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GENETIC CONTROL AND ASSOCIATION AMONG ECONOMIC TRAITS IN SAHIWAL CATTLE: A REVIEW

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ABSTRACT

Sahiwal cattle breed of Pakistan is one of the best zebu cattle breed that can potentially play the same role as Holstein for tropical environment. The lifetime story of Sahiwal cattle in Pakistan represents a genetic resource unaltered and awaiting genetic improvement to satisfy the local and international needs of milk and meat. The genetic factors are generally influenced the Sahiwals' performance and the supporting reports from other breeds in the region are also presented for comparison. The performance traits reviewed were age at first calving, milk yield, lactation length, dry period, calving interval and service period of Sahiwal cows. The genetic parameters such as heritability and genetic correlations are helpful in determining the selection strategy for a single or multiple selection objectives. The repeatability estimates are used in determining the amount of culling that can be practiced on the basis of initial records. The genetic correlations among various performance traits have been reported by various workers but agreement between any two studies for any two traits is difficult to find. Genetic trend was close to zero. However, due to appreciable additive genetic variation, it was suggested that genetic improvement in traits like milk yield was possible.

Key words: Sahiwal cattle, milk yield, repeatabilty, heritability, genetic correlation.

INTRODUCTION

The performance of Sahiwal cattle is remarkable in the hot climate and has gained worldwide credit as one of the best milch breeds (Ilatsia *et al.*, 2011). Due to its resistance against contagious diseases and heat tolerance properties, many countries have exported this breed from Pakistan and India for the production of synthetics (Australian-Friesian-Sahiwal, Australian Milking Zebu, Frieswal, Jamaica Hope, Karan Swiss, Mafriwal, Mpwapwa and Taurindicus etc.). There is decreasing trend in the population of Sahiwal breed (6.8% of total cattle population) as indicated in the Livestock census published in 2006 mainly because of abrupt crossbreeding with imported breeds for getting high milk production (GOP, 2006). Ilatsia *et al*., (2007) also reported that Sahiwal breed has been decreasing over the years in the tropics.

Genetic parameters in Sahiwal cattle have been reported in many studies. Heritability of first lactation milk yield was reported to be in the range of 0.01 to 0.1 (Mohiuddin *et al*. 1994; Javed *et al*. 2001; Rehman *et al*. 2008). For multiple lactations, estimates were similar to that of first lactation. Rehman and Khan (2012) used 5897 lactation records on Sahiwal cattle and reported that the heritability estimates for 305-day milk yield, total milk yield, lactation length, dry period, calving interval and service period were 0.10±0.016, 0.09±0.016, 0.06±0.013, 0.14±0.009, 0.15±0.010, and 0.14±0.010, respectively. Dahlin *et al*. (1998) used 4029 lactation records on Sahiwal cattle and reported that first lactation milk yield was 15% heritable while second and third lactations were 12 and 17% heritable. The 305-day lactation milk yield had a similar range. Heritability estimates of Talbott *et al*. (1997) were similar to those of Dahlin *et al*. (1998). Higher estimates of 0.26 ± 0.09 (Ahmad, 1972) and 0.28 ± 0.17 (Shah and Zafar, 1986) for first lactation milk yield in Sahiwal cattle have also been reported. An estimate of 0.51 ± 0.21 is also available in the literature (Khanna and Bhat, 1971) for Indian Sahiwal. Bajwa *et al*. (2004) reported that heritability estimate varied with the lactation length adjustment procedure. Heritability estimate for unadjusted milk yield was reported as 0.15 ±0.042 while adjusted lactation yields were reported to have estimates between 0.13 ± 0.037 and 0.20 ± 0.041 depending on the method of lactation length adjustment.

The genetic correlations between productive and reproductive traits play important role in deciding single vs multiple trait selection strategy. Reports vary widely for direction and extent of correlations among various traits both within and across breeds. Rehman and Khan (2012) observed the phenotypic, genetic and environmental correlation of 305-d milk yield with lactation length was 0.71, 0.48 and 0.70, respectively, with dry period was -0.31, -0.43 and -0.22, respectively while with calving interval and service period exhibited similar pattern (0.08, 0.25 and 0.08, respectively). Genetic correlation between first lactation milk yield and age at first calving has been reported as –0.12 ± 0.38 by Choudhary *et al*. (2003) in an Indian study which is a

quite different from 0.44 reported by Mohiuddin *et al*. (1991) and 0.60 reported by Javed *et al*. (2004). For first lactation milk yield and lactation length genetic correlation reported by Dahlin *et al*. (1998) was 0.83 while Javed *et al*. (2004) reported an estimate of 0.48. Choudhary *et al*. (2003) on the other hand reported a lower estimate of 0.23 between the two traits for Indian Sahiwal. No specific genetic trend was observed for performance traits in Sahiwal cattle (Rehman *et al*. 2008; Rehman and Khan 2012).

Genetic Parameters: The repeatability and heritability estimates for productive and reproductive traits in Sahiwal and other breeds in the tropics are presented below.

Milk Yield: The repeatability estimates of milk yield in Sahiwal cattle ranged from 0.28 (Javed, 1999) to 0.48 (Chand and Naraine, 1984). Dahlin *et al*. (1998) in a study of 4069 cows belonging to eleven herds in Pakistan reported repeatability estimate of 0.42 for Sahiwal cows. Bajwa *et al*. (2004) and Rehman and Khan (2012) reported repeatability estimates for Pakistani Sahiwals were 0.46±0.041 and 0.40±0.016, respectively. For Tharparkar and Red Sindhi breeds, the repeatability estimates ranged from 0.31 to 0.54 (Amble *et al*., 1967; Ghaffar, 1983). The crossbred cows have low (0.13) repeatability estimates while Friesian cows in hot climate have similar repeatability estimates as was in Sahiwal cattle. Datasets used for estimation of repeatability varied between 57 to 5897 cows.

