

*Original Research***Phenotypic and Genetic Parameters Estimation for Birth Weight in Zebu and Crossbred Calves Born Under Organized Farm Conditions in India****A. Sakthivel Selvan¹, M. S. Tania², A. Kumaresan^{3*}, Anshuman Kumar¹, D. Ravi Kumar¹, T. Karuthadurai¹ and Arpan Upadhyay¹**¹Dairy Cattle Breeding Division, ICAR-National Dairy Research Institute, Karnal – 132001 Haryana, INDIA²Principal Scientist, ICAR-National Bureau of Animal Genetic Resources, Karnal – 132001 Haryana, INDIA³Senior Scientist, Livestock Research Centre, ICAR- National Dairy Research Institute, Karnal – 132001 Haryana, INDIA***Corresponding author:** ogkumaresan@gmail.com

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Abstract

Data on birth weight of Zebu (Sahiwal and Tharparkar) and Crossbred (Holstein Friesian X Tharparkar) cattle spread over 16 years were utilized to assess the influence of genetic and environmental factors on calf birth weight, and to estimate variance components and genetic parameters. Non genetic factors taken into consideration were season of birth, period of birth, sex of the calf, dam's parity and gestation period. Least squares means for birth weights of Sahiwal (S), Tharparkar (TP) and crossbred (CB) cattle was 19.92 ± 0.18 , 20.91 ± 0.25 and 28.29 ± 0.29 kg respectively. All the non genetic factors, except period of birth (Sahiwal) and gestation period (Tharparkar), included in the study had a significant effect on birth weight of calves in all the three breeds. Heritability estimate for birth weight by paternal half-sib method on 1520 progeny from 48 sires was 0.149 ± 0.055 in Sahiwal, whereas on 2360 progeny from 101 sires was 0.323 ± 0.063 in crossbred. Variance components and genetic parameters due to direct additive genetic and maternal additive genetic effects were estimated by using two univariate animal models (Model 1 and 2) using AIREML algorithm of WOMBAT software. Model 1 produced highest estimate of additive genetic variance (3.65 Kg^2 , 3.90 Kg^2 and 15.38 Kg^2 for Sahiwal, Tharparkar and crossbred respectively) and direct heritability (0.57, 0.60 and 0.67 for Sahiwal, Tharparkar and crossbred respectively) in all the three breeds. When maternal influence was included in the Model 2, the direct heritability (h^2_d) estimate were 0.14, 0.55 and 0.34 and the maternal heritability (h^2_m) estimate for birth weight were 0.19, 0.16 and 0.13 in Sahiwal, Tharparkar and crossbred respectively. Model 2 was better in estimation of variance components of birth weight for all three breeds because of significant improvement in likelihood value.

Key words: Crossbred, Direct Heritability, Maternal Heritability, Paternal Half Sib, Zebu

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Introduction

Birth weight of calves is often considered in genetic improvement programs for many reasons like it is easily measured and correlated with a number of other performance traits. The weight of the newly born calf is of great importance to breeder, producer and livestock owner in judging its health as well as of its dam, and also gives a good indication of the subsequent development. It is not only the easiest and most reliable measurement of the prenatal period, but also a substantial factor that affects post natal growth and development (Akbulut *et al.*, 2001). The rate of death and calving difficulty increased in both very low and very high birth weight calves (Johanson and Berger, 2003). Calves having birth weight lower than the optimum are associated with lack of vigor, lowered thermo regulatory capability and resistance to pathological agents, and less ability to overcome parturition stresses during adaptation to extra uterine life (Holland and Odde, 1992). Numerous genetic and environmental factors such as age, gestation length, nutritional conditions, mothering ability and calving weight of dam, season, sire, calf gender, type of birth, geographical region and altitude may influence birth weight of calf (Mee, 2008; Aksakal and Bayram, 2009; Raja *et al.*, 2010; Manoj *et al.*, 2014).

A number of non-genetic factors affect birth weight and directly obscure recognition of genetic potential. Hence, correction for classifiable non-genetic sources of variation is essential for obtaining precise estimates of genetic parameters. Although information on the genetic and non genetic factors affecting the birth weight of calves under temperate agroclimatic conditions is available, the factors influencing calf birth weight in Zebu and crossbred cows reared under subtropical agroclimatic conditions has not been studied in detail. Thus the present study was conducted to examine the influence of genetic and non genetic factors on birth weight and to estimate variance and covariance components due to direct genetic effects and maternal genetic effects for birth weight in Zebu and crossbred calves using animal model methodology.

