



Genetic parameters for direct and maternal effects on birth weight of crossbred calves

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Birth weight of an animal and its early growth performance is not only determined by its own genetic potential but also by environmental and maternal (environment and genetic) effects. In most of the species, the higher birth weight is generally associated with greater physiological maturity, high growth rate, more energy reserves and better isolation, and thus with better chances of survival of the newborn (Lawrence and Fowler 2002). Numerous studies have also demonstrated that both direct and maternal influences are important for pre-weaning as well as post-weaning growth in cattle (Tilki *et al.* 2008, Assan 2012, Vostrý *et al.* 2015). Many of the published heritability estimates for growth traits in Indian cattle breeds were derived from sire models that did not take account of additive maternal effects. The present study was undertaken to estimate the genetic parameters of direct and maternal effects on birth weight of Jersey crossbred calves.

Data on birth weight of Jersey crossbred calves, maintained at the Eastern Regional Station of National Dairy Research Institute, Kalyani, Nadia, West Bengal, India, were collected for the present study. Records of 1613 calves descended from 63 sires and 473 dams over a period of 37 years (1979 through 2015) were used in the study. The location and climatic condition of the study area has been described by Mandal *et al.* (2013). In this study, majority of the crossbred animals were produced from the mating of two *Bos indicus* breeds, Tharparkar and Red Sindhi by out-crossing using imported semen of Jersey (J) breed. A total of ten genetic groups having different levels of Jersey inheritance produced in the breeding program were used in this study.

(Co) variance components were estimated by restricted maximum likelihood (REML) using a derivative-free algorithm fitting an animal model (DFREML, Meyer 2000). The analytical models included random effects and fixed effects of year of birth, season of birth, parity of dam, genetic

group of calves and sex of calves, which were found significant in least-squares analysis of variance (Harvey 1990). By ignoring or including maternal genetic or environmental effects, a total of six animal models were fitted for each trait. Model 1 was a simple animal model fitting animals' direct additive genetic effects only i.e. ignoring any maternal effects. Model 2 allowed for a maternal effect in addition but attributed it solely to the permanent environmental effect of the dam. Model 3 assumed that all maternal influence was of genetic origin. Model 4 allowed for a respective non-zero covariance. Model 5 and 6 were corresponded to model 3 and 4, respectively. But fitted both dams' genetic and permanent environmental effects i.e. three random factors altogether. 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. Depending on the model, the log-likelihood function was maximized with respect to the direct and maternal additive variances, the permanent environmental variance of the dam and the genetic covariance between direct and maternal genetic effects. Standard errors were calculated for the estimated parameters as a part of the DFREML program (Meyer 2000). Log-likelihood ratio tests were used to choose the most appropriate model for the trait (Meyer 1992). The total heritability for each trait was estimated (Willham 1972) as $h^2_t = h^2 + 0.5m^2 + 1.5mr_{am}h$, which predicts the expected response to phenotypic selection. The total maternal effect, $t_m = \frac{1}{4}h^2 + m^2 + c^2 + mr_{am}h$ was calculated to estimate repeatability of dam performance.

Number of observations, phenotypic means, standard deviations and coefficient of variation for birth weight of Jersey crossbred calves are shown in Table 1. In this data set, birth periods of calves were classified in 1 to 8 periods with 47, 233, 211, 251, 254, 253, 264 and 100 calves born in each period. Birth season discriminated between calves born in winter (n=485), summer (n=560) and rainy (n=568). Parity of the dam ranged from 1 to 10 with 461, 355, 255,

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Table 1. Characteristics of data structure for birth weight of Jersey crossbred calves

Items/traits	Birth weight
No. of records	1613
No. of animals†	1769
No. of sires with progeny record	63
No. of dams with progeny record	473
Progeny per sire	25.60
Progeny per dam	3.41
Mean (kg)	22.75
Standard deviation (kg)	4.49
CV (%)	19.74
Years of records	37

†Animals in pedigrees

189, 139, 91, 59, 29, 14 and 21 calves produced at parity 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 or above, respectively. Further, the genetic groups of calves having different levels of Jersey inheritance were classified as 1 to 10 groups having 101, 115, 372, 246, 234, 159, 110, 51, 122 and 103 calves in each group, respectively. In this study, 51% of the calves were males and 49% were females.

