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ANALYSIS OF THE LACTATION CURVE MODELS FOR PREDICTING FL305DMY IN JAFARABADI BUFFALOES

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ABSTRACT

The present investigation was conducted on first lactation production traits of 213 Jafarabadi buffaloes spread over a period of 24 years (1991 to 2014), maintained at Cattle Breeding Farm, Kamdhenu University, Junagadh. The objectives of the study were to find the best fit of lactation curve model which can describe the first lactation curve in Jafarabadi buffalo and to examine the curve pattern of first lactation yield using MTDYs in Jafarabadi buffalo. Four different lactation curve models *viz*. Parabolic Exponential Function (PEF), Inverse Polynomial Function (IPF), Gamma Type Function (GF) and mixed Log Function (MLF) were used for predicting FL305DMY using MTDMY. The coefficient of determination (R^2 -value) for PEF, IPF, GF and MLF were 83.28%, 98.84%, 96.80%, and 92.73%, respectively. The average root mean square error (RMSE) was found to be minimum for GF (0.073 litre) followed by PEF (0.149 litre), MLF (0.102 litre) and IPF (0.376 litre). Graphical presentation indicated that GF was found to be best fit for MTDYs in Jafarabadi buffalo, while PEF was least fitted. The trend of GF indicated that this function was most suitable to Jafarabadi buffaloes.

Keywords: *Bubalus bubalis*, buffaloes, Jafarabadi, parabolic exponential function (PEF), inverse polynomial function (IPF), gamma type function (GF), Mixed log function (MLF)

INTRODUCTION

Livestock rearing is one of the most important economic activity in rural areas of country contributing significantly to the national economy. This sector contributes 30.47% of the total Agriculture GVA. Asian countries have been producing nearly 95% of world's total buffalo milk. Buffalo is the animal of prime importance for the dairy industry in India as it produces nearly half of the country's total milk production in India (BAHS, 2023). Indian riverine buffaloes being an

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outstanding species among all ruminants in ability to convert coarse plant material and lignified agricultural waste into good quality protein (meat and milk protein) has special importance to Indian subcontinent as primary source of milk.

As per the 20th Livestock Census 2019, India has a total livestock population of 535.78 million showing an increase of 4.6%, over the previous livestock census. Gujarat possesses around 27.13 million total livestock heads, which equals to 5.30% of total livestock population of the country. Gujarat state located on west most part of India is home tract of some well-known buffalo breeds viz. Mehsana, Surti, Jafarabadi and Banni. The buffalo population of Gujarat was 10.2 million during 2012 which increased to 10.5 million during 2019 thus showing an increase of 1.52%. This highlights the high level of state wise acceptance of Jafarabadi breed of buffalo among the farmers Jafarabadi is considered to be one of the best dairy buffalo breeds in India. They are the heaviest and massive type of riverine buffalo. They are good milker and thrive well on natural grazing due to their greater feed conversion efficiency. These buffaloes are found in and around Gir forest area which is also inhabited by the famous Asiatic lions. It is also known as “Bhavnagri”, “Gir” or “Jaffari” by the local people. The native breeding tract of Jaffarabadi buffalo is Saurashtra region of Gujarat, *viz*. Junagadh, Bhavanagar, Jamnagar, Amreli, Gir Somnath, Rajkot and Morbi districts as well as some part of Surendranagar district

Milk Yield is the most important economic trait determining economic returns to the dairy farmers and is influenced by several factors. Milk production during the entire lactation is a continuous physiological function which describes the rate of milk secretion with advancement in lactation. The study of lactation curve of the animals could be a step towards understanding the productivity of animal. The lactation curve is an important expression of pattern of milk production characterized by peak yield, lactation persistency and days in milk (Cunha *et al*., 2010). The lactation curve can be defined as the graphical representation of milk yield against time (Brody *et al*., 1923). The lactation curve models can help in predicting the milk yield at any stage of lactation and can also be used to predict the lactation yield of concerned animal of the breed. Appropriate models for describing lactation curves provide useful information for breeding programmes and management practices, especially for culling and in assessing the nutritional and health status of animals (Keown *et al*., 1986). Different workers have suggested different models for modelling the lactation curve and modified them timely. To compare efficacy of fitness of different lactation curve models in Jafarabadi buffaloes.

