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Shashank Kshandakar
Division of Livestock Economics, Statistics and Information Technology, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

Med Ram Verma
Division of Livestock Economics, Statistics and Information Technology, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

Yash Pal Singh
Division of Livestock Economics, Statistics and Information Technology, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

Sanjay Kumar
Division of Livestock Economics, Statistics and Information Technology, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

Correspondence
Med Ram Verma
Division of Livestock Economics, Statistics and Information Technology, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, India

Effect of Parity and calving season on modelling of lactation curves of Vrindavani Cattle

Shashank Kshandakar, Med Ram Verma, Yash Pal Singh and Sanjay Kumar

Abstract
The present study was conducted on lactation data of Vrindavani cattle maintained at Cattle and Buffalo Farm, ICAR-Indian Veterinary Research Institute, Izatnagar over a period of 5 years (2010-2014). The aim of this study was to determine best fitted lactation curve model explaining the pattern of Vrindavani cattle milk production in different parity and calving season. The Cobby and Le Du model (CL), Mitscherlich x Exponential model (ME), Mixed log model (ML), Wilmink model (WL) and Wood model (WD) were fitted on DTDMY of 243 Vrindavani cattle. The best model was judged by five measures of goodness of fit *viz.*, $R^2_{adj.}$, MAE, MSE, MSPE, AICc and BIC. Two-way repeated measure ANOVA was used to study the effect of calving season and parity on the milk production of Vrindavani cattle.Mixed log model was best fitted to DTDMY records of Multiparous Vrindavani cattle and Vrindavani cattle calving in the winter season. Mitscherlich cum Exponential model was best fitted to DTDMY records of Primiparous Vrindavani cattle and Vrindavani cattle calving in summer and rainy season.The Vrindavani cattle calving in winter season produced 13.53% and 6.12% more milk than Vrindavani cattle calving in summer season and rainy season respectively. The 4th parity Vrindavani cattle were superior in milk production (305 DIM) and produced 15.65%, 12.44%, and 8.24% more milk than 1st, 2nd and 3rd parity cattle respectively.

Keywords: goodness of fit, heritability, lactation curve, peak yield, vrindavani cattle

1. Introduction

Dairy animals continue to be an integral part of human life since the process of civilization started and has considerable potential to contribute towards the alleviation of problems of unemployment, under-nutrition and poverty. Animal husbandry practices and agriculture are intrinsically linked and both are crucial for overall food security. As per the first advance estimates of the Central Statistics Office Report-2016, growth rate for the agriculture and allied sectors is estimated to be 4.1 percent for 2016-17 and the value of livestock sector. Output at current prices was about 28.5% of the value of output from agricultural and allied sector during 2015-16.

Livestock is an important component of virtually all rural livelihood system, with a greater diversity of animal species and husbandry practice. Livestock sector continuously provides highly nutritious food supply rich in protein and other vital nutrients in different adverse climatic conditions, draught animal power, maintaining ecological balance and provides employment in the rural sector, particularly among the women, landless, small and marginal farmers. Poverty is largely prevalent among the landless, marginal and small farm households. About three-fourth of country's population lives in rural areas, and more than one-fourth of it is below the poverty line. At present scenario, 38 percent of the population was undernourished as the diet of an average Indian is cereal based and lack of diversification towards nutrient-rich foods. The problem is more severe to the world second largest population as there is continuously shrinking of agricultural land across country leads to less access to land for crop and livestock production.

India continues to be the largest producer and consumer of milk across the globe. Several measures have been initiated by the Government to increase the productivity of livestock, which has resulted in increasing the milk production significantly to 155.5 million tonnes during 2015-16 with an annual growth of 6.27%. Out of which, 39% of the milk production is contributed by Indigenous Buffaloes followed by 26% by crossbred cattle, 13% by non-descript buffaloes, 12% by Indigenous cattle and 9% by non-descript cattle (DAHD&F [1]).

Cattle are fairly distributed all over the country. The overall population of livestock declined by 3.33% (529 million to 512 million) due to mechanization but in the meantime, there is an increase in female cattle population by 6.52%. The number of Indigenous milch cattle increased from 48.04 million to 48.12 million (0.17%) whereas the increase in exotic/crossbred cattle is from 14.4 million to 19.42 million (34.87%) (BAHS, 2013).