The heritability of first lactation milk yield in Sahiwal cattle and other dairy breeds are given in Table 2. The estimates for first lactation milk yield in different breeds of cattle ranged from 0.01 to 0.69. The heritability of milk yield in Sahiwal cattle ranged from 0.01±0.022 (Javed *et al*. 2001) to 0.54±0.36 (Sharma and Singh, 1981). For breeds such as Red Sindhi it was reported to be 0.25±0.10 (Ruvuna *et al*., 1984) while for Tharparkar estimate ranged from 0.03±0.18 to 0.69±0.26 (Panneerselvam *et al*., 1990; Bhat *et al*., 1980). A wide variation for heritability was reported in Hariana cattle. Tomar and Singh (1981) analysed data collected over a period of 12 years on 418 normal lactations of Hariana cows and reported that the heritability was 0.14±0.02. Estimate reported by Singh (1969) was very high (0.58±0.17).

For multiple lactations heritability estimate for Sahiwal cattle ranged from 0.05 to 0.40 (Gandhi and Gurnani, 1988; Wakhungu *et al*., 1991; Rege *et al*., 1992; Talbott *et al*., 1997; Dahlin *et al*., 1998; Javed *et al*. 2001; Rehman and Khan 2012). Talbott *et al*. (1997) analysed data on 1776 lactations of 632 Sahiwal cows maintained at Livestock Production Research Institute, Bahadarnagar, Okara (Pakistan) and reported additive genetic proportion of phenotypic variance as 0.18 for lactation milk yield but later Javed *et al*. (2001) reported a low estimate of 0.05±0.032 for cows at Livestock Experiment Station, Jahangirabad. However, Rehman and Khan (2012) reported high heritability estimates (0.40) for Sahiwal cattle.

Table 1. Repeatability estimates for milk yield in different cattle breeds

Breed	Country	No.	Estimate	Reference
Sahiwal	Pakistan	2450	0.32	Talbott *et al*. (1997)
Sahiwal	Pakistan	4069	0.42	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	0.39±0.07	Ahmad (1999)
Sahiwal	Pakistan	1615	0.28	Javed (1999)
Sahiwal	Pakistan	661	0.46±0.041	Bajwa *et al*. (2004)
Sahiwal	Pakistan	5897	0.40±0.016	Rehman and Khan (2012)
Sahiwal	India	-	0.48	Chand and Naraine (1984)
Sahiwal	India	1731	0.40±0.12	Gandhi and Gurnani (1992)
Sahiwal	Kenya	3500	0.46±0.02	Wakhungu *et al*. (1991)
HF x Sahiwal	India	642	0.13±0.04	Lakshmi *et al*. (2009)
Red Sindhi	India	-	0.54	Amble *et al*. (1967)
Red Sindhi	India	57	0.43	Johar and Taylor (1967a)
Red Sindhi	India	160	0.34	Pundir and Singh (2007)
Hariana	India	-	0.50	Chand and Naraine (1983)
Tharparkar	Pakistan	506	0.31±0.03	Ghaffar (1983)
Tharparker	India	-	0.47	Amble *et al*. (1967)
Friesian	Sudan		0.361±0.047	Eid *et al*. (2012)

Table 2. Heritability estimates for first lactation milk yield in different breeds of dairy cattle

