 per cent), 1963.22 ± 118.07 (CV = 25.51 per cent) and 2038.37 ± 128.44 (CV = 16.67 per cent) kg respectively.

In Jersey crossbreds, the average total yield for the dry, rainy and moderate seasons were 1629.35 ± 48.49 kg (CV = 23.24 per cent), 1705.12 ± 57.74 kg (CV = 23.70 per cent) and 1635.17 ± 53.35 kg (CV = 26.10 per cent) respectively. In Brown Swiss crossbreds, the corresponding figures were 1860.42 ± 112.07 kg (CV = 26.94 per cent), 1872.32 ± 73.26 kg (CV = 22.13 per cent) and 1938.06 ± 60.62 kg (CV = 21.90 per cent) respectively (Table 4).

4.2. Effect of breed type, order of lactation and season of calving on total yield

It was found from Table 3 that Brown Swiss crossbreds were producing significantly ($P < 0.01$) more milk than Jersey crossbreds. It showed that breed type had significant effect on total milk yield.

Analysis of variance of total milk yield in different lactations and seasons of calving are presented seperately for Jersey and Brown Swiss crossbreds in Table 5. The result showed that in both the genetic groups, order of lactation had no significant effect on total milk yield. Seasonal differences in milk yield were also found not significant in both the crossbreds. No evidence of interaction between lactation order and season of calving was observed in both the genetic groups under study.

4.3. Fitting lactation curves

Six types of curves, viz., the exponential, the parabolic exponential, the quadratic, the quadratic-cum-log, the gamma and the inverse polynomial functions were fitted to the average daily milk yield (kg) seperately for each of the four lactations and also to the pooled data (Table 1) for each breed under study. Lactation-wise and pooled estimates of the constants of these six functions are detailed, seperately for Jersey and Brown Swiss crossbreds, in Tables 6 to 11. The values of coefficient of determination (R^2) and Furnival index (I) are also shown in these tables.

4.4. Comparison of lactation curves

Efficiency of various curves were compared using coefficient of determination (R^2 values) and Furnival index (I values). The curve having higher value of R^2 and lower value of I was selected as the most suitable curve.

4.4.1. Comparison of curves fitted to first lactation records

R^2 values and Furnival indices (Tables 6 to 11) showed that the gamma function was the best fitted curve in the 1st lactation records of Jersey and Brown Swiss crossbreds. This function had the higher value of R^2 (0.9854 in Jersey and 0.9841 in Brown Swiss and lower value of I (0.1994 in Jersey and 0.2133 in Brown Swiss) in both the crossbreds. The equations (in linear form) of this function in the 1st lactation records of Jersey and Brown Swiss crossbreds were

$$\log_e Y_t = 1.97579 + 0.16812 \log_e t - 0.04794\ t \text{ and}$$
$$\log_e Y_t = 2.09824 + 0.13299 \log_e t - 0.04149\ t \text{ respectively.}$$

In both the crossbreds under study, the quadratic-cum-log curve gave the second best fit. R^2 values of this function in Jersey and Brown Swiss crossbreds were 0.9778 and 0.9810 respectively with corresponding I values 0.2493 and 0.2402. The equation of this curve in the abow two crossbreds were

$$Y_t = 7.2868 - 0.49931\ t + 0.00596\ t^2 = 1.60789 \log_e t \text{ and}$$
$$Y_t = 8.09356 - 0.58401\ t + 0.00763\ t^2 + 1.89496 \log_e t$$

respectively.

Further, it could be seen that the quadratic curve gave the last fit with R^2 values 0.9087 (in Jersey) and 0.9042 (in Brown Swiss) and I values 0.4964 (in Jersey) and 0.5293 (Brown Swiss).

Analysis of variance for testing the significance of the sum of squares due to regression of the best fitted function in the first lactation records is shown separately for each breed in Table 12. It was found that the sum of squares due to regression and R^2 were highly significant ($P < 0.01$) in both the breeds.

4.4.2. Comparison of curves fitted to second lactation records

R^2 values of quadratic-cum-log curve in the 2nd lactation records of Jersey and Brown Swiss crossbreds were 0.9878 and 0.9804 respectively with corresponding Furnival indices 0.2287 and 0.2723. This function accounted for higher values of R^2 and lower values of I than the other functions. The mathematical form of this curve was

$Y_t = 7.08996 - 0.50737\ t + 0.00454\ t^2 + 1.7531 \log_e t$ in Jersey crossbreds and

$Y_t = 7.81832 - 0.35602\ t + 0.00156\ t^2 + 1.26049 \log_e t$ in Brown Swiss crossbreds.

The gamma function was the second best choice with R^2 values 0.9801 (in Jersey) and 0.9609 (in Brown Swiss) and Furnival indices (I) 0.3064 (in Jersey) and 0.4105 (in Brown Swiss). The equations (in linear form) of this function were

$\log_e Y_t = 1.88624 + 0.35276 \log_e t - 0.07986\ t$ (in Jersey) and
$\log_e Y_t = 1.99529 + 0.27765 \log_e t - 0.06197\ t$ (in Brown Swiss).

Tables 6 to 11 also showed that the inverse polynomial function gave the least fit in the 2nd lactation records of both the breeds. The R^2 values of this function in Jersey and Brown Swiss crossbreds were 0.8519 and 0.8382 respectively with corresponding I values 1.0808 and 1.0364.

From the analysis of variance (Table 13) it could be seen that the sum of squares due to regression and R^2 values of the quadratic-cum-log curve were highly significant ($P < 0.01$) in both the genetic groups.

4.4.3. Comparison of curves fitted third lactation records

Gamma function provided the best fit in the 3rd lactation records of Jersey crossbreds. The values of R^2 and I for this curve in Jersey crossbreds were 0.9902 and 0.2051 respectively (Table 10). The linear form of the equation representing the curve was

$$\log_e Y_t = 2.01914 + 0.22805 \log_e t - 0.06594\ t.$$

Analysis of variance for testing the significance of R^2 of this equation showed that it was highly significant ($P < 0.01$) (Table 14).

But in the 3rd lactation records of Brown Swiss crossbreds, the quadratic-cum-log curve was found to be better than the other curves. The form of this curve was $Y_t = 8.76377 - 0.33885\ t + 0.0014\ t^2 + 0.92737 \log_e t$. This equation has an R^2 value of 0.9842 and an I value of 0.2620. This R^2 was found to be highly significant ($P < 0.01$) (Table 14).

Quadratic-cum-log curve ($Y_t = 7.79828 - 0.54676\ t + 0.00623\ t^2 + 1.55541 \log_e t$) gave the 2nd best fit in the 3rd lactation records of Jersey crossbreds ($R^2 = 0.9846$, $I = 0.2586$) and the gamma function ($\log_e Y_t = 2.11639 + 0.22585 \log_e t - 0.05797\ t$) with $R^2 = 0.9695$ and $I = 0.3812$ gave the 2nd best fit in the 3rd lactation records of Brown Swiss crossbreds.

It could be seen from tables 6 to 11 that the least fitted curve to the 3rd lactation records of Jersey and Brown Swiss crossbreds was the inverse polynomial function with lower values of R^2 (0.9210 and 0.8644) and higher values of I (0.6871 and 0.9722).

4.4.4. Comparison of curves fitted to fourth lactation records

The quadratic-cum-log curve accounted for 99.14 per cent of the total variability in the 4th lactation records of Jersey crossbreds while it explained only 96.90 per cent of the total variability in Brown Swiss crossbreds (Table 9). I values of this function in the 4th lactation records of the above two crossbreds were found to be 0.2440 and 0.3755 respectively. Since the R^2 values of the other functions were lower than that of this function in both the genetic groups, the quadratic-cum-log curve was considered as the best fitted curve. Comparison of curves based on I values also gave the same result. The equations of this curve in the two breeds were

Y_t = 8.08035-0.73567 t + 0.00891 t^2 + 2.0834 $\log_e t$ (in Jersey) and Y_t=8.31712-0.13937 t - 0.00375 t^2 + 0.53511 $\log_e t$ (in Brown Swiss).

Analysis of variance (Table 15) for testing the goodness of fit of these two equations showed very high significance ($p<0.01$) of the sum of squares due to regression of these fitted curves. Hence they provided good fit.

The gamma function with R^2 = 0.9859 and I = 0.3157 gave the next best fit in Jersey crossbreds, but in Brown Swiss crossbreds the quadratic curve (R^2 = 0.9246 and I = 0.5749) was the second best fitted curve. The linear form of the equations of these two curves were

$\log_e Y_t$ = 1.98701 + 0.44159 $\log_e t$ -0.11102 t (in Jersey) and

Y_t = 8.45479-0.02521 t - 0.00559 t^2 (in Brown Swiss)

In both Jersey and Brown Swiss crossbreds, the inverse polynomial function gave the least fit (R^2 = 0.8168 and 0.6989, I = 1.6862 and 1.9362).

4.4.5. Comparison of curves fitted to pooled data

In order to suggest a single curve for each breed under study, the six types of curves were fitted to the pooled data (pooled over lactations), seperately for Jersey and Brown Swiss crossbreds. The estimates of the constants together with R^2 and I values are presented in Tables 6 to 11.

It was found that all the six functions explained more than 90 per cent of the total variability in the average daily yield except the inverse polynomial function in the case of Brown Swiss crossbreds which accounted for only 86 per cent of the total variability in the average daily yield.

From Tables 9 and 10, it could be observed that the R^2 values of gamma function and quadratic-cum-log curve were much higher than those of other functions in both Jersey and Brown Swiss crossbreds. Moreover, the Furnival indices of these two functions were considerably lower than those of other functions in both the breeds under study.

In order to suggest the most suitable form of lactation curve in Jersey and Brown Swiss crossbreds a critical comparison between the R^2 values and Furnival indices of gamma function and quadratic-cum-log curve was made. Since the R^2 values of these two functions in Jersey crossbreds were nearly equal (0.9907 and 0.9874) the I values of these two functions (0.2042 and 0.2369) were also compared and the curve having least value of I was selected. Thus, the gamma function $-\log_e Y_t = 1.97940 + 0.27094 \log_e t - 0.07182\, t$ - was suggested as the most suitable form of lactation curve in Jersey crossbreds.

In Brown Swiss crossbreds, the R^2 values of gamma function and quadratic-cum-log curve were 0.9663 and 0.9804 respectively and the values of Furnival index were 0.3799 and 0.2752 respectively. Since the quadratic-cum-log curve had higher R^2 (0.9804) and also lower value of I (0.2752), in the case of Brown Swiss crossbreds, the quadratic-cum-log curve followed by gamma function gave better fit than the other functions. The mathematical form of the best fitted curve in Brown Swiss crossbreds was $Y_t = 8.24678 - 0.35623\, t + 0.00174\, t^2 + 1.16191 \log_e t$.

The equations (in linear form) of the 2nd best fitted curves in Jersey and Brown Swiss crossbreds were $Y_t = 7.56149 - 0.57243\, t + 0.00641\, t^2 + 1.75166 \log_e t$ and $\log_e Y_t = 2.05711 + 0.24206 \log_e t - 0.05743\, t$ respectively

It was also observed that the inverse polynomial function gave the least fit in both the crossbred groups (R^2=0.9070 and 0.8586; and I = 0.7836 and 0.9407).

Analysis of variance (Table 16) showed that R^2 values of the best fitted functions were highly significant ($P < 0.01$).

4.5. Graphical representation of lactation curves

Using the equations fitted to the pooled data, the average daily yields upto 310 days were estimated for Jersey and Brown Swiss crossbreds (Table 17).

4.5.1. Curves fitted to pooled data

The estimated yields (Table 17) from the six functions were plotted seperately for each breed and were compared with the observed yields (Fig. 2 and 3). From Fig. 2(a), 2(b), 2(c), 3(a), 3(b) and 3 (c) it could be easily concluded that, irrespective of the position of peak yield, the exponential, parabolic exponential and the quadratic models failed to represent the ascending phase of the lactation curve eventhough their R^2 values were highly significant. The same result hold good for both Jersey and Brown Swiss crossbreds. Hence the above three curves were excluded from further comparison studies.

It is evident from Fig. 2 (f) and 3 (f) that in both the genetic groups, the inverse polynomial function overestimated the production during the early stage (upto 110 days) of lactation and underestimated the initial production and the production after 110 days of lactation. The rate of overestimation was very high at the position of the peak yield.

From Fig. 2 (d), 2 (e), 3 (d) and 3 (e) it is clear that the quadratic-cum-log curve and the gamma function were similar in shape except that the former slightly overestimated the initial production whereas the later estimated the initial production almost accurately. Both these curves slightly underestimated the peak yield and the yield during the later stages (after 170 days) of lactation and overestimated the production during the early stages (between 60 and 150 days) of lactation.

4.5.2. Best fitted curves for pooled data

The lactation curves of the best fitted functions for the two breeds viz., the gamma function for Jersey and the quadratic-cum-log curve for Brown Swiss crossbreds were drawn seperately for each breed in Fig. 4.