The per capita availability of milk in India has increased from 112 gram/day (1970 -71) to about 337 gram/day (2015-16), whereas world average is only 229 gram/day. However, there are wide inter-state and inter-regional differences in terms of per capita availability of milk *i.e.* average per capita availability varies from as low as 57 gram/day in Mizoram to 1032 gram/day in Punjab and only thirteen states have the per capita availability higher than the minimum nutritional requirement of 280 gram/day recommended by the Indian Council of Medical Research (ICMR), while all other states have below this level (http://www.nddb.org).

Lactation curve provides a summary pattern of milk yield and is very useful for various manage mental practices, total or partial milk yield prediction at any point of lactation, peak yield, lactation persistency and days in milk. Lactation performance for all species follows a common pattern curve, increases to peak yield and then gradually declines until the end of lactation. Lactation performance is a function of two interrelate factor *i.e.* peak yield and lactation persistency. Lactation curves aided as a valuable tools for dairy producers for making management decision and selection. Proper knowledge of the lactation curve allows prediction of total milk yield from a single or several test days records or early test day records. The behaviour of lactation pattern is described by different methods *viz.* Percentage decline method, Ratio method, Persistency in milk production, Regression coefficient method and artificial neural network (ANN). Wood *et al.* [2] suggests the importance of lactation persistency and defined as the ability of the dairy animals to maintain production following peak yield.Persistency is a trait of direct economic interest because of its relationship with reproduction, disease condition, feed and manage mental decision (Harder *et al.* [3]). Similar study was conducted by Appuhamy *et al.* [4] and he reported that diseases tend to significantly affect lactation persistency, rather than persistency affecting disease occurrence, he also concluded that lactation persistency have undesirable genetic correlations with milk fat percentage and occurrence of metabolic diseases may be due to negative energy balance and improper nutrition.

Comprehensive lactation curve studies begin to uncover the behaviour of milk yield and pointing the various factors and estimate its impact on milk production of dairy animals. The study of lactation curve started with the work of Brody *et al.* [5] but advances with the work of Wood *et al.* [2] as an incomplete gamma function. However, after the Wood's model various researchers attempted to develop a standard model by making a significant adjustment by adding/modifying a number of parameters or by using empirical/mechanist concept. The attempts to model the shape of the lactation curve of the dairy animals have been numerous and wider, with the advancement of computer-based methodology, various machines learning technique are also used to predict production easily and accurately by using more easily accessible training data. Grzesiak *et al.* [6] used ANN model for milk yield prediction and conclude that the ANN model is easier to implement and have higher prediction accuracy than Wood model. Murphy *et al.* [8] proposed the nonlinear auto-regressive model with exogenous input and concluded that the proposed model was best for prediction of milk yield followed by a multiple linear regression model and ANN.

Although, the study of lactation curve has been very effective and reliable to identify the various factors and its impact on milk production. The major cause of variation in milk production is due to dairy animal (individual own performance), breeds (genetic variation), farm (different geographical location and climatic condition), parity and stage of lactation, season of calving, incidence of disease occurrence, age at 1st calving and various nutritional and farm management practices. The estimation of the effects of various factors may be very challenging, keeping in view the above facts, the present study was aimed to compare the standard lactation curves model that explain the milk production pattern and to model the effect of parity and calving season on lactation curve Vrindavani cattle.

2. Material and Methods

Vrindavani cattle are synthetic crossbred cattle strain of India having mixed inheritance of both exotic and Indigenous cattle milch breed. The exotic inheritance of Holstein-Friesian, Brown Swiss, Jersey and indigenous inheritance of Hariana cattle make the Vrindavani cattle more robust and high prolific milch breed of India. The coat colour of Vrindavani was predominantly brown though some animals had black, white and beige coat colour. (Singh *et al.* [9])

2.1. Source of data

The data regarding The Animal number, Season of Calving, Lactation Order (Parity) of Animal and Daily milk yield from Day 1st to 305thdays was recorded from individual history sheets over a period of 5 years (2009-2014). These data of Vrindavani cattle collected from Cattle and Buffalo farm of LPM Section ICAR-IVRI, Izatnagar (Uttar Pradesh).