Breed	Country	No.	Method*	Heritability (h^2)	Reference
Sahiwal	Pakistan	106	ISRDD	0.16	Khan (1968)
Sahiwal	Pakistan	129	PHSC	0.07	Khan (1968)
Sahiwal	Pakistan	892	PHSC	0.26±0.09	Ahmad, (1972)
Sahiwal	Pakistan	647	ISRDD	0.16±0.09	Ahmad, (1972)
Sahiwal	Pakistan	-	PHSC	0.27±0.19	Qureshi (1974)
Sahiwal	Pakistan	442	PHSC	0.28±0.17	Shah and Zafar, (1986)
Sahiwal	Pakistan	918	PHSC	0.11±0.07	Mohiuddin *et al*. (1990)
Sahiwal	Pakistan	847	PHSC	0.11±0.07	Mohiuddin *et al*. (1994)
Sahiwal	Pakistan	732	REML	0.18	Talbott *et al*. (1997)
Sahiwal	Pakistan	4069	REML	0.15±0.02	Dahlin *et al*. (1998)
Sahiwal	Pakistan	2532	REML	0.013±0.022	Javed *et al*. (2001)
Sahiwal	Pakistan	-	REML	0.15	Bajwa *et al*. (2002)
Sahiwal	Pakistan	-	REML	0.11±0.018	Rehman *et al*. (2008)
Sahiwal	India	400	-	0.51±0.21	Khanna and Bhat (1971)
Sahiwal	India	258	-	0.31±0.19	Tomar *et al*. (1974)
Sahiwal	India	-	-	0.41	Taneja *et al*. (1978)
Sahiwal	India	816		0.43±0.03	Bhatia (1980)
Sahiwal	India	108	-	0.54±0.36	Sharma and Singh (1981)
Sahiwal	India	315	-	0.25±0.08	Bhatia (1982)
Sahiwal	India	580	-	0.25±0.12	Bhatnagar *et al*. (1983)
Sahiwal	India	198	-	0.42±0.27	Chand and Narain (1984)
Sahiwal	India	-	PHSC	0.22±0.07	Ruvuna *et al*. (1984)
Sahiwal	India	173	ISRDD	0.30±.023	Sharma *et al*. (1987)
Sahiwal	India	-	-	0.52±0.16	Reddy and Nagarcenkar (1989)
Sahiwal	India	341	REML	0.28±0.18	Pundir and Raheja (1994)
Sahiwal	India	2181	PHSC	0.17	Gandhi and Gurnani (1995)
Sahiwal	India	-	REML	0.18	Choudhary *et al*. (2003)
Sahiwal	India	1223	REML	0.32	Kumar *et al*. (2009)
Sahiwal	Kenya	1744	-	0.35±0.09	Kimenye (1980)
Sahiwal	Kenya	2238	PHSC	0.35	Rege *et al*. (1992)
Red Sindhi	India	-	PHSC	0.25±0.10	Ruvuna *et al*. (1984)
Hariana	India	505	PHSC	0.58±0.17	Singh (1969)
Hariana	India	532	-	0.40±0.15	Gill and Balaine (1971)
Hariana	India	684	ISRDD	0.41	Hingane (1982)
Hariana	India	1142	PHSC	0.15	Hingane (1982)
Hariana	India	-	-	0.39±0.20	Misra *et al*. (1980)
Hariana	India	418	-	0.14±0.02	Tomer and Singh (1981)
Hariana	India	753	PHSC	0.22	Taneja *et al*. (1982)
Hariana	India	-	-	0.48±0.14	Chhikara and Pander (1988)
Hariana	India	410	REML	0.26±0.15	Pundir and Raheja (1994)
Tharparkar	India	-	ISRDD	0.42±0.16	Amble *et al*. (1967)
Tharparkar	India	345	ISRDD	0.30±0.16	Singh and Sundaresan (1969)
Tharparkar	India	742	ISRDD	0.25±0.10	Reddy and Bhatnagar (1971)
Tharparkar	India	400	-	0.05	Prasad and Prasad (1972)
Tharparkar	India	-	-	0.69±0.26	Bhat *et al*. (1980)
Tharparkar	India	-	PHSC	0.18	Gurnani *et al*. (1984)
Tharparkar	India	-	IRDD	0.25	Gurnani *et al*. (1984)
Tharparkar	India	-	PHSC	0.29±0.06	Ruvuna *et al*. (1984)
Tharparkar	India	322	-	0.35±0.18	Taneja and Bhatnagar (1985)
Tharparkar	India	117	-	0.03±0.18	Panneerselvam *et al*. (1990)

* Method= PHSC: Paternal halfsib correlation, ISRDD: Intrasire regression of daughter on dam, REML: Restricted maximum likelihood, Lac: Lactation

Table 3. Heritability estimates of total lactation milk yield in different breeds of dairy cattle

Breed	Country	No.	Method*	Estimate	References
Sahiwal	Pakistan	725	REML	0.18	Talbott *et al*. (1997)
Sahiwal	Pakistan	4069	AM	0.15	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	REML	0.20±0.07	Ahmad (1999)
Sahiwal	Pakistan	1615	REML	0.05±0.032	Javed *et al*. (2001)
Sahiwal	Pakistan		REML	0.40±0.016	Rehman and Khan (2012)
Sahiwal	India	424	-	0.27	Gandhi and Gurnani (1988)
Sahiwal	Kenya	4800	REML	0.27±0.06	Wakhungu *et al*. (1991)
Sahiwal	Kenya	4837	PHSC	0.27	Rege *et al*. (1992)
Sahiwal	Kenya	-	REML	0.16	Ilatsia *et al*. (2007)
Hols.Fr. x Sahiwal	India	642	-	0.20±0.08	Lakshmi *et al*. (2009)
Red Sindhi	India	160	REML	0.275±0.051	Pundir and Singh (2007)
Hariana	India	2nd Parity	-	0.37±0.14	Chhikara and Pander (1988)
Hariana	India	3rd Parity	-	0.42±0.13	Chhikara and Pander (1988)
Hariana	India	4th Parity	-	0.21±0.18	Chhikara and Pander (1988)
Hariana	India	5th Parity	-	0.38±0.19	Chhikara and Pander (1988)
Hariana	India	270	-	0.07±0.07	Yadav and Rathi (1991)
Hariana	India	867	PHSC	0.25	Kumar *et al*. (1992)
Tharparkar	India	-	PHSC	0.38±0.12	Bhatnagar *et al*. (1982)
Tharparkar	India	117	-	0.11±0.23	Panneerselvam *et al*. (1990)
Tharparkar	India	151	-	0.03±0.06	Yadav *et al*. (1994)
Friesian	Sudan			0.10±0.15	Eid *et al*. (2012)

*Method= PHSC: Paternal halfsib correlation, ISRDD: Intrasire regression of daughter on dam, REML: Restricted maximum likelihood, Lac: Lactation

Heritability estimates for lactation milk yield in Hariana breed for various parities ranged between 0.21 and 0.42 (Chhikara and Pander, 1988) while Kumar *et al*. (1992) estimated it as 0.25. In Tharparkar breed heritability estimate for lactation milk yield has been reported to be 0.03 to 0.38 (Bhatnagar *et al*., 1982; Panneerselvam *et al*., 1990; Yadav *et al*., 1994). Lakshmi *et al*. (2009) reported heritability estimate in Sahiwal crossbred was to be 0.20, while in Friesian cattle present in hot climate was 0.10 (Eid *et al*. 2012). Many factors are responsible for variable estimates, including managemental conditions which may mask the additive genetic variation.

