Influence of genetic and non-genetic factors on milk production in sahiwal cattle: A review

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ABSTRACT: India has about 48.12 million indigenous cattle out of total 190.90 million (37.28%) cattle population as per the all India livestock census, 2012. The trend in livestock population over decades showed that the composition of cattle population is in favor of crossbred/exotic cattle (increased by 20.18%) than the indigenous cattle (decreased by 8.94%). Thus improving the indigenous stock by proper selection is the need of the hour. Selection is mostly based on the milk production of the animal which is affected by various genetic and non-genetic factors. Sire, season of calving, period of calving, parity of animals, age group of animals etc affect the milk production. Adjustment of significant effect of non-genetic factors on milk production helps in accurate estimation of genetic parameters. The production traits reviewed in the article were monthly test day milk yield (MTDMY), 305 days milk yield (305MY) and lifetime milk yield (LTMY). Understanding the factors affecting milk production in Sahiwal cattle is essential to enhance the selection process and thus the productivity of indigenous cattle.

Key words: Genetic and non-genetic factors, lifetime milk yield, Sahiwal cattle, test day milk yield, 305 days milk yield

Livestock plays an important role in Indian economy by providing employment to about 8.8% of the population. Livestock resources contribute about 16% to the income of small farm households and an average of 14% for all rural households and provides livelihood to two-third of rural community. Its contribution to the GDP is 4.11% and to the total agricultural GDP is 25.6%. India has 190.90 million (37.28%) cattle as per the all India livestock census, 2012. The decade wise trend in livestock population (1997 to 2012) is quite unfavorable for our indigenous cattle which declined by 8.94% [1].

There are 43 registered breeds of cattle [2]. India ranks first in milk production with an annual output of 163.6 million tons in 2017. However, as far as the productivity per animal is considered it's very low. Various reasons for low productivity include poor genetic pool, unbalanced and inadequate nutrition, low quality animal health services, adverse climatic conditions, managemental inadequacy etc.

The productivity of indigenous dairy animals could be increased by combining proper managemental conditions along with early and accurate selection and breeding strategies. The milk production records of dairy animals serves as an important criteria in selecting animals to be the parents for next generation. The major prerequisite for any selection or breeding program is the knowledge of genetic properties of milk production. As a large number of genetic and non-genetic factors affect the milk production, so for accurate and unbiased estimates of genetic parameters, adjustment of effects of significant factors is important. This review deals with the effect of various genetic and non-genetic factors affecting the monthly test day milk yield (MTDMY), 305 days milk yield (305MY) and lifetime milk yield (LTMY) of Sahiwal cattle and their average values along with genetic parameters.

Average Values of Milk Production Traits

The average of different milk production traits of Sahiwal cattle as reviewed is as follows:

305 Days Milk Yield

The overall least squares means of 305 days milk yield in Sahiwal cattle varied from 1183.00–2585.00 Kg. Different researchers estimated the average value of 305 days milk yield as shown in Table 1.

Lifetime milk yield

The mean lifetime production in cattle as reported by various workers is presented in Table 1. There is no clear cut definition of lifetime production and different workers defined lifetime production differently. The period of lifetime taken varied from first 3 (Khanna and Bhat, 1971; Nagpal and Acharya, 1971; Reddy, 1983; Kumar, 2003) to first 8 lactations (Jadhav *et al*., 1991) or from 5 years (Chaudhry and Shafiq, 1995) to 10 years (Rao, 1985; Gandhi and Gurnani, 1990). The lifetime milk production ranged between 4192 ± 123.8 Kg (Pundir and Raheja, 1994) to 24,406 Kg (Gopal and Bhatnagar, 1972) in Sahiwal cattle.

Test day milk yield

In India mostly first lactation 305 days or less milk yield is used to select or cull the animals which is time and money consuming, leads to increased generation interval, decreased genetic gain per unit of time and also is based on less number of records. All these constraints may be overcome by using test day milk yield records at monthly interval (Kokate *et al*., 2013; Gupta, 2013; Singh, 2014, Pandey, 2018). The research work based on monthly test day milk yield records in Sahiwal is very limited. The average milk yields for different test days in Sahiwal cattle have been reviewed in Table 2.