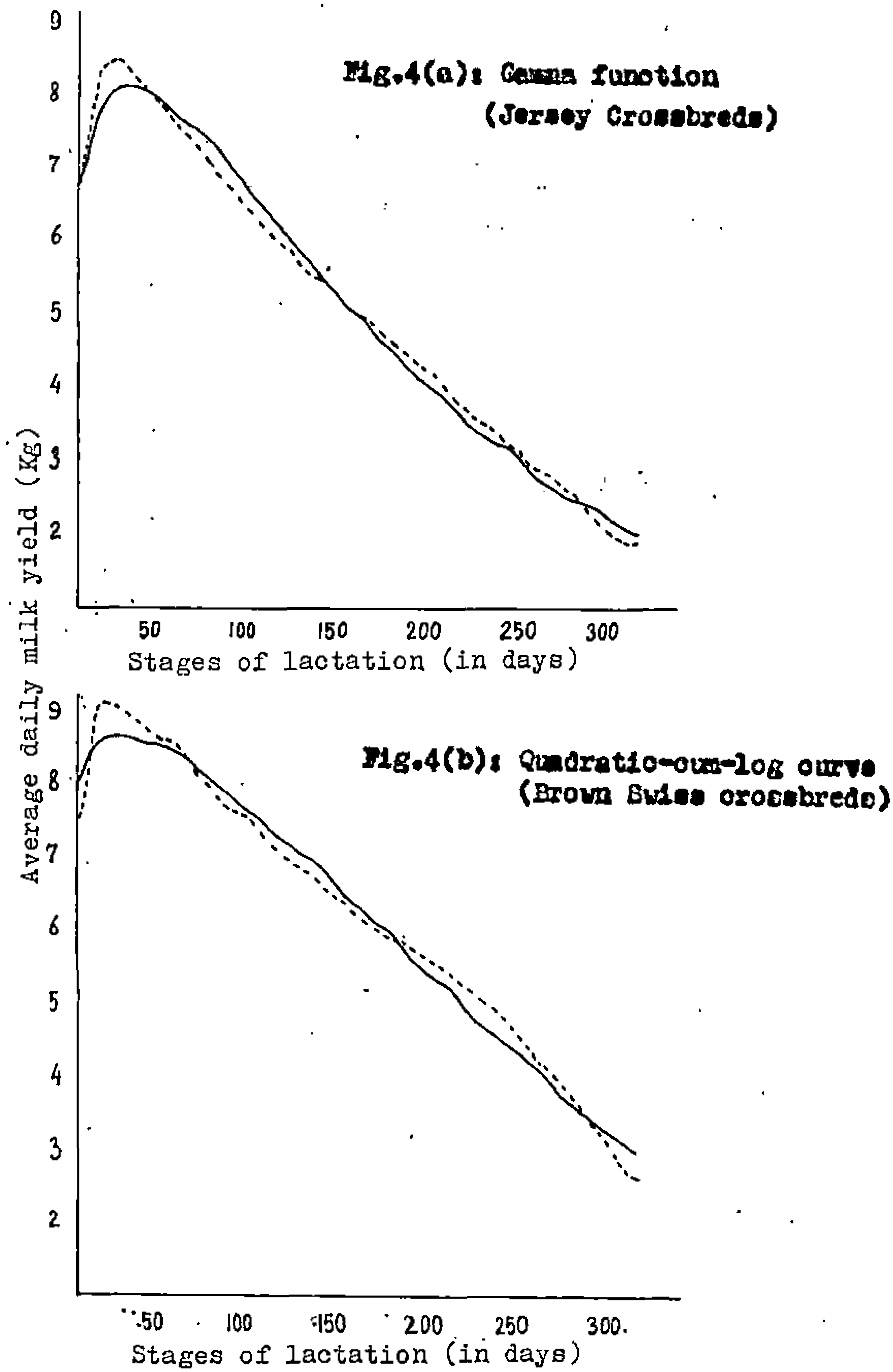

Fig. 4. Lactation curves showing best fit for pooled data in crossbred cows (---observed, ___expecte

4.5.3. Curves fitted to different lactations

Comparison of various curves fitted seperately for different lactations showed that either the gamma function or the quadratic-cum-log curve provided better fit than the other curves in all the eight lactations under study. The average daily milk yield estimated by these two functions were presented in Tables 18 and 19 respectively.

4.5.4. Best fitted curves for different lactations

The best fitted curves for different lactations viz., the gamma function for the 1st lactations of Jersey and Brown Swiss crossbreds and 3rd lactation of Jersey crossbred and the quadratic-cum-log curve for all the other lactations under study, were drawn seperately for each breed in Fig. 5 and Fig.6.

4.6. Prediction of total yield using part yields

To predict 310 days lactation yield from different part lactation yields, the total milk produced by a cow during the first 30, 60, 90, 120 and 150 days of a lactation were considered as part yields. Lactation-wise means (kg) of part lactation milk yields in Jersey and Brown Swiss crossbreds were presented in Table 20.

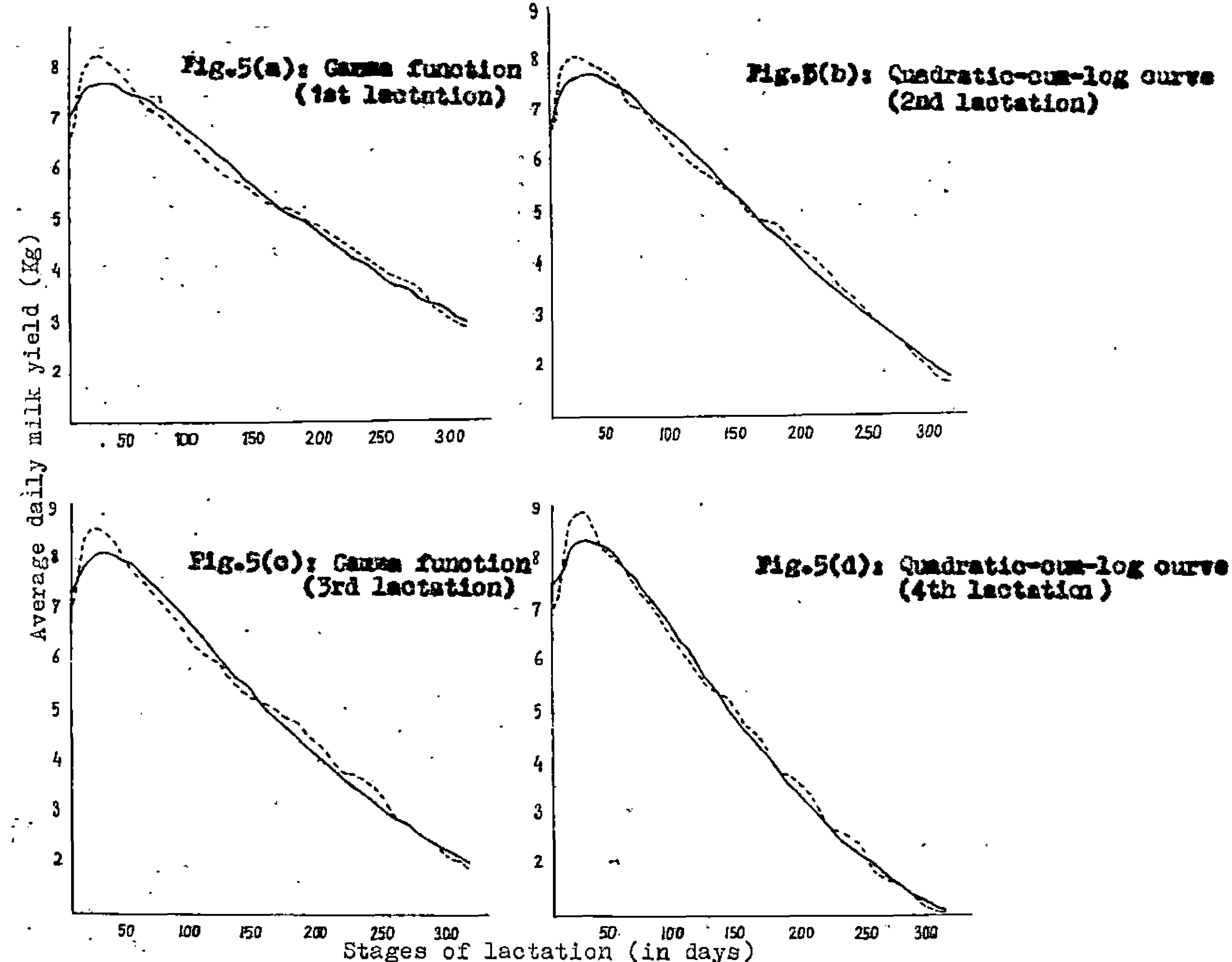

Fig. 5. Lactation curves showing best fit for the first four lactations of Jersey crossbreds (---- observed, ____ expected)

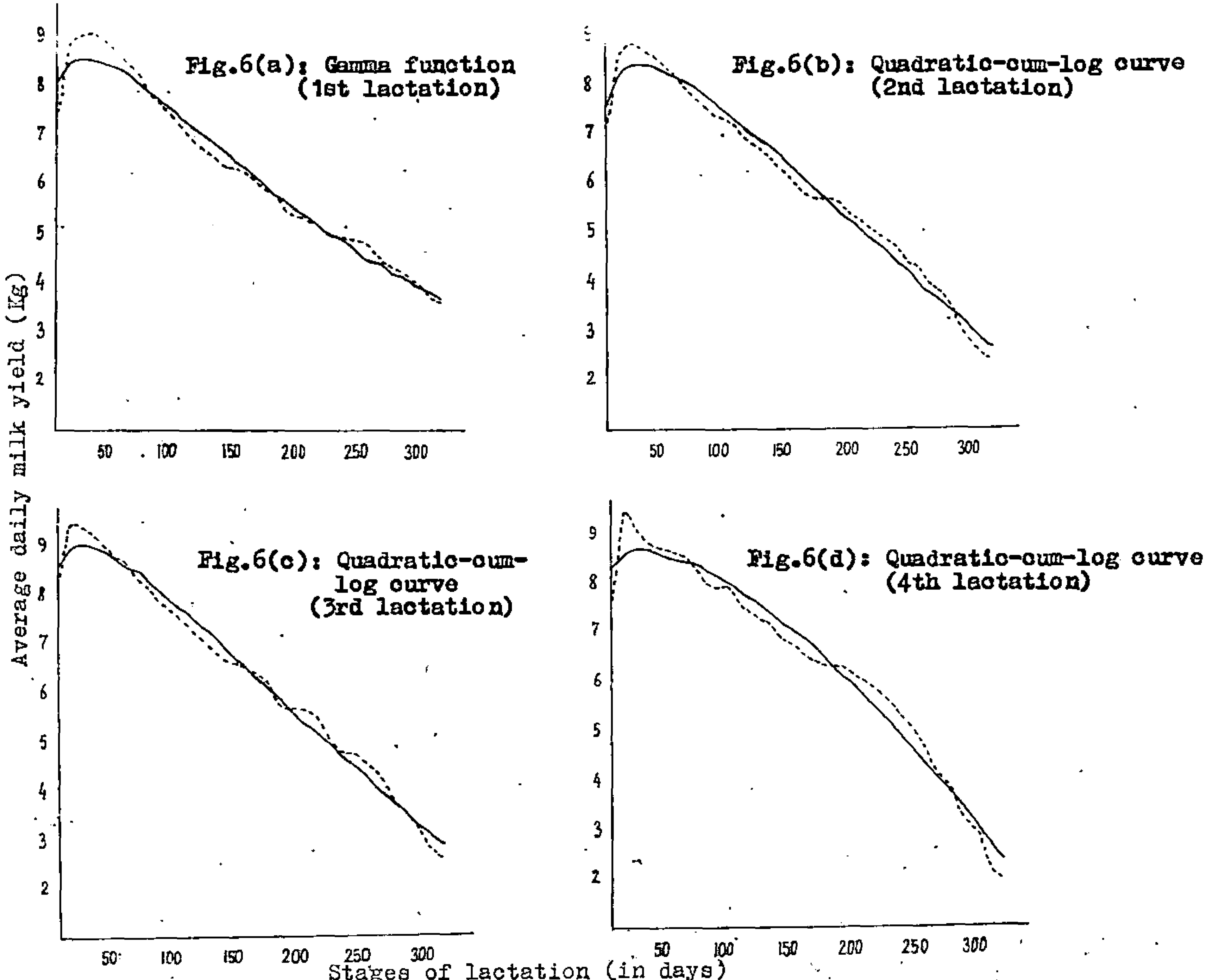

Fig. 6. Lactation curves showing best fit for the first four lactations of Brown Swiss crossbreds (---- observed, ___ expected)

4.6.1. <u>Correlation between full and part lactation yields</u>

The coefficients of phenotypic correlation between different part lactation yields and the 310 days yield in the first four lactations, seperately for each of the two genetic groups, were presented in Table 21.

The average correlation coefficient of 310 days yield with the cumulative yields at the 30, 60, 90, 120 and 150 days of lactation in Jersey crossbreds were 0.6963, 0.8018, 0.8514, 0.8843 and 0.9130 respectively. The corresponding values in Brown Swiss crossbreds were 0.7843, 0.8329, 0.8706, 0.8004 and 0.9264 respectively. All the correlations were highly significant ($P < 0.01$). It is evident from Table 21 that the values of the coefficients of correlation increased with each added part yield, and were more than 0.85 by 120th day of lactation. The rate of increase in the correlation coefficients after 120 day yield was low.

4.6.2. <u>Methods of predicting total yield using part yields</u>

Two methods were used for predicting 310 days yield using part yields viz., (1) regression method (2) ratio method.

4.6.2.1. <u>Regression method</u>

Regression equations to predict full lactation yields

(310 day yields) from the cumulative part yields at different stages are shown, seperately for the two genetic groups, in Table 22. In developing these equations, the observed 310 day yields were considered as regressonds (Y) and the cumulative yields at 30, 60, 90, 120 and 150 days were considered as regressors (X). The 310 days yield could be predicted from any of their respective part lactation yields by inserting the part lactation yields in appropriate regression equation.

4.6.2.2. Ratio method

Lactation-wise and pooled ratio factors (b) for predicting 310 dayo milk yield (Y) from the cumulative yields (X) at different stages of lactation are presented in Table 23. These factors were calculated as explained in section 3.5.1. The 310 days yield could be predicted from any of their respective part lactation yields by multiplying the part lactation yields (X) with their respective ratio factors (b).

4.6.2.3. Comparison between ratio and regression methods of prediction

Comparing Tables 22 and 23 it could be seen that in both the breeds under study, the values of R^2 by ratio method were higher than those obtained by regression method when the first 30, 60 and 90 days of lactation were considered as part lactations. But when the first 120 and 150 days of lactation were considered as part lactations, the values of R^2 obtained by regression method were found to be higher than those calculated from ratio method.

In order to make the comparison between the two methods more clear, a random sample of 20 part yield records were drawn from the pooled (pooled over all lactations) data, seperately for Jersey and Brown Swiss crossbreds. Seperate randomisation was done for different stages of part lactation. In each case, the 310 days yield were estimated by ratio and regression methods and were presented, along with the observed values, in Appendix 1.

4.6.2.4. Prediction of total yield using peak yield

using ratio method, linear equations were developed for predicting total yield (Y) from peak yield (X). The prediction equations for Jersey and Brown Swiss crossbreds were $Y = 192.86\ X$ and $Y = 205.57\ X$ respectively.