2.2. Location & climatic condition of study area

The ICAR-Indian veterinary Research Institute (ICAR-IVRI), Izatnagar is situated at 28.3939° N latitude, 79.4324°E longitude and an altitude of 178 meters above mean sea level. The average annual rainfall is approximately 1714 mm (28.1 inches), and maximum rainfall reported during the monsoons in July and August. (http://en.wikipedia.org)

2.3. Statistical Analysis

2.3.1. Modeling the shape of lactation curve

Five lactation curve model was fitted for test day milk yield are as follows;

A. Incomplete Gamma function (Wood *et al.* [2])

$$Y_t = at^b e^{-ct}$$

B. Linear decline model (Cobby and Le Du [10])

$$Y_t = a-bt-ae^{-ct}$$

C. Wilmink lactation curve model (Wilmink *et al.* [11])

$$Y_t = a + be^{-kt} + ct$$

D. Mixed log model (Guo *and Swalve* [12])

Y_t= a+bt$^{1/2}$+cln (t)

E. Mitscherlich x Exponential (Rook e*t al.* [13])

Y_t= a(1-be^{-ct})-dt

where, $Y_t$is the milk production at day "t", "a" is the scale factor or milk yield at the beginning of lactation, "b" is the rate of change from initial production to maximum yield, "c" is the rate of change from maximum yield to the end of lactation, "k" is the factor associated to the time of peak yield and "d" represent the parameter related to maximum milk yield.

2.3.1.1. Estimation of Model Parameter
Lactation curve has been classified into linear and nonlinear lactation curve models. In the linear lactation curve models, parameters are linear functions of days in lactation and parameters can be computed by using simple linear regression methodology. However, nonlinear lactation curve models need iterative techniques to be solved. Iteration techniquesmay refer to the process of applying a function repeatedly, in this procedure the output of one iteration used as the input to the next and this step repeated till approximate numerical solutions to certain mathematical problems obtained. In this research, Levenberg–Marquardt algorithm (LMA) also known as Damped least squares (DLS) method was usedto estimate the value of parameters.The whole statistical analysis was conducted by nonlinear regression procedure (PROC NLIN) of statistical package SAS 9.3 version.

2.3.1.2. Goodness of fit of different lactation curve model
The goodness of fit explains how well the given standard model (Lactation curve model) fits a set of observations (DTDMY records). Measures of goodness of fit typically summarize the discrepancy between observed and predictive values under the model in question. In this research work goodness of fit of a model was accessed by.

A. Coefficient of determination (R^2)
The coefficient of determination (R^2) is a statistical measure of how well the regression line approximates the real data points. Its value ranges between 0-1. An R^2 of 1 indicates that the regression line perfectly fits the data. Most general definition of the coefficient of determination is:

$$R^2=1-\frac{\text{Residual sum of square}}{\text{Total sum of square}}$$

$$R^2_{adj}=1-\frac{\text{MSPE}}{\text{MS(corrected total)}}$$

$$R^2_{adj}=1-\frac{(1-R^2)(N-1)}{N-P-1}$$

$R^2_{adj.}$ is more accurate measure of goodness of fit than the R^2, when we compare models with different number of parameters. A model with large R^2_{adj} is more fitted.
If R^2_{adj} =1; Better fitted model

B. Mean Square Error (MSE)

$$MSE=\sum_{i=1}^{n}\frac{(Y_i-\overline{Y}_i)^2}{N-P}$$

C. Mean Absolute Error (MAE)

$$MAE=\sum_{i=1}^{n}\frac{\left|Y_t-\overline{Y}_t\right|}{N}$$

D. Mean square prediction error (MSPE)

$$MSPE=\sum_{i=1}^{n}\frac{(O_i-P_I)^2}{N}$$

where, i =1, 2, 3,…,N; N =No. of experimental observation; O = Observed value; P = predicted value.A small value of MSE, MAE and MSPE indicates better fitted model.

E. Akaike's Information Criteria (AIC)

AIC = 2k-2ln (L)
AIC=nlog$_e$MSE+2k

If the number of Parameters is more than corrected Akaike's Information Criteria (AICc) is used instead of Akaike's Information Criteria (AIC)
Corrected Akaike's Information Criteria (AICc)

$$(AICc)=AIC+\frac{2k(k+1)}{n-k-1}$$

where "k"is the number of parameters in the model and "L"is the maximized value of the likelihood function for the model. The preferred model is the one which has minimum AIC value

F. Bayesian information criterion (BIC)

BIC=nlog$_e$(MSE)+k log$_e$(n)

The preferred model is the one which has minimum BIC value

2.3.1.3. Examination of Residuals (errors)
Residuals or errors are defined as the difference between the observed and predicted value of the response. For modeling purpose, there are two assumptions *viz,*
a) The errors are independently and identically distributed *i.e.*$\varepsilon \sim N(0,1)$
b) The errors have constant variance

The assumption may be tested by using
a) Durbin-Watson Test
b) Shapiro-Wilk Test

2.3.2. Repeated Measurement analysis
The term repeated measures refer to responses taken in sequence on the same experimental unit such as an animal, on multiple occasions/times/period under same or different experimental conditions. The different conditions over time

might be the designed experimental conditions such as milk production changed from one period to another. Such designs economize on animals and the animals serve as their control.

