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Estimates of genetic and phenotypic parameters of production performance traits in crossbreed cattle: A review

Kapil Dev and Ravinder Dahiya

Abstract
The success of dairy industry largely depends on the level of production and reproduction performance of the animals and in dairy cattle, milk yield is considered as the most important trait. Crossbreeding programmes has significantly enhanced milk production in India. For maintaining high level of milk production productivity of crossbreed cattle and their further improvement, it is necessary to execute proper programme of genetic evaluation of males and females for selection of animals of high genetic merit. Therefore, including production efficiency traits along with production traits in sire evaluation would enable genetic improvement in production potential along with improvement in fertility traits. The non-genetic factors (e.g. environmental) have an important bearing on these traits and directly obscure recognition of genetic potential. Moreover, the performance records of an animal should be corrected for classifiable non-genetic sources of variation, which is essential for obtaining precise estimates of genetic parameters. The literature pertinent to genetic and phenotypic parameters of various production performance traits up to fifth lactation viz. lactation milk yield (LMY), lactation milk yield-305 (LMY-305), lactation length (LL), peak yield (PY), average daily milk yield (AMY), milk yield per day of calving interval (MCI), milk yield per day of age at second calving (MSC), persistency, age at first calving(AFC), service period (SP), calving interval (CI) and dry period (DP) were reviewed in crossbred cattle. In order to improve performance of dairy animals, it is necessary to develop an understanding of the factors affecting various production performance traits.

Keywords: Crossbred cattle, Heritability, Non-genetic factors

1. Introduction
India occupies pre-eminent position in milk production with an annual output of 165.40 million tonnes accounting for 18.5 per cent of world production. Out of which, share of milk production by exotic/crossbred cows was 25% and that of indigenous/non-descript was 20% (BAHS, 2017). Out of the 190.90 million cattle population, crossbred population was 19.42 million while that of indigenous was 48.12 million (19th Livestock census, DAHD-GOI). Crossing Zebu cattle (Bos indicus) with temperate breed (Bos taurus), undertaken for improving the milk production to cater the needs of ever increasing human population has led to the synthesis of several new crossbred strains of cattle. For maintaining high level of milk production productivity of crossbreed cattle and their further improvement, it is necessary to execute proper programme of genetic evaluation of males and females for selection of animals of high genetic merit. The investigations conducted on genetic improvement of cattle around the world indicate that proper genetic evaluation and selection of bulls brings about nearly 66-75 percent of the realized genetic improvement. Therefore, an accurate evaluation of the bull at minimum possible cost becomes of paramount importance for bringing about rapid genetic progress in dairy cattle. The accuracy of estimating the breeding value of an animal is the major factor that affects the genetic progress due to selection. The success of a breeding programme depends on how early and how accurately young bulls can be proved. If the time required for ranking the sires on the basis of their breeding values can be shortened, it will reduce the generation interval and enhance the selection intensity. In India, the sire evaluation is done mainly on the basis of 305-day or less first lactation milk yield at organized farms. This leads to increased generation interval, decreased genetic gain per unit of time and fewer numbers of daughters per sire due to smaller herd size. Varying reports in vast amount about the genetic and phenotypic parameters of production performance traits in crossbred cattle are available in literature, out of which recent studies has been reviewed.

1.1. Least-squares mean and factors affecting production performance traits

The available literature pertinent to first and overall lactations for various production performance traits viz. lactation milk yield (LMY), lactation milk yield-305 (LMY-305), lactation length (LL), peak yield (PY), average daily milk yield (AMY), milk yield per day of calving interval (MCI), milk yield per day of age at second calving (MSC), persistency, age at first calving(AFC), service period (SP), calving interval (CI) and dry period (DP) has been presented in Table 1. The contents of Table 1 indicated that least-squares mean value of production performance traits viz. LMY, LMY-305, LL, PY, AMY, MCI, MSC, Persistency, AFC, SP, CI and DP ranged from 819.98 ± 16.50 to 3919.66±42.99 kg; 1633 ± 47.00 to 5807.83±78.27 kg; 195.23 ± 2.63 to 343.58±10.37 days; 3.14±0.18 to 13.3 kg; 2.19±0.08 to 12.93±0.99 kg/day; 5.10±0.129 to 15.44 kg/day; 0.60±0.03 to 4.91 kg/day; 61.55 ± 2.06 to 187.207 ± 26.40 days; 891.60±13.5 to 1371.06±15.49 days, 115.46 ± 2.14 to 272±17.1 days, 403.91 ± 2.54 to 529.48±8.51 days and 84.20±8.50 to 318±21.4 days, respectively. The large variations in production performance traits indicated that there is a vast scope of improvement in these traits. The relevant literature pertinent to the effect of period of calving, season of calving and parity on various production performance traits had been summarized in Table 1 indicated that these traits by and large affected by these factors. Therefore, data must be standardised for various significant effect.

