A COMPARATIVE STUDY OF LACTATION CURVES IN GOATS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **'A Comparative Study of Lactation Curves in Goats'** is a bonafide record of research work done by me during the course of research and that the thesis has 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.

Vellanikkara,
31-8-1991

ANITA, S.

CERTIFICATE

Certified that this thesis entitled **'A Comparative Study of Lactation Curves in Goats'** is a record of research work done independently by **Kumari Anita, S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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Dedicated to

My Loving Parents

CONTENTS

Introduction

INTRODUCTION

Goat keeping is one of the important avocations of rural India. Its main contributions to Indian economy are the much liked and popular chevon, milk, skin and hairs and the droppings which is also popular as a good manure. Prolificacy of the goat is also contributing to the economy. The economic gains of the rural goat keeper has earned it a name as the poor man's cow. Despite the stigma on the species as the enemy of the vegetation of its characteristic desultorily browsing habit one can find their population is steadily growing with every quinquennial census from 1961 onwards. This indicates that more and more people are taking up goat rearing as an avocation though it is not as popular as keeping cows and buffaloes. Probably low cost of maintenance and comparatively high returns coupled with the low risk capital investment had made goat rearing more a popular avocation of small and marginal farmers and of landless labourers.

In Kerala also a steady growth in the population of goats during the last three decades could be seen. Kerala lying between 8° 12' - 12° 48' of north latitude and on the west of Western ghats and east of Lakshadweep sea - has a climate characteristic of this region with wide spread rain for more than half of the year. This characteristic geographical factors and the consequent climate has almost completely excluded sheep rearing in this area whereas goat keeping is becoming more and more popular, suggesting that the climate is suitable for the latter to thrive. Probably this may be the reason why unlike in the case of cows and buffaloes there is a naturally evolved breed of goat in this region identified as the Malabari or the Tellicherry breed. The Malabari goat, in its production potential, is competently comparable with any other Indian and exotic breeds of goats. But there has been no scientific efforts to improve the breed and that led to degradation. Scientific efforts as selective breeding, cross breeding, controlled grazing and adoption of stall feeding will help to get over the problems. Various attempts are now in progress and if these attempts prove successful and economical too, the goat farming will get a tremendous boost in the years to come.

Little attention was given for the improvement of goat farming until 1971. During 1971, the All India Co-ordinated Research Project on Goats was launched by ICAR for the development of high producing strains with special reference to milk, meat and fibre production. At Kerala Agricultural University, Mannuthy also one goat unit was started in the same year for the purpose of milk with Malabari as the native breed and Alpine and Saanen as the improver breeds.

Malabari (Tellicherry) is the native breed of Kerala but more descriptive types are seen in North Malabar in taluks of Kusum, Kottayam, Calicut and Ponnani. Breed Alpine was originated in the Alps and probably derived from French, Swiss and Rock Alpine breeds. A pure bred doe of this breed during 10 months of lactation produced 2,316 kg of milk. Saanen breed was originated in the Saanen Valley of Switzerland. It was famous for high production and persistency in yield. The average milk yield of this breed ranges from 2 to 5 kg per day during a lactation period of 8 to 10 months.

By experience, cross breeding using developed breeds is the best way to raise the production within a short period of time. Lactation curve, persistency, prediction of total yield from part records etc. play vital roles in cross breeding procedures for the improvement of goat rearing programmes with a view to gain maximum yield. So far, very few research workers have made an attempt to investigate especially the lactation trends with the help of lactation curves for the comparison of various prominent breeds. The different authors who attempted these aspects are Prakash and Khanna (1972), Gill and Dev (1972), Singh and Singh (1974) Das *et al.* (1982), Mukundan and Bhat (1983), Kumar *et al.* (1984), Chawla and Bhatnagar (1984), Misra and Rawat (1985) and Garcia *et al.* (1985). None of these research workers attempted to give a mathematical dimension to the lactation trends of milk yield in goats. Hence it was thought to be highly essential to have a mathematically oriented study of milk yield in various prominent breeds of goats available in Kerala based on the milk production in different parities. A comparative study of lactation curves in goats has been undertaken with the following objectives.

1. To fit the various lactation curve models in different breeds of goats and to select the most suitable one.

2. To suggest a procedure for predicting complete lactation yield using various part lactation records.

3. To study the effects of genetic and non genetic factors on milk production traits.

Over the above these it was attempted to compare the persistency of milk yield among selected breeds.

The present investigation is based on the data collected from the seven breeds of goats, viz., Alpine Malabari, Malabari, Saanen Malabari, F_2A, F_2S, F_3A and F_3S maintained at the AICRP on goats at KAU, Mannuthy.

Review of Literature

REVIEW OF LITERATURE

Success of dairy husbandry depends on the ability of the farmer to produce milk well in accordance with the market fluctuations, in other words if more milk is produced at a time when there is great demand it is not only disposed of easily but it also fetches a premium price. This type of market planning is possible only when predictions of demand and supply are made in advance. It is through deriving equations to predict the demand and supply the dairy cattle husbandry has assumed an enviable position compared to dairy goat keeping. A glance through the literature reveals umpteen publications on dairy cattle on the lactation and its persistency and the influence of genetic, seasonal and the like on the lactation to make prediction of lactation possible. Whereas in the area of goat husbandry there has been some attempts to study the effect of genetic, seasonal and the like. But there has been only scanty attempts to derive a lactation curve. As a prelude to derive a lactation curve for goats the relevant literature on cattle and goat is reviewed as given below.

2.1 Milk production in cattle

Van Vleck and Henderson (1961) developed the regression factors for extending part lactation milk records from the within herd analysis of age-at-calving and season-of-calving corrected monthly test day records of Holstein cows in 374 herds. The correlation between the predicted records and the complete records obtained was 0.85 by testing the fourth, fifth and sixth month, the best single months for estimation. The prediction equations were also developed and the criterion used by them in determining the accuracy of prediction was multiple correlation co-efficient.

Dutt *et al.* (1964) reported that the correlation co-efficient of the milk yield in 15, 75 and 135 days with 305-day lactation yield were 0.501, 0.731 and 0.859 respectively for Hariana cows. The regression of milk yield in pounds on the production upto 15, 75 and 135 days in same lactation were obtained as 7.63, 2.54 and 1.68 respectively and were significant. Three prediction equations for the prediction of total lactational yield were also developed.

Wood (1969) explained a model of the form $Y_n = An^b e^{-cn}$, where Y_n is the average daily yield in the n^{th} week and A, b, c are constants, for describing a lactation curve in 859 Friesian lactation record and showed that the curve reached maximum when $n = \frac{b}{c}$, so that the expected maximum yield was $A(b/c)^b e^{-b}$. The expected 305 day yield was derived from

$$Y_k = A \sum_n (n^b e^{-cn} f_{n+k}), \quad n = 1, 2, \ldots\ldots\ldots\ldots, 44$$

where f_{n+k} is the factor adjusting for spring hump seasonality, Y_k from above differed from actual Y_k by a factor g_k, the calving month seasonality effect so that the best estimate of

305 day yield was estimated as $Y_k\ g_k$ where g_k was estimated by dividing the least square estimates of total yield for each calving month, effect of parity removed by corresponding Y_k in the above equation. It was noticed that winter calvers tended to produce more in total lactation than spring calvers.

Appleman *et al.* (1969) collected the monthly test-day records from Holstein cows to determine if age, season of freshening, level of peak production and days open affected the precision of predicted factors used in extending incomplete lactation records and to develop improved regression equations for predicting complete lactation records from month records. The separate least square analysis of monthly means for both the milk and the fat indicated statistical difference between the main effects and presence of interaction. High interactions in the lactation number by month and peak level by month indicated difference in the shape of the lactation curve resulted in the development of separate prediction factors for cows of different age groups and different levels of peak production. For estimating total milk and fat, ratio method was also used and R^2 was chosen to measure the amount of variation. The regression method accounted for upto 8 per cent more variation than did the ratio estimators, with large differences occurring in the early lactation.

Patel and Patel (1975) have shown that the variability of first 60 days and 305 days milk yield were more or less similar and was significant but the age at first calving was not significant and had low variability showing only 6.8 per cent cv in Jersey cattle. Considering the significant contributors, the equation for the prediction of 305 days yield was $Y_j = \alpha + \beta_1 X_j$ where X_j is the cumulative yield at first 60 days of j^{th} cow. ANOVA revealed that the partial yield of 60 days had significant effect on 305 days yield.

Rathi *et al.* (1976) computed eight multiple regression equations with their R^2 for determining the significant contributors on yield from the records of 201 Haryana cattle pertaining to age at puberty, age at first calving, weight at first calving, first service period and first lactation yield. From this it was found that increase in age at first calving would increase the first lactation milk yield which was statistically significant. The relative contribution of age at first calving to the total variability of first lactation milk yield was also high. It was suggested that combining first service period with weight and age at first calving would increase the reliability of prediction equations.

Kellogg *et al.* (1977) analysed the milk production records of healthy Holstein cows with the model $Y_i = \beta_1 t_i^{\beta_2} e^{-\beta_3 t_i} + \varepsilon_i$ where Y_i is the milk production in kg at a specific time 't_i' in months and β_1, β_2 and β_3 are constants to be estimated, by non linear regression. The estimated curves were found to be lower and flatter for the first lactation than for latter lactations and the variances of deviation from the estimated curves were approximately equal after the first month of lactation. Most of the lactations were estimated closely by the above curve (gamma) and the co-efficient of determination was close to zero for means of cows but were not consistent for individual cows.

Yadav *et al.* (1977) compared the relative efficiency of four models, viz. exponential, parabolic exponential, inverse polynomial function and gamma type function based on 745 lactation records of 249 cows of Haryana and its Friesian crosses. The above comparison revealed that inverse polynomial function described the average curve to the extent of 99 per cent with lowest value of standard error followed by gamma type function which described the average curve to an extent of 95 per cent based on R^2 values.

Schaeffer and Minder (1977) described a technique of non-linear model for the prediction of 305 days milk and fat yields of Canadian Holstein and Jersey cattle as

$$Y_{ij} = \frac{A\ \exp(-\beta(i-to))\ (1 - \exp(-B(i-to)))}{B\ \exp(\ \epsilon_{ij}\ )}$$

where Y_{ij} is the amount of milk given on the i^{th} day of the lactation of j^{th} cow, 'to' is a lag time parameter and may indicate when a cow's udder begins to lactate prior to calving, B is the slope of the lactation curve during the increasing production stage, A is associate with peak production, β is the slope during the decline in production after the peak, ϵ_{ij} is a residual effect which subsequently can split into

$$\exp(\epsilon_{ij}) = \exp(r_i \sin(ip))\exp(e_{ij})$$

where i = sin (ip) is a periodic effect observed in the initial analysis and corresponds to seasonal effect in the curve, r represents the amount of periodic effect in a particular set of records and p is 2π divided by the length of period which could differ among lactation groups. The prediction of total yield was worked out also by multiplicative factor and regression co-efficients derived from data. These three methods were then compared and found that the method of non-linear model was atleast as accurate as either the multiplicative or regression method and requires only less computer storage for the estimation of parameters.

Singh and Bhat (1978) compared the relative efficiencies of exponential, gamma type, parabolic exponential and inverse polynomial functions in abstracting lactation curves to establish some suitable models of the lactation curves from the weekly milk production records of Haryana cows. The gamma type function had the better fit for those individual lactations which were having ideal lactation length of 44 weeks. The parabolic function was found to be better for the individual lactations in varying duration. The inverse polynomial was superior in abstracting the average lactation curves while the exponential function did not give better fit in any of the curves.

Cobby and LeDu (1978) proposed a model

$$Y = A(1-e^{-qn})\ e^{-kn} \doteq A\ e^{-kn} - Ae^{-dn}$$

by replacing n^b in Woods model

$Y = A\ n^b\ e^{-cn}$ by (1-exp(-qn)) an asymptotic curve, for which, by large values of 'n' the milk yield approximately follows an exponential decline of K kg/kg/wk. By replacing A exp(-cn) by a line A-kn, another model was obtained as $Y = A-kn-A\ e^{-dn}$, in which after peak the curve tends to the straight line A-kn, K measuring in kg/week and A/k an estimate of length of lactation. Both models were non linear functions of atleast one parameter and therefore non linear estimation method was used. First model did not fit as well as Wood's model while second model was an improvement over Wood's model in just over 36 lactations of dairy cows.

Kumar and Bhat (1979) fitted each of the mathematical models namely, exponential, parabolic exponential, gamma and inverse polynomial by two methods (i) Iterative procedure (non linear) and (ii) logarithmic transformation of function into linear, on average lactation records of six lactations in Indian buffaloes. The gamma type function gave the best possible fit followed by inverse polynomial, parabolic exponential and exponential explaining the variability upto the extent of 99.0-99.3, 98.0-98.5, 94.5-96.4 and 75.3-79.6 per cent respectively for iterative procedure. Similar trend was observed for sum of squares due to deviation from regression.

Malhotra *et al.* (1980) used four mathematical models viz. quadratic, quadratic-cum-log, inverse polynomial and gamma function for studying the lactation curve in karan-swiss cows. Method of least squares was used to determine the parameters and the quadratic-cum-log was their best choice which was based on the percentage of total variation accounted for by the curve (R^2) adjusted for the number of constants in the equation.

Chillar *et al.* (1980) adopted the least square procedure to analyse the records for finding the effect of genetic and non-genetic factors on yield in Hariana and its Friesian crosses. The mathematical model used for the analysis was

$$Y_{ijklm} = \mu + G_i + F_j + L_k + S_l + b(A_{ijkm} - \bar{A}) + e_{ijklm}$$

where Y_{ijklm} is the yield of m^{th} cow of i^{th} genetic group, j^{th} farm, k^{th} lactation sequence and l^{th} season of calving; μ is the population mean when equal subclass numbers exist, G_i is the effect of i^{th} genetic group, F_j is the effect of j^{th} farm, L_k is the effect of k^{th} lactation sequence, S_l is the effect of l^{th} season of calving, b is the regression co-efficient of yield on age at first calving, A_{ijklm} is the age at first calving of m^{th} cow, $\bar{A}$ is the mean age at first calving and e_{ijklm} is the random error associated with Y_{ijklm} NID $(0, \sigma e^2)$. The data then adjusted for the significant effects was utilized to calculate the part-whole correlation. It was found that correlation co-efficient increased with each added successive part lactation yield and the appropriate part record for the prediction of total yield by developing the prediction equation was the 150 days part record.

Saigaonkar *et al.* (1981) studied the persistency of milk yield and the correlation of part record with total yield in Sahiwal herd. It was observed that the persistency was higher in the first lactation than in subsequent lactations. The correlations and linear regression equations for prediction of total yield were developed and established that milk yield upto 52 weeks could be predicted from a yield record of 12 weeks in all lactation except the fourth lactation. But the efficiency of prediction (upto 52 weeks) from the peak yield appeared less than 52 per cent in all lactations.

Dhanoa and LeDu (1982) proposed a new model to describe a lactation curve in dairy cow. It uses the fact that milk yield at a given stage of lactation is largely determined by the yield in the preceeding stage. The model used was

$$Y_t = \lambda(m_o - m_1 t) + (1-\lambda) Y_{t-1}, \; t \geq 1, \; 0 \leq \lambda \leq 1,$$

where Y_t and Y_{t-1} are the current and preceeding milk yield in kg/wk, 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 was used to define a measure of persistency as $P = (1-\lambda)\frac{m_o}{m_1}$, where m_1 is the rate of decline in kg/wk and m_o is a constant.

Rowlands *et al.* (1982) investigated seasonal variation in milk yield and compared four models of the lactation curve

(i) $\log_e y(n) = \log_e a + b \log_e n - cn$

(ii) $y(n) = an^b e^{-cn}$

(iii) $y(n) = a\ e^{-pn} - ae^{qn}$

(iv) $y(n) = a - p'n - a\ e^{-q'n}$

where $y(n)$ is the milk yield in the n^{th} week of lactation, a, b, c are positive parameters describing the shape of the curve and p(exponential decline) or p' (slope of straight line) measures persistency directly, undertaking 468 lactations in two herds of British Friesian cows sampled weekly. Model (ii) fitted the data slightly better on average than models (iii) and (iv), and were all better than model (i). Compared with model (i) model (ii) reduced the average residual mean square proportionally by 0.10 in cows and 0.04 in heifers. Model (iv) described the initial rise in milk yield upto week 5 better than model (i) and (ii) but reached a maximum value slightly early. Models (i), (ii) and (iv) slightly under estimated and (iii) slightly over estimated maximum milk yield, but (ii) provided the best estimate of the position of maximum yield.

Singh and Gopal (1982) preferred to use quadratic-cum-log (Khandekar 1956) among the five models viz. linear-cum-log, quadratic-cum-log, exponential, inverse polynomial and gamma type for explaining a lactation curve in about 46 normal lactation records of non-descript buffaloes. The above model accounted for more than 90 per cent of the variation and was highest than any other model and so it was taken as the standard lactation curve.

Pathak *et al.* (1982) formulated the prediction equations for the prediction of 300 day yield from part record of 100 day yield in Gir cows and observed that these were positively and significantly correlated. They suggested that selection on the basis of 100 days production was sufficiently accurate to select the animals for 300 days production and may increase the genetic gain by permitting early selection of cows and it would give a greater gain in average production than 300 days lactation yield record.

Malhotra and Singh (1982) observed that the lactation curve upto 3 months lactation of 50 karan-swiss breed was quadratic in nature and hence 4 representative sampled points would suffice, but thereafter since the curve was almost linear 3 more points along with first 4 points could explain the entire lactation. Based on this strategy of sampling both random sampling and systematic sampling were studied and found that variance was more for systematic sampled points indicated that the curve based on sampled points provides as good an estimate as based on systematic sampled points.

Cheema and Basu (1983) compared four models of lactation curves in Murrah buffaloes viz. exponential function, parabolic function, gamma-type, inverse polynomial. Among these inverse polynomial explained maximum variation (R^2 = 0.9683) followed by gamma-type, parabolic exponential and exponential. Graphical comparison of the above models showed that gamma-type function was more close to the average lactation curve which shows a best fit to lactation data having lowest total absolute deviation.

Pande (1983) fitted the lactation curves to 968 Gaolao, 24 Brown Swiss x Gaolao, 12 Jersey x Gaolao and 43 Holstein Friesian x Gaolao using 4 mathematical functions viz. exponential, parabolic exponential, inverse polynomial and gamma type. Graphs drawn separately for each function for the breed groups showed that the gamma function gave the best fit with R^2 values ranged from 68.57 to 83.76 per cent for the four functions.

Runpei *et al.* (1983) fitted an incomplete gamma function for 175 lactations of Holstein Friesian cows. Root mean square error in predicting 305 day yield was obtained as 0.716 $\pm$ 0.274 kg with a bias of -0.68 kg. The estimates of yield were found to be high in lactation months 2 and 9 while it was low in months 3 and 8. Errors in estimating 305 day yield from actual 240 day yield in 2 samples comprising 60 lactations were 40.01 and 36.00 kg or less than 0.8 per cent of total yield. Parameters were found to be affected by farm, calving month while persistency and peak yield were found to be affected by calving month and farm respectively.

Shrivastava *et al.* (1984) analysed the first lactation records of 211 and 167 sahiwals and found that differences between farms on monthly milk yield to be highly significant in all the 10 months of lactation. Peak yield was attained in the second month of lactation in one farm while in the other it was in the third month.

Shah and Singh (1984) analysed the lactation records of 128 and 109 Jersey cows in two breeding farms. On one farm 305 days average yield was found to increase from 1-5 lactation while on the other it was higher in second lactation. They noticed that the prediction of lactation yield from 60 days yield was more reliable in the first and second lactation. Persistency index of 92.3-93.9 per cent and rate of decline of 7.3-8.5 per cent per month were also obtained.

Jenkins and Ferrel (1984) estimated the lactation curve by using the empirical equation $y(n) = \frac{n}{ae^{kn}}$ from the milk production data collected on 8-9 years old cross-bred cows at 8 different days after parturition. Individual animal observations were used to estimate the parameters from the above lactation curve $y(n) = \frac{n}{ae^{kn}}$, where y(n) is the daily milk yield of the n^{th} week post partum and 'a', 'k' define the shape of lactation curve. From the ANOVA differences were observed among the breed crosses in 25 weeks of lactation yield and time of peak lactation. The parameter 'k' was found to be not affected the general shape of curve and noticed that it was a very indirect measure of persistency.

Yadav *et al.* (1984) observed that the linear correlation between 300 days milk yield and yields in part lactations of 12-40 weeks by 2 week interval were 0.84-0.90, 0.80-0.90 and 0.72-0.86 for the 3 groups, Jersey, Brown Swiss and Holstein Friesian cross-breds respectively. It was also revealed that the standard error of 300 day estimate decreased linearly with increasing length of part lactation from 16 weeks for Jersey and 12 weeks for Brown Swiss and Holstein Friesian.

Goodall and Sprevak (1984) studied the behaviour of time series obtained from the difference between the observed and fitted values of milk yield and a stochastic model for the milk yield was derived. For the derivation of the model, the milk yield at week 't', y(t) was modelled in two possible ways viz. $y(t) = y^*(t) + \epsilon(t)$ or $y(t) = y^*(t)\,\epsilon(t)$, the deterministic model $y^*(t)$ being the Wood's model $y^*(t) = At^b e^{-ct}$ and $\epsilon(t)$ is a random error term. By logarithmic transformation the model was linearised such that the error term $\log_e \epsilon(t)$ forms an auto-correlation function which was modelled by a first order auto-regressive model of the form

$$\log_e \epsilon(t) = \alpha \log_e \epsilon(t-1) + e\ (t)$$

where e(t) is an independent normally distributed random term with zero mean and α is such that $|\alpha| < 1$. α was estimated by minimising mean square error of the residual averaged over the herd, the MSE (α) being

$$\frac{1}{N}\sum_{i=1}^{N}\frac{1}{ni}\sum_{t=1}^{ni}\left[\log_e\left(\frac{y_i(t)}{y_i^*(t)}\cdot\left\{\frac{y_i^*(t-1)}{y_i(t-1)}\right\}^{\alpha}\right)\right]^2$$

where the index i corresponds to a particular cow in a herd, n_i is the length of the i^{th} series and N the number of cows in a herd. The optimum value of α was 0.55 and any α greater than zero and less than one leads to improvement over the Wood's model. The time series of milk yield was modelled as

$$\log_e y(t) = \log_e y^*(t) + a \log_e(y(t-1) - \log_e y^*(t-1)) + e(t)$$

and the improved fitted values was written as

$$\hat{y}(t) = \left[\frac{y(t-1)}{y^*(t-1)}\right]^{\alpha} y^*(t), \quad \frac{y(t-1)}{y^*(t-1)}$$

being correction factor for trend values. K week ahead forecast milk yield was estimated as

$$\hat{y}(t+k) = y^*(t+K)\left[\frac{y(t)}{y(t)}\right]^{\alpha^k}$$

Murthy *et al.* (1984) predicted the total lactation milk yield using 15, 30 and 45 as test days in the first two lactations of 110 Holstein Friesian x Ongole and 56 Brown Swiss x Ongole. By multiple regression method squared multiple correlations for the prediction equations were obtained as 0.98 and 0.99 for the two breed groups.

Gondal and Rowlinson (1984) used the wood's model

$$y = an^b e^{-cn}$$

('a' is a general scaling factor associated with average daily milk yield at the start of lactation, b and c denote the rise and decline of the lactation curve respectively) for the analysis of 707 lactations of more than 26 weeks in buffaloes. The lactation length was found to be significantly affecting b and c and it was concluded that although season of calving and length of lactation explain much of the variation in the shape of lactation curve, a considerable proportion of the variation was attributed to other factors.

Mainland (1985) estimated the parameters of lactation curve of dairy cows pertaining to three breeds, three lactation groups and three areas in Scotland. The data was grouped into 27 subgroups and then averaged so as to give a curve for each week of calving, lactation number and area. By the regression analysis the data were further reduced to a series of equations similar to equation by Wood (1969) as

$$y(n) = an^b e^{-cn}$$

(y(n) is the milk yield in kg at week 'n' of lactation and a, b, c are parameters). Different areas and breeds were found to affect the shape of the lactation curve.

Goodall and Sprevak (1985) showed that the error term $\log_e \varepsilon(t)$ in the logarithmic convertion of Wood's model (1967), $y_t = At^b e^{-ct} \varepsilon(t)$, was a highly correlated series and they proposed a model to take account of the correlation in the observations. They modelled the error term with a first order autoregressive model of the form

$$\varepsilon(t) = \log_e \varepsilon(t-1) + e'(t)$$

where e'(t) is an independent normally distributed random term with zero mean and α is a parameter such that $|\alpha|<1$ which leads to a one week ahead predictor for the lactation curve and observed that this model gave a good improvement on the fit of data over the second model by Wood (1969). The lactation curves was well specified just after 5 weeks information based on kalman filter estimate. It was compared with ordinary least square estimate using the first 10 weeks data and showed clearly that the ordinary least squares was a totally unsuitable estimation procedure when there was partial information on the lactation and the observations were not independent. While the two methods converges to same precision as the lactation concludes.

Yadav and Sharma (1985) used five different mathematical models viz. linear, exponential, exponential parabolic, inverse polynomial and gamma-type for the study of the trend in lactation curves in cross-bred dairy cattle. Based on R^2 values linear, exponential and exponential parabolic could explain only the declining trend and could not define the shape of lactation curve efficiently and suggested that these curves can be fitted only for low yielders. The lactation curves obtained for high yielders were dome or loop shaped. They preferred to use inverse polynomial and gamma function since these curves could define the shape of lactation curve and could estimate the trend of milk production more satisfactorily.

Sosamma *et al.* (1985) considered 305, 100, 101-200 days yield and peak yield in cross-breds of Jersey and Brown Swiss with local cattle of Kerala to analyse the part-whole records. The least square analysis revealed that farms, year of calving and farm x age interaction effects were significant for 305, 100, 101-200 days yield and peak yield while season did not exert any significant influence.

Hoekstra (1986) demonstrated that the weight parameter in the model

$$Y_t = \lambda(m_o - m_1 t) + (1 - \lambda) Y_{t-1}, \; t \geq 1, \; 0 \leq \lambda \leq 1$$

(where Y_t and Y_{t-1} are the current and preceeding milk yield in kg/wk) proposed by Dhanoa and LeDu (1982) was partially determined by the time from calving to peak yield and hence does not represent the correlation between successive yields satisfactorily.