MATERIALS AND METHODS

Sources of data

The data was collected from the history cum-pedigree register of Jafarabadi buffaloes maintained at Cattle Breeding Farm, Kamdhenu University, Junagadh located in the South Saurashtra Agro-climatic Zone VII. The records on first lactation production traits of Jafarabadi buffaloes spread over a period of 24 years (1991 to 2014) were collected for the present study.

General management

All animals were provided with good quality chaffed green fodder hay and other roughages ad lib. A let down ration of 2.0 kg of concentrate was provided at the time of milking.

Additional concentrates were provided to meet the requirement of high yielders with mineral mixture to meet the dietar. The animals were supplemented with mineral mixture to meet the dietary requirement.

Loose housing system has been followed to maintain the buffaloes in the herd. Concentrates were provided to buffaloes as per their milk production. Calves of both sexes were reared together up to 6 months of age. The calves were weaned at the age of 7 months. The animals were supplemented with mineral mixture to meet dietary requirements. In order to ensure good health of the animals, all types of veterinary aids, prophylactic and sanitary measures were taken care of for all buffaloes throughout the year. All the females were bred using Artificial insemination. Selective breeding policy with a major emphasis on the selection of bulls on the basis of performance of their progeny was followed.

Data collection and standardization

A total of 11 individual monthly milk yield records with an interval of 30 days (i.e. 4th day, 34th day, 64th day and 304th day of lactation) for each animal were collected from daily milk yield register of Jafarabadi buffaloes. Jafarabadi buffaloes were milked twice a day, and daily milk yield was calculated by adding the milk yield obtained in a particular day. Standard lactation milk yield was calculated by adding daily milk yield till 305th days of lactation. Colostrum yield for the first three days after calving was not added. The records of animals with lactation length lesser than 120 days were not considered for study. To ensure the normal distribution, the outliers were removed and data within the range of mean ± 2SD were only considered for the present study.

Statistical analysis

Fitting of lactation curve model

On the basis of the review, the following four important models were selected to model the lactation curve for first lactation in Jaffarabadi buffaloes.

Comparison of different lactation curve models

The above stated models were fitted to MTDYs for first lactation 305 day or less milk yield (FL305DMY). The most suitable model was identified on the basis of the highest R^2 -value, lowest root means square error (RMSE) value and graphical presentation of the lactation curves. Residuals were plotted graphically which gave an accuracy of the model to fit the lactation curves. The best model chosen from the above four models on the basis of highest R^2 -value as well as least RMSE value and graphical presentation was used for prediction of standard lactation yield.

RESULTS AND DISCUSSIONS

In the present study, MTDYs were used to develop the best lactation curve models for the first lactation 305-days milk yield in Jafarabadi buffalo using four models *viz.* parabolic exponential function, inverse polynomial function, gamma-type function and mixed log function. Therefore, this function could not explain the ascending as well as peak yield of the lactation in Jafarabadi buffalo as those of the other models of the lactation curve.

The data of 2343 MTDYs of first lactation pertaining to 213 Jafarabadi buffaloes were used to estimate various parameters of above four lactation curve models for selecting the best model. The average MTDY increased from 2.73 litre in month 1 to a peak yield of 5.87 litre in month 4 and subsequently declined to 2.74 litre in month 11 (Table 2).

The observed and predicted first lactation MTDYs estimated by four different functions has been presented in Table 2. The peak MTDY was found to be 8.34 litre in the 3rd month of lactation by inverse polynomial function.

Fitting of different lactation curve models on MTDYs

The estimated lactation curves parameters i.e. a, b and c of all four lactation curve models have been presented in Table 2.

Parabolic exponential function

The fitting of observed and predicted MTDYs for parabolic exponential function for Jaffarabadi buffalo has been graphically presented in Figure1.The parabolic exponential function explained moderate R^2-value (83.28%) with 0.149 litre RMSE (Table3). Similar results were reported by Cheema and Basu (1983) who reported 84.38% accuracy with 0.4054 Kg RMSE in Surti buffaloes higher estimates of R^2-values of this function were reported by Sahin *et al*. (2014); Sahoo *et al*. (2016) in Anatolian and Murrah buffaloes respectively.

Inverse polynomial function

The fitting of observed and predicted MTDYs from inverse polynomial function in Jafarabadi buffalo has been graphically presented in Figure 2. This function explained best fit for MTDYs in Jafarabadi buffalo with highest coefficient of determination (R^2 = 98.84%). However, root mean square error (RMSE) was highest (0.376 litre) (Table 3). Cheema and Basu (1983); Appannayar and Kumar (1997) similarly reported R^2-value of inverse polynomial function as 99.83 and 94.6%, respectively and suggested that this function gave the best fit for lactation curve with the highest R^2-value for Surti buffalo using the test day models. Dimauro *et al*. (2005) also reported similar results (R^2 = 96.7%) for Italian water buffalo using monthly test day model. However, Barbosa *et al*. (2007) reported lower estimates of R^2 -values (62.00 % and 59.00 %) for this function for prediction of first lactation yield for two different populations of crossbred buffaloes.