The repeated observations, being made on the same animal, are usually correlated. These observations may be correlated in space and or in time. Accounting for correlations among repeated observations is important in making of correct statistical inference.

2.3.3. Hypothesis for Repeated Measures ANOVA

The repeated measures ANOVA tests whether there are any differences between related population means. The null hypothesis (H_0) states that the means are equal;

H_0: $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_k$

where μ = population mean and k = number of related groups.

The alternative hypothesis (H_A) states that the related population means are not equal (at least one mean is different to another mean);

H_A: At least two means are significantly different

If repeated measures ANOVA is statistically significant we can use post hoc tests to do the multiple comparisons.

2.3.4. Model of Two Way Repeated Measures ANOVA

$y_{ij}=\mu+g_i+ID(g_i)+P_j+(gXP)_{ij}+e_{ij}$

$e_{ij} \sim N(0, \sigma_e^2)$

$i = 1, 2, \ldots g; j = 1, 2, \ldots, p;$

where, μ is the general mean effect, g_i is the effect of i^{th} group, P_j is theeffect of j^{th} time period,$(gXP)_{ij}$ represent interaction effect of group and period and e_{ij} represent the residual.

3. Results and Discussion

Knowledge of the lactation curve allows prediction of total milk yield from a single or several test days early in lactation. With such knowledge, a dairy producer can make management decisions early based on individual production. Modelling the shape of lactation curve in different condition is used to validate different model parameter under different biological, genetical and environmental factors. This study was aimed to investigate the goodness of five different lactation curve models on daily milk production of Vrindavani cattle in different condition. The five models Incomplete Gamma function (WD), Linear decline model (CL), Wilmink lactation curve model (WL), Mixed log model (ML) and Mitscherlich x Exponential model (ME) were fitted on DTDMY (Daily test day milk yield) data of 243 Vrindavani cattle maintained at cattle and buffalo farm (LPM section, ICAR-IVRI, Izatnagar). WD, WL, ML and CL are based on 3 parameters ME based on 4 parameters. In Vrindavani cattle, Peak production was highest in fourth parity and cattle calving in winter season and lowest in primiparous and cattle calving in summer season. However, primiparous and cattle calving in summer season showed highest persistency. The number of parameter in lactation curve model had a significant effect of goodness of fit andgoodness of fit increases with increase in the number of parameters. (Dematawewa *et al.* [14])

In present study, the milk production varied significantly from season to season and from parity to parity (p<0.05/0.01). The average milk production of primiparous and multiparous Vrindavani cattle was 3121.99±.10 3257.57±0.13 kg, respectively, while forth parity Vrindavani cattle produces 3696.93 ± 0.17 kg milk in 305 days. There was no significant change in lactation length but the peak production of forth parity cattle was 19.23 kg/days. The patterns of fortnight test day milk record of Vrindavani cattle in different parity are described in figure 1.

