



Identification of optimum test-day records for accurate prediction of lactation yield in Murrah buffaloes under farmers' herd conditions

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ABSTRACT

Accurate estimation of lactation yield under field conditions can increase the pace of selection and genetic improvement in Indian buffaloes. Monthly test day records can predict the 305-day milk yield. In the present study, daily lactation yield data from first and second lactation were used to identify the minimum number of test-day records, which could be used to predict the 305-day milk yield with accuracy and maximum correlation with actual lactation yield in Murrah buffaloes. Seventeen general linear models were developed using monthly test-day records and significant days of lactation. A combination of significant days were identified from the test-day model and the principal component analysis based significant days were used to build the final best fit model, which in the predicted data set, showed a comparatively lower RMSE (471.78) and higher R^2 of 0.67. Our model showed a high correlation coefficient of 0.82 with the test-day interval method of the International Council of Animal Recording for predicted lactation yield.

Keywords: Buffalo, Linear model, Optimum records, Test day

Recording precise estimate of dairy performance in a herd is of utmost importance for managing any dairy farm. The milk recording process used to evaluate the dairy potential in a cow or buffalo has been assessed using different measures across the organized herds and at farmers' herds. At organized herds, various production traits namely, standard or total lactation yield, average daily yield, monthly yield and 24-hour yield has been used to assess the lactation performance among dairy animals. Various methods for estimating 24-hour yield include method of Delorenzo and Wiggans (1986) and method of Liu *et al.* (2000), using data on more than one day (Lazenby *et al.* 2002), using data on 1 day (Bouloc *et al.* 2002), using data on more than one day (Hand *et al.* 2006). The methods have also been used for calculating accumulated yields, namely, Test Interval Method (TIM) (Sargent, 1968), Interpolation using Standard Lactation Curves (ISLC) (Wilmink, 1987), Best prediction (VanRaden, 1997), Multiple-Trait Procedure (MTP) (Schaeffer and Jamrozik, 1996). Attempts have also been made by scientists to identify and optimize the test-day. The monthly milk yield is maximum for the second month (Bhaduarua *et al.* 1986, Zaman *et al.* 1990); whereas the minimum test day monthly

yields were obtained in the first three lactations (Koko and Chakravarty, 2008).

Although India is the leading milk-producing country with an annual production of 187.75 mMT (BAHS, 2019) and the dairy sector is growing @6.5% annually (BAHS, 2019). The evaluation of the performance of dairy bovines, particularly in buffaloes, has not been standardized. The major reason could be that dairy husbandry in India is being practiced as an allied activity with small herd size, and secondly, farmers do not maintain proper performance recording of their animals and their management decisions are often empirical in nature. Various countries of the world have adopted the International Council for Animal Recording (2003) as a gold standard for calculating the 305-day milk yield using the test-day interval method. Indian dairy germplasm can be well evaluated using Test-day interval method under field conditions. This objective of this study was to identify the minimum number and optimum time interval between subsequent test-day milk records required for accurate prediction of lactation yield in Murrah buffaloes under field conditions, which can be used in Sire evaluation programs.

MATERIALS AND METHODS

Dataset: Data comprising of first and second lactations of same buffalos recorded during a period of 13 years (2004 to 2017) was obtained from Livestock Record Unit, NDRI (29° 42' N and 72° 02' E). After standardization and normalization (a lactation of min. 90-days and more than 500 kg milk were considered) of the data set, a total of 366

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lactation records of Murrah buffaloes having a minimum lactation up to 240 days was considered for the analysis. Daily milk yield and 305-day milk yield (SLMY) records were collected for the study.

Statistical analysis: Test day (TD) model used: To develop the prediction model for 305-day milk yield (SLMY) of the dairy buffaloes, monthly test-day records were considered as predictor variables. Eight monthly test-day records, and 1st day of milk secretion (5th day of lactation) thus, a total of 9 total test day records, were included in the study. The first TD model considered was having a test-day interval of 30 days. Using all available test day records SLMY was predicted. Significant test-days were identified and SLMY was re-predicted using only significant test days (based on p-values).