Materials and Methods

Data Collection and Management

The birth weight data of Zebu (Sahiwal and Tharparkar), Crossbred (Holstein Friesian X Tharparkar) calves (spread over 16 years; 1999-2014) born at Livestock Research Centre, National Dairy Research Institute, Karnal were utilized for the study. Data on 1520 Sahiwal, 328 Tharparkar and 2360 Crossbred calves sired by 48 Sahiwal and 101 Crossbred sires were obtained from history sheets, birth register

maintained at different sections of the farm and from the record unit of Dairy Cattle Breeding Division. Data on normal births and normal calves were only included in this study. The data related to calf (date of birth, sex and birth weight of calf) and its sire (sire number), dam (parity and gestation period) were utilized for analysis. At the farm, calves were weaned at the time of birth and kept under similar environment condition with a similar management practices.

Classification of Data

The data of calf birth weight was classified according to season of birth, period of birth, calf sex, dam's parity and gestation period and assigned separate codes for statistical analysis. Different seasons were classified as winter (December to March), summer (April to June), rainy (July to September) and autumn (October and November). Periods were classified as P-1 (1999-2002), P-2 (2003-2006), P-3 (2007-2010) and P-4 (2011-2014). The dam's parity were classified as 1st, 2nd, 3rd, 4th, 5th, 6th and >6th. Gestation period of Zebu and crossbred cows were classified as 270-280 days, 280-290 days, 290-300 days. Grouping of gestation period was carried out using the formula: Mean $\pm$ 1Standard deviation. Data were normalised using Mean $\pm$ 1Standard deviation.

Statistical Analysis

Effect of Genetic and Non Genetic Factors

Least squares analysis was used for analyzing data related to calf (season of birth, period of birth, sex and birth weight of calf) and its sire, dam (parity and gestation period) in order to study the effect of these factors on calf's birth weight (Harvey, 1990). Duncan test was used to determine the degree of significance between the means (Kramer, 1957). The following model was used for this purpose-

$$Y_{ijklmno} = \mu + S_i + SE_j + P_k + SX_l + DP_m + GP_n + e_{ijklmno}$$

Where,

Y_{ijklmn} = Observation of individual calves birth weight corresponding to i^{th} sire, j^{th} season of birth, k^{th} period of birth, l^{th} sex of calf, m^{th} dam's parity and n^{th} gestation period

μ = General mean

S_i = Effect of i^{th} sire

SE_j = Effect of j^{th} season of birth ($j = 1-4$)

P_k = Effect of k^{th} period of birth ($k = 1-4$)

SX_l = Effect of l^{th} sex ($l = 1$ and 2)

DP_m = Effect of m^{th} dam's parity ($m = 1-7$)

GP_n = Effect of n^{th} gestation period ($n=1-3$)

$e_{ijklmno}$ = experimental error associated with the $Y_{ijklmno}$ assumed to be randomly distributed

Estimation of Heritability

By Paternal Half-Sib Method

Heritability for birth weight was estimated by paternal half sib method in Sahiwal and crossbred cattle by Mixed Model Least square and Maximum Likelihood, PC-2 Version Computer Programme (Harvey, 1990). The sires having three or more progenies were considered for estimating genetic and phenotypic parameters of birth weight. The heritability estimate of birth weight for Tharparkar was not attempted due to less number of observations in each subclass.

By Animal Model

Variance components and heritability due to direct additive genetic and maternal additive genetic effects for birth weight in Zebu and crossbred calves were also estimated by two univariate animal models (Model 1 and 2) using average information restricted maximum likelihood (AIREML) algorithm of WOMBAT software (Meyer, 2007). These univariate animal models were simple animal model (Model 1) and animal model with additional random maternal effect (Model 2). The two univariate animal models used were given below-

$$\text{Model 1: } Y = X\beta + Z_a + e$$

$$\text{Model 2: } Y = X\beta + Z_a + Z_m + e \text{ Cov (a,m) = 0}$$

Where, Y was the vector of observations. The vector β contained season of birth, period of birth, sex of calf, dam's parity and dam's gestation period as fixed effects. The vectors of direct additive genetic effects, maternal additive genetic effects and the residual were a, m and e, respectively. X, Z_a and Z_m were the incidence matrices relating observations to β , a and m, respectively.