Lactation Length: In Sahiwal cattle the repeatability estimate for lactation length were reported in the range of 0.18 and 0.40 (Table 4). Talbott *et al*. (1997) analysed data on 1776 lactations of 632 Sahiwal cows maintained at Livestock Production Research Institute, Bahadarnagar, Okara (Pakistan) and reported repeatability estimate of 0.40 for lactation length. Javed (1999) reported the repeatability estimate for lactation length was 0.18 for another Sahiwal herd in Pakistan. Bajwa *et al*. (2004) and Rehman and Khan (2012) reported similar repeatability estimates in Sahiwal cattle (0.33). Ghaffar (1983) analysed data on 506 Tharparkar cows in Pakistan and reported the repeatability estimate of 0.22±0.05 for lactation length. Javed *et al*. (2001) estimated the repeatability for lactation length was 0.15 in Cholistani breed at one of the experimental herds in Pakistan. High repeatability estimates (0.50) were reported by Lakshmi *et al*. (2009) in Sahiwal crossbred, while low estimates (0.094) in Friesian cattle present in hot climate was reported by Eid *et al*. (2012).The largest dataset used for estimation of repeatability was of Dahlin *et al*. (1998) and lactation length was found to have repeatability of 0.31.

The estimates of heritability for lactation length in Sahiwal were relatively low ranging from 0.03 to 0.19. (Ahmad, 1972; Taneja *et al*., 1978; Bhatnagar *et al*., 1983; Gandhi and Gurnani, 1988; Reddy and Nagarcenkar, 1989; Singh *et al*, 1993; Mohiuddin *et al*, 1994; Gandhi and Gurnani, 1995; Dahlin *et al*., 1998; Javed *et al*. 2001; Rehman *et al*. 2008; Rehman and Khan, 2012). However, moderate to high estimates of (0.26±0.05 to 0.44±0.27) for Sahiwal breed has also been reported by some workers (Ahmad, 1972; Ahmad *et al*., 1974a; Chand and Narain, 1984 and Pundir and Raheja, 1994). A very wide range of heritability estimates exist for Tharparkar, Hariana, Red Sindhi, Cholistani breeds, Sahiwal crossbreds and Friesian cattle in hot climate. Method of analysis and models contribute to the differences apart from actual breed differences and environmental variation.

Age at First Calving: The heritability estimates of age at first calving in Sahiwal cattle ranged from 0.01±0.07 to 0.80±0.19 (Table 6). With the exception of Shah and

Zafar (1986), heritability for age at first calving in Sahiwal cattle was reported to be low (Ahmad *et al*., 1974a; Mohiuddin *et al*., 1994; Javed, 1999; Rehman *et al*. 2008).

Table 4. Repeatability estimates for lactation length in different breeds of dairy cattle

Breed	Country	N	Estimate	References
Sahiwal	Pakistan	2450	0.40	Talbott *et al*. (1997)
Sahiwal	Pakistan	4069	0.31	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	0.21±0.06	Ahmad (1999)
Sahiwal	Pakistan	1615	0.18	Javed (1999)
Sahiwal	Pakistan	661	0.326±0.025	Bajwa *et al*. (2004)
Sahiwal	Pakistan	5897	0.33±0.013	Rehman and Khan (2012)
Sahiwal	India	180	0.34	Kumar and Narain (1978)
Sahiwal	India	-	0.22	Chand and Narain (1984)
Sahiwal	India	2162	0.25±0.01	Gandhi and Gurnani (1992)
Hols.Fr. x Sahiwal	India	642	0.50±0.04	Lakshmi *et al*. (2009)
Hariana	India	-	0.29	Chand and Narain (1983)
Tharparkar	Pakistan	506	022±0.05	Ghaffar (1983)
Red Kandhari	India	218	0.14	Dhumal *et al*. (1989)
Red Sindhi	India	160	0.11	Pundir and Singh (2007)
Damictta	Egypt	430	0.40	Alim (1990)
Gir	Brazil	1049	0.37	Santos *et al*. (1990)
Karan Swiss	India	117	0.09	Sethi and Bhatnagar (1982)
Cholistani	Pakistan	-	0.152	Javed *et al*. (2001a)
Friesian	Sudan	-	0.094±0.044	Eid *et al*. (2012)

Table 5. Heritability estimates of lactation length in different breeds of dairy cattle

Breed	Country	No.	Method*	Heritability	Reference
Sahiwal	Pakistan	892	PHSC	0.26±0.096	Ahmad (1972)
Sahiwal	Pakistan	647	ISRDD	0.16±0.09	Ahmad (1972)
Sahiwal	Pakistan	900	PHSC	0.39±0.12	Ahmad *et al*. (1974)
Sahiwal	Pakistan	556	ISRDD	0.26±0.05	Ahmad *et al*. (1974)
Sahiwal	Pakistan	847	PHSC	0.06±0.05	Mohiuddin *et al*. (1994)
Sahiwal	Pakistan	4069	REML	0.14±0.02	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	REML	0.11±0.06	Ahmad (1999)
Sahiwal	Pakistan	1615	AM	0.027±0.013	Javed *et al*. (2001)
Sahiwal	Pakistan	1619	REML	0.062±0.039	Javed *et al*. (2001)
Sahiwal	Pakistan	5897	AM	0.09±0.027	Rehman *et al*. (2008)
Sahiwal	Pakistan	5897	AM	0.06±0.013	Rehman and Khan (2012)
Sahiwal	India	-	-	0.16	Teneja *et al*. (1978)
Sahiwal	India	580	-	Very low	Bhatnagar *et al*. (1983)
Sahiwal	India	198	-	0.44±0.27	Chand and Narain (1984)
Sahiwal	India	424	PHSC	0.07	Gandhi and Gurnani, (1988)
Sahiwal	India	-	-	0.19±0.20	Reddy and Nagarcenkar (1989)
Sahiwal	India	299	PHSC	0.05±0.02	Singh *et al*. (1993)
Sahiwal	India	-	-	0.32±0.19	Pundir and Raheja (1994)
Sahiwal	India	2181	PHSC	0.032	Gandhi and Gurnani (1995)
Sahiwal	India	-	AM	0.13	Choudhary *et al*. (2003)
Sahiwal	Kenya	-	AM	0.07	Ilatsia *et al*. (2007)
Hols.Fr. x Sahiwal	India	642		0.06	Lakshmi *et al*. (2009)
Red Sindhi	India	160	REML	0.064±0.036	Pundir and Singh (2007)
Sindhi	India	-	-	0.06	Gogoi *et al*. (1992)
Hariana	India	453	-	0.19±0.17	Misra *et al*. (1980)
Hariana	India	164	PHSC	zero	Arora and Shrama (1981)