The inverse polynomial function indicated slight gap between observed and expected MTDYs at initial stages of the lactation up to 2nd monthly test day. However, it showed very high predicted peak yield at early stage of the lactation. However, this model specified lower estimates of predicted values for the descending slope of the lactation curve indicating that this model could describe the descending phase with lower accuracy. The trend indicated that the function might be most suitable to Jafarabadi buffaloes which start their lactation at a very low level of production, reach their peak yield very early and then start declining at an early stage.

Gamma type function

The fitting of observed and predicted MTDYs using coefficients of gamma type function in Jaffarabadi buffalo has been graphically presented in Figure 3. The gamma type function gave estimate of R^2 -value of 96.80% and least RMSE (0.073 litre) in the present study (Table3). Cheema and Basu (1983); Singh *et al*. (2015) reported almost same R^2 (96.83 and 96.42 %, respectively) and RMSE (0.082 and 0.077 litre respectively) values in Murrah buffalo. Nearly similar findings were reported by Bhat and Kumar (1980); Sahoo *et al*. (2014b); Sahoo *et al*. (2015); Sahoo *et al*. (2016) in Murrah buffalo. Sahin *et al*. (2014); Barbosa *et al*. (2007)

also reported similar findings in Anatolian buffalo and crossbred buffaloes whereas, Dematawewa and Dekkers (2014) reported that gamma Function explained lactation curve with moderate accuracy of prediction (81.31%) in Murrah and Surti buffalo breeds. However, Soysal *et al*. (2015) reported lower estimates of R^2 -value (77.00%) for this function in Aatolian buffalo.

The gamma type function indicated very close relationship between observed and expected MTDYs at initial stage of the lactation up to 2nd monthly test day. Thereafter, the predicted values showed a marked gap with observed values at 3rd monthly test day record indicating slightly higher estimation of predicted peak yield than the observed one. Afterwards predicted value and observed values were in close relation up to 6th MTDY. The predicted values and observed values showed marked gap at 7th and 8th MTDY and specified slightly underestimated prediction of early descending phase of the lactation curve by this function. However, 9th MTDY onwards the predicted and observed values were similar showing slightly higher predicted values. This could be due to linear predictability of the descending phase of the lactation curve by gamma function. Overall, it was evident that gamma type function accounted for rising, peak yield and the declining segments of the lactation curve.

Mixed log function

The fitting of observed and predicted MTDYs for mixed log function in Jaffarabadi buffalo has been graphically presented in Figure 4. Mixed log function gave higher R^2 -value (92.73%) after inverse polynomial function and comparatively lower RMSE value of 0.102 litre (Table 3). Similar findings were reported by Sahoo *et al*. (2014b); Singh *et al*. (2015); Sahoo *et al*. (2016) in Murrah buffalo. However, lower value (59.1%) was reported by Kocak and Ekiz (2008) in Holstein Friesian cows for this function. However, Olori *et al*. (1999); Dongre (2012) showed that mixed log function under predicted the milk yield around peak production and then over-predicted immediately afterwards.

The mixed log function gave a close fit with the observed lactation curve. The predicted values were in close relation with observed values in the initial stage of the lactation curve upto 2nd MTDY. However, the peak yield predicted by this function was slightly higher than the observed one specified that noticeable gap between predicted and observed values during the 2nd and 3rd MTDY. Mixed log function described the descending phase of lactation with slightly underestimated predicted values up to 9th MTDY after 4th MTDY. However, it projected slightly higher predicted values for 9th MTDY onwards. The differences in predicted and observed values during the descending phase of the lactation might be due to linear predictability of this function, because this function accounted for rising and the declining segments of the lactation curve. Therefore, the mixed log function could be describing lactation curve in low milk producing buffalo having long descending phase of the lactation

CONCLUSIONS

The prime objective of the present study was to find the best fit of lactation curve model for first lactation 305 day or less milk yield and to examine the curve pattern of first standard lactation milk yield using test day milk yields in Jafarabadi buffaloes. The highest peak MTDY was found to be 8.34 litre in the 3rd month of lactation by inverse

Table 1. Model the lactation curve for first lactation in Jaffarabadi buffaloes.

