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Comparative Evaluation of Lactation Curves of Crossbred Dairy Cows in Field Conditions in Tamil Nadu, India

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ABSTRACT

Background: Various mathematical models have been tried by different researchers to fit the lactation curves in indigenous, exotic and crossbred cows maintained in organised farms only. Hence, this study was aimed to fit various lactation models and to identify the best fit model (s) for prediction of milk production in crossbred dairy cows in field conditions.

Methods: Multistage random sampling procedure was used for selection of 100 dairy cows for the purpose of data collection. The monthly milk yield data (up to 10 months of lactation) of the selected crossbred cows reared in field conditions of Tamil Nadu State, relating to the period from 2017-20, were collected for lactation curve modelling. The milk data so collected were used to fit 14 lactation curve models in the study. The highest Coefficient of Determination (R^2) value and the least Root Mean Square Error (RMSE) value were used as the criteria to select the best fit model(s).

Result: The overall average total milk production was estimated to be 2223.19 kg per lactation in 10 months of lactation in the selected crossbred cows. Average daily milk yield at the first month of lactation was 9.16 kg and the highest daily milk yield of 9.56 kg was observed at the second month of lactation. At the end of the lactation, the lowest yield was 5.01 kg per day and hence the overall average daily milk yield was found to be 7.41 kg. Based on the selection criteria, the Mitscherlich X Exponential model was identified as the best fit model, followed by Ali and Schaeffer and Morant and Gnanasakthy model for prediction of milk production in crossbred dairy cows reared in field conditions and the estimated lactation curve model parameters a, b, c and d values for the best fit model were 331.71, 1519.82, 9.56 and 0.07 kg, respectively.

Key words: Best model identification, Crossbred cows, Lactation curve models.

INTRODUCTION

Livestock sector plays a crucial role in Indian rural development, by assuring income, employment and nutrition to the rural poor. The agriculture allied sector such as dairying, poultry, goatry, horticulture etc. will play crucial role in achieving the government's goal to double farmer's income by 2022 and the innovative measures are needed to be explored and shall be implemented on large scale to improve the share of dairying in rural farmers income (Chopde *et al.,* 2019). More importantly, dairying provides sustainable livelihood to millions of small, marginal and landless farmers in the country, by providing regular additional income to compensate the losses accruing, if any, due to crop failures, arising because of droughts. Tamil Nadu depends mainly on crossbred cows, especially Jersey crossbreds (5.281 million numbers), for milk production, with a few Holstein-Friesian crossbred cows (1.498 million numbers) particularly in hilly regions (NDDB, 2014). It is well known that the profitability of dairy farm business, irrespective of farm size, depends mostly on the quantum of milk produced in different stages of a lactation, with parity having a significant effect on 305 days milk yield and lactation milk yield in Jersey cattle and the milk yields being the lowest in first lactation and increasing in advanced lactation (Thiruvenkadan (2020).

Lactation curve models are fitted and used to predict milk yield at any stage of the lactation and also to predict future milk yields of an animal (Banu *et al.,* 2012). Mathematical modelling of a lactation, popularly called as lactation curve modelling, is useful in making farm management decisions, especially breeding and feeding decisions, by simulating milk production. Biswal *et al.* (2017) also fitted different lactation curve models in Jersey crossbred cows of a few organised dairy farms in Tamil Nadu and reported that the Ali and Schaeffer model was the best fit model for lactation curves in Jersey crossbred cows. Though various mathematical models had been tried by different researchers to fit the lactation curves for indigenous, exotic, crossbred cows reared in organised farms, there are

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no documented reports available on the lactation curves fitted for crossbred dairy cows reared in field conditions especially in Tamil Nadu. Hence, this study on “Comparative Evaluation of Lactation Curve of Crossbred Dairy Cattle in Field Conditions in Tamil Nadu” was undertaken to compare and identify the best fit lactation curve model for the crossbred dairy cattle in field conditions of Tamil Nadu.