Breed	Country	No.	Method*	Heritability	Reference
Hariana	India	700	-	0.40±0.02	Tomar and Singh (1981)
Hariana	India	418	-	0.42	Hingane (1982)
Hariana	India	684	PHSC	0.12	Hingane (1982)
Hariana	India	270		0.07±0.07	Yadav and Rathi (1991)
Hariana	India	-	-	0.26±0.16	Pundir and Raheja (1994)
Tharparkar	India	400	-	0.09	Prasad and Prasad (1972)
Tharparkar	India	-	-	0.39±0.02	Bhat *et al*. (1980)
Tharparkar	India	117		0.05±0.19	Panneerselvam *et al*. (1990)
Red Sindhi	India	188	ISDDR	0.42±0.35	Rao and Patro (1984)
Cholistani	Pakistan	310	REML	0.066±0.049	Javed *et al*. (2001a)
Friesian	Sudan	-	PHSC	0.003	Eid *et al*. (2012)

* Method= PHSC: Paternal half-sib correlation, ISRDD: Intrasire regression of daughter on dam, REML: Restricted maximum likelihood, AM: Animal Model, Lac: Lactation

Table 6. Heritability estimates for age at first calving in different breeds of dairy cattle

Breed	Country	N	Method*	Estimate	Reference
Sahiwal	Pakistan	992	PHSC	0.12±0.02	Muhammad (1968)
Sahiwal	Pakistan	992	ISRDD	0.01±0.07	Muhammad (1968)
Sahiwal	Pakistan	647	ISRDD	0.08±0.09	Ahmad (1972)
Sahiwal	Pakistan	900	PHSC	0.80±0.19	Ahmad *et al*. (1974a)
Sahiwal	Pakistan	556	ISRDD	0.08±0.10	Ahmad *et al*. (1974a)
Sahiwal	Pakistan	442	-	0.69±0.29	Shah and Zafar (1986)
Sahiwal	Pakistan	6000	PHSC	0.16±0.04	Khan *et al*. (1992)
Sahiwal	Pakistan	974	PHSC	0.02±0.04	Mohiuddin *et al*. (1994)
Sahiwal	Pakistan	732	REML	0.13	Talbott et a.l (1997)
Sahiwal	Pakistan	4213	REML	0.12±0.02	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	REML	0.05±0.06	Ahmad (1999)
Sahiwal	Pakistan	-	REML	0.037±0.026	Javed (1999)
Sahiwal	Pakistan	5897	AM	0.02±0.019	Rehman *et al*. (2008)
Sahiwal	India	456	-	0.46±0.18	Nagpal and Acharya (1970)
Sahiwal	India	258	-	0.24	Tomar *et al*. (1974)
Sahiwal	India	424	PHSC	0.19	Gandhi and Gurnani (1988)
Sahiwal	India	8009	PHSC	0.36	Gandhi and Gurnani (1989)
Sahiwal	India	-	-	0.53±0.22	Reddy and Nagarcenkar (1989)
Sahiwal	India	108	-	0.20	Singh *et al*. (1990)
Sahiwal	Kenya	2015	PHSC	0.29	Rege *et al*. (1992)
Sahiwal	Kenya		AM	0.04	Ilatsia *et al*. (2007)
Red Sindhi	India	188	PHSC	0.46±0.28	Patro and Rao (1983)
Red Sindhi	India	188	ISRDD	0.24±0.28	Patro and Rao (1983)
Tharparkar	India	750	-	0.38±0.12	Kumar (1982)
Tharparkar	India	117	-	0.30±0.33	Panneerselvam *et al*. (1990)
Hariana	India	-	ISRDD	0.34±0.12	Singh and Desai (1961)
Hariana	India	-	PHSC	0.34±0.19	Singh and Desai (1961)
Hariana	India	667	PHSC	0.38±0.11	Guha *et al*. (1968)
Hariana	India	103	ISRDD	0.15±0.03	Dadlani *et al*. (1969)
Hariana	India	619	-	0.04	Balaine (1971)
Hariana	India	160	PHSC	0.38	Tomar *et al*. (1974)
Hariana	India	164	PHSC	0.40±0.22	Misra *et al*. (1980)
Hariana	India	418	-	0.14±0.02	Tomar and Singh (1981)
Hariana	India	684	ISRDD	0.27	Hingane (1982)
Hariana	India	1142	PHSC	0.25	Hingane (1982)
Hariana	India	1187	-	0.23±0.08	Kumar (1982)
Friesian	Sudan		PHSC	0.190±0.140	Eid *et al*. (2012)

* Method= PHSC: Paternal halfsib correlation, ISRDD: Intrasire regression of daughter on dam, REML: Restricted maximum likelihood, Lac: Lactation

Table 7. Repeatability estimates for dry period in different breeds of dairy cattle