Sr. No.	Model	Functional form	Reference
1	Parabolic exponential function	$Y_t = a \exp(bt - ct^2)$	Sikka, 1950
2	Inverse polynomial function	$Y_t = t (a + bt + ct^2)^{-1}$	Nelder, 1966
3	Gamma-type function	$Y_t = at^b e^{-ct}$	Wood, 1967
4	Mixed log function	$Y_t = a + bt^{12} + c \log t + e_t$	Guo and Swalve, 1995a

Where; Yt =Average yield in the t^{th} time period of lactation

a = Initial milk yield after calving

b = Ascending slope parameter up to the peak yield

c = Descending slope parameter

t = length of time since calving

e_t = residual error

Table 2. Estimated lactation curve parameters of different models in Jafarabadi buffalo.

Sr. No.	Function	Parameters		
		a	b	c
1	Parabolic exponential function	3.4009	0.0081	-0.00003
2	Inverse polynomial function	6.5916	-0.0663	0.0013
3	Gamma type function	1.5037	0.4282	-0.0059
4	Mixed log function	0.0042	-0.8074	13.8387

(a = initial milk yield after calving; b = ascending slope parameter up to peak yield; c = descending slope parameter).

Table 3. Different lactation curve functions with parameters for prediction of MTDMYs in Jaffarabadi buffalo.

Sr. No.	Function	Parameters of Funtion	R^2-value (%)	RMSE (litre)
1	Parabolic exponential model	$Yt = 3.4009 \exp (0.0081*t - (-0.00003)*t^2)$	83.28	0.149
2	Inverse polynomial model	$Yt = t (6.5916 + (-0.0663)*t + 0.0013*t^2)^{-1}$	98.84	0.376
3	Gamma-type function	Yt = 1.5037 *t0.4282 e-0.0059*t	96.80	0.073
4	Mixed log function	$Yt = 0.0042 + (-0.8074) *t^{½} + 13.8387 \log t + et$	92.73	0.102

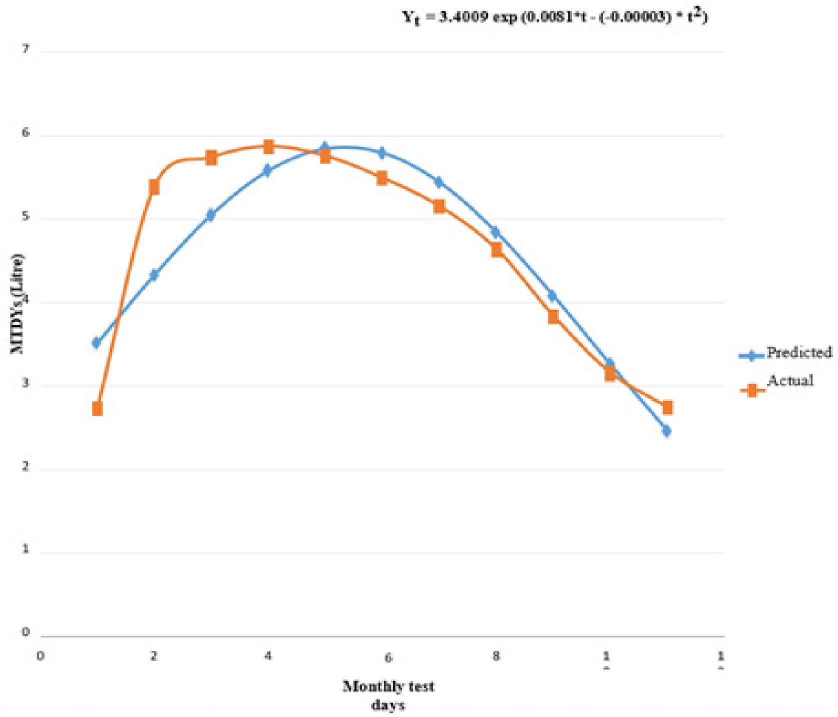

Figure 1. Observed and predicted MTDMYs (litre) for parabolic exponential function in Jafarabadi buffalo.