The least-squares mean for birth weight of Jersey crossbred calves in this study was 23.64±0.22 kg (Table 2) and this value was well comparable with the other studies in different cattle breeds (Dezfuli and Mashayekhi 2009, Singh *et al.* 2010, Abera *et al.* 2012). In this study, birth periods of calves significantly ($P<0.01$) affected the birth weight of calves but no definite pattern of birth weight of calves was observed over the years. However, birth season had non-significant ($P>0.05$) effect on birth weight of calves (Table 2). Parity of dam also showed significant effect on birth weight of calves in the present study. Calves having different genetic constitution showed significant ($P<0.01$) variations in their birth weights (Table 2). Different environmental factors (genetic group of calves, birth year, birth season, parity of dam and sex of calf) was found to have significant effect on birth weight of calves of various cattle breeds (Abera *et al.* 2012, Ali *et al.* 2015, Rahman *et al.* 2015, Yaylak *et al.* 2015).

Estimates of (co)variance components and genetic parameters for birth weight along with their likelihood values for each analysis under the six different models are summarized in Table 3. Estimates of direct additive heritability for birth weight depended on the model used, ranging from 0.20 to 0.47. Ignoring maternal effects (model 1) produced higher estimates of σ_a^2 and h^2 than those obtained from other models. Thus model 1, which ignored maternal effects, resulted in overestimation of the direct heritability for this trait. Fitting of a permanent environmental maternal effect (model 2) led to a reduction in additive direct heritability of 26% as compared to model 1 for birth weight and this effect accounted for 11% of phenotypic variance ($P<0.05$) for this trait. Model 3, which included only direct and maternal additive effects, yielded an estimate of m^2 that explained 17% of phenotypic variance

Table 2. Least-squares means along with standard errors of birth weight of Jersey crossbred calves

Effect	Birth weight (kg)
Overall mean	23.64±0.22
<i>Birth periods</i>	**
Pd-1	26.93 ^a ±0.70
Pd-2	22.93 ^{de} ±0.38
Pd-3	22.18 ^c ±0.37
Pd-4	22.99 ^{de} ±0.34
Pd-5	22.40 ^e ±0.33
Pd-6	23.51 ^d ±0.32
Pd-7	24.38 ^{bc} ±0.33
Pd-8	23.82 ^{cd} ±0.48
<i>Birth seasons</i>	NS
Winter (Nov.-Feb.)	23.73 ^a ±0.28
Summer (March-June)	23.87 ^a ±0.27
Rainy (July-Oct.)	23.32 ^a ±0.27
<i>Parity of dam</i>	**
P-1	21.93 ^c ±0.22
P-2	23.22 ^b ±0.25
P-3	23.41 ^{ab} ±0.29
P-4	23.90 ^{ab} ±0.33
P-5	23.26 ^{ab} ±0.39
P-6	23.76 ^{ab} ±0.47
P-7	23.97 ^{ab} ±0.57
P-8	24.13 ^{ab} ±0.81
P-9	25.42 ^a ±1.16
P-10 or more	23.40 ^{ab} ±0.96
<i>Genetic group of calves</i>	**
G-1 ($\frac{1}{2}$ J × $\frac{1}{2}$ RS)	23.96 ^{ab} ±0.46
G-2 ($\frac{1}{2}$ J × $\frac{1}{2}$ T)	23.62 ^{ab} ±0.45
G-3 (> 50% to 62.5% J)	23.96 ^{ab} ±0.31
G-4 ($\frac{1}{2}$ J × $\frac{1}{4}$ RS × $\frac{1}{4}$ T)	23.32 ^{bc} ±0.33
G-5 ($\frac{1}{2}$ J × $\frac{1}{4}$ RS × $\frac{1}{8}$ T × $\frac{1}{8}$ D)	23.89 ^{ab} ±0.36
G-6 ($\frac{1}{2}$ J × $\frac{3}{8}$ RS × $\frac{1}{8}$ T)	23.58 ^{ab} ±0.42
G-7 (Misc. 50% J)	24.66 ^a ±0.45
G-8 (< 50% J)	23.03 ^c ±0.64
G-9 (> 62.5 to 75% J)	24.09 ^{ab} ±0.45
G-10 (above 75%J)	22.30 ^{ab} ±0.50
<i>Sex of calves</i>	**
Male	24.19 ^a ±0.24
Female	23.09 ^b ±0.25

J, Jersey; T, Tharparkar; RS, Red Sindhi; D, Deshi/Non-descript. Means with different superscripts in each subclass within a column differ significantly ($P<0.05$) from each other. NS, nonsignificant. **indicate significance at 1% level ($P<0.01$).