Principal Component (PC) analysis: In addition to monthly test day records, PC analysis was performed on the complete lactation records of all the buffaloes with the aim to screen some major predictor days of lactation, in addition to the monthly test days. Based on high loadings on the 1st PC as well as its high correlation with SLMY, the top 22 test days were selected. Using significant selected test days, a model was developed to predict SLMY.

General linear model: Many different regression models were used to predict SLMY using various combinations of monthly test days, and a model comprising a mix of monthly test days and significant days of lactation (Table 1). For each model, adjusted R² was estimated for the full dataset and further, the dataset was split into train and test datasets with 80:20 ratios. Each model was trained in the training dataset and further prediction was made in the test dataset. Correlation between predicted SLMY and observed SLMY in the test dataset was observed.

All the statistical analysis was carried out through “R” programming environment using the base, “tidyverse” and “caret” packages.

RESULTS AND DISCUSSION

A total of 3294 test-day records (366 × 9) were considered as predictors in the preliminary model. PC derived significant test days were also included as predictors, as a separate model (M₆) and also along with subsequent models with the aim to reduce the number of predictors. A total of 17 models having different predictors, based on their statistical significance, were identified using the backward elimination method of linear regression (Cramer, 1998). The entire dataset was partitioned into a training and prediction set with an 80:20 ratios. In the training dataset, highest R² was 0.74 for model M₁ & M₂ (Fig. 1). The trained model was then tested in the test data set where different models were used, and the adjusted R² for the predicted dataset was found to be varying from 0.59 (M₁₄) to 0.77 (M₁), and root mean square error (RMSE) of the prediction ranged from 393.22 (M₁) to 526.36 (M₁₄). The correlation between actual SLMY observations of the test dataset and predicted SLMY values was also checked and observed to be 0.88. The monthly interval for various

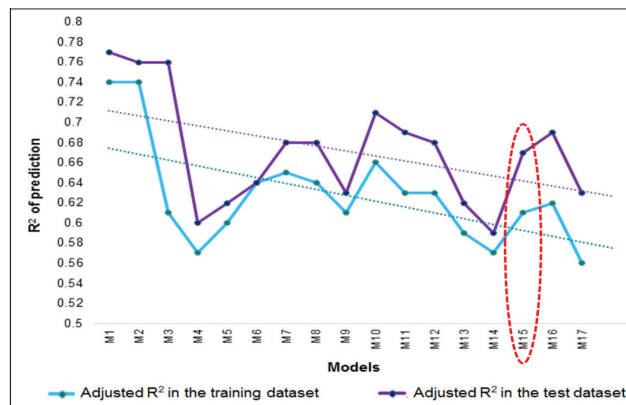


Fig. 1. Adjusted R² of predictions in training and test dataset for all the models tested

test-day, TD1, TD3, TD4, TD5, and TD8 were found to have a significant effect on SLMY.

PC analysis on all the records revealed that PC₁ could explain 57.38% of the total variance in the dataset while cumulative variance explainable by the first two PC were 70.68% that of the total variance. As PC₁ could explain a

Table 1. List of model and predictors used to estimate the total lactation milk yield in the Murrah buffaloes

Model	No. of predictors	Independent predictors used
M ₁	9	5 th Day of lactation + TD1 + TD2 + TD3 + TD4 + TD5 + TD6 + TD7 + TD8
M ₂	5	TD1 + TD3 + TD4 + TD5 + TD8
M ₃	4	TD1 + TD3 + TD4 + TD5
M ₄	3	TD1 + TD3 + TD4
M ₅	3	TD3 + TD4 + TD5
M ₆	22	Day104 + Day105 + Day106 + Day107 + Day108 + Day109 + Day112 + Day126 + Day127 + Day128 + Day137 + Day140 + Day143 + Day144 + Day145 + Day147 + Day148 + Day153 + Day154 + Day155 + Day156 + Day167
M ₇	5	Day106 + Day137 + Day144 + Day145 + Day167
M ₈	3	Day106 + Day144 + Day167
M ₉	2	Day106 + Day144
M ₁₀	7	TD1 + TD3 + TD4 + Day106 + Day144 + TD5 + Day167
M ₁₁	6	TD1 + TD3 + TD4 + Day106 + Day144 + TD5
M ₁₂	5	TD1 + TD3 + TD4 + Day106 + Day144
M ₁₃	4	TD1 + TD3 + TD4 + Day106
M ₁₄	3	TD3 + TD4 + Day106
M ₁₅	3	TD3 + TD5 + Day106
M ₁₆	4	TD1 + TD3 + TD5 + Day106
M ₁₇	3	TD1 + TD3 + Day106