Log-likelihood ratios tests (LRT) was applied for significance of random effects and choosing the most appropriate model for birth weight. Suitability of the model was considered when a significant ($P < 0.05$) increase in the log likelihood occurred when adding additional random maternal effect.

Result and Discussion

Least square analysis of variance to study the effect of various factors and the mean birth weight of calves grouped into different factors viz., season of birth, period of birth, sex of calf, dam's parity and gestation period are shown in Table 1 and 2. All the factors included in the study viz. sire, season of birth or calving, period of birth or calving, parity order of cows, calf sex and dam's gestation period had significant effect on calf birth weight in Zebu and crossbred cattle except for period of birth and gestation period in Sahiwal and Tharparkar cattle respectively. The birth weight of calves increased with an increasing parity till 4th parity and thereafter the birth weight of the calves decreased with increasing parity. Higher birth weight of calves was observed when the gestation period was > 290 days compared to 280-290 or < 280 days ($p < 0.01$) in Sahiwal and crossbred cattle.

Table 1: Analysis of variance for birth weight in Zebu and crossbred calves

Breed		Sahiwal		Tharparkar			Crossbred		
Source of variation	d f	Mean sum of squares	F-value	d f	Mean sum of squares	F-value	d f	Mean sum of squares	F-value
Sire	47	12.152	2.102**	-	-	-	100	57.561	2.949**
Season of birth	3	36.409	6.299**	3	40.922	5.795**	3	405.858	20.792**
Period of birth	3	8.438	1.46	3	77.109	10.919**	3	57.884	2.965*
Sex of calf	1	508.869	88.031**	1	153.899	21.793**	1	736.884	37.750**
Dam's parity	6	63.978	11.068**	6	22.966	3.252*	6	528.959	27.098**
Gestation period	2	306.827	53.079**	2	13.566	1.921	2	1546.648	79.234**
Error	1457	5.78		312	7.061		2244	19.52	

** Significant ($p < 0.01$), * Significant ($p < 0.05$), cannot be estimated as less number of observations in each subclass

By paternal half-sib method, the heritability estimate for birth weight on 1520 progeny from 48 sires was 0.149 ± 0.055 in Sahiwal, whereas on 2360 progeny from 101 sires was 0.323 ± 0.063 in crossbred cattle. Male calves had higher birth weight compared to female calves ($p < 0.01$).

Table 2: Least square means of birth weight (kg) with their standard error and multiple comparison test results (a,b,c) grouped for various factors in Zebu and crossbred calves

Effect	No. of calves born	Sahiwal	No. of calves born	Tharparkar	No. of calves born	Crossbred
Overall	1520	19.92 ± 0.18	328	20.91 ± 0.25	2360	28.29 ± 0.29
Season of birth		S ($p < 0.01$)		S ($p < 0.01$)		S ($p < 0.01$)
S1 (Dec – Mar)	670	$20.35^b \pm 0.19$	120	$21.89^b \pm 0.32$	900	$29.20^b \pm 0.31$
S2 (Apr – June)	414	$19.90^a \pm 0.20$	96	$20.93^a \pm 0.33$	530	$28.91^b \pm 0.34$
S3 (July – Sep)	300	$19.65^a \pm 0.21$	66	$20.80^{ab} \pm 0.39$	571	$27.93^a \pm 0.33$
S4 (Oct – Nov)	136	$19.77^a \pm 0.26$	46	$20.02^a \pm 0.45$	359	$27.11^a \pm 0.36$
Period of birth		NS		S ($p < 0.01$)		S ($p < 0.05$)
P1 (1999 – 2002)	284	20.42 ± 0.38	33	$22.21^c \pm 0.52$	537	$27.23^b \pm 0.53$
P2 (2003 – 2006)	428	20.14 ± 0.29	48	$21.29^b \pm 0.43$	619	$28.41^a \pm 0.42$
P3 (2007 – 2010)	447	19.89 ± 0.26	120	$20.64^{ab} \pm 0.30$	686	$29.17^b \pm 0.43$
P4 (2011 – 2014)	538	19.24 ± 0.38	127	$19.48^a \pm 0.32$	518	$28.35^a \pm 0.57$
Sex of calf		S ($p < 0.01$)		S ($p < 0.01$)		S ($p < 0.01$)
Male	786	$20.52^a \pm 0.19$	159	$21.63^a \pm 0.31$	1177	$28.86^a \pm 0.30$
Female	734	$19.31^b \pm 0.19$	169	$20.18^b \pm 0.29$	1183	$27.71^b \pm 0.30$
Dam's parity		S ($p < 0.01$)		S ($p < 0.05$)		S ($p < 0.01$)
1	407	$19.02^a \pm 0.21$	102	$20.21^{ab} \pm 0.33$	719	$26.10^a \pm 0.31$
2	331	$19.93^b \pm 0.22$	75	$21.14^{ab} \pm 0.36$	572	$27.42^b \pm 0.32$
3	253	$20.03^b \pm 0.23$	50	$21.87^b \pm 0.43$	395	$28.84^c \pm 0.34$
4	179	$20.51^b \pm 0.25$	34	$21.81^b \pm 0.49$	239	$29.36^c \pm 0.39$
5	136	$20.48^b \pm 0.27$	22	$20.35^{ab} \pm 0.60$	171	$29.05^c \pm 0.43$
6	89	$19.74^b \pm 0.31$	13	$19.91^a \pm 0.75$	99	$28.58^c \pm 0.52$
Greater than 6	125	$19.73^b \pm 0.30$	32	$21.03^b \pm 0.51$	165	$28.67^c \pm 0.46$
Dam's gestation period (days)		S ($p < 0.01$)		NS		S ($p < 0.01$)
270 – 280 days	90	$18.49^a \pm 0.30$	29	20.33 ± 0.54	767	$26.27^a \pm 0.31$
280 – 290 days	993	$20.09^b \pm 0.17$	220	20.92 ± 0.24	1382	$28.57^b \pm 0.29$
290 – 300 days	437	$21.18^c \pm 0.19$	79	21.48 ± 0.35	211	$30.03^c \pm 0.41$

