

Optimum model for prediction of daughters pregnancy rate in Holstein Friesian crossbred cattle of Kerala, India

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Abstract: To improve the overall performances of dairy cattle, fertility should be given due weightage along with milk yield in breeding programmes. The study was initiated to genetic evaluate the crossbred cattle of Kerala based on fertility traits especially daughters pregnancy rate (DPR). An optimum model for the prediction of DPR based on standardized Voluntary Waiting Period (VWP) has been developed. Data pertaining to 1180 crossbred cattle sired by 208 Frieswal bulls, spread over a period of 17 years from 2003 to 2020, maintained at different farms of Kerala Veterinary and Animal Sciences University and field centres of ICAR- Field Progeny Testing Scheme were analysed in the study. VWP is standardized as 55 days as cattle inseminated during 55-63 days after calving had highest milk yield and pregnancy rate. Average DPR in the study was estimated as 0.34 ± 0.01 with coefficient of variation 74.61%. Low heritability (0.092) for DPR was observed compared to 305 days milk yield (MY) (0.170) and AFC (0.172). It also showed unfavourable genetic correlation with MY (-0.119). Seven simple and multiple regression models were developed using all possible combinations of age at first calving (AFC), service period (SP) and milk yield per day of lactation (MY/LL) for the prediction of DPR. It was observed that model containing only SP as independent variable fulfilled four criteria's *viz.* highest R^2 , minimum mean sum of squares due to error (MSSe), lowest Aaike information criterion (AIC), Bayesian information criterion (BIC) values and the optimum model developed was $DPR = 0.002(309-SP)$. The study standardized VWP and developed an optimum model for prediction of DPR in crossbred cattle also emphasis the importance of fertility in genetic evaluation and selection criteria of dairy cattle.

Keywords: Voluntary Waiting Period, Daughters Pregnancy Rate, crossbred cattle, optimum model

Introduction

According to 20th livestock census, India possessed 193.46 million cattle comprising of 142.11 million indigenous/non-descript and 51.63 million crossbred/exotic heads (20th Livestock Census All India Report, 2019). Crossbred cattle constitutes more than 93% of cattle population of Kerala state as crossbreeding is the accepted breeding policy for genetic improvement of cattle in the state. Cross breeding with exotic cattle mainly Holstein Friesian breed was under taken in Kerala state since 1960.

Progeny testing programme for Holstein Friesian crossbred bulls was implemented in the state since 1985 by Indian Council of Agricultural Research (ICAR). Semen of Frieswal bulls is being used for breeding of cattle. During past decades, the breeding values for milk production for crossbred cattle of Kerala increased about 450-500 kg. Despite of the considerable increase in milk production, fertility remains low as the conception rate of cattle is only 40-45% (ICAR-Annual Report, 2019). Genetic evaluation of dairy animals in the country is done mainly on the basis of first lactation milk yield only without considering major functional traits *viz.* fertility, may lead to increased generation interval, decreased genetic gain and reduces overall performance of cattle. Most of the developed countries have reversed this situation by estimating breeding values for fertility along with milk yield and including them with appropriate weightage in a multi-trait selection index for estimating the overall breeding objective of dairy farm (USDA, 2019). In 2003, United States Department of Agriculture introduced 21 days pregnancy rate as a direct measure for evaluation of fertility in dairy animals. Pregnancy rate measures the percentage of non pregnant animals that become pregnant during each oestrous cycle. It is calculated as the ratio of number of animals that become pregnant during oestrous cycle (21 days) to the number of non-pregnant animals passed the voluntary waiting period that were eligible for breeding at least 11 days of 21 day oestrous cycle (Van Raden et al. 2004). Voluntary waiting period (VWP) is the initial phase of lactation during which no insemination is carried out varies from breed to breed in different herds. VWP mainly depends on management practices followed

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during transition period. VWP in various Indian breeds were standardized as 53 days in Karan Fries cattle (Dash et al. 2016) and 63 days in Murrah breed of buffalo (Patil et al. 2014).