Grossman *et al.* (1986) used a model similar to Wood's model modified by sine and cosine terms to account for seasonal variations other than season of calving. Based on the first lactation of 397 cows with varying percentages of Holstein and Guernsey provided a means of studying genetic and environmental effects on the co-efficient of the lactation curve,

$$y = an^b e^{-cn} [1 + u \sin(x) + v \cos(x)]$$

where a, b, c, u and v are co-efficients to be estimated, n is the day of lactation and x is the day of the year computed in radians. No evidence of additive genetic variation could be found out associated with co-efficient of the lactation curve except with $\log_e a$ (after logarithmic convertion), the initial yield or general scaling of the curve. But there was some evidence of non additive genetic variation with significant interaction of breed of sire with breed of dam.

Bianchini-Sobrinho *et al.* (1986) used the linear hyperbolic model $y = \beta_o + \beta_1 x + \frac{\beta_2}{x}$ (where y is the milk yield at stage 'x' and β_o, β_1, β_2 are parameters that determine the shape of the curve) as well as the gamma model $y = A x^b e^{-cx}$ (y is the mean daily milk yield during the x^{th} lactation week and A, b, c are positive parameters that determine the shape of lactation curve) to describe the lactation curves of 553 Gir cows in first three lactations. The co-efficient of determination for lactation stage means was 0.96 for both models. When the models were used individually for each cow in the herd, the linear hyperbolic model showed a slightly better fit than the gamma model and they suggested that due to simplicity of linear hyperbolic model it can be preferred over gamma model for estimating total yield from incomplete records.

Mathew and George (1986) considered 174 lactation records of Jersey crossbreds and 90 lactation records of Brown Swiss crossbreds for a study on extending the part lactation records. Total milk yield produced during first 30, 60, 90, 120 and 150 days upto fourth lactation were included in order to find the most suitable part yield for predicting total yield. Linear prediction equations were developed by ratio and regression methods, and from the correlation co-efficient between 310 days yield and various part records revealed 120 days cumulative yield was the most suitable part yield for predicting 310 days yield. Ratio method would be more precise for prediction of total yield from 30, 60 and 90 days cumulative yield while it was 120 and 150 days cumulative yield by the regression method for both crossbreds.

Hayashi *et al.* (1986) described that a normal lactation curve with an initial rapid rise followed by a slower decline from peak yield was similar to the pattern of motion of a particle subjected to a transient acceleration. The equation $y = b(e^{t/c} - e^{-t/ac})$ describing the free oscillation of such a particle was compared with Wood's equation as a model of lactation curve, taking y as milk yield in t days after calving. Applied to daily milk yield data from 32 Holstein Friesian cows there was no significant difference between the two equations, goodness of fit varying between 0.68 to 0.96.

Mathew and George (1986) compared the relative efficiencies of exponential, parabolic exponential, quadratic, quadratic-cum-log, gamma and inverse polynomial functions as lactation curve models on the data comprising of 264 normal lactation records of 148 Jersey and Brown Swiss crossbreds. Models were compared based on multiple correlation co-efficient and furnival indices obtained. It was noticed that exponential, parabolic exponential and quadratic functions explained only the declining trend and could not define the shape of lactation curve efficiently. Gamma and quadratic-cum-log functions provided better fit than other functions while inverse polynomial was found to be the least fitting in both the genetic groups.

Wilmink (1987) estimated the regression models for prediction of 305 day yield for which the relation between known test day yields and remaining yields as well as their means within classes of environmental effects need to be known. For a group of purebred Dutch Friesian cows, single regression, multiple regression and factor analysis models for prediction were compared taking all known test day yields for both multiple regression and factor analysis and last known test day yield for single regression as information source. Lactation curves were estimated per herd on all records adjusted for age and season of calving. No difference was found between any of these three methods. The correlation between predicted and realised yield was obtained as 0.87, 0.88 and 0.88 respectively for parity 1, 2 and greater than 2 when the last test day yield was known at 50 days post partum.

Singh *et al.* (1987) selected a sample from a population of Holstein x Haryana cows without replacement and the relationship between milk yield and days of lactation was determined by fitting inverse polynomial, exponential parabolic function and gamma-type function. The R^2 values revealed that inverse polynomial function was the most suitable function and under this assumption a new estimator was defined for finding the population mean and total. The relationship between milk yield and days in lactation was not linear and hence recommended to use this new estimator and an empirical comparison with sample mean reveals a gain in efficiency of 121.02 to 1139.36 per cent.

Khoda and Trivedi (1987) estimated the single variable regression co-efficient for monthly records and multivariable regression co-efficient for cases where monthly sequential records were available and also for cases where early sequential records were not available in different lactations (1-10) of Jersey cows. The prediction equation for cows entering the herd in third month of first lactation and having 3 months record was developed. With the available 4 months record sequential monthly equations were also developed. Although latter was found to be more accurate for prediction, equations with single monthly records or cumulative records were only a little less accurate. For prediction of total yield, 3rd, 4th, 5th and 6th month gave the best results.

Grossman and Koops (1988) described a lactation curve by a multiphasic function that considered milk yield to result from an accumulation from more than one phase of lactation. The estimated mean milk yields from purebred Dutch Black pied cows from 15 test days with 20 days interval starting from 10 days in milk were fitted by non linear regression using the sum of logistic functions. The diphasic function was at last chosen to estimate parameters of lactation curve for purebred Dutch Black pied and purebred Meuse-Rhine-Yssel cows and the relationship between the two phases of lactation were examined using correlation between the function of estimates for parameters within and between phases.

2.2 Milk production in goats

Prakash and Khanna (1972) studied the effect of order of lactation in a closed herd of Beetal goats and observed that the milk yield increased by 20 per cent upto third lactation where it attained its maximum and declined thereafter. Lactation length was significantly correlated with the lactation yield and the regression co-efficient of lactation yield on lactation length was obtained as 0.765 kg/day.

Gill and Dev (1972) observed that the average birth weight, age at first kidding, lactation yield and lactation length were 3.5 kg, 20.8 months, 310 kg and 239 days respectively based on 75 records of a flock of French Alpine and 2.9 kg, 25.4 months, 289 kg and 240 days respectively based on 31 records of Anglo-Nubian goats.

Singh and Singh (1974) analysed the performance of a flock of Jamnapari goats in U.P. and noticed that the kidding percentage ranged between 57.58 and 100.00 with an average of 79.65. Maximum milk yield observed was in the second lactation and then an abrupt decline upto fifth lactation was noticed. Overall pail yield of 201.96 kg in an average lactation period of 191 days with a varying dry period of 111-128 days in all lactations were also observed. Lactation period was found almost same in first two lactation and thereafter a regular decline was noted. The correlation between lactation yield and lactation period was obtained as 0.71 which was statistically significant.

Mittal *et al.* (1977) conducted a study to find out the effect of breed, season of kidding and age of the dam on milk secreting capacity of Barbari and Jamnapari goats. Jamnapari goats were found to be producing more milk than Barbari goats throughout the period of study. Breed had significant influence on milk yield in Jamnapari while in Barbari season of kidding had significant influence. A highly significant effect of age of dam on yield was also observed.

Das *et al.* (1982) computed the rate of decline per litre per month in four genetic groups viz. Jamnapari, Barbari, Black Bengal and halfbred Saanen x halfbred Jamnapari as per the formula described by Kartha (1934). The mean milk yield was found to be decreasing from first to eighth lactation for Barbari, Saanen x Jamnapari and Jamnapari while in Black Bengal it decreased from first to sixth lactation.

Mukundan and Bhat (1983) examined four functions viz. exponential, parabolic exponential, inverse polynomial and gamma-type functions to establish the best shape of lactation curve in goats. The observed curve in both breeds (Malabari and Saanen halfbreds) showed the same configuration characterised by an initial increase with a steep fall, followed by gradual and slow decrease which was almost linear. Among the functions, inverse polynomial accounted for 99.2, 99.6 and 99.4 per cent of the variability in the lactation curve for Malabari, Saanen halfbred and pooled data respectively. The four functions explained only the descending phase of the lactation curve in which inverse polynomial compared very closely to the actual weekly milk production in both breeds after second week. It was concluded that none of these functions were able to describe the lactation curve in goats however all the functions succeeded in describing the descending phase of curve very satisfactorily.

Singh *et al.* (1983) utilized the data pertaining to a closed flock of Beetal goats adjusted for significant non genetic factors affecting economic characters for finding the optima for age at first kidding, first lactation length and first kidding interval. A third degree equation explained the best relationship between age at first kidding (days) and first lactation milk yield (R^2 = 56.18%) while the relationship between age at first kidding and first lactation yield was curvilinear. The relationship between first lactation length and first lactation yield (R^2 = 94.49%) and the relationship between first kidding interval and first lactation length (R^2 = 43.66%) were found to be linear. The average age at first kidding, first lactation length and first kidding interval was obtained as 776, 174 and 381 days respectively. It was suggested that if these characters were restricted to their optima of 510, 150 and 285 days respectively there will be a little or no decline in first lactation yield but one more kidding was possible by that time which was more economical.

Gupta and Gill (1983) analysed the lactation records of 34 Alpine, 55 Alpine x Beetal and 100 Beetal goats and from the analysis lactation length and yield were found to vary considerably between groups. The daily milk yield in 1-3 lactations averaged 0.92, 1.42 and 0.69 kg respectively in Alpines while in

Beetal it increased from 0.65 kg in first lactation to 0.81 kg in third lactation and in crossbreds it was from 0.79 to 1.52 kg. Similar trend was observed in peak yield also.

Kumar *et al.* (1984) recorded the monthly yields of Saanen, Jamnapari, Barbari, Black Bengal along with lactation length and lactation yield and the rate of decline per litre per month was calculated according to the formula described by Kartha (1934). The milk yield rate of eight Saanen and eight halfbred Saanen x halfbred Black Bengal was also observed. The milk yield was found to be highest during second month in Saanen, halfbred Saanen x halfbred Black Bengal, Barbari and Black Bengal while in Jamnapari it was highest in first month and then declined gradually. Lactation yield was maximum during second lactation in Saanen and Black Bengal and during third in half Saanen x half Black Bengal. Persistency of milk yield in Black Bengal goats during first two lactations was about 81 per cent and the rate of decline of milk yield in Black Bengal was higher (0.4931) in second lactation than in first (0.1561) lactation.

Chawla and Bhatnagar (1984) showed significant differences among lactation with each genetic group, among genetic groups between 2-and 3-breed crosses and among different grades within genetic group based on the study of 377 lactation of Alpine Beetal (AB), Saanen Beetal (SB), Saanen-Alpine-Beetal (SAB), Alpine-Saanen-Beetal (ASB) in which AB comprised of

F_1, F_2, F_3 and 75% grades, SB of F_1 and 75% grades, SAB and ASB were 75% with 2 exotic breeds. Average milk yield of these genetic groups were found to be increasing from 1 to 3 lactation. The effect of order of lactation was significant in all the groups and the highest milk yield was observed in the third lactation and lowest in first. Pooled average milk yield was higher in SB and also noticed that effect of grade on milk yield was significant in AB, SB and SAB. Significant decline in milk production from F_1 to F_2 and F_3 was also noticed. Significant difference in mean milk production among first generation halfbreds with various levels of Alpine and Saanen cross-breds with Beetal indicated that these improved exotic breeds would be advantageous for increased lactation yield.

Misra and Rawat (1985) reported that there was no significant difference between the two genotypes Sirohi and Beetal x Sirohi with respect to part yields and total yields in all the three lactations studied utilizing the part lactation records of 50, 90 and 150 days of 184 lactations. The effect of parity was found to be highly significant. The product moment correlations between part and total yields were highly positive and significant. They also observed that, for the first two lactations the first monthly yield was the earliest information that could be utilized in predicting the total yield, correlation ranging from $r = 0.79 \pm 0.07$ to 0.86 ± 0.06 whereas for the third it was 90 days yield.

Garcia *et al.* (1985) estimated the curve of lactation during suckling by analysing the kid weight and milk yield from 50 goats in a herd. During suckling, the daily milk yield was found to be increasing in weeks 1-4 and then decreasing. Average milk yield obtained was 1.80-2.08 kg in months 1-6 peaking in month 4 and then decreasing by 8th month. Maximum yield was attained in the fourth lactation.

Joshi and Singh (1986) observed that the lactation milk yield was significantly correlated with kids birth weight (0.72) and with dam's weight at kidding (0.61) from the lactation records collected from 40 Barbari goats. Together, they accounted for 16 per cent variation in milk yield. The prediction equation developed for lactation milk yield (y) was $y = -11.383 + 37.825\ x_1 + 1.426\ x_2$, where x_1 is the kid weight and x_2 is the dam's weight at kidding. The difference between the average predicted yield (85.8 kg) and average actual yield (80.3 kg) was found to be not significant.

2.3 Persistency of lactation

Persistency denotes the capacity of an animal to maintain lactation without much decline throughout the lactation period. It is expressed as the rate of decline in milk production from the peak in a lactation to cessation of production. Peak yield, lactation length and persistency are the three major factors determining the shape of the lactation curve. Persistency index and the shape of the lactation curve will give good indication about the performance and hence can be utilized in selection.

Asker and Bedeir (1961), based on the statistical analysis of 722 lactations of 328 buffaloes, a formula for estimating persistency was developed, viz.,

$$\text{Persistency} = 0.357 \frac{x_2}{x_1} + 0.333 \frac{x_3}{x_2} + 0.310 \frac{x_4}{x_3}$$

where x_1 is milk yield during 56 days (28th to 84th), x_2 is milk yield during second 56 days (84th to 140th), x_3 is milk yield during third 56 days (140th to 196th) and x_4 is milk yield during fourth 56 days (196th to 252nd). The three constants (0.357, 0.333, 0.310) were derived from data to weight the three ratios which represent the comparative decline in milk yield. By this formula persistency was found to be lowest during first lactation and it increases at the second lactation where it reached the maximum after which variations during subsequent lactations was negligible. The effects of month of calving and lactation period on persistency was found to be highly significant. The correlation between calving interval and persistency was also found to be highly significant.

Anakawiang (1963) compared two methods for finding persistency for the data comprising of Sahiwal, Tharparkar and Red Sindhi cows considering only the 305 day milk yield. First method (Mahadevan, 1951) used was $p = \frac{a-b}{b}$ where 'a' is the total yield in 305 days and 'b' is the initial yield in first 60 days of lactation and the second method (Ludwick and Petersen, 1943) was

$$p = \frac{x_2}{x_1} k_1 + \frac{x_3}{x_2} k_2 + \frac{x_4}{x_3} k_3 \quad \text{where}$$

x_1 is milk yield in the 2nd + 3rd month,

x_2 is milk yield in the 4th + 5th month,

x_3 is milk yield in the 6th + 7th month,

x_4 is milk yield in the 8th + 9th month

and the constants k_1, k_2, k_3 represent the weights of the three ratios $\frac{x_2}{x_1}$, $\frac{x_3}{x_2}$ and $\frac{x_4}{x_3}$. When values of persistency were grouped according to lactation number, breed of cow and method of calculation the persistency values of first lactation was found to be higher than those in subsequent lactation. Differences in persistency among breeds as well as among lactation were also found to be highly significant.

Rao *et al.* (1970) analysed the first six lactation records of Murrah buffaloes and revealed that maximum yield was attained in the fifth lactation in one herd while in the other herd it was in the fourth lactation. In all lactations, peak production was attained in the second month. Persistency estimated by the method developed by Mahadevan (1951) showed that first lactation had the highest persistency. It was noted that age at first calving had no significant effect on persistency.

Also noticed that peak yield, persistency and other production traits had greater influence on milk production.

Pradhan and Dave (1973) observed that Kankrej cows reached their peak weekly production of 61.91 kg in the 7th week after freshening and then gradually and regularly declined to 33.79 kg, in the 41st week. The average persistency of milk yield was observed as 97.907 ± 0.74 per cent and noticed that parity had significant effect on persistency. The persistency was found to be decreasing from 1-6 lactations, the decrease being marked from 4th lactation onwards.

Bhat *et al.* (1979) indicated that persistency was significantly affected by farm, lactation order and year of calving in Indian buffaloes. The heretability estimates of persistency index was obtained as 0.003 ± 0.114 and these estimates suggested that persistency cannot be taken as a trait for selection and can be improved only by better feeding and management.

Moon *et al.* (1982) applied the model

$$y = a\, n^{b}\, e^{-cn}$$

(where y is the milk yield in month 'n' and a, b, c are constants to be estimated) to the lactation records of cows classified according to season of calving, parity, lactation length and milk yield. The constants were estimated with $R^2 = 0.99$ and found that the initial yield, peak yield after 1.8 months and persistency were 16.7 kg, 22.5 kg and 13.6 respectively. Differences in lactation curve among parities was observed. Peak yield in lactations 1-2, 3-4, 5-6 and 7-8 were 19.02, 24.23, 25.25 and 21.83 kg respectively while persistency showed a reverse trend. Also, persistency was found to increase as lactation length increase.

Rao and Sundaresan (1982) fitted lactation curves to the data came from 455 lactations of Sahiwal cows and crossbreds with 1/4, 1/2, 5/8 and 3/4 Friesian inheritance using a gamma function. Lactation persistency was estimated by (i) co-efficient of variation among daily yields in different weeks of lactation (ii) The ratio of 300 day yield to peak yield (iii) $-(b + 1) \log_e c$ in the gamma function. Lactation curve shape, persistency and 300 day yield were all found to be influenced by genetic group, parity and calving season. Persistency was highest in the first lactation and for those calving in the monsoon season. Crossbreds with 1/2 to 5/8 Friesian inheritance were superior to other genetic groups both in lactation milk yield and persistency.

Bhat *et al.* (1982) tried to estimate the persistency of milk yield by eight different methods utilizing the weekly milk yield records of Murrah buffaloes during first six lactations. Persistency indices P_1, P_2, P_3 were estimated using the method suggested by Ludwick and Petersen (1943) by dividing the lactation period of each animal into 2, 4 and 11 weekly intervals.

P_4 was calculated as $P = \frac{A-B}{B}$ (Mahadevan, 1951) where 'A' is the yield during first 26 weeks and 'B' is the yield upto peak. P_5 was computed on the basis of the method by Anakawiang (1963) as $\frac{a-b}{a}$ where 'a' is the toal yield upto 305 days and 'b' is the milk yield upto peak. The lactation period of each animal was divided into 14 weeks period and P_6 and P_7 were computed as

$$P_6 = \frac{\text{Milk yield from 15th to 28th week}}{\text{Milk yield from 1st to 14th week}}$$ and

$$P_7 = \frac{\text{Milk yield from 29th to 42nd week}}{\text{Milk yield from 1st to 14th week}}.$$ The ratio between the average daily yield till peak yield and the average daily yield in the remaining part of the lacatation was taken as P_8. Mean persistency indices obtained was in the range of 0.673 ± 0.006, 4.70% to 4.63 ± 0.109, 56%. Farms, sequence of lactation and year of calving had significant influence on measures of persistency and a comparative study of the efficiency of above methods showed P_2 was most suitable for buffaloes.

Shah *et al.* (1983) calculated the persistency of part lactations in all the four lactations of 32 halfbred Friesian cows according to the method by Ludwick and Petersen (1943). In all lactations, milk yield reached a maximum in one or two months after calving and then declined thereafter. Persistency averaged 92.18, 92.93, 94.49 and 83.80 per cent in first 4 lactations respectively. Rate of decline in milk yield was also calculated (Kartha 1934) and the values obtained were 7.125, 12.31, 16.14 and 8.58 per cent respectively for first 4 lactations.

Girija *et al.* (1984) used the formula of persistency, developed by Mahadevan (1951), for Jersey x Zebu and Brown Swiss x Zebu crossbreds. It was found that the persistency indices were 4.78 ± 0.30 and 4.18 ± 0.15 respectively for the crossbreds Jersey x Zebu and Brown Swiss x Zebu. Correlations of persistency with lactation length, peak yield and 305 days yield were found to be highly significant in the case of Brown Swiss crossbred but not in Jersey crossbred whereas both types were quite persistent in production. The lactation curves obtained revealed that following parturition the yield sharply increased upto 3rd week and then rather slowly rose to maximum by 7th week which was more or less maintained upto 9th week and thereafter declined.

Goel and Tomar (1984) expressed the means of month to month milk production in the lactation as least square means, gamma function means and inverse polynomial means utilizing the milk production data in Hariana cows upto fifth lactation. The persistency in milk production was then estimated in terms of (i) observed rate of month to month decline in milk production (ii) Standard deviation of rate of decline and regression of rate of decline and (iii) regression of rate of decline on time (month). With all these methods, the milk production was more persistent in first lactation and gamma function method was found to be more precise to express the persistency with any measure.

Malhotra *et al.* (1984) calculated the persistency index of individual animals from the data of Murrah buffaloes in first 4 lactations by the formula

$$P = W_1 R_1 + W_2 R_2 + \text{-----------------} + W_9 R_9$$

$$\text{where } W_1 = \frac{R_1}{R_1 + \text{----} + R_9}, \text{ ----------}, \quad W_9 = \frac{R_9}{R_1 + \text{------} + R_9}$$

R_1, R_2, ------, R_9 being the ratio between the yield of each segment with the yield of its preceeding segment taking biweekly yield. Lactation wise persistency for the first four lactations were obtained as 0.98, 0.98, 0.98 and 0.96 respectively. Correlation between persistency index and total milk yield was found to be significant in the first three lactations.

Singh and Shukla (1985) on utilizing 595 normal lactations of Gir cattle, persistency of milk production was calculated by the method of Sturtevant (1887) which was modified by Pradhan and Dave (1973) (Instead of monthly yield, weekly yield was utilized) and the mean persistency values was obtained as 97.67 per cent. The persistency was found to be significantly affected by parity while season of calving, preceeding dry period and sire had no effect on persistency of milk production. Persistency was found to be more in first lactation than in higher lactations.

Bhutia and Pandey (1989) analysed the monthly milk production records from 974 normal lactations of Friesian (HF)X Sahiwal cross-bred cows comprising (i) 3/4 HF (ii) 5/8 HF (iii) 1/2 HF and (iv)3/8 HF and noticed that estimates of persistency based upon co-efficient of variation was in the order (i) > (ii) = (iv) > (iii). Based upon the ratio of total yield; peak yield was in the order (ii) > (iii) > (i) > (iv) and the phenotypic correlation of persistency with peak yield in first lactation was found to be negative and significant in all groups except (iv) while with peak yield of pooled lactation, the correlation was negative in group (ii) and positive in all the other groups. Phenotypic correlation of persistency with 300 days yield was positive and significant for first lactation in all groups and for pooled lactation in groups (ii), (iii) and (iv).

Materials and Methods

MATERIALS AND METHODS

3.1 Materials

In the present investigation - 'A comparative study of lactation curves in goats', the data pertaining to the milk production for different parities of various breeds brought up at the AICRP on goats at Kerala Agricultural University, Mannuthy farm during the period 1976-'87 are collected and utilized. The number of goats under different parities of the different breeds are as given below:

Parity / Breed	1	2	3	4	5	6	7	8	9	10	11
Alpine Malabari	120	117	99	68	48	31	22	13	3	1	1
Malabari	50	42	23	15	9	8	2	1	-	-	-
Saanen Malabari	63	50	43	31	13	7	1	1	1	1	-
F_2A	105	79	50	30	17	6	1	1	-	-	-
F_2S	59	41	26	15	9	7	4	1	-	-	-
F_3A	27	17	4	2	-	-	-	-	-	-	-
F_3S	29	18	10	7	2	1	1	-	-	-	-
	453	364	255	168	98	60	31	17	4	2	1

Alpine Malabari

Saanen Malabari

Malabari

F_2A

F_2S

F_3A

F_3S

All the animals are born and brought up in one farm under identical conditions of management and feeding regime. Incomplete lactation records due to culling, death, sale and other pathological conditions are not included in this study. Abnormal records such as those affected by abortion, premature birth, still birth, mastitis and death during lactation are excluded. Abnormal lactations of less than 20 weeks duration are also excluded from this study. The weekly milk yield data of 20 weeks duration thus obtained are utilized for studying the lactation curves, prediction of total lactation yield, effect of genetic and non-genetic factors on milk production and persistency of milk production.

3.2 Methods

3.2.1 Milk production curves

The following lactation curves are fitted to find the best representative curve in seven breeds of goats viz. Malabari, Alpine Malabari, Saanen Malabari, F_2A, F_2S, F_3A and F_3S.

Linear	: $Y_t = a + bt$
Exponential (Brody *et al.*, 1923)	: $Y_t = a \exp(bt)$
Parabolic exponential (Sikka, 1950)	: $Y_t = a \exp(bt + ct^2)$
Inverse polynomial (Nelder, 1966)	: $Y_t = t(a + bt + ct^2)^{-1}$
Gamma type (Wood, 1967)	: $Y_t = at^b \exp(-ct)$

McNally Model (McNally, 1971)	: $Y_t = at^b \exp(-ct + dt^{1/2})$
Quadratic (Ramachandra *et al.*,1979)	: $Y_t = a + bt + ct^2$
Quadratic log scale (Ramachandra *et al.*,1979)	: $Y_t = a + b \log_e t + C(\log_e t)^2$
Quadratic-cum-log (Malhotra, 1980)	: $Y_t = a + bt + ct^2 + d \log_e t$
Empirical equation (Jenkins and Ferrel, 1984)	: $Y_t = t\,(a \exp(bt))^{-1}$
Linear hyperbolic equation (Bianchini-Sobrinho *et al.*,1986)	: $Y_t = a + bt + ct^{-1}$

3.3 Fitting lactation curves

The functions mentioned above are fitted to the weekly milk yield (kg) data separately for each parity and also for the pooled data of each breed under study with the help of least square analysis technique. In the above functions, Y_t refers to the weekly milk yield at time t.

3.3.1 Estimation of parameters

The parameters of the curves are estimated as follows. (Kendall *et al.*, 1983) : General linear model is

$$\underline{Y}_{n \times 1} = \underline{X}_{n \times k}\, \underline{B}_{k \times 1} + \underline{U}_{n \times 1}$$

where $\underline{B}$ is a (k x 1) vector of regression co-efficients, $\underline{X}$ is an (n x k) matrix of known co-efficients and $\underline{U}$ an (n x 1) vector of 'error' random variables with mean and dispersion matrix

$E(\underline{u}) = o$, $V(\underline{u}) = \sigma^2 I$. The vector of least square estimators of $\underline{B}$ is given by $(\underline{X}'\underline{X})^{-1} \underline{X}'\underline{Y}$ and its dispersion matrix is $V(\underline{B}) = \sigma^2 (\underline{X}'\underline{X})^{-1}$. Unbiased estimators of σ^2 is s^2 where $(n-k)s^2 = (\underline{Y}-\underline{X}\underline{B})' (\underline{Y}-\underline{X}\underline{B}) = \underline{Y}'\underline{Y} - \underline{B}'\underline{X}'\underline{Y}$.

