Indian Journal of Animal Sciences **86** (5): 578–580, May 2016/Article
https://doi.org/10.56093/ijans.v86i5.58502

Investigation of direct and maternal genetic effects on days open in Jersey crossbred cattle

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Received: 26 August 2015; Accepted: 28 September 2015

ABSTRACT

Estimates of (co)variance and genetic parameters for days open (DO) of Jersey crossbred cattle were estimated by restricted maximum likelihood (REML), fitting 6 animal models, including various combinations of maternal effects. Data on 792 records of 223 Jersey crossbred animals, descended from 51 sires and 170 dams were used. The direct heritability estimates for days open ranged from 0.04 to 0.10 depending on the model applied. The additive maternal effects varied from 0.06 to 0.09 in different models in this study, whereas the estimates of the fraction of variance due to maternal permanent environmental effects were practically negligible to very low (0–4% of the phenotypic variance), irrespective of the models used. Results suggested that direct and maternal additive effects were important for this trait but, the low heritability estimates indicated little scope of genetic progress through selection for this trait.

Key words: Animal model, Cattle, Days open, Heritability, Maternal effects

Studies on reproductive traits showed that the effects attributed to dam (maternal effects) such as cytoplasmic inheritance (Henkes *et al.* 2004) in addition to direct additive genetic effects are important. Ignoring maternal effects results in biased upward estimates of genetic parameters and reduced realized selection efficiency. Moreover, accounting for maternal effects also increases accuracy of selection (Robison 1981). Hence, to maximize the genetic gain in any selection programme and implementing accurate genetic evaluation programme, accurate estimates of variances for direct and maternal effects and correlation between them is required. But, in India, knowledge of precise magnitude of (co)variance components for days open are scanty and most of the published estimates are derived from sire model that did not account for maternal effects. Therefore, the present study was conducted to estimate variance and (co)variance components due to additive direct and maternal genetic effects and maternal permanent environmental effects for days open in Jersey crossbred cattle.

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MATERIALS AND METHODS

The present study was carried out on Jersey crossbred cattle, maintained at the Eastern Regional Station of ICAR-National Dairy Research Institute, Kalyani, Nadia, West Bengal, India. Mandal *et al.* (2013) described the climatic conditions of this study area. There are animals having different levels of Jersey inheritance. Majority of the animals were either crosses of Jersey and Tharparkar or Jersey and Red Sindhi crosses.

Data: Data on days open of the 792 records of 223 Jersey crossbred cattle, descended from 51 sires having genetic composition either of ½ Jersey × ½ Tharparkar or ½ Jersey × ½ Red Sindhi, and 170 dam were obtained from animal breeding section and cattle yard from 1976 to 2011 were used for this analysis. Days open was calculated as interval between calving and conception. Cows without identified sire and dam were removed from the analysis. Characteristics of the data structure and phenotypic mean and standard deviation for this trait are summarized in Table 1.

Genetic analyses and statistical model: (co)variance components were estimated by restricted maximum likelihood (REML) using a derivative-free algorithm (DFREML, Meyer 2000) fitting an animal model. The analytical models included random effects and fixed effects of genetic group of animal and season which were found significant in least square analysis of variance (Harvey 1990). Six univariate animal models were fitted for this

Table 1. Characteristics of data structure for days open of Jersey crossbred cattle

Item	Days open
Number of records	792
Number of animals[a]	381
Number of sires with progeny records	51
Number of dams with progeny records	170
Number of grand-sires with progeny records	43
Number of grand-dams with progeny records	93
Mean (days)	106.29
SD (days)	48.73
CV(%)	45.92

[a] Animals in pedigrees.

trait to estimate (co)variance components and corresponding genetic parameters. Convergence of the REML solutions was assumed when the variance of function values (–2 Log L) in the simplex was less than 10^{-8}. To ensure that a global maximum was reached, analyses were restarted for several other rounds of iterations using results from the previous round as starting values. When estimates did not change, convergence was confirmed. Standard errors were calculated for the estimated parameters as the part of the DFREML programme (Meyer 2000). The following six models were used:

Model 1: $Y = X\beta + Z_1a + e$ (1)

Model 2: $Y = X\beta + Z_1a + Z_3c + e$ (2)

Model 3: $Y = X\beta + Z_1a + Z_2m + e$ with Cov (a,m) = 0 (3)

Model 4: $Y = X\beta + Z_1a + Z_2m + e$ with Cov (a, m) = $A\sigma_{am}$ (4)

Model 5: $Y = X\beta + Z_1a + Z_2m + Z_3c + e$ with Cov (a, m) = 0 (5)

Model 6: $Y = X\beta + Z_1a + Z_2m + Z_3c + e$ with Cov (a, m) $=A\sigma_{am}$ (6)

where, y is the vector of observations while β, a, m, c and e are the vectors of fixed effects, direct additive genetic effects (animal), maternal genetic effects, permanent environmental effects of dam and the residual, respectively. x, Z_1, Z_2 and Z_3 are incidence matrices of fixed effects, direct additive genetic effects, maternal additive genetic effects and permanent environmental effects of the dam. A is the numerator additive genetic relationship matrix between animals, I the identity matrix, $V(a)= A\sigma^2_a$, $V(m)= A\sigma^2_m$, $V(c)= I\sigma^2_c$, $V(e)= I\sigma^2_e$ and Cov(a, m)= $A\sigma_{am}$, where σ_{am} is the covariance between direct and maternal genetic effects, σ^2a, the direct additive genetic variance, σ^2_m, the maternal additive genetic variance, σ^2c, the variance of the permanent environmental effect of the dam, and σ^2e, the variance of the residuals. Estimated variance and covariance components were used to obtain direct heritability ($h^2 = \sigma^2_a/\sigma^2_p$), maternal heritability ($m^2 = \sigma^2_m/\sigma^2_p$), maternal permanent environmental variance as a proportion of phenotypic variance ($c^2 = \sigma^2_c/\sigma^2_p$), and direct-maternal genetic correlation ($r_{am} = \sigma_{am}/s^2_a \times \sigma^2_m$). Likelihood ratio tests (LRT) as described by Meyer (1992) were used to test whether random effects contributed significantly to the likelihood for the given data set.