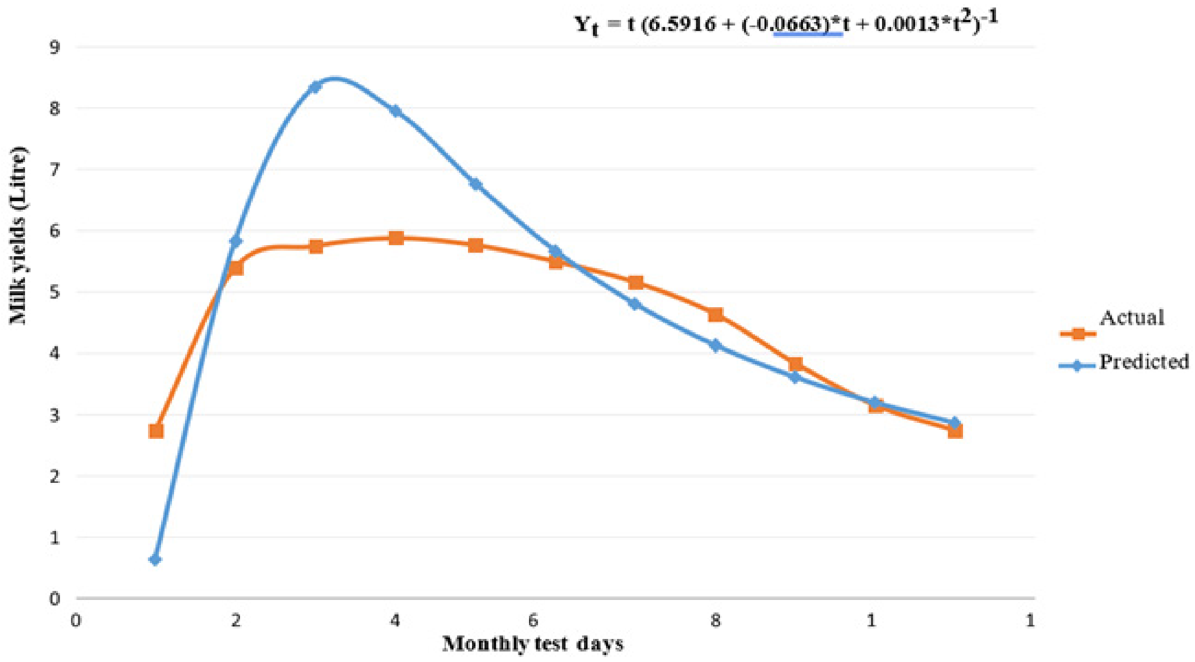

Figure 2. Observed and predicted MTDMYs (litre) for Inverse Polynomial function in Jafarabadi buffalo.

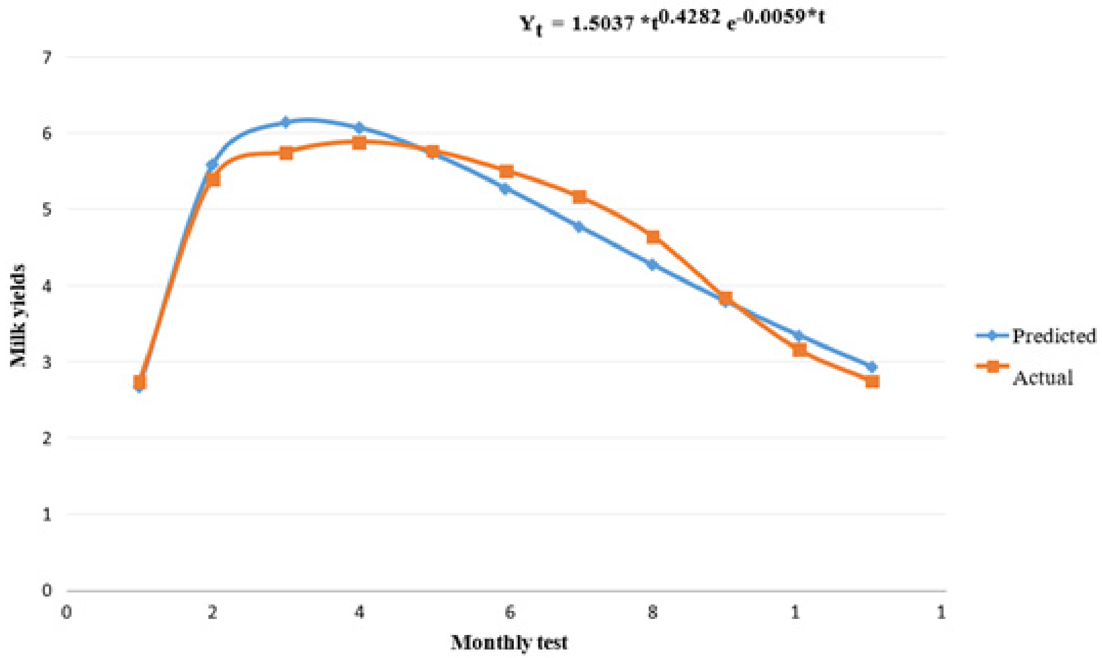

Figure 3. Observed and predicted MTDMYs (litre) for Gamma type function in Jafarabadi buffalo.