3.4 Comparison of lactation curves

For comparing the relative efficiency of various fitted models and for selecting the most suitable curve, methods used are

(i) Co-efficient of determination (r^2)

(ii) Standard error of the estimate (s)

(iii) Furnival index (I)

3.4.1 Co-efficient of determination (r^2)

It is calculated as the square of the correlation co-efficient between the observed and the predicted values. A large value of r^2 indicates best fit of the curve.

3.4.2 Standard error of the estimate (s)

The standard error of the estimate measures the inadequacy of fit of the equation or of the error which is made in the estimation or prediction of Y_t from given values of t.

The standard error of the estimate is calculated as

$$s = \sqrt{\frac{\Sigma(y_i - \hat{y}_i)^2}{n-2}}$$

where $\hat{y}_i$ is the predicted values and 'n' is the number of observations. A small value of 's' indicates goodness of fit of the curve.

3.4.3 Furnival index (I)

Furnival (1961) constructed an index I of fit as

$$I = \left[\frac{1}{\prod_{i=1}^{n} f'(y_i)} \right]^{1/n} x\ s$$

where $f'(y_i)$ is derivative of some function of f(y) of the dependent variable y w.r.t. y, n is the number of data points, s is the root mean square residual obtained from fitted regression. A large value of I indicates a poor fit and vice versa.

3.5 Predicting complete lactation from part records

Total yield produced by a goat during the first 4, 8 and 12 weeks of a lactation are considered as part lactation yield for predicting total lactation yield. Records of part lactation are analysed separately for each parity of the seven genetic groups.

Taking yields at the first 4 weeks of a lactation, the best equation selected in the previous study is fitted. Using this as the prediction equation the total yields at various time points are estimated. The prediction equations are developed separately for each lactation of each breed and the accuracy of prediction is assessed using r^2 and s values. The most appropriate part lactation record among the three sets (4, 8 and 12 weeks) for predicting complete lactation are compared and the best period is suggested.

3.6 Estimation of effects of genetic and non-genetic factors

As the data involves unequal number of observations under each parity and under each breed a two way classified non-orthogonal data analysis with interaction is performed as suggested by Harvey (1960). Since F_3A breed is having data only upto fourth parity and under each parity the number of animals are also very less this breed is excluded from the study. The data for all the other six breeds upto the sixth parity are made use of for this analysis.

3.6.1 Statistical analysis

In order to study the effect of breed, order of lactation and their interaction on total yield, the model used is

$$Y_{ijk} = \mu + a_i + b_j + (ab)ij + e_{ijk}$$

where Y_{ijk} is the value (yield) on the $(i, j, k)^{th}$ unit for i = 1, 2 -----------------, I, j = 1, 2 ---------------, J and k = 0, 1, 2, --------------, n_{ij}. Here I = 6 (number of breeds),

$J = 6$ (order of lactation) and n_{ij} = number of animals belonging to each unit.

μ is the overall mean

a_i, b_j, $(ab)_{ij}$ and e_{ijk} are random variables with zero means and variances σ_A^2, σ_B^2, σ_{AB}^2 and σ_e^2 respectively. The correlations between any two variables (not the same) are assumed to be zero. Here $N_{i.} = \sum_j n_{ij}$, $N_{.j} = \sum_i n_{ij}$, $N_{..} = \sum\sum_{ij} n_{ij}$ and $N'_{..}$ is the number of subsclasses filled in the two way table with A (breed) and B (order of lactation) factors.

The ANOVA table is as follows:

Source	df	SS	MS	E(MS)
A	I-1	$\sum_i \frac{Y^2_{i..}}{N_{i.}} - \frac{Y^2_{...}}{N_{..}}$	A.M.S.	$\sigma_e^2 + K_7\sigma_{AB}^2 + K_8\sigma_A^2 + K_9\sigma_B^2$
B	J-1	$\sum_j \frac{Y^2_{.j.}}{N_{.j}} - \frac{Y^2_{...}}{N_{..}}$	B.M.S.	$\sigma_e^2 + k_4\sigma_{AB}^2 + k_5\sigma_A^2 + k_6\sigma_B^2$
AB	$(N'_{..}-I-J+1)$	$\sum\sum_{ij} \frac{Y^2_{ij.}}{n_{ij}} - \sum_i \frac{Y^2_{i..}}{N_{i.}} - \sum_j \frac{Y^2_{.j.}}{N_{.j}} + \frac{Y^2_{...}}{N_{..}}$	AB.M.S.	$\sigma_e^2 + k_1\sigma_{AB}^2 + k_2\sigma_A^2 + k_3\sigma_B^2$
Error	$N_{..}-N'_{..}$	$\sum_i\sum_j\sum_k Y^2_{ijk} - \sum\sum_{ij} \frac{Y^2_{ij.}}{n_{ij}}$	E.M.S.	σ_e^2
Total	$N_{..}-1$	$\sum_i\sum_j\sum_k Y^2_{ijk} - \frac{Y^2_{...}}{N_{..}}$		

where

$$k_1\ (I-1)(J-1) = N_{..} - \sum_i \sum_j \frac{n_{ij}^2}{N_{i.}} - \sum_i \sum_j \frac{n_{ij}^2}{N_{.j}} + \sum_i \sum_j \frac{n_{ij}^2}{N_{..}}$$

$$k_2\ (I-1)(J-1) = \sum_i \frac{N_{i.}^2}{N_{..}} - \sum_i \sum_j \frac{n_{ij}^2}{N_{.j}}$$

$$k_3\ (I-1)(J-1) = \sum_j \frac{N_{.j}^2}{N_{..}} - \sum_i \sum_j \frac{n_{ij}^2}{N_{i.}}$$

$$k_4\ (J-1) = \sum_i \sum_j \frac{n_{ij}^2}{N_{.j}} - \sum_i \sum_j \frac{n_{ij}^2}{N_{..}}$$

$$k_5\ (J-1) = \sum_i \sum_j \frac{n_{ij}^2}{N_{.j}} - \sum_i \frac{N_{i.}^2}{N_{..}}$$

$$k_6\ (I-1) = N_{..} - \sum_j \frac{N_{.j}^2}{N_{..}}$$

$$k_7\ (I-1) = \sum_i \sum_j \frac{n_{ij}^2}{N_{i.}} - \sum_i \sum_j \frac{n_{ij}^2}{N_{..}}$$

$$k_8\ (I-1) = N_{..} - \sum_i \frac{N_{i.}^2}{N_{..}}$$

$$k_9\ (I-1) = \sum_i \sum_j \frac{n_{ij}^2}{N_{i.}} - \sum_j \frac{N_{.j}^2}{N_{..}}$$

The k-functions are defined for filled cells only. After obtaining the values of k functions the estimates of variances σ_A^2, σ_B^2, σ_{AB}^2 and σ_e^2 are obtained by equating MS and E(MS) and solving for the estimate of variances. The different sources of variation are tested and their mean values are compared by calculating appropriate CD values.

3.7 Comparison of persistency indices among the breeds

Persistency denotes the extent of capacity of the animal to maintain the level of milk production after attaining the peak throughout the lactation. Measure of persistency is a dimensionless quantity, which has been used to compare different lactations and different breeds of goats by four different methods.

3.7.1 Method I

Ludwick and Petersen (1943) formulated a general measure for persistency. Here, any logical number of division of the lactation can be accommodated and two variables are involved. The number of divisions into which the curve is divided (n) and the production in any specific period (x_1 to x_n). The denominator of the fraction representing persistency included only one variable (n) and is merely another method of expressing partial factorials or the summation of consecutive figures within given limits. The formula is

$$P = \frac{\frac{x_2}{x_1} n + \frac{x_3}{x_2} (n-1) + \ldots\ldots\ldots + \frac{x_n}{x_{n-1}} (n-(n-2))}{n(n-1) - \frac{(n-1)(n-2)}{2}}$$

where P is the persistency, x (with the aid of subscripts) designates the production of any particular period, n the number of divisions into which the lactation is divided.

Taking 20 weeks lactation record and dividing it into 4 parts the persistency is calculated by the formula

$$P = \frac{4}{9} \frac{x_2}{x_1} + \frac{1}{3} \frac{x_3}{x_2} + \frac{2}{9} \frac{x_4}{x_3}$$

3.7.2 Method II

Mahadevan (1951) developed the formula for persistency as $P = \frac{a - b}{b}$ where 'a' is the total yield and 'b' is the yield upto peak.

Here total yield is taken as 20 weeks yield and yield upto peak is taken as yield at the end of one month after kidding.

3.7.3 Method III

Wood (1967) defined persistency as $P = -(b + 1)\log_e c$ in the gamma type function $y_t = at^b e^{-ct}$ where y_t is yield (kg) at time 't' and a, b, c are constants.

3.7.4 Method IV

Malhotra *et al.* (1984) used the measure of persistency as $P = W_1 R_1 + \ldots\ldots\ldots + W_9 R_9$ by dividing the lactation length into 10 segments where

$$W_1 = \frac{R_1}{R_1 + \ldots\ldots\ldots + R_9}, \quad W_2 = \frac{R_2}{R_1 + \ldots\ldots + R_9},$$

$$\ldots\ldots, W_9 = \frac{R_9}{R_1 + \ldots\ldots\ldots\ldots + R_9}, \quad R_1, R_2, \ldots\ldots\ldots\ldots\ldots, R_9$$

being the ratio between the yield in each segment with the yield of its preceeding segment. The same procedure is carried out here also taking 20 weeks lactation yield and dividing it into 10 segments.

Breeds having highest degree of persistency over all parities are the most economic yielders. Low persistency corresponds to poor yielders and to goats drying up earlier than normal period.

Results

RESULTS

The present investigation - 'A comparative study of lactation curves in goats' was undertaken mainly to study the lactation curves of goats with the following objectives

1. To fit various lactation curve models in different breeds of goats and to select the most suitable one
2. To suggest a procedure for predicting complete lactation yield using various part lactation yields
3. To study the effects of genetic and non-genetic factors on milk production traits
4. To compare the persistency of milk yield among the selected breeds

based on the milk yield in each lactation of the seven genetic groups maintained at the AICRP on goats, KAU, Mannuthy.

4.1 Average milk production in various breeds of goats

4.1.1 Alpine Malabari

The average weekly milk yield of this breed and the standard error (SE) are presented in Table 1. From the table it was observed that the mean yield in the first week of first parity was 4.9358 kg. This yield increased to 5.2164 kg during the second week and then slowly decreased to 2.5582 kg by the end of twentieth week. In the second parity also this trend of first increasing and then decreasing was noticed but the yield had increased a little from the first parity. All the available eight parities of this breed were considered for this study and in almost all parities the same lactation trend was observed except for fifth and sixth parity. The highest average milk production of 5.0733 kg was attained in the seventh parity.

4.1.2 Malabari

The average weekly milk yield and SE of the available six parities of this breed are shown in Table 2. It was noticed from this table that the mean yield in the first week of first parity was 3.6686 kg and then it declined to 2.0400 kg by the end of twentieth week. During the second parity the average weekly yield decreased from 4.6806 kg to 2.2839 kg. But the general trend of progressive increase in the first month of lactation followed by a gradual decrease to the minimum yield was observed in the remaining four parities. The maximum average milk yield was observed in the fifth parity (4.0688 kg).

4.1.3 Saanen Malabari

The available data of five parities were taken into consideration for this breed and their average weekly yield and SE are presented in Table 3. During the first week of first parity the average yield was 5.9367 kg. It has increased to 6.0878 kg during the second week and then declined to 3.2490 kg in the twentieth week. The mean yields during second and third parity were higher than the first parity but these parities showed only a declining trend. While, fourth and fifth parities manifested the lactation trend correctly. The highest average yield of 5.5583 kg was noticed in the fourth parity.

4.1.4 F_2A

All the data of available six lactation yields average and their SE are shown in Table 4. From this table, it was noticed that the average yield during the first week of the three parities were 4.1022 kg, 4.6588 kg and 5.7421 kg and it decreased to 2.3444 kg, 2.7765 kg and 3.1132 kg respectively by the end of twentieth week thus exhibited only the descending phase of lactation. But the remaining three parities showed both the ascending and descending phase of lactation more satisfactorily. The superior average yield of 4.4869 kg was seen in the fifth parity.

4.1.5 F_2S

The mean yield and SE of this breed over the data of available seven parities are shown in Table 5. It was noticed from this table that the yield during first week of first parity was 4.9056 kg, reached peak after one month (5.0778 kg) and then decreased throughout the lactation. First six parities showed both the ascending and descending phases of lactation but in the seventh parity only the descending phase could be seen. The overall of the weekly average yield was highest in the sixth parity (6.2533 kg).

4.1.6 F_3A

Average yield with their corresponding SE for each of three parities available are given in Table 6. During the first week of three parities the average yields were 4.4760 kg, 5.1692 kg and 4.1000 kg respectively. Yield reached maximum after a period of about one and a half month from the commencement of lactation and then a declining trend was noticed in all the parities.

4.1.7 F_3S

For this breed, data of only four parities were available and it was considered for this study. The mean yield and SE of the four parities are shown in Table 7. For the first and second parities only the declining trend was noticed but for the third and fourth parities, typical lactation trend as well as higher yields were noticed. Peak production was observed in the third parity with an average yield of 4.9000 kg/week.

4.1.8 Pooled average analysis

Under the pooled average analysis the data had been pooled over all parities under each breed. The average yield and the corresponding SE for the twenty weeks for each of the seven breeds are presented in Table 8. From this table both the phases of lactation was exhibited by each of the breed.

4.2 Fitting of lactation curves

All the eleven types of curves mentioned in section 3.2.1 were fitted to each of the parity and also to the pooled data of the seven breeds under study. The estimate of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) obtained for each lactation curve were given in Tables 9-19.

4.2.1 Alpine Malabari

Among the eleven different types of curves fitted to this breed it was observed that quadratic-cum-log function (Table 17) and linear hyperbolic function (Table 19) gave the best fits for the pooled data. The fitted form of the quadratic-cum-log was as given

$$Y_t = 5.6720 - 0.2309\ t + 0.0011\ t^2 + 0.4600\ \log_e t$$

with r^2, s and I as 0.9935, 0.0786, 0.0786 respectively. The second best fitted function (linear hyperbolic) was of the form

$$Y_t = 6.2404 - 0.1667\ t - \frac{0.6410}{t}$$

with r^2, s and I as 0.9916, 0.0866, 0.0866 respectively.

4.2.2 Malabari

The quadratic-cum-log (Table 17) and linear hyperbolic (Table 19) functions ranked first and second respectively in fitting the lactation trend to the pooled data of Malabari. The former had got the form

$$Y_t = 4.4999 - 0.1995 + 0.0009\ t^2 + 0.4630 \log_e t$$

with r^2, s and I as 0.9799, 0.1145 and 0.1145 respectively while the latter had got the form

$$Y_t = 5.0952 - 0.1399\ t - \frac{0.6584}{t}$$

with r^2, s and I as 0.9756, 0.1222 and 0.1222 respectively.

4.2.3 Saanen Malabari

The linear hyperbolic function (Table 19) and quadratic log scale function (Table 16) were the best two selected curves for the pooled data among the three (linear hyperbolic, quadratic log scale, gamma type) which could explain both the phases of lactation. The linear hyperbolic function had got the form

$$Y_t = 6.9215 - 0.1511\ t - \frac{0.5728}{t}$$

with r^2, s and I as 0.9750, 0.1369, 0.1369 while the quadratic log scale function had got the form

$$Y_t = 6.0964 + 0.8035 \log_e t - 0.5021 (\log_e t)^2$$

with r^2, s and I as 0.9587, 0.1759 and 0.1759 respectively.

4.2.4 F_2A

The quadratic-cum-log (Table 17) and linear hyperbolic (Table 19) functions were found to be the most suitable curves for the pooled data of this breed. The former had got the form

$$Y_t = 4.9673 - 0.2888\ t + 0.0019\ t^2 + 0.8128\ \log_e t$$

with r^2, s and I as 0.9904, 0.0941 and 0.0941 respectively while the latter has got the form

$$Y_t = 5.9802 - 0.1753\ t - \frac{1.1559}{t}$$

with r^2, s and I as 0.9864, 0.1086 and 0.1086 respectively.

4.2.5 F_2S

For this breed, the linear hyperbolic function (Table 19) and the quadratic-cum-log (Table 17) were found to be the best two fitted curves for the pooled data. The linear hyperbolic function had got the form

$$Y_t = 6.9632 - 0.1887\ t - \frac{0.8255}{t}$$

with r^2, s and I as 0.9733, 0.1742 and 0.1742 respectively while the quadratic-cum-log had got the form

$$Y_t = 6.2407 - 0.2619\ t + 0.0011\ t^2 + 0.5566\ \log_e t$$

with r^2, s and I as 0.9745, 0.1755 and 0.1755 respectively.

4.2.6 F_3A

Among the different types of curves fitted to F_3A, the quadratic-cum-log (Table 17) stood first and the linear hyperbolic (Table 19) stood second for the pooled data. The first function had got the form

$$Y_t = 4.9027 - 0.2173\ t - 0.0020\ t^2 + 0.8361 \log_e t$$

with r^2, s and I as 0.9585, 0.2154 and 0.2154 respectively while the second function had got the form

$$Y_t = 6.5427 - 0.2010\ t - \frac{1.8228}{t}$$

with r^2, s and I as 0.9483, 0.2310 and 0.2310 respectively.

4.2.7 F_3S

The linear hyperbolic function (Table 19) and quadratic-log-scale function (Table 16) were the selected curves for the pooled data of this breed among the three (linear hyperbolic, quadratic log scale, gamma type) which could explain both the phases of lactation. The fitted form of the linear hyperbolic function was

$$Y_t = 5.8240 - 0.1336\ t - \frac{0.4038}{t}$$

with r^2, s and I as 0.9740, 0.1259 and 0.1259 respectively while the quadratic log scale function in its fitted form was

$$Y_t = 5.1695 + 0.6668 \log_e t - 0.4371 (\log_e t)^2$$

with r^2, s and I as 0.9524, 0.1705 and 0.1705 respectively.

4.2.8 Graphical representation of the curves

The best two selected curves along with the observed curve were drawn for the pooled data in each of the seven genetic groups and presented in Figures 1-7.

4.3 Prediction of total yield using part records

For the prediction of total yield from various part records, the milk yield produced by a goat during the first 4, 8 and 12 weeks of a lactation were considered. Cumulative milk yields during various part records were fitted using the linear hyperbolic function (as mentioned in section 3.5) for each of the parity and for the pooled data of the seven genetic groups. The estimate of the constants obtained along with the co-efficient of determination (r^2) and SE (s) are given in Tables 20-26. The observed and the predicted cumulative yields obtained for the pooled data of the seven genetic groups are presented in Tables 27-33.

4.3.1 Alpine Malabari

The estimated constants, r^2 and s obtained by fitting linear hyperbolic function for the various part records of this breed are given in Table 20. For each parity and for pooled data the best function (linear hyperbolic) was fitted and for the pooled data r^2 was obtained as 0.9909, 0.9919 and 0.9932 respectively for the part records of 4, 8 and 12 weeks The observed and the predicted cumulative yields of 20 weeks obtained for the pooled data using various part records are presented in Table 27.

4.3.2 Malabari

The linear hyperbolic function was fitted separately for each parity and for the pooled data using various part records and the estimated constants along with r^2 and s are given in Table 21. For the pooled data r^2 was obtained as 0.9900, 0.9907 and 0.9919 for the part records of 4, 8 and 12 weeks respectively. The observed and the predicted cumulative milk yields obtained for 20 weeks using the part records for the pooled data are given in Table 28.

4.3.3 Saanen Malabari

The values of the parameters estimated along with r^2 and s obtained for pooled and parity-wise data by fitting the linear hyperbolic function to the cumulative part records of 4, 8 and 12 weeks are presented in Table 22. For the pooled data r^2 was obtained as 0.9956, 0.9964 and 0.9969 respectively for the part records of 4, 8 and 12 weeks. For the pooled data, the observed and the predicted cumulative yields of each part record were computed for 20 weeks and presented in Table 29.

4.3.4 F_2A

The best equation (linear hyperbolic) was fitted separately for each of the parity and to the pooled data using various part records and the results obtained are given in Table 23. The r^2 values of 0.9886, 0.9894 and 0.9912 were obtained for the pooled data of this breed using 4, 8 and 12 weeks cumulative yield respectively. The observed and the predicted cumulative yields of 20 weeks for each part record are given in Table 30.

4.3.5 F_2S

By fitting the linear hyperbolic function to the parity-wise and pooled data using various part records, the constants estimated, r^2 and s are given in Table 24. The r^2 values obtained for the pooled data were 0.9909, 0.9918 and 0.9935 respectively for the part record of 4, 8 and 12 weeks. The observed cumulative yields along with the predicted cumulative yields over 20 weeks for each part record are given in Table 31.

4.3.6 F_3A

The best selected curve (linear hyperbolic) was fitted for each parity and for pooled data of this breed and the estimated value of parameters, r^2 and s are given in Table 25. The curve gave r^2 values of 0.9889, 0.9890 and 0.9901 for the various part records of 4, 8 and 12 weeks respectively for the pooled data. For the first 20 weeks observed and the predicted cumulative milk yields obtained for various part records are shown in Table 32.

4.3.7 F_3S

The computed values of r^2, s and the constants estimated by fitting the linear hyperbolic function for the pooled and parity-wise data are given in Table 26. The r^2 values obtained by fitting the suited curve to the pooled data were 0.9945, 0.9945 and 0.9953 respectively for 4, 8 and 12 weeks. The observed and the predicted cumulative yields of the first 20 weeks for each part record are given in Table 33.

4.4 Effect of genetic and non-genetic factors

In order to find the effect of genetic group, order of lactation and their interaction on average yield a two way classified non-orthogonal data analysis with interaction was carried out as described in section 3.6. The non-orthogonal two way classified data (Breed Vs Parity) with number of animals belonging to each cell and their corresponding average yield are given in Table 34. ANOVA obtained is presented in Table 35.

From Table 35, the breed, order of lactation and their interaction were found to be highly significant.

As the genetic, non-genetic and their interaction were significant their CD values at 5% and 1% were worked out for the comparison and presented in Tables 36 and 37.

4.5 Persistency indices

Persistency indices for each parity and for pooled data of the seven genetic groups were worked out by four different methods (mentioned in section 3.7) and presented in Table 38 for the comparison of the genetic groups.

Persistency of milk yield was calculated by the method developed by Ludwick and Petersen (described in section 3.7.1) for each of the parities and for pooled data of the seven genetic groups and presented as Method I in Table 38.

Using total yield and yield upto peak persistency indices of each parity and pooled data of the seven genetic groups were worked out by the method of Mahadevan (described in section 3.7.2) and presented as Model II in Table 38.

Using gamma function persistency indices were computed as described in section 3.7.3 for the pooled and parity-wise data of the seven genetic groups and given as Method III in Table 38.

By dividing the lactation length into ten segments, persistency indices were calculated by the method of Malhotra *et al.* (as in section 3.7.4) separately for the parity-wise and pooled data and the obtained values were presented under Method IV in Table 38.