MATERIALS AND METHODS

Multistage random sampling procedure was used for selection of crossbred dairy cows. In the first stage of sampling, five major agro climatic zones (North eastern, North western, Western, Cauvery delta and Southern zones) were selected and the remaining two zones (High altitude and High rainfall zones) were excluded, as both the zones had only less number of dairy animals. In the second stage, two districts were randomly chosen from each of the selected agro climatic zones (North eastern, North western, Western, Cauvery delta and Southern zones of the State), *i.e.*, totally 10 districts were selected. In the third stage, from each of the selected districts, 10 crossbred dairy cows were purposively selected, with the help of milk procurement primary co-operative societies, for the purpose of data collection. Hence, the total number of crossbred dairy cows selected was 100 which included 75 Jersey crossbred and 25 Holstein-crossbred dairy cows. The monthly milk yield data (up to 10 months of lactation) of the selected crossbred dairy cows maintained in the field conditions of Tamil Nadu state, relating to the period from 2017-20 were collected for lactation curve modelling. First 5 days of colostrum yield and milk consumption by calves were not included for model building.

Lactation curve modelling

The milk data so collected were used to fit various lactation curve models and the fitted lactation curve models in the study are presented in Table 1.

Criteria for identifying the best fit lactation curve model

The highest coefficient of determination (R^2) value and the least Root Mean Square Error (RMSE) value were considered to be the indicators of the best fit model.

- The R^2 is the proportion of the variance in the dependent variable that is predictable from the independent variable which equals the percentage of variance of monthly milk yields explained by the model.

$$R^2 = [1- \frac{SSE}{SST}] \times 100$$

Where, SSE is Error Sum of Square and SSt is Total Sum of Square.

- RMSE is the standard deviation of the residuals (prediction errors).

$$RMSE = \sqrt{\frac{\Sigma (Y_t - Y_t)^2}{n}}$$

Where Y_t is actual milk yield at time ‘t’ and ‘Y_t is predicted milk yield.

The analysis was done using IBM SPSS Statictics® 22.0 software.

RESULTS AND DISCUSSION

The details of the monthly milk yields of sampled crossbred cows are presented in Table 3. The average total milk production was estimated to be 2223.19 kg per lactation in 10 months of lactation among the selected cows. The peak yield of 286.82 kg was recorded at the second month of lactation. After the peak, the yield started declining gradually to 150.44 kg at the end of the lactation. Average daily milk yield at the first month of lactation was 9.16 kg and the highest daily milk yield of 9.56 kg was observed at the second month of lactation. At the end of the lactation, the lowest yield was 5.01 kg per day and hence the overall average daily milk yield was found to be 7.41 kg in crossbred cows, which was slightly higher than the national average

Table 1: Lactation curve models fitted.

Name of the model	Function	Source
Morant and gnanasakthy	Y_t=exp(a-bt+ct^2/2+d/t)	S. Morant and A. Gnanasakthy (1989)
Mitscherlich X Exponential	Y_t=a(1-b e^{-ct})e^{-dt}	Rook *et al.* (1993)
Wilmink model (k=0.050)	Y_t=a+be^{-kt}+ct+e	Wilmink (1987)
Wilmink model (k=0.065)	Y_t=a+be^{-kt}+ct+e	Wilmink (1987)
Wilmink model (k=0.610)	Y_t=a+be^{-kt}+ct+e	Wilmink (1987)
Wilmink model (k=0.100)	Y_t=a+be^{-kt}+ct+e	Wilmink (1987)
Gamma model	Y_t=at^{b}e^{-ct}	Wood (1967)
Cubic model	Y_t=a+bt+ct^2+dt^3+e	Dag *et al.* (2005)
Mixed log function	Y_t=a+bt$^{1/2}$+clog(t)+e	Guo and Swalve (1995)
Polynomial regression function (Ali and Schaeffer)	Y_t=a+bx+cx^2+dlog(1/x)+flog(1/x)^2+e	Ali and Schaeffer (1987)
Quadratic	Y_t=a+bt-ct^2	Dave (1971)
Quadratic cum log	Y_t=a+bt+ct^2+dln (t) +e	Malhotra *et al.* (1980)
Exponential decline	Y_t=ae^{-ct}	Brody *et al.* (1923
Parabolic exponential	Y_t=aexp(bt-ct^2)	Sikka (1950)

Where, = average monthly milk yield in the 1th month of lactation, a= constant describing rising phase of lactation curve, b= inclining slope parameter up to peak yield, c= declining slope parameter, d= curve parameter and x = t/10.