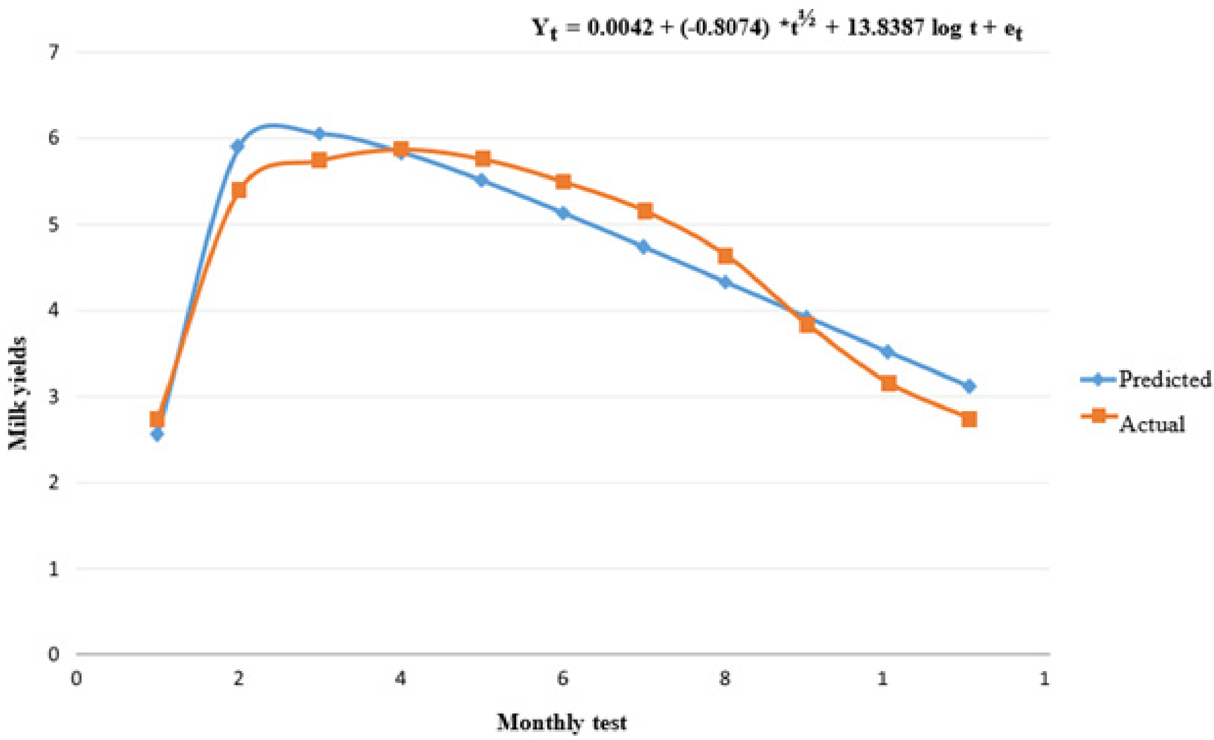

Figure 4. Observed and predicted MTDMYs (litre) for Mixed Log Function in Jafarabadi.

polynomial function. Graphical presentation indicated that gamma type function was found to be best fit for MTDYs in Jafarabadi buffalo with higher coefficient of determination and least root mean square error, while parabolic exponential function was least fitted with lowest coefficient of determination and comparatively higher root mean square error. The trend of gamma type function indicated that this function might be most suitable to Jafarabadi buffaloes which started their lactation at low level of production, reached their peak yield very early and then started declining at an early stage. However, parabolic exponential decline function could neither describe the initial increase of milk yield or the peak yield, it could only describe the declining phase of the lactation. Therefore, it had the merit to represent only the descending segment of the lactation curve in Jafarabadi buffalo. Understanding the lactation curve has a lot of potential for improving the herd average. It also provides a brief review of buffalo's efficiency and enables the creation of appropriate breeding and management strategies for breed improvement programmes.

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