Table 1. Average milk yield (kg) with SE in the eight parities of Alpine Malabari over twenty weeks

Parity	1		2		3		4		5		6		7		8	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	4.9358	0.2358	5.1824	0.2606	5.5026	0.2723	5.2917	0.4175	6.2000	0.4361	5.7650	0.4726	6.4250	0.7382	4.9000	0.6950
2	5.2164	0.2460	5.4576	0.2776	5.5039	0.2732	5.1979	0.3750	5.9889	0.4250	5.4400	0.4073	5.2917	0.7436	4.7600	0.6562
3	5.1522	0.2588	5.5529	0.3033	5.5289	0.2722	5.5250	0.3973	5.9611	0.4787	5.4100	0.4565	5.3417	0.7372	5.1000	0.6656
4	5.0090	0.2705	5.5118	0.3245	5.4211	0.2720	5.7958	0.4022	5.7861	0.4881	5.2300	0.4637	6.0333	0.6705	5.1000	0.6356
5	4.8597	0.2518	5.4235	0.3129	5.2829	0.2668	5.7812	0.4204	5.5306	0.4348	4.8350	0.4496	6.7666	0.6725	4.9200	0.5229
6	4.7418	0.2361	5.2824	0.3271	4.8618	0.2655	5.5917	0.4051	4.9833	0.3392	4.6700	0.4059	6.3750	0.7863	4.4800	0.5953
7	4.3687	0.2289	5.0365	0.3007	4.6553	0.2465	5.7354	0.3789	4.7028	0.4162	4.6150	0.4675	6.0917	0.7905	4.1800	0.4116
8	4.1731	0.2070	4.9847	0.3073	4.6224	0.2342	5.5958	0.3815	4.7111	0.3397	4.8450	0.4833	6.1333	0.8215	3.9200	0.4779
9	4.2284	0.2019	4.7647	0.2832	4.4316	0.2291	5.5854	0.3726	4.5722	0.3389	4.6200	0.4581	5.8333	0.8823	3.9800	0.6232
10	4.0015	0.2061	4.5082	0.2872	4.3342	0.2300	5.3229	0.3352	4.4944	0.3525	4.4250	0.5507	5.3000	0.7103	4.0600	0.7194
11	3.7000	0.1967	4.3624	0.2580	4.0789	0.2151	5.0625	0.3136	4.3667	0.3277	3.9950	0.5381	5.2083	0.6817	3.6200	0.8114
12	3.6582	0.2022	4.3153	0.2517	4.0197	0.2263	4.9875	0.3091	4.2389	0.3267	3.9600	0.5083	4.8667	0.5968	3.6200	0.8958
13	3.5851	0.2011	4.1118	0.2526	4.1171	0.2406	4.8667	0.3069	4.1083	0.2954	3.9900	4.4980	4.7500	0.6015	2.8400	0.7153
14	3.3940	0.1948	4.0224	0.2665	3.8618	0.2402	4.6313	0.3282	4.0389	0.2826	3.6700	0.4968	4.6167	0.5927	2.6200	0.6127
15	3.2672	0.1909	3.7094	0.2308	3.7092	0.2360	4.5021	0.3138	3.8556	0.2461	3.3350	0.4075	4.0667	0.4776	2.5000	0.6042
16	3.0731	0.1709	3.6024	0.2161	3.6592	0.2489	4.3771	0.2782	3.4278	0.2568	3.2200	0.3637	3.9917	0.5062	2.3600	0.8959
17	3.0254	0.1631	3.6294	0.2103	3.5816	0.2351	3.9979	0.2639	3.2944	0.2830	3.2700	0.3864	4.0750	0.5565	2.5200	0.7965
18	2.7970	0.1555	3.5071	0.2040	3.4592	0.2351	3.7646	0.2561	3.2361	0.3267	3.0950	0.4058	3.7500	0.5253	2.2400	0.7607
19	2.7687	0.1563	3.3494	0.1930	3.3263	0.2277	3.5271	0.2501	3.0667	0.3066	2.9100	0.3812	3.4000	0.5002	1.8800	0.7632
20	2.5582	0.1532	3.2012	0.1859	3.1184	0.2168	3.5313	0.2610	2.8778	0.3074	2.6200	0.3850	3.1500	0.5076	1.8200	0.7473
Average	3.9257		4.4758		4.3537		4.9335		4.4721		4.1960		5.0733		3.5710	

Table 2. Average milk yield (kg) with SE in the six parities of Malabari over twenty weeks

Parity	1		2		3		4		5		6	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	3.6686	0.2759	4.6806	0.3177	4.3692	0.5387	4.0182	0.3000	4.9750	0.6395	4.7000	0.4139
2	3.5886	0.2522	4.3839	0.3205	4.3077	0.5834	3.9545	0.4057	4.9750	0.6047	4.4500	0.4667
3	3.3886	0.2601	4.0226	0.3039	4.6692	0.5799	3.9819	0.4902	5.1500	1.0626	4.8833	0.5338
4	3.4314	0.2979	3.9194	0.2878	4.6770	0.5587	4.5364	0.5789	4.8750	1.1933	4.5833	0.5154
5	3.2857	0.2736	4.2097	0.2575	4.6769	0.6105	4.4910	0.4757	5.1250	0.6872	4.2167	0.4534
6	3.1800	0.2340	3.8935	0.2648	4.5385	0.5183	4.4910	0.4495	5.2000	0.7627	4.1333	0.4425
7	3.0800	0.2663	3.7194	0.2357	4.3077	0.5395	3.9000	0.4832	4.6750	0.7630	3.8667	0.6667
8	3.0886	0.2759	3.7452	0.2688	3.8308	0.5101	4.1182	0.6199	4.8750	1.1707	4.0500	0.6222
9	2.9171	0.2725	3.5935	0.2761	4.1077	0.5240	4.1818	0.5782	4.5750	1.0475	3.8833	0.5700
10	3.0600	0.2628	3.5419	0.2818	3.7385	0.4852	3.8182	0.4889	4.5500	0.9751	3.7667	0.5572
11	2.9314	0.2641	3.3258	0.2442	3.9923	0.4815	3.6091	0.4284	4.8250	1.0703	3.7667	0.5846
12	2.9371	0.2647	3.1355	0.2422	3.6538	0.4341	3.1727	0.4843	4.1750	0.5692	3.3167	0.5016
13	2.9714	0.2541	3.2065	0.2410	3.1692	0.3766	3.2910	0.4658	3.2750	0.3924	2.9500	0.3471
14	2.9286	0.2711	2.9645	0.2101	3.2000	0.3468	3.0182	0.4379	3.3250	0.4905	2.2500	0.4829
15	2.7971	0.2767	2.8387	0.2329	3.0923	0.3520	3.0455	0.4728	2.7250	0.0853	2.1667	0.2348
16	2.6571	0.2665	2.7419	0.2583	2.9538	0.3962	3.1364	0.4991	2.5000	0.3440	2.3833	0.4847
17	2.6200	0.2504	2.5581	0.2314	3.0231	0.4156	2.9182	0.3981	2.9500	0.0289	2.2500	0.5038
18	2.4400	0.2442	2.4710	0.2318	2.7923	0.3903	2.4545	0.3326	2.6250	0.1493	2.2500	0.3810
19	2.2486	0.2006	2.4387	0.2235	2.6769	0.4196	2.4727	0.3938	3.0250	0.5498	1.8500	0.2997
20	2.0400	0.1792	2.2839	0.2097	2.1846	0.3695	2.6364	0.4533	2.9750	0.6537	1.7167	0.2469
Average	2.9630		3.3837		3.6981		3.5623		4.0688		3.3717	

Table 3. Average milk yield (kg) with SE in the five parities of Saanen Malabari over twenty weeks

Parity	1		2		3		4		5	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	5.9367	0.2303	5.5714	0.3387	6.3462	0.3687	6.5792	0.5716	6.5625	0.6900
2	6.0878	0.3296	5.4257	0.4266	6.3308	0.3774	6.5792	0.3795	7.1375	0.7015
3	6.0429	0.3611	5.4914	0.4507	6.1500	0.4312	6.5833	0.4345	8.0375	0.8053
4	5.8306	0.3576	5.2143	0.4541	5.6769	0.3501	6.7458	0.3796	7.5625	0.5301
5	5.4082	0.3349	5.1200	0.4482	5.2731	0.3801	6.4667	0.3547	6.8500	0.7033
6	5.5510	0.3381	4.9543	0.4600	5.1077	0.3788	6.1625	0.4136	6.8000	0.7829
7	5.5388	0.3341	4.9286	0.4337	5.6885	0.3612	6.1292	0.4171	6.5375	0.7808
8	5.5306	0.3217	4.8743	0.3576	5.6346	0.4652	5.9667	0.3760	5.6250	0.7973
9	5.4939	0.3244	4.7886	0.3504	5.5654	0.4661	5.9167	0.3955	5.4125	0.6865
10	5.2796	0.3507	4.7829	0.3418	5.5846	0.4395	5.8167	0.3741	5.5750	0.7153
11	5.0633	0.3609	4.8029	0.3876	5.6885	0.4347	5.5542	0.3452	5.4625	0.7486
12	5.0408	0.3312	4.5314	0.3788	5.5000	0.3874	5.6917	0.3535	5.5000	0.8716
13	4.8020	0.3115	4.5971	0.3829	5.2731	0.4380	5.6083	0.3350	4.9250	0.8752
14	4.8020	0.3435	4.5000	0.3874	5.1808	0.3811	5.3625	0.3436	4.7375	0.8650
15	4.5755	0.3145	4.4200	0.4107	5.1231	0.4080	4.7458	0.3644	4.5500	0.9144
16	4.2571	0.2883	4.1400	0.3940	5.3885	0.3346	4.4750	0.3264	4.0750	0.8366
17	4.0184	0.2800	4.2971	0.4106	5.0615	0.3767	4.5292	0.3399	4.2875	0.8169
18	3.7592	0.2587	3.8686	0.3950	4.7923	0.3915	4.3083	0.3002	3.9250	0.9007
19	3.4878	0.2627	3.8257	0.3791	4.3654	0.3523	4.1792	0.3109	3.6250	0.8345
20	3.2490	0.2525	3.6343	0.3818	4.0769	0.3366	3.7667	0.2810	3.5500	0.9849
Average	4.9878		4.6884		5.3904		5.5583		5.5369	

Table 4. Average milk yield (kg) with SE in the six parities of F_2A over twenty weeks

Parity	1		2		3		4		5		6	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	4.1022	0.1685	4.6588	0.2572	5.7421	0.3226	5.2652	0.3448	4.7875	0.9382	4.0000	0.3000
2	3.9124	0.1557	4.4000	0.2395	5.5500	0.3184	5.0435	0.3830	5.6000	0.6987	4.4000	1.2000
3	3.6865	0.1688	4.2294	0.2236	5.4474	0.2838	5.0261	0.3678	6.2875	0.9261	4.8500	2.0500
4	3.8157	0.1812	4.1324	0.2133	5.1816	0.3007	5.3304	0.3688	6.4250	0.7547	5.2500	0.4500
5	3.7360	0.1878	4.1279	0.2361	4.9053	0.3013	5.2217	0.3470	5.9750	0.7081	5.9500	0.0500
6	3.4539	0.1743	4.0206	0.2238	4.6158	0.2920	5.4435	0.4411	5.6000	0.6164	5.8500	0.1500
7	3.4202	0.1927	3.9162	0.2093	4.5421	0.2650	5.0913	4.4119	5.2125	0.8147	5.2500	0.7500
8	3.3292	0.1854	3.9691	0.2177	4.5868	0.2550	5.1348	0.4226	5.1125	0.8245	5.5000	1.1000
9	3.2989	0.1917	3.9368	0.2278	4.5421	0.2492	5.1326	0.3779	4.9625	0.5561	4.1500	0.0500
10	3.2787	0.1958	3.7132	0.2161	4.3789	0.2491	4.8870	0.4145	4.4125	0.5393	3.0000	0.1000
11	3.1427	0.1873	3.8103	0.2193	4.1763	0.2555	4.4652	0.3820	4.8250	0.6622	3.0500	0.1500
12	3.1416	0.1892	3.6750	0.2220	3.9421	0.2421	4.5174	0.3300	4.9000	0.7702	3.2000	0.2000
13	2.9326	0.1813	3.4515	0.2083	3.8526	0.2839	4.2087	0.3071	4.6125	0.7165	2.3000	0.4000
14	2.9315	0.1751	3.3603	0.2026	3.7763	0.3016	3.9217	0.2975	4.1625	0.8523	2.4000	0.3000
15	2.7955	0.1618	3.3103	0.2100	3.9132	0.2826	3.6609	0.3191	3.8250	0.6894	2.0000	0.9000
16	2.7461	0.1564	3.2794	0.2056	3.8842	0.2864	3.7043	0.3718	3.2500	0.6830	2.0000	0.7000
17	2.6067	0.1461	3.2265	0.1973	3.6711	0.2921	3.7043	0.3270	2.7625	0.6436	1.8000	0.9000
18	2.4798	0.1353	3.0971	0.1915	3.5947	0.2915	3.0956	0.3441	2.4750	0.6304	1.5000	0.4000
19	2.4011	0.1331	2.9765	0.1850	3.4026	0.2698	2.8348	0.3310	2.4250	0.6178	1.6500	0.4500
20	2.3449	0.1336	2.7765	0.1576	3.1132	0.2577	2.5739	0.3272	2.1250	0.6259	1.2500	0.5500
Average	3.1778		3.7034		4.3409		4.4131		4.4869		3.4675	

Table 5. Average milk yield (kg) with SE in the seven parities of F_2S over twenty weeks

Parity	1		2		3		4		5		6		7	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	4.9056	0.2679	5.7033	0.5154	6.0824	0.5641	5.7700	0.7085	5.8000	1.0520	7.5333	2.0184	6.4667	1.7295
2	4.7481	0.2544	5.9133	0.4947	6.2118	0.5701	5.3600	0.6590	5.6500	0.9559	7.9000	1.9632	5.6667	1.8224
3	4.8722	0.2393	5.5333	0.3822	6.5294	0.5855	5.6300	0.5688	6.9000	0.8595	8.6333	2.1352	4.6667	1.6045
4	4.9852	0.2636	5.8567	0.3901	6.3588	0.4960	6.2000	0.6530	6.3833	0.8735	8.5000	2.0229	4.3667	1.5762
5	5.0778	0.2836	5.5667	0.4070	5.9294	0.4686	6.5100	0.5730	5.8500	1.0056	8.3167	2.0228	3.7333	0.7311
6	5.1741	0.3034	5.5967	0.3557	5.4059	0.4251	6.3200	0.5635	5.8000	1.0602	7.7333	1.9835	4.0000	0.5000
7	5.1315	0.3108	5.3100	0.3151	4.9529	0.3475	6.2800	0.6315	6.6667	1.2943	7.9167	1.8823	4.0333	0.4807
8	4.9167	0.3182	5.2567	0.3177	4.7765	0.3324	5.7800	0.5656	6.5333	1.1059	7.1833	2.0795	3.4667	0.8373
9	4.5537	0.2964	4.8033	0.3571	4.8000	0.3180	5.8300	0.5686	6.4167	0.9275	7.1167	1.8260	3.0000	0.5292
10	4.5426	0.2962	4.6733	0.3569	4.6000	0.3224	5.6200	0.7030	5.6833	0.8738	5.9667	1.7599	2.5667	0.6667
11	4.1852	0.2761	4.5400	0.3451	4.2588	0.3227	5.1200	0.5680	4.9833	0.9127	5.5833	1.6877	2.3000	0.3215
12	4.1981	0.2667	4.3900	0.3177	3.9176	0.3387	5.2000	0.6899	5.5667	0.8492	5.7500	1.7703	2.3667	0.3283
13	4.1574	0.2404	4.2867	0.2840	3.9059	0.3694	5.1300	0.6904	6.1000	0.7729	5.5000	1.6894	3.3333	0.2186
14	4.2315	0.2473	4.0667	0.2935	3.6882	0.2906	4.9600	0.8138	5.0333	0.8073	5.7667	1.7612	3.8333	0.9939
15	4.0019	0.2582	3.9100	0.2538	3.5059	0.2798	4.9400	0.8061	4.8500	0.8306	5.3000	1.6205	3.5333	1.0588
16	3.4407	0.2311	3.8267	0.2868	3.2588	0.2611	4.3500	0.7583	4.3000	0.7616	4.4833	1.6015	2.9000	0.7572
17	3.6667	0.2595	3.6833	0.2926	3.1294	0.3355	4.4200	0.7447	3.9333	1.0613	4.6167	1.5441	2.5000	0.7024
18	3.4796	0.2550	3.5767	0.2684	3.0412	0.3161	4.6100	0.7117	3.7500	0.8887	4.2667	1.4191	2.3333	0.8647
19	3.1611	0.2289	3.3300	0.2463	2.9176	0.3421	4.3300	0.5776	3.8000	0.7685	3.6833	1.3812	1.6667	0.3844
20	3.0185	0.2220	3.1067	0.2425	2.7765	0.3261	4.2400	0.7234	3.4667	0.8864	3.3167	1.2395	1.4000	0.4509
Average	4.3224		4.6465		4.5024		5.3300		5.3733		6.2533		3.4067	

Table 6. Average milk yield (kg) with SE in the three parities of F_3A over twenty weeks

Parity	1		2		3	
Weeks	Mean	SE	Mean	SE	Mean	SE
1	4.4760	0.3476	5.1692	0.5067	4.1000	0.4000
2	4.4080	0.4870	5.3154	0.4777	6.0000	1.3000
3	4.0120	0.4392	5.8154	0.6049	6.5000	0.6000
4	4.1480	0.3203	5.9077	0.6180	4.4000	3.1000
5	4.5880	0.3924	5.4538	0.5724	4.1000	1.7000
6	4.6840	0.3352	5.0154	0.3995	5.3500	0.1500
7	4.5040	0.3106	5.2000	0.5162	5.9500	1.0500
8	4.4240	0.2894	4.9769	0.5167	5.5000	0.8000
9	4.0880	0.2342	4.7769	0.5692	4.8500	1.0500
10	3.3720	0.2391	4.6077	0.4774	4.8000	0.9000
11	3.7800	0.2259	4.2231	0.5170	5.0000	1.0000
12	3.6920	0.2179	3.9923	0.6112	5.0000	0.9000
13	3.6240	0.2171	3.7846	0.6334	4.1000	0.6000
14	3.3720	0.2295	3.6692	0.5616	4.1000	1.0000
15	3.4120	0.2315	3.4846	0.4540	3.7000	1.0000
16	3.3120	0.2442	3.0385	0.4948	3.4000	0.5000
17	2.9640	0.2257	2.3769	0.4816	2.7000	1.3000
18	2.7400	0.2486	2.4923	0.4729	2.9500	1.0500
19	2.6800	0.2263	2.4077	0.5034	2.9000	0.8000
20	2.6360	0.2175	2.0769	0.4255	2.1500	1.3500
Average	3.7458		4.1892		4.3775	

Table 7. Average milk yield (kg) with SE in the four parities of F_3S over twenty weeks

Parity	1		2		3		4	
Weeks	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	4.5308	0.3979	5.4867	0.6499	5.9000	0.6293	5.5750	0.8439
2	4.3077	0.3646	5.3000	0.6979	6.0667	0.7406	5.4750	0.9420
3	4.1692	0.4564	4.9267	0.8535	6.3667	0.7383	5.1250	0.8469
4	4.1385	0.4200	4.4467	0.7528	6.1167	0.5856	5.2500	1.4033
5	4.1308	0.4506	4.5800	0.7461	6.1167	0.7391	5.0750	1.4062
6	4.2038	0.5435	4.5200	0.6717	5.7667	1.1327	5.3250	1.4716
7	4.2654	0.5361	4.4000	0.5615	5.8833	0.9918	5.6000	1.0870
8	4.0769	0.5872	4.5667	0.5884	5.3167	0.7236	6.0000	0.9941
9	3.9423	0.5314	4.0267	0.4852	5.2333	1.0230	5.2750	1.1757
10	4.1923	0.4986	4.1933	0.5100	4.4167	0.8987	4.7500	0.8302
11	4.1577	0.5197	4.1533	0.5213	4.8500	0.9164	4.5000	0.9009
12	3.8269	0.5060	3.6267	0.4867	4.6667	0.8241	4.1250	0.6033
13	4.1654	0.5785	3.6000	0.5261	4.7000	0.9723	4.3000	0.8756
14	3.9731	0.4882	3.5000	0.5157	4.1667	0.7775	4.3000	1.1438
15	3.8962	0.4839	3.1200	0.4405	3.9500	0.8310	4.1250	1.0734
16	3.5308	0.4540	2.7467	0.3881	4.0000	0.7398	4.3000	1.1803
17	3.5423	0.3898	2.4867	0.4000	3.6500	0.4724	4.2500	1.1807
18	3.3577	0.3137	2.4733	0.3835	3.7167	0.7254	3.7500	1.1288
19	3.4577	0.3980	2.3000	0.3950	3.6000	0.4940	3.6250	0.9961
20	3.3423	0.4297	2.0600	0.3597	3.5167	0.7264	3.4250	1.1954
Average	3.9604		3.8257		4.9000		4.7075	

Table 8. Pooled average yield (kg) with SE of the seven breeds over twenty weeks

Breed / Weeks	Alpine Malabari		Malabari		Saanen Malabari		F_2A		F_2S		F_3A		F_3S	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	5.5253	0.1997	4.4019	0.1984	6.1992	0.1951	4.7593	0.2733	6.0373	0.3065	4.5817	0.3131	5.3731	0.2945
2	5.3571	0.1227	4.2767	0.1921	6.3122	0.2819	4.8177	0.2809	5.9214	0.3726	5.2411	0.4611	5.2874	0.3654
3	5.4465	0.0953	4.3493	0.2704	6.4610	0.4308	4.9212	0.3725	6.1093	0.5197	5.4420	0.7420	5.1469	0.4558
4	5.4859	0.1290	4.3371	0.2236	6.2060	0.4205	5.0225	0.3824	6.0930	0.4934	4.8186	0.5494	4.9880	0.4432
5	5.4250	0.2268	4.3342	0.2514	5.8236	0.3491	4.9860	0.3772	5.8548	0.4883	4.7139	0.3958	4.9756	0.4264
6	5.1233	0.2181	4.2394	0.2786	5.7151	0.3429	4.8306	0.3918	5.7186	0.4307	5.0165	0.1923	4.9539	0.3593
7	4.9231	0.2358	3.9248	0.2213	5.7645	0.2726	4.5721	0.3108	5.7559	0.4873	5.2180	0.4175	5.0372	0.4117
8	4.8732	0.2539	3.9513	0.2375	5.5262	0.1790	4.6054	0.3352	5.4162	0.4626	4.9670	0.3107	4.9901	0.4223
9	4.7520	0.2270	3.8764	0.2335	5.4354	0.1831	4.3372	0.2792	5.2172	0.5146	4.5716	0.2427	4.6193	0.3670
10	4.5558	0.0316	3.7459	0.1970	5.4078	0.1781	3.9451	0.2992	4.8075	0.4343	4.2599	0.4474	4.3881	0.1317
11	4.2992	0.2061	3.7417	0.2636	5.3143	0.1649	3.9116	0.2918	4.4244	0.4009	4.3344	0.3566	4.4153	0.1661
12	4.2083	0.1792	3.3985	0.1833	5.2528	0.2098	3.8960	0.2886	4.4842	0.4414	4.2281	0.3956	4.0613	0.2263
13	4.0461	0.2257	3.1439	0.0608	5.0411	0.1793	3.5597	0.3468	4.6305	0.3689	3.8362	0.1398	4.1914	0.2275
14	3.8569	0.2321	2.9477	0.1526	4.9166	0.1561	3.4254	0.2716	4.5114	0.2871	3.7137	0.2113	3.9850	0.1750
15	3.6182	0.2117	2.7776	0.1355	4.6829	0.1217	3.2508	0.3007	4.2916	0.2748	3.5322	0.0865	3.7728	0.2230
16	3.4639	0.2156	2.7288	0.1146	4.4671	0.2402	3.1440	0.2804	3.7942	0.2316	3.2502	0.1088	3.6444	0.3385
17	3.4242	0.1811	2.7199	0.1213	4.4387	0.1754	2.9619	0.2967	3.7071	0.2752	2.6803	0.1698	3.4823	0.3665
18	3.2311	0.1828	2.5055	0.0753	4.1307	0.1895	2.7070	0.2974	3.5796	0.2852	2.7274	0.1323	3.3244	0.2973
19	3.0285	0.1881	2.4520	0.1616	3.8966	0.1652	2.6150	0.2458	3.2698	0.3194	2.6626	0.1424	3.2457	0.3174
20	2.8596	0.1865	2.3061	0.1817	3.6554	0.1354	2.3639	0.2629	3.0464	0.3260	2.2876	0.1755	3.0860	0.3438
Overall mean	4.3752		3.5079		5.2324		3.9316		4.8335		4.1042		4.3484	

Table 9. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2) standard error of the estimate (s) and Furnival index (I) of the linear function $Y_t = a + bt$ in different breeds of goats

Breeds	Parity No.	Estimates		r^2	s	I
		a	b			
Alpine Malabari	1	5.4462	-0.1488	0.9798	0.1263	0.1263
	2	5.8636	-0.1322	0.9539	0.1766	0.1766
	3	5.7360	-0.1316	0.9754	0.1271	0.1271
	4	6.1202	-0.1130	0.7793	0.3655	0.3655
	5	6.2732	-0.1715	0.9773	0.1589	0.1589
	6	5.8227	-0.1549	0.9774	0.1433	0.1433
	7	6.7727	-0.1618	0.7909	0.5058	0.5058
	8	5.5268	-0.1863	0.9511	0.2567	0.2567
	Pooled	5.9452	-0.1495	0.9788	0.1338	0.1338
Malabari	1	3.6781	-0.0681	0.9181	0.1237	0.1237
	2	4.6057	-0.1164	0.9758	0.1114	0.1114
	3	4.9851	-0.1226	0.9001	0.2474	0.2474
	4	4.5942	-0.1002	0.8188	0.2864	0.2864
	5	5.6759	-0.1531	0.8191	0.4370	0.4370
	6	5.1646	-0.1708	0.9370	0.2691	0.2691
	Pooled	4.7920	-0.1223	0.9559	0.1597	0.1597
Saanen Malabari	1	6.4475	-0.1390	0.9265	0.2379	0.2379
	2	5.6437	-0.0910	0.9575	0.1164	0.1164
	3	6.2504	-0.0819	0.7151	0.3143	0.3143
	4	7.1368	-0.1503	0.9364	0.2382	0.2382
	5	7.8101	-0.2165	0.9111	0.4110	0.4110
	Pooled	6.6577	-0.1357	0.9627	0.1623	0.1623
F_2A	1	4.0914	-0.0870	0.9833	0.0690	0.0690
	2	4.5846	-0.0839	0.9717	0.0871	0.0871
	3	5.6236	-0.1222	0.9522	0.1663	0.1663
	4	5.9058	-0.1433	0.8625	0.3479	0.3479
	5	6.5785	-0.1992	0.8206	0.5661	0.5661
	6	5.9224	-0.2338	0.7573	0.8046	0.8046
	Pooled	5.4478	-0.1444	0.9433	0.2152	0.2152
F_2S	1	5.4351	-0.1060	0.8479	0.2728	0.2728
	2	6.2263	-0.1505	0.9716	0.1565	0.1565
	3	6.6796	-0.2074	0.9636	0.2448	0.2448
	4	6.4043	-0.1023	0.7149	0.3927	0.3927
	5	6.9312	-0.1484	0.6873	0.6083	0.6083
	6	9.0939	-0.2705	0.9119	0.5112	0.5112
	7	5.3104	-0.1813	0.7166	0.6929	0.6929
	Pooled	6.5830	-0.1666	0.9565	0.2158	0.2158
F_3A	1	4.8482	-0.1033	0.8456	0.2683	0.2683
	2	6.2710	-0.1983	0.9216	0.3515	0.3515
	3	6.0113	-0.1556	0.6028	0.7678	0.7678
	Pooled	5.7031	-0.1523	0.8614	0.3713	0.3713
F_3S	1	4.4997	-0.0514	0.7863	0.1627	0.1627
	2	5.5903	-0.1681	0.9550	0.2218	0.2218
	3	6.5976	-0.1617	0.9334	0.2624	0.2624
	4	5.8645	-0.1102	0.7854	0.3501	0.3501
	Pooled	5.6380	-0.1228	0.9666	0.1388	0.1388

Table 10. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of the exponential function $Y_t = ae^{bt}$ in different breeds of goats

Breeds	Parity No.	Estimates a	Estimates b	r^2	s	I
Alpine Malabari	1	5.7061	-0.0379	0.9677	0.1617	1.4267
	2	6.0574	-0.0303	0.9333	0.2142	2.1731
	3	5.9007	-0.0304	0.9797	0.1155	1.1398
	4	6.2967	-0.0244	0.7292	0.4101	4.6023
	5	6.5731	-0.0391	0.9798	0.1505	1.5102
	6	6.1127	-0.0382	0.9653	0.1804	1.7011
	7	7.0789	-0.0339	0.7398	0.5712	6.5207
	8	6.1008	-0.0562	0.9091	0.3636	2.8353
	Pooled	6.2227	-0.0356	0.9525	0.2053	2.0252
Malabari	1	3.7636	-0.0238	0.9047	0.1343	0.9067
	2	4.7975	-0.0352	0.9677	0.1298	0.9904
	3	5.2209	-0.0349	0.8630	0.2952	2.4592
	4	4.7518	-0.0296	0.7809	0.3176	2.5464
	5	5.9970	-0.0400	0.7822	0.4851	4.4028
	6	5.6926	-0.0548	0.8932	0.3635	2.6801
	Pooled	5.0297	-0.0365	0.9231	0.2125	1.6990
Saanen Malabari	1	6.6957	-0.0295	0.8887	0.2998	3.3898
	2	5.7306	-0.0198	0.9486	0.1287	1.3796
	3	6.3117	-0.0156	0.7059	0.3198	0.9464
	4	7.3782	-0.0283	0.9047	0.2967	3.7447
	5	8.2117	-0.0403	0.8932	0.4526	5.6072
	Pooled	6.8511	-0.0268	0.9410	0.2073	2.4670
F_2A	1	4.2016	-0.0278	0.9780	0.0796	0.5752
	2	4.6732	-0.0230	0.9652	0.0969	0.8189
	3	5.7507	-0.0281	0.9665	0.1397	1.3771
	4	6.2383	-0.0355	0.7997	0.4325	4.2817
	5	7.2471	-0.0502	0.7372	0.7149	7.0416
	6	6.9662	-0.0771	0.6516	0.9978	7.1229
	Pooled	5.7657	-0.0389	0.8992	0.2949	2.6014
F_2S	1	5.5948	-0.0258	0.8083	0.3098	3.0443
	2	6.4753	-0.0334	0.9517	0.2067	2.1705
	3	7.1138	-0.0471	0.9625	0.2498	2.4896
	4	6.4987	-0.0197	0.6864	0.4130	5.0245
	5	7.2110	-0.0299	0.6330	0.6680	8.0986
	6	9.7896	-0.0463	0.8666	0.6441	8.9333
	7	5.6609	-0.0547	0.7632	0.6374	4.6768
	Pooled	6.9028	-0.0361	0.9282	0.2830	3.0810
F_3A	1	5.0151	-0.0288	0.8056	0.3043	2.5959
	2	6.9167	-0.0522	0.8529	0.5063	4.6587
	3	6.3571	-0.0392	0.5401	0.8383	8.1305
	Pooled	6.0903	-0.0405	0.7971	0.4629	4.2439
F_3S	1	4.5369	-0.0133	0.7715	0.1686	1.5319
	2	6.0471	-0.0472	0.9184	0.3109	2.6376
	3	6.8441	-0.0337	0.9200	0.2887	3.1936
	4	5.9947	-0.0242	0.7625	0.3696	3.9584
	Pooled	5.8233	-0.0292	0.9434	0.1828	1.8037