Effect of Genetic and Non-Genetic Factors on Different Milk Production Traits

305 Days Milk Yield

The season of calving had significantly influenced ($P < 0.01$) FL305DMY in Sahiwal cattle (Singh, 1981) and Sahiwal crosses (Sain *et al*.,1988); whereas Mishra and Prasad (1994), Kannan, (2002), Kumar (2003), Banik (2004), Raja (2004), Bajetha (2006), Sentitula (2007), Kumar (2007), Kathiravan (2009) and Manoj (2009), Raja (2010), Debbarma *et al.* (2010), Dongre (2012), Mundhe (2012), Ved Prakash (2015) and Pandey (2018) reported that there is no-significant effect of season of calving on FL305DMY. Mohanty (2001) reported statistically significant effect ($P < 0.05$) of season of calving on this trait. According to his report animals that calved during winter season produced maximum milk (1574.76 ± 78.82 kg); whereas those animals calved during autumn season produced minimum milk (769.22 ±247.88 kg).

Many workers (Jain and Dhillon, 1975; Taneja and Sikka, 1981; Singh,1981; Jadhav *et al*., 1996; Tomar *et al*., 1996) reported significant influence of period of calving on FL305DMY ($P<0.05$); while Chawla and Mishra (1982) and Rao (1985) reported non-significant effect of period of calving on this trait. On the contrary, Kumar (2007), Sentitula (2007), Kathiravan (2009) and Manoj (2009), Raja (2010), Debbarma *et al.* (2010), Dongre (2012) reported highly significant ($P < 0.01$) effect of period of calving on this trait in Sahiwal (Table 3).

Age at first calving has significant influence on FL305DMY as reported by Banik (2004) whereas non-significant as per Mohanty (2001), Sentitula (2007), Raja (2010), Debbarma *et al.* (2010), Dongre (2012), Gupta (2013),Ved Prakash (2015) and Pandey (2018).

Lifetime milk yield

The effect of various non genetic factors *viz*. season of calving, period of calving, age at first calving on life time milk yield was studied thoroughly by many workers. Gandhi and Gurnani (1990) observed significant influence of season of first calving on lifetime milk yield in Sahiwal cattle but its effect was reported to be non significant by Pandey (2018). Similarly significant influence of period of first calving on lifetime milk yield in Sahiwal cattle was reported by Nagpal and Acharya (1971), Reddy (1983), Hegde and Bhatnagar (1985), Gandhi and Gurnani (1995), Pundir and Raheja (1997), Kannan (2002) and Kumar (2003). As per the findings of Pandey (2018), the effect of age group was highly significant on lifetime milk yield. She observed the highest life time milk yield (8871.48 Kg) in animals of age group- 1124 to 1204 days, however no definite trend was observed among the various age groups (Table 3).

Test day milk yield

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Test day milk yield

Earlier studies showed that the effect of different non genetic factors on different test days is quite different. Some test days are significantly affected whereas others not. Season of calving had significant effect on monthly test day milk yield one and six as reported by Debbarma *et al.* (2010) and on ninth and tenth monthly test day milk yield as reported by Pandey (2018). Dongre (2012) found that weekly test day milk yield five, thirteen and thirty eight were highly affected by season of calving. As per Gupta (2013), season of calving had highly significant effect on second, third, ninth and tenth monthly test day milk yield, had significant effect on fourth, fifth, seventh and eighth monthly test day milk yield whereas it had non-significant effect on first and sixth monthly test day milk yield. Similarly Ved Prakash (2015) also reported that different test days were affected differently by the season of calving. As per his reports season of calving had highly significant effect on third, fourth, sixth monthly test day

Table1: Average of first lactation 305 days or less milk yield (FL305DMY) and lifetime milk yield in Sahiwal cattle