TD: monthly test-day of lactation

significant fraction of variance, the days with the highest component loadings on PC1 were selected, and later used in combination with monthly test days for prediction of SLMY. The days having a high correlation with SLMY were also taken into consideration. A total of 22 Days were selected to be included in the model and it was observed that the R^2 of the prediction was 0.64 and only Day106, Day137, Day144, Day145, and Day167 were having significant on SLMY. Thus, the prediction was continued with only records of these days.

Best possible combinations from all these days including conventional test days and days other than test days were tested through linear regression on SLMY for developing the best prediction model. Several combinations were tested, and the best-performing model is depicted in Fig 1 and 2. The adjusted R^2 in both training and test datasets followed an almost similar trend across all 17 models used for prediction (Fig 1). A higher adjusted R^2 in the test dataset often occurs due to differences in phenotypic variance and noise structure between training and test datasets and might have happened due to random splitting of the dataset in to training and test without specifying any rule for splitting. Certain test-day combinations capture biologically stable stages of lactation more effectively, leading to improved variance explanation in the test set. This high adjusted R^2 pattern in test dataset reflects the generalization ability rather than overfitting, and adjusted R^2 is used here for comparative purposes only. However, the adjusted R^2 of predictions in the test dataset was found to be higher across all models tested than those estimated in the training dataset. Root mean square error (RMSE) of predictions in test dataset across all models followed an antiparallel trend with the correlation between observed and predicted values indicating the inverse linear relationship between the two (Fig 2). Models having lower prediction RMSE in the test dataset were able to predict the SLMY with a high correlation to the actual SLMY.

Various methods of test-day-based evaluations have been used in animal breeding research but with the variation in duration or interval between two consecutive test days and the number of test-day. The test-day interval method of International Council of Animal Recording (ICAR), 2003, is a widely accepted method. In dairy buffaloes in India, which have comparatively shorter lactation length

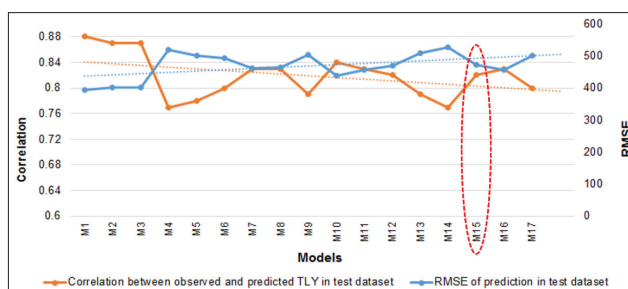


Fig. 2. Correlation between observed and predicted SLMY/TLY, and root mean square error of prediction in the test dataset for all the models tested

when compared to cattle, the feasibility of performance recording under farmer's herd, where dairy animals are housed as part of the house with separate enclosure, and the cost of data recording limits the test-day data recording in a farmers' herd. This can be addressed by minimizing the number of test days with maximum correlation with ICAR standard, where 10 test day records at a monthly interval are recommended. A model (M15) with 3 test-day recordings was identified, namely, the monthly TD3 i.e. 90th day, TD5 i.e. 106th day, and 150th day of lactation. The M_{15} model was found to be best in predicting the actual SLMY and the model showed a high correlation of 0.82 and comparatively lower RMSE with actual TLY/SLMY recorded in buffaloes (Fig. 2).

TD3 + TD5 + Day106 predicted the 305-day milk yield with an accuracy of 0.81; and the predicted 305-day milk yield had a correlation of 0.90 with test day milk yield estimate of International Council for Animal Recording, the 10 test-day interval method. Model 15 a high correlation of 0.90 with the SLMY predicted using the ICAR method along with a comparatively lower RMSE 471.78 indicating the suitability of the model. The developed model (M15) with assigned weights to different test days is indicated below, where TD3, TD5, and TD106 were the 24-hour milk recording for a buffalo:

$$\text{SLMY} = \beta_0 + \beta_1 * \text{TD3} + \beta_2 * \text{TD106} + \beta_3 * \text{TD5} + \text{Error}$$

$$\text{i.e., SLMY} = 37.88 + 64.74 \text{ TD3} + 85.28 \text{ TD106} + 107.77 \text{ TD5} + 471.78$$