Breed	Country	N	Estimates	References
Sahiwal	Pakistan	1749	0.34	Talbott *et al*. (1997)
Sahiwal	Pakistan	1928	0.08±0.02	Ahmad (1999)
Sahiwal	Pakistan	-	0.152	Javed (1999)
Sahiwal	Pakistan	5897	0.140±0.009	Rehman and Khan (2012)
Sahiwal	India	-	0.15	Chand and Naraine (1983)
Sahiwal	India	173	0.31±0.25	Sharma and Khan 1989
Hariana	India	-	0.23	Chand and Naraine (1983)
Eskisehir	Turkey	92	0.19±0.03	Ulusan (1988)
Damictta	Egypt	430	0.34	Alim (1990)
Red Sindhi	India	160	0.24	Pundir and Singh (2007)

Dry period is generally considered an environmental trait. The heritability estimates for dry period in Sahiwal cattle are more oftenly reported than the repeatability estimates. For the eight studies on Sahiwal cattle in Pakistan estimates ranged between 0 and 0.16. For Indian studies data sets were very limited (n=173-299) and estimates are difficult to be generalized even for a small population. For other breeds, problem is similar.

Calving Interval: For Sahiwal breed, the repeatability estimates ranged from 0.08±0.04 (Ahmad, 1999) to 0.39±0.02 (Wakhungu *et al*., 1991). Considering reasonably large data sets only, trait has repeatability in the low to medium range. For Red Sindhi, estimates are a bit higher (0.21 to 0.47) and same can be concluded for other zebu breeds reviewed (Table 9).

The heritability estimates for calving interval for Sahiwal cattle ranged from 0.03 to 0.216. The REML estimates (Wakhungu *et al*., 1991; Dahlin *et al*., 1998; Ahmad, 1999; Javed *et al*., 2001; Rehman *et al*. 2008; Rehman and Khan, 2012) indicated that heritability of the trait is most likely to be low, similar to more productive breeds such as Holstein. For other breeds there is a lot of variation and heritability has been reported between 0 and 0.42 (Patro and Rao, 1983) yet, records used for these estimates were very limited.

Service Period: The repeatability estimates for service period in Sahiwal cattle, although reported less frequently, ranged between 0.09 (Ahmad, 1999) and 0.34 (Talbott *et al*., 1997) (Table 11).

Table 8. Heritability estimates for dry period in different breeds of dairy cattle

Breed	Country	N	Method*	Estimate	Reference
Sahiwal	Pakistan	900	PHSC	Negative	Ahmad and Ahmad (1974)
Sahiwal	Pakistan	811	PHSC	0.04±0.05	Mohiuddin *et al*. (1991)
Sahiwal	Pakistan	6000	PHSC	0.12±0.04	Khan *et al*. (1992)
Sahiwal	Pakistan	1771	REML	0.16	Talbott *et al*. (1997)
Sahiwal	Pakistan	1928	REML	0.01±0.02	Ahmad (1999)
Sahiwal	Pakistan	1909	REML	0.028±0.027	Javed *et al*. (2001)
Sahiwal	Pakistan	5897	REML	0.05 ± 0.019	Rehman *et al*. (2008)
Sahiwal	Pakistan	5897	REML	0.14±0.009	Rehman and Khan (2012)
Sahiwal	India	-	-	0.17	Taneja *et al*. (1978)
Sahiwal	India	173	PHSC	0.16±0.21	Sharma and Khan (1989)
Sahiwal	India	173	ISRDD	0.23±0.18	Sharma and Khan (1989)
Sahiwal	India	-	-	0.14±0.21	Reddy and Nagarcenkar (1989)
Sahiwal	India	299	-	0.01±0.00	Singh *et al*. (1993)
Sahiwal	India	-	-	0.16±0.13	Pundir and Raheja (1994)
Red Sindhi	India	160	-	0.153±0.046	Pundir and Singh (2007)
Sindhi	India	293	-	0.22	Gogoi *et al*. (1992)
Tharparkar	India	-	-	0.00	Pandey *et al*. (1978)
Hariana	India	-	-	0.32	Dadlani *et al*. (1969)
Hariana	India	-	-	0.11±0.10	Pundir and Raheja (1994)
Damictta	Egypt	430	ISRDD	0.39±0.27	Alim (1990)

Table 9. Repeatability estimates for calving interval in different breeds of dairy cattle

Breed	Country	N	Estimate	Reference
Sahiwal	Pakistan	3154	0.215±0.019	Ahmad and Ahmad (1972)
Sahiwal	Pakistan	1749	0.35	Talbott *et al*. (1997)
Sahiwal	Pakistan	1928	0.08±0.04	Ahmad (1999)
Sahiwal	Pakistan	-	0.178	Javed (1999)
Sahiwal	Pakistan	5897	0.15±0.010	Rehman and Khan (2012)
Sahiwal	India	180	0.16	Kumar and Narain (1978)
Sahiwal	India	8798	0.14±0.01	Gandhi and Gurnani (1992)
Sahiwal	Kenya	3500	0.39±0.02	Wakhungu *et al*. (1991)
Red Sindhi	India	729	0.21	Amble *et al*. (1958)
Red Sindhi	India	-	0.40	Amble *et al*. (1967)
Red Sindhi	India	160	0.31	Pundir and Singh (2007)
Hariana	India	586	0.10	Singh and Desai (1961)
Tharparkar	India	582	0.23±0.05	Singh (1958)
Tharparkar	India	1582	0.19	Amble *et al*. (1958)
Tharparkar	India	-	0.37	Amble *et al*. (1967)
Gir	India	130	0.17	Amble *et al*. (1958)
Gir	India	-	0.54	Amble *et al*. (1967)
Gir	India	112	0.37	Singh *et al*. (1982)
Kangayam	India	1013	0.08	Amble *et al*. (1958)
Kangayam	India	-	0.50	Amble *et al*. (1967)
Kankrej	India	100	0.17	Amble *et al*. (1958)
Kankrej	India	-	0.50	Amble *et al*. (1967)
Nagauri	India	177	0.41	Barhat and Chowdhary (1980)