FL305DMY		LTMY		
Mean± SE	**Reference**	**Period up to**	**Mean ± SE**	**Reference**
2218	Sundaresan *et al.* (1965)	3 lactations	5677.94±94.15	Khanna and Bhat (1971)
1596 ± 21	Nagpal and Acharya (1971)	5 lactations	10018.87±221.28	
2236.00±33.46	Gopal and Bhatnagar (1972)	3 lactations	5696±88	Nagpal and Acharya (1971)
2138.00±44.20	Chopra *et al.* (1973)	6 years	12044	
1597.23±31.19	Taneja (1974)	8 years	16270	Gopal and Bhatnagar (1972)
1929.87	Jain and Dhillon (1975)	10 years	24406	
1703	Taneja and Chawla (1978)	5 lactations	17652	
1602.50 ± 180.83	Basu *et al.* (1979)	3 lactations	5244	
2028.53 ± 51.17	Taneja and Sikka (1981)	5 lactations	8928	Reddy (1983)
1853.60 ± 33.32	Chawla and Mishra (1982)	7 lactations	12921	
1183.00 ± 31.00	Shah *et al.* (1982)	10 years	13908.99±174.45	Rao (1985)
2083.75 ± 32.91	Bhatnagar *et al.* (1983)	5 years	2555.67±35.02	
1553.44 ±32.64	Singh (1986)	8 years	7884.85±117.93	Gandhi and Gurnani (1990)
2106.95 ± 28.94	Gandhi and Gurnani (1988)	10 years	10793.84±135.83	
1502.7	Khan *et al.* (1992)	4 lactations	4246.68±224.84	Deulkar and Kothekar (1999)
1877.11 ± 33.44	Mishra and Prasad (1994)	6 years	6391.06±219.20	Kannan (2002)
2585.0 ± 86.0	Tomar *et al.* (1996)	9 years	13455±587	
1755.0 ± 615.6	Ahmad *et al.* (2001)	3 lactations	6546.86±157.10	Kumar (2003)
1365.93 ± 81.46	Mohanty (2001)	4 lactations	8932.63±221.14	
1511.06 ± 29.42	Singh *et al.* (2001)	5 lactations	11009.87±306.47	Kumar (2007)
1714.09 ± 48.29	Kannan (2002)	-	9533.99±81.69	
1494.29 ± 69.71	Kumar (2003)	5 lactations	6430.37±72.57	Kathiravan (2009)
1491.64 ± 49.91	Naskar (2003)	4 lactations	7105.42±0.21	Pandey M (2018)
1496.36 ± 19.72	Banik (2004)	-	-	-
1756.41 ± 47.61	Raja (2004)	-	-	-
1622.59±106.01	Dubey and Singh (2005)	-	-	-
2052.93±206.96	Singh *et al.* (2005)	-	-	-
1759.99 ± 43.52	Kumar (2007)	-	-	-
1756.41± 47.61	Raja and Narula (2007)	-	-	-
1721.30 ± 36.50	Sentitula (2007)	-	-	-
1393.00 ± 11.70	Rehman *et al.* (2008)	-	-	-
1894.11 ± 47.79	Manoj (2009)	-	-	-
1834.27 ± 36.89	Debbarma *et al.*(2010)	-	-	-
1759.86 ± 43.65	Raja (2010)	-	-	-
1846.55±44.31	Dongre (2012)	-	-	-
2189.16±47.60	Mundhe (2012)	-	-	-
1885.60±25.44	Gupta (2013)	-	-	-
1990.78±41.67	Ved Prakash (2015)	-	-	-
1844.16±0.17	Pandey M (2018)	-	-	-

milk yield, had significant effect on second, fifth, seventh, ninth monthly test day milk yield and non significant effect on first, eighth and tenth monthly test day milk yield.

The effect of period of calving was reported to be highly significant on all weekly test day milk yields by Dongre (2012). Findings of Gupta (2013) indicated significant effect of period of calving on all monthly test day milk yields.

Age at first calving was reported to have significant effect on monthly test day milk yield second, sixth, tenth by Debbarma *et al.* (2010), monthly test day milk yield second, third by Gupta (2013), monthly test day milk yield second and sixth by Ved Prakash (2015) and monthly test day milk yield fourth by Pandey (2018).

Heritability Estimates

Heritability plays a very important role in predicting the genetic worth as well as the genetic improvement expected from any selection program. The heritability estimates as reviewed in Sahiwal breed of cattle for milk production traits are presented in Table 4.

Khan *et al.* (2008) reported heritability estimates of 0.024 ± 0.046 for MTDMY in Sahiwal. Debbarma *et al.* (2010) reported the heritability ranging from 0.05±0.07 (MTDY-