Means bearing different superscripts differ significantly ($p < 0.05$)

Among two univariate animal models, the model in which additive maternal effects was ignored (Model 1), produced highest estimate of additive genetic variance (3.65 Kg², 3.90 Kg² and 15.38 Kg² for Sahiwal, Tharparkar and crossbred, respectively) and direct heritability (0.57, 0.60 and 0.67 for Sahiwal, Tharparkar and crossbred respectively) in all the three breeds. When maternal influence was included in the Model 2, the direct heritability (h^2_d) estimate were 0.14, 0.55 and 0.34 and the maternal heritability (h^2_m) estimate for birth weight were 0.19, 0.16 and 0.13 in Sahiwal, Tharparkar and crossbred respectively (Table 3). In Tharparkar and crossbred, direct heritability was higher than maternal heritability, whereas in Sahiwal cattle, h^2_m was higher than h^2_d .

Table 3: Estimates of variance components (kg²) and genetic parameters for birth weight in Zebu and crossbred calves under different animal models

Breed	Model	σ^2_a	σ^2_m	σ^2_e	σ^2_p	h^2_d	h^2_m	-2 Log L	CV (%)
Sahiwal	1	3.65	-	2.74	6.4	0.57 (0.07)	-	-2118.81	13.78
	2	0.81	1.09	4	5.91	0.14 (0.05)	0.19 (0.03)	-2106.59	
Tharparkar	1	3.9	-	2.56	6.46	0.60 (0.12)	-	-447.03	13.27
	2	3.68	1.07	3.68	6.64	0.55 (0.14)	0.16 (0.07)	-443.325	
Crossbred	1	15.38	-	7.63	23	0.67 (0.06)	-	-4869.3	18.32
	2	7.55	2.81	11.32	21.69	0.34 (0.07)	0.13 (0.03)	-4864.22	

Figures in parentheses indicate standard error; σ^2_a : Direct additive genetic variance; σ^2_m : Maternal genetic variance; σ^2_e : Random residual variance; σ^2_p : Phenotypic variance; h^2_d : Direct heritability (σ^2_a / σ^2_p); h^2_m : Maternal heritability (σ^2_m / σ^2_p); 2 Log L: Log likelihood; CV, (%): Coefficient of variation