Genetic evaluation of bulls based on DPR measures the genetic ability of his daughters to become pregnant in each oestrous cycle. Evaluations are expressed as predicted transmitting ability for pregnancy rate (Van Raden et al. 2004). About 18 countries already evaluated cow fertility based on non-return rate, conception rate, pregnancy rate, interval from calving to first service and days open (Interbull, 2012). A comparison of pregnancy rate with other fertility traits from 14 countries had been conducted by Interbull in 2007 indicated that pregnancy rate is highly correlated with other fertility traits. These correlations indicate that pregnancy rate can be expected to improve fertility in dairy animals (Jorjani, 2007). Norman et al. (2009) reported that bulls of superior genetic merit for DPR had negative relationship with daughter days open, which resulted in longer productive life and reduced culling for reproduction traits. Keeping this in view, the present investigation was made to develop an optimum predictive model for prediction of Daughters Pregnancy Rate in crossbred cattle of Kerala.

Materials and methods

Source of data

In the present study, breeding records of 1180 crossbred cattle, pertaining to first lactation spread over a period of 17 years from 2003 to 2020, were collected from the history-cum-pedigree sheet and milk yield registers maintained different farms of Kerala Veterinary and Animal Sciences University *viz.* University Livestock Farm, Mannuthy; University Livestock Research station, Thiruvazhamkunnu; Cattle Breeding Farm, Thumburmuzhy and different field centres of ICAR- Filed progeny testing scheme, Thrissur. Semen of Frieswal bulls under Indian Council of Agriculture Research- Field progeny Testing scheme is being used for breeding of cattle in the study.

Data editing and Statistical analysis

The major traits considered were age at first calving (AFC), service period (SP), daughter pregnancy rate (DPR) and 305 days or less milk yield (MY). Data were checked for its normality and outliers as well as abnormal records were eliminated. After normalisation of records with mean \pm 2SD, 1005 first lactation records of crossbred cows sired by 208 sires were considered for this study. The data were adjusted for significant non-genetic factors *viz.* different periods, seasons, centres and age group at first calving using fixed linear models. Since the data was non-orthogonal, least squares analysis of variance by SPSS V.21 (SPSS Inc., Chicago, IL, USA) was used to estimate the effect of non-genetic factors, and the means were compared using Duncan's multiple range test.

The model considered was as follows: $Y_{ijklm} = \mu + S_i + P_j + A_k + C_l + e_{ijklm}$

where, Y_{ijklm} is the observation of m^{th} crossbred cattle born in the l^{th} centre, k^{th} age group, j^{th} period, and i^{th} season; μ , the overall mean; S_i , the fixed effect of i^{th} season of calving (winter (January-February), summer (March-May), rainy (June-September), and autumn (October-December)); P_j , the fixed effect of the j^{th} period of calving (1 to 15); A_k , the fixed effect of the k^{th} age group of calving (1 to 10); C_l , the fixed effect of the l^{th} centre (1-10) and e_{ijklm} , the random error~NID (0, $\sigma^2 e$)

Genetic parameters *viz.* heritability, genetic and phenotypic correlations of different traits were estimated with "Average Information" restricted maximum likelihood (AI-REML) procedure with various multi-trait models, using WOMBAT software (Meyer 2008).

Standardization of Voluntary Waiting period

The waiting period (WP) or days to first service is the initial phase of lactation, during which no insemination occurs. It was estimated as

$$WP = \text{DOFAI} - \text{DOFC}$$

Where, DOFAI is the date of first AI after first calving and DOFC is the date of first calving. The crossbred cattle having a WP of 43, 63, 84, and 105 days were considered for this study. In order to standardize the VWP period, 1005 cattle were classified into four groups based on the minimum WP of 43, 63, 84, and 105 days and they were 341,220, 329, and 115, respectively. Before standardization of VWP, in order to find the significant effect of WP on milk production traits, the group having maximum number of cattle *i.e.* 43- 62 group was further classified into 3 subclasses with five days class intervals. The major production trait considered was total milk yield per day of lactation length (MY/LL). Averages of MY/LL corresponding to each WP subclasses were also calculated. Voluntary waiting period for crossbred was standardized based on the groups having highest number of observations and having comparatively high MY/LL and DPR.