Table 2: Mean ± SE of different test days in Sahiwal cattle

	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
TD1	6.0 ± 0.0	6.1 ± 0.10	4.88 ± 0.14	5.41 ± 0.09	5.12 ± 0.09	4.54±0.13
TD2	6.4 ± 2.6	6.4 ± 0.12	7.8 ± 0.16	8.22 ± 0.11	8.14 ± 0.11	8.06±0.15
TD3	5.6 ± 2.5	6.0 ± 0.12	7.75 ± 0.15	8.08 ± 0.11	8.08 ± 0.10	8.28±0.15
TD4	4.8 ± 2.3	5.7 ± 0.11	7.38 ± 0.14	7.61 ± 0.10	7.52 ± 0.10	7.77±0.17
TD5	4.2 ± 2.1	5.3 ± 0.11	7.01 ± 0.14	7.23 ± 0.10	6.99 ± 0.09	7.27±0.15
TD6	3.7 ± 1.9	4.9 ± 0.12	6.54 ± 0.13	6.77 ± 0.10	6.57 ± 0.09	6.76±0.15
TD7	3.4 ± 1.8	4.8 ± 0.12	6.34 ± 0.13	6.50 ± 0.11	6.22 ± 0.09	6.48±0.14
TD8	3.0 ± 0.0	4.8 ± 0.14	6.15 ± 0.13	6.23 ± 0.11	5.99 ± 0.09	6.21±0.13
TD9	-	4.6 ± 0.14	6.07 ± 0.13	6.02 ± 0.11	5.76 ± 0.09	5.92±0.15
TD10	-	4.3 ± 0.18	5.73 ± 0.12	5.63 ± 0.12	5.42 ± 0.09	5.71±0.13
TD11	-	-	-	-	-	5.63±0.12
Reference	Ilatsia *et al.* (2007)	Bilal *et al.* (2008)	Debbarma*et al*.(2010)	Gupta (2013)	Ved Prakash (2015)	Pandey (2018)

Table 3: Effect of non genetic factors on FL305DMY or less milk yield (Kg) in Sahiwal cattle

Season of calving	Period of calving	AFC	References
NS	S	-	Nagpal and Acharya (1971)
-	S	-	Jain and Dhillon (1975)
NS	NS	-	Basu *et al.* (1979)
S	S	-	Singh *et al.* (1981)
NS	S	-	Taneja and Sikka (1981)
S	NS	-	Chawla and Mishra (1982)
NS	S	-	Singh (1986)
-	S	-	Yadav *et al.*(1992)
S	-	-	Mishra and Prasad (1994)
-	S	-	Tomar *et al.* (1996)
S	S	-	Mohanty (2001)
NS	S	-	Kumar (2003)
NS	S	-	Banik (2004)
NS	S	-	Kannan and Gandhi (2004)
NS	S	-	Dubey and Singh (2005)
NS	S	-	Singh *et al.* (2005)
NS	S	-	Kumar (2007)
-	S	NS	Raja and Narula (2007)
NS	S	S	Sentitula (2007)
NS	S	S	Manoj (2009)
NS	S	NS	Debbarma *et al.*(2010)
NS	S	NS	Raja (2010)
S	NS	-	Dongre (2012)
S	NS	NS	Mundhe (2012)
NS	-	NS	Gupta (2013)
NS	-	NS	Ved Prakash (2015)

6) to 0.36±0.14 (MTDY-245) in Sahiwal cattle. Rashia (2010) reported that heritability estimate was lowest for MTDY-1 (0.12±0.06) and highest for MTDY-3 and MTDY-5 (0.44±0.09).

Cobuci *et al.* (2011) obtained heritability values which increased from beginning until 210-240 days of lactation and decreased thereafter to end of lactation. Using multiple regression for fixed lactation curve, the heritability estimates for first, second and third lactations were 0.22-0.32, 0.11-0.21 and 0.10- 0.19 respectively. Dongre (2012) worked on weekly test day milk yields in Sahiwal and found that the heritability ranged from 0.005±0.079 (WTDMY1) to 0.441±0.143 (WTDMY5). Gupta (2013) reported the heritability estimates of monthly test day yield ranging from 0.244 ± 0.127 (MTDMY8) to 0.463 ± 0.172 (MTDMY10), 0.137 ± 0.063 (MTDMY7) to 0.428 ± 0.117 (MTDMY 10) and 0.157 ± 0.087 (MTDMY 5) to 0.467 ± 0.103 (MTDMY 4) for first, second, third lactation respectively.

Ved Prakash (2015) reported the heritability estimates ranging from 0.01 to 0.10 for first, 0.04 to 0.26 for second and 0.07 to 0.26 for third lactation using RRM-HOM and 0.012 to 0.109 for first, 0.046 to 0.263 for second and 0.065 to 0.146 for third lactation using RRM-HET in Sahiwal cattle. As reported by Pandey (2018) the heritability of monthly test day milk yields ranged from

Table 4: Heritability estimates of FL305DMY and LTMY in Sahiwal cattle.