Table 1. Lactation-wise and pooled average daily milk yield (calculated from successive 10 day yields) in crossbred cows

	Average daily milk yield (Y_t**) in kg									
	Jersey crossbreds					Brown Swiss crossbreds				
Lact.No. / Time(t*) in days	1	2	3	4	Pooled	1	2	3	4	Pooled
1	6.27	6.15	6.71	6.88	6.50	7.08	6.97	7.92	7.40	7.34
2	7.84	7.70	8.32	8.63	8.12	8.63	8.34	9.19	9.27	8.86
3	8.10	7.36	8.36	8.72	8.26	8.75	8.60	9.20	8.86	8.86
4	7.88	7.80	8.18	8.22	8.02	8.78	8.46	8.94	8.62	8.70
5	7.68	7.65	7.81	7.88	7.76	8.58	8.27	8.64	8.49	8.50
6	7.34	7.41	7.46	7.68	7.47	8.38	8.06	8.51	8.43	8.35
7	7.13	6.99	7.21	7.34	7.17	8.15	7.76	8.19	8.26	8.09
8	6.93	6.89	6.91	6.99	6.93	7.70	7.50	8.02	7.85	7.77
9	6.63	6.61	6.63	6.61	6.62	7.46	7.32	7.68	7.68	7.54
10	6.36	6.30	6.24	6.18	6.27	7.17	7.16	7.49	7.76	7.40
11	6.12	5.99	6.04	5.90	6.01	6.85	6.98	7.24	7.36	7.11
12	5.91	5.80	5.85	5.52	5.77	6.57	6.71	6.97	7.15	6.85
13	5.69	5.62	5.52	5.30	5.53	6.41	6.56	6.75	7.00	6.68
14	5.57	5.41	5.30	5.13	5.35	6.23	6.32	6.52	6.71	6.45
15	5.37	5.19	5.14	4.73	5.11	6.18	6.03	6.44	6.56	6.30
16	5.24	4.91	4.97	4.45	4.89	6.02	5.76	6.32	6.27	6.09
17	5.13	4.75	4.80	4.14	4.71	5.77	5.63	6.07	6.20	5.92
18	5.01	4.68	4.67	3.78	4.54	5.61	5.62	5.68	6.18	5.77
19	4.81	4.39	4.40	3.54	4.29	5.31	5.49	5.56	6.05	5.60
20	4.68	4.17	4.18	3.36	4.10	5.23	5.25	5.53	5.89	5.48
21	4.50	4.01	3.84	2.93	3.82	5.06	5.07	5.42	5.69	5.31
22	4.36	3.72	3.74	2.69	3.63	4.95	4.84	4.94	5.49	5.06
23	4.18	3.40	3.61	2.51	3.43	4.82	4.68	4.71	5.20	4.85
24	3.97	3.15	3.43	2.33	3.22	4.69	4.40	4.66	4.90	4.66
25	3.79	2.93	3.07	1.87	2.92	4.65	4.21	4.38	4.52	4.44
26	3.70	2.26	2.94	1.70	2.78	4.38	3.89	4.14	3.99	4.10
27	3.58	2.52	2.68	1.58	2.59	4.23	3.69	3.70	3.67	3.82
28	3.33	2.23	2.48	1.41	2.36	4.11	3.24	3.44	3.13	3.48
29	3.11	1.97	2.25	1.18	2.13	3.87	2.78	3.10	2.84	3.15
30	2.91	1.72	2.15	0.92	1.93	3.64	2.47	2.71	2.12	2.74
31	2.79	1.61	2.01	0.98	1.85	3.45	2.37	2.55	1.86	2.56

* t = 1 refers to 1 to 10 days
  1 = 2 refers to 10 to 20 days and so on

**Y_t is the average daily yield in time t (t = 1,2,......31).

Table 2. Peak yield and days to attain peak yield in different genetic groups of cattle

Genetic group	Lact. No.	No. of obser-vations	Peak yield (kg)			Days to attain peak yield		
			Average	S.E.	C.V.(%)	Average	S.E.	C.V.(%)
Jersey cross-breds	1	74	8.43	0.19	19.45	37.70	1.75	39.89
	2	47	8.38	0.28	23.09	38.58	2.13	37.88
	3	38	8.81	0.42	29.12	35.85	2.09	35.95
	4	15	9.28	0.69	28.88	33.26	1.97	22.94
	Pooled	174	8.57	0.21	32.32	37.15	1.15	40.83
Brown Swiss cross-breds	1	30	9.06	0.45	27.20	43.90	2.47	30.83
	2	35	9.08	0.41	26.81	40.97	2.20	31.77
	3	18	9.78	0.56	24.39	38.68	3.31	36.27
	4	7	9.29	1.00	28.58	24.75	3.66	27.87
	Pooled	90	9.23	0.42	43.17	41.00	2.63	57.73

Table 3. Lactation-wise and pooled average total milk yield in different genetic groups of cattle

Genetic group	Lact. No.	No. of obser-vations	Average total yield (kg)		
			Average	S.E.	C.V.(%)
Jersey cross-breds	1	74	1659.46	44.87	23.26
	2	47	1601.04	49.61	21.24
	3	38	1699.45	79.42	28.81
	4	15	1664.26	116.20	27.04
	Pooled	174	1652.83	30.56	24.39
Brown Swiss cross-breds	1	30	1856.96	75.78	22.35
	2	35	1870.11	65.64	20.76
	3	18	1963.22	118.07	25.51
	4	7	2038.37	128.44	16.67
	Pooled	90	1897.43	43.81	21.90

't' value for comparing pooled averages is 4.62 ($P < 0.01$)

Table 4. Season-wise and pooled average total milk yield in different genetic groups of cattle

Genetic group	Season	No. of observations	Average total yield (kg)		
			Average	S.E.	C.V.(%)
Jersey crossbreds	Dry	61	1629.35	48.49	23.24
	Rainy	49	1705.12	57.74	23.70
	Moderate	64	1635.17	53.35	26.10
	Pooled	174	1652.83	30.56	24.39
Brown Swiss crossbreds	Dry	20	1860.42	112.07	26.94
	Rainy	32	1872.32	73.26	22.13
	Moderate	38	1938.06	60.62	19.28
	Pooled	90	1897.43	43.81	21.90

Table 5. Analyses of variance table showing the effects of non-genetic factors on total milk yield of crossbred cows

i) Jersey crossbreds

Source	df	MSS	F
Lactation sequence	3	71285.20	0.44 (NS)
Season	2	93804.52	0.58 (NS)
Lactation sequence X season	6	233433.18	1.44 (NS)
Error	162	162467.35	

ii) Brown Swiss crossbreds

Source	df	MSS	F
Lactation sequence	3	97406.52	0.53 (NS)
Season	2	55150.04	0.30 (NS)
Lactation sequence X season	6	102107.07	0.55 (NS)
Error	78	184079.51	

NS : Not significant

Table 6. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the exponential function in crossbred cows

Lactation number	Estimates a	Estimates b	R^2	I
		Jersey crossbreds		
1	2.16714	0.03343	0.9528	0.3522
2	2.28768	0.04941	0.9167	0.6160
3	2.27866	0.04626	0.9586	0.4140
4	2.48945	0.07290	0.9391	0.6450
Pooled	2.28775	0.04843	0.9504	0.4652
		Brown Swiss crossbreds		
1	2.24956	0.03001	0.9581	0.3569
2	2.31119	0.03800	0.8959	0.6567
3	2.37340	0.03847	0.9271	0.5788
4	2.40717	0.04103	0.8154	1.0398
Pooled	2.33248	0.03653	0.9118	0.6023

Table 7. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the parabolic exponential function in crossbred cows

Lactation number	Estimates a	b	c	R^2	I
		Jersey crossbreds			
1	2.04030	-0.01326	-0.00058	0.9297	0.4371
2	1.96004	0.00570	-0.00165	0.9417	0.5240
3	2.07716	-0.01369	-0.00095	0.9423	0.4976
4	2.06770	-0.00274	-0.00209	0.9469	0.6127
Pooled	2.04890	-0.00930	-0.00115	0.9430	0.5069
		Brown Swiss crossbreds			
1	2.16460	-0.01715	-0.00036	0.9250	0.4634
2	2.04240	0.00743	-0.00136	0.9303	0.5478
3	2.14451	-0.00029	-0.00114	0.9371	0.5473
4	2.01706	0.02608	-0.00204	0.9079	0.7471
Pooled	2.09732	0.00294	-0.00118	0.9324	0.5375

Table 8. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the quadratic function in crossbred cows

Lactation number	Estimates a	Estimates b	Estimates c	R^2	I
		Jersey crossbreds			
1	7.91935	-0.15624	-0.00020	0.9087	0.4964
2	7.76675	-0.13333	-0.00215	0.9235	0.5621
3	8.38942	-0.21490	0.00033	0.9269	0.5527
4	8.87907	-0.29116	0.00098	0.9318	0.6764
Pooled	8.23729	-0.19869	-0.00026	0.9252	0.5667
		Brown Swiss crossbreds			
1	8.84983	-0.17969	0.00034	0.9042	0.5293
2	8.28376	-0.08708	-0.00319	0.9252	0.5228
3	9.07655	-0.14099	-0.00200	0.9361	0.5175
4	8.45479	-0.02521	-0.00559	0.9246	0.5749
Pooled	8.66812	-0.10832	-0.00261	0.9275	0.5197

Table 9. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the quadratic-cum-log curve in crossbred cows

Lactation number	Estimates				R^2	I
	a	b	c	d		
			Jersey crossbreds			
1	7.28680	-0.49931	0.00596	1.60789	0.9778	0.2493
2	7.08996	-0.50737	0.00454	1.75310	0.9878	0.2287
3	7.79828	-0.54676	0.00623	1.55541	0.9846	0.2586
4	8.08035	-0.73567	0.00891	2.08342	0.9914	0.2440
Pooled	7.56149	-0.57243	0.00641	1.75166	0.9874	0.2369
			Brown Swiss crossbreds			
1	8.09356	-0.58401	0.00763	1.89496	0.9810	0.2402
2	7.81832	-0.35602	0.00156	1.26049	0.9804	0.2723
3	8.76377	-0.33885	0.00140	0.92737	0.9842	0.2620
4	8.31712	-0.13937	-0.00375	0.53511	0.9690	0.3755
Pooled	8.24678	-0.35623	0.00174	1.16191	0.9804	0.2752

Table 10. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the gamma function in crossbred cows

Lactation number	Estimates a	b	c	R^2	I
		Jersey crossbreds			
1	1.97579	0.16812	0.04794	0.9854	0.1994
2	1.88624	0.35276	0.07986	0.9801	0.3064
3	2.01914	0.22805	0.06594	0.9902	0.2051
4	1.98701	0.44159	0.11102	0.9859	0.3157
Pooled	1.97940	0.27094	0.07182	0.9907	0.2042
		Brown Swiss crossbreds			
1	2.09824	0.13299	0.04149	0.9841	0.2133
2	1.99529	0.27765	0.06197	0.9609	0.4105
3	2.11639	0.22585	0.05797	0.9695	0.3812
4	2.00256	0.35556	0.07172	0.8987	0.7839
Pooled	2.05711	0.24206	0.05743	0.9663	0.3799

Table 11. Lactation-wise and pooled estimates of the constants, coefficients of determination (R^2) and Furnival indices (I) of the inverse polynomial function in crossbred cows

Lactation number	Estimates a	b	c	R^2	I
		Jersey crossbreds			
1	0.05884	0.10054	0.00833	0.9592	0.3635
2	-0.04169	0.23320	0.01642	0.8519	1.0808
3	0.00046	0.16220	0.01338	0.9210	0.6871
4	-0.22746	0.44767	0.03188	0.8168	1.6862
Pooled	-0.01694	0.18928	0.01480	0.9070	0.7836
		Brown Swiss crossbreds			
1	0.06646	0.07218	0.00632	0.9796	0.2553
2	0.01927	0.13896	0.00988	0.8382	1.0364
3	0.02480	0.11371	0.00907	0.8644	0.9722
4	-0.01308	0.17343	0.01137	0.6989	1.9362
Pooled	0.02911	0.11804	0.00882	0.8586	0.9407

Table 12. Analyses of variance table for computing and testing R^2 of the best fitted functions to the first lactation records of crossbred cows

i) Jersey crossbreds (gamma function)

Source	df	SS	MSS	R^2	F
Due to regression	2	2.8666	1.4333	0.9854	943.57**
Error	28	0.0426	0.00152		
Total	30	2.9092			

ii) Brown Swiss crossbreds (gamma function)

Source	df	SS	MSS	R^2	F
Due to regression	2	2.2930	1.1465	0.9841	867.87**
Error	28	0.0370	0.00132		
Total	30	2.330			

** $P < 0.01$

Table 13. Analyses of variance table for computing and testing R^2 of the best fitted functions to the second lactation records of crossbred cows

i) Jersey crossbreds (quadratic-cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	114.2283	38.0761	0.9878	727.75**
Error	27	1.4121	0.0523		
Total	30	115.6404			

ii) Brown Swiss crossbreds (quadratic-cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	100.2300	33.4100	0.9804	450.76**
Error	27	2.0007	0.0741		
Total	30	102.2307			

** $P < 0.01$

Table 14. Analyses of variance table for computing and testing R^2 of the best fitted functions to the third lactation records of crossbred cows

i) Jersey crossbreds (gamma function)

Source	df	SS	MSS	R^2	F
Due to regression	2	5.4810	2.7405	0.9902	1413.33**
Error	28	0.0543	0.00194		
Total	30	5.5353			

ii) Brown Swiss crossbreds (quadratic-cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	115.5096	38.5032	0.9842	561.11**
Error	27	1.8522	0.0686		
Total	30	117.3618			

** $P < 0.01$

Table 15. Analyses of variance table for computing and testing R^2 of the best fitted functions to the fourth lactation records of crossbred cows

i) Jersey crossbreds (quadratic-cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	186.1902	62.0634	0.9914	1042.56**
Error	27	1.6065	0.0595		
Total	30	187.7967			

ii) Brown Swiss crossbreds (quadratic cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	118.9356	39.6452	0.9690	281.17**
Error	27	3.8070	0.1410		
Total	30	122.7426			

** $P < 0.01$

Table 16. Analyses of variance table for computing and testing R^2 of the best fitted functions to the pooled (pooled over lactations) data of crossbred cows

i) Jersey crossbreds (gamma function)

Source	df	SS	MSS	R^2	F
Due to regression	2	6.0644	3.0322	0.9907	1498.11**
Error	28	0.0566	0.00202		
Total	30	6.1210			

ii) Brown Swiss crossbreds (quadratic cum-log curve)

Source	df	SS	MSS	R^2	F
Due to regression	3	102.2559	34.0853	0.9804	449.97**
Error	27	2.0466	0.0758		
Total	30	104.3025			

** $P < 0.01$

Table 17. Average daily milk yields estimated by the various functions fitted to the pooled data (pooled over lactations) in Jersey and Brown Swiss crossbreds

1) Jersey crossbreds

Function / Time (t^*) days	Average daily milk yield (Y_t^{**}) in kg exp.	p.exp.	Quadr.	q.o.l.	gamma	inv.poly.
1	9.39	7.68	8.04	7.00	6.74	5.34
2	8.94	7.58	7.84	7.66	7.57	9.32
3	8.52	7.47	7.64	7.83	7.86	11.04
4	8.12	7.34	7.44	7.80	7.91	11.16
5	7.73	7.20	7.24	7.68	7.82	10.54
6	7.37	7.04	7.04	7.50	7.64	9.67
7	7.02	6.87	6.83	7.28	7.42	8.80
8	6.69	6.69	6.63	7.04	7.16	7.99
9	6.37	6.50	6.43	6.78	6.88	7.28
10	6.07	6.30	6.22	6.51	6.59	6.67
11	5.78	6.09	6.02	6.24	6.29	6.13
12	5.51	5.88	5.82	5.97	5.99	5.67
13	5.25	5.66	5.61	5.70	5.70	5.26
14	5.00	5.43	5.40	5.43	5.41	4.91
15	4.77	5.21	5.20	5.16	5.13	4.59
16	4.54	4.98	4.99	4.90	4.86	4.32
17	4.33	4.75	4.78	4.65	4.60	4.07
18	4.12	4.52	4.58	4.40	4.35	3.85
19	3.93	4.29	4.37	4.16	4.11	3.65
20	3.74	4.06	4.16	3.93	3.88	3.47
21	3.56	3.84	3.95	3.70	3.65	3.30
22	3.39	3.62	3.74	3.49	3.44	3.15
23	3.23	3.40	3.53	3.28	3.24	3.02
24	3.08	3.20	3.32	3.08	3.06	3.89
25	2.94	2.99	3.11	2.90	2.87	2.77
26	2.80	2.80	2.89	2.72	2.70	2.67
27	2.66	2.61	2.68	2.55	2.54	2.57
28	2.54	2.42	2.47	2.40	2.39	2.47
29	2.42	2.25	2.26	2.25	2.25	2.39
30	2.30	2.08	2.04	2.12	2.11	2.31
31	2.20	1.92	1.83	2.00	1.98	2.23

contd....