Table 10. Heritability estimates of calving interval in different breeds of dairy cattle

Breed	Country	No.	Method	Estimate	Reference
Sahiwal	Pakistan	818	PHSC	0.216	Ahmad (1972)
Sahiwal	Pakistan	811	PHSC	0.04±0.05	Ahmad *et al*. (1992)
Sahiwal	Pakistan	6000	PHSC	0.18±0.05	Khan *et al*. (1992)
Sahiwal	Pakistan	4000	REML	0.05±0.02	Dahlin *et al*. (1998)
Sahiwal	Pakistan	1928	REML	0.07±0.04	Ahmad (1999)
Sahiwal	Pakistan	1466	REML	0.030±0.024	Javed *et al*. (2001)
Sahiwal	Pakistan	5897	REML	0.12 ± 0.027	Rehman *et al*. (2008)
Sahiwal	Pakistan	5897	REML	0.15±0.010	Rehman and Khan (2012)
Sahiwal	India	198	-	0.03±0.22	Chand and Narian (1984)
Sahiwal	India	-	-	0.17±0.22	Reddy and Nagarcenkar (1989)
Sahiwal	India	108	-	0.21±0.061	Singh *et al*. (1990)
Sahiwal	India	8009	PHSC	0.065	Gandhi and Gurnani (1995)
Sahiwal	Kenya	3500	REML	0.15±0.1	Wakhungu *et al*. (1991)
Sahiwal	Kenya	2015	PHSC	0.15	Rege *et al*. (1992)
Sahiwal	Kenya	-	AM	0.03	Ilatsia *et al*. (2007)
Hariana	India	270	-	0.09±0.08	Yadav and Rathi (1991)
Gir	India	112	-	0.22±0.11	Singh *et al*. (1982)
Red Sindhi	India	188	PHSC	0.42±0.27	Patro and Rao (1983)
Red Sindhi	India	188	ISRDD	-0.080±0.20	Patro and Rao (1983)
Red Sindhi	India	293	-	0.25	Gogoi *et al*. (1992)
Red Sindhi	India	160		0.127±0.046	Pundir and Singh (2007)

The heritability estimates of service period in Sahiwal cattle had a slightly wider range between 0.04±0.020 (Rehman *et al*. 2008) to 0.357±0.098 in Pakistani Sahiwals while similar range were reported in Indian Sahiwals (Reddy and Nagarcenkar, 1989; Rathi *et al*. (1992). Khan *et al*. (1992) used data form 11 Sahiwal herds in Pakistan while Rehman and Khan (2012) and Reddy and Nagarcenkar (1989) used data from five

Sahiwal herds in Pakistan and India, respectively. For some of these herds, heritability estimates were close to zero as well. Low estimates have been reported for other breeds such as Gir and Kankrej.

Table 11. Repeatability estimates for service period in different breeds of dairy cattle

Breed	Country	N	Estimate	Reference
Sahiwal	Pakistan	875	0.22±0.03	Shah and Shah (1983)
Sahiwal	Pakistan	1749	0.34	Talbott *et al*. (1997)
Sahiwal	Pakistan	1928	0.09±0.03	Ahmad (1999)
Sahiwal	Pakistan	-	0.19	Javed (1999)
Sahiwal	Pakistan	5897	0.14±0.005	Rehman and Khan (2012)
Nagauri	India	147	0.08	Barhat and Chowdhary (1980)
Red Sindhi	India	160	0.22	Pundir and Singh (2007)

Table 12. Heritability estimates for service period in different breeds of dairy cattle

Breed	Country	N	Method*	Estimate	Reference
Sahiwal	Pakistan	1357	PHSC	0.357±0.098	Shah and Shah (1983)
Sahiwal	Pakistan	6000	PHSC	0.18±0.05	Khan *et al*. (1992)
Sahiwal	Pakistan	1928	REML	0.04±0.03	Ahmad (1999)
Sahiwal	Pakistan	1476	REML	0.042±0.032	Javed *et al*. (2001)
Sahiwal	Pakistan	5897	REML	0.04±0.020	Rehman *et al*. (2008)
Sahiwal	Pakistan	5897	REML	0.14±0.010	Rehman and Khan (2012)
Sahiwal	India	-	-	0.40±0.19	Reddy and Nagarcenkar (1989)
Sahiwal	India	-	-	0.03	Rathi *et al*. (1992)
Gir	Brazil	422	PHSC	0.045±0.101	Lobo *et al*. (1984a)
Kankrej	India	1527	PHSC	0.05±0.57	Chaudhary *et al*. (1995)
Red Sindhi	India	160	-	0.085±0.044	Pundir and Singh (2007)

Genetic Correlations among Different Performance Traits: The phenotypic and genetic correlations (r_g) among various performance traits have been reported by various workers but agreement between any two studies for any two traits is difficult to find. Lactation milk yield has been reported to have high genetic correlation (0.73) with 305-day milk yield (Rehman and Khan, 2012). Dahlin *et al*. (1998) reported that both the traits had perfect (0.99 to 1.00) correlation for first three parities but Gaur and Rao (1994) reported that coefficient was 0.76. Kimenye (1980) studied the genetic improvement in milk yield of Sahiwal cattle and determined the genetic correlation of the 1st- with 2nd-lactation milk yield 0.67, and genetic correlations of yields in the 1st and 2nd lactations with the yield in the 3rd lactation were 0.61 and 0.83, respectively. It was concluded that selection should be based on either the average of the first two records or the 2nd lactation only.

