Haryana Veterinarian (June, 2026) **65(1),** 17-22 ISSN 0033-4359 (P) **Research Article**

MODELLING AND FORECASTING OF BREEDING EFFICIENCY IN HARIANA CATTLE

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ABSTRACT

The present investigation was undertaken to predict the breeding efficiency by Wilcox method (BEW) using early life reproduction traits. Under this study, multiple linear regression (MLR) approach was used. Breeding data were obtained from history sheet registers and herd inventory records of Hariana cattle maintained at the Livestock Farm Complex, Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, DUVASU, Mathura. Information was collected on productive animals born between 1962 and 2024 with total 756 records. The overall least-squares mean for breeding efficiency (Wilcox method) estimated was 69.5±0.69 percent. Period of birth, AFC and parity had significant effect on breeding efficiency in the present study. The heritability estimates for BEW was 0.533. Breeding efficiency was predicted by multiple linear regression (MLR) analysis. In MLR study, it was observed that model 3 having only one independent variable (First Service Period) fulfilled most criteria such as higher R^2 and lower MSE, RMSE, MAE, MAPE and U values. The MLR explained 55.4% of accuracy of prediction of BEW in Hariana cattle. MLR method could be used for the prediction of BEW, which is a simple and easy method.

Keywords: AIC, BIC, Breeding efficiency, Hariana cattle, MLR

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Cattle hold immense significance in India's agricultural economy, culture, and everyday life. They play a crucial role in food production, rural livelihoods, and sustainable farming. As the world's largest producer of milk, India relies heavily on cattle for dairy products, with indigenous breeds such as Gir, Sahiwal, and Hariana supporting millions of dairy farmers. Small and marginal farmers depend on cattle for income, employment, and nutrition. In many rural areas, bullocks continue to be used for plowing, transportation and various farm activities, particularly where mechanization remains limited. Cattle dung serves as natural manure, enhancing soil fertility and reducing reliance on chemical fertilizers. It is also used for biogas production, offering an eco-friendly energy source. Cattle contribute to sustainable farming by improving soil health through natural fertilization. Additionally, in Hinduism, cows are considered sacred and hold a vital place in religious rituals. Milk and dairy products are an integral part of the Indian diet, providing essential nutrients like protein and calcium. Beyond milk production and farm labor, cattle are deeply embedded in India's rural economy, traditional agricultural practices and ecological balance. Cattle breeds in India are categorized based on their milk yield, with high-yielding breeds distinguished from low or medium-yielding ones. The Hariana breed, native to Haryana, is primarily found in the districts of Rohtak, Hisar, Jind and Gurgaon. These cattle have a white or light grey coat, a strong and muscular build, long legs and a small hump. While primarily used as draught animals in agriculture, Hariana cows produce a moderate amount of milk, approximately 5-8 liters per day under proper management. They are known for their resilience, disease resistance and adaptability to hot climates, making them highly valuable to farmers in northern India. Breeders have always aimed to evaluate the production potential of dairy animals. Since the economic viability of the dairy industry depends on the productive and reproductive performance of cattle, identifying effective selection criteria is essential. According to Bakir and Cilek (2009), cattle reproduction is the foundation of economic returns. Breeding efficiency directly impacts profitability. Negussie *et al.* (1998) emphasized that developing suitable breeding strategies requires an accurate assessment of the reproductive efficiency of native cattle under different production conditions. Since breeding efficiency is a lifetime trait, selecting cattle based on this factor alone is often delayed due to the age of the animal at the time of evaluation. Predicting breeding efficiency early, using reproductive traits, helps in identifying high-performing animals sooner. This approach also aids in the timely culling of less productive animals, reducing maintenance costs. According to Shetkar *et al.* (2021), lifetime productivity is a key factor in maximizing financial returns from an individual animal. Based on this understanding, research was conducted on Hariana cattle to develop a predictive model for breeding efficiency using multiple regression analysis.

MATERIALS AND METHODS

In the present study breeding data were obtained from history sheet registers and herd inventory records of

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Hariana cattle maintained at the Livestock Farm Complex, Pandit Deen Dayal Upadhyaya Pashu Chikitsa Vigyan Vishwavidyalaya Evam Go Anusandhan Sansthan, DUVASU, Mathura (UP). Information was collected on productive animals born between 1962 and 2024, totaling 756 records. To assess breeding efficiency, outliers were removed and only data within the mean ± 3SD range were considered to ensure a normal distribution.