Table 17. contd.

2) Brown Swiss crossbreds

Time (t^*) days	Function: exp.	p.exp.	quadr.	q.c.l.	gamma	inv.poly.
	Average daily milk yield (Y_t^{**}) in kg					
1	9.93	8.16	8.56	7.89	7.39	6.41
2	9.58	8.15	8.44	8.35	8.25	9.46
3	9.23	8.13	8.32	8.47	8.59	10.54
4	8.90	8.09	8.19	8.46	8.70	10.65
5	8.58	8.02	8.06	8.38	8.67	10.33
6	8.28	7.94	7.92	8.25	8.55	9.84
7	7.98	7.85	7.78	8.10	8.38	9.29
8	7.69	7.73	7.63	7.92	8.17	8.74
9	7.42	7.60	7.48	7.73	7.94	8.23
10	7.15	7.45	7.32	7.53	7.69	7.75
11	6.89	7.29	7.16	7.33	7.43	7.31
12	6.65	7.12	6.99	7.11	7.12	6.91
13	6.41	6.93	6.82	6.89	6.90	6.55
14	6.18	6.73	6.64	6.67	6.63	6.21
15	5.96	6.53	6.46	6.44	6.37	5.91
16	5.74	6.31	6.27	6.21	6.11	5.63
17	5.54	6.09	6.07	5.99	5.85	5.38
18	5.34	5.86	5.87	5.76	5.60	5.15
19	5.15	5.62	5.67	5.53	5.36	4.93
20	4.96	5.39	5.46	5.30	5.12	4.73
21	4.78	5.15	5.24	5.07	4.89	4.55
22	4.61	4.91	5.02	4.84	4.67	4.38
23	4.45	4.67	4.80	4.62	4.46	4.22
24	4.29	4.43	4.57	4.39	4.25	4.07
25	4.13	4.19	4.33	4.17	4.06	3.93
26	3.99	3.96	4.09	3.95	3.87	3.80
27	3.84	3.73	3.84	3.73	3.69	3.68
28	3.70	3.51	3.59	3.51	3.51	3.58
29	3.57	3.29	3.33	3.29	3.34	3.46
30	3.44	3.08	3.07	3.08	3.18	3.36
31	3.32	2.87	2.80	2.87	3.03	3.27

* t = 1 stands for 1 to 10 days
t = 2 stands for 10 to 20 days and so on

**Y_t is the average daily milk yield in time t (t=1,2,...31)

Table 18. Lactation-wise ~~and pooled~~ average daily milk yields estimated by the gamma function in crossbred cows

Lact. No. / Time(t*) in days	Average daily milk yield (Y_t**) in kg: Jersey crossbreds 1	2	3	4	Brown Swiss crossbreds 1	2	3	4
1	6.87	6.09	7.05	6.53	7.82	6.91	7.83	6.90
2	7.36	7.18	7.73	7.93	8.23	7.88	8.65	8.21
3	7.51	7.65	7.94	8.49	8.33	8.29	8.94	8.83
4	7.52	7.81	7.94	8.63	8.30	8.43	9.00	9.10
5	7.43	7.80	7.82	8.52	8.21	8.43	8.94	9.17
6	7.31	7.68	7.63	8.27	8.07	8.34	8.79	9.11
7	7.15	7.49	7.40	7.92	7.90	8.18	8.59	8.96
8	6.97	7.25	7.14	7.52	7.71	7.98	8.35	8.74
9	6.78	6.98	6.87	7.09	7.52	7.75	8.09	8.49
10	6.58	6.69	6.59	6.64	7.31	7.50	7.82	8.20
11	6.37	6.38	6.30	6.20	7.10	7.24	7.54	7.90
12	6.16	6.08	6.02	5.77	6.90	6.97	7.26	7.58
13	5.95	5.77	5.74	5.35	6.69	6.70	6.97	7.26
14	5.74	5.47	5.46	4.94	6.48	6.43	6.69	6.94
15	5.54	5.17	5.20	4.56	6.27	6.16	6.41	6.62
16	5.34	4.89	4.94	4.20	6.07	5.89	6.14	6.30
17	5.14	4.61	4.69	3.86	5.87	5.63	5.88	5.99
18	4.95	4.34	4.44	3.54	5.67	5.38	5.62	5.69
19	4.76	4.09	4.21	3.25	5.48	5.13	5.37	5.40
20	4.58	3.84	3.99	2.97	5.30	4.89	5.12	5.12
21	4.40	3.61	3.78	2.72	5.11	4.66	4.89	4.85
22	4.22	3.39	3.57	2.48	4.94	4.44	4.66	4.59
23	4.06	3.18	3.38	2.27	4.76	4.22	4.44	4.34
24	3.89	2.98	3.19	2.07	4.60	4.02	4.23	4.17
25	3.74	2.79	3.02	1.88	4.43	3.82	4.03	3.87
26	3.59	2.61	2.85	1.72	4.28	3.63	3.84	3.66
27	3.44	2.44	2.69	1.56	4.12	3.45	3.65	3.45
28	3.30	2.28	2.54	1.42	3.97	3.27	3.48	3.25
29	3.16	2.13	2.40	1.29	3.83	3.11	3.31	3.06
30	3.03	1.99	2.26	1.17	3.69	2.95	3.14	2.89
31	2.91	1.86	2.13	1.06	3.56	2.79	3.00	2.72

* t = 1 stands for 1 to 10 days
t = 2 stands for 10 to 20 days and so on

** Y_t is the average daily milk yield in time t (t = 1,2,....31)

Table 19. Lactation-wise and pooled average daily milk yields estimated by the quadratic-cum-log curve in crossbred cows

Lact. No. / Time(t*) in days	Average daily milk yield (Y_t^{**}) in kg							
	Jersey crossbreds				Brown Swiss crossbreds			
	1	2	3	4	1	2	3	4
1	6.79	6.59	7.26	7.35	7.52	7.46	8.43	8.17
2	7.43	7.31	7.81	8.09	8.27	7.99	8.73	8.39
3	7.61	7.53	7.92	8.24	8.49	8.15	8.78	8.45
4	7.61	7.56	7.87	8.17	8.51	8.17	8.72	8.44
5	7.53	7.49	7.72	7.98	8.41	8.11	8.60	8.34
6	7.39	7.35	7.53	7.72	8.26	8.00	8.44	8.31
7	7.21	7.17	7.30	7.42	8.07	7.86	8.27	8.20
8	7.02	6.97	7.06	7.10	7.85	7.69	8.07	8.07
9	6.81	6.74	6.80	6.76	7.62	7.51	7.87	7.94
10	6.59	6.51	6.54	6.41	7.38	7.32	7.65	7.78
11	6.37	6.26	6.27	6.06	7.14	7.11	7.43	7.61
12	6.15	6.01	6.00	5.71	6.89	6.90	7.20	7.43
13	5.93	5.78	5.73	5.37	6.65	6.69	6.97	7.24
14	5.71	5.50	5.47	5.03	6.41	6.47	6.74	7.04
15	5.49	5.25	5.21	4.69	6.18	6.24	6.51	6.83
16	5.28	4.99	4.96	4.37	5.96	6.02	6.27	6.61
17	5.08	474	4.71	4.05	5.74	5.79	6.04	6.38
18	4.88	4.49	4.47	3.75	5.53	5.56	5.80	6.14
19	4.69	4.25	4.24	3.45	5.33	5.33	5.56	5.89
20	4.50	4.01	4.01	3.17	5.14	5.10	5.33	5.63
21	4.33	3.77	3.80	2.90	4.96	4.87	5.09	5.36
22	4.16	3.54	3.59	2.65	4.80	4.64	4.85	5.09
23	4.00	3.32	3.40	2.40	4.64	4.41	4.62	4.80
24	3.85	3.10	3.21	2.18	4.50	4.18	4.39	4.51
25	3.71	2.88	3.03	1.96	4.36	3.95	4.15	4.21
26	3.57	2.68	2.86	1.76	4.24	3.72	3.92	3.90
27	3.45	2.48	2.70	1.58	4.13	3.50	3.69	3.58
28	3.34	2.28	2.56	1.41	4.04	3.27	3.46	3.26
29	3.24	2.10	2.42	1.25	3.96	3.05	3.24	2.92
30	3.14	1.91	2.29	1.11	3.89	2.83	3.01	2.58
31	3.06	1.74	2.18	0.99	3.83	2.61	2.79	2.23

* t = 1 stands for 1 to 10 days
t = 2 stands for 10 to 20 days and so on

**Y_t is the average daily milk yield in time t (t = 1,2,......31)

Table 20. Lactation-wise and pooled average part lactation milk yields in Jersey and Brown Swiss crossbreds

Part lact. yield upto (days) / Lact. No.	Average part lactation milk yield (kg)									
	Jersey crossbreds					Brown Swiss crossbreds				
	1	2	3	4	pooled	1	2	3	4	pooled
30	223.4	217.1	241.6	249.3	228.1	247.5	245.4	249.8	261.5	248.5
60	451.3	445.7	484.9	496.4	461.4	507.5	498.8	496.5	523.0	503.8
90	658.2	650.5	700.4	716.0	670.8	742.9	730.6	723.1	771.2	737.4
120	842.1	831.4	889.1	903.2	855.3	950.6	945.5	927.9	1005.4	949.5
150	1008.4	993.6	1057.9	1070.5	1021.0	1140.8	1140.4	1114.5	1220.7	1142.9

Table 21. Lactation-wise and pooled correlation coefficients of total (310 days) lactation yield with different part lactation yields in Jersey and Brown Swiss crossbreds

Part lact. yield upto (days) / Lact. No.	Correlation coefficients with total yield									
	Jersey crossbreds					Brown Swiss crossbreds				
	1	2	3	4	pooled	1	2	3	4	pooled
30	0.4688	0.7424	0.7764	0.8375	0.6963	0.7912	0.7653	0.7466	0.8340	0.7843
60	0.7172	0.7969	0.8406	0.8524	0.8018	0.8524	0.8193	0.8039	0.8460	0.8329
90	0.8079	0.8411	0.8924	0.8643	0.8514	0.8992	0.8605	0.8574	0.8653	0.8706
120	0.8563	0.8731	0.9281	0.8798	0.8343	0.9260	0.8943	0.9008	0.8805	0.9004
150	0.8894	0.9028	0.9477	0.9122	0.9130	0.9467	0.9245	0.9504	0.9040	0.9264

All the correlation coefficients are highly significant ($P < 0.01$)

Table 22. Lactation-wise and pooled regression equations for predicting total (310 days) milk yields from part lactation yields in crossbred cows

1. Jersey crossbreds

Lact. No.	Part lact. yield upto (days)	Prediction equation (Y = a+bX) a	b	R^2 of the equation
1	30	760.1448	4.0251	0.2198
	60	248.6581	3.1260	0.5144
	90	45.8464	2.4517	0.6527
	120	-49.7079	2.0297	0.7332
	150	-100.8925	1.7457	0.7910
2	30	415.0052	5.1023	0.4934
	60	146.7776	3.0878	0.6361
	90	40.0111	2.2794	0.7075
	120	-31.6579	1.8698	0.7623
	150	-73.1180	1.6063	0.8150
3	30	185.2676	6.0505	0.6028
	60	-46.1910	3.4924	0.7066
	90	-218.9209	2.6646	0.7963
	120	-300.6191	2.1908	0.8614
	150	-292.5004	1.8336	0.8981
4	30	61.1136	5.7993	0.7015
	60	-47.5881	3.1318	0.7265
	90	-109.4787	2.2577	0.7470
	120	-134.0029	1.8168	0.7740
	150	-183.8438	1.5795	0.8321
Pooled	30	446.0848	5.0724	0.4393
	60	157.8781	3.1325	0.6002
	90	9.3697	2.3760	0.6884
	120	-75.0063	1.9623	0.7523
	150	-117.6191	1.6855	0.8061

contd.......

Table 22. contd.

2. Brown Swiss crossbreds

Lact. No.	Part lact. yield upto (days)	Prediction equation (Y = a+bX) a	b	R^2 of the equation
1	30	371.9297	6.2440	0.6260
	60	99.5505	3.5801	0.7438
	90	-18.6042	2.6048	0.8087
	120	-117.0524	2.1391	0.8575
	150	-156.9061	1.8174	0.8962
2	30	597.6361	5.1739	0.5857
	60	400.0271	2.9416	0.6713
	90	259.9873	2.2001	0.7404
	120	115.1411	1.8531	0.7997
	150	-17.4483	1.6527	0.8548
3	30	217.6807	6.2956	0.5574
	60	71.1245	3.4632	0.6462
	90	-91.2496	2.6024	0.7352
	120	-184.4373	2.1282	0.8115
	150	-224.2963	1.8077	0.8656
4	30	606.3778	5.4627	0.6956
	60	544.5737	2.8491	0.7157
	90	452.3774	2.0517	0.7487
	120	384.1284	1.6417	0.7752
	150	324.7674	1.4008	0.8173
Pooled	30	429.1803	5.8621	0.5943
	60	222.8552	3.3013	0.6894
	90	88.0755	2.4382	0.7599
	120	-77.0068	2.0674	0.8410
	150	-87.0387	1.7263	0.8642

Predicted total yields (Y) are obtained by inserting the part yields (X) in the appropriate regression equation (Y = a +bX)

Table 23. Lactation-wise and pooled ratio factors (b) for predicting total (310 days) milk yields from part yields in crossbred cows

Lact. No.	Part lact. yield upto (days)	Jersey crossbreds		Brown Swiss crossbreds	
		b	R^2 of equations	b	R^2 of equations
1	30	7.4273	0.4056	7.7432	0.7768
	60	3.6770	0.6050	3.7763	0.7845
	90	2.5213	0.6712	2.5798	0.8009
	120	1.9706	0.7118	2.0160	0.8082
	150	1.6457	0.7456	1.6799	0.8284
2	30	7.0136	0.6782	7.6093	0.8614
	60	3.4171	0.7034	3.7436	0.8543
	90	2.3409	0.7266	2.5560	0.8602
	120	1.8317	0.7467	1.9749	0.8523
	150	1.5327	0.7776	1.6574	0.8469
3	30	6.8172	0.6792	7.1669	0.6345
	60	3.3971	0.6873	3.6065	0.6729
	90	2.3520	0.7029	2.4762	0.6995
	120	1.8527	0.7285	1.9294	0.7357
	150	1.5571	0.7627	1.6065	0.7693
4	30	6.0444	0.7311	7.7818	0.9908
	60	3.0359	0.7043	3.8903	0.9772
	90	2.1048	0.6964	2.6383	0.9628
	120	1.6684	0.7108	2.0238	0.9557
	150	1.4078	0.7417	1.6669	0.9726
Pooled	30	7.0277	0.6086	7.5890	0.7694
	60	3.4747	0.6658	3.7436	0.7818
	90	2.3900	0.6925	2.5576	0.7971
	120	1.8746	0.7187	1.9863	0.8081
	150	1.5703	0.7510	1.6501	0.8260

Predicted total yields (Y) are obtained by multiplying the part yields (X) with the appropriate ratio factors (b)

DISCUSSION

DISCUSSION

In the present investigation attempts were made to (i) compare the relative efficiency of six expressions of lactation curve models and find out the best one for Jersey and Brown Swiss crossbred cows maintained at the University Livestock Farm, Mannuthy (ii) compare the two crossbreds based on order of lactation and season of calving and (iii) develop equations for predicting 310 days lactation yield from cumulative yields at 30, 60, 90, 120 and 150 days of lactation. The salient features of the findings of the study have been discussed under the following heads.