1.2 Effect of period, season and parity of calving: The effect of period of calving on production performance traits had been reviewed and presented below:

2. Estimates of heritability for production performance traits: The available literature pertaining to estimates of heritability of various production performance traits have been presented in Table 1 which indicated that the heritability estimates for LMY, LMY-305, LL, PY, AMY, MCI, MSC, persistency, AFC, SP, CI and DP ranged from 0.12 to 0.48; 0.12 to 0.51; 0.04 to 0.28; 0.02 to 0.28; 0.27 to 0.54; 0.17 to 0.63; 0.25 to 0.41; 0.08 to 0.28, 0.02 to 0.40, 0.07 to 0.35 and 0.26 to 0.42, respectively. From the reports of various workers, it may be concluded that most of traits under study had low to moderate estimates of heritability hence progeny testing coupled with better managemental practices could be a tool for bringing out desirable changes in these traits.

3. Estimates of genetic and phenotypic correlations among production performance traits: The genetic and phenotypic correlations reported among various production performance traits in cattle are reviewed and presented in Table 2.

Table 1: Estimates of least-squares means, effect of non-genetic factors and heritability on various production and reproduction performance traits in crossbreed cattle

Traits	Breed (No. of lactations)	Means ± S.E	Non Genetic factors			h^2±S.E	References
			Period	Season	Parity		
Lactation milk yield (Kg)	H.F cross (1)	832.80±40.34	NS	NS	-	0.40±0.38	Kharat *et al.* (2008) [28]
	Frieswal (1)	2871.11+32.64	S	NS	-	0.35+0.11	Kumar *et al.* (2008) [54]
	Sahiwal cross (1)	3064.74±49.40	S	NS	-	0.12±0.06	Singh *et al.* (2008)
	Friesian×Sahiwal (12)	2864.32	S	S	S	0.20 ± 0.08	Lakshmi *et al.* (2009) [34]
	Girhalf	2971.94±101.84	S	S	S	-	Jadhav *et al.* (2010) [24]
	Karan Fries (1)	2822.91±121.94	S	S	-	0.26+0.06	Saha *et al.* (2010) [45]
	Karan Fries (1)	3762 ± 67	NS	S	-	0.48 ± 0.14	Nehra *et al.* (2011) [38]
	H.F×Deoni (5)	1661.35±15.17	S	S	S	-	Wondifraw *et al.* (2013) [59]
	H.F crossbreed (5)	2331.18±52.16	NS	NS	S	0.17±0.19	Kumar *et al.* (2014) [53]
	H.F	3919.66±42.99	S	NS	S	0.35	Al-Samarai *et al.* (2015) [47]
	H.F×Jersey×Sahiwa (1)	-	S	S	S	-	Japheth *et al.* (2015) [25]
	Hardhenu (1)	2262.98±57.52	S	S	-	0.32 ±0.17	Verma *et al.* (2016) [58]
	Deoni (5)	819.98 ± 16.50	S	S	S	-	Basak *et al.* (2018) [2]
Lactation milk yield-305 (kg)	Karan-Fries (1)	3068±23	S	S		0.39 ± 0.09	Kokate (2009)
	Friesian×Sahiwal (12)	2593.84	S	-	S	0.18 ± 0.07	Lakshmi *et al.* (2009) [34]
	Sahiwal (1)	2700.52±144.84	-	-	-	0.12	Dandapat *et al.* (2010) [10]
	Karan Fries (1)	2470.35±80.75	S	-	-	0.30±0.02	Saha *et al.* (2010) [45]
	Karan-Fries (1)	3234±64	NS	NS	-	0.21±0.14	Divya (2012) [45]
	Friesian (7)	3408.17±48.54	S	S	S	-	Katok and Yanar (2012) [27]
	Tunisian Holstein (5)	5807.83±78.27	S	S	S	-	M'hamdi *et al.* (2012)
	H.F Cross	1633 ± 47	-	-	-	-	Hassan and Khan (2013)
	H.F×Deoni (5)	1707.25±13.25	S	NS	S	-	Wondifraw *et al.* (2013) [59]
	H.F×Jersey×Sahiwal	4113.61±55.90	S	S	S	-	Japheth *et al.* (2015) [25]
	Hardhenu (1)	2331.18±52.16	NS	NS	-	0.17±0.19	Kumar (2015) [33]
	Karan Fries (4)	3027.11±203.1	S	S	S	0.39±0.09	Dash *et al.* (2016) [14]
	Hardhenu (1)	1782.97±68.37	S	NS	S	-	Verma *et al.* (2016) [58]
	Frieswal (7)	2997.01 ± 123.24	NS	S	S	0.51 ± 0.14	Kakati *et. al.* (2017)
Lactation length (days)	Zebu x Friesian (6)	292.64 0± 8.28	NS	NS	S	-	Ahmed *et al.* (2007)
	Frieswal (1)	313.34±2.21	S	NS	-	0.04±0.06	Kumar *et al.* (2008) [28]
	Friesian×Sahiwal (12)	329.03	S	NS	S	0.06±0.05	Lakshmi *et al.* (2009) [34]
	Karan-Fries (1)	315.25±10.10	NS	NS	-	0.21+0.05	Saha *et al.* (2010) [45]
	Girhalf	333.59±6.34	NS	NS	NS	-	Jadhav *et al.* (2010) [24]
	Tunisian Holstein (5)	309.6±7.01	S	S	S	-	M'hamdi *et al.* (2012)
	H.F×Deoni (5)	296.80±2.29	S	NS	-	-	Wondifraw *et al.* (2013) [59]
	Deoni (1)	213.9±13.74	NS	NS	-	-	Bhutkar *et al.* (2014)