Breeding efficiency was estimated by formula given by Wilcox *et al.* (1957).

$$BE = \frac{365 \times (N-1) \times 100}{D}$$

Where,

B.E. = Breeding efficiency in percentage

N = number of calving

D = Number of days from first to last calving

Means, standard deviations, standard errors and coefficients of variations of the BE were calculated according to the statistical method given by Snedecor and Cochran (1994).

The non-genetic factor effects such as period of birth, season of birth, AFC age group (lower and higher AFC age group based in individual value lower or higher than population average) and parity (class 1 with 2-3 parity; class 2 with 4-6 parity; and class 3 with 7 or more parity) of various traits were studied by least-squares analysis using the technique suggested by Harvey (1987). The models used were as follows:

$$Y_{ijklm} = \mu + P_i + S_j + A_k + L_l + e_{ijklm}$$

Where,

Y_{ijklm} - m^{th} observation in l^{th} parity, k^{th} age group, j^{th} season and i^{th} period of calving

μ - Overall mean

P_i - Effect of i^{th} period of birth (i = 1 to 6)

S_j - Effect of j^{th} season of birth (j = 1 to 4)

A_k - Effect of k^{th} AFC age group (k = 1 to 2)

L_l - Effect of l^{th} parity (l = 1 to 3)

e_{ijklm} - Random error ~NID $(0, \sigma^2_e)$

Heritability was estimated by paternal half-sib (PHS) correlation method as suggested by Becker (1975). Correlation of breeding efficiency with first service period and first dry period was estimated as suggested by Becker (1975).

The Variance Inflation Factor (VIF) tool is used to measure and quantify the extent of variance inflation. When predictors are correlated, the coefficient of determination becomes biased, leading to an increase in the standard error of predictor coefficients. As a result, the variance of predictor coefficients is inflated (Kumar *et al.*, 2019). VIF can be determined using the following formula:

$$VIF = \frac{1}{1-R^2_i}$$

Where R^2_i is the R^2– value obtained by regressing the ith predictor on the remaining predictors. A variance inflation factor exists for each of the i predictors in a multiple regression model.

The multiple regression analysis was done as suggested by Draper and Smith (1987) with the help of following model:

$$Y_i = a + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + e_i$$

Where,

Y_i - Variable to be predicted

$a, b_1, b_2, \ldots, b_n$ - Unknown parameters to be estimated.

$X_1, X_2, \ldots, X_n$ - Traits whose values are known.

e_i - Random error, NID $(0, \sigma^2_e)$

The coefficient of determination (R^2) represents the percentage of total variability in the prediction that is explained by a set of independent variables. It is calculated through analysis of variance and varies across different models.

Various statistical metrics, including Akaike information criterion (AIC), Bayesian Information Criterion (BIC), Mallow's Conceptual Predictive Value (MCp), coefficients of determination (R^2), mean absolute error (MAE), mean absolute percentage error (MAPE), Theil's U-statistic (U) and root mean square error (RMSE), were used to identify the optimal model(s) for predicting BEW in Hariana cattle. The best models were those with higher coefficients of determination (R^2) and lower values of RMSE, MAE, MAPE, BIC, and RMSE. Additionally, models developed using artificial neural networks (ANN) were compared with the best multiple regression analysis (MLR) model. According to Kumar *et al.* (2019), the primary goal of model development is to predict the response variable using predictor variables. Since model development is research-intensive and time-consuming, evaluating a model's predictive capability is crucial. Therefore, an ideal model should be both simple and highly accurate in its predictions.