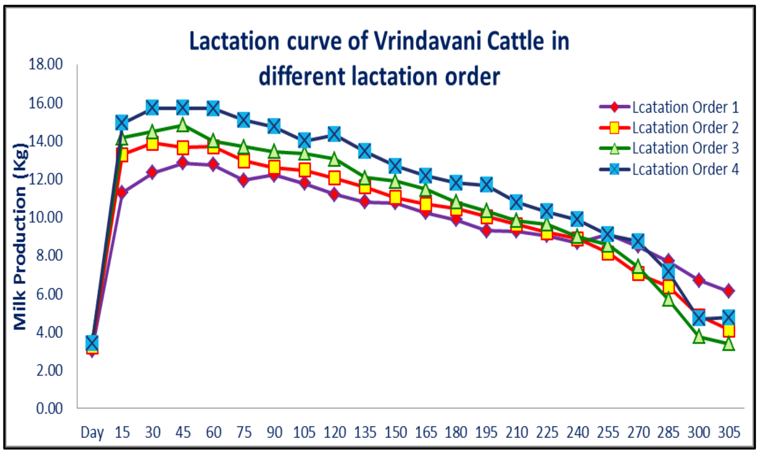

Fig 1: Lactation curve of Vrindavani cattle in different lactation order

3.1. Lactation curve of Primiparous Vrindavani cattle

The ME model was best fitted model to describe the DTDMY (Daily test day milk yield) data of Primiparous Vrindavani cattle (MAE=0.225, MSE=0.094, MSPE=0.093, $R^2_{adj.}$= 0.970, AICc=-712.4 and BIC=-697.5) ML model was 2nd best fitted ($R^2_{adj.}$=0.968) followed by CL model ($R^2_{adj.}$=0.961) and WL model ($R^2_{adj.}$=0.945). WD model was least fitted to describe the DTDMY data of primiparous Vrindavani cattle ($R^2_{adj.}$=0.928). All model under predicted the initial milk production and peak production. The value of parameters of different lactation curves are mentioned below (Table-1) and Comparison of Lactation curve of Observed vs. Predicted Vrindavani cattle lactation curve in Primiparous and Multiparous condition are presented in figure 2.Contrary to the present study, CL model in which exponential decline of Brody model was replaced by a linear decline function fitted well to the lactation data of primiparous HF cow (Sherchand *et al.* [15]) and primiparous local cow (Verbyla *et al.* [16]). However, according to Olori *et al.*[17], WD and ML under predicted milk yield around peak production and over predicted immediately after peak production and WD was least fitted model (R^2=94.4%) to WTDMY records of primiparous HF cow; Cunha *et al.* [18] concluded that WL better adjusted for primiparous cows; Dongre*etal.* [7] and Banger *et al.* [25]concluded that the ML

(R^2=88.75%) was the best fittedlactationcurve model that describe the lactation pattern of primiparous Sahiwal and Gir cattle respectively.

Table 1: Estimated value of parameter of different lactation curve models of Primiparous Vrindavani cattle along with different measures of goodness of fit

Model	Parameter	Estimate	SE	MAE	MSE	MSPE	$R^2_{(adj)}$	AICc	BIC
CL	a	13.593	0.047	0.256	0.123	0.122	0.961	-633.3	-622.1
	b	0.020	0.000						
	c	0.157	0.004						
ME	a	13.715	0.045	0.225	0.094	0.093	0.970	-712.4	-697.5
	b	0.798	0.018						
	c	0.118	0.004						
	d	0.021	0.000						
ML	a	4.117	0.143	0.236	0.100	0.099	0.968	-696.5	-685.4
	b	-1.289	0.015						
	c	4.471	0.063						
WL	a	14.137	0.059	0.277	0.173	0.172	0.945	-528.4	-517.2
	b	-8.424	0.192						
	c	-0.023	0.000						
WD	a	6.303	0.144	0.348	0.228	0.226	0.928	-444.3	-433.2
	b	0.221	0.007						
	c	0.004	0.000						

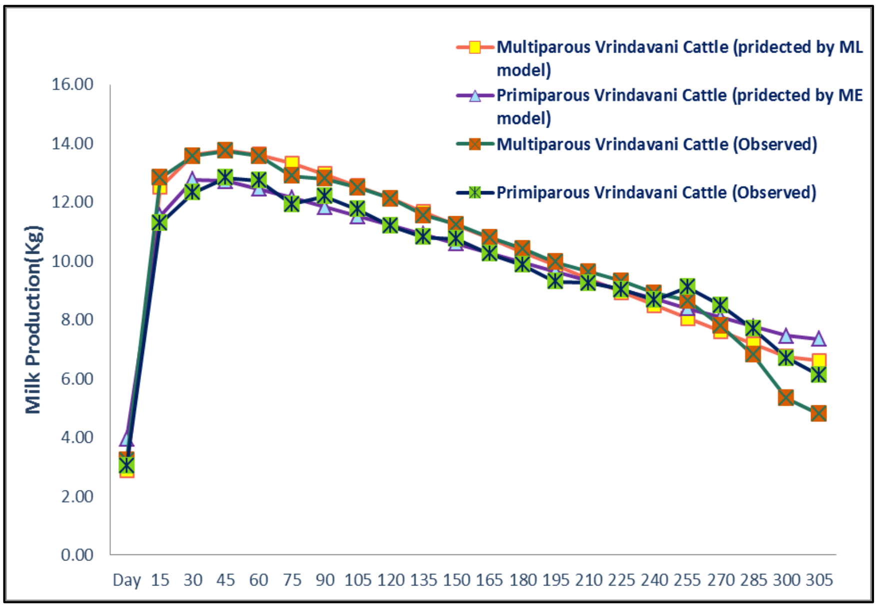

Fig 2: Comparison of Lactation curve of Observed vs. Predicted Vrindavani cattle lactation curve in Primiparous and Multiparous condition

