



Multi-trait animal model based estimation of direct and correlated responses in Frieswal cattle

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Received: 7 August 2019; Accepted: 15 November 2019

ABSTRACT

The study was undertaken to estimate the genetic parameters, direct and correlated responses for the test day and lactation milk yield in Frieswal cattle. Data on 9,955 daily milk yield records of 973 Frieswal cows calved during 2005 to 2014 at Ambala and Meerut dairy farms were utilized. The variance components, heritability estimates, genetic and phenotypic correlations for all the 11 traits were estimated simultaneously by fitting multi-trait animal model using the Wombat program of Meyer (2006) with contemporary groups as fixed effect, the additive genetic random effects, linear and quadratic regressions of covariate age at first calving and linear regression of covariate first lactation length. The expected genetic gain (DG), correlated response (CR) in cumulative 305-day yield and vice versa and the relative efficiency (RE %) of selection based on different test day yields were estimated. The results revealed lower additive genetic variance and heritability estimates for different test days and cumulative 305-day yield. The genetic correlations between the test days up to 225 and cumulative 305-days were higher which indicated the positive relationship between these traits. The higher correlated responses in cumulative 305-day yield estimated through the selection for TD135, TD165 and TD45, in that order indicated that early selection of sires using test day records would be efficient in genetic improvement for lactational milk yield in Frieswal breed of cattle.

Keywords: Animal model, Correlated responses, First lactation milk yield, Frieswal cattle, Indirect selection, Test day yields

The dairy cattle production system in India is unique with its own inherent constraints and opportunities to act as an important sector for socio-economic development of the rural farmers. Crossbreeding and other developmental programmes has contributed significantly for increasing the milk production. The “Frieswal Project” initiated in 1987 by the Indian Council of Agricultural Research in collaboration with the Military Dairy Farms, Ministry of Defence under AICRP on Cattle envisaged to evolve a national milch breed “Frieswal” having 5/8 Holstein Friesian and 3/8 Sahiwal blood, 4,000 kg of milk with 4% butter fat in a mature lactation of 300 days. The evaluation of Frieswal crossbred bulls for their milk production potential is done through large scale progeny testing in both farm and field conditions. In this process the breeding values of the bulls are estimated and subsequently the superior bulls are selected for breeding.

The use of test day milk yields (TDMY) as such for the genetic evaluation of breeding bulls is proposed and proved as an effective alternative approach to lactation models by many workers (Ptak and Schaeffer, 1993; Tailor and Singh, 2011; Kaygisiz, 2013). Ptak and Schaeffer (1993) and El Faro and Albuquerque (2003) explained the advantages of

using test day models in genetic evaluation of breeding bulls.

The genetic constitution of the population with respect to the economically important traits is reflected by the estimates of (co)variance components and the genetic parameters. Since the cumulative 305-day milk yield is considered as the primary trait for selection, genetic gain obtained over years in this trait would provide efficiency of selection programme implemented. Further, estimates of genetic parameters for test day milk records and their association with 305-day milk yield will also help to understand correlated responses obtained in different TDMY. In this view, present investigation was undertaken to estimate genetic parameters for monthly test day yields and their association with cumulative 305-day yields using multi-trait animal model. The study also aimed to estimate the expected genetic gain in cumulative 305-day milk yield and correlated responses in different test day yields.

MATERIALS AND METHODS

Data on first lactation daily milk yield records of Holstein crossbred cows calved during 2005 to 2014 at Meerut and Ambala Military Farms were collected. To ensure the normal distribution, the outliers were removed and data within the range of mean $\pm$ 2SD were only considered. Finally, a total

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of 9,955 daily milk yield records of 973 Frieswal cows sired by 42 bulls were utilized. The first test day milk yield was recorded at 15th day and subsequent records were taken at 30-days interval so as to get 10 test day records viz. TDMY15, TDMY45, TDMY75, TDMY105, TDMY135, TDMY165, TDMY195, TDMY225, TDMY255 and TDMY285. The cumulative first lactation 305-day or less yield was taken as the total milk produced during the first 6th day to 305 day of lactation.

The recorded data were classified according to the farm, sire, season and period of calving. The year of calving was divided into three seasons as winter (November to February), summer (March to June) and rainy (July to October). The herd, year and season of calving information were used to classify the contemporary groups as the animals calved in the same herd; year and season were defined as contemporaries. The contemporary groups for FL305DMY was defined as the combination of herd, year and season of calving while for TDMY it was considered as the herd, year and season of test day.