1. Milk production performance and comparison of Jersey and Brown Swiss crossbreds
2. Comparison of various lactation curve models
3. Prediction of 310 days lactation yield from various part records.

5.1. Milk production performance and comparison of Jersey and Brown Swiss crossbreds

The average lactation yield upto 310 days in Jersey and Brown Swiss crossbreds were 1652.83 ± 30.56 kg and 1897.43 ± 43.81 kg respectively. Both these averages are higher than those (1411.23 ± 32.58 kg and 1453.92 ± 77.89 kg respectively) reported by Girija (1980) in the same crossbred cows maintained at the same farm during the period 1963-to 1979. The present study was based on cows maintained at the farm during the period 1978-1983. Hence, this superiority can be thought to be due to the improvement occured in the herd due to managemental practices. The average lactation yield observed in the present study is also higher than those (1109.1 ± 37.36 kg and 1527.7 ± 80.32 kg respectively in non-descript and Rathi cows) reported by Singh and Raut (1982) under village conditions. Differences in genetic-make up and managemental conditions may be the reasons for this.

The time taken to attain peak yield, obtained in the present study (37.15 ± 1.15 days in Jersey crossbreds and 41.00 ± 2.63 days in Brown Swiss crossbreds), is shorter than those (44.75 ± 1.23 and 49.86 ± 3.06 days respectively) reported by Girija (1980) in the same crossbred cows. This may be due to the change in the genetic structure of the animals. However, the time taken to attain peak, observed in the study, is longer than those reported by Labouche (1957) in Zebu X European crossbred cows and Chauhan et al. (1974) in Brown Swiss crossbred cows (F_1). Considering the days to attain peak yield, the results are in agreement with the findings of Pradhan (1970) and Dave and Patel (1971) in Kankrej cattle and Rajagopalan and Dave (1976) in pure Jersey cows.

The average peak daily yield of 8.57 ± 0.21 kg (in Jersey crossbreds) and 9.23 ± 0.42 kg (in Brown Swiss crossbreds) are higher than those (7.91 ± 0.15 kg and 7.70 ± 0.31 kg respectively) reported by Girija (1980) in the same crossbred cows maintained at the same farm during the period 1963-1979. This also shows the genetic improvement occured in the herd during the time interval between the two studies.

The average lactation yield upto 310 days was more in Brown Swiss crossbreds (1897.43 ± 43.81 kg) than in Jersey crossbreds (1652.83 ± 30.56 kg). Comparison of these two means revealed thatthe two genetic groups were significantly (P ∠ 0.01) different. This result is akin to the findings of Mathew (1983) who reported that Brown Swiss half-breds were producing significantly more milk than Jersey half-breds under Kerala conditions. The superiority of Brown Swiss crossbreds over Jersey crossbreds can be assumed to the due to the difference between the exotic breeds.

The average lactation yield upto 310 days in the first four lactations of Jersey crossbreds were 1659.46 ± 44.87, 1601.04 ± 49.61, 1699.45 ± 79.42 and 1664.26 ± 116.20 kg respectively. The corresponding figures in Brown Swiss crossbreds were 1856.96 ± 75.78 kg, 1870.11 ± 65.64 kg, 1963.22 ± 118.07 kg and 2038.37 ± 128.44 kg respectively. It shows that, in Jersey crossbreds, the lactation yield in the first four lactations are more or less equal and the maximum yield was obtained in the 3rd lactation. But in Brow Swiss crossbreds, the lactation yield showed an increasing trend as the order of lactation advanced and the maximum yield was recorded in the 4th lactation. But these differences in milk yield were statistically not significant in both the genetic groups. This shows that order of lactation had no significant influence on lactation yield. Similar results were also reported by Singh and Raut (1982) in Rathi cows and Shimisv *et al.* (1983) in Holstein-Friesian cows.

The non-significant difference in milk yield between different lactation sequences may be because of the late sexual maturity of Indian breeds compared to the early sexual maturity of exotic breeds. In dairy cattle, milk production is directly related to body weight. By the time the Indian cows attain sexual maturity their body weight might have reached the peak value. Thereafter there will not be much increase in body weight and hence in milk production. This may be the reason for the stability of milk production in the first two or three lactations. When the cow reaches its 3rd or 4th lactation its body weight start declining and consequently there will be gradual decrease in milk production. But in the case of exotic breeds, because of their earlier sexual maturity, milk production increases upto the 3rd or 4th lactation and then decreases. Since the crossbred cows in the present study contains animals of varying exotic inheritance as such different cows will show variations in milk yields in different lactations.

In Jersey crossbreds, the average milk yield upto 310 days in the dry, rainy and moderate seasons of calving were 1629.35 ± 48.49 kg, 1705.12 ± 57.74 kg and 1635.17 ± 53.35 kg respectively. In Brown Swiss crossbreds, the corresponding figures were 1860.42 ± 112.07 kg, 1872.32 ± 73.26 kg and 1938.06 ± 60.62 kg respectively. It was found that cows calving in rainy season produced more milk than cows calving in dry season. However, season did not exert any significant influence on lactation yield. This result is in agreement with the findings of Mathew (1983) in Jersey and Brown Swiss half-breds.

The lack of influence of season of calving on lactation yield observed in the present study can be attributed to systems of management. The crossbred cows under study are reared in almost intensive systems of feeding. Most of the nutrient requirement is met by stall feeding rather than grazing and throughout the year feeding is more or less the same. When greens are scarce, additional concentrates are given to compensate, probably resulting in a non-significant seasonal variation. Further, a slightly higher milk yield for the rainy season observed in the present study could not be assumed to be due to the availability of more grass during the rainy season because of seasons described above and also due to the fact that a lactation starting from one season will, usually, pass through the other two seasons also.

5.2. Comparison of various lactation curve models

Among the various six models examined, the gamma and quadratic-cum-log curves accounted for maximum values of R^2 (0.98 each) in the 1st lactation records of both Jersey and Brown Swiss crossbreds. Since the Furnival index (I) values of gamma function were lower than those of quadratic-cum-log curve in both the crossbreds, the former function was selected as the most suitable curve in the 1st lactation records of both the genetic groups. The equations (in the original form) of this curve in

Jersey and Brown Swiss crossbreds were

$Y_t = 7.2123\ t^{0.16812} e^{-0.04794\ t}$ ($R^2 = 0.9854$; $I = 0.1994$) an

$Y_t = 8.1518\ t^{0.13299} e^{-0.04149\ t}$ ($R^2 = 0.9841$; $I = 0.2135$)

respectively.

Singh and Gopal (1982) also reported similar results in the 1st lactation records of buffaloes maintained under village conditions. The quadratic function accounted for the minimum values of R^2 in both Jersey and Brown Swiss crossbreds ($R^2 = 0.9087$ and 0.9042 respectively). R^2 valu of exponential and parabolic exponential functions were also less than 0.96 in both the crossbreds.

In the 2nd lactation records of both Jersey and Brown Swiss crossbreds, the quadratic-cum-log curve followed by the gamma function provided better fit than the other functions. The equations of quadratic-cum-log curve in Jersey and Brown Swiss crossbreds were

$$Y_t = 7.08996 - 0.50737\ t + 0.00454\ t^2 + 1.75310 \log_e t$$
($R^2 = 0.9878$; $I = 0.2287$) and

$$Y_t = 7.81832 - 0.35602\ t + 0.00156\ t^2 + 1.26049 \log_e t$$
($R^2 = 0.9804$; $I = 0.2723$)

respectively. The superiority of quadratic-cum-log curve over other curves in the 2nd lactations of buffaloes was also established by Singh and Gopal (1982). The inverse polynomial function gave the least fit in both the crossbreds (R^2 = 0.8519 in Jersey and 0.8382 in Brown Swiss). R^2 values of exponential, parabolic exponential and quadratic functions were less than 0.94 in both the genetic groups.

Values of R^2 and I revealed that the gamma function - $Y_t = 7.5318\ t^{0.22805}\ e^{-0.06594\ t}$ (R^2 = 0.9902; I = 0.2051)- and the quadratic-cum-log curve - T

$$Y_t = 8.76377 - 0.33885\ t + 0.00140\ t^2 + 0.92737\ \log_e t$$
$$(R^2 = 0.9842;\ I = 0.2620)$$

- were better than the other functions in the 3rd lactation records of Jersey and Brown Swiss crossbreds respectively. The result obtained for Jersey crossbreds is in agreement with the findings of Singh and Gopal (1982) in buffaloes. All the other four functions gave poor fit (R^2=0.8644-0.9586, I = 0.4140-0.9722).

The quadratic-cum-log curve was found to be better than the other functions in the 4th lactation records of both Jersey and Brown Swiss crossbred cows. The equations of this curve in the abo■ two breeds of cattle were

$$Y_t = 8.08035 - 0.73567\ t + 0.00891\ t^2 + 2.08340\ \log_e t$$
$$(R^2 = 0.9914;\ I = 0.2440) \text{ and}$$
$$Y_t = 8.31712 - 0.13937\ t - 0.00375\ t^2 + 0.53511\ \log_e t$$
$$(R^2 = 0.9690;\ I = 0.3755) \text{ respectively.}$$

Singh and Gopal (1982) also reported that the quadratic-cum-log curve was the most suitable curve in the 4th lactations of buffaloes. The second best fitted curves in Jersey and Brown Swiss crossbreds were gamma function (R^2 = 0.9859; I = 0.3157) and quadratic curve (R^2 = 0.9246; I = 0.5749) respectively. All the other functions gave poor fit in both the genetic groups (R^2 = 0.6989-0.9469, I = 0.6127-1.9362).

In the pooled data (pooled over lactations) of Jersey crossbreds, the gamma function -

$Y_t = 7.2384\ t^{0.27094}\ e^{-0.07182\ t}$ (R^2 = 0.9907; I = 0.2042)-

was the best fitted curve. But in the pooled data of Brown Swiss crossbreds the quadratic-cum-log curve-

$$Y_t = 8.24678 - 0.35623\ t + 0.00174\ t^2 + 1.16191\ \log_e t$$

(R^2 = 0.9804; I = 0.2752)-

provided better fit than the other curves. The 2nd best fitted curves in Jersey and Brown Swiss crossbreds were quadratic-cum-log curve and gamma function respectively. In both the crossbreds, the inverse polynomial function (R^2 = 0.9070 and 0.8586) gave the least fit.

Considering the best fitted curve to the pooled data of Jersey crossbreds, the results obtained in the present study were in agreement with the findings of Yadav et al. (1977 b) in Hariana crossbreds, Kumar and Bhat (1979 b, 1980) and Cheema (1982) in Indian buffaloes. The choice of quadratic-cum-log as the best fitted curve to the pooled data of Brown Swiss crossbreeds was also akin to the findings of Malhotra et al. (1980) in Karan Swiss cattle and Singh and Gopal (1982) in buffaloes.

From the results it was evident that in most of the cases, R^2 values of inverse polynomial function were lower than those of other functions. This finding was not in agreement with the findings of Yadav et al. (1977 b) Basavaiah et al. (1978), Kumar and Bhat (1978, 1979 b), Bhat and Kumar (1980) and Cheema (1982) in buffaloes. These workers had proved the superiority of inverse polynomial function over other functions.

The graphs of the fitted functions revealed that the exponential, parabolic exponential and quadratic functions could describe only the descending phase of the lactation curve with a fair degree of accuracy. The inefficiency of exponential and parabolic exponential functions in explaining the rising phase of lactation curve was also reported by Brody et al. (1923) and Yadav and Sharma (1985) in Jersey, Holstein Friesian and Brown Swiss half-breds.

It may be expected that these three curves will give the same results in other breeds at cattle also. Hence the present study indicated that the exponential,parabolic exponential and quadratic models were not useful in defining the shape of lactation curve efficiency.

It is also evident from Fig. 2(f) and 3(f) that, in both Jersey and Brown Swiss crossbreds, the inverse polynomial function overestimated the peak yield and number of days to attain peak yield. The actual peak yields in the pooled data of Jersey and Brown Swiss crossbreds were 8.26 kg and 8.86 kg respectively. But the corresponding values obtained from the fitted inverse polynomial function were 11.16 kg and 10.65 kg respectively. The estimated average number of days to attain peak yield (40 days) was also higher than the observed value of 37.15 days in Jersey. Comparatively lower R^2 values and higher I values of inverse polynomial function, observed in the results, can be thought to be due to this higher rate of overestimation at the position of peak yield. Moreover, this function also under estimated the yield at the time of parturition and the production during the later (after 110 days) stages of lactation. Because of these reasons it was concluded that the inverse polynomial function did not fit well in representing the lactation curves of Jersey and Brown Swiss crossbred cows under study. However, this function could explain the shape of the curve satisfactorily.

The graphs of gamma function and quadratic-cum-log curves showed that these two curves had similar shape in both the crossbreds except that the former estimated the initial production accurately whereas, the later slightly overestimated the initial production. Both these curves slightly underestimated the Peak yield and the yield during the later stages (after 170 days) lactation and overestimated the production during the early stages (between 60 and 150 days) of lactation. The same result hold good for lactation curves fitted seperately for different lactations also.

In short, lactation-wise and pooled comparison of the fitted models showed, that irrespective of breed type and order of lactation either the gamma function or the quadratic-cum-log curve provided better fit than the other functions. The only reason that could be attributable to the superiority of these two functions over other functions was the nature of the data under study. Hence it was concluded, in general, that either the gamma function or the quadratic-cum-log curve should be used for representing the lactation curves of Jersey and Brown Swiss crossbred cows accurately.