Table 11. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2) standard error of the estimate (s) and Furnival index (I) of the parabolic exponential function $Y_t = a\exp(bt + ct^2)$ in different breeds of goats

Breeds	Parity No.	Estimates			r^2	s	I
		a	b	c			
	1	5.3960	-0.0227	-0.0007	0.9871	0.0272	0.2403
	2	5.6551	-0.0116	-0.0009	0.9736	0.0316	0.3206
	3	5.8803	-0.0295	0.0000	0.9831	0.0250	0.2464
Alpine Malabari	4	5.2112	0.0272	-0.0025	0.9778	0.0259	0.2903
	5	6.3787	-0.0309	-0.0004	0.9819	0.0333	0.3339
	6	5.7141	-0.0198	-0.0009	0.9789	0.0352	0.3322
	7	5.8203	0.0195	-0.0025	0.9202	0.0669	0.7642
	8	5.2099	-0.0128	-0.0021	0.9670	0.0661	0.5151
	Pooled	5.6563	-0.0095	-0.0012	0.9936	0.0181	0.1782
	1	3.5174	-0.0053	-0.0009	0.9172	0.0454	0.3068
	2	4.5608	-0.0214	-0.0007	0.9823	0.0297	0.2266
Malabari	3	4.5565	0.0022	-0.0018	0.9439	0.0551	0.4586
	4	4.1577	0.0068	-0.0017	0.8972	0.0655	0.5249
	5	5.3816	-0.0104	-0.0014	0.8206	0.1188	1.0781
	6	4.8350	-0.0103	-0.0021	0.9454	0.0839	0.6190
	Pooled	4.5061	-0.0065	-0.0014	0.9788	0.0343	0.2705
	1	5.8135	0.0090	-0.0018	0.9782	0.0290	0.3276
	2	5.5057	-0.0088	-0.0005	0.9593	0.0257	0.2756
Saanen Malabari	3	5.9783	-0.0008	-0.0007	0.7360	0.0599	0.7387
	4	6.5867	0.0026	-0.0015	0.9739	0.0300	0.3789
	5	7.6120	-0.0196	-0.0010	0.9432	0.0623	0.7713
	Pooled	6.2995	-0.0040	-0.0011	0.9808	0.0240	0.2856
	1	4.0588	-0.0184	-0.0004	0.9856	0.0211	0.1523
	2	4.5160	-0.0137	-0.0004	0.9741	0.0236	0.1992
	3	5.8743	-0.0339	0.0003	0.9654	0.0333	0.3284
F_2A	4	4.9750	0.0263	-0.0029	0.9859	0.0288	0.2851
	5	5.2029	0.0402	-0.0043	0.9503	0.0785	0.7733
	6	4.9166	0.0179	-0.0045	0.9039	0.1642	1.1724
	Pooled	4.9524	0.0025	-0.0020	0.9873	0.0285	0.2515
	1	4.8573	0.0128	-0.0018	0.9483	0.0401	0.3938
	2	6.0140	-0.0132	-0.0010	0.9847	0.0263	0.2763
	3	6.9133	-0.0393	-0.0004	0.9807	0.0414	0.4133
F_2S	4	5.8098	0.0109	-0.0015	0.8407	0.0574	0.6982
	5	5.7147	0.0335	-0.0030	0.8889	0.0746	0.9042
	6	8.2678	-0.0002	-0.0022	0.9534	0.0659	0.9133
	7	5.7883	-0.0608	0.0003	0.7197	0.2137	1.5680
	Pooled	6.2035	-0.0069	-0.0014	0.9732	0.0381	0.4150
	1	4.3389	0.0107	-0.0019	0.9384	0.0488	0.4159
F_3A	2	5.4067	0.0149	-0.0032	0.9757	0.0540	0.4970
	3	4.5557	0.0517	-0.0043	0.8235	0.1305	1.2657
	Pooled	4.8139	0.0237	-0.0031	0.9654	0.0514	0.4715
	1	4.2736	0.0030	-0.0008	0.8494	0.0366	0.3321
F_3S	2	5.1290	-0.0023	-0.0021	0.9717	0.0517	0.4388
	3	6.5316	-0.0210	-0.0006	0.9447	0.0512	0.5666
	4	5.4928	-0.0003	-0.0011	0.8490	0.0656	0.7021
	Pooled	5.3673	-0.0070	-0.0011	0.9851	0.0228	0.2253

Table 12. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of estiamte (s) and Furnival index (I) of the inverse polynomial function $Y_t = t(a+bt+ct^2)^{-1}$ in different breeds of goats

Breeds	Parity No.	Estimates			r^2	s	I
		a	b	c			
Alpine Malabari	1	0.1890	0.0903	0.0140	0.9984	0.0997	1.4204
	2	0.1035	0.1138	0.0095	0.9992	0.0564	1.0946
	3	0.0701	0.1366	0.0085	0.9985	0.0780	1.4336
	4	0.2917	0.0440	0.0112	0.9965	0.1054	2.5039
	5	0.2112	0.0667	0.0130	0.9966	0.1274	2.4216
	6	0.2647	0.0562	0.0146	0.9953	0.1600	2.6838
	7	0.3245	0.0100	0.0138	0.9948	0.1394	3.4274
	8	0.5710	-0.0855	0.0294	0.9895	0.3549	4.0695
	Pooled	0.2335	0.0623	0.0133	0.9983	0.0900	1.6522
Malabari	1	0.4391	0.1136	0.0158	0.9879	0.3139	2.7006
	2	0.2409	0.1079	0.0155	0.9986	0.1037	1.1385
	3	0.3782	0.0387	0.0176	0.9856	0.3166	4.1435
	4	0.2230	0.1084	0.0140	0.9810	0.2571	3.1172
	5	-0.0354	0.1383	0.0118	0.9607	0.4954	7.6961
	6	0.5657	-0.0742	0.0300	0.9841	0.4582	4.6992
	Pooled	0.2655	0.0801	0.0167	0.9982	0.1159	1.3632
Saanen Malabari	1	0.3422	0.0219	0.0127	0.9926	0.1590	3.8350
	2	0.1411	0.1240	0.0068	0.9934	0.1011	2.1917
	3	0.2089	0.0904	0.0064	0.9877	0.1576	4.5283
	4	0.2164	0.0517	0.0095	0.9947	0.1172	3.5193
	5	0.1554	0.0514	0.0110	0.9962	0.1102	3.1914
	Pooled	0.2054	0.0685	0.0092	0.9959	0.1068	2.8523
F_2A	1	0.1959	0.1606	0.0126	0.9987	0.0975	0.9592
	2	0.1594	0.1542	0.0092	0.9977	0.1046	1.4093
	3	0.0762	0.1446	0.0077	0.9950	0.1378	2.5276
	4	0.5172	-0.0402	0.0189	0.9913	0.2171	4.0126
	5	0.8645	-0.2010	0.0299	0.9802	0.4042	7.3951
	6	1.0279	-0.3303	0.0503	0.9836	0.6225	5.9830
	Pooled	0.3906	0.0124	0.0185	0.9960	0.1641	2.4084
F_2S	1	0.2688	0.0719	0.0117	0.9940	0.1576	2.8710
	2	0.1712	0.0809	0.0110	0.9979	0.0905	1.8825
	3	0.1304	0.0709	0.0140	0.9994	0.0592	1.1134
	4	0.0797	0.1143	0.0059	0.9966	0.0883	2.4640
	5	0.3583	-0.0015	0.0133	0.9895	0.1835	5.0886
	6	0.3319	-0.0329	0.0147	0.9852	0.2186	7.9304
	7	1.0999	-0.1993	0.0359	0.8844	1.3225	13.4278
	Pooled	0.2657	0.0379	0.0131	0.9937	0.1597	3.5691
F_3A	1	0.3239	0.0693	0.0147	0.9959	0.1549	2.1262
	2	0.6767	-0.1331	0.0277	0.9861	0.3498	5.5869
	3	0.7908	-0.1435	0.0256	0.9687	0.4665	8.2758
	Pooled	0.5739	-0.0642	0.0223	0.9894	0.2715	4.3048
F_3S	1	0.1636	0.1624	0.0064	0.9957	0.1225	1.9075
	2	0.6365	-0.0844	0.0257	0.9913	0.2774	3.7647
	3	0.0525	0.1120	0.0086	0.9970	0.1016	2.3431
	4	0.1485	0.1061	0.0084	0.9920	0.1605	3.4725
	Pooled	0.1893	0.0940	0.0108	0.9987	0.0733	1.3467

Table 13. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of the gamma function $Y_t = at^b \exp(-ct)$ in different breeds of goats

Breeds	Parity No.	Estimates a	Estimates b	Estimates c	r^2	s	I
Alpine Malabari	1	5.3053	0.0942	0.0499	0.9928	0.0204	0.1801
	2	5.5072	0.1231	0.0461	0.9911	0.0184	0.1863
	3	5.8136	0.0192	0.0329	0.9840	0.0243	0.2395
	4	5.2263	0.2409	0.0552	0.9595	0.0350	0.3923
	5	6.4512	0.0242	0.0422	0.9803	0.0347	0.3486
	6	5.8203	0.0634	0.0463	0.9722	0.0405	0.3818
	7	5.9028	0.2349	0.0640	0.8975	0.0758	0.8659
	8	5.1390	0.2235	0.0848	0.9706	0.0623	0.4860
	Pooled	5.6430	0.1264	0.0517	0.9932	0.0186	0.1839
Malabari	1	3.6571	0.0371	0.0285	0.8906	0.0522	0.3526
	2	4.6497	0.0404	0.0404	0.9766	0.0342	0.2608
	3	4.5043	0.1909	0.0594	0.9502	0.0519	0.4320
	4	4.0701	0.2002	0.0552	0.9168	0.0589	0.4721
	5	5.1485	0.1973	0.0652	0.8431	0.1111	1.0083
	6	4.8251	0.2138	0.0821	0.9441	0.0849	0.6263
	Pooled	4.4766	0.1506	0.0557	0.9809	0.0325	0.2566
Saanen Malabari	1	5.9886	0.1443	0.0480	0.9407	0.0477	0.5396
	2	5.6081	0.0279	0.0233	0.9468	0.0294	0.3151
	3	6.2824	0.0060	0.0163	0.6985	0.0640	0.7895
	4	6.6664	0.1312	0.0451	0.9577	0.0382	0.4821
	5	7.3308	0.1467	0.0590	0.9594	0.0526	0.6519
	Pooled	6.3793	0.0923	0.0387	0.9677	0.0311	0.3706
F_2A	1	4.1202	0.0253	0.0311	0.9809	0.0243	0.1755
	2	4.6124	0.0169	0.0252	0.9659	0.0270	0.2286
	3	5.9299	-0.0397	0.0230	0.9677	0.0322	0.3170
	4	5.0988	0.2608	0.0688	0.9476	0.0556	0.5501
	5	5.1941	0.4307	0.1053	0.9425	0.0844	0.8316
	6	4.4355	0.5836	0.1518	0.9474	0.1215	0.8674
	Pooled	4.9129	0.2069	0.0654	0.9899	0.0254	0.2241
F_2S	1	4.8640	0.1810	0.0489	0.9396	0.0433	0.4259
	2	5.9544	0.1084	0.0473	0.9891	0.0222	0.2331
	3	6.6917	0.0791	0.0572	0.9860	0.0352	0.3520
	4	5.6762	0.1750	0.0421	0.8800	0.0498	0.6062
	5	5.7678	0.2887	0.0669	0.8638	0.0826	1.0011
	6	8.0871	0.2470	0.0779	0.9642	0.0577	0.8006
	7	6.4529	-0.1693	0.0331	0.7364	0.2072	1.5206
	Pooled	6.2014	0.1385	0.0538	0.9712	0.0395	0.4301
F_3A	1	4.3832	0.1741	0.0511	0.9207	0.0553	0.4719
	2	5.3930	0.3217	0.0934	0.9722	0.0579	0.5324
	3	4.6095	0.4156	0.0924	0.7984	0.1395	1.3527
	Pooled	4.8307	0.2996	0.0788	0.9543	0.0591	0.5416
F_3S	1	4.3934	0.0416	0.0186	0.7983	0.0423	0.3844
	2	5.3930	0.1480	0.0661	0.9444	0.0725	0.6149
	3	6.3154	0.1039	0.0470	0.9590	0.0441	0.4879
	4	5.5186	0.1070	0.0378	0.8416	0.0671	0.7191
	Pooled	5.4108	0.0950	0.0413	0.9773	0.0282	0.2783

Table 14. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of the McNally function $Y_t = at^b \exp(-ct+dt^{\frac{1}{2}})$ in different breeds of goats

Breeds	Parity No.	Estimates a	b	c	d	r^2	s	I
Alpine Malabari	1	6.8810	0.2698	0.0203	-0.3059	0.9938	0.0195	0.1723
	2	7.7503	0.3538	0.0071	-0.4019	0.9939	0.0157	0.1591
	3	8.2436	0.2550	-0.0069	-0.4108	0.9871	0.0225	0.2217
	4	2.1007	-0.3743	0.1591	1.0718	0.9863	0.0209	0.2350
	5	5.0501	-0.1410	0.0701	0.2879	0.9811	0.0350	0.3512
	6	2.8726	-0.4131	0.1268	0.8303	0.9802	0.0352	0.3317
	7	1.2945	-0.7892	0.2369	1.7842	0.9375	0.0611	0.6972
	8	3.5356	-0.0290	0.1274	0.4399	0.9717	0.0630	0.4914
	Pooled	3.9219	-0.1191	0.0932	0.4279	0.9958	0.0152	0.1500
Malabari	1	1.3821	-0.6197	0.1394	1.1443	0.9277	0.0438	0.3526
	2	2.1878	-0.4683	0.1263	0.8865	0.9876	0.0257	0.2608
	3	3.4927	0.0192	0.0884	0.2991	0.9513	0.0529	0.4320
	4	3.2706	0.0526	0.0802	0.2572	0.9180	0.0603	0.4721
	5	5.8347	0.2818	0.0509	-0.1472	0.8432	0.1145	1.0083
	6	2.2878	-0.2897	0.1672	0.8773	0.9481	0.0844	0.6263
	Pooled	2.9535	-0.1300	0.1032	0.4890	0.9838	0.0308	0.2433
Saanen Malabari	1	1.9490	-0.6133	0.1760	1.3200	0.9726	0.0334	0.5396
	2	3.4207	-0.3057	0.0797	0.5813	0.9613	0.0258	0.3151
	3	1.9753	-0.7749	0.1482	1.3606	0.7946	0.0544	0.7895
	4	3.3983	-0.3237	0.1219	0.7925	0.9707	0.0328	0.4821
	5	16.0087	0.6739	-0.0300	-0.9185	0.9682	0.0481	0.6519
	Pooled	3.9410	-0.2328	0.0936	0.5664	0.9753	0.0280	0.3338
F_2A	1	2.5356	-0.3024	0.0864	0.5709	0.9883	0.0196	0.1755
	2	2.4049	-0.4226	0.0994	0.7658	0.9851	0.0184	0.2286
	3	5.7794	-0.0570	0.0259	0.0302	0.9677	0.0331	0.3170
	4	1.0494	-0.8061	0.2490	1.8589	0.9889	0.0264	0.5501
	5	2.0250	-0.2051	0.2127	1.1076	0.9494	0.0816	0.8316
	6	7.6841	0.9542	0.0891	-0.6462	0.9485	0.1240	0.8674
	Pooled	3.1762	-0.0874	0.1151	0.5129	0.9927	0.0223	0.1965
F_2S	1	2.4406	-0.2844	0.1276	0.8109	0.9544	0.0388	0.4259
	2	5.6127	0.0686	0.0540	0.0695	0.9891	0.0229	0.2331
	3	13.8315	0.5692	-0.0256	-0.0854	0.9917	0.0279	0.3520
	4	4.7438	0.0539	0.0625	0.2110	0.8814	0.0511	0.6062
	5	1.7988	-0.4977	0.1997	1.3701	0.8902	0.0764	1.0011
	6	7.8456	0.2267	0.0813	0.0355	0.9640	0.0596	0.8006
	7	1.1297	-1.3454	0.0232	2.0491	0.7545	0.2061	1.5206
	Pooled	4.2515	-0.1162	0.0968	0.4439	0.9737	0.0389	0.4236
F_3A	1	1.6136	-0.5003	0.1650	1.1751	0.9458	0.0471	0.4719
	2	2.2265	-0.2753	0.1943	1.0403	0.9784	0.0525	0.5324
	3	1.3463	-0.4151	0.2327	1.4474	0.8137	0.1382	1.3527
	Pooled	1.9163	-0.3244	0.1842	1.0872	0.9651	0.0532	0.4878
$F_3'S$	1	1.7490	-0.5801	0.1236	1.0831	0.8916	0.0320	0.3844
	2	0.8556	-1.0947	0.2760	2.1651	0.9794	0.0454	0.6149
	3	11.2419	0.4932	-0.0187	-0.6782	0.9658	0.0415	0.4879
	4	2.9480	-0.3162	0.1093	0.7373	0.8550	0.0662	0.7191
	Pooled	3.0314	-0.2960	0.1074	0.6812	0.9865	0.0224	0.2213

Table 15. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of quadratic function $Y_t = a + bt + ct^2$ in different breeds of goats

Breeds	Parity No.	Estimates a	Estimates b	Estimates c	r^2	s	I
Alpine Malabari	1	5.4229	-0.1384	-0.0003	0.9799	0.1296	0.1296
	2	5.6792	-0.0819	-0.0024	0.9622	0.1646	0.1646
	3	5.8713	-0.1685	0.0018	0.9800	0.1180	0.1180
	4	5.2984	0.1111	-0.0107	0.9628	0.1544	0.1544
	5	6.4259	-0.2132	0.0020	0.9808	0.1505	0.1505
	6	5.7837	-0.1443	-0.0005	0.9776	0.1465	0.1465
	7	5.9815	0.0539	-0.0103	0.8750	0.4024	0.4024
	8	5.3183	-0.1294	-0.0027	0.9564	0.2494	0.2494
	Pooled	5.7227	-0.0888	-0.0029	0.9884	0.1017	0.1017
Malabari	1	3.5773	-0.0406	-0.0013	0.9270	0.1201	0.1201
	2	4.6015	-0.1152	-0.0001	0.9758	0.1147	0.1147
	3	4.6448	-0.0298	-0.0044	0.9316	0.2113	0.2113
	4	4.2040	0.0062	-0.0051	0.8742	0.2456	0.2456
	5	5.3243	-0.0572	-0.0046	0.8385	0.4250	0.4250
	6	4.9280	-0.1062	-0.0031	0.9450	0.2587	0.2587
	Pooled	4.5509	-0.0565	-0.0031	0.9724	0.1300	0.1300
Saanen Malabari	1	5.9495	-0.0032	-0.0065	0.9795	0.1294	0.1294
	2	5.5462	-0.0644	-0.0013	0.9625	0.1127	0.1127
	3	6.0610	-0.0302	-0.0025	0.7321	0.3136	0.3136
	4	6.6881	-0.0279	-0.0058	0.9735	0.1582	0.1582
	5	7.6937	-0.1847	-0.0015	0.9123	0.4201	0.4201
	Pooled	6.3877	-0.0621	-0.0035	0.9797	0.1233	0.1233
F_2A	1	4.0855	-0.0854	-0.0001	0.9833	0.0709	0.0709
	2	4.5465	-0.0735	-0.0005	0.9725	0.0882	0.0882
	3	5.8710	-0.1896	0.0032	0.9696	0.1364	0.1364
	4	5.1316	0.0678	-0.0101	0.9745	0.1541	0.1541
	5	5.5740	0.0747	-0.0130	0.9135	0.4045	0.4045
	6	5.1331	-0.0185	-0.0102	0.7957	0.7595	0.7595
	Pooled	5.0568	-0.0378	-0.0051	0.9741	0.1497	0.1497
F_2S	1	4.9277	0.0324	-0.0066	0.9345	0.1843	0.1843
	2	6.0625	-0.1058	-0.0021	0.9767	0.1458	0.1458
	3	6.8753	-0.2607	0.0025	0.9675	0.2383	0.2383
	4	5.8502	0.0488	-0.0072	0.8082	0.3314	0.3314
	5	5.8583	0.1442	-0.0139	0.8473	0.4374	0.4374
	6	8.5118	-0.1118	-0.0076	0.9307	0.4666	0.4666
	7	6.0279	-0.3770	0.0093	0.7666	0.6471	0.6471
	Pooled	6.3019	-0.0900	-0.0036	0.9687	0.1886	0.1886
F_3A	1	4.4114	0.0159	-0.0057	0.9129	0.2073	0.2073
	2	5.6474	-0.0282	-0.0081	0.9622	0.2512	0.2512
	3	4.8949	0.1489	-0.0145	0.7409	0.6381	0.6381
	Pooled	4.9948	0.0409	-0.0092	0.9444	0.2420	0.2420
F_3S	1	4.2963	0.0041	-0.0026	0.8412	0.1443	0.1443
	2	5.3218	-0.0948	-0.0035	0.9658	0.1988	0.1988
	3	6.5218	-0.1410	-0.0010	0.9344	0.2682	0.2682
	4	5.5307	-0.0192	-0.0043	0.8175	0.3322	0.3322
	Pooled	5.4176	-0.0627	-0.0029	0.9804	0.1093	0.1093

Table 16. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of the quadratic log scale function $Y_t = a + b \log_e t + C(\log_e t)^2$ in different breeds of goats

Breeds	Parity No.	Estimates a	b	c	r^2	s	I
Alpine Malabari	1	4.9379	0.7594	-0.5128	0.9946	0.0670	0.0670
	2	5.1122	1.0827	-0.5732	0.9927	0.0725	0.0725
	3	5.5118	0.3694	-0.3798	0.9872	0.0942	0.0942
	4	4.8597	1.7227	-0.6994	0.8926	0.2624	0.2624
	5	6.1525	0.2319	-0.4250	0.9804	0.1521	0.1521
	6	5.5814	0.3719	-0.4253	0.9622	0.1905	0.1905
	7	5.5852	1.6181	-0.7707	0.7990	0.5103	0.5103
	8	4.6886	1.2131	-0.7215	0.9640	0.2266	0.2266
	Pooled	5.3037	0.9212	-0.5635	0.9804	0.1324	0.1324
Malabari	1	3.5877	0.1335	-0.1776	0.8891	0.1480	0.1480
	2	4.4985	0.1739	-0.2903	0.9578	0.1514	0.1514
	3	4.1606	1.1644	-0.5730	0.9414	0.1956	0.1956
	4	3.7543	1.1714	-0.5269	0.8836	0.2362	0.2362
	5	4.6806	1.4048	-0.7019	0.8502	0.4093	0.4093
	6	4.4551	1.0199	-0.6347	0.9368	0.2773	0.2773
	Pooled	4.1858	0.8610	-0.4895	0.9615	0.1536	0.1536
Saanen Malabari	1	5.7305	0.9968	-0.5585	0.9157	0.2622	0.2622
	2	5.4732	0.2532	-0.2585	0.9360	0.1471	0.1471
	3	6.2770	-0.0394	-0.1572	0.6839	0.3406	0.3406
	4	6.3350	1.1254	-0.6184	0.9381	0.2418	0.2418
	5	6.6665	1.6812	-0.9178	0.9583	0.2897	0.2897
	Pooled	6.0964	0.8035	-0.5021	0.9587	0.1759	0.1759
F_2A	1	3.9929	0.1580	-0.2250	0.9685	0.0974	0.0974
	2	4.5168	0.1082	-0.2041	0.9479	0.1216	0.1216
	3	5.7481	-0.1191	-0.2261	0.9738	0.1267	0.1267
	4	4.7745	1.5478	-0.7146	0.8894	0.3210	0.3210
	5	4.5940	2.7700	-1.1688	0.9375	0.3439	0.3439
	6	3.5418	3.3509	-1.4031	0.8868	0.5655	0.5655
	Pooled	4.5302	1.2953	-0.6539	0.9752	0.1465	0.1465
F_2S	1	4.5727	1.1903	-0.5423	0.8927	0.2357	0.2357
	2	5.5851	0.9300	-0.5691	0.9811	0.1311	0.1311
	3	6.1352	0.8539	-0.6735	0.9840	0.1670	0.1670
	4	5.3089	1.5117	-0.6223	0.8213	0.3199	0.3199
	5	5.3076	2.2213	-0.9076	0.7826	0.5219	0.5219
	6	7.2988	2.5613	-1.2660	0.9638	0.3371	0.3371
	7	6.4756	-1.5349	0.0353	0.8264	0.5582	0.5582
	Pooled	5.8119	1.1049	-0.6494	0.9634	0.2038	0.2038
F_3A	1	4.1515	0.9589	-0.4733	0.8542	0.2682	0.2682
	2	4.8814	1.9559	-0.9460	0.9666	0.2361	0.2361
	3	4.1694	2.5445	-1.0137	0.7258	0.6564	0.6564
	Pooled	4.4085	1.8010	-0.8059	0.9291	0.2732	0.2732
F_3S	1	4.3495	0.1982	-0.1583	0.7325	0.1873	0.1873
	2	5.2136	0.5386	-0.4949	0.9233	0.2978	0.2978
	3	5.8361	1.1170	-0.6461	0.9633	0.2006	0.2006
	4	5.2789	0.8134	-0.4489	0.7779	0.3665	0.3665
	Pooled	5.1695	0.6668	-0.4371	0.9524	0.1705	0.1705