Table 2: Estimated parameters and goodness of fit statistics of the lactation curve models for crossbred dairy cows.

Model	a	b	c	d	f	R^2	RMSE
Morant and gnanasakthy	5.89	-0.01	-0.09	-0.19	-	98.10	5.93
Mitscherlich X Exponential	331.71	1519.82	9.56	0.07	-	98.50	5.32
Wilmink (k=0.050)	644.01	-347.84	-28.14	-	-	97.10	7.38
Wilmink (k=0.065)	520.17	-224.20	-25.14	-	-	97.10	7.37
Wilmink (k=0.610)	317.84	-36.28	-16.59	-	-	97.40	6.97
Wilmink (k=0.100)	410.82	-115.37	-21.67	-	-	97.10	7.36
Gamma	308.35	0.13	0.10	-	-	97.80	6.43
Cubic	291.73	-6.76	-1.30	0.06	-	97.20	7.32
Mixed log	299.93	-37.35	16.61	-	-	97.50	6.90
Ali and schaeffer	-19.93	-3377.83	34169.92	-224.49	-42.29	98.20	5.75
Quadratic	296.81	-11.26	0.33	-	-	97.10	7.39
Quadratic cum log	312.60	-34.81	0.88	44.44	-	97.80	6.46
Exponential decline	313.57	-0.01	0.07	-	-	95.20	9.48
Parabolic exponential	293.06	-0.03	0.01	-	-	97.10	7.32

of daily milk yield of crossbred cows of 7.33 kg per day (Anon., 2017).

Vijayakumar *et al.* (2019) also found a higher total milk production and average daily milk yield in a lactation in crossbred cows of Livestock Farm Complex, Veterinary College and Research Institute, Orathanadu, Tamil Nadu, which were 2459.27 ± 68.98 and 8.06 ± 0.23 kg, respectively at 305 days of milk production. Banu *et al.* (2012) reported an average daily milk yield of 10.14 kg on 6th day of lactation and the peak yield of 12.85 kg per day on the 36th day of lactation in Karan Fries cows. It can thus be concluded that the cows maintained under better management practices might be the reasons for higher milk production in organised dairy farms, as compared to dairy cows maintained in field conditions.

The estimated model parameters and goodness of fit statistics of various lactation curve models fitted for crossbred dairy cattle raised in field conditions are presented in Table 2. All the lactation curve models fitted appeared to be good fit models, as could be ascertained from the R^2 of all the models (>95.20). However, the maximum accuracy could be seen in Mitscherlich X Exponential model, as the R^2 obtained in this model was the highest (98.50%) in this model. Further, the RMSE values of different models fitted ranged between 5.32 and 9.48 kg.

In this study, based on the selection criteria of the highest R^2 (98.50%) and the lowest RMSE (5.32) value, the Mitscherlich X Exponential model was identified as the best fit model. Ali and Schaeffer model and Morant and Gnanasakthy model also were better fit models with slightly less R^2 and slightly higher RMSE than the Mitscherlich X Exponential model. Dohare *et al.* (2015) also found that the Mitscherlich X Exponential model was the best fit model for the Frieswal cattle of Military Dairy Farm, Bareilly, Uttar Pradesh. However, Kocak and Ekiz (2008), Banu *et al.* (2012) and Biswal *et al.* (2017) and Mohanty *et al.* (2017) found Ali and Schaeffer model as the best fit for the lactation curve modelling in Holstein-Friesian cows, Karan Fries cows and Jersey crossbred cows maintained at organized dairy

Table 3: Actual and predicted month wise milk production (in kg) in crossbred dairy cows.