5.3. Prediction of 310 days lactation yield from various part records

High phenotypic correlations between various part and full (310 days) lactation yields indicated that the part lactation yields could be a valuable guide to that a cow would produce in 310 days. The values of correlation coefficients increased with each added part yield and were more than 0.85 by 120th day of lactation in both Jersey and Brown Swiss crossbreds. The values of correlation coefficients reached 0.90 by 150th day of lactation. Highly significant correlations between various part and full lactation yields were also reported by Cannon et al. (1942) and Lamb and McGillard (1967 a,b) in exotic breeds of cattle; Dutt et al. (1964), Singh et al. (1967), Singh and Acharya (1969) and Chillar et al. (1980) in Hariana cattle; Velea et al. (1977) in Romanian cows; Adenoye and Adebanjo (1978) in Friesian cows; Contreras and Rincon (1979) in Limonero cows; Saiganonkar et al. (1981) in Sahiwal cows; Pathak et al. (1982) in Gir cows and Reiser and Haussmann (1982) in Simmental cows.

The rate of increase in the correlation coefficients between the total (310 days) yield and the cumulative yields after 120 days was low and did not add much to the accuracy of predicted 310 days yield so as to compensate for the loss of time and expenditure involved in recording their yields over long periods. Hence, it was concluded that to assess 310 days yield 120 days cumulative yields should be used. In different lactations of Jersey and Brown Swiss crossbreds, the correlation coefficients of 310 days yield with 120 day cumulative yields ranged from 0.8563 to 0.8798 (average 0.8843 ± 0.0154) and 0.8805 to 0.9260 (average 0.9004 ± 0.0095) respectively. These ranges of correlation were more or less the same as those reported by Chillar *et al.* (1980) in Hariana cattle, and are considerably higher than those reported by Saigaonkar *et al.* (1981) in Sahiwal cows.

The choice of 120 days cumulative yield as the most appropriate part record for predicting 310 days yield was in conformity with the findings of Mascherpa *et al.* (1967) in Brown Alpine cows and Contreras and Rincon (1979) in Limonero cows. But these results are contrary to the findings of Bussert (1957) in heifers and Adeneye and Adebanjo (1978) in Friesian cows. These workers selected 200 days cumulative yield as the most suitable part record for predicting 310 days lactation yield. Those differences might be due to differences in genetic constitution, environmental conditions, managerial practices and genotype-environmental interaction in these herds.

In order to predict 310 days milk yield from part records simple linear equations were developed by two methods, viz. regression method and ratio method. In the regression method, regression coefficients were estimated by least square method with part yield as the independent variable and 310 days yield as the dependent variable. But in the case of ratio method, regression coefficients were estimated as the ratio of 310 days yield to the part yields. In both the methods of prediction, the values of R^2 increased with increase in length of part records. Irrespective of breed group and order of lactation, this result was found to be correct which indicated that the accuracy of prediction by linear regression equations increased as the length of part lactation increased. This may be because of the fact that the relationship between full (310 days) and part lactation yields increases with increase in length of part records. The results also indicated that the magnitudes of the intercept (a) and the regression coefficient (b) decreased with each added part yield.

Cannon _et al._ (1942), Dutt _et al._ (1964), Chillar _et al._ (1980) and Pathak _et al._ (1982) also developed simple linear regression equations (by regression method) for predicting full lactation yield from part records in different breeds of dairy cattle. Their accuracy of prediction was similar to the results obtained in this study.

Comparison between ratio and regression methods of prediction revealed that values of R^2 obtained by ratio method were higher than those obtained by regression method when the first 30, 60 and 90 day cumulative yields were considered as part yields. But when the cumulative yields at 120 and 150 days of lactation were considered as part yields, R^2 values obtained by regression method were found to be higher than those obtained by ratio method.

Hence it was concluded that for predicting 310 days yield from first 30, 60 and 90 day cumulative yield, the ratio method should be used. But for predicting 310 days yield from 120 and 150 day cumulative yields regression method will be more precise.

Based on R^2 values, the following equations were suggested for accurate prediction of 310 days yield (Y) from 30, 60, 90, 120 and 150 day cumulative yields (X) seperately for each of the four lactations of Jersey and Brown Swiss crossbreds.

1. Jersey crossbreds

Part lact. yield upto / Lact. No.	30 days	60 days	90 days	120 days	150 days
1	Y=7.4273 X	Y=3.677 X	Y=2.5213 X	Y=-49.7079 + 2.0297 X	Y=-100.8925 + 1.7457 X
2	Y=7.0136 X	Y=3.4171 X	Y=2.3409 X	Y=-31.6579 + 1.8698 X	Y=-73.1180 + 1.6063 X
3	Y=6.8172 X	Y=-46.1910 + 3.4924 X	Y=-218.9209 + 2.6646 X	Y=-300.6191 + 2.1908 X	Y=-292.5004 + 1.8336 X
4	Y=6.0444 X	Y=-47.5881 + 3.1318 X	Y=-109.4787 + 2.2577 X	Y=-134.0029 + 1.8168 X	Y=-183.8438 + 1.5795 X
Pooled	Y=7.0277 X	Y=3.4747 X	Y=2.3900 X	Y=-75.0063 + 1.9623 X	Y =-117.6191 + 1.6855 X

2. Brown Swiss crossbreds

Part lact. yield upto / Lact. No.	30 days	60 days	90 days	120 days	150days
1	$Y=7.7432\,X$	$Y=3.7763\,X$	$Y=-18.6042+2.6048\,X$	$Y=-117.0524+2.1391\,X$	$Y=-156.9061+1.8174\,X$
2	$Y=7.6093\,X$	$Y=3.7436\,X$	$Y=2.5560\,X$	$Y=1.9749\,X$	$Y=-17.4483+1.6527\,X$
3	$Y=7.1669\,X$	$Y=3.6065\,X$	$Y=2.4762\,X$	$Y=-184.4373+2.1282\,X$	$Y=-224.2963+1.8077\,X$
4	$Y=7.7818\,X$	$Y=3.8903\,X$	$Y=2.6383\,X$	$Y=2.0238\,X$	$Y=1.6669\,X$
Pooled	$Y=7.5890\,X$	$Y=3.7436\,X$	$Y=2.5576\,X$	$Y=-77.0068+2.0674\,X$	$Y=-87.0387+1.7263\,X$

Genetic and non-genetic factors may not affect the part lactation milk yield and complete lactation milk yield in the same way. Age at calving, period and season of calving and days open may have more effect in the early part of lactation as compared to total lactation yield. A possible reason is that there is more physiological and nutritional stress in the early part of lactation compared with mid or later stages of lactation. Therefore, prediction equations for projecting complete lactation milk yield from part records of animals having different age at calving and days open may be different. Secondly, eventhough the seasonal variations have no significant influence on total lactation yield, it may have significant influence on part yields. Hense, it is still unresolved whether part yield data should or should not be adjusted when attempting to project them to a full lactation.

SUMMARY

SUMMARY

Milk yield data of 93 Jersey and 55 Brown Swiss crossbred cows maintained at the University Livestock Farm, Mannuthy, during the period 1978-1983 were utilised in the present study with the following objectives:

(i) To compare the relative efficiency of various lactation curve models and suggest the most suitable one for cows under study

(ii) To compare the two genetic groups of cattle based on order of lactation and season of calving

(iii) To develop equations for predicting 310 days yield from part yields of different stages.

Records upto the 4th lactation were included in the study. There were a total of 264 lactation records which include 174 lactation records of Jersey crossbreds and 90 lactation records of Brown Swiss crossbreds. To examine the effect of season of calving on lactation yield, the year was delineated into dry, rainy and moderate seasons. The average daily milk yield (calculated from successive 10 day yields) upto 310th day of lactation was the main item of observation.

The average lactation yield upto 310 days in Jersey and Brown Swiss crossbreds were 1652.83 ± 30.56 kg and 1897.43 ± 43.81 kg respectively. Statistical analysis

showed highly significant ($P < 0.01$) effect of breed type on total milk yield.

The average lactation yield upto 310 days in the first four lactations of Jersey crossbreds were 1659.46 ± 44.87 kg, 1601.04 ± 49.61 kg, 1699.45 ± 79.42 kg and 1664.26 ± 116.20 kg respectively. In Brown Swiss crossbreds, the corresponding figures were 1856.96 ± 75.78 kg, 1870.11 ± 65.64 kg, 1963.22 ± 118.07 kg and 2038.37 ± 128.44 kg respectively. Analysis of variance showed that in both the crossbreds, order of lactation had no significant effect on total milk yield.

In Jersey crossbreds, the average total yield for the dry, rainy and moderate seasons were 1629.35 ± 48.49 kg, 1705.12 ± 57.74 kg and 1635.17 ± 53.35 kg respectively. In Brown Swiss crossbreds, the corresponding values were 1860.42 ± 112.07 kg, 1872.32 ± 73.26 kg and 1938.06 ± 60.62 kg respectively. In both the crossbreds, season of calving did not exert any significant influence on total milk yield.

The days to attain peak yield in Jersey and Brown Swiss crossbreds were 37.15 ± 1.15 days and 41.00 ± 2.63 days respectively. The average peak yield in these two crossbreds were 8.57 ± 0.21 kg and 9.23 ± 0.42 kg respectively.

To compare the relative efficiency of various lactation curve models, the exponential, parabolic exponential, quadratic, quadratic-cum-log, gamma and inverse polynomial functions were fitted to the average daily milk yield, seperately for each of the four lactations and to the pooled data, for each genetic group under study. Equations of the best fitted functions in different lactations of Jersey and Brown Swiss crossbreds were as follows:

1. <u>Jersey crossbreds</u>

1st lactation : Gamma function (R^2=0.9854; I=0.1994)

$$Y_t=7.21232\ t^{0.16812}\ e^{-0.04794\ t}$$

2nd lactation : Quadratic-cum-log curve(R^2=0.9878; I=0.2287)

$$Y_t=7.08996-0.50737\ t+0.00454\ t^2+1.75310\ \log_e t$$

3rd lactation : Gamma function (R^2=0.9902; I=0.2051)

$$Y_t=7.53184\ t^{0.22805}\ e^{-0.06594\ t}$$

4th lactation : Quadratic-cum-log curve (R^2=0.9914; I=0.2440)

$$Y_t=8.08035-0.73567\ t+0.00891\ t^2+2.08342\ \log_e t$$

Pooled : Gamma function (R^2=0.9907; I=0.2042)

$$Y_t=7.23840\ t^{0.27094}\ e^{-0.07182\ t}$$

2. <u>Brown Swiss crossbreds</u>

1st lactation : Gamma function (R^2=0.9841; I=0.2133)

$$Y_t=8.15181\ t^{0.13299}\ e^{-0.04149\ t}$$

2nd lactation : Quadratic-cum-log curve(R^2=0.9804; I=0.2723)

$$Y_t = 7.81832-0.35602\ t + 0.00156\ t^2 + 1.26049\ \log_e t$$

3rd lactation : Quadratic-cum-log curve(R^2=0.9842; I=0.2620)

$$Y_t = 8.76377-0.33885\ t + 0.00140\ t^2+0.92737\ \log_e t$$

4th lactation : Quadratic-cum-log curve(R^2=0.9690; I=0.3755)

$$Y_t = 8.31712-0.13937\ t - 0.00375\ t^2 + 0.53511\ \log_e t$$

Pooled : Quadratic-cum-log curve(R^2=0.9804; I=0.2752)

$$Y_t = 8.24678-0.35623\ t + 0.00174\ t^2 + 1.16191\ \log_e t$$

(Y_t is the average daily yield in time t (t=1,2,.....31); R^2 = coefficient of determination; I = Furnival index)

The graphs of the fitted functions showed that, in both the genetic groups, the exponential, parabolic exponential and quadratic models failed to represent the ascending phase of the lactation curve. The inverse polynomial function overestimated the peak yield and the number of days to attain peak yield and underestimated the initial production and the production during the later stages (after 110 days) of lactation. Because of these reasons, the inverse polynomial function gave the least fit in both Jersey and Brown Swiss crossbreds. Irrespective of breed type and order of lactation, either the gamma function or the qudratic-cum-log curve provided better fit than the other functions.

To predict 310 days yield from part yields, the cumulative yields at 30, 60, 90, 120 and 150 days of lactation were considered as part yields. In Jersey crossbreds, the average correlation coefficients of 310 days yield with the above part yields were 0.6963, 0.8018, 0.8514, 0.8843 and 0.9130 respectively. The corresponding figures in Brown Swiss crossbreds were 0.7843, 0.8329, 0.8706, 0.9004 and 0.9264 respectively. The correlation coefficients increased with each added part yield, and were more than 0.85 by 120th day of lactation. The rate of increase in the correlation coefficients between the total (310 days) yield and cumulative yields after 120 days was low. Hence, it was concluded that for predicting 310 days yield with reliable accuracy, 120 day record was most appropriate.

Prediction equations for projecting 310 days lactation yield from different part yields were developed by ratio and regression methods. Comparison, based on R^2 values, between these two methods revealed that the values of R^2 obtained by ratio method were higher than those obtained by regression method when the first 30, 60, and 90 day cumulative yields were considered as part records. But when the cumulative yields at first 120 and 150 days were considered as part yields, R^2 values obtained by regression method were found to be higher than those obtained by ratio method. Hence it was concluded that for predicting 310 days yield from 30, 60 and 90 day cumulative yields, the ratio method would be more appropriate. But for predicting 310 days yield from 120 and 150 day cumulative yields, the regression method should be used.

For the pooled data of Jersey and Brown Swiss crossbreds, the most appropriate equations for predicting 310 days yield from the 120 day cumulative yields were

$Y = -75.0063 + 1.9623\ X\ (R^2 = 0.7523)$ and

$Y = -77.0068 + 2.0674\ X\ (R^2 = 0.8410)$ respectively

where Y is the estimated 310 days yield and X is the total yield upto 120th day of lactation.

REFERENCES

REFERENCES

Adeneye, J.A. and Adebanjo, A.K. (1978). Lactational characteristics of imported British Friesian cattle in Western Nigeria. J. Agric. Sci. Camb. 91 : 645-651.

Agarwala, O.P. (1962). Estimation of lactation yield in buffaloes from production for short intervals in a lactation. Indian Vet. J. 39 (2) : 69-72.

Al-Rawi, A.A. and Said, S.I. (1980). Significance of the age at first calving and lactation length on the first lactation yield. Anim. Breed. Abstr. (1982)50 (11): 6017.

Arendonk, J.A.M. Van and Fimland, E. (1983). Comparison of two methods to extend Partial records. Anim. Breed. Abstr. (1983) 51 (10) : 5894.

Basavaiah, P., Sharma, K.N.S. and Nagarcekkar, R. (1978). Studies on lactation curves in Murrah buffaloes. Anim. Breed. Abstr. (1979). 47 (3) : 1148.

Batra, T.R. and Lee, A.J. (1981). Extending records in progress to 305-day lactation production by using 1965 USDA and modified extension factors. Can. J. Anim. Sci. 61 (3) : 523-529.