3.2. Lactation curve of Multiparous Vrindavani cattle

The ML model was best fitted model to describe the DTDMY data of multiparous Vrindavani cattle (MAE=0.256, MSE=0.147, MSPE=0.146, $R^2_{adj.}$=0.973, AICc= -578.6 and BIC = -567.4).Apart from present study, MLwas also used to study the lactation behaviour of HF cattle (Olori *et al.* [17]). ME model was 2nd best fitted ($R^2_{adj.}$=0.966) followed by CL model ($R^2_{adj.}$=0.961) and WL model ($R^2_{adj.}$=0.951). WD model was least fitted to describe the DTDMY data of multiparous Vrindavani cattle ($R^2_{adj.}$=0.948). Nevertheless, Adediran *et al.* [20]) and Banu *et al.*[21] studied and concluded that the WD was the least fitted model to the lactation data of HF and Karan Fries cattle respectively. Contrary to the current study, WD provided best fit of the lactation curve of medium to low milkproducer groups of cattle (Cunha *et al.*[18]), Jersey cattle (Cankaya *et al.*[22]), HF cattle (Torshizi *et al.*[23]) and multiparous Gir cattle (Bangar *et al.*[19]).

ML over predicted the peak production whereas, WD under predicted the peak milk production. The value of parameters of different lactation curves are mentioned below (Table-2);

Table 2: Estimated value of parameter of different lactation curve models of Multiparous Vrindavani cattle along with different measures of goodness of fit

Model	Parameter	Estimate	SE	MAE	MSE	MSPE	$R^2_{(adj)}$	AICc	BIC
CL	a	15.121	0.062	0.329	0.216	0.214	0.961	-460.7	-449.6
	b	0.027	0.000						
	c	0.168	0.005						

ME	a	15.265	0.062	0.296	0.186	0.183	0.966	-505.2	-490.3
	b	0.794	0.023						
	c	0.124	0.005						
	d	0.028	0.000						
ML	a	4.490	0.173	0.256	0.147	0.146	0.973	-578.6	-567.4
	b	-1.601	0.018						
	c	5.257	0.076						
WL	a	15.761	0.074	0.336	0.268	0.266	0.951	-395.1	-383.9
	b	-9.159	0.239						
	c	-0.030	0.000						
WD	a	6.710	0.159	0.370	0.285	0.282	0.948	-376.6	-365.5
	b	0.239	0.007						
	c	0.005	0.000						

3.3. Effect of calving season on Lactation curve of Vrindavani cattle

The ML model was best fitted model to describe the DTDMY data of Vrindavani cattle calving in winter season (MAE=0.274, MSE=0.163, MSPE=0.161, $R^2_{adj.}$=0.983, AICc=-548.2 and BIC = -537.0) ME model was 2nd best fitted ($R^2_{adj.}$=0.981) followed by CL model ($R^2_{adj.}$=0.976) and WL model ($R^2_{adj.}$=0.971). WD model was least fitted to describe the DTDMY data of Vrindavani cattle calving in winter season ($R^2_{adj.}$=0.967). All model predicted the peak production with accuracy except ML over predicted the peak production. The value of parameters of different lactation curves are mentioned below (Table-3).Comparison of Lactation curve of Observed vs. Predicted Vrindavani cattle lactation curve in calving in different season in figure 3.

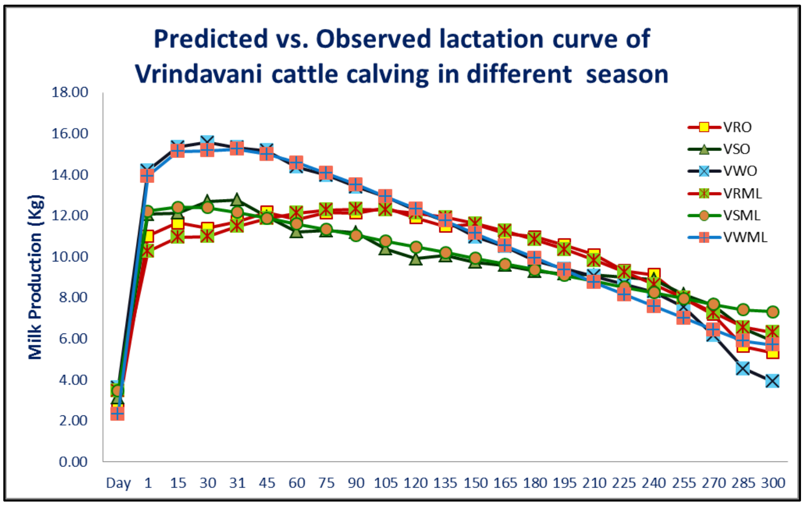

Fig 3: Comparison of lactation curve of Vrindavani cattle (calving in different season) milk production vs. predicted milk production by ML model