	H.F crossbreed (5)	275.11±65.23	NS	NS	S	0.28±0.19	Kumar *et al.* (2014) [53]
	H.F	-	S	NS	NS	0.06	Al-Samarai *et al.* (2015) [47]
	Karan-Fries (5)	298.28±5.48	S		S		Japheth *et al.* (2015) [25]
	Sahiwal (6)	215.83±3.08	S	NS	NS	0.22±0.07	Narwaria *et al.* (2015)
	Gir (1)	343.58±10.37	NS	NS	-	0.17± 0.24	Sawant *et al.* (2016)
	Karan-Fries (4)	326.57 ± 2.60	S	S	S	0.11±0.05	Dash *et al.* (2016) [14]
	Murrah (4)	344.0±102.0	-	-	NS	-	Poudal *et al.* (2017)
	Frieswal (7)	303.31 ± 7.02	S	NS	NS	0.17 ± 0.10	Kakati *et. al.* (2017)
	Deoni (5)	195.23 ± 2.63	S	NS	S	-	Basak *et al* (2018) [2]
Peak yield (kg)	Friesian×Sahiwal (12)	13.3	S	NS	S	0.16±0.07	Lakshmi *et al.* (2009) [34]
	Vrindavani (6)	9.5±0.1			S	0.02±0.09	Singh *et al.* (2011)
	Deoni (1)	3.14±0.18	S	NS	-	-	Bhutkar *et al.* (2014)
	H.F crossbreed (5)	6.88±0.38	NS	S	S	-	Kumar *et al.* (2014) [53]
	Frieswal (1)	10.86±0.16	NS	S	-	0.26±0.22	Kumar (2015) [33]
	Hardhenu (1)	10.30±0.21	S	S	-	0.28±0.17	Verma *et al.* (2016) [58]
Average daily milk yield (kg/day)	Friesian×Sahiwal (12)	8.69±0.27	S	S	S	0.27	Lakshmi *et al.* (2009) [34]
	Sindhi×Jersey (4)	6.78±0.17	NS	NS	S	0.44± 0.17	Verma and Thakur (2013) [57]
	H.F×Deoni (5)	5.65±0.04	S	S	S	-	Wondifraw *et al.* (2013) [59]
	Karan-Fries (1)	10.8±0.2	S	S	-	-	Divya *et al.* (2014)
	Sahiwal (1)	5.34±0.08	S	S	-	0.42±0.08	Dhawan *et al.* (2015)
	Karan Fries (5)	12.93±0.99	S	S	S	-	Japheth *et al.* (2015) [25]
	Karan-Fries (4)	2.19 ± 0.08	S	S	S	0.35±0.08	Dash *et al.* (2016) [14]
	Jersey (7)	6.97±0.21	S	S	S	0.54	Ratwan *et al.* (2017)
Milk yield per day of calving interval (kg/day)	Jersey ×Red Dane	5.10±0.129	S	S	-	-	Das *et al.* (2002)
	Karan-Swiss (1)	8.9±0.2	S	S	-	-	Singh and Gurnani (2004)
	Holstein (4)	15.44	S	NS	S	0.41	Tekerli and Gundogan (2005)
	Friesian×Sahiwal (12)	6.40±0.24	S	S	S	0.17	Lakshmi *et al.* (2009) [34]
	Sindi×Jersey (4)	5.61±0.16	NS	NS	S	-	Verma and Thakur (2013) [57]
	Karan-Fries (1)	9.0±0.2	NS	NS	-	-	Divya *et al* (2014)
	Karan-Fries (5)	11.08±0.13	S	S	S	-	Japheth *et al.* (2015) [25]
	Karan fries (4)	10.28 ± 0.08	S	S	S	0.42±0.10	Dash *et al.* (2016) [14]
	Jersey (7)	6.02±0.23	S	NS	S	0.63	Ratwan *et al.* (2017)
Milk yield per day of age at second calving(kg/day)	Hariana (1)	0.60±0.03	NS	NS	-	0.25±0.12	Dhaka *et al.* (2002)