Bhat, P.N. and Kumar, R. (1978). A note on factors affecting the shape of the lactation curve in buffaloes. Indian J. Anim. Sci. 48 (8) : 608-610.

Bhat, P.N. and Kumar, R. (1980). Comparative efficiency of various mathematical functions on adjusted lactation curve in Indian buffaloes. Indian J. Dairy Sci. 33 (3) : 408-409.

*Blau, G. (1961). Studies about the course of the lactation curve. Ziichtungskunde 33 (4) : 161-177 (Cited by Wood, 1969).

Bouma, E. (1956). An investigation into the shape of the lactation curve in Meuse-Rhine-Yssel cattle in Gelder land and on the use of the standard cow for this breed. Biol. Abstr. 31 : 24787.

*Brody, S., Ragsdale, A.C. and Turner, C.W. (1923). The rate of decline of milk secretion with the advance of the period of lactation. J. Gen. Physiol. 5 : 441-444 (Cited by Yadav et al., 1977b).

*Brody, S. (1927). Growth of development. Missouri. Agri. Exp. Sta. Res. Bul. 105 (Cited by Girija, 1980).

Bussert, K. (1957). Part yields of heifers in relation to th shape of the lactation curve and their value for estimating genetic merit. Biol. Abstr. 32 : 28379.

Cannon, C.Y., Frye, J.B. (Jr) and Sims, J. A. (1942). Predicting 305-day yield from short time records. J. Dairy Sci. 25 (1) : 991.

*Caukas, Z. (1939). The genetics of lactation curve. Proc. 7th Internat. Genetics Congress. Edinburg. 93 (Cited by Girija, 1980).

*Cersovsky, H. (1957). The significance of the shape of lactation curve in cows. Tierzucht 11 : 185-188 (cited by Wood, 1969).

Chauhan, R.S., Mishra, R.S. and Bhatnagar, D.S. (1974). Peak yield and days to attain peak yield in Brown Swiss crossbred cows. Indian J. Dairy Sci. 27 (1): 58-61.

Cheema, J.S. (1982). Studies on lactation curves of Murrah buffaloes. Anim. Breed. Abstr. (1983). 51 (9) : 5399.

Chillar, R.S., Raina, B.L. and Bhat, P.N. (1980). Studies on extending part lactation records in Hariana and its Friesian crossbreds. Indian J. Anim. Sci. 50 (9) : 685-689.

Contreras, B. and Rincon, E. (1979). Lactation curves of Limonero Criollo cows in humid tropics. Anim. Breed. Abstr. (1982). 50 (12) : 6987.

Costa, C.N., Milagres, J.C., Castro, A.C.G. and Garcia, J.A. (1982). Effects of season and age at first calving on the lactation curve of HF cows. Anim. Breed. Abstr. (1984). 51 (6) : 3456.

Dave, A.D. and Patel, U.G. (1971). Persistency of milk production in Kankrej cattle - a ratio measure. Dairy Sci. Abstr. (1972). 34 (10) : 4396.

Delage, J., Leroy, A.M. and Poly, J. (1953). Lactation curves. Anim. Breed. Abstr. (1954). 22 (1) : 83.

Dhanoa, M.S., Du, Y.L.P.LE (1982). A Partial adjustment model to describe the lactation curve of a dairy cow. Anim. Prod. 34 (3) : 243-247.

Dutt, M., Singh, S.P. and Singh, S.B. (1964). Prediction of lactation yields in Hariana cattle. Indian Vet. J. 41 : 273-275.

Furnival, G.M. (1961). An index for comparing equations used in constructing volume tables. Forest Sci. 7 (4) : 337-341.

Gaines, W.L. (1927). Deferred short-time test as a measure of the performance of dairy cows. J. Agric. Res. 35 : 237.

Gaskins, Charles, T. and Anderson, D.C. (1980). Comparison of lactation curves in Angus-Hereford, Jersey-Angus and Simmental-Angus cows. J. Anim. Sci. (USA) 50 (5) : 828-832.

*Gerdemann, H. (1964). Investigations on the relationship between milk yield and fertility in cows with particular consideration of the shape of the lactation curve. Inaug. Diss. Doct. Med. Vet., Hanover (Cited by Wood, 1969).

Girija, C.R. (1980). Studies on the peak yield and persistency of lactation in crossbred dairy cows. M.V.Sc. Thesis, College of Veterinary and Animal Sciences, Mannuthy-Trichur (Unpublished).

Goodall, E.A. and Sprevak, D. (1984). A note on a stochastic model to describe the milk yield of a dairy cow. Anim. Prod. 38 (1) : 133-136.

Huth, F.W. and Schutzbar, W.V. (1981). Lactation curves in cattle. Anim. Breed. Abstr. (1983). 51 (3) : 1440.

Kartha, K.P.R. (1934). A study of the data of milk yields of various types of cattle obtained from the records of Government Military dairy farms. 3. Prediction of milk yields. Indian J. Vet. Sci. 4 : 218-220.

Kendall, M., Stuart, A. and Ord, J.K. (1983). The Advanced Theory of Statistics. Charles Griffin and Co. Ltd., London. Vol. 3 4th Ed. 23.

Krefft, R. (1967). Construction of a mathematical model showing the milk yield of cows during a single lactation. Biol. Abstr. 49 : 72367.

Kumar, R. and Bhat, P.N. (1978). A note on the models of lactation curve in Indian buffaloes. Indian J. Anim. Sci. 48 (12) : 910-911.

Kumar, R. and Bhat, P.N. (1979 a). A note on lactation curve in Indian buffaloes as estimated by parabolic exponential function. Indian J. Anim. Sci. 49 (11) : 942-944.

Kumar, R. and Bhat, P.N. (1979 b). Lactation curve in Indian buffaloes. Indian J. Dairy Sci. 32 (2) : 156-160.

Labouche, C. (1957). The physiology of lactation in a tropical environment (1) Lactation curves studied in the sub-Guinean region of the cop Vert Peninsula (Senegal). Biol. Abstr. 32 : 26197.

Lamb, R.C. and McGillard, L.D. (1967 a) Ratio factors to estimate 305-day production from lactation records in progress. J. Dairy Sci. 50 (2) : 1101-1106.

Lamb, R.C. and McGillard, L.D. (1967 b). Usefullness of part records to estimate the breeding values of dairy cattle. J. Dairy Sci. 50 (2) : 1458-1461.

Madalena, F.E., Martinz, M.L. and Freitas, A.F. (1979). Lactation curves of HF and HF x Gir cows. Anim. Prod. 29 (1) : 101-107.

Malhotra, P.K., Singh, R.P. and Singh, R.N. (1980). Estimating lactation curve in Karan-Swiss cattle. Indian J. Anim. Sci. 50 (10) : 799-804.

Mascherpa, C., Barbieri, V. and Fiorentini, A. (1967). Value of partial lactation records in evaluating the milk production of Brown Alpine cows. Biol. Abstr. 49 : 122531.

Mathew, S. (1983). Evaluation of lactation performance of Zebu X Taurus cattle in Kerala. M.V.Sc. Thesis, College of Veterinary and Animal Sciences, Mannuthy-Trichur (Unpublished).

Matsuo, T., Okamoto, S. and Kobayashi, S. (1982). Effects of calving month on the shape of the lactation curve in dairy cows. Anim. Breed. Abstr. (1982). 50 (12): 6998.

*Maymone, B. and Molossini, F. (1959). The rising phase of lactation curve in dairy cows. Ann. Sper. Agr. 13 : 1005-1033 (Cited by Wood, 1969).

Mehto, L., Kaushik, S.N. and Koul, G.L. (1980). Influence of various factors on components of gamma type function of a lactation curve in Hariana crossbreds. Indian J. Anim. Sci. 50 (7) : 538-541.

Miller, R.H. and Pearson, R.E. (1972). Methods of projecting complete lactation production from part lactation yield. J. Dairy Sci. 55 (11) : 1602-1606.

Moon, J.J., Kim, H.K. and Kim, J.H. (1982). Studies on the estimation of milk yields by the lactation curve. Anim. Breed. Abstr. (1983). 51 (9) : 5408.

Mukundan, G. and Bhat, P.N. (1983). Lactation curve in Malabari goats and their Saanen half-breds. Indian J. Anim. Sci. 53 (6) : 666-669.

Nair, B.R.K. (1973). A preliminary report on the performance of Jersey crossbreds and Jersey grades in Kerala. Kerala J. Vet. Sci. 4 (1) : 99-105.

*Nair, P.N.R. (1973). Evolutionary crossbreeding as a basis for cattle development in Kerala State. D.V.M. Thesis, University of Zurich, Faculty of Veterinary Medicine (Cited by Girija, 1980).

Nelder, J. (1966). Inverse polynomials, a useful group of multifactor response functions. Biometrics 22 (1) : 128-141.

Pathak, S.C., Dhingra, M.M. and Gurung, B.S. (1982). Study of prediction of 300 days milk yield from part time production in Gir cows. Indian Vet. J. 59 (7) : 572-573.

Powell, R.L., Cassell, B.G., Norman, H.D. and Dodoh, G.W. (1978). Variation in cow evaluation from records in progress. J. Dairy Sci. 61 (6) : 788-793.

*Pradhan, V.D. (1977). Study of lactation curve and the rate of decline in milk yield of Kankrej cattle. M.Sc. (Agri.) Thesis. Sardar Patel University (Cited by Girija, 1980).

*Rajagopalan, T.G. and Dave, A.D. (1976). Persistency of milk production in Jersey cows. Gujarat Agric. Univ. Res. J. 2 (1) : 39-42 (Cited by Girija, 1980).

Rao, M.V., Katpatal, B.G. and Bisht, G.S. (1980). Predicting succeeding complete lactation from the part records of a preceeding lactation. Indian J. Anim. Sci. 50 (1) : 11-15.

Rao, M.K. and Sundaresan, D. (1981). Studies on lactation curves on Brown Swiss X Sahiwal crossbred cows. Anim. Breed. Abstr. (1982). 50 (6) : 2981.

Ratheiser, N. (1972). Relationship between birth weight, milk and fat production and persistency in first lactation of Australian Fleckvich (Simmental) cows. Dairy Sci. Abstr. (1973): 1534.

Reiser, G. and Haussmann, H. (1982). Extending part lactations. Anim. Breed. Abstr. (1983). 51 (3): 1448.

Rowlands, G.J., Lucey, S. and Russell, A.M. (1982). A comparison of different models of the lactation curve in dairy cattle. Anim Prod. 35 (1) : 135-144.

Runpei, W., Zhou, W. and Guo, W. (1983). A mathematical description of the lactation curve of dairy cows and its application. Anim. Breed. Abstr. (1984). 52 (6) : 3118.

Saigaonkar, P.B. and Deshmukh, S.N. (1981). Prediction of total lactation milk yield in Sahiwal cattle. Indian J. Anim. Res. 15 (2) : 87-92.

*Sanders, H.G. (1930). The analysis of lactation curve into maximum yield and persistency. J. Agric. Sci. 20 : 145 (Cited by Girija, 1980).

Schueffer, L.R., Minder, C.E., Mcmillan, I. and Burnside, E.B. (1977). Non linear techniques for predicting 305-day lactation production of Holsteins and Jerseys. J. Dairy Sci. 60 (10) : 1636-1644.

Shah, S.M. and Singh, C.S.P. (1983). Lactation yield, part lactation, persistency of milk yield and rate of decline in Jersey cows. Anim. Breed. Abstr. (1984). 52 (11) : 6362.

Shimizv, H., Hachinohe, Y., Umrod, S. and Fukuyama, K. (1983). The trends of variations in some measures of lactation curves among lactations and calving seasons in dairy cows. Anim. Breed. Abstr. (1984). 52 (11) : 6363.

*Sikka, L.C. (1950). A study of lactation as affected by heredity and environment. J. Dairy Res. 17 : 231-252 (Cited by Yadav et al., 1977 b).

Singh, B. and Bhat, P.N. (1978 a). Models of lactation curves for Hariana cattle. Indian J. Anim. Sci. 48 (11): 791-797.

Singh, B. and Bhat, P.N. (1978 b). Some factors affecting the lactation curve in Hariana cattle. Indian J. Anim. Sci. 48 (10) : 716-719.

Singh, B., Bhat, P.N. and Kumar, R. (1979). Factors affecting the shape of the lactation curve in Hariana cattle. Indian J. Anim. Sci. 49 (7) :495-498.

Singh, B.P., Dutt, M. and Kumar, J. (1967). Estimation of genetic parameters of part lactation records. Indian Vet. J. 44 (7) : 579-584.

Singh, M. and Acharya, R.M. (1969). Inheritance of part lactation in Hariana cattle. J. Dairy Sci. 52 (6) : 775-779.

Singh, R.P. and Gopal, R. (1982). Lactation curve analysis of buffaloes maintained under village conditions. Indian J. Anim. Sci. 52 (12) : 1157-1160.

Singh, R.P. and Raut, K.C. (1982). Studies on the lactation curve for cows under village conditions. Indian J. Anim. Sci. 52 (6) : 375-378.

Singh, S.P and Singh, P. (1984). Indian livestock population and production dynamics. Agric. Situation India 39 (5): 311-315.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical Methods. Oxfor and IBH Publishing Co., New Delhi. 6th ed. 478-481.

Teixeira, N. Duraes, M.C. and Freitas, A.F. (1982). A comparison of some methods of predicting total lactation milk yield from part lactation yields. Anim. Breed. Abstr. (1983). 51 (3) : 1452.

Turner, C.D. (1955). General Endocrinology, Philadelphia, London, 2nd ed. 381.

Velea, C., Marcu, N. and Muresan, I. (1977). Estimating milk production in normal lactations based on part lactations. Anim. Breed. Abstr. (1979). 47 (8) : 4142.

Wiggans, G.R. and Van vleck, L.D. (1979). Extending partial lactation milk and fat records with a function of last sample production. J. Dairy Sci. 62 (2) : 316-325.

*Wood, P.D.P. (1967). Algebraic model of the lactation curve in cattle. Nature 216 : 164-165(Cited by Yadav et al., 1977 b).

Wood, P.D.P. (1969). Factors affecting the shape of the lactation curve in cattle. Anim. Prod. 11 (3) : 307-316.

Wood, P.D.P. (1980). A note on the lactation curves of some high-yielding British Friesian cows. Anim. Prod. 30 (2) : 299-302.

Yadav, M.C., Katpatal, B.G. and Kaushik, S.N. (1977 a). Components of gamma type function of a lactation curve and factors affecting them in Hariana and its Friesian crosses. Indian J. Anim. Sci. 47 (9): 520-525.

Yadav, M.C., Katpatal, B.G. and Kaushik, S.N. (1977 b). Study of lactation curve in Hariana and its Friesian crosses. Indian J. Anim. Sci. 47 (10) : 607-609.

Yadav, M.C., Katpatal, B.G. and Kaushik, S.N. (1977 c). Components of inverse polynomial function of lactation curve, and factors affecting them in Hariana and its Friesian crosses. Indian J. Anim. Sci. 47 (12): 777-781.