Genetic correlation between milk yield and age at first calving has also been studied by various workers. Ilatsia (2011) reported genetic correlation between these two triats was 0.17 in Kenyian Sahiwals. Gandhi and Gurnani (1988) reported that the r_g was -0.18 for Sahiwal in India, while it was zero in the study of Ahmad *et al*. (1971) for Sahiwal breed in Pakistan. Rehman *et al*. (2008) has complied information on phenotypic and genetic correlations among various productive and reproductive traits of Sahiwal cows in Pakistan. The phenotypic and genetic correlation between age at first calving and first lactation milk yield were 0.22 and 0.44, respectively. Javed *et al*. (2004) observed the phenotypic and genetic correlation between these two traits were 0.667 and 0.605, respectively.

Lactation length has also been reported to have moderate to high r_g with milk yield. Rehman *et al*. (2008) reported that lactation length has moderate genetic correlation (0.40) with lactation milk yield and 305-day milk yield. Javed *et al*. (2004) also reported similar genetic correlation (0.48) between first lactation milk yield and first lactation length. The genetic correlation between lactation length and 305-day milk yield was 0.48 (Rehman and Khan, 2012). Dahlin *et al*. (1998) reported that the two traits had r_g of 0.83 in first parity Sahiwal cows even higher than the phenotypic correlation of 0.71. The r_g decreased (0.70) in second parity and third parity (0.59) records. Mohiuddin *et al* (1991) on the other hand had reported that breeding values of lactation length and milk yield had poor association (0.16) while Sharma and Singh (1981) reported r_g of 0.39 between lactation length and milk yield.

Genetic Trends: Although, directional selection has not been reported in any study on Sahiwal, phenotypic

selection for breed characters of AI bulls from high producing dams has been reported (Bhatti, 2005). The genetic trends do indicate success and failure of selection strategy. Ahmad *et al*. (1978) analyzed the milk yield records of a Sahiwal herd and reported that for 1926-1966, there was slight improvement (1.2 kg/year) in lactation milk yield. Selection of bulls on the performance of progeny was suggested. Talbott *et al*. (1997) analysed data on performance records of Sahiwal cattle kept at Livestock Production Research Institute, Bahadurnagar, Okara (Pakistan) and observed no genetic improvement for milk yield in the herd during 1974-1985. Dahlin *et al*. (1998) analysed data on performance records of eleven Sahiwal herds in Pakistan collected during 1972-1985 and reported that there was no genetic change for milk yield. Similar trends were also observed for age at first calving and calving interval. Phenotypic deterioration in milk yield was noted over the years indicating managemental problems during the period under study. However, due to appreciable additive genetic variation, it was suggested that genetic improvement in traits like milk yield was possible.

Some workers in Pakistan estimated the breeding values and genetic trends for various performance traits in a Sahiwal herd. Javed *et al*. (2002) estimated breeding values for age at first calving, first lactation milk yield, milk yield considering all lactations, lifetime milk yield, lactation length and calving interval ranged from -91.71 to 93.76 days, -52.86 to 85.94 kg, -334.96 to 756.17 kg, -1414.20 to 2612.38 kg, -20.29 to 21.84 days and -72.50 to 78.35 days, respectively. Rehman *et al*. (2008) reported estimated breeding values for first lactation traits e.g. 305-day milk yield, total milk yield, lactation length, age at first calving, dry period, calving interval and service period were ranged from -125 to 181 kg, -110 to 160 kg, -27 to 41 days, -21 to 22 days, -40 to 34 days, -69 to 60 days and -27 to 33 days, respectively. Rehman and Khan (2012) reported estimated breeding values for all lactation traits e.g. 305-day milk yield, total milk yield, lactation length, dry period, calving interval and service period were ranged from -447 to 1254 kg, -442 to 1265 kg, -24 to 38 days, -78 to 116 days, -84 to 107 days and -81 to 91 days, respectively. Genetic change in milk yield was close to zero. Joshi and Singh (2005) has summarized various studies on Sahiwal herds indicating that some of the herds had positive genetic trend for first lactation milk yield while others had negative trend with average year change in breeding values ranging from -27 to 77 litres.

Conclusions: Genetic control of performance traits reported in the literature has been quite variable. Studies on Sahiwal cattle with large data sets are few and most of these studies pertain to the experiment stations where governmental inadequacies play important role for animals not to express various economic traits. Absence of selection except for phenotypic appraisals, reproductive reasons and diseases may be the reasons for variation exhibited by the cows. As indicated by the heritability estimates, most of the traits were governed by the environment. The temporary variation was so huge that additive variance was masked by its effect. A peculiar observation was high variation due to permanent environment in milk yield and age at first calving and little variation in calving interval, service period and dry period. Reproductive traits are generally expected to have low genetic control but yield traits have medium heritabilities. Lactation length adjustment does play an important role in squeezing variation. Projection of small lactations to a higher base makes lactation records unrealistic and exaggerates differences in EBVs. Genetic trend were expected to be close to zero because selection on EBVs has almost been missing in the herds. Genetic parameter estimates and trends in estimated breeding values are helpful in devising the strategy aiming to improve productivity of the breed. Wide variation in performance across and within herds keeps the hope alive. Selection of genetically superior animals may help improve the breed when recording of pedigree and performance is accurate and rational decisions are made for choosing and culling animals.

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