	Holstein (4)	4.91	S	NS	S	0.41	Tekerli and Gundogan (2005)
	Sahiwal (1)	1.14±0.02	S	NS	-	0.33±0.07	Dhawan *et al.* (2015)
	Sindi×Jersey (4)	1.37±0.03	S	NS	-	0.26± 0.20	Verma *et al.* (2016) [58]
Persistency (days)	Jersey (4)	67.83+0.73	S	NS	S	-	Patond *et al.* (2014)
	Red sindhi (6)	61.55 ± 2.06	NS	S	S	0.08	Sahito *et al.* (2016)
	H.F Cross	187.207 ± 26.398	S	S	-	0.28 ± 0.11	Sharma *et al.* (2018)
Age at first calving (Days)	Frieswal (1)	962.13+6.34	S	NS	-	0.27±0.10	Kumar *et al.* (2008) [54]
	Sahiwal (1)	1371.06±15.49	S	NS	-	0.12±0.06	Singh *et al.* (2008)
	Karan-Fries (1)	1006 ± 8	NS	NS	-	0.43 ± 0.13	Nehra (2011)
	Karan-Fries (1)	1023±5	S	NS	-	0.54 ± 0.17	Divya (2012)
	Frieswal (1)	1213.54±8.85	S	NS	-	0.46±0.20	Chaudhari *et al.* (2013)
	H.F (1)	1300±5.5	-	-	-	-	Hassan and Khan (2013)
	H.F (1)	1225±14	-	-	-	0.53±0.12	Ghosu *et al.* (2014)
	Frieswal (1)	891.6±13.5	-	-	-	-	Singh *et al.* (2014)
	Sahiwal (1)	1117.02±05.21	S	NS	-		Raja and Gandhi (2015)
	Frieswal (1)	1227.41±18.81	S	NS	-	0.16±0.14	Kumar (2015) [33]
	Jersey (1)	1089.36±13.99	S	S	-	0.30 ±0.19	Kumar *et al.* (2017) [31]
Service period (Days)	Karan-Fries (1)	127.69+11.27	NS	S	-	0.16+0.07	Saha *et al.* (2010) [45]
	Karan-Fries (1)	131.26±3.15	S	S	-	0.40±0.14	Chaudhari *et al.* (2013)
	H.F (1)	272±17.1	S	S	-	-	Hassan and Khan (2013)
	Karan-Fries (1)	125± 5	S	NS	-	0.05 ± 0.13	Divya *et al.* (2014)
	H.F (1)	256±7.3	-	-	-	0.26±0.11	Goshu *et al.* (2014)
	Sahiwal (1)	149.63±5.25	S	NS	-	-	Raja and Gandhi (2015)
	Karan-Fries (4)	115.46 ± 2.14	S	S	S	0.18±0.08	Dash *et al.* (2016) [14]
	Frieswal (1)	131.80±4.82	S	NS	-	0.02±0.17	Kumar (2015) [33]
	Deoni (5)	158.78 ± 3.50	S	NS	S	-	Basak *et al.* (2018) [2]
Calving interval (Days)	Hardhenu (1)	529.48±8.51	S	NS	-	0.09±0.06	Singh *et al.* (2008)
	Karan-Fries (1)	423.20+13.17	NS	S	-	0.35+0.10	Saha *et al.* (2010) [45]
	Karan-Fries (1)	438± 5	S	NS	-	-	Nehra (2011)
	Karan-Fries (1)	410±3	S	NS	-	0.07 ± 0.13	Divya (2012)
	Frieswal (1)	420.8±3.41	S	S	-	0.16±0.10	Chaudhari *et al.* (2013)
	Karan-Fries (4)	403.91 ± 2.54	S	S	S	0.15±0.07	Dash *et al.* (2016) [14]
	Deoni (5)	445.97 ± 3.67	NS	NS	S	-	Basak *et al.* (2018) [2]
Dry period (Days)	Zebu x Friesian (6)	84.20±8.50	NS	NS	S	-	Ahmed *et al.* (2007)
	Frieswal (1)	105.00±2.73	S	S	-	0.32±012	Chaudhari *et al.* (2013)