The variance components, heritability estimates, genetic and phenotypic correlations for all the 11 traits were estimated simultaneously by Restricted Maximum likelihood method (REML). The Wombat program of Meyer (2006) was used to fit the multi-trait animal model utilizing the 10 test day yields and one cumulative 305-day yield. The model consisted of contemporary groups as fixed effect, the additive genetic random effects, linear and quadratic regressions of covariate age at first calving and linear regression of covariate first lactation length.

The following animal model was considered for the estimation of genetic parameters:

$$Y_{ijk} = Xb_i + Zu_j + e_{ijk}$$

where, Y_{ijk} is the k^{th} observation of j^{th} random effect of i^{th} fixed effect, i.e. the vector consisting of the test day or cumulative 305-day yield; b_i is the vector of observation of fixed effects; u_j , vector of additive genetic random effect; X , design/ incidence matrix of fixed effect; Z , design/ incidence matrix of random effect and e_{ijk} , vector of residual random effects. The assumptions considered about the expectations and variances were as follows:

$$E \begin{bmatrix} y \\ a \\ e \end{bmatrix} = \begin{bmatrix} xb \\ 0 \\ 0 \end{bmatrix} \text{ and, } V \begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} G & O \\ O & R \end{bmatrix}$$

where, G , additive genetic (co)variance matrix between different traits and R , residual (co)variance matrix between different traits.

The estimates of heritability, phenotypic standard deviation and genetic correlations between the test day yields and cumulative 305-day yield were used to calculate the expected genetic gain (DG), correlated response (CR) in cumulative 305-day yield and vice versa and the relative efficiency (RE%) of selection based on different test day

yields. The intensity of selection was considered as unity for all the traits studied. The equations used to calculate the above measures are as follows:

1. Genetic gain (DG_j) = $h^2 i s_j$
2. Correlated response (CR) = $r_a h_j h_k i s_j$
3. Relative efficiency (RE%) = $(DG/CR) \times 100$

where, DG, genetic response or gain due to direct selection for j^{th} trait; h^2 , heritability of j^{th} trait; i , intensity of selection considered as unity or one; s_j , phenotypic standard deviation of j^{th} trait; r_a , genetic correlation between traits j and k ; h_j and h_k , square roots of the heritability estimates of traits j and k , respectively; and RE, relative efficiency of indirect selection for cumulative 305-day milk yield through different test day yields.

RESULTS AND DISCUSSION

Descriptive statistics of the data revealed an overall average first lactation 305-day milk yield of 2678.51 kg in Frieswal cows. The average mean values of different test days ranged from 6.85 in TD285 to 11.75 kg in TD45. The coefficient of variations ranged from 29.886 to 40.073%.

The estimates of additive genetic, error and phenotypic variances and heritability for different test days and cumulative 305-day yield are presented in Table 1. The additive genetic variances were comparatively lower than estimates reported by Santos *et al.* (2013) in Guzerat cows. However, estimates showed an increasing trend from TD15 (0.360) to TD135 (0.939) and thereafter decreased gradually to reach the lowest estimate of 0.160 for TD285 (Table 1). The phenotypic and residual variances showed almost similar trends as estimates were maximum at TD45 and reduced gradually during the later months of lactation. The variance estimates of first five test day yields were comparatively higher than the last five test day yields. The heritability estimates of test day yields were very low with a narrow range of 0.023 for TD225 to 0.090 for TD135 in Holstein crossbred cows. On the contrary, Cruz *et al.* (2006) reported medium heritability estimates ranging widely from 0.03 to 0.29 in fifth and eighth months of lactation, respectively in Guzerat cattle. Herrera *et al.* (2008) also

Table 1. Estimates of additive genetic (σ_a^2), residual (σ_e^2) and phenotypic variances (σ_p^2) and heritability estimates for different milk yields traits in Holstein crossbred cows

Trait	σ_a^2	σ_e^2	σ_p^2	h^2
TD15	0.360	10.433	10.793	0.033
TD45	0.559	12.568	13.127	0.043
TD75	0.540	11.874	12.414	0.043
TD105	0.592	10.794	11.386	0.052
TD135	0.939	9.476	10.415	0.090
TD165	0.442	8.727	9.169	0.048
TD195	0.417	7.744	8.161	0.051
TD225	0.183	7.693	7.876	0.023
TD255	0.227	7.278	7.505	0.030
TD285	0.160	5.372	5.531	0.029
FL305DMY	19292.000	496660.000	515952.000	0.037

reported heritability estimates for first lactation test day yields with a range of 0.14 (in 8th month) to 0.34 (in first month) in Gir cattle. Similarly, Singh *et al.* (2016) also reported the heritability ranges of 0.11 to 0.22 and 0.11 to 0.34 by Random regression model and least squares methods, respectively in Karan Fries cattle. The comparatively lowered heritability estimates obtained in the study reflected lowered additive genetic variance and comparatively higher phenotypic variance. One of the reasons for lowered additive genetic variance may be that the sires used in the crossbreeding programme had similar expected breeding values (EBVs). Higher phenotypic variances obtained in the study may be attributed to the variations in the managerial conditions and the exposure of crossbred cows to extreme climatic conditions.