Estimation of Daughter Pregnancy Rate

Daughter pregnancy rate (DPR) measures how quickly cows become pregnant again after calving. DPRs were estimated as

$$DPR = 21 / (\text{Service Period} - \text{Voluntary Waiting Period} (55) + 11)$$

The constant factor 11 centralizes the measure of possible conception within each 21-day time period (Van Raden et al. 2004). DPR measures expected differences in 21-d pregnancy rate when comparing the daughter of a sire to a population (AIPL, 2013).

Development of optimum model for prediction of DPR in crossbred cattle

Multiple regression analysis was performed using R software version 3.4.3 (<https://www.r-project.org/>) for the prediction of DPR:

$$Y_i = a + b_1X_1 + b_2X_2 + b_3X_3 + e_i$$

Where, Y_i is the DPR of the i^{th} cattle; a is the intercept, X_1 , X_2 and X_3 are AFC, SP and MY/LL respectively; b_1 , b_2 and b_3 are the partial regression coefficients of AFC, SP and MY/LL respectively; and e_i is the random error of the i^{th} observation, normally and independently distributed with zero mean and variance (σ^2e). Seven simple and multiple regression models were developed using all possible combinations of the two independent reproduction traits (AFC, SP) and production trait (MY/LL) for the prediction of DPR. The coefficient of determination (R^2), mean sum of squares due to error (MSSe), Aaiki information criterion (AIC), and Bayesian information criterion (BIC) were used for predicting the optimum model for DPR of crossbred cattle. The best model to predict DPR was the model with the lowest AIC value (Akaike, 1974), BIC value (Schwarz, 1978), highest R^2 , and minimum mean sum of squares due to error (Kebede and Gebretsadik, 2010) using various combinations of the traits.

Results and Discussion

The data was adjusted for significant non-genetic factors. The overall least square mean of AFC, DFS, SP and MY were 1052.35 ± 10.68 days, 84.46 ± 0.89 days, 119.80 ± 2.51 days and 2596.07 ± 32.05 kg, respectively. Season of calving had significant effect ($P < 0.01$) on both DFS and SP where, winter and post monsoon were favourable for fertility traits in crossbred cattle of Kerala. Period of calving significantly influenced ($P < 0.01$) all fertility traits and MY in the present study. Age group at first calving had significant effect only on MY ($P < 0.05$). Different centres significantly influenced AFC, SP and FLMY. In the present study DPR had low heritability (0.092 ± 0.029). Heritability of AFC, SP and MY were 0.172, 0.032 and 0.170 ± 0.094 respectively. Phenotypic (rp), genetic (rg), and residual correlation (re) estimates are detailed in Table 4. MY had negative genetic correlation with DPR (-0.119), AFC (-0.197) and SP (-0.08).

Standardisation of VWP

On the basis of waiting period (WP) observed (days), total cattle were first classified into four classes with an increment of 20

Table 1: Different levels of Waiting period with corresponding number of animals and DPR

Range of WP	No of Animals	DPR
43-62	341	0.30
63-83	220	0.30
84-104	329	0.35
105-236	115	0.41

WP, Waiting period; DPR, Daughters Pregnancy Rate

days. Even though higher pregnancy rate was obtained for the class 105-236, practically WP above 85 days cannot be advised for cattle. Therefore, WP group having maximum number of cattle (43-62) was further classified into three classes (Table 1). This was plotted against corresponding mean of MY/LL (litre/day). The WP group (55-62 days) were having maximum number of cattle, highest DPR and highest MY/LL. The crossbred cattle which were inseminated before 55 days after calving (VWP < 55 days) produced relatively lower amount of MY/LL, presented in Table 2 and depicted in Figure 1. Crossbred cattle inseminated during 55-62 days after calving (class-III) produced highest MY/LL and higher pregnancy rate which was 8.56 kg per day and 0.34, respectively. Therefore, VWP of crossbred cattle was standardized as minimum 55 days and were used for the estimation of daughter pregnancy rate in crossbred cattle of Kerala. The average daughters pregnancy rate (DPR) was estimated as 0.34 ± 0.01 with coefficient of variation 74.61%. DPR in the study ranged from 0.11 to 0.95.