RESULTS AND DISCUSSION

Phenotypic mean, standard deviation and coefficient of variation for days open are shown in Table 1. In this data, 45.2% of available dams became pregnant within a period of 87 days and 65.91% within a range of 117 days from last calving in order to attain ideal performance of one calving every 12–13 months. So, rest 34% cows remained open after that and do not achieve the desired result. Estimates of (co)variance components and genetic parameters for days open and likelihood values for each of the six different models are summarized in Table 2. Estimates of direct additive heritability for days open (Table 2) depended on the model used, ranging from 0.04 to 0.10. Ignoring maternal effects (Model 1) produced higher estimates of σ^2_a and h^2 than those obtained from other models. Fitting a permanent environmental maternal effect (Model 2) markedly decreased both σ^2_a and h^2 compared to model 1, indicating maternal effect accounting for 4% of total variance in this trait. Model 3, which included only direct and maternal additive effects, yielded an estimate of m^2 that also explained 6% of phenotypic variance, with a corresponding decrease in the estimate of direct heritability

Table 2. Estimates of (co)variance components (days^2) and genetic parameters for days open of Jersey crossbred cattle of India

Parameters	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
σ^2_a	226.81	146.07	95.68	108.98	95.33	108.37
σ^2_m	-	-	135.92	220.82	135.98	223.19
σ_{am}	-	-	-	–93.34	-	–94.94
σ^2_c	-	86.33	-	-	0.02	0.00
σ^2_e	2155.04	2143.89	2149.91	2138.15	2150.09	2138.07
σ^2_p	2381.85	2376.29	2381.51	2374.62	2381.42	2374.69
h^2	0.10(0.04)	0.06(0.05)	0.04(0.04)	0.05	0.04	0.05
m^2	-	-	0.06(0.04)	0.09	0.06	0.09
c^2	-	0.04(0.04)	-	-	0.00	0.00
r_{am}	-	-	-	–0.60	-	–0.61
Log L	–3446.53	–3446.07	–3445.38	–3444.99	–3445.38	–3444.99

σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ^2_c, maternal permanent environmental variance; σ^2_e, environmental variance; σ^2_p, phenotypic variance; h^2, heritability; m^2, maternal heritability; $c^2 = \sigma^2_c/\sigma^2_p$ and log L is the log likelihood values. Values in parentheses are standard errors of estimates.

to 4%. Fitting a non-zero covariance (r_{am}) along with a maternal genetic effects (Model 4) detected maternal effects contributing 9% of total variation and also resulted in large negative (–0.60) direct maternal covariance (r_{am}) estimates and there was no significant improvement in log likelihood values as compared to Model 3. Fitting both genetic and environmental components of the dam effect (Model 5) did not yielded any better fit as compared to model 1, 2, and 3. Allowing for a direct-maternal covariance in Model 6 also yielded large negative (–0.61) estimate of r_{am}. This high and negative correlation can be either due to existence of true genetic antagonism between the components or overestimation of the parameters arising from small datasets and of poor structure (Wasike *et al.* 2006). The direct heritability estimates of 0.04–0.10 for the days open under different models in this study were in agreement with the findings of Dematawewa and Berger (1998), Van Raden *et al.* (2004), Demeke *et al.* (2004), Pundir and Singh (2007) and Ghiasi *et al.* (2011) who observed the estimate of 0.04, 0.04, 0.04, 0.09 and 0.07 in different breeds of dairy cattle using animal model.

Although, the maternal genetic component has not been studied much globally for reproductive traits, the maternal heritability estimates for days open (0.06–0.09) in this study were consistent with the estimates of Jamrozik *et al.* (2005) who observed m^2 value ranging from 0.02 to 0.14 for different fertility traits in Canadian Holstein dairy cattle.

Permanent environmental effect due to dam can be attributed to the uterine environment, feeding level at late gestation and maternal behavior of the dam. Estimate of permanent environmental maternal effect (c^2) for days open (0.00–0.04) in the present study was in agreement with the findings of Kadarmideen *et al.* (2003) who reported estimate of 0.024 in dairy cattle. Similar results were also reported by Goyache *et al.* (2005) who estimated the c^2 value of 0.09 and 0.03 in young and adults of Austuriana de los valles beef cattle respectively.

The low estimate of heritability of days open is attributed to high phenotypic variance arising from large environmental variation and it could be improved through better reproduction management and a slow genetic progress for this trait is possible by selection. Heritability estimates were substantially higher when maternal effects were ignored and reduced when maternal effects were included in the model. The maternal genetic effect was important for this trait, but permanent environmental maternal effect had little or no influence on this trait. Therefore, both direct additive effects and maternal genetic effect need to be considered for improving this trait by selection.

ACKNOWLEDGEMENT

The authors would wish to acknowledge the contribution of the former In-charges and staffs of the cattle section of Eastern Regional Station of ICAR-NDRI for management and recording of animals over the years. The support extended by Director, ICAR-NDRI in providing facilities to carry out this study is also gratefully acknowledged.

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