	H.F Cross	318±21.4	S	S	-	-	Hassan and Khan (2013)
	Deoni (1)	211.93±26.23	S	NS	-	-	Bhutkar *et al.* (2014)
	Sahiwal (1)	196.69±2.63	S	NS	-	0.26±0.06	Dhawan *et al.* (2015)
	Frieswal (1)	102.46±4.88	S	NS	-	0.38±0.23	Kumar (2015) [33]
	Sahiwal (1)	163.75±6.77	S	S	-	-	Raja and Gandhi (2015)
	Gir (1)	177.29±10.59	NS	NS	-	0.42± 0.23	Sawant *et al.* (2016)
	Murrah	110.9±61.4	-	-	NS	-	Poudal *et al.* (2017)

Table 2: Estimates of genetic correlation (r_g) and phenotypic correlations (r_p) among various production performance traits

Trait		$\mathbf{r_g}$	$\mathbf{r_p}$	**References**
LMY	LMY-305	0.93±0.95	>1	Lakshmi *et al.* (2009) [34]
LMY	LMY-305	1.00	0.90**	Singh *et al.* (2011)
LMY	LL	0.87±0.46	0.73**±0.01	Kumar (2000) [30]
LMY	LL	0.66±0.66	0.79** ± 0.15	Lakshmi *et al.* (2009) [34]
LMY	PY	0.03±-0.02	0.25 ± 0.28	Lakshmi *et al.* (2009) [34]
LMY	PY	0.939	0.430**	Patond and Bhoite (2014)
LMY	PY	0.70±0.04	0.85±0.28	Verma *et al* (2016) [58]
LMY	AMY	0.94±0.03	0.83**±0.02	Dash (2014) [13]
LMY	AMY	.340±.158	0.58**±0.03	Dhawan *et al.* (2015)
LMY	MCI	0.97±0.02	0.88**±0.01	Dash (2014) [13]
LMY	MCI	0.759±0.084	0.73**±.024	Dhawan *et al.* (2015)
LMY	MSC	0.70±0.09	0.84**±0.02	Dhawan *et al.* (2015)
LMY	MSC	0.92±0.02	0.65**±0.32	Verma *et al* (2016) [58]
LMY	Persistency	0.56 ± 0.39	0.38 ± 0.33	Seangjun *et al.* (2009) Sahiwal cross
LMY	Persistency	0.610	-	Sahito *et al.* (2016) Red Sindhi
LMY-305	LL	0.61	0.45**	Singh *et al.* (2011)
LMY-305	LL	0.78**±0.12	0.44**±0.03	Dash (2014) [13]
LMY-305	PY	0.03±-0.02	0.26 ± 0.28	Lakshmi *et al.* (2009) [34]
LMY-305	PY	0.863	0.288**	Patond and Bhoite (2014) Gir
LMY-305	AMY	0.97±0.01	0.94**±0.01	Dash (2014) [13]
LMY-305	MCI	0.99±0.01	0.95**±0.01	Dash (2014) [13]
LMY-305	Persistency	0.89	0.25	Boujenane and Hilal (2012) H.F
LL	PY	0.01±-0.01	0.15 ± 0.40	Lakshmi *et al.* (2009) [34]
LL	PY	-0.693	-0.101*	Patond and Bhoite (2014)