Table 17. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2) standard error of the estimate (s) and Furnival index (I) of the quadratic-cum-log equation $Y_t = a + bt + ct^2 + d \log_e t$ in different breeds of goats

Breeds	Parity No.	Estimates				r^2	s	I
		a	b	c	d			
Alpine Malabari	1	5.3454	-0.3557	0.0058	0.7035	0.9925	0.0816	0.0816
	2	5.5630	-0.4080	0.0067	1.0558	0.9953	0.0598	0.0698
	3	5.8277	-0.2908	0.0052	0.3960	0.9848	0.1060	0.1060
	4	5.2283	-0.0856	-0.0052	0.6369	0.9763	0.1271	0.1271
	5	6.4433	-0.1643	0.0006	-0.1583	0.9812	0.1533	0.1533
	6	5.8145	-0.0579	-0.0029	-0.2798	0.9794	0.1451	0.1451
	7	5.9402	-0.0619	-0.0070	0.3750	0.8773	0.4109	0.4109
	8	5.2137	-0.4230	0.0055	0.9507	0.9699	0.2137	0.2137
	Pooled	5.6720	-0.2309	0.0011	0.4600	0.9935	0.0786	0.0786
Malabari	1	3.6358	0.1235	-0.0059	-0.5315	0.9574	0.0945	0.0945
	2	4.6388	-0.0104	-0.0030	-0.3394	0.9803	0.1067	0.1067
	3	4.5559	-0.2793	0.0025	0.8079	0.9529	0.1807	0.1807
	4	4.1079	-0.2633	0.0025	0.8727	0.9080	0.2165	0.2165
	5	5.1822	-0.4555	0.0065	1.2899	0.8702	0.3929	0.3929
	6	4.8703	-0.2682	0.0014	0.5244	0.9498	0.2548	0.2548
	Pooled	4.4999	-0.1995	0.0009	0.4630	0.9799	0.1145	0.1145
Saanen Malabari	1	5.9824	0.0891	-0.0090	-0.2990	0.9818	0.1256	0.1256
	2	5.5882	0.0533	-0.0045	-0.3812	0.9716	0.1010	0.1010
	3	6.2146	0.4007	-0.0145	-1.3954	0.8451	0.2458	0.2458
	4	6.6740	-0.0674	-0.0047	0.1278	0.9739	0.1619	0.1619
	5	7.4741	-0.8006	0.0157	1.9940	0.9544	0.3124	0.3124
	Pooled	6.3867	-0.0650	-0.0034	0.0094	0.9797	0.1271	0.1271
F_2A	1	4.1104	-0.0155	-0.0020	-0.2263	0.9869	0.0647	0.0647
	2	4.5927	0.0562	-0.0041	-0.4201	0.9858	0.0654	0.0654
	3	5.9066	-0.0898	0.0004	-0.3232	0.9733	0.1320	0.1320
	4	5.1097	0.0064	-0.0083	0.1987	0.9754	0.1560	0.1560
	5	5.3848	-0.4562	0.0018	1.7190	0.9468	0.3271	0.3271
	6	4.6971	-1.2417	0.0239	3.9603	0.9139	0.5081	0.5081
	Pooled	4.9673	-0.2888	0.0019	0.8128	0.9904	0.0941	0.0941
F_2S	1	4.8756	-0.1136	-0.0025	0.4729	0.9437	0.1761	0.1761
	2	5.9912	-0.3060	0.0035	0.6482	0.9865	0.1144	0.1144
	3	6.7409	-0.6378	0.0131	1.2207	0.9856	0.1632	0.1632
	4	5.7169	-0.3251	0.0032	1.2108	0.8627	0.2890	0.2890
	5	5.7810	-0.0725	-0.0079	0.7017	0.8557	0.4383	0.4383
	6	8.2635	-0.8084	0.0119	2.2555	0.9652	0.3409	0.3409
	7	6.3158	0.4306	-0.0131	-2.6148	0.8478	0.5387	0.5387
	Pooled	6.2407	-0.2619	0.0011	0.5566	0.9745	0.1755	0.1755
F_3A	1	4.3884	-0.0485	-0.0039	0.2084	0.9148	0.2113	0.2113
	2	5.5142	-0.4018	0.0023	1.2096	0.9808	0.1844	0.1844
	3	4.7785	-0.1775	-0.0054	1.0567	0.7560	0.6382	0.6382
	Pooled	4.9027	-0.2173	-0.0020	0.8361	0.9585	0.2154	0.2154
F_3S	1	4.3555	0.1704	-0.0073	-0.5384	0.8883	0.1248	0.1248
	2	5.4025	0.1317	-0.0098	-0.7333	0.9757	0.1727	0.1727
	3	6.3777	-0.5452	0.0103	1.3089	0.9676	0.1941	0.1941
	4	5.5116	-0.0727	-0.0028	0.1735	0.8186	0.3414	0.3414
	Pooled	5.4118	-0.0790	-0.0024	0.0527	0.9805	0.1124	0.1124

Table 18. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2) standard error of the estimate (s) and Furnival index (I) of the empirical function $Y_t = t[a \exp(bt)]^{-1}$ in different breeds of goats

Breeds	Parity No.	Estimates a	Estimates b	r^2	s	I
Alpine Malabari	1	0.3798	0.1658	0.4265	1.0690	9.4340
	2	0.3578	0.1583	0.4519	1.1295	11.4584
	3	0.3673	0.1584	0.2593	1.2611	12.4463
	4	0.3442	0.1523	0.6526	1.0484	11.7642
	5	0.3297	0.1671	0.3089	1.3576	13.6265
	6	0.3545	0.1661	0.3573	1.2118	11.4258
	7	0.3062	0.1618	0.5853	1.1535	13.1689
	8	0.3548	0.1841	0.6436	0.8951	6.9798
	Pooled	0.3483	0.1635	0.4682	1.1319	11.1643
Malabari	1	0.5758	0.1517	0.1832	0.8480	5.7269
	2	0.4517	0.1632	0.3132	0.9849	7.5157
	3	0.4151	0.1629	0.5473	0.8869	7.3879
	4	0.4561	0.1576	0.5594	0.8112	6.5036
	5	0.3614	0.1679	0.5667	0.9779	8.8743
	6	0.3807	0.1827	0.6088	0.8732	6.4385
	Pooled	0.4309	0.1644	0.5130	0.8788	6.9390
Saanen Malabari	1	0.3237	0.1575	0.4188	1.2829	14.5074
	2	0.3782	0.1477	0.1712	1.3065	14.0094
	3	0.3434	0.1435	0.0590	1.5544	19.1846
	4	0.2937	0.1563	0.4190	1.4188	17.9043
	5	0.2639	0.1682	0.4872	1.4529	18.0014
	Pooled	0.3163	0.1548	0.3345	1.3978	16.6335
F_2A	1	0.5158	0.1558	0.2383	0.9113	6.5821
	2	0.4638	0.1509	0.1861	1.0517	8.8877
	3	0.3769	0.1560	0.1398	1.3430	13.2414
	4	0.3474	0.1634	0.6356	0.9777	9.6785
	5	0.2990	0.1782	0.7553	0.9060	8.9233
	6	0.3111	0.2050	0.8985	0.5352	3.8208
	Pooled	0.3759	0.1669	0.5978	0.9262	8.1697
F_2S	1	0.3874	0.1537	0.5308	1.0057	9.8829
	2	0.3347	0.1613	0.4304	1.2176	12.7852
	3	0.3046	0.1751	0.4640	1.2854	12.8387
	4	0.3335	0.1476	0.5347	1.2013	14.6150
	5	0.3005	0.1579	0.5986	1.1718	14.2079
	6	0.2214	0.1742	0.6428	1.4579	20.2188
	7	0.3828	0.1827	0.1268	1.5218	11.1659
	Pooled	0.3140	0.1640	0.4734	1.2477	13.5817
F_3A	1	0.4321	0.1568	0.5042	0.9005	7.6815
	2	0.3133	0.1802	0.7211	0.9176	8.4436
	3	0.3409	0.1671	0.5690	1.0278	9.9679
	Pooled	0.3558	0.1684	0.6640	0.9018	8.2678
F_3S	1	0.4777	0.1412	0.1640	1.0559	9.5933
	2	0.3584	0.1751	0.4622	1.0917	9.2605
	3	0.3167	0.1617	0.4292	1.2844	14.2063
	4	0.3615	0.1521	0.3510	1.2104	12.9649
	Pooled	0.3722	0.1571	0.3800	1.1466	11.3156

Table 19. Parity-wise and pooled estimates of the constants, co-efficient of determination (r^2), standard error of the estimate (s) and Furnival index (I) of the linear hyperbolic function Y_t = a+bt+c/t in different breeds of goats

Breeds	Parity No.	Estimates a	b	c	r^2	s	I
Alpine Malabari	1	5.6696	-0.1578	-0.4852	0.9877	0.1016	0.1016
	2	6.2983	-0.1574	-0.9439	0.9886	0.0905	0.0905
	3	5.7433	-0.1321	-0.0158	0.9754	0.1308	0.1308
	4	6.9525	-0.1613	-1.8071	0.9213	0.2246	0.2246
	5	6.1282	-0.1631	0.3148	0.9797	0.1548	0.1548
	6	5.7779	-0.1523	0.0973	0.9776	0.1466	0.1466
	7	7.4139	-0.1991	-1.3922	0.8326	0.4657	0.4657
	8	5.9395	-0.2102	-0.8960	0.9668	0.2177	0.2177
	Pooled	6.2404	-0.1667	-0.6410	0.9916	0.0866	0.0866
Malabari	1	3.6445	-0.0662	0.0728	0.9188	0.1267	0.1267
	2	4.5011	-0.1103	0.2270	0.9784	0.1083	0.1083
	3	5.4760	-0.1511	-1.0658	0.9492	0.1821	0.1821
	4	5.1188	-0.1306	-1.1389	0.8942	0.2252	0.2252
	5	6.2473	-0.1862	-1.2407	0.8576	0.3991	0.3991
	6	5.4831	-0.1892	-0.6916	0.9480	0.2517	0.2517
	Pooled	5.0952	-0.1399	-0.6584	0.9756	0.1222	0.1222
Saanen Malabari	1	6.8174	-0.1605	-0.8031	0.9486	0.2048	0.2048
	2	5.6434	-0.0910	0.0005	0.9576	0.1198	0.1198
	3	6.0966	-0.0730	0.3341	0.7236	0.3185	0.3185
	4	7.5599	-0.1749	-0.9187	0.9613	0.1912	0.1912
	5	8.4902	-0.2560	-1.4767	0.9413	0.3437	0.3437
	Pooled	6.9215	-0.1511	-0.5728	0.9750	0.1369	0.1369
F_2A	1	4.0343	-0.0837	0.1240	0.9847	0.0679	0.0679
	2	4.4998	-0.0790	0.1840	0.9750	0.0842	0.0842
	3	5.3488	-0.1062	0.5967	0.9684	0.1391	0.1391
	4	6.5749	-0.1822	-1.4528	0.9256	0.2633	0.2633
	5	7.9377	-0.2781	-2.9513	0.9489	0.3108	0.3108
	6	7.5256	-0.3268	-3.4809	0.8769	0.5897	0.5897
	Pooled	5.9802	-0.1753	-1.1559	0.9864	0.1086	0.1086
F_2S	1	5.9584	-0.1363	-1.1363	0.9173	0.2069	0.2069
	2	6.5329	-0.1682	-0.6657	0.9851	0.1165	0.1165
	3	6.8593	-0.2178	-0.3900	0.9661	0.2433	0.2433
	4	7.1124	-0.1434	-1.5374	0.8299	0.3122	0.3122
	5	8.0109	-0.2110	-2.3443	0.8095	0.4885	0.4885
	6	10.1910	-0.3342	-2.3821	0.9622	0.3443	0.3443
	7	4.0771	-0.1097	2.6776	0.8280	0.5555	0.5555
	Pooled	6.9632	-0.1887	-0.8255	0.9733	0.1742	0.1742
F_3A	1	5.2329	-0.1256	-0.8353	0.8850	0.2382	0.2382
	2	7.1165	-0.2473	-1.8358	0.9779	0.1922	0.1922
	3	7.3323	-0.2323	-2.8682	0.7487	0.6284	0.6284
	Pooled	6.5427	-0.2010	-1.8228	0.9493	0.2310	0.2310
F_3S	1	4.5229	-0.0527	-0.0504	0.7869	0.1672	0.1672
	2	5.6206	-0.1698	-0.0658	0.9551	0.2280	0.2280
	3	7.0028	-0.1852	-0.8797	0.9531	0.2266	0.2266
	4	6.1496	-0.1267	-0.6190	0.8031	0.3451	0.3451
	Pooled	5.8240	-0.1336	-0.4038	0.9740	0.1259	0.1259

Table 20. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of Alpine Malabari

Part record	Parity	Estimates			r^2	s
		a	b	c		
4 weeks	1	0.3536	5.0214	-0.4430	0.9902	2.3344
	2	-0.5278	5.5502	0.1581	0.9926	2.3357
	3	0.1961	5.4529	-0.1498	0.9938	2.0516
	4	-1.8917	5.8353	1.3538	0.9944	2.2958
	5	0.7926	5.8168	-0.4144	0.9910	2.5222
	6	0.9286	5.2611	-0.4299	0.9913	2.3547
	7	-0.9363	5.8937	1.4878	0.9897	3.1810
	8	-1.1592	5.2040	0.8526	0.9774	3.2486
	Pooled	-0.2805	5.5044	0.3018	0.9909	2.5239
8 weeks	1	2.4169	4.5881	-2.1976	0.9916	2.1614
	2	0.9997	5.2288	-1.1393	0.9933	2.2110
	3	2.7649	4.9074	-2.3215	0.9951	1.8251
	4	-1.4110	5.7374	0.9399	0.9945	2.2610
	5	4.4039	5.0436	-3.4556	0.9931	2.2144
	6	3.1732	4.7500	-2.2636	0.9925	2.1784
	7	-2.8299	6.3848	2.9261	0.9890	3.2906
	8	2.2017	4.4956	-1.9991	0.9806	3.0079
	Pooled	1.4650	5.1420	-1.1889	0.9919	2.3859
12 weeks	1	4.8807	4.2058	-4.6023	0.9933	1.9250
	2	3.4997	4.8410	-3.5797	0.9947	1.9782
	3	5.2324	4.5227	-4.7248	0.9963	1.5796
	4	0.0494	5.5161	-0.4998	0.9951	2.1415
	5	6.8249	4.6631	-5.8055	0.9945	1.9785
	6	4.7086	4.5180	-3.7793	0.9935	2.0360
	7	0.3807	5.8929	-0.2244	0.9906	3.0381
	8	4.7904	4.0889	-4.5126	0.9834	2.7794
	Pooled	3.7960	4.7810	-3.4662	0.9932	2.1749

Table 21. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of Malabari

Part record	Parity	Estimates a	b	c	r^2	s
4 weeks	1	0.7277	3.3606	-0.4171	0.9975	0.8899
	2	1.9576	3.8319	-1.1092	0.9931	1.6891
	3	-1.3408	4.7858	0.9217	0.9902	2.2295
	4	-1.5470	4.4206	1.1610	0.9914	2.0145
	5	0.0783	4.9901	-0.1029	0.9853	3.0062
	6	-0.5909	4.7831	0.4956	0.9792	2.9498
	Pooled	-0.1193	4.3620	0.1582	0.9900	2.1350
8 weeks	1	1.6252	3.1688	-1.1735	0.9979	0.8147
	2	1.9635	3.8624	-1.1720	0.9931	1.6841
	3	0.3510	4.4427	-0.5400	0.9914	2.0983
	4	-0.4802	4.2167	0.2186	0.9921	1.9329
	5	0.2653	4.9697	-0.2974	0.9855	2.9900
	6	2.3451	4.1244	-1.9222	0.9819	2.7460
	Pooled	0.9323	4.1492	-0.7504	0.9907	2.0536
12 weeks	1	2.4126	3.0441	-1.9350	0.9983	0.7460
	2	3.4504	3.6334	-2.6281	0.9942	1.5481
	3	2.4956	4.1059	-2.6220	0.9929	1.9075
	4	1.0560	3.9853	-1.3000	0.9931	1.8005
	5	1.6586	4.7516	-1.6521	0.9866	2.8770
	6	3.8374	3.8932	-3.3799	0.9836	2.6170
	Pooled	2.4695	3.9105	-2.2507	0.9919	1.9188

Table 22. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of Saanen Malabari

Part record	Parity	Estimates a	b	c	r^2	s
	1	0.5972	5.8644	-0.5309	0.9950	2.1606
	2	0.6474	5.2964	-0.3812	0.9979	1.2888
4 weeks	3	1.9914	5.7275	-1.3855	0.9992	0.9087
	4	-0.4571	6.7107	0.3305	0.9946	2.4977
	5	-2.7235	7.9442	1.3209	0.9869	3.8107
	Pooled	0.0111	6.3086	-0.1292	0.9956	2.1062
	1	2.0755	5.5128	-1.7121	0.9955	2.0525
	2	2.0776	4.9801	-1.5672	0.9983	1.1682
8 weeks	3	3.3888	5.3712	-2.4562	0.9994	0.8307
	4	1.6871	6.2501	-1.4726	0.9953	2.3308
	5	3.0896	6.6617	-3.5094	0.9899	3.3572
	Pooled	2.4637	5.7552	-2.1435	0.9964	1.9087
	1	2.9741	5.3780	-2.6019	0.9958	1.9755
	2	2.9819	4.8388	-2.4469	0.9985	1.0863
	3	2.6307	5.4910	-1.7223	0.9993	0.8786
12 weeks	4	3.5406	5.9609	-3.2772	0.9959	2.1685
	5	7.6929	5.9311	-7.9576	0.9924	2.9126
	Pooled	3.9641	5.5199	-3.6012	0.9969	1.7724

Table 23. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of F_2A

Part record	Parity	Estimates			r^2	s
		a	b	c		
	1	0.7017	3.7177	-0.3117	0.9955	1.2856
	2	1.1742	4.1019	-0.6189	0.9972	1.1878
4 weeks	3	1.3062	5.2097	-0.7810	0.9958	1.6713
	4	-0.5385	5.2570	0.5560	0.9908	2.6185
	5	-3.8129	6.6046	1.9948	0.9821	3.7436
	6	-3.2060	5.2981	1.9164	0.9464	5.0360
	Pooled	-0.7292	5.0315	0.4592	0.9886	2.5621
	1	1.7321	3.5077	-1.1987	0.9961	1.1969
	2	1.6789	3.9974	-1.0504	0.9974	1.1452
8 weeks	3	3.7202	4.6755	-2.7818	0.9968	1.4509
	4	-0.5158	5.2638	0.5142	0.9908	2.6149
	5	0.6281	5.6464	-1.7328	0.9848	3.4416
	6	-4.7019	5.6900	3.0447	0.9449	5.1046
	Pooled	0.4236	4.7968	-0.5342	0.9894	2.4742
	1	2.8211	3.3373	-2.2578	0.9967	1.0956
	2	2.4038	3.8859	-1.7605	0.9977	1.0783
12 weeks	3	5.1449	4.4568	-4.1791	0.9974	1.3061
	4	0.9610	5.0415	-0.9459	0.9916	2.4952
	5	4.0429	5.1070	-5.0389	0.9873	3.1554
	6	2.5362	4.5729	-4.0353	0.9554	4.5927
	Pooled	2.9930	4.3989	-3.0438	0.9912	2.2488

Table 24. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of F_2S

Part record	Parity	Estimates a	Estimates b	Estimates c	r^2	s
	1	-0.6236	4.9979	0.5338	0.9945	1.9711
	2	0.3635	5.6680	-0.3157	0.9921	2.4872
	3	-0.8799	6.4942	0.4606	0.9834	3.4471
4 weeks	4	-2.1701	6.1550	1.8000	0.9951	2.3017
	5	-3.2228	6.8815	2.1166	0.9919	3.0042
	6	-2.8064	8.7542	1.5761	0.9837	4.8695
	7	5.4357	4.1279	-3.0984	0.9914	1.8140
	Pooled	-0.5579	6.1542	0.4391	0.9909	2.7973
	1	-1.0594	5.1041	0.8761	0.9943	2.0012
	2	1.3270	5.4702	-1.1437	0.9926	2.4077
	3	4.1999	5.4024	-3.8108	0.9871	3.0433
8 weeks	4	-2.7150	6.3234	2.1631	0.9949	2.3308
	5	-0.8091	6.2694	0.2599	0.9927	2.8600
	6	0.9648	7.9435	-1.5950	0.9854	4.5946
	7	6.9402	3.7749	-4.3112	0.9927	1.6710
	Pooled	1.2640	5.7554	-1.0802	0.9918	2.6562
	1	1.1656	4.7610	-1.3015	0.9953	1.8105
	2	4.1754	5.0276	-3.9218	0.9942	2.1434
	3	7.9023	4.8249	-7.4163	0.9900	2.6788
12 weeks	4	0.0767	5.8932	-0.5698	0.9959	2.0922
	5	0.7165	6.0497	-1.2752	0.9933	2.7372
	6	7.0844	7.0003	-7.5847	0.9887	4.0430
	7	10.9520	3.1551	-8.2338	0.9957	1.2737
	Pooled	4.5817	5.2446	-4.3289	0.9935	2.3537

Table 25. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of F_3A

Part record	Parity	Estimates			r^2	s
		a	b	c		
	1	1.2116	3.9964	-0.7250	0.9939	1.7970
4 weeks	2	-2.3075	6.0401	1.4357	0.9804	3.6038
	3	1.8940	5.0231	-2.8835	0.9901	2.7252
	Pooled	0.2664	5.0196	-0.7244	0.9889	2.6733
	1	-0.9692	4.5074	1.0302	0.9929	1.9507
8 weeks	2	1.1322	5.2783	-1.4142	0.9829	3.3710
	3	1.1373	5.0562	-2.0130	0.9897	2.7899
	Pooled	0.4328	4.9473	-0.7984	0.9890	2.6663
	1	1.0421	4.1988	-0.9422	0.9940	1.7824
12 weeks	2	4.0178	4.8327	-4.2368	0.9853	3.1248
	3	1.1723	5.0561	-2.0616	0.9897	2.7862
	Pooled	2.1893	4.6783	-2.5224	0.9901	2.5190

Table 26. Parity-wise and pooled estimates of constants, co-efficient of determination (r^2) and SE(s) obtained by fitting linear hyperbolic function for the prediction of total yield from part records of F_3S

Part record	Parity	Estimates a	Estimates b	Estimates c	r^2	s
	1	0.8357	4.1030	-0.4078	0.9990	0.7686
	2	2.9169	4.4399	-1.8817	0.9889	2.4419
4 weeks	3	-0.6338	6.2644	0.2597	0.9907	2.8454
	4	1.0979	5.1149	-0.6315	0.9955	1.9207
	Pooled	1.0542	4.9806	-0.6653	0.9945	1.9623
	1	0.5640	4.1619	-0.1809	0.9989	0.7870
8 weeks	2	2.9220	4.4383	-1.8848	0.9889	2.4417
	3	1.3569	5.8422	-1.4252	0.9917	2.6845
	4	-0.4370	5.4154	0.7144	0.9949	2.0409
	Pooled	1.1016	4.9645	-0.6943	0.9945	1.9593
	1	0.9240	4.1049	-0.5296	0.9990	0.7588
	2	4.1757	4.2450	-3.1120	0.9898	2.3347
12 weeks	3	5.0077	5.2738	-4.9825	0.9937	2.3414
	4	1.1732	5.1835	-0.9062	0.9956	1.8983
	Pooled	2.8202	4.7018	-2.3827	0.9953	1.8051

Table 27. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for Alpine Malabari

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	5.5253	5.5258	5.4181	5.1109
2	10.8824	10.8793	11.1545	11.6250
3	16.3289	16.3335	16.4946	16.9838
4	21.8148	21.8128	21.7357	22.0537
5	27.2398	27.3021	26.9371	27.0081
6	32.3631	32.7965	32.1187	31.9048
7	37.2862	38.2938	37.2890	36.7684
8	42.1594	43.7928	42.4522	41.6113
9	46.9114	49.2931	47.6107	46.4406
10	51.4672	54.7942	52.7659	51.2602
11	55.7664	60.2959	57.9187	56.0727
12	59.9747	65.7981	63.0697	60.8801
13	64.0208	71.3006	68.2193	65.6834
14	67.8777	76.8034	73.3678	70.4835
15	71.4959	82.3064	78.5154	75.2811
16	74.9598	87.8096	83.6624	80.0766
17	78.3840	93.3129	88.8087	84.8704
18	81.6151	98.8164	93.9546	89.6629
19	84.6436	104.3199	99.1000	94.4541
20	87.5032	109.8236	104.2451	99.2443

Table 28. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for Malabari

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	4.4019	4.4010	4.3310	4.1294
2	8.6785	8.6839	8.8554	9.1653
3	13.0278	13.0196	13.1296	13.4509
4	17.3649	17.3685	17.3413	17.5490
5	21.6991	21.7227	21.5280	21.5721
6	25.9385	26.0795	25.7022	25.5577
7	29.8633	30.4378	29.8692	29.5218
8	33.8146	34.7970	34.0318	33.4725
9	37.6910	39.1568	38.1914	37.4143
10	41.4369	43.5171	42.3489	41.3499
11	45.1786	47.8778	46.5049	45.2809
12	48.5771	52.2386	50.6597	49.2085
13	51.7210	56.5997	54.8137	53.1334
14	54.6687	60.9609	58.9670	57.0563
15	57.4463	65.3222	63.1198	60.9776
16	60.1751	69.6836	67.2721	64.8975
17	62.8950	74.0451	71.4239	68.8163
18	65.4005	78.4066	75.5756	72.7342
19	67.8525	82.7682	79.7269	76.6513
20	70.1586	87.1298	83.8781	80.5678

Table 29. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for Saanen Malabari

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	6.1992	6.1905	6.0754	5.8828
2	12.5114	12.5637	12.9023	13.2033
3	18.9724	18.8939	19.0147	19.3234
4	25.1784	25.2133	24.9484	25.1435
5	31.0020	31.5284	30.8108	30.8434
6	36.7171	37.8413	36.6374	36.4834
7	42.4816	44.1531	42.4436	42.0891
8	48.0078	50.4640	48.2371	47.6733
9	53.4432	56.7744	54.0220	53.2433
10	58.8510	63.0845	59.8010	58.8032
11	64.1653	69.3943	65.5756	64.3559
12	69.4181	75.7039	71.3470	69.9031
13	74.4592	82.0134	77.1159	75.4461
14	79.3758	88.3227	82.8829	80.9858
15	84.0587	94.6320	88.6483	86.5228
16	88.5258	100.9412	94.4123	92.0578
17	92.9645	107.2503	100.1754	97.5909
18	97.0952	113.5593	105.9376	103.1226
19	100.9918	119.8683	111.6990	108.6531
20	104.6472	126.1773	117.4598	114.1825