Optimum model for prediction of DPR

For prediction of optimum DPR in crossbred cattle, seven regression models were developed using different combinations of AFC, SP, and MY/LL traits as independent traits, presented in Table 3. It was observed that Model II, having SP only as independent variable fulfilled four criteria's viz. highest R^2 , minimum mean sum of squares due to error (MSSe), lowest AIC value and BIC values. Model VII, incorporating three independent variables AFC, SP, and MY/LL had also comparatively high R^2 , low AIC value and BIC values, but MSSe values was higher. Therefore, Model II was considered as best model for prediction of DPR in crossbred cattle of Kerala. The model was made as follows:

$$DPR = 0.002(309 - SP)$$

Comparison of average and predicted value

The average daughters pregnancy rate (DPR) in the study was estimated as 0.34 ± 0.01 . Using the optimum model, predicted value was 0.36 ± 0.002 . The average error, variance was comparatively low for predicted value than estimated DPR.

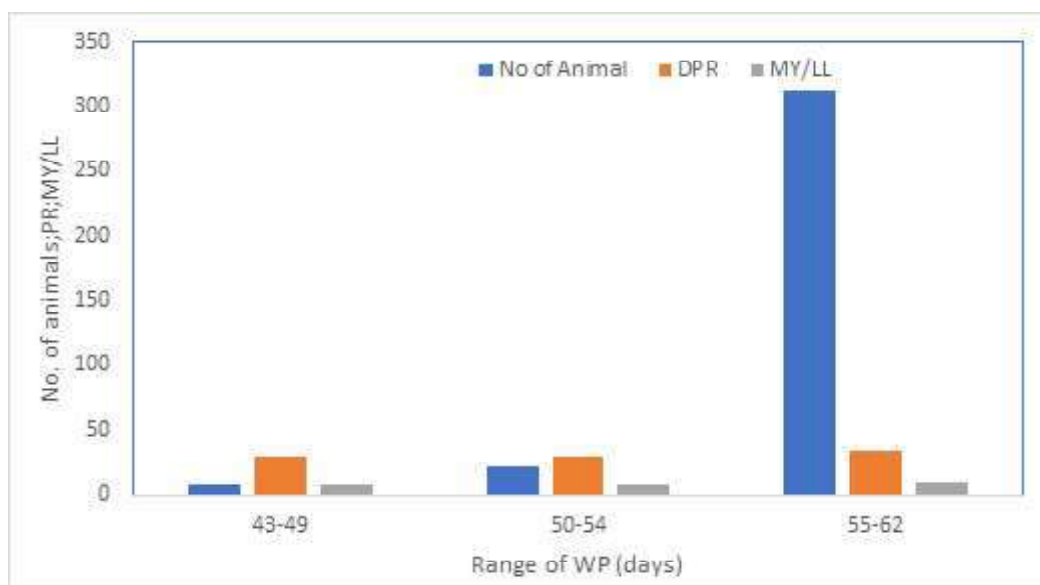
Fertility of dairy cattle influences genetic improvement as well as financial stability of herd. Fertility traits like Daughters Pregnancy

Table 2: Different levels of Waiting period with corresponding number of animals, DPR and milk yield

Range of WP	No of Animals	DPR	MY/LL
43-49	8	0.29	7.84
50-54	21	0.30	8.42
55-62	312	0.34	8.56

WP, Waiting period; DPR, Daughters Pregnancy Rate; MY/LL, milk yield per day of lactation

Fig 1. Different levels of Waiting period with corresponding number of animals, DPR and milk yield



rate is highly correlated with all other fertility traits *viz.* service period, non return rate, age at first calving and can improve overall performance of dairy animals (Jorjani, 2007). But selection criteria of elite cattle under field condition of the country are mainly carried out through conventional selection criteria like phenotypic information of animal related to production traits only. It results in declining of overall performance of crossbred cattle, as there exists negative association between production and fertility traits. However, for genetic evaluation of dairy animals, majority of the developed nations have incorporated important performance traits like fertility based on pregnancy rate (Van Raden et al. 2007; De Vries, 2010). In the present study, performance of crossbred cattle was assessed through major reproduction traits with greater economic impact like daughter pregnancy rate (DPR) and standardised VWP on the basis of performance of animals in terms of MY/LL to obtain a better DPR of crossbred cattle of Kerala.