The estimates of genetic and phenotypic correlations between different test day yields are presented in Table 2. The results revealed positive phenotypic correlations ranging from 0.262 (between TD15 and TD285) to 0.858 (between TD135 and TD165). The genetic correlations between different test day yields were comparatively higher than their respective phenotypic correlations however, the early test day yields from TD15 to TD135 had negative genetic correlation with TD255 and TD285. Similar to the present findings Singh *et al.* (2016) also reported negative genetic correlations of the first test day yield with 7th to 10th test day yields in Karan Fries cattle. The results also revealed that the genetic correlations between the adjacent test days were higher and the estimates decreased as the interval between the test days increased. Similar trend of comparatively higher genetic correlations between adjacent test day yields were reported by Pander *et al.* (1992), Rekaya *et al.* (1999), Lidauer *et al.* (2003), Melo *et al.* (2005), Geetha *et al.* (2006) and Bignardi *et al.* (2008) in different breeds of cattle. The results obtained in the present study suggested that the genetic and environmental factors controlling the different test day yields varied during different months of lactation. The low and negative genetic correlations of different test day yields with the TD255 and TD285 obtained in the present study might be attributed to the variations in the data set as the last two test days had lower number of observations (749 and 563, respectively). Hence, it need not necessarily be inferred that different test

day milk yields are controlled by entirely different genes and the genes responsible for higher milk production during the initial months of lactations are different from the genes regulating the daily yields during the final months of lactation. Contrary to the genetic correlation, all the phenotypic correlations between the test day yields were positive and ranged from 0.262 to 0.858. The estimates of phenotypic correlations showed a decreasing trend as the interval between the test day yields increased and the phenotypic correlations between any two adjacent test days were higher than the distant test days.

The genetic and phenotypic correlations between different test day yields and cumulative 305-day milk yield were in general high and positive. The first eight test day yields (TD15 to TD225) had high and positive genetic correlation with cumulative 305-day yield. TD165 had the highest genetic correlation of 0.929 while TD225 had the lowest genetic correlation of 0.662. However, the last two test day yields, viz. TD255 and TD285 had the negative and low genetic correlations of -0.058 and -0.241 with the cumulative 305-day yield. The high genetic correlations between the test days and 305-day yields obtained in the present study were in accordance with the results reported by Machado *et al.* (1999) in Holstein breed of cattle. The high and positive genetic correlations between the test days and cumulative 305-day yield revealed that these test days can give favourable indications on the genetic potential of Frieswal cows for cumulative 305-day milk yield and can be used as a selection criterion for improving the lactational milk yield. The phenotypic correlations between test days and 305-day milk yield were always positive and high with a range of 0.504 (TD285) to 0.883 (TD165).

The expected genetic gain in cumulative 305-day milk yield through direct selection and correlated responses through selection of different test day yields and their relative efficiencies and the correlated responses in test day yields due to the selection for cumulative 305-day milk yield are presented in Table 3. The results revealed an overall direct genetic gain of 26.577 kg, which was comparatively lower than the gain of 137.98 kg estimated by Santos *et al.* (2013) in Guzerat cattle. The genetic gain estimates for different test day yields ranged from 0.0645 for TD225 to 0.2905 kg for TD135. The results on the correlated

Table 2. Estimates of genetic (above diagonal) and phenotypic (below diagonal) correlations between different first lactation test day milk yields in Holstein crossbred cows

Test day	TD15	TD45	TD75	TD105	TD135	TD165	TD195	TD225	TD255	TD285
TD15		0.906	0.787	0.714	0.802	0.825	0.776	0.536	-0.095	-0.364
TD45	0.757		0.901	0.784	0.888	0.889	0.764	0.506	-0.128	-0.337
TD75	0.681	0.853		0.892	0.876	0.771	0.617	0.371	-0.228	-0.416
TD105	0.626	0.776	0.841		0.870	0.648	0.357	0.298	-0.361	-0.273
TD135	0.577	0.717	0.775	0.855		0.833	0.556	0.442	-0.366	-0.397
TD165	0.557	0.672	0.722	0.790	0.858		0.832	0.708	0.012	-0.196
TD195	0.481	0.595	0.639	0.701	0.765	0.845		0.606	0.076	-0.216
TD225	0.424	0.509	0.531	0.573	0.618	0.690	0.750		0.419	0.228
TD255	0.364	0.430	0.411	0.424	0.447	0.535	0.575	0.666		0.593
TD285	0.262	0.286	0.302	0.313	0.353	0.399	0.401	0.446	0.578	