Table 30. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for F_2A

Weeks	Observed cumulative yields	Predicted cumulative yield using part records of		
		4 weeks	8 weeks	12 weeks
1	4.7593	4.7616	4.6863	4.3481
2	9.5770	9.5635	9.7502	10.2689
3	14.4982	14.5185	14.6361	15.1752
4	19.5207	19.5117	19.4774	19.8277
5	24.5067	24.5203	24.3010	24.3788
6	29.3373	29.5365	29.1156	28.8792
7	33.9094	34.5571	33.9252	33.3506
8	38.5148	39.5804	38.7316	37.8039
9	42.8520	44.6055	43.5358	42.2450
10	46.7971	49.6319	48.3386	46.6778
11	50.7087	54.6593	53.1403	51.1044
12	54.6047	59.6873	57.9412	55.5263
13	58.1644	64.7159	62.7414	59.9448
14	61.5898	69.7449	67.5412	64.3604
15	64.8406	74.7742	72.3406	68.7738
16	67.9846	79.8038	77.1396	73.1854
17	70.9465	84.8336	81.9384	77.5955
18	73.6535	89.8637	86.7370	82.0043
19	76.2685	94.8938	91.5354	86.4122
20	78.6324	99.9241	96.3337	90.8191

Table 31. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for F_2S

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	6.0373	6.0354	5.9392	5.4974
2	11.9587	11.9700	12.2348	12.9064
3	18.0680	18.0510	18.1703	18.8724
4	24.1610	24.1686	24.0157	24.4777
5	30.0158	30.3008	29.8252	29.9387
6	35.7344	36.4403	35.6166	35.3276
7	41.4903	42.5840	41.3978	40.6752
8	46.9065	48.7303	47.1725	45.9970
9	52.1237	54.8784	52.9430	51.3017
10	56.9312	61.0277	58.7104	56.5944
11	61.3556	67.1778	64.4757	61.8783
12	65.8398	73.3287	70.2393	67.1556
13	70.4703	79.4800	76.0017	72.4279
14	74.9817	85.6318	81.7630	77.6963
15	79.2733	91.7839	87.5236	82.9614
16	83.0675	97.9362	93.2836	88.2240
17	86.7746	104.0887	99.0430	93.4845
18	90.3542	110.2415	104.8020	98.7432
19	93.6240	116.3944	110.5606	104.0004
20	96.6704	122.5474	116.3189	109.2564

Table 32. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for F_3A

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	4.5817	4.5616	4.5817	4.3453
2	9.8228	9.9434	9.9282	10.2848
3	15.2648	15.0838	15.0085	15.3835
4	20.0834	20.1638	20.0223	20.2720
5	24.7973	25.2197	25.0095	25.0764
6	29.8138	30.2635	29.9834	29.8388
7	35.0318	35.3003	34.9497	34.5772
8	39.9988	40.3329	39.9112	39.3005
9	44.5704	45.3626	44.8696	44.0138
10	48.8303	50.3903	49.8257	48.7202
11	53.1647	55.4165	54.7802	53.4214
12	57.3928	60.4416	59.7336	58.1188
13	61.2290	65.4659	64.6859	62.8133
14	64.9427	70.4895	69.6376	67.5055
15	68.4749	75.5126	74.5887	72.1958
16	71.7251	80.5352	79.5393	76.8846
17	74.4054	85.5575	84.4895	81.5722
18	77.1328	90.5795	89.4394	86.2587
19	79.7954	95.6012	94.3890	90.9444
20	82.0830	100.6228	99.3384	95.6294

Table 33. The observed and the predicted cumulative yields over 20 weeks obtained by fitting linear hyperbolic function to the pooled data by taking various part records of milk yield for F_3S

Weeks	Observed cumulative yields	Predicted cumulative yields using part records of		
		4 weeks	8 weeks	12 weeks
1	5.3731	5.3694	5.3718	5.1394
2	10.6605	10.6827	10.6834	11.0325
3	15.8074	15.7742	15.7636	16.1314
4	20.7954	20.8102	20.7859	21.0317
5	25.7710	25.8240	25.7851	25.8527
6	30.7249	30.8268	30.7727	30.6339
7	35.7621	35.8232	35.7537	35.3924
8	40.7522	40.8157	40.7306	40.1368
9	45.3715	45.8055	45.7047	44.8716
10	49.7596	50.7935	50.6769	49.5999
11	54.1749	55.7801	55.6477	54.3234
12	58.2362	60.7658	60.6174	59.0432
13	62.4276	65.7506	65.5863	63.7603
14	66.4126	70.7349	70.5546	68.4752
15	70.1854	75.7186	75.5224	73.1883
16	73.8298	80.7020	80.4897	77.9000
17	77.3121	85.6850	85.4568	82.6106
18	80.6365	90.6678	90.4235	87.3202
19	83.8822	95.6503	95.3900	92.0289
20	86.9682	100.6326	100.3563	96.7370

Table 34. Two way table showing number of animals in each parity with their corresponding average yield (kg) per week

Breed \ Parity	1	2	3	4	5	6	Total
Alpine Malabari	67 3.9254	85 4.4758	76 4.3538	48 4.9335	36 4.4721	20 4.1960	332 4.3857
Malabari	35 2.9630	31 3.3837	13 3.6981	11 3.5423	4 4.6688	6 20.2300	100 3.3215
Saanen Malabari	49 4.9878	35 4.6884	26 5.3904	24 5.5583	8 5.5369	1 6.5750	143 5.1253
F_2A	89 3.1778	68 3.7034	38 4.3409	23 4.4007	8 4.4869	2 3.4675	228 3.7002
F_2S	54 4.3224	30 4.6465	17 4.5024	10 5.3300	6 5.3733	6 6.2533	123 4.6537
F_3S	26 3.9604	15 3.8257	6 4.9000	4 4.7075	1 4.5450	1 3.7700	53 4.0925
Total	320 3.8447	264 4.1592	176 4.4887	120 4.8543	63 4.6706	36 4.4153	979

Table 35. Analysis of variance for testing the significance of breed, parity and their interaction (Breed x Parity) on average yield of individual animals

Source	df	SS	MS	E(MS)	F
Breed	5	292.1143	58.4229	58.4229	145.4381**
Parity	5	120.6697	24.1339	24.1339	60.0791**
Breed x Parity	25	29.1660	1.1666	1.1666	2.9042**
Error	943	378.8056	0.4017		
Total	978	820.7556			

** P <0.01

Table 36. CD matrix for the comparison of breeds

Breed	Alpine Malabari (AM)	Malabari (M)	Saanen Malabari (SM)	F_2A	F_2S	F_3S
Alpine Malabari (AM)		0.1417 0.1865	0.1243 0.1636	0.1068 0.1406	0.1311 0.1726	0.1838 0.2419
Malabari (M)			0.1619 0.2132	0.1490 0.1961	0.1673 0.2202	0.2111 0.2778
Saanen Malabari (SM)				0.1325 0.1744	0.1528 0.2011	0.1998 0.2630
F_2A					0.1390 0.1829	0.1894 0.2494
F_2S						0.2041 0.2687
F_3S						

First value corresponds to 5 per cent level of significance
Second value corresponds to 1 per cent level of significance

Rank	1	2	3	4	5	6
Breed	SM	F_2S	AM	F_3S	F_2A	M
Mean yield (kg)	5.1253	4.6537	4.3857	4.0925	3.7002	3.3215

Table 37. CD matrix obtained for the comparison of parities

Parity	1	2	3	4	5	6
1		0.1033 0.1360	0.1166 0.1535	0.1330 0.1750	0.1712 0.2254	0.2184 0.2875
2			0.1209 0.1591	0.1368 0.1800	0.1742 0.2293	0.2207 0.2905
3				0.1471 0.1936	0.1824 0.2401	0.2272 0.2991
4					0.1933 0.2544	0.2361 0.3107
5						0.2595 0.3416
6						

First value corresponds to 5 per cent level of significance
Second value corresponds to 1 per cent level of significance

Rank	1	2	3	4	5	6
Parity	4	5	3	6	2	1
Mean yield (kg)	4.8543	4.6706	4.4887	4.4153	4.1592	3.8447

Table 38. Persistency indices obtained by four different methods for the pooled and parity-wise data in various breeds of goats, along with the average weekly yield

Breeds	Parity No.	Method I	Method II	Method III	Method IV	Average weekly yield (kg)
Alpine Malabari	1	0.8321	2.8651	3.2790	0.9327	3.9257
	2	0.8682	3.1245	3.4565	0.9499	4.4758
	3	0.8542	2.9658	3.4798	0.9435	4.3537
	4	0.9137	3.5240	3.5941	0.9621	4.9335
	5	0.8182	2.7367	3.2417	0.9247	4.4721
	6	0.8359	2.8416	3.2683	0.9283	4.1960
	7	0.8797	3.3941	3.3953	0.9491	5.0733
	8	0.7737	2.5962	3.0192	0.9132	3.5710
	Pooled	0.8485	3.0112	3.3360	0.9359	4.3752
Malabari	1	0.8923	3.2096	3.6899	0.9461	2.9630
	2	0.8457	2.9793	3.3386	0.9327	3.3837
	3	0.8567	3.1037	3.3633	0.9463	3.6981
	4	0.8810	3.3203	3.4761	0.9584	3.5623
	5	0.8493	3.0738	3.2686	0.9657	4.0688
	6	0.7887	2.6222	3.0337	0.9143	3.3717
	Pooled	0.8551	3.0403	3.3217	0.9384	3.5079
Saanen Malabari	1	0.8827	3.1742	3.4752	0.9409	4.9878
	2	0.9084	3.3206	3.8628	0.9585	4.6884
	3	0.9318	3.3996	4.1394	0.9629	5.3904
	4	0.8794	3.1969	3.5055	0.9490	5.5583
	5	0.8202	2.7794	3.2449	0.9421	5.5369
	Pooled	0.8825	3.1562	3.5533	0.9477	5.2324
F_2A	1	0.8713	3.0960	3.5593	0.9438	3.1778
	2	0.8973	3.2517	3.7443	0.9519	3.7034
	3	0.8643	4.1308	3.6221	0.9431	4.3409
	4	0.8780	3.2711	3.3741	0.9369	4.4131
	5	0.8107	2.8847	3.2202	0.9398	4.4869
	6	0.7542	2.7486	2.9858	0.9338	3.4675
	Pooled	0.8439	3.0282	3.2913	0.9338	3.9316
F_2S	1	0.9037	3.4307	3.5632	0.9570	4.3224
	2	0.8581	3.0393	3.3829	0.9380	4.6465
	3	0.7867	2.4567	3.0869	0.9280	4.5024
	4	0.9256	3.6429	3.7221	0.9766	5.3300
	5	0.8976	3.3450	3.4857	0.9729	5.3733
	6	0.8116	2.8403	3.1834	0.9281	6.2533
	7	0.7609	2.2189	2.8319	0.9551	3.4067
	Pooled	0.8483	3.0011	3.3278	0.9366	4.8335
F_3A	1	0.8965	3.3954	3.4914	0.9536	3.7458
	2	0.7984	2.7728	3.1336	0.9238	4.1892
	3	0.8874	3.1690	3.3718	0.9537	4.3775
	Pooled	0.8571	3.0871	3.3020	0.9363	4.1042
F_3S	1	0.8459	3.6196	3.1495	0.9731	3.9604
	2	0.8153	2.7953	3.1181	0.9087	3.8257
	3	0.8506	3.0082	3.3750	0.9477	4.9000
	4	0.9175	3.3944	3.6246	0.9605	4.7075
	Pooled	0.8801	3.1821	3.4884	0.9456	4.3484

Method I - Method by Ludwick and Petersen (1943)

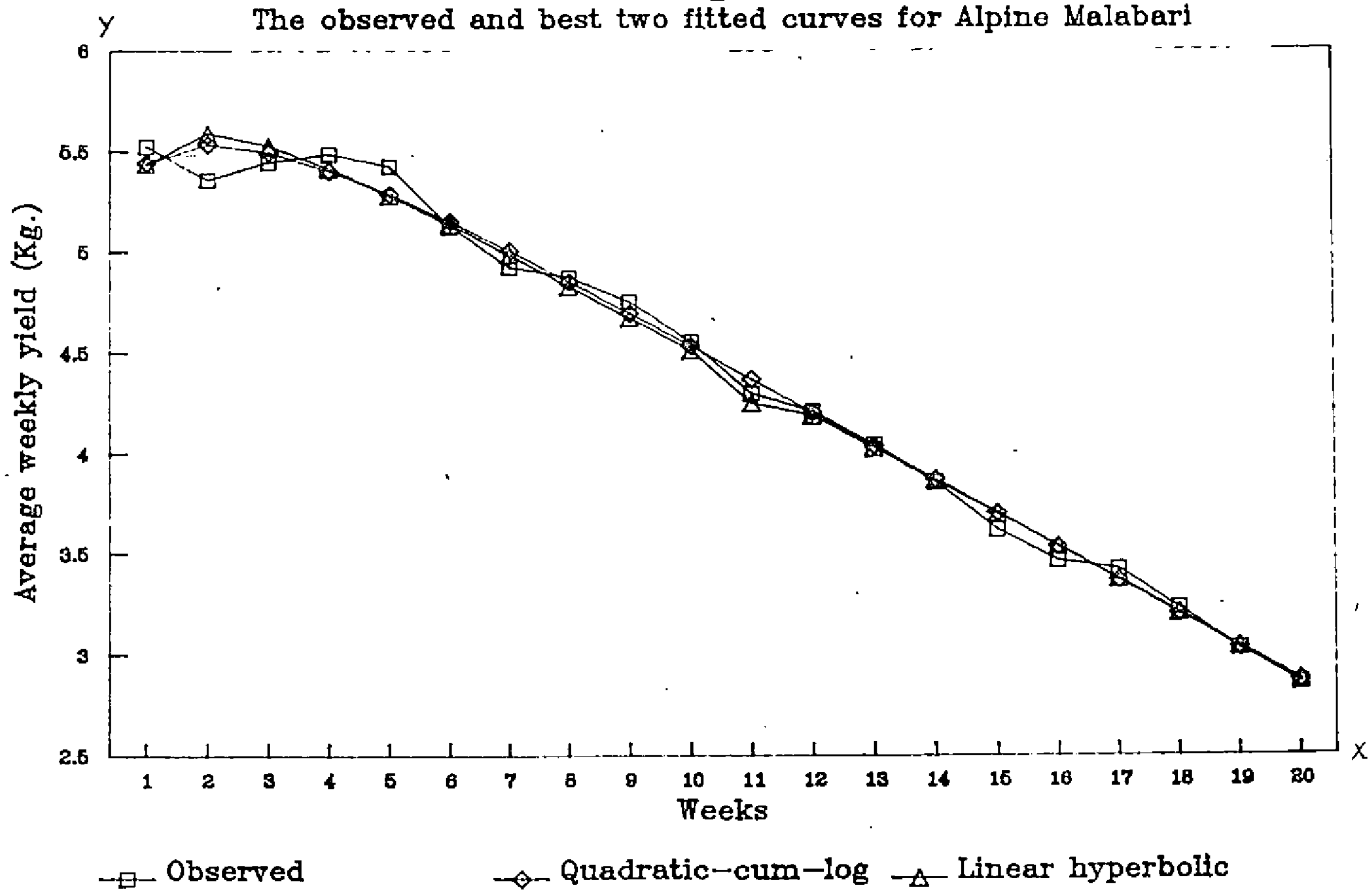
Method II - Method by Mahadevan (1951)

Method III - Method by Wood (1967)

Method IV - Method by Malhotra *et al.* (1984)

Fig.1

The observed and best two fitted curves for Alpine Malabari

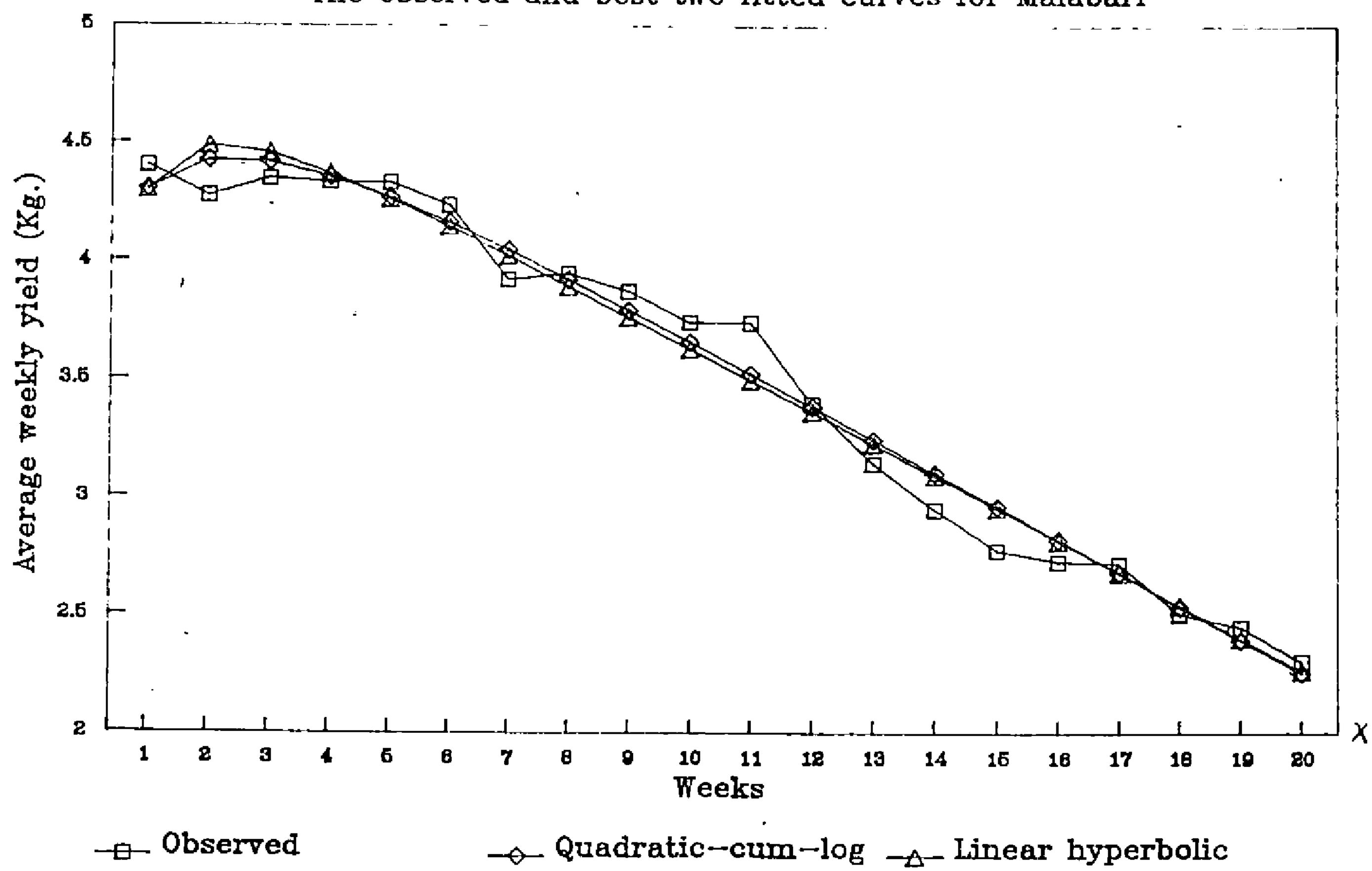


Scale: X axis - 1 unit = 1 week

Y axis - 1 unit = 0.5 kg

Fig.2

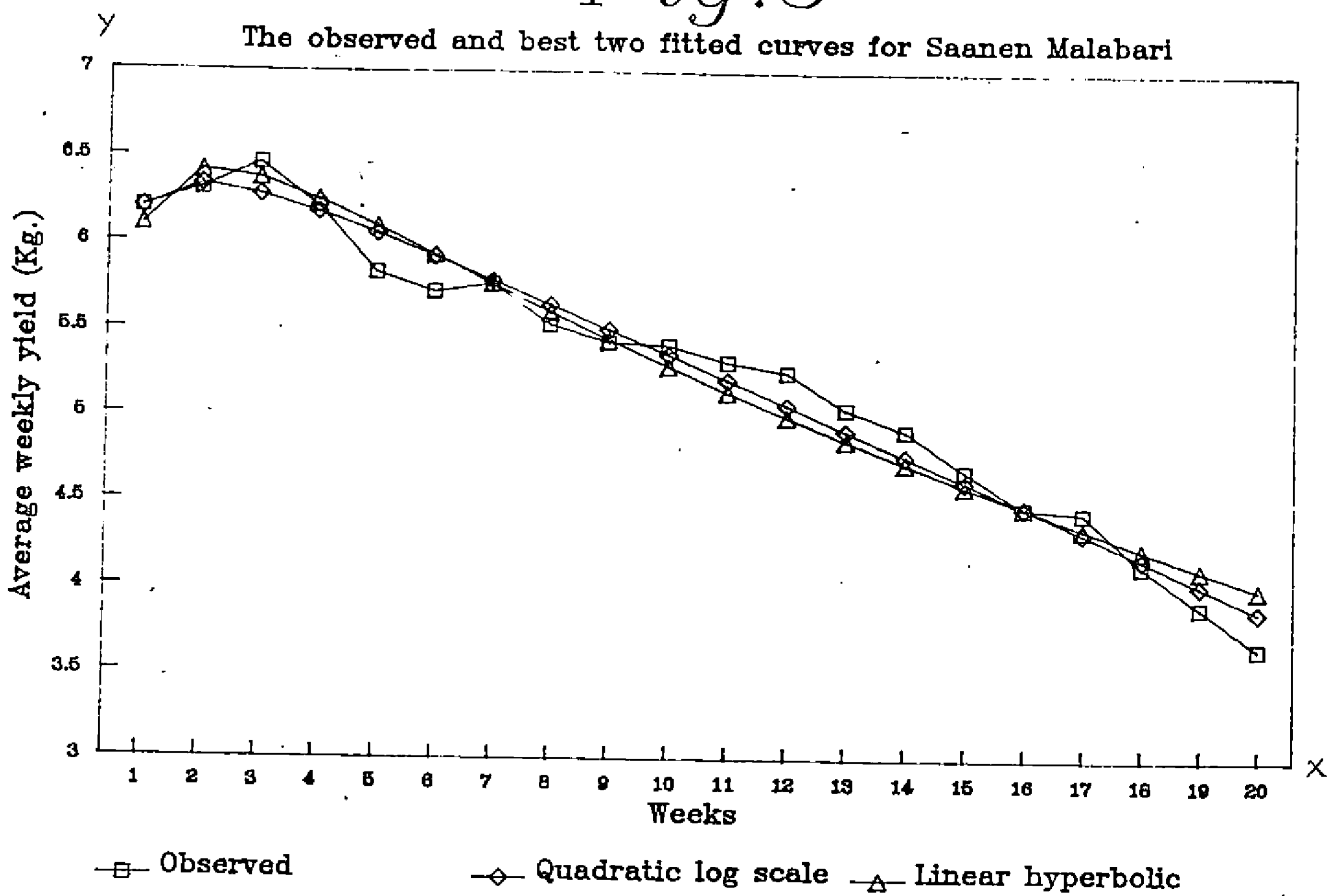
The observed and best two fitted curves for Malabari



Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

Fig.3

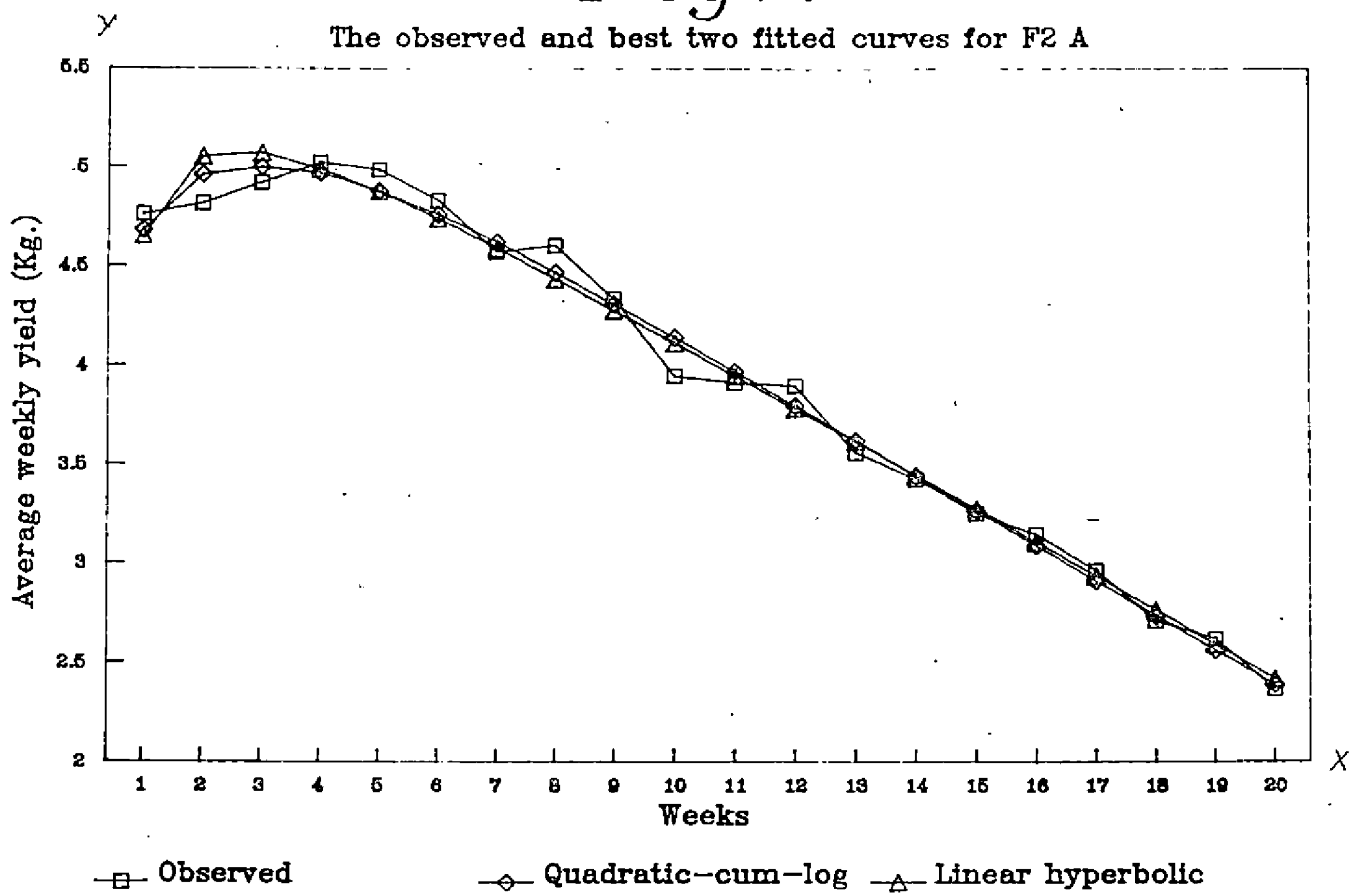


Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

Fig.4

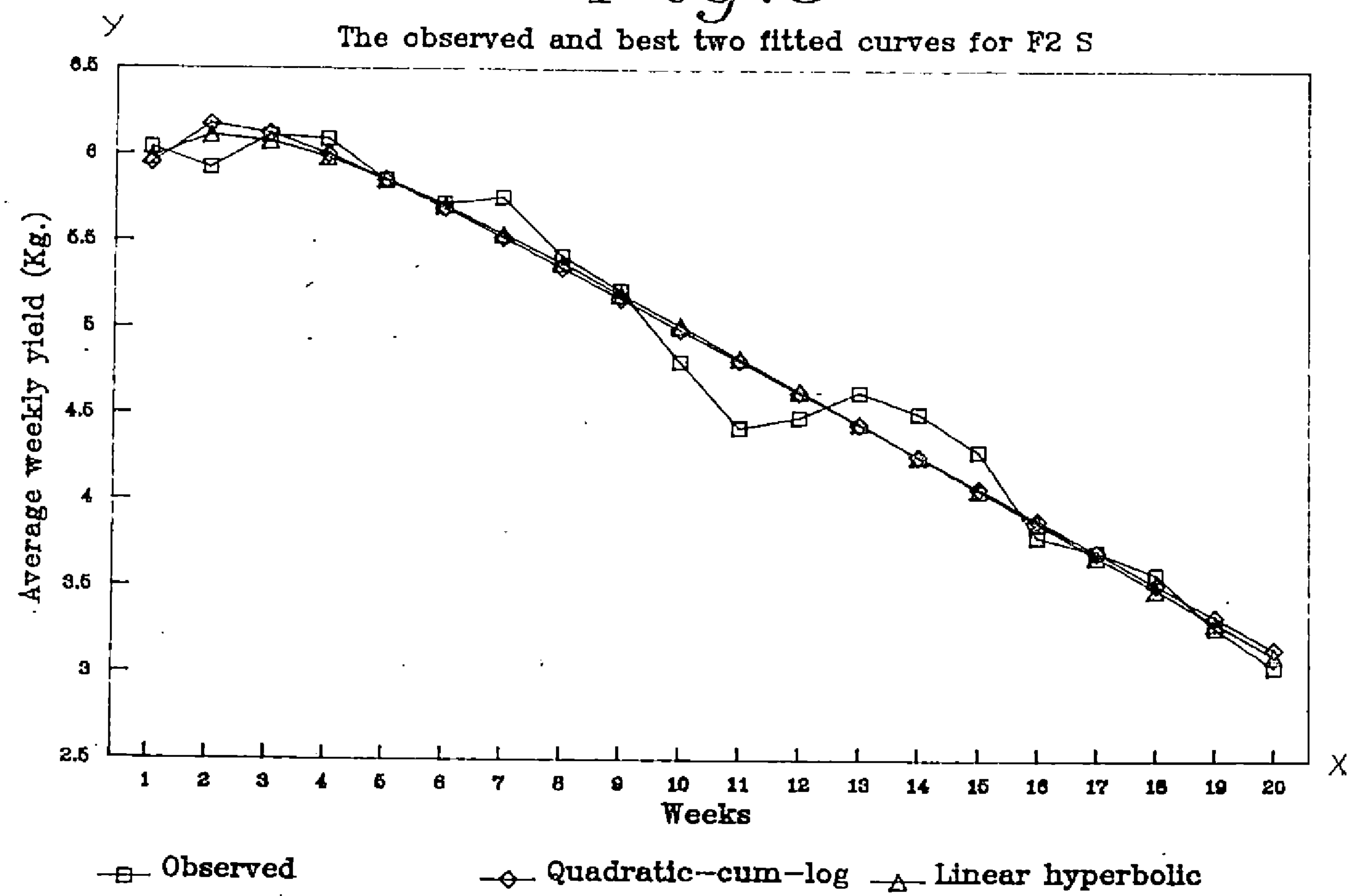
The observed and best two fitted curves for F2 A



Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

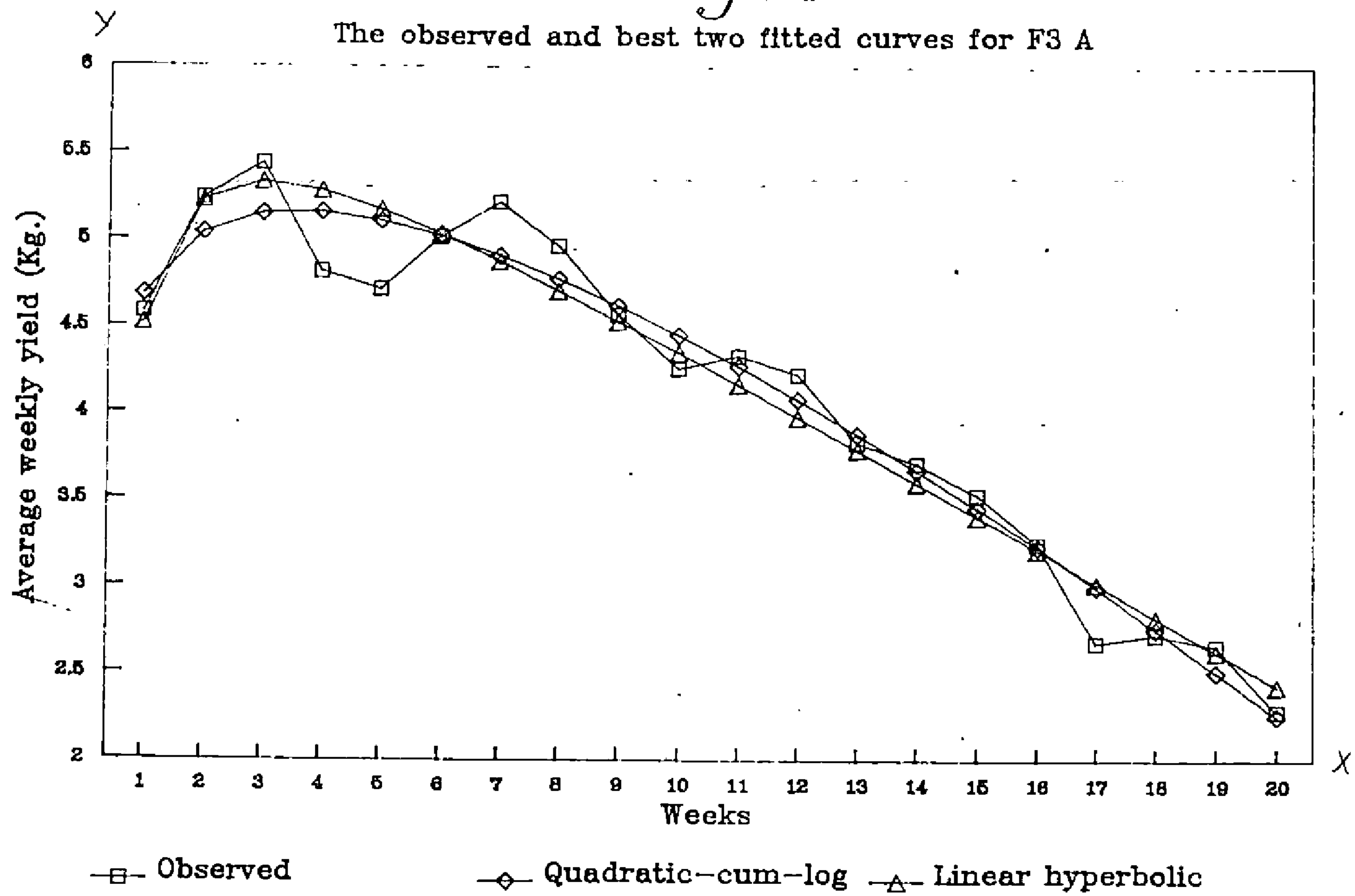
Fig.5



Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

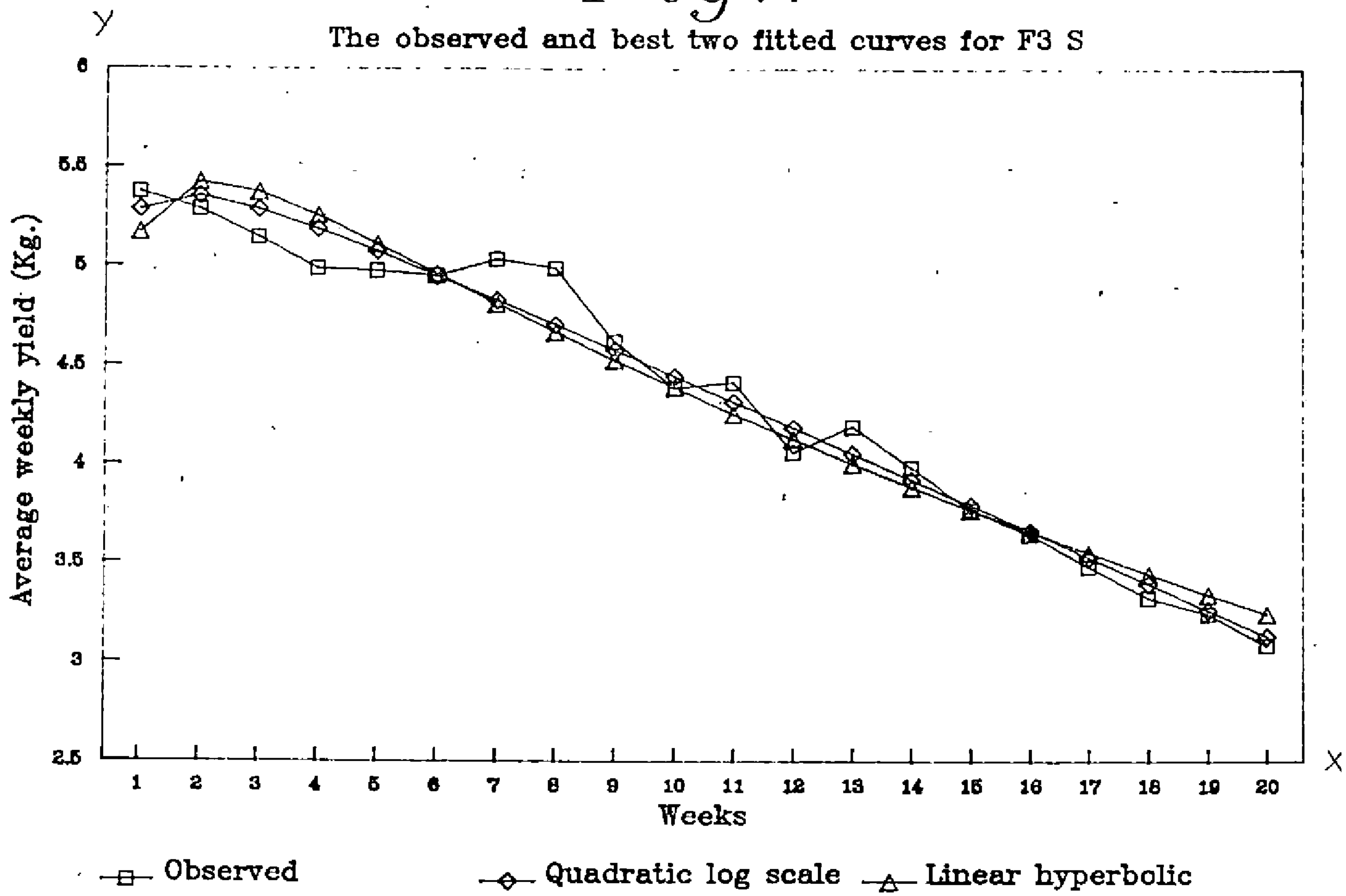
Fig.6



Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

Fig.7



Scale: X axis 1 unit = 1 week

Y axis 1 unit = 0.5 kg

Discussion

DISCUSSION

Of the scant literature available on this type of work some are in full agreement with the result obtained in the present study. In this chapter the results obtained are not only critically discussed but well compared with the established results also.

5.1 Comparison of average milk production

5.1.1 Alpine Malabari

From Table 1 it was seen that the average milk yield of Alpine Malabari over eight parities, increases from the first parity upto the seventh parity attaining a maximum of 5.0733 kg and then started declining. The average yield during second, third, fourth, fifth and sixth parities were almost consistent though with a slight variability in a random manner. The lower average yield of 3.5710 kg was recorded during the eighth parity. This was quite natural with the age.

5.1.2 Malabari

From Table 2 it was seen that the average milk yield over six parities of Malabari increases from the first parity upto fifth parity attaining a maximum of 4.0688 kg and then declining thereafter. The average yield during second, third and fourth parities were found to be almost consistent though with a slight variability. The lowest average yield of 2.9630 kg was noted in the first parity.

5.1.3 Saanen Malabari

From Table 3 it was found that the average milk yield over the five parities of Saanen Malabari increases from the first parity to fourth parity attaining a maximum yield of 5.5583 kg and then declining. The lowest yield of 4.6884 kg was recorded in the second parity.

5.1.4 F_2A

From Table 4 it was seen that the average milk yield over the six parities of F_2A increases from first parity to fifth parity reaching a maximum of 4.4869 kg and then declining slowly. The mean yields during the second to fourth parity were found to be almost consistent and the lowest yield of 3.1778 kg was noticed in the first parity.

5.1.5 F_2S

From Table 5 it was seen that the mean milk yield over the seven parities of F_2S increases from first to sixth parity attaining a maximum of 6.2533 kg and then started declining. The lowest average yield of 3.4067 kg was noted in the seventh parity which was quite natural.

5.1.6 F_3A

From the Table 6 it was seen that the average milk yield over the three parities of F_3A increases from first to third parity reaching a maximum of 4.3775 kg. The average yields of the various parities were almost consistent and the lowest yield recorded was 3.7458 kg in the first parity.

5.1.7 F_3S

From Table 7 it was seen that the mean milk yield over the four parities of F_3S increases from first to third parity attaining a maximum of 4.9000 kg and then slowly declining. The lowest average yield of 3.8257 kg was recorded during the second parity.

The tendency of increasing the milk yield in the first few parities and then declining was also established by Prakash and Khanna (1972). They reported that the milk yield increased by 20 per cent upto third lactation where it attains maximum and then declines in Beetal goats. This was in conformity with the results of present investigation. Similar result was also reported by Singh and Singh (1974) in Jamnapari goats, Das *et al.* (1982) in Saanen, Jamnapari and their crossbreds and Kumar *et al.* (1984) in Saanen, Black Bengal and their crossbreds.

5.1.8 Pooled average

From Table 8, representing the pooled average milk yield of the seven breeds over twenty weeks, it was observed that the overall mean yield over 20 weeks of each breed varies considerably. The maximum average yield of 5.2324 kg per week was produced by Saanen Malabari followed by F_2S (4.8335 kg/week). The lowest yielder was Malabari (3.5079 kg/week). It was a general accepted fact that the crossbred Saanen Malabari is a superior breed adopted to the Kerala condition for the purpose of milk.

5.2 Comparison of lactation curves

Based on the Tables 9-19, a comparative study of the eleven lactation curves fitted to the average milk production over various parities and pooled data of the seven breeds of goats were made as follows. The curves fitted were compared by suitable criterions viz. Furnival index (I), co-efficient of determination (r^2) and standard error (s) giving first preference to I as this holds good for the comparison of both linear and non linear functions.

The best fitted two functions on the basis of these criterions for the seven breeds were as follows.

5.2.1 Alpine Malabari

In the case of Alpine Malabari the quadratic-cum-log function was the best followed by linear hyperbolic function for the pooled data. It was interesting to note that out of the eight parities, six parities hold these functions good except for fifth and sixth parities. Hence it could be generally accepted that either quadratic-cum-log function or linear hyperbolic function will be a suitable lactation curve for this breed.

5.2.2 Malabari

In Malabari, the quadratic-cum-log stood first followed by linear hyperbolic function among the eleven curves for the pooled data. It was noted that out of the six parities except the first and second parities these functions hold good. Hence the functions quadratic-cum-log or the linear hyperbolic can be generally accepted as suitable lactation curves for this breed.

5.2.3 Saanen Malabari

For Saanen Malabari the linear hyperbolic function stood first followed by quadratic log scale function for the pooled data. It was found that these functions holds good for all parities except the second and third out of the five parities. Hence it could be accepted that either the linear hyperbolic function or the quadratic log scale function will be a representative curve for this breed.

5.2.4 F_2A

In the case of F_2A the quadratic-cum-log function was the best followed by linear hyperbolic for the pooled data. It was observed that out of the six parities, three parities (except first three) hold these functions good. Thus either quadratic-cum-log or linear hyperbolic could be considered as suitable lactation curve for this breed.

5.2.5 F_2S

For F_2S the linear hyperbolic function and quadratic-cum-log function stood as the first and second fitted curves respectively for pooled data of this breed. It was noted that out of the seven parities, six parities holds good these functions (except the seventh parity). Hence the linear hyperbolic function or the quadratic-cum-log function could be generally accepted as the suited curve for this breed.

5.2.6 F_3A

In the case of F_3A the quadratic-cum-log stood best followed by linear hyperbolic function for pooled data. It was interesting to note that all the three parities hold these functions good. Hence either the quadratic-cum-log or the linear hyperbolic functions could be generally accepted as a representative curve for this breed.

5.2.7 F_3S

For F_3S, the linear hyperbolic function was the best fitted curve followed by quadratic log scale for the pooled data. It was noted that out of the four parities these functions hold good except for the first two parities. Eventhough either the linear hyperbolic function or the quadratic log scale function could be taken as a suitable lactation curve for this breed.

From the observations made above it could be reasonably concluded that either the linear hyperbolic function or the quadratic-cum-log function can be taken as the best lactation curves. Since the linear hyperbolic function stood as the first function for three breeds and second function for the remaining four breeds with co-efficient of determination of more than 95 per cent in each case it could be recommended as the best lactation curve for the study of seven genetic groups. From the best two curves along with observed curve as presented in Figures 1-7 also, it could be reasonably concluded that the linear hyperbolic function showed a consistent trend in representing the lactation curve for the seven breeds of goats as this curve was the only curve either stood as first or second best fitted curve for all the genetic groups at KAU, Goat Farm. The general form of this function was as follows,

$$Y_t = a + bt + \frac{c}{t}$$

None of the research workers had attempted to study the lactation trend in goats except the work done by Mukundan and Bhat (1983) in Malabari and their Saanen halfbreds. They reported that eventhough inverse polynomial accounts for higher R^2 among the four functions (exponential, parabolic exponential, inverse polynomial and gamma type) compared, none of these functions were able to describe the lactation curve however all succeeded in describing the declining trend. In the present study also, these functions were found to be not suited as a representative curve.

5.3 Comparison of part lactation studies

As the linear hyperbolic function emerged as the best function while fitting the lactation yields, this equation had been considered for predicting the total yield based on the part yields of 4, 8 and 12 weeks. For the comparison of three types of part lactation of this curve r^2 and s criterions were used. While fitting this curve based on the pooled data of 4 weeks, 8 weeks and 12 weeks cumulative yield it was observed that all these part lactation gave around 99 per cent of efficiency in predicting the total yield though the efficiency increases from 4 weeks to 12 weeks. The same pattern of efficiency was observed with the s values also. This was true for all the seven breeds. The predicted total lactation yield of the three part lactation and the observed values were quite comparable in all the seven breeds. Hence it was concluded that the linear hyperbolic function is a suitable prediction equation which could be used for predicting total lactation yield from part records.

From the available literature, only Misra and Rawat (1985) had reported that there was no significant difference between the genotypes Sirohi and Beetal x Sirohi with respect to the part and total yield and found that the product moment correlation between the part yields (50, 90 and 150 days) and the total yield were highly positive and significant. They also observed that first monthly yield was the earliest information that could be utilized in predicting total yield ($r = 0.79 \pm 0.07$ to 0.86 ± 0.06).

5.4 Study of genetic and non genetic factors

From the ANOVA table (Table 35) it was observed that breed, order of lactation as well as their interaction were highly significant. While comparing with the CD values it was observed that the Saanen Malabari ranked first which was significantly different from other breeds followed by F_2S. While comparing the lactation wise yield it was found that on the average fourth parity was the best followed by the fifth parity.

The significant effect of breed and parity on yield was also noticed by Chawla and Bhatnagar (1984). They showed significant difference among lactation with each genetic group, among genetic groups and among different grades within genetic groups of goats. Misra and Rawat (1985) also reported that the effect of parity on yield was highly significant. These two findings are in agreement with the result of present investigation.

5.5 Study of persistency indices

Based on the four different methods the persistency indices were worked out for parity-wise and pooled data of the seven genetic groups. On comparing the persistency indices it was found that all the methods (except Method II) gave highest persistency for Saanen Malabari. In the case of Method II the highest index was for the breed F_3S closely followed by Saanen Malabari. Hence it could be reasonably concluded that the Saanen Malabari breed showed the maximum persistency with respect to milk yield. In other words Saanen Malabari is the best breed with respect to overall milk yield as well as for parity-wise milk yield.

Summary

SUMMARY

The milk yield data over 20 weeks during various parities of the seven genetic groups viz. Alpine Malabari, Malabari, Saanen Malabari, F_2A, F_2S, F_3A and F_3S maintained at the Goat Farm of Kerala Agricultural University during the period 1976-'87 were utilized for the present study with the objectives as (i) to fit various lactation curve models in different breeds of goats and to select the most suitable one (ii) to suggest a procedure for predicting complete lactation yield using various part lactation yields (iii) to study the effects of genetic and non-genetic factors on milk production traits and (iv) to compare the persistency of milk yield among the selected breeds.

For the selection of most suitable lactation curve the relative efficiencies of eleven curves viz. linear, exponential, parabolic exponential, inverse polynomial, gamma-type, McNally model, quadratic, quadratic log scale, quadratic-cum-log, empirical equation and linear hyperbolic function were fitted to the average weekly milk yield separately for each parity and for pooled data of the seven genetic groups under study. Based on the criterions Furnival index (I), co-efficient of determination (r^2) and standard error of the estimate (s) the best two selected functions for each of the breeds were as follows.

Breed	I Function	II Function
Alpine Malabari	Quadratic-cum-log	Linear hyperbolic
Malabari	Quadratic-cum-log	Linear hyperbolic
Saanen Malabari	Linear hyperbolic	Quadratic log scale
F_2A	Quadratic-cum-log	Linear hyperbolic
F_2S	Linear hyperbolic	Quadratic-cum-log
F_3A	Quadratic-cum-log	Linear hyperbolic
F_3S	Linear hyperbolic	Quadratic log scale

The graphs drawn also showed that the best two fitted curves of each breed were almost close to the observed curve. Since the linear hyperbolic function was found to be suitable for all the genetic groups, either as first or as second function, it was selected as the most representative lactation curve for goats under study.

For the prediction of total yield from part records the cumulative milk yield at 4, 8 and 12 weeks were considered as part lactation yields. The linear hyperbolic function was then fitted to the above part records separately for pooled and parity-wise data of the seven genetic groups, co-efficient of determination (r^2) and standard error (s) being taken as the criterions. The r^2 values of about 98-99 per cent were attained for all the part records in all the genetic groups though the efficiency increases from the part record of 4 weeks to 12 weeks.

Hence it was concluded that for the prediction of total yield from part records linear hyperbolic function will be a suitable prediction equation.

To study the effect of breed, order of lactation and their interaction on the average yield a two way classified non-orthogonal data analysis was carried out. The ANOVA obtained showed that the breed, lactation order as well as their interaction had highly significant influence on the average yield. Comparison of breeds revealed that all the breeds were significantly different from each other and among the breeds Saanen Malabari had the highest average yield followed by F_2S. While comparing the lactation-wise yield it was observed that the fourth parity produced the highest average yield followed by fifth parity.

For the comparison of persistency indices among the seven genetic groups, four different methods were used and for each method the indices were calculated separately for each of the parities and pooled data. On comparison, except by Method II the highest index was attained by Saanen Malabari. By Method II the highest index obtained was for F_3S closely followed by Saanen Malabari. Based on average yield also, Saanen Malabari had the highest average yield for all the parities and pooled data. Hence, Saanen Malabari was selected as the most persistent and high yielder.

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A COMPARATIVE STUDY OF LACTATION CURVES IN GOATS

By

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ABSTRACT OF A THESIS

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ABSTRACT

Based on the weekly milk yield data of 20 weeks duration over different parities of the seven genetic groups viz. Alpine Malabari, Malabari, Saanen Malabari, F_2A, F_2S, F_3A and F_3S maintained at the KAU, Goat Farm during the period 1976-'87, the following objectives were investigated.

1. To fit various lactation curve models in different breeds of goats and to select the most suitable one.

2. To suggest a procedure for predicting complete lactation yield using various part lactation yields.

3. To study the effect of genetic and non-genetic factors on milk production traits.

4. To compare the persistency of milk yield among the selected breeds.

On the basis of the criterions I, r^2 and s eleven types of fitted lactation curves were compared. Among the curves compared the quadratic-cum-log and linear hyperbolic functions were selected as the best two curves for the genetic groups, Alpine Malabari, Malabari, F_2A, F_2S, F_3A while for genetic groups Saanen Malabari and F_3S the linear hyperbolic and quadratic log scale functions were the best two selected curves. As the linear hyperbolic function was found to be suited for all

breeds under study it was selected as the best fitted curve for goats.

Taking various cumulative part records of 4, 8 and 12 weeks the linear hyperbolic function was then fitted to the parity-wise and pooled data of the seven genetic groups. It revealed that efficiency of over 98 per cent was achieved for all the part records though the efficiency increases with each added part record and hence this function could be selected as a prediction equation for the prediction of total yield from part record.

Based on the ANOVA obtained by a two way classified non orthogonal data analysis the breed, order of lactation and their interaction were found to have significant influence on average yield. Among the breeds Saanen Malabari and among the parities fourth parity were found to be significantly different from the others and have the highest average weekly yield.

Among the four methods used for comparing the seven genetic groups by calculating the persistency index, three methods (except method II) gave Saanen Malabari as the highest persistent one. By method II the highest index was attained by F_3S followed by Saanen Malabari. Since Saanen Malabari gave the highest yield for pooled and individual parity data it was selected as the most persistent and high yielding breed.