GENETIC AND PHENOTYPIC CORRELATIONS AMONG LINEAR TYPE TRAITS IN SAHIWAL COWS

Musarrat Abbas Khan, Muhammad Sajjad Khan and Arshad Iqbal[1]
Department of Animal Breeding and Genetics, University of Agriculture Faisalabad
[1]Department of Livestock Management, University of Agriculture Faisalabad

The objective of the present study was to find phenotypic and genetic correlations among linear type traits in Sahiwal cows. The 15 linear type traits recommended by the International Committee for Animal Recording for dairy cattle were recorded for 310 Sahiwal cows over a period of one year at three institutional herds in Pakistan. These cows were progeny of 53 sires. Cows were recorded for the linear traits on a scale of 1-9 at the start, mid and towards end of lactation (provided cows were still in milk). A multiple trait animal model was utilized for estimation of (co)variances components. It included fixed effects of herd (three), parity group (two: 1st and later) and stage of lactation (three: start, mid and end). The random animal effect was also fitted and all the known relationships were accounted for. Phenotypic correlations among body and feet and legs traits were in low to medium range. Correlations ranged from -0.17±0.05 between body depth and foot angle to 0.55±0.03 between body depth and thurl width. Feet and legs traits showed very low or negative genetic correlation with body traits and among themselves. Genetic correlations among udder traits were in low to medium range. Rear udder height, for example, showed negative genetic correlation with stature, chest width and body depth. Therefore, care is needed to avoid deterioration among undesirably negatively associated traits. This information should, however, be considered preliminary because of smaller data set.

Keywords: Genetic and phenotypic correlations, linear traits, Sahiwal cows

INTRODUCTION

One of the best known Zebu breed is the Sahiwal cattle of Pakistan. It is considered to be one of the most productive of the *Bos indicus* species for tropical environments and has been suggested as model for developing dairy programs in less developed countries (Talbott, 1994). The main recorded population of Sahiwal cattle in Pakistan is found at Government Livestock Farms in public sector. The cows are recorded for their productive and reproductive performance. The bull calves are selected on the basis of milk yield of their dams (Bhatti *et al.*, 2007). A breed improvement program for genetic improvement in lactation milk yield has recently started.

There is an increasing interest at the farmer level to broaden the breeding objectives and to include more traits of economic importance, especially the conformation traits (Khan, 2007). Basic information on linear type traits recommended by the International Committee for Animal Recording (ICAR, 2003) was collected. Recording a large number of type traits needs a lot of financial input and trained personnel. Also, a large number of traits cannot be included in selection indices for selection at one and the same time when recording for traits such as milk yield is being experienced at small-holder set up. Information on genetic parameters of traits of interest can help narrow down recording and genetic selection parameters and help in sustainability of such programs.

Several studies are available on genetic parameter estimates on conformation traits for different dairy cattle breeds in various countries. Most of these studies pertain to developed breeds of *Bos taurus* type. Wiggans *et al.* (2004) reported animal model estimates of heritabilities of and genetic and phenotypic correlations for 15 linear type traits of Ayrshire, Brown Swiss and Guernsey and 14 traits for Jersey. Such estimates for udder traits were reported by Rupp and Boichard (1999) for French Holsteins. Earlier, Gengler *et al.* (1997) reported genetic parameters for linear type traits for US Jersey cows while Harris *et al.* (1992) reported genetic and phenotypic correlations among type traits of Guernsey cows using a sire model. Heritability estimates of linear type traits for Holstein cows with sire model have also been reported (Thompson *et al.*, 1981). Additive variance components estimated with different methods for linear type traits have been reported for Jerseys (Thomas *et al.*, 1985). Dahiya (2005; 2005a) has recently reported inheritance pattern for 13 linear type traits for Sahiwal and Hariana cattle using paternal half-sib correlations. For tropical cattle breeds, therefore, studies on genetic control of type traits and genetic correlations among them are very limited. Such data are not available because infrastructures to record and genetically select cattle for type traits do not exist in developing setups. Information on genetic control of linear type traits and association among the type traits is lacking for Sahiwal cattle breed. Such information is likely to be helpful for designing breeding strategies for genetic improvement programs. The present study was thus planned to get heritability estimates for linear type traits and to find out genetic correlations among linear type traits.