for birth weight of calves with a corresponding reduction of the estimates of direct heritability to 42% and model 2 was superior in goodness of fit to model 1 and model 2 ($P<0.05$). Further, fitting a non-zero covariance (σ_{am}) along with a maternal genetic effect (Model 4) resulted in very similar log-likelihood values to that of Model 3 for this trait. In Model 5, which attempted to disentangle genetic and environmental components of the dam effects, the estimates of c^2 converged to 0.01 or very small, indicating practically no permanent environmental maternal variance for this trait, but it yielded an estimate of m^2 that explained 12% of phenotypic variance. Moreover, model 5 did not

Table 3. Estimates of (co) variance components (kg²) and genetic parameters for birth weight of Jersey crossbred calves

Trait	Model 1	Model 2	Model 3 [#]	Model 4	Model 5	Model 6
σ_a^2	9.133	6.767	3.843	3.797	3.906	3.857
σ_m^2	-	-	3.229	3.183	2.97	2.917
σ_{am}	-	-	-	0.065	-	0.08
σ_c^2	-	2.065	-	-	0.27	0.267
σ_e^2	10.182	10.059	11.558	11.585	11.459	11.488
σ_p^2	19.315	18.891	18.63	18.63	18.605	18.609
h^2	0.47 (0.07)	0.36 (0.09)	0.21 (0.08)	0.20 (0.09)	0.21 (0.08)	0.21 (0.09)
m^2	-	-	0.17 (0.04)	0.17 (0.06)	0.16 (0.05)	0.16 (0.07)
r_{am}	-	-	-	0.02	-	0.02
c^2	-	0.11 (0.04)	-	-	0.01 (0.03)	0.01 (0.04)
σ_t^2	0.47	0.36	0.29	0.29	0.29	0.29
t_m	0.12	0.2	0.22	0.22	0.22	0.23
logL	-3071.93	-3064.56	-3058.55	-3058.54	-3058.47	-3058.47

σ_a^2 , direct additive genetic variance; σ_m^2 , maternal additive genetic variance; σ_{am} , direct-maternal genetic covariance; σ_c^2 , maternal permanent environmental variance; σ_e^2 , residual variance; σ_p^2 , phenotypic variance; h^2 , direct heritability; m^2 , maternal heritability; r_{am} , direct-maternal genetic correlation; c^2 : σ_c^2/σ_p^2 ; h_t^2 , total heritability; t_m , repeatability of the dam performance. Values in the parenthesis are standard errors of the estimates. [#]Best model.

yield any significant improvement in likelihood compared to models 3 and 4. Allowing a direct-maternal genetic covariance (σ_{am}) in Model 6 yielded an estimate of r_{am} of 0.02 for birth weight, and further the inclusion of the covariance component did not improve goodness of fit when compared to model 5. Thus the model which included only direct and maternal additive effects (Model 3) was the best fitted model for birth weight of calves in the present dataset (Table 3).

The estimate of direct heritability of birth weight (0.21) of calves under the best model in the present study was in agreement with some of the published values reported in the literature (Singh *et al.* 2010, Nesar *et al.* 2012) for other cattle breeds. The moderate heritability estimates for birth weight in our study can perhaps be explained by a generally optimum nutritional level of dam creating a small environmental variation. Our estimate of maternal heritability (0.17) for birth weight of calves was similar to the findings of other workers (Abera *et al.* 2011, Estrada-León *et al.* 2014) in various cattle breeds. The total heritability for birth weight of calves was moderate (0.29) in magnitude under the best model, indicating ample scope for selection response for this trait. The total heritability for birth weight observed in this study was well comparable to the findings of other studies (Phocas and Laloe 2004, Singh *et al.* 2010, Nesar *et al.* 2012). The estimate of repeatability of dam effects for birth weight include both total maternal and ewe transmitted additive effects, ranged from 0.12 to 0.23 in different models and the estimate was 0.22 under the best model (Table 3). Our estimated value for maternal repeatability of birth weight in this study was similar to the reported/estimated values of the study of Ferreira *et al.* (1999) and Tilki *et al.* (2008) for this trait of other cattle breeds.

SUMMARY

Birth weight records of 1,613 Jersey crossbred calves,

maintained at the Eastern Regional Station of National Dairy Research Institute, Kalyani, Nadia, West Bengal, India, over a period of 37 years (1979 through 2015) were used to estimate the genetic parameters of direct and maternal effects on birth weight of calves. Analyses were carried out by restricted maximum likelihood (REML) fitting six animal models including various combinations of maternal effects. Log-likelihood ratio test was applied to select the best fitted model for the trait. The direct heritability estimates for birth weight was moderate (0.21) in nature under the best model, suggesting ample genetic progress possible for this trait under the prevalent management condition of the farm. Maternal genetic effect significantly contributed (17%) of the total variance for this trait. Hence, both direct and maternal effects must be taking into consideration while improving this trait genetically.

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