Table 3. Expected genetic gain through direct selection and correlated responses through indirect selection in different milk yield traits in Holstein crossbred cows

Trait	DG (kg)	CR (kg)	RE %	CR in TDMY (kg)
TD15	0.1084	22.3886	84.24	0.1024
TD45	0.1558	27.3904	103.06	0.1382
TD75	0.1515	26.3303	99.07	0.1292
TD105	0.1755	26.2138	98.63	0.1231
TD135	0.2905	37.4710	140.99	0.1684
TD165	0.1453	28.1217	105.81	0.1185
TD195	0.1457	23.6516	88.99	0.0941
TD225	0.0645	13.8716	52.19	0.0542
TD255	0.0822	-1.3880	-5.22	-0.0053
TD285	0.0682	-5.6705	-21.34	-0.0186
FL305DMY	26.5770	-	100.00	26.5770

DG (kg), Genetic gain due to direct selection; CR, Correlated response in FL305DMY for selection done on TDMY; RE, Relative efficiency of improvement in FL305DMY for selection done on TDMY; CR in TDMY, Correlated response in TDMYs for selection done on FL305DMY.

responses in cumulative 305-day yield and different test day yields revealed the ranges of -1.388 to 37.471 kg and -0.0053 to 0.1684 kg for TD255 and TD135, respectively.

The early test day yields from TD15 to TD195 had comparatively higher direct genetic gain than the rest of the test days. The results revealed that the indirect selection of Frieswal cows based on TD135, TD165 and TD45 would yield genetic gains higher than the genetic gain of 26.577 kg obtained by direct selection for cumulative 305-day yield. The relative efficiency estimates of TD135, TD165 and TD45 were 140.99, 105.81 and 103.06%, respectively. Thus, it can be recommended that the above test days or precisely TD135 can be considered as a selection criterion for increasing the milk production in Frieswal animals as it had the maximum relative efficiency percentage. The higher relative efficiencies ranging from 84.24 to 140.99% obtained for the test day yields up to TD195 was in accordance with the results of Ledic *et al.* (2002) and Herrera *et al.* (2008) in Gyr cattle and Melo *et al.* (2005) and Santos *et al.* (2013) in Holstein breed of cattle.

The degree of correlated responses in TDMY ranged from -0.0186 for TD285 to 0.1684 kg for TD135. These results indicated that the selection criterion based on 305-day milk yield was not effective in improving the TDMY to the desired extent possible. Contrary to the present findings Santos *et al.* (2013) reported that selection based on 305-day milk yield would provide better genetic gain in TDMYs than the direct selection based on mid-lactation test day records in Guzarat cattle.

The results on direct and correlated responses in different test days and cumulative 305-day yield revealed that the test day records especially the test day records up to 195 days can be used as the selection criterion for genetic improvement of lactational milk yield in Frieswal cattle. Since the test day records are easily available before the

completion of lactation, their use in the selection programme would help to complete the selection process earlier. It will also provide scope for including the information from the animals with incomplete records and thereby increase the number of daughters per bull and the accuracy of prediction of expected breeding values (EBVs) of the sires, increase the intensity of selection, accuracy of selection. The selection based on test day milk yields would also reduce the generation interval, cost of milk recording and the genetic evaluation of dairy animals.

The present study revealed lower heritability estimates for different test days and cumulative 305-day yield. The lowered additive genetic variance obtained in the present study might be an indication of the absence of variation in the EBVs of sires used in the genetic improvement programme. The higher genetic correlations between the test days up to 225 and cumulative 305-days indicated the positive relationship between these traits and hence the test days can be used in the selection programme for increasing the lactational milk yield in Frieswal cows. The higher correlated responses in cumulative 305-day yield estimated through the selection for TD135, TD165 and TD45, in that order showed that the early selection of sires using test day records would be efficient in genetic improvement for lactational milk yield in Frieswal breed of cattle.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, ICAR-CIRC, Meerut for providing necessary facilities to carry out the present research. Authors are also thankful to the DDG, Military Farm and Director, Frieswal Project for providing permission to collect the data from Ambala and Meerut dairy farms.

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