FL305DMY			LTMY		
Method	**Heritability**	**Reference**	**Period up to**	**Heritability**	**Reference**
ISRD	0.36±0.10	Gopal and Bhatnagar (1972)	3 lactations	1.00±0.56	Khanna and Bhat (1971)
ISRD	0.58 ± 0.56	Chopra *et al.* (1973)	5 lactations	0.92±0.63	-
HS	0.48 ± 0.26	Singh (1977)	6 lactations	0.07±0.28	Gopal and Bhatnagar (1972)
HS	0.55 ± 0.16	Singh (1981)	-	0.15±0.09	Bhatia (1980)
HS	0.27 ± 0.23	Singh (1981)	10 lactations	0.21±0.27	Rao (1985)
HS	0.08 ± 0.14	Singh (1981)	5 lactations	0.49±0.03	Singh (1986)
HS	0.04 ± 0.08	Singh (1981)	8 lactations	0.73±0.54	-
HS	0.39 ± 0.03	Singh (1981)	10 lactations	0.43±0.06	-
-	0.27 ± 0.06	Wakhungu *et al.* (1991)	-	0.23	Gandhi and Gurnani (1988)
HS	0.16 ± 0.04	Khan *et al.* (1992)	-	0.33±0.19	Pundir and Raheja (1994)
HS	0.32 ± 0.16	Yadav *et al.* (1992)	-	0.15±0.11	Pundir and Raheja (1997)
HS	0.27	Gandhi and Gurnani (1995)	-	0.55±0.31	Pundir and Raheja (1997)
HS	0.37 ± 0.07	Gandhi and Gurnani (1995)	4 lactations	0.20±0.03	Deulkar and Kothekar (1999)
HS	0.77 ± 0.37	Tomar *et al.* (1996)	6 lactations	0.40±0.36	Kannan (2002)
REML	0.14 ± 0.02	Dahlin *et al.*(1998)	-	0.23±0.06	Bajetha (2006)
HS	0.44 ± 0.22	Mohanty (2001)	-	0.18±0.05	Kumar (2007)
HS	0.63 ± 0.26	Kannan (2002)	5 lactations	0.042±0.066	Kathiravan (2009)
HS	0.21 ± 0.18	Kumar (2003)	4 lactations	0.34 ± 0.07	Pandey (2018)
HS	0.22 ± 0.07	Banik (2004)	-	-	-
HS	0.24 ± 0.14	Banik (2004)	-	-	-
HS	0.60 ± 0.12	Banik (2004)	-	-	-
HS	0.56 ± 0.19	Raja (2004)	-	-	-
HS	0.69 ± 0.12	Dubey and Singh (2005)	-	-	-
HS	0.956 ± 0.24	Singh *et al.* (2005)	-	-	-
REML	0.22 ± 0.04	Ilatsia *et al.* (2007)	-	-	-
HS	0.29 ± 0.07	Kumar (2007)	-	-	-
REML	0.11 ± 0.029	Rehman *et al.* (2008)	-	-	-
HS	0.061 ± 0.068	Kathiravan (2009)	-	-	-
HS	0.2512 ± 0.12	Manoj (2009)	-	-	-
HS	0.22 ± 0.07	Banik and Gandhi (2010)	-	-	-
HS	0.24 ± 0.14	Banik and Gandhi (2010)	-	-	-
HS	0.60 ± 0.12	Banik and Gandhi (2010)	-	-	-
HS	0.36 ± 0.13	Debbarma *et al.* (2010)	-	-	-
HS	0.35 ± 0.13	Raja (2010)	-	-	-
HS	0.54 ± 0.15	Dongre (2012)	-	-	-
HS	0.17 ± 0.14	Mundhe (2012)	-	-	-
HS	0.54 ± 0.15	Gupta (2013)	-	-	-
RRM-HOM	0.073	Ved Prakash (2015)	-	-	-
HS	0.40 ± 0.09	Pandey (2018)	-	-	-

0.12 ± 0.06 (TD10) to 0.48 ± 0.09 (TD4).

CONCLUSION

Accurate identification of genetically superior animals is the basis of genetic improvement of any breeding program. Selection is generally based on the records of milk production. Besides the genetics that play an important role in determining the milk production of an animal, environment too plays its role in creating variations in the level of production. As per review, all important genetic and non-genetic factors like sire, season of calving, period of calving and age group of animals had significant influence on the production levels in Sahiwal cattle. Significant effect of sire on production level suggests that superior sires can effectively improve lactation in Sahiwal cattle. Differences in management and environmental conditions such as temperature, rainfall, humidity etc contribute to differences in production levels in different periods and seasons of calving. So, for accurate and unbiased estimates of genetic parameters, adjusting the effect of genetic and non-genetic factors is mandatory.

REFERENCES

Ahmad, M., Werf, J.H.J. Van Der and Javed, K. (2001). Genetic and phenotypic correlations for some

economic traits in dairy cattle. *Pakistan. Vet. J*., 21(2): 81-86. (Cited: Anim. Breed. Abstr). 70 (5): 2703.