LL	AMY	0.61±0.16	0.19**±0.03	Dash (2014) [13]
LL	MCI	0.73±0.13	0.35**±0.03	Dash (2014) [13]
LL	MSC	0.50±0.05	0.40±0.12	Verma *et al* (2016) [58]
LL	PERS.	0.665	-	Sahito *et al.* (2016) Red Sindhi
PY	AMY	0.74±0.03	0.51±0.26	Verma *et al* (2016) [58]
PY	MCI	0.77±0.03	0.60±0.19	Verma *et al* (2016) [58]
PY	MSC	0.69±0.04	0.62±0.26	Verma *et al* (2016) [58]
PY	PERS.	0.56 ± 0.39	0.38 ± 0.33	Seangjun *et al.* (2009)
AMY	MCI	0.98±0.01	0.94**±0.01	Dash (2014) [13]
AMY	MCI	0.727±0.085	0.79±0.02	Dhawan *et al.* (2015)
AMY	MSC	0.780 ± 0.273	0.414 ± 0.047	Dhaka *et al* (2002)
AMY	MSC	0.718 ± 0.503	0.673 ±0.043	Dhaka *et al.* (2009) Tharparkar
AMY	MSC	0.429±0.149	0.489±0.031	Dhawan *et al.* (2015)
MCI	MSC	0.963 ± 0.055	0.808 ±0.026	Dhaka *et al* (2002) Hariana cattle
MCI	MSC	>1.00	0.673 ± 0.043	Dhaka *et al.* (2009) Tharparkar cattle
MCI	MSC	0.656±0.112	0.624±0.027	Dhawan *et al.* (2015)
MCI	Persistency	-	0.34	Dhaka *et al.* (1997) Murrah
MSC	Persistency	-	0.57	Dhaka *et al.* (1997), Murrah
LMY	AFC	0.26 ± 0.23	-0.05 ± 0.02	Mukherjee (2005) Frieswal
LMY-305	AFC	-0.23 ± 0.32	0.04 ± 0.04**	Divya (2012)
LMY-305	AFC	0.64±0.16	0.57**	Dash (2014) [13]
LMY-305	AFC	–0.49	–0.25**	Cayo *et al.* (2018) Girolando cattle
LL	AFC	0.75 ± 0.23	0.22 ± 0.23	Dangar and Vataliya (2015) Gir
LL	AFC	-0.15±0.30	0.06±0.09	Manjeet (2015)
PY	AFC	0.07 ± 0.20	– 0.07± 0.20	Dangar and Vataliya (2015) Gir
AMY	AFC	0.05±0.06	-0.29±0.28	Verma *et al.* (2016) [58]
MCI	AFC	0.17±0.06	-0.03±0.28	Verma *et al.* (2016) [58]
MSC	AFC	-0.21±0.06	-0.35±0.29	Verma *et al.* (2016) [58]
LMY	SP	0.12±0.11	0.33±0.03	Chander (2002)
LMY	SP	0.270 ± 0.212	0.22 ± 0.004	Kadarmideen *et al.* (2003)
LMY	SP	0.390 ± 0.070	-	Zink *et al.* (2012) H.F
LMY-305	SP	-0.17 ± 0.33	0.12 ± 0.04	Divya (2012)
LMY-305	SP	0.66±0.15	0.24**±0.03	Dash 2014 [13]
LL	SP	-0.32±0.195	-0.04±0.105	Ulutaş and Sezer (2009) Simmental Cattle