Almost all models describe the lactation pattern of Vrindavani cattle calving in rainy season with great precision. The $R^2_{adj.}$ value ranges from 0.7570 to 0.841 and CL model was least fitted to describe the DTDMY data of Vrindavani cattle calving in rainy season ($R^2_{adj.}$=0.757). All models predicted peak production with accuracy except under predicted by WD model. In case of cattle calving in summer season, the $R^2_{adj.}$ value ranges from 0.878 to 0.923 for lactation curve of Vrindavani cattle calving in summer season. WD model was least fitted to describe the DTDMY data of Vrindavani cattle calving in summer season ($R^2_{adj.}$=0.868). However, all model under predicted the peak production.

Table 3: Estimated value of parameter of Mixed log models (Vrindavani cattle calving in different season) along with different measures of goodness of fit

Model	Parameter	Estimate	SE	MAE	MSE	MSPE	$R^2_{(adj)}$	AICc	BIC
Rainy	a	3.056	0.330	0.598	0.532	0.527	0.841	-186.3	-175.1
Season	b	-1.302	0.034						
	c	4.797	0.144						
Summer	a	6.088	0.209	0.384	0.213	0.211	0.923	-465.6	-454.5
Season	b	-1.086	0.021						
	c	3.500	0.091						
Winter	a	4.364	0.182	0.274	0.163	0.161	0.983	-548.2	-537.0
Season	b	-2.035	0.019						
	c	6.447	0.080						

3.4. Test for the presence of autocorrelation and normality of residual

Durbin-Watson test and Shapiro-Wilk's test was used to test the presence of autocorrelation and normality of residual in Vrindavani cattle by different models. The range of DW statistics is always between 0 and 4. DW statistic value approaching 0 indicate positive autocorrelation; values toward 4 indicate negative autocorrelation and value equal to 0 indicate no autocorrelation in the sample. In present study, positive autocorrelation present in residual obtained by different model in different condition.

3.5. Repeated Measure Analysis

3.5.1 Effect of lactation order (parity) on the milk production of Vrindavani cattle using repeated measure analysis

Repeated measure ANOVA was used to study the effect of Lactation order (Parity) on the milk production of Vrindavani cattle. Based on the analysis, effect of Lactation order, effect of Period and interaction between Lactation order and period were significant ($p< 0.001$) which indicate that Vrindavani cattle in different parity have different milk yield over different period. Similar to present finding Cobuci *et al.* [24] reported that genetic group, calving season, age at 1stcalvinghad a significant effect on total milk yield and peak production.

Table 4: Repeated measure ANOVA table to study the effect of lactation order (parity) on the milk production

Repeated measure Analysis of Variance					
Source	**DF**	**SS**	**MS**	**F Ratio**	**Prob> F**
LO	3	3188.03	1062.68	6.4978	0.0003*
ID[LO]&Random	239	39418	164.929	32.3136	0.0000*
Period	43	46375	1078.49	211.3024	0.0000*
LO*Period	129	2772.17	21.4897	4.2104	<.0001*
Error	10089	51494.33	5.104	47.5135	
C. Total	10503	10503	151893.2		

Table 5: Least squares means table showing Vrindavani cattle (different Lactation order) average daily milk yield

Least Squares Means Table			
Lactation order	**Least Square Mean**	**S.E**	**Mean**
Lactation order 1	10.237883(b)	0.203319	10.2501
Lactation order 2	10.631489(b)	0.211857	10.7116
Lactation order 3	11.141000(ab)	0.294486	11.2877
Lactation order 4	12.135925(a)	0.414712	12.2115

The 4th parity Vrindavani cattle were superior in average milk production (305 DIM) and produced 15.65%, 12.44%, and 8.24% more milk than 1st, 2nd and 3rd parity cattle respectively. Period has also a significant effect on milk production peak production obtained from 3rd week after calving to 14th week after calving and minimum production obtained in 1st week after calving and from 41st week after calving to 44th week after calving. The maximum and minimum peak production was reported in 4th parity and 1st parity Vrindavani cattle, while 1st parity Vrindavani cattle are most persistent in milk production. Similar to current study, Epaphras *et al.* [25] concluded that the average daily production for cows of 3rd parity produced more milk with respect to other parity. Scott *et al.* [26] stated that the farm and season of calving account 34.1 and 44.3% of variation in milk production among primiparous and multiparous cows respectively. Rekik *et al.* [27] also concluded that the Primiparous cow produces lower milk yield but they are more persistence in milk production with respect to multiparous cow.