Bajetha, G. (2006). Sire evaluation of Sahiwal and crossbred cattle. Ph.D. Thesis, G.B.Pant Univ. Agric. & Tech., Pantnagar, India.

Banik, S. (2004). Sire evaluation in Sahiwal cattle. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India.

Banik, S. and Gandhi, R. S. (2010). Estimation of genetic parameters in Sahiwal cattle using single and multi-trait restricted maximum likelihood method. *Indian J. Anim. Sci*., 80(3): 266-268.

Basu, S.B., Bhatnagar, D.S., Taneja, V.K. and Rao, V.P. (1979). Comparative performance of Indian dairy herds. *Indian J. Dairy Sci.,* 32 (4): 497-499.

Bhatia, S.S. (1980). Note on the selection for lifetime milk production in Sahiwal cattle. *Indian J. Anim. Sci.,* 50 (5): 450-453.

Bhatnagar, D.S., Taneja, V.K., Basu, S.B. and Murthy, K.M.K. (1983). Genetic parameters for some economic traits in Sahiwal cattle. *Indian J. Dairy Sci.,* 36(4): 402-406

Bilal, G., Khan, M. S., Bajwa I. R. and Shafiq, M., (2008). Genetic control of test-day milk yield in Sahiwal cattle. *Pakistan Vet. J*., 28(1): 21-24.

Chaudhry, M.Z. and Shafiq, M. (1995). Life time production performance of Holstein Friesian X Sahiwal crossbreds. *Asian Aust. J. Anim. Sci.,* 8 (5): 499-503.

Chawla, D. S. and Mishra, R. R. (1982). Non-genetic factors affecting production traits in Sahiwal cattle. *Indian Vet. J.,* 59(1): 44-48.

Chopra, R.C., Bhatnagar, D.S and Gurnani, M. (1973). Influence of service period on lactation length and lactation yield in Sahiwal, Red Sindhi and Brown Swiss crossbred cows. *Indian J. Dairy Sci.,* 26(4): 263-269.

Cobuci, J. A., Costa, C.N., Neto, J.B. and Freitas, A. F. de. (2011). Genetic parameters for milk production by using random regression models with different alternatives of fixed regression modeling. *R. Brasil. zootec*., 40(3): 557-567

Dahlin, A., Khan, U.N., Zafar, A.H., Saleem, M., Chaudry, M.A. and Philipsson, J. (1998). Genetic and environmental causes of variation in milk production traits of Sahiwal cattle in Pakistan. *Anim. Sci*., 66(2): 307-318

Debbarma, M., Gandhi R.S., Raja, T.V. Singh A and Sachdeva, G.K.. (2010). Influence of certain non-genetic factors on test day milk records in Sahiwal cattle. *Indian J. Dairy Sci*., 63(6): 504-506.

Deulkar, P.B. and Kothekar, M.D. (1999). Sire evaluation considering first lactation yield for improvement of lifetime production in Sahiwal. *Indian J. Anim.Sci*., 69 (4): 240-242

Dongre, V.B. (2012). Modeling lactation curve for sire evaluation in sahiwal cattle. Ph.D. Thesis, NDRI, Karnal, India.

Dubey, P.P. and Singh, C.V. (2005). Estimates of genetic and phenotypic parameters considering first lactation and lifetime performance traits in Sahiwal and crossbred cattle. *Indian J. Anim. Sci.,* 75(11): 1289-1294.

Gandhi, R.S. and Gurnani, M. (1988). Association amongst different productive and reproductive traits in Sahiwal cattle. *Asian J. Dairy Res.,* 7(3): 171-174.

Gandhi, R.S. and Gurnani, M. (1990). Breeding efficiency and producing ability as contrasting

Gandhi, R.S. and Gurnani, M. (1995). Lactation-wise heritabilities of some economic traits in Sahiwal cattle. *Indian J. Dairy Sci.,* 48 (1):75-77.

Gopal, D. and Bhatnagar, D.S. 1972. The effect of age at first calving and first lactation yield on lifetime production in Sahiwal cattle. *Indian J. Dairy Sci.,* 25: 129-133

Gupta, A.K. 2013.Genetic evaluation of Sahiwal cattle using lactation curve models. Ph.D. Thesis, NDRI (Deemed University), Karnal, Haryana, India.

Hegde, M. and Bhatnagar, D.S. (1985). Lifetime performance of different genetic groups of Brown Swiss crossbred cows. *Indian J. Dairy Sci*., 38 (4): 321-325.