LL	SP	0.98±0.01	0.97**±0.01	Dash 2014[13]
PY	SP	0.23±0.I	0.22±0.19	Dubey and Singh (2005)
AMY	SP	-0.15±0.06	-0.02±0.33	Verma *et al.* (2016) [58]
MCI	SP	-0.19±0.06	-0.21±0.34	Verma *et al.* (2016) [58]
MSC	SP	0.20±0.06	0.09±0.32	Verma *et al.* (2016) [58]
LMY	CI	0.07±0.40	0.42±0.04	Chander (2002) Sahiwal
LMY	CI	0.400 ± 0.094	0.23 ± 0.005	Kadarmideen *et al.* (2003)
LMY	CI	-	0.090 ± 0.400	Nehra (2011) [38]
LMY	CI	0.77±0.12	0.50**±0.03	Dash 2014, Karanfries[13]
LMY-305	CI	-0.24 ± 0.33	0.12** ± 0.04	Divya (2012)
LMY-305	CI	0.71±0.16	0.26**±0.03	Dash (2014) Frieswal
LMY-305	CI	–0.54±0.37	0.14**±0.03	Cayo *et al.* (2018) Girolando cattle
LL	CI	0.89±0.076	0.78**±0.084	Ulutaş and Sezer (2009) Simmental Cattle
LL	CI	0.81±0.08	0.74**±0.02	Dash (2014) [13]
LL	CI	0.81±0.06	0.55	Birhanu *et al.* (2015) Ethopian boran cattle
PY	CI	O.39±0.IS	0.75±0.10	Dubey and Singh (2005)
AMY	CI	0.16±0.06	-0.08±0.32	Verma *et al*. (2016) [58]
MCI	CI	-0.21±0.06	-0.31±0.33	Verma *et al*. (2016) [58]
MSC	CI	0.18±0.06	-0.02±0.31	Verma *et al*. (2016) [58]
LMY	DP	-0.404	-	Deb *et al*. (2008)
LMY-305	DP	-0.47±0.234	-0.07±0.065	Ulutaş and Sezer (2009) Simmental Cattle
LMY-305	DP	–0.62±0.23	–0.40**±0.02	Cayo *et al.* (2018) Girolando cattle
LL	DP	-0.580	-	Deb *et al*. (2008)
PY	DP	-0.14±0.06	-0.17±0.19	Verma *et al*. (2016) [58]
AMY	DP	0.39±0.05	-0.30±0.39	Verma *et al*. (2016) [58]
MCI	DP	-0.480	-	Deb *et al*. (2008)
MSC	DP	-0.32±0.05	-0.14±0.39	Verma *et al*. (2016) [58]
AFC	SP	-0.13±0.33	0.03±0.09	Manjeet (2015)
AFC	CI	-0.29±0.49	-0.08±0.09	Manjeet (2015)
AFC	DP	0.06 ± 0.20[NS]	0.04± 0.20	Dangar and Vataliya (2015) Gir
SP	CI	0.99±0.002	0.99 ± 0.002	Ghiasi *et al*. (2011) HF
SP	DP	0.51±0.243	-0.04±0.105	Ulutaş and Sezer (2009)
DP	CI	0.356	-	Deb *et al*. (2008)
DP	CI	0.26±0.62	0.54**±0.02	Cayo *et al.* (2018) Girolando cattle

*Significant (*P*<0.05) **Significant (*P*<0.5)

Genetic improvement through selection in a breeding program depends on the accuracy of identifying genetically superior animals. Selection of dairy animals is generally based on the records of performance traits. As per the literature, genetic and non-genetic factors had significant influence on the performance traits in crossbred cattle. Therefore, adjustment of effect of non-genetic factors becomes essential for accurate and unbiased estimates of genetic parameters. Heritability estimates indicated that individual and progeny testing could be a tool for bringing out desirable changes in production traits, whereas improvement in reproduction traits can be done through better managemental practices. Critical appraisal of heritability estimates, genetic and phenotypic correlations between production performance traits, it may be inferred that selection based on milk yield per day of age at second calving that had high estimates of heritability (0.50) and appreciably high genetic and phenotypic correlations with production performance traits, would not only improve production performance but also take care of reproductive performance. Therefore, selection based on MSC would result in improvement in desirable direction through positive correlated response in all the traits under study.

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