A number of reports are available indicating that in multiple linear regression, $R^2 > 60\%$ is generally acceptable as a good model fit whereas $R^2 < 40\%$ is considered as a poor model fit (Luszniewicz and Slaby, 2001; Grzesiak *et al.* 2003; Saini *et al.* 2005; Singh *et al.* 2021). Singh *et al.* (2021) reported that the 45th, 105th, and 165th days of lactation when used to predict first lactation 305-day milk yield with 83% accuracy in Murrah buffaloes. However, we report that the 305-day milk yield can be predicted with an optimum accuracy using the test-day interval model with minimum (3) number of test days.

This work established the proof of concept that the number of test day records, as low as three in numbers, can be used to predict the 305-day milk yield in dairy buffaloes at the farmers' herd improving field data recordings in sire evaluation. In our study, the 90th day, 106th day, and 150th day 24-hour milk yield records together were a strong predictor of lactation milk yield with 90% correlation with the existing method of International Council for Animal Recording, wherein 10 test day recordings are required for the estimation of 305-day milk yield.

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REFERENCES

- Bouloc N, Delacroix J and Dervishi V. 2002. Milk recording and automatic milking systems: features and simplification possibilities of recording procedures. (In) *Proceedings of 33th biennial Session of ICAR*, Interlaken, Switzerland, May 26–31.
- Cramer D. 1998. *Fundamental statistics for social research: Step by step calculations and computer techniques using SPSS for Windows*. New York, NY: Routledge.
- Delorenzo M A and Wiggans G R. 1986. Factors for estimating daily yield of milk, fat, and protein from a single milking for herds milked twice a day. *Journal of Dairy Science* **69**: 2386.
- Grzesiak W, Wojcik J and Binerowska B. 2003. Prediction of 305-day first lactation milk yield in cows with selected regression models. *Archives Animal Breeding* **46**(3): 213–224.
- Hand K J, Lazenby D, Miglior F and Kelton D F. 2006. Comparison of Protocols to Estimate Twenty-Four-Hour Fat and Protein Percentages for Herds with a Robotic Milking System. *Journal of Dairy Science* **89**: 1723–1726.
- ICAR. 2003. International Agreement of Recording Practices. *International Committee for Animal Recording*, Interlaken, Switzerland.
- Lazenby D, Bohlsen E, Hand K J, Kelton D F, Miglior F and Lissemore K D. 2002. Methods to estimate 24-hour yields for milk, fat and protein in robotic milking herds. (In) *Proceedings of 33th biennial Session of ICAR*, Interlaken, Switzerland, May 26–31, 2002.
- Liu Z, Reents R, Reinhardt F and Kuwan K. 2000. Approaches to estimating daily yield from single milk testing schemes and use of a.m.-p.m. records in test-day model genetic evaluation in dairy cattle. *Journal of Dairy Science* **83**: 2672–2682.
- Luszniewicz A and Slaby T. 2001. *Statistic with a computer package STATISTICATMPL*. Warsaw, CH Beck.
- Saini T, Gahlot G C and Kachwaha R N. 2005. Prediction of 300 days' lactation yield on the basis of test day milk yield in Rathu cows. *The Indian Journal of Animal Sciences* **75**(9).
- Schaeffer L R and Jamrozik J. 1996. Multiple-trait prediction of lactation yields for dairy cows. *Journal of Dairy Science* **79**: 2044–2055.
- Singh M, Prakash V, Dash S, Dixit S and Gupta A K. 2021. Multiple linear regression analysis using monthly test day milk yield predicting the first lactation production performance for sire evaluation in Murrah buffaloes. *Indian Journal of Dairy Science* **74**(1): 89–94.
- VanRaden P M. 1997. Lactation yields and accuracies computed from test day yields and (co)variances by best prediction. *Journal of Dairy Science* **80**: 3015–3022.
- Wilmink J B M. 1987. Comparison of different methods of predicting 305-day milk yield using means calculated from within-herd lactation curves. *Livestock Production Science* **17**:1–17.