Ilatsia, E. D., Muasya, T. K., Muhuyi, W. B. and Khai, A. K. (2007). Genetic and phenotypic parameters for test day milk yield of Sahiwal cattle in semi arid tropics. *Animal 1*: 185 – 192.

Jadhav, K. L., Tripathi, V. N. and Kale, M. M. (1996). Incidence and economics of various health disorders in crossbred cows. *Indian J. Anim. Prod. Mgmt*., 12(1): 45-50

Jadhav, K.L., Tripathi, V.N., Taneja, V.K. and Kale, M.M. (1991). Performance of variousHolstein X Sahiwal grades for first lactation reproduction and production traits. *Indian J. Dairy Sci*., 44 (3): 209-211.

Jain, A. K and Dhillon, J. S. (1975). Comparative performance of Sahiwal and Holstein-Friesian x Sahiwal crossbreds. *Punjab Univ. J. Res*., 12: 180-183.

Kannan, D. S. (2002). Lifetime performance evaluation of Sahiwal cattle. M. Sc. Thesis, NDRI, Karnal, India

Kathiravan, P. (2009). Genetic evaluation of lifetime performance of Sahiwal cattle. Ph.D. Thesis, NDRI, Karnal, India.

Khan, M. S., Bilal, G., Bajwa, I. R., Rehman, Z. and Ahmad S. (2008). Estimation of breeding values of Sahiwal cattle using test day milk yields. *Pakistan Vet. J.,* 28(3): 131-135.

Khan, U.N., Olsson, A., Philipsson, J., Bunyavejchewin, P., Sangdid, S. and Hangsanet, K. (1992). Sahiwal breed development in Pakistan. Animal production and Rural Development. Proceedings of the Sixth AAAP Anim. Sci. Cong. Vol. I. Pp. 171-178.

Khanna, R.S. and Bhat, P.N. (1971). The genetic architecture of Sahiwal cattle. *Indian J. Animal Sci.,* 41(12): 1091-1098.

Kokate,S., Singh, A., Banu, R., Gandhi, R. S., Chakravarty, A. K.., Gupta, A. K . and Sachdeva, G. K., (2013).Genetic and non-genetic factors affecting monthly test day milk yields in Karan Fries cattle. Indian *J. Animal Sci*., 83 (4): 385–389.

Kumar, A. (2007). Genetic analysis of stayability in Sahiwal cattle. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India

Kumar, V. (2003). Prediction of lifetime milk and milk constituents yield from first lactation traits in Sahiwal cattle. M. Sc. Thesis, NDRI, Karnal, India

Manoj, M. (2009). Evolving multi-trait selection criteria using body weights and first lactation traits in Sahiwal cattle. M.V.Sc. Thesis, NDRI, Karnal, India.

Mishra, A.K. and Prasad, R.B. (1994). Peak yield effect on first lactation economic traits in Sahiwal. Indian J. Dairy Sci. 47(9): 727-729.

Mohanty, J.S. (2001). Principal component analysis: A multi trait selection criterion in Sahiwal cattle. M.Sc. Thesis, NDRI, (Deemed University), Karnal, India

Mundhe U.T. (2012). Part lactation records for sahiwal cow Evaluation M.V.Sc. Thesis, NDRI, (Deemed University), Karnal, India

Nagpal, M. P. and Acharya, R. M. (1971). Studies on Sahiwal dairy herd records: Effect of non-genetic factors. *Indian J. Anim. Sci*., 41(7): 515-520.

Naskar, S. (2003). Path analysis of economic traits of Sahiwal cattle. M.Sc. Thesis, NDRI, (Deemed University), Karnal, India.

Pandey, M. (2018). Prediction of first lactation 305 days and lifetime milk yield using test day milk records in Sahiwal cattle. M.V.Sc. Thesis, NDRI, Karnal, India.

Pundir, R.K. and Raheja, K.L. (1994). Direct and correlated responses to selection in the first lactation and lifetime traits in Hariana and Sahiwal cows. *Indian J. Dairy Sci*., 48 (2): 150-153

Pundir, R.K. and Raheja, K.L. (1997). Genetic parameters estimation for first lactation and lifetime traits in Sahiwal and Hariana using multi trait maximum likelihood. *Indian J. Dairy Sci*., 50 (5): 359-366.

Raja, K. N. and Narula H.K. (2007). Effects of non-genetic factors on production traits of Sahiwal cattle. *Indian Vet. J.,* 84(4): 374-376.