MATERIALS AND METHODS

The present study was started in October 2005 at three Government livestock farms in Punjab (Pakistan). These farms included: Livestock Experiment Station, Bahadurnagar, District Okara; Livestock Experiment Station, Jahangirabad, District Khanewal and Livestock Experiment Station, Khizerabad, District Sargodha. These herds in public sector are major source of future breeding bulls. The information on linear type traits lacking previously has been generated following the guidelines provided by International Committee for Animal Recording (ICAR, 2003). Two additional traits (rear udder width and thurl width) were also recorded. The linear type traits included were:

1. Stature
2. Chest width
3. Body depth
4. Angularity
5. Rump angle
6. Rump width
7. Rear legs set
8. Rear legs rear view
9. Foot angle
10. Fore udder attachment
11. Rear udder height
12. Central ligament
13. Udder depth
14. Teat placement rear view
15. Fore teat length
16. Rear udder width
17. Thurl width

For these traits, 310 freshly calved cows from first to fifth lactation were selected from all three farms. The cows were progeny of 53 sires. Cows were recorded for the linear traits on a scale of 1-9 at the start, mid and towards end of lactation (provided cows were still in milk). Information on birth and calving records and pedigree was collected from history sheets of these cows maintained routinely at these farms where a separate page has been allocated for each cow. The final data set consisted of 790 observations on 310 cows.

A multiple trait animal model was utilized for estimation of (co)variances. It included fixed effects of herd (three), parity group (two: 1st and later) and stage of lactation (three: start, mid and end). The linear and quadratic effects of age at classification of cow and interaction effect of parity by stage of lactation were fitted in initial analysis but interaction effects were dropped from the final analyses as they were non-significant. The random animal effect was also fitted and all the known relationships were accounted for. Variance parameters were estimated using residual or restricted maximum likelihood (REML) procedures developed by Patterson and Thompson (1971). The ASReml (Version 2.0) was used for analysis (Gilmour *et al.*, 2007).

RESULTS

The genetic correlations among linear type traits are presented in Table 1. A diverse picture of genetic correlations was seen from this study. In general, magnitude and direction of correlations was not very different from that reported in literature. The correlations bear both negative and positive signs.

The genetic correlations among body traits possessed positive signs with exception of that between chest width and rump angle (-0.13±0.07) and rump angle and thurl width (-0.16±0.07). The correlations ranged from -0.13±0.07 between chest width and rump angle to as high as 0.71±0.04 between body depth and thurl width. The genetic correlations were less than 0.10 between angularity and stature and chest width. Correlations in medium to high range were of stature with chest width (0.43±0.05), body depth (0.64±0.04), thurl width (0.58±0.05), and of chest width with body depth (0.56±0.05), thurl width (0.60±0.05) and of body depth with angularity (0.47±0.06). Rump width had correlation of (0.35±0.06) with stature and (0.31±0.06) with body depth and 0.33±0.06 with thurl width. Most of correlations of rump angle with body traits were in low range.

The correlations among feet and leg traits were very low. Rear legs set had zero genetic correlation with rear legs rear view. Rear legs rear view had correlations of magnitude -0.03±0.07 with foot angle. The correlation between foot angle and rear legs set was 0.09±0.07.

Correlations between body traits and feet and leg traits were usually small. Maximum correlation (0.22±0.06) was observed between chest width and rear legs rear view and between angularity and rear legs set (0.20±0.07). Highest negative correlation (-0.24±0.06) was found between chest width and rear legs set and body depth and foot angle. Most of other correlations between body and feet and legs traits were less than 0.10 in both directions.

Diverse correlations among udder traits with both positive and negative values were observed. The correlations ranged from -0.65±0.06 between rear udder width and udder depth to 0.47±0.06 between udder depth and rear udder height. Other correlations with positive values and in medium range were of fore udder attachment with udder depth (0.40±0.06), teat placement rear view (0.40±0.05) and between rear udder height and udder depth (0.47±0.06) and central ligament and rear udder width (0.39±0.07) and between fore teat length and rear udder width (0.45±0.07). Negative correlations of reasonable magnitude were between udder depth and central ligament (-0.40±0.06), of fore teat length with udder depth (-0.42±0.05) and between rear udder height and rear udder width (-0.48±0.09).