RESULTS AND DISCUSSION

Information was collected on productive animals born between 1962 and 2024, totaling 756 records. After

Table 1. Least-squares means and standard error of breeding efficiency in Hariana cattle

Effects	BEW (%)
Overall mean (μ)	69.5 ± 0.69 (738)
Season of Birth	
Winter	69.2 ± 0.83 (365)
Summer	68.4 ± 1.20 (159)
Rainy	71.5 ± 1.59 (87)
Autumn	68.9 ± 1.33 (127)
Period of Birth	
1962-1970	69.0 ± 1.37^{a} (139)**
1971-1980	71.3 ± 1.20^{b} (155)
1981-1990	68.4 ± 1.21^{b} (171)
1991-2000	55.7 ± 1.21^{b} (167)
2001-2010	70.7 ± 1.98^{b} (57)
2011-2018	81.9 ± 2.13^{c} (49)
AFC Class	
Lower AFC Class	71.1 ± 0.88^{a} (404)**
Higher AFC Class	67.9 ± 0.95^{b} (334)
Parity Groups	
2-3	64.1 ± 0.96^{a} (270)**
4-6	67.9 ± 0.94^{b} (314)
>7	76.5 ± 1.26^{c} (154)

Winter: December to march, Summer: April to June, Rainy: July to August, Autumn: September to November. Similar/dissimilar superscript indicates the non-significant/significant differences between subclasses of means. Figures in parentheses are the number of observations. **Level of significance ($P<0.01$)

Table 2. VIF value for Breeding Efficiency by Tomar

Trait	VIF value
Age at first calving	1.005
First service period	2.262
First dry period	2.254

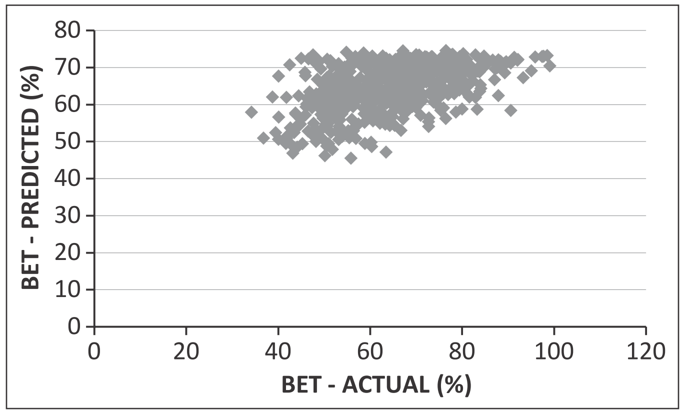

Fig. 1. Regression of predicted on the actual BEW using MRA model 3 in Hariana cattle

normalization, outliers were removed to estimate overall mean for breeding efficiency (Wilcox method). BEW was 66.3% with standard error and standard deviation of 0.61 and 16.9, respectively. The coefficient of variation estimated for breeding efficiency (Wilcox method) was 25.49. The higher average of breeding efficiency (Wilcox

Table 3. Prediction equation for breeding efficiency (Wilcox)

S. No.	Dependent variable	Independent variables	R^2 (%)	Linear regression equation's
1.	Breeding	AFC	0.3	BE (W) = 70.609 -0.0022AFC
2.	efficiency	FDP	32.4	BE (W) = 81.998 – 0.0494FDP
3.	(Wilcox)	FSP	55.4	BE (W) = 88.134 – 0.0654FSP
4.		AFC, FDP	32.5	BE (W) = 85.511 - 0.00152AFC – 0.04933FDP
5.		AFC, FSP	55.4	BE (W) = 88.460 – 0.0002AFC – 0.0654FSP
6.		FDP, FSP	55.4	BE (W) = 88.305 – 0.0633FDP - 0.002FSP
7.		AFC, FDP, FSP	55.4	BE (W) = 88.673 – 0.0002AFC – 0.063FSP – 0.002FDP

Table 4. Estimation of intercept and regression coefficient(s) for breeding efficiency (Wilcox) in Hariana cattle

Model	Variable	A	AFC	FSP	FDP	RMSE	R^2	MAE	MAPE	U
1.	AFC	70.609	-0.002	-	-	16.51	0.3	13.67	22.84	0.239
2.	FDP	81.998	-	-	-0.049	13.59	32.4	10.92	17.68	0.197
3.	FSP	88.134	-	-0.065	-	11.04	55.4	8.90	14.47	0.160
4.	AFC, FDP	85.511	-0.001	-	-0.049	13.58	32.5	10.89	17.61	0.197
5.	AFC, FSP	88.460	-0.0002	-0.065	-	11.04	55.4	8.92	14.46	0.160
6.	FDP, FSP	88.305	-	-0.063	-0.002	11.04	55.4	8.92	14.45	0.160
7.	AFC, FDP, FSP	88.673	-0.0002	-0.063	-0.002	11.05	55.4	9.00	14.44	0.160