Raja, K.N. (2004). Genetic and phenotypic trends for production and reproduction performance of Sahiwal cattle. M.V.Sc. Thesis, NDRI, (Deemed University), Karnal, India.

Raja, T. V. (2010). Part lactation records for Sahiwal sire evaluation. Ph.D. Thesis, NDRI, Karnal, India.

Rao, D. S. (1985). Sire evaluation on the basis of multiple traits in Sahiwal. M. Sc. Thesis, Kurukshetra University, Kurukshetra, India.

Rashia Banu N. (2010). Genetic evaluation of the lactation curve in Karan Fries cattle. Ph. D. Thesis, NDRI, Karnal, India.

Reddy, K.M. (1983). Breed structure and genetic analysis of pedigreed Sahiwal cattle. Ph.D.Thesis, Kurukshetra University, Kurukshetra, India.

Rehman, Z.U., Khan, S.M., Bhatti, S.A. and Iqbal, J. (2008). Factors affecting first lactation performance of Sahiwal cattle in Pakistan. *Arch. Tierz. Dummerstorf*., 51 (4): 305-317

Sain, K., Singh, R.V., Singh, C.V. and Singh, Y.P. (1988). Age at first calving affecting thelactation traits during first three lactations in F1 crossbred cows. *Livestock Advisor*, 13(8): 5-10.

Sentitula, (2007). Ascertaining periodicity in Sahiwal data through time series analysis. M. V. Sc. Thesis, NDRI, Karnal, India.

Shah, S. I., Shah, S. K., Tahir, M. and Ahmad, N. (1982). Comparative production performance of pure and crossbred Sahiwal cows under subtropical environment. *Pakistan Vet. J.,* 2(4): 176-178. (Cited: Anim. Breed. Abstr.55: 2359).

Singh, A. (2014). Genetic evaluation of Karan Fries cattle using test day milk yields by random regression models. M.V.Sc.Thesis, NDRI (Deemed University)

Singh, D. (1977). Genetic architecture of growth in relation to lactation performance in Sahiwal and its crosses in Northern India. Ph.D. Thesis, Punjab University, Chandigarh, India.

Singh, R. (1986). Selection of optimum combinations of early traits for maximizing genetic improvement in dairy cattle. Ph.D. Thesis, Kurukshetra University, Kurukshetra, India.

Singh, R., Arora, V.K. and Goel, R. (2001). Genetic studies on first lactation traits of Sahiwal cattle. *Indian J. Anim. Res.,* 35 (2): 147-149.

Singh, S. K. (1981). Herd size and its influence on genetic change for economic traits in Sahiwal. Ph.D. Thesis, Kurukshetra University, Kurukshetra, India.

Singh, V.K., Singh, C.V., Kumar, D. and Kumar, A. (2005). Genetic evaluation of some economic traits in Sahiwal and its crossbreds. *Indian J. Dairy Sci.,* 58: 206-210.

Sundaresan, D., Ray, S.N. and Iya, K.K. (1965). The performance of the dairy herds at the National Dairy Research Institute, Karnal. *Indian J. Dairy Sci*. 18(1): 34-44.

Taneja, V. K. and Chawla, D.S. (1978). Heterosis for economic traits in Brown Swiss-Sahiwal crosses. *Indian J. Dairy Sci.*, 31(1): 208-213.

Taneja, V.K. (1974). Comparative study of various economic traits in indigenous cattle. *J.N.K.V.V. Res. J.,* 8: 68-69.

Taneja, V.K. and Sikka, A.K. (1981). Factors affecting some economic traits in Indian dairy breeds. *Indian J. Dairy Sci.,* 34(3): 347-349.

Tomar, A. K., Prasad, R. B. and Bhadula, S. K. (1996). First lactation performance of Holstein, Sahiwal and their half-breds in Tarai region of Northern India. *Indian J. Anim. Res*., 30 (2): 129-133.

Ved Prakash. (2015). Genetic evaluation of Sahiwal cattle using test day milk yield models. Ph.D. Thesis, NDRI, (Deemed University), Karnal, India.

Wakhungu, J.W., Rege, J.E.O. and Itulya, S. (1991). Genetic and phenotypic parameters and trends in production and reproduction performance of the Kenyan Sahiwal cattle. Bulletin Anim. Health Prod. Africa 39(4): 365-372. (Cited: Anim. Breed. Abstr.) 61(1): 130.

Yadav, A.S., Rathi, S.S., Dahiya, S.P. and Arora, D.N. (1992). Factors affecting some performance traits in Sahiwal cattle. *Indian J. Dairy Sci*., 45(10): 522-527.

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