Birth weight is commonly used as an early selection criterion in cattle breeding (Kaygisiz *et al.*, 2012). Birth weight is the true indicator of future body weight of mature animals and a substantial, positive relationship exist between the birth weight and age at first calving (Bakir *et al.*, 2004; Heinrichs *et al.*, 2005). Thus obtaining calves with desired body weight assumes significance. In the present study we report the effect of genetic and non genetic factors on birth weight and estimated variance and covariance components for birth weight in Zebu and crossbred calves. The least square means for birth weight of calves in Sahiwal, Tharparkar and Crossbred cattle was found to be 19.92 ± 0.18 , 20.91 ± 0.25 and 28.29 ± 0.29 kgs, respectively. The findings of the study indicate that crossbred progenies were heavier at birth compared to Zebu cattle. Mean birth weight of Sahiwal, Tharparkar and crossbred calves observed in the present study are comparable with those reported earlier. The reported birth weight of calves in for Zebu cattle ranged from was 20 kg (Wakchaure and Meena, 2010; Dandapat *et al.*, 2010; Manoj *et al.*, 2014) to 30 kg (Paschal *et al.*, 1991), while the reported birth weight for crossbred cattle ranged around 26 kg (Hiremath *et al.*, 2007; Raja *et al.*, 2010; Dandapat *et al.*, 2010).

Fixed and Random Effects

Effect of sires on birth weight of calves was found to be highly significant ($P < 0.01$). Season of birth had highly significant effect ($P < 0.01$) on birth weight in zebu and crossbred cattle. Similar significant effect

of season of birth on birth weight was reported by Wakchaure and Meena (2010); Atashi *et al.* (2012) and Aksakal *et al.* (2012). On the contrary, non significant effect of season of birth on birth weight was reported by Manoj *et al.* (2014) which might be due to difference in period of birth and population size. For Zebu and crossbred cattle, calves born during S1 (winter) season had highest birth weight, whereas lowest birth weight was observed in calves born in rainy (Sahiwal) and autumn (Tharparkar and crossbred) season, respectively. Similar findings was reported by Topal *et al.* (2010) in Swedish red cattle, who found that calves born in autumn season were found to have a lower birth weight than those born in other seasons and Colburn *et al.* (1997) found that calves born in colder climates were heavier than calves born in warmer climates. The effect of calving season on birth weight is related to environmental factors such as nutrient availability and subject to significant variation due to geography and management regimes.

Period of birth significantly affected birth weight of calves in Tharparkar and crossbred but not in Sahiwal cattle. Our findings are in contradictory with those reported by Manoj *et al.* (2014) and Wakchaure and Meena, 2010, where significant effect of period of birth on birth weight was reported in Sahiwal cattle. Although, foetus is under protection of dam in prenatal period, environmental factors that affect the dam also affect calf's birth weight either in a positive or negative way. Therefore difference in calf birth weight from period to period may be due to changes occurring in the climate and feeding conditions of dam from period to period. For Tharparkar and crossbred cattle, calves born during P4 had lowest [19.48 ± 0.32 (TP); 28.35 ± 0.57 (CB)] birth weight, whereas calves born during P1 [22.21 ± 0.52 (Tharparkar)] and P3 [29.17 ± 0.43 (crossbred)] had highest birth weight.

Sex of calf was found to have highly significant ($P < 0.01$) influence on the birth weight of zebu and crossbred cattle. Birth weight of male calves was about 1.21 kg (5.89%), 1.45 kg (6.71%) and 1.15 kg (3.98%) higher than the birth weight of female calves in Sahiwal Tharparkar and crossbred cattle, respectively. This result is supported by the results obtained by Dhakal *et al.* (2013); Yaylak *et al.* (2015) and Nelson *et al.* (2016). It might be due to the longer gestation periods of male calves and higher androgen hormone intensity of fetus serum (Uzmay *et al.*, 2010; Manzi *et al.*, 2012).

Dam's parity also had significant influence on the birth weight of zebu and crossbred cattle. Lowest birth weight has been observed in the first parturition which may be due to the fact that dam cannot complete its growth and development completely. In all the three breeds, the birth weight of calves increased till 4th parity and thereafter the birth weight of the calves decreased with increasing parity. This may be due to the heavier weight of the dam, expansion of intra uterine space and higher inflow of nutrition to the foetus at late parities. Similar trend were noticed by Raja *et al.* (2010); Atashi *et al.* (2012) and Dhakal *et al.* (2013). On the contrary, Nelson *et al.* (2016) found that as the number of parity increased, birth weight

decreased significantly. However, Freitas *et al.* (1988) reported that parity of dam had no significant effect on birth weight of calves.