method) were reported by Dhangar and Patel (1991) in Jersey×Kankrej (JK) F1 cross, Shelke *et al.* (1992) in Jersey ×Red Kandhari half bred and Red Kandhari, respectively. Panwer *et al.* (1996) in Rathi, Habib *et al.* (2013) in Red Chittagong Cattle, Singh *et al.* (2016) in different Crossbred cattle and Barros *et al.* (2020) in Red Sindhi cattle also reported the higher mean of breeding efficiency (Wilcox method). Ebrahim (2018) in Friesian cattle estimated lower mean of breeding efficiency (Wilcox method) in Friesian cattle.

Least-Squares Analysis

The overall least-squares mean for breeding efficiency (Wilcox method) estimated was 69.5±0.69 percent (Table 1). In the present study it was observed that the season of birth had non-significant effect on breeding efficiency of the animal with least-squares mean of breeding efficiency 69.2 ± 0.83 percent in winters, 68.4 ± 1.20 percent in summer, 71.5 ± 1.59 percent in rainy season and 68.9 ± 1.33 percent in autumn season. Period of birth had highly significant effect on breeding efficiency in the present study, the animals born during 2011-2018 period had highest breeding efficiency with least-squares mean of 81.9 ± 2.13 percent and those born during the period of 1962-1970, 1971-1980, 1981-1990, 1991-2000 and 2001-2010 with observed least-squares means of 69.0±1.37, 71.3 ± 1.20, 68.4 ± 1.21, 55.7±1.21 and 70.7±1.98 percent, respectively. In this study age at first calving had highly-significant effect on breeding efficiency in Hariana cattle. Animals with Lower AFC were observed higher breeding efficiency of 71.1±0.88 percent as compared to higher AFC animals with least-squares mean of breeding efficiency 67.9 ± 0.95 percent. In the present study parity of animals had highly significant effect on breeding efficiency of animals. Cows with more than 7 parity had higher breeding efficiency of 76.5±1.26 percent as compared to the animals with 2 to 3 parity and 4 to 6 parity with least-squares mean of breeding efficiency 64.1 ± 0.96 and 67.9 ± 0.94 percent, respectively.

Singh *et al.* (2016) in crossbred, Dash *et al.* (2017) in Karan Fries, Ambhore *et al.* (2017) in Phule Triveni, Tomar *et al.* (2022) in Hariana reported higher estimates for least-squares mean of breeding efficiency (Wilcox method). Significant effect of period on breeding efficiency was reported by Singh *et al.* (2016), Dash *et al.* (2017), Ambhore *et al.* (2017) in Crossbred cattle, Karan Fries cattle and Phule Triveni cattle, respectively. Season of birth had significant effect on breeding efficiency in the studies reported by Singh *et al.* (2016) in Crossbred cattle.

Heritability and correlation

Precise approximations of the heritability of different reproductive traits are crucial for evaluating the improvement of different traits and designing the future breeding and selection plans. The heritability estimates for BEW was high 0.533. The breeding efficiency had genetic correlation of 0.134±0.198 with age at first calving. The breeding efficiency had negative genetic correlations with first service period, first dry period with estimates as -0.666±0.561, -0.946 ± 0.702, respectively. The breeding efficiency (Wilcox) had positive phenotypic correlations with age at first calving with estimate as 0.047. Breeding efficiency (Wilcox) had negative phenotypic correlations with first service period and first dry period with estimated as -0.684 and -0.451. The breeding efficiency (Wilcox) had positive environmental correlations with age at first calving with estimate as 0.248. Breeding efficiency (Wilcox) had negative environmental correlations with first service period and first dry period with estimate as -0.747 and -0.275.

Shetkar (2021) estimated similar heritability for breeding efficiency in Hariana cattle. Lower estimates for heritability of breeding efficiency was observed Tekerli and Kocak (2009) in HF cattle. Tomar (2022) in Hariana cattle reported the similar positive genetic correlation with AFC and negative genetic correlation with first service period and first dry period in Hariana cattle. Tomar (2022) in Hariana cattle reported the similar positive phenotypic correlation between AFC and BEW. Tomar (2022) in Hariana cattle also reported negative phenotypic correlation between BEW with FSP and FDP.