Month	Actual	Morant and gnanasakthy	Mitscherlich X exponential	Ali and schaeffer
1	274.92 (9.16)	276.95	274.92	276.69
2	286.82 (9.56)	279.99	285.99	280.91
3	268.36 (8.95)	265.97	265.55	266.17
4	239.55 (7.99)	248.75	246.57	248.41
5	224.70 (7.49)	231.20	228.94	230.70
6	212.94 (7.10)	214.22	212.58	213.81
7	206.10 (6.87)	198.13	197.38	197.95
8	191.53 (6.38)	183.05	183.27	183.11
9	167.83 (5.59)	168.99	170.17	169.23
10	150.44 (5.01)	155.93	158.01	156.23
Total#	2223.19 (7.41)	-	-	-

Figures in parentheses indicated average daily milk yield #Total milk production at 10 months of lactation.

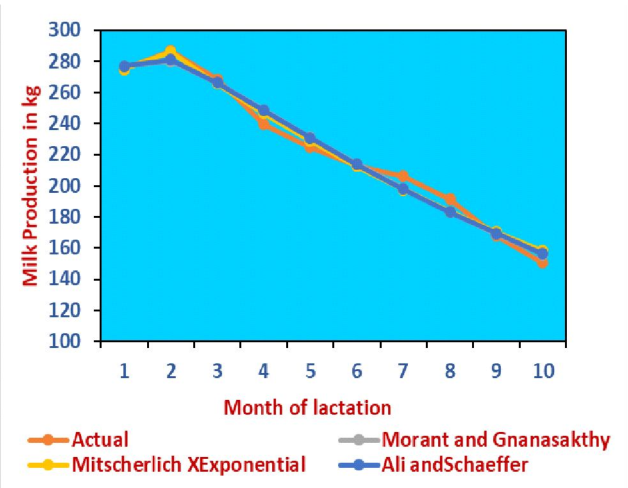

Fig 1: Lactation curves for actual and predicted milk production.

farms. Dongre *et al.* (2012) reported mixed log function model as the best fit model for predicting the first lactation in Sahiwal cattle reared at National Dairy Research Institute, Haryana.

The estimated values of the parameters a, b, c and d in the best fit Mitscherlich X Exponential model were 331.71, 1519.82, 9.56 and 0.07 kg, respectively. The actual average monthly milk yields and those predicted by different models used are presented in Table 3. The results revealed that the peak milk yield occurred at the second month of lactation in all the lactation curve models fitted. As expected, the actual observed monthly milk yield and the predicted monthly milk yield by the best fit model were almost similar in all the stages of lactation. At the first month of lactation, the actual and predicted milk yields by the best model were same (274.92 kg). The peak yield predicted by the best fit (Mitscherlich X Exponential) model was 285.99 kg in the second month of lactation and the actual peak milk was 286.82 kg. Also, the result revealed that the predicted milk yield (158.01 kg) was more close to the actual milk yield (150.44 kg) at the end of the lactation. The lactation curves for actual and the milk production predicted by the best fitted models are also depicted in Fig 1, which showed that the actual yield and the yields predicted by the best fitted models are almost similar and hence can be used to fit lactation curves of Holstein Friesian and Jersey crossbred cows available in field conditions of similar agro-climatic areas.

CONCLUSION

Among 14 models studied, it is concluded that the Mitscherlich X Exponential model was found to be best model, followed by Ali and Schaeffer model and Morant and Gnanasakthy model, based on the highest R^2 and lowest RMSE for fitting lactation curves for Jersey and Holstein Friesian crossbred cows in field conditions. Hence, these three models (Mitscherlich X Exponential model, Ali and Schaeffer model and Morant and Gnanasakthy model) are recommended for predicting monthly milk yields in Jersey and Holstein Friesian crossbred dairy cows reared in field conditions of Tamil Nadu and areas of similar agro-climatic conditions in the country.

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