The least-squares means of fertility traits *viz.* age at first calving (AFC) and service period (SP) and production traits *viz.* 305 days or less milk yield (MY) were in consonance with the estimates obtained by many other workers (Naicy and Anilkumar, 2009; Reshmi and Stephen, 2010; Kumar et al. 2011; Girimal et al. 2020). Fertility and production traits were significantly influenced by different non-genetic factors and the results indicated the importance of environmental and management effects on the traits and inclusion of major fixed effects *viz.* season, centre, year and herd in the genetic evaluation of traits. The heritability estimates of fertility traits in the present study were low which was comparable with Van Raden et al. (2007) in Holstein Friesian cattle. Reported heritability estimates of 0.17 for MY in the present study is in agreement with study of Rincon et al. (2015) who showed that heritability for MY were 0.16 and 0.15 for Holstein and Jersey cattle respectively. In consistent with observed negative genetic correlation between DPR and MY in the present study Van Raden

et al.(2007) also found that genetic association of pregnancy rate with MY in HF cows as “0.20. The antagonistic relationship between the production traits and fertility traits emphasizes the role of fertility traits as indirect variable in the selection criteria of dairy cattle.

For obtaining better pregnancy rate and to improve reproductive efficiency in dairy cattle, a waiting period after calving should be voluntary left by the management. In the present study, VWP of crossbred cattle of Kerala was standardized as 55 days. Fetrow et al. (2007) suggested that after pregnancy for complete uterine involution, resumption of normal ovarian cyclicity and to improve the rate of successful conception in dairy cattle a minimal VWP of 45 to 60 day post-partum is required. In the present study, maximum numbers of cattle were falling in WP group 55-62 days and total milk yield per day of lactation length (MY/LL) was also found to be higher (8.56 kg) for this group. Hence, minimum VWP of 55 days after calving was standardized as VWP in the studied crossbred cattle population. Present result is comparable with VanRaden et al. (2004) and Chang et al. (2007). They also standardized WP as 60 days for obtaining optimum pregnancy rate in Holstein cows. In contrast Norman et al. (2009) reported WP as 85 days in Holstein cows and 86 days in Jersey cows, respectively which is higher than present result. Scanty reports were available regarding the standardization of VWP in Indian cattle. Divya et al. (2014) standardized VWP as 51 days in Karan Fries cattle. Patil et al. (2014) and Sathwara et al. (2020) reported 63 days of VWP is most appropriate for Murrah and Mehsana buffaloes, respectively. To achieve one calf per year goal in the dairy herd, cows should conceive within a period of 85 days post-partum, for which cyclicity should commence as early as 45 days and should be bred by 60 days. In general, a minimal VWP of 50 to 60 days post-partum breeding interval could be recommended allowing for complete uterine involution in crossbred cattle of Kerala.

Daughters Pregnancy Rate of different cattle breeds ranged from 19.1% in Guernsey cattle to 26.4% in Jersey cattle, reported by Lima et al. 2020. Van Raden et al. 2007 reported average DPR in Holstein Friesian and Jersey as 19.1% and 22%, respectively. Average pregnancy rate of Karan Fries cattle, Indian Murrah and Mehsana buffaloes were reported as 33%, 36% and 31%, respectively (Dash, 2014; Valsalan et al. 2014 and Sathwara et al. 2020). A comparison of pregnancy rate with other fertility traits from 14 countries had been conducted by Interbull in 2007 indicated that pregnancy rate is highly correlated with other fertility traits. These correlations indicate that pregnancy rate can be expected to improve fertility in dairy animals (Jorjani, 2007).