Effect of gestation length on birth weight was statistically highly significant ($P < 0.01$) in Sahiwal and crossbred cattle but not in Tharparkar. Maximum birth weight was observed when the gestation period was 290-300 days and less when the gestation period was 270- 280 days. It seems logical that there should be a correlation between gestation period and birth weight, since the fetus is increasing in age and should therefore be growing. This result is similar to the findings of Raja *et al.* (2010). Therefore, it can be concluded that cows which tend to carry calves longer than the mean gestation period, tend to have heavier calves than those that carry their calves lesser than mean gestation period. Moreover calf birth weight and dam's gestation length were found to influence calving ease in cattle (Jamrozik and Miller, 2014). Dam's with shorter gestation length produces lower birth weight calves thus having less difficult calvings. So, indirect selection for calving ease using highly heritable gestation length and (or) birth weight could be considered. Response to this type of selection may be limited due to opposing natural tendencies of gestation time and a minimum birth weight under which calf survival could become an overriding factor (Kemp *et al.*, 1988).

Variance Components and Heritability Estimates

Birth weight of calves and its early growth rate are determined not only by its own genetic potential but also by the maternal environment. Dam's genotype affects the calf growth through a sample of half of her direct additive genes as well as through her genotype for maternal effects on calf weight. Therefore the phenotype of an animal's birth weight is the result of the genetic potential and the influence of environment as well as maternal effects (Mandal *et al.*, 2008; Tilki *et al.*, 2008). Any environmental influence that the dam contributes to the phenotype of her offspring is called maternal effect. Heritability estimates are essential population parameter required in animal breeding research. Generally, sire models had lower estimates of direct heritability than full animal models for birth weight (Ferreira *et al.* 1999). Heritability of birth weight was estimated by paternal half-sib method without consideration of maternal effects. By this method, the heritability estimate for birth weight was 0.149 ± 0.055 in Sahiwal, whereas was 0.323 ± 0.063 in crossbred cattle. Similar findings of low (Bakir *et al.*, 2004) and medium (Unalan, 2009; Raja *et al.* 2010) heritability for birth weight were also reported in Zebu and crossbred cattle. Medium heritability of birth weight in crossbred cattle showed that this trait is not much influenced by environment, thereby indicating sufficient possibility for improvement through selection. On contrary, Rabeya *et al.* (2009) reported higher estimates of heritability for birth weight in Red Chittagong cattle. Among two univariate animal models, the model1 in which additive maternal effects was ignored produced highest estimate of additive genetic variance and direct heritability in all the three breeds. When

maternal influence was included in the Model 2, the direct heritability (h^2_d) estimate were 0.14, 0.55 and 0.34 and the maternal heritability (h^2_m) estimate for birth weight were 0.19, 0.16 and 0.13 in Sahiwal, Tharparkar and crossbred respectively (Table 3). The direct heritability estimate was reduced in the Model 2 as compared to Model 1, indicating that animal models which ignored maternal effects tend to overestimate direct heritability. It may be due to improper partitioning of variance in the absence of maternal effect. Similar trend was noticed by Tilki *et al.* (2008) in Brown Swiss calves. In our study, maternal heritability for birth weight ranged between 0.13 and 0.19 for 3 different cattle breeds (Table 3). Similar moderate direct and maternal heritability estimates for birth weight was also reported by several researchers (Akbulut *et al.*, 2001; Stamer *et al.*, 2004; Atil *et al.*, 2005 and Tilki *et al.*, 2008). A lower estimate of maternal heritability was also reported by Singh *et al.* (2010) and Kaygisiz *et al.* (2011) in crossbred and Brown Swiss cattle respectively.

Fitting a maternal genetic effect (Model 2) markedly increased the log likelihood value over that for model 1 (Table 3), indicating a significant maternal effect accounting for 13-19% of the total variance for birth weight of calves in the studied three breeds of cattle.

Conclusion

All the genetic and non genetic factors, except period of birth (Sahiwal) and gestation period (Tharparkar), included in the study had a significant effect on birth weight of calves in all the three breeds. Thus it is concluded that correction for above studied environmental effects will help in formulation of management and selection decisions. Medium estimate of heritability for birth weight of cattle in this study indicates that the genetic improvement for this trait is possible by selection. Furthermore, the medium maternal heritability estimates suggest that maternal genetic effect is important and needs to be considered along with direct additive effect for achieving optimum genetic progress for birth weight by selection.

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