Yadav, S.B.S. and Sharma, J.S. (1982). A study on factors affecting the lactating and non-lactating period of crossbred cows. Anim. Breed. Abstr. (1984). 52 (5): 2398.

Yadav, S.B.S. and Sharma, J.S. (1985). Functions for lactation curves in crossbred dairy cattle. Indian J. Anim. Sci. 55 (1) : 42-47.

Zarnecki, A. and Dworak, D. (1981). Gamma type lactation curve models in the comparison of Friesian strains. Dairy Sci. Abstr. (1983). 45 (5) :

* Originals not consulted.

APPENDIX

Appendix I

Actual and predicted total milk yields from various part records (sample) in crossbred cows

1. <u>Jersey crossbreds</u>

a) 30 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield (Y) Regression method	Ratio method
1	065	175.8	844.2	1327.6	1221.4
2	170	393.7	2564.8	2443.1	2766.8
3	064	228.7	1618.5	1606.1	1607.2
4	119	169.1	1044.4	1303.8	1188.4
5	006	184.5	1201.9	1381.9	1296.6
6	125	153.0	1377.4	1222.2	1075.2
7	177	214.8	1138.0	1535.6	1509.5
8	016	223.3	1430.1	1578.8	1569.3
9	076	160.8	1142.9	1257.7	1124.4
10	003	193.8	1826.9	1429.1	1362.0
11	172	118.0	1346.1	1044.6	829.3
12	104	225.4	1891.4	1589.4	1584.0
13	161	217.7	1746.9	1550.3	1529.9
14	179	268.6	1231.4	1808.5	1887.6
15	069	232.3	2097.1	1624.4	1632.5
16	033	257.9	2024.2	1754.3	1812.4
17	141	258.4	1998.4	1756.8	1815.9
18	019	211.0	2096.0	1516.4	1482.8
19	054	193.9	1772.5	1429.6	1362.7
20	085	230.6	1448.3	1615.8	1620.6

b) 60 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	065	330.9	844.2	1194.4	1149.8
2	144	666.7	2157.7	2246.3	2316.6
3	005	274.4	1103.8	1017.4	953.5
4	156	432.9	1505.9	1513.9	1504.2
5	137	447.2	1360.0	1558.7	1553.9
6	118	350.1	942.0	1254.6	1216.5
7	141	506.0	1998.4	1742.9	1758.2
8	053	524.5	2049.3	1800.9	1822.5
9	016	434.2	1430.1	1518.0	1508.7
10	128	485.9	1644.0	1679.9	1688.4
11	059	409.1	1815.8	1439.4	1421.5
12	108	577.8	1865.3	1967.8	2007.7
13	112	472.8	1281.2	1638.9	1642.8
14	183	493.9	1323.1	1705.0	1716.2
15	162	394.8	1822.5	1394.6	1371.8
16	058	388.6	1499.7	1375.2	1350.3
17	007	563.8	1374.2	1923.9	1959.0
18	169	609.4	1484.6	2066.8	2117.5
19	163	303.9	768.3	1109.8	1055.9
20	074	451.0	1873.3	1570.6	1567.1

c) 90 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	122	624.7	1528.3	1493.7	1493.0
2	116	883.7	2041.6	2109.0	2112.0
3	142	666.3	1765.5	1592.5	1592.5
4	171	687.7	1675.5	1643.3	1643.6
5	145	496.3	709.3	1188.6	1186.2
6	165	546.9	1286.1	1308.8	1307.1
7	141	748.1	1998.4	1786.9	1787.9
8	084	735.2	1238.5	1756.2	1757.1
9	090	727.2	1774.0	1737.2	1738.0
10	095	818.9	1460.8	1955.1	1957.2
11	117	411.6	872.9	987.3	983.7
12	012	800.8	1881.1	1912.1	1913.9
13	140	423.4	874.3	1015.4	1011.9
14	033	761.6	2024.2	1818.9	1820.2
15	072	642.8	1681.8	1536.7	1536.3
16	070	757.7	2277.2	1809.7	1810.9
17	131	607.7	1200.9	1453.3	1452.4
18	164	359.0	947.5	862.4	858.0
19	146	733.8	1405.9	1752.2	1753.1
20	158	777.0	1726.9	1855.5	1857.0

d) 120 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	072	836.9	1681.8	1567.2	1568.9
2	112	763.7	1281.2	1423.6	1431.6
3	048	1050.3	2246.0	1985.9	1968.9
4	119	526.9	1044.4	958.9	987.7
5	052	768.4	1096.4	1432.8	1440.4
6	131	740.2	1200.9	1377.5	1387.6
7	121	951.2	1590.9	1791.5	1783.1
8	102	1444.3	2789.4	2759.1	2707.5
9	109	780.7	1221.5	1456.9	1463.5
10	129	939.6	1523.1	1768.8	1761.4
11	059	791.6	1815.8	1478.4	1483.9
12	095	1009.3	1460.8	1905.5	1892.0
13	054	789.5	1772.5	1474.2	1480.0
14	068	959.6	1832.4	1803.0	1798.9
15	076	609.1	1142.9	1120.2	1141.8
16	094	832.7	1645.0	1559.0	1560.9
17	003	844.8	1826.9	1582.7	1583.7
18	041	915.6	1931.9	1721.7	1716.4
19	018	709.6	1338.7	1317.4	1330.2
20	132	841.2	1966.8	1571.7	1576.9

e) 150 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	151	1673.3	2568.3	2702.7	2627.6
2	060	655.2	827.4	986.7	1028.9
3	049	1170.4	1777.9	1855.1	1837.9
4	021	1120.8	1890.9	1771.5	1760.0
5	104	1055.9	1891.4	1662.1	1658.1
6	027	1019.5	1827.8	1600.7	1600.9
7	084	1029.8	1238.5	1618.1	1617.1
8	182	577.4	828.5	855.6	906.7
9	107	545.9	843.9	802.5	857.2
10	146	1098.7	1405.9	1734.2	1725.3
11	113	1016.6	1475.5	1595.9	1596.4
12	164	588.2	947.5	873.8	923.7
13	158	1094.3	1726.9	1726.8	1718.4
14	096	1153.8	2084.2	1827.1	1811.8
15	072	1015.1	1681.8	1593.3	1594.0
16	047	1262.0	1786.8	2009.5	1981.7
17	128	1138.9	1644.0	1802.0	1788.4
18	006	785.8	1201.9	1206.8	1233.9
19	101	727.7	1380.4	1108.9	1142.7
20	179	1054.9	1231.4	1660.4	1656.5

2. <u>Brown Swiss crossbreds</u>

a) 30 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	041	241.1	1971.6	1842.5	1829.7
2	003	321.4	2069.7	2313.3	2439.1
3	102	216.1	2066.2	1695.9	1639.9
4	057	311.0	2408.8	2252.3	2360.2
5	026	236.5	2020.9	1815.6	1794.8
6	007	270.3	1549.2	2013.7	2051.3
7	089	372.0	1701.4	2609.9	2823.1
8	104	222.9	2126.3	1735.8	1691.6
9	051	190.7	1491.7	1547.1	1447.2
10	028	141.4	1154.7	1258.1	1073.1
11	047	175.6	1228.1	1458.6	1332.6
12	084	213.4	1440.1	1680.2	1619.5
13	044	209.9	1636.9	1659.6	1592.9
14	048	255.9	1566.1	1929.3	1942.0
15	097	209.8	1526.5	1659.0	1592.2
16	070	340.3	2119.9	2424.1	2582.5
17	015	209.2	1603.4	1655.5	1587.6
18	049	141.5	920.3	1258.7	1073.8
19	040	252.7	2469.0	1910.5	1917.7
20	027	340.0	2748.2	2422.3	2580.3

b) 60 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	070	657.3	2119.9	2392.8	2460.7
2	056	451.5	1725.6	1713.4	1690.2
3	027	735.0	2748.2	2649.3	2751.5
4	102	437.9	2066.2	1668.5	1639.3
5	099	609.3	2249.9	2234.3	2280.9
6	026	505.8	2020.9	1892.7	1893.5
7	003	611.0	2069.7	2241.1	2287.3
8	086	364.4	1717.0	1425.8	1364.2
9	077	508.9	2209.9	1902.9	1905.1
10	001	264.4	1307.6	1095.7	989.8
11	094	632.3	2488.1	2310.3	2366.7
12	034	555.9	1849.7	2058.0	2081.1
13	043	569.9	2069.2	2103.9	2133.1
14	020	325.9	964.4	1298.4	1219.7
15	010	629.5	2456.0	2301.0	2356.6
16	015	421.9	1603.4	1615.7	1579.4
17	002	410.0	1756.3	1576.4	1534.9
18	079	259.4	818.5	1079.2	971.1
19	078	460.7	1945.5	1743.8	1724.7
20	091	721.5	2804.8	2664.7	2701.0

c) 90 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	058	445.7	1134.4	1174.8	1139.9
2	070	907.7	2119.9	2301.2	2321.5
3	069	790.7	1874.0	2015.9	2022.3
4	033	900.3	2100.4	2283.2	2302.6
5	062	778.2	1995.0	1985.5	1990.3
6	059	638.4	1727.5	1644.6	1632.8
7	052	773.4	1378.6	1973.8	1978.0
8	057	984.5	2408.8	2488.5	2517.9
9	054	741.9	1784.5	1896.9	1897.5
10	036	875.9	2330.9	2223.7	2240.2
11	024	545.8	1304.5	1418.8	1395.9
12	068	860.0	2077.9	2184.9	2199.5
13	078	693.8	1945.5	1779.7	1774.5
14	063	784.8	1933.3	2001.6	2007.2
15	015	586.0	1603.4	1516.9	1498.8
16	083	316.9	568.8	860.7	810.5
17	005	881.0	2610.2	2236.1	2253.2
18	074	949.1	2566.1	2402.2	2427.4
19	104	653.2	2126.3	1680.7	1670.6
20	106	323.0	925.20	875.6	826.1

d) 120 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	068	1107.8	2077.9	2213.3	2200.4
2	083	406.8	568.8	764.0	808.0
3	046	810.4	1798.4	1598.4	1609.7
4	084	816.9	1440.1	1611.9	1622.6
5	099	1135.3	2249.9	2270.1	2255.0
6	019	1017.3	2317.2	2026.2	2020.7
7	088	952.8	2044.3	1892.8	1892.5
8	012	900.6	1882.0	1784.9	1788.9
9	089	1130.2	1701.4	2259.6	2244.9
10	025	607.1	1595.5	1178.1	1205.9
11	082	813.5	1370.2	1604.8	1615.9
12	013	1294.3	2605.8	2598.8	2570.9
13	066	767.9	1543.7	1510.5	1525.3
14	041	956.5	1971.6	1900.5	1899.9
15	037	1200.0	2519.9	2403.9	2383.6
16	052	962.1	1378.6	1912.0	1911.0
17	063	982.2	1933.3	1953.6	1950.9
18	041	956.5	1971.6	1900.5	1899.9
19	027	1341.4	2748.2	2696.2	2664.4
20	083	1253.4	3001.4	2514.3	2489.7

d) 150 day cumulative yields as part record

Sl. No.	Sampling number	Part yield	Actual total yield	Predicted total yield	
				Regression method	Ratio method
1	069	1165.2	1874.0	1924.4	1922.7
2	092	1235.5	1348.5	2045.8	2038.7
3	095	1357.2	2221.9	2255.9	2239.5
4	094	1430.8	2488.1	2382.9	2360.9
5	096	1120.4	1879.1	1847.1	1848.8
6	064	989.1	1512.5	1620.4	1632.1
7	009	1106.2	1871.0	1822.6	1825.3
8	061	1219.1	2204.6	2017.5	2011.6
9	010	1370.5	2456.0	2278.9	2261.5
10	007	994.2	1549.2	1629.2	1640.5
11	098	537.5	874.7	840.8	886.9
12	104	1102.0	2126.3	1815.3	1818.4
13	026	1142.7	2020.9	1885.6	1885.6
14	036	841.7	1409.8	1365.9	1388.9
15	087	1181.9	1940.1	1953.3	1950.3
16	041	1177.1	1971.6	1944.9	1942.3
17	054	1173.0	1784.5	1937.9	1935.6
18	052	1129.9	1378.6	1863.5	1864.4
19	066	959.4	1543.7	1569.2	1583.1
20	002	1016.6	1756.3	1667.9	1677.5

A COMPARATIVE STUDY OF LACTATION CURVES IN CATTLE

By

MATHEW SEBASTIAN

ABSTRACT OF A THESIS

submitted in partial fulfilment of
the requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
Mannuthy - Trichur

1985

ABSTRACT

An investigation, based on 174 normal lactation records of 93 Jersey crossbred cows and 90 normal lactation records of 55 Brown Swiss crossbred cows belonged to the University Livestock Farm, Mannuthy, was undertaken: (i) to compare the relative efficiency of various lactation curve models and to select the best one (ii) to compare the two genetic groups based on order of lactation and season of calving and (iii) to develop equations for predicting total milk yield from part yields.

Records upto the 4th lactation were included in the study. The observations spread over a period of six years from 1978 to 1983. The year was delineated into dry, rainy and moderate seasons.

Statistical analysis showed highly significant ($P < 0.01$) effect of breed type on total (310 days) milk yield; but the effects of order of lactation and season of calving were not significant in both the genetic groups.

Comparison of exponential, parabolic exponential, quadratic, quadratic-cum-log, gamma and inverse polynomial functions of lactation curve models showed that the gamma function - $Y_t = 7.2384\, t^{0.2709} e^{-0.0718\, t}$ ($R^2 = 0.9907$, $I = 0.2042$) - and the quadratic-cum-log curve - $Y_t = 8.2468 - 0.3562\, t + 0.0017\, t^2 + 1.1619 \log_e t$ ($R^2 = 0.9804$, $I = 0.2752$) - gave the best fit in the pooled data of Jersey and Brown Swiss crossbreds respectively.

It was also found that in all the 8 lactations studied, either the gamma function or the quadratic-cum-log curve provided better fit than the other models.

Graphs of fitted functions showed that, in both the genetic groups, the exponential, parabolic exponential and quadratic models could not explain the rising phase of the lactation curve. In all the cases, the inverse polynomial function was found to be the least fitting. The gamma function and the quadratic-cum-log curves gave close fit to the observed values.

Correlation coefficients between total (310 days) yield and the cumulative yields at 30, 60, 90, 120 and 150 days of lactation were found to be highly significant ($P < 0.01$). The present study revealed 120 days cumulative yield to be the most suitable part yield for predicting total (310 days) yield accurately.

Regression equations for predicting total (310 days) yield from various part records were developed by ratio and regression methods. Comparison of these two methods showed that the ratio method would be more precise for predicting total yield from the first 30, 60 and 90 day cumulative yields. But for predicting total yield from 120 and 150 day cumulative yields, the regression method should be used.