Scanty reports were available about the literature reviewing the development of an optimum model for prediction of DPR in dairy cattle. Van Raden et al. 2004 developed a linear model using days open for prediction of DPR in Holstein Friesian cattle, pregnancy rate = 0.25 (233 - days open). Evaluations were expressed as predicted transmitting ability (PTA) for daughter pregnancy rate. He also reported that each increase of 1% in PTA pregnancy rate, resulted a decrease of 4 days PTA days open. Patil et al. 2014 reported the best prediction model for DPR in Indian Murrah buffaloes was $DPR = 0.0033(274-SP)$. Chebel and Veronese, 2020

developed linear between genomic merit DPR and conception rate as $GDPR = (0.7793 \times GCCR) - 0.3865$; and milk yield as $GDPR = (-0.001 \times GMY) + 2.589$. Gobikrusanth et al. 2020 reported that variability of sires PTA for DPR is strongly due to variation in cow conception rate.

Conclusions

In the present study, an optimum model for prediction of cow fertility based on DPR has been developed in crossbred cattle of Kerala. Voluntary Waiting Period of the cattle has been standardized as 55 days corresponding to pregnancy rate and per day milk yield. DPR had low h^2 (0.092) and exhibited negative correlation with milk yield (-0.119), Seven simple and multiple regression models were developed using all possible combinations of age at First Calving (AFC), service Period (SP) and milk yield per day of lactation (MY/LL) for the prediction of DPR. It was observed that model containing only SP as independent variable fulfilled four criteria's viz. highest R^2 , minimum mean sum of squares due to error (MSSe), lowest Aaike information criterion (AIC), Bayesian information criterion (BIC) values and the optimum model developed was $DPR = 0.002(309-SP)$. The average daughters pregnancy rate (DPR) in the study

Table 3: Estimates of phenotypic (rp), genetic (rg) and residual (re) correlation between the milk yield and fertility traits in crossbred cattle

Estimates	Milk Yield		
	Phenotypic correlation (rp)	Genetic correlation (rg)	Residual correlation (re)
Age at first calving	-0.009±0.032	-0.197±0.414	0.025±0.077
Service period	0.052±0.032	-0.08*	-0.025±0.068
Daughters pregnancy rate	0.040±0.003	-0.119±0.029	0.108±0.122

*Indicate failure in approximation of standard error (SE)

Table 4: Estimation of intercept, regression coefficient (s), criterion values for judging the optimum model for DPR

Model	Traits	Intercept	AFC	SP	MY/LL	Number of parameters	R ²	MSSe	AIC	BIC
I	AFC		0.008			2	0.6189	0.05	-	-
II	SP			0.002		2	0.6695	0.01	-9761.1	-
III	MY/LL	0.306			0.037	2	0.6170	0.068	-	-
IV	AFC,SP	0.634661	0.015	-		3	0.6548	0.057	-7565.2	-
V	AFC,MY/LL	0.6295	0.004	0.001	0.018	3	0.6280	0.063	-7395.2	-
VI	SP, MY/LL	0.602		-	0.069	3	0.6607	0.074	-7121.8	-
VII	AFC,SP, MY/LL	0.624	0.008	-	0.043	4	0.6956	0.071	-9288.1	-
				0.002						4439.05

AFC, Age at first calving; SP, Service period, MY/LL, milk yield per lactation length; R² coefficient of determination; MSSe Mean sum of square due to error; AIC Akaike information criterion, BIC Bayesian information criterion

was estimated as 0.34 ± 0.01 . Using the optimum model, predicted value was 0.36 ± 0.002 . The average error, variance was comparatively low for predicted value than estimated DPR. The study suggests that a waiting period of 55 days should be voluntarily left by the management for better pregnancy rate and fertility i.e. DPR would be included in the genetic evaluation of crossbred cattle of Kerala.

Conflict of interest

The authors declare that there is no actual or potential conflict of interest that could inappropriately influence in this work.

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