Prediction model

To determine the correlations between the independent traits in the study of prediction, the variance inflation factor (VIF) was employed. The lower VIF values for AFC, FSP and FDP were observed which means that these traits were not correlated (Table 2). Multiple regression analysis was carried out for the prediction of BEW. First lactation production and reproduction traits were taken as independent variables viz. AFC, FSP and FDP. Prediction equations for prediction of BEW from early reproductive traits are presented in the Table 3. The best model for the lifetime BEW were selected based on their higher co-efficient of determination (R^2) value and lower RMSE, MAE, MAPE and Theil's U-statistic values. AIC, BIC and MCp values were also estimated for various model for interpretation of results and get more accurate prediction.

Development of MLR model for breeding efficiency

To predict the breeding efficiency (Wilcox) reproduction traits like AFC, FDP and FSP were used as independent variable for multiple regression analysis method. The model for the prediction of breeding efficiency (Wilcox) using reproduction traits are represented in Table 3.

The developed models were in different combinations ofAFC, FDP and FSP. Out of 7 models developed model 3 having independent variable first service period was best for prediction of BEW. Although few models had similar coefficient of determination but model 3 using only one independent variable so will be more useful. Hence model 3 with coefficient of determination (R^2) 55.4% and lower

RMSE, MAE, MAPE, U-statistic values has fulfilled the criterions. AIC (Akaike information criterion), BIC (Bayesian Information Criterion) and MCp (Mallow's Conceptual Predictive Value) values for model 3 were -1973.905, -496.27 and 2.001, respectively. BIC value for Model 3 is lowest as compared to other models. The linear regression equation developed is given below.

BE (W) = 88.134 – 0.0654FSP

The R^2 value of prediction was relatively high suggesting that the relationship between the predictors and the response variable is linear. The regression of predicted on actual breeding efficiency (Wilcox) using MRA model 3 is represented in Fig. 1.

Step wise regression procedure was used to predict the breeding efficiency (BEW) from first lactation traits viz. AFC, FDP and FSP under the present study. On analysis the co-efficient of determinations of 0.3%, 32.4%, 55.4%, 32.5%, 55.4%, 55.4% and 55.4% for BEW were observed when AFC, FDP, FSP, AFC-FDP, AFC-FSP, FDP-FSP and AFC-FDP-FSP were used as independent variables, respectively. The model with FSP (R^2 = 55.4%) as independent trait has been selected as optimum model to predict the breeding efficiency (Wilcox method). The model using AFC as independent variable had very low co-efficient of determination (R^2 value) of 0.3%. Model using FDP for predicting BEW the R^2 was observed as 32.4 percent only. Results clearly depicted that the AFC and FDP didn't influence BEW as that of FSP alone. In this study the FSP had a more influential effect on animals BEW as compared to different combinations of independent variables. Tomar *et al.* (2023) predicted BEW with lower co-efficient of determination of 36.3%. Gahlot (2003) predicted life time milk production in Tharparkar cattle with higher co-efficient of determination of 74.48%. Shetkar *et al.* (2023) predicted the lifetime II milk yield with higher co-efficient of determination of 75.46%. Second lactation milk yield was predicted by Das *et al.* (2022) with higher co-efficient of determination of 83.7 percent in Deoni cattle. Dangar and Vataliya (2022) predicted life time milk yield with higher coefficient of determination of 98% in Gir cattle.

CONCLUSIONS

The present study found a significant difference in breeding efficiency based on periods of birth, AFC class, and parity. This suggests that the breeding efficiency of Hariana cattle can be enhanced through optimal management practices. Multiple regression analysis (MRA) was used to predict BEW, with the best models selected based on higher coefficients of determination (R^2) and lower values of AIC, BIC, RMSE, MAE, MAPE, and Theil's U-statistic. The analysis considered various first lactation reproductive traits as independent variables, while breeding efficiency served as the dependent variable. The optimal model for BEW included the first service period as an independent variable and was expressed as BE(W)= 88.134-0.0654FSP, with an R^2 of 55.4%. The MLR method proved to be a simple and effective approach for predicting BEW.

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