3.5.2. Effect of season of calving on the milk production of Vrindavani cattle using repeated measure analysis

Repeated measure ANOVA was used to study the effect of season of calving on the milk production of Vrindavani cattle. Based on the analysis, the effect of season of calving, the effect of Period and interaction between season of calving and period were significant *(*$p< 0.001$) which indicate that cow in different season of calving had different milk yield over different period.

Table 6: Repeated measure ANOVA table to study the effect of calving season on the milk production

Repeated measure Analysis of Variance					
Source	**DF**	**SS**	**MS**	**F Ratio**	**Prob> F**
Season	2	2726.34	1363.17	8.2306	0.0003*
ID[Season]&Random	240	39776.6	165.736	35.0263	0.0000*
Period	43	43569	1013.23	214.135	0.0000*
Season *Period	86	6324.39	73.5394	15.5417	<.0001*
Error	10132	47942.1	4.7320		
C. Total	10503	151893	103951		

Table 7: Least squares means table showing Vrindavani cattle (calving in different season) average daily milk yield

Least Squares Means Table			
Season	**Least Squares Mean**	**S.E**	**Mean**
Summer	10.000413(b)	0.24454249	10.0347
Rainy	10.521505(ab)	0.24948112	10.5477
Winter	11.207087(a)	0.18186473	11.3094

The Vrindavani cattle calving in winter season were superior in average milk production (305 DIM) and produced 3418 kg milk per lactation. The Vrindavani cattle calving in winter season produced 13.53% and 6.12% more milk than Vrindavani cattle calving in summer season and rainy season respectively. Winter season is more favourable to the Vrindavani cattle as it contains 50-75% exotic inheritance and 25-50% indigenous inheritance of cattle. The other factor was availability of lush green fodder in winter season and better management condition at farm level. Similar to present finding, Madalena *et al.* [28] reported that cow calving in rainy season produced 4% more milk than cow calving in dry season. Keown *et al*. [29] stated that total andpeak yield were lowest for cow calving in the summer season when feeding resources arelimited and the heat stress effect is maximum. Madani *et al.* [30] concluded that cows calving in summer produced 23% and 24% lower milk per lactation than cows calving in winter and spring season respectively.

4. Conclusion

Vrindavani cattle are synthetic crossbred cattle strain of India having 50-75% exotic inheritance of Holstein-Friesian, Brown Swiss, Jersey and 25-50% indigenous inheritance of Hariana cattle. The average milk production (305 DIM), peak yield and lactation length of Vrindavani cattle were 3257.57±0.13 kg, 17.98±0.21 kg and 299.58±0.76 days respectively. The estimated value of coefficient of heritability (±standard error) from half-sib data for Vrindavani cattle milk production is 0.28578 (± 0.29712).

Mixed log model was best fitted to DTDMY records of Multiparous Vrindavani cattle and Vrindavani cattle calving in the winter season. Mitscherlich cum Exponential model was best fitted to DTDMY records of Primiparous Vrindavani cattle and Vrindavani cattle calving in summer and rainy season. Incomplete gamma function was the least fitted model to describe the lactation behaviour. Multiparous Vrindavani cattle and Vrindavani cattle calving in the winter season produces more milk than primiparous Vrindavani cattle and Vrindavani cattle calving in summer and rainy season so, it is better to say that Mixed log model and Mitscherlich cum Exponential model are the best fitted model to describe the lactation pattern of high yielding and low yielding Vrindavani cattle.

The Vrindavani cattle calving in winter season produced 13.53% and 6.12% more milk than Vrindavani cattle calving in summer season and rainy season respectively. The 4th parity Vrindavani cattle were superior in milk production (305 DIM) and produced 15.65%, 12.44%, and 8.24% more milk than 1st, 2nd and 3rd parity cattle respectively. The maximum and minimum peak production was reported in 4th parity and 1st parity Vrindavani cattle, while 1st parity Vrindavani cattle are most persistent in milk production. The Primiparous cow produces lower milk yield but they are more persistence in milk production with respect to multiparous cow.

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