Direction and magnitude of genetic correlations between body traits and udder traits was also variable. There was a range of correlation from (-0.68±0.05) between thurl width and rear udder height to (0.62±0.07) between body depth and rear udder width.

The phenotypic correlations along with standard errors among linear type traits are presented in Table 2.

Phenotypic correlations among body and feet and leg traits were in low to medium range. Correlations ranged from -0.17±0.05 between body depth and foot angle to 0.55±0.03 between body depth and thurl width. Most of the body traits were phenotypically positively correlated with only exception of correlation between chest width and rump angle -0.07±0.05. The correlations in medium range were between stature and chest width (0.35±0.04), body depth (0.50±0.04), rump width (0.27±0.05), thurl width (0.45±0.04) and between chest width and body depth (0.42±0.04), thurl width 0.43±0.04 and of body depth with angularity (0.52±0.03). Most of other correlations among body traits were less than 0.20 and were negligible .Correlations among feet and legs traits were in lower range with magnitude less than 0.10. Rear legs rear view and rear legs set had a correlation of magnitude (0.00). Correlations between body and feet and leg traits were generally in low range. The highest positive correlation (0.18±0.05) was observed between chest width and rear leg rear view. All other correlations between body and feet and leg traits were of magnitude less than 0.10.

Most of the correlations among udder traits possessed negative signs. The correlations ranged from -0.48±0.03 to 0.38±0.04 between udder depth and rear udder width and between fore udder attachment and teat placement rear view. Correlations in medium range of udder depth with fore udder attachment (0.29±0.04), rear udder height (0.25±0.04) and of rear udder width with central ligament (0.25±0.04) and fore teat length (0.29±0.04) were important. Fore teat length had a negative correlation (-0.36±0.04) with udder depth and udder depth had a negative correlation (-0.32±0.04) with central ligament. Fore udder attachment and central ligament had a negative correlation (-0.26±0.05). Correlations among other udder traits were in low range with both directions.

A diverse picture of correlations between body and udder traits was observed. Most of the correlations were in low to medium range. Correlations in medium range of rear udder height with stature (-0.30±0.04), chest width (-0.42±0.04) and body depth (-0.38±0.04) and of rear udder width with stature (0.26±0.04), chest width (0.29±0.04) and body depth (0.22±0.04) and of fore teat length with stature (0.27±0.05), chest width (0.30±0.05) and body depth (0.35±0.04) and of udder depth with chest width (-0.39±0.04) and body depth (-0.44±0.04) and of thurl width with rear udder height (-0.44±0.04), fore teat length (0.33±0.05), rear udder width (0.26±0.04), udder depth (-0.27±0.04) were important. Correlation of magnitude 0.00 between fore udder attachment and stature was observed. Most of other correlations among body and udder traits were in low range. Udder depth and teat placement rear view had negative correlations with all body traits. All correlations between feet and leg traits and udder traits were in lower range. Correlations ranged from -0.19±0.05 between udder depth and rear legs rear view to 0.12±0.05 between fore teat length and rear legs rear view and between udder depth and foot angle.

DISCUSSION

Genetic correlations are function of additive genetic relationship between different traits. Liturature on this aspect is available in abundance.

Genetic correlations higher than present study between stature and chest width 0.65 (Thompson *et al.*, 1983), 0.68 (Klassen *et al.*, 1992), 0.70 (Lawstuen *et al.*, 1987) and more than 0.70 (Vanraden *et al.*, 1990; Harris *et al.*, 1992) and correlation comparable to present study 0.43 (Meyer *et al.*, 1987) were reported. Genetic correlation between stature and body depth 0.78 (Lawstuen *et al.*, 1987), 0.82 (Vanraden *et al.*, 1990) were higher and 0.58 (Gengler *et al.*, 1997), 0.71 (Harris *et al.*, 1992; Wiggans *et al.*, 2004) were comparable to present study. Correlation of magnitude 0.64 between stature and body depth was exactly the same as found in this study (Meyer *et al.*, 1987). Correlation between stature and rump width in medium range but slightly higher than present study 0.48 (Klei *et al.*, 1988) and 0.55 (Lawstuen *et al.*, 1987) were reported. Correlation of 0.64 (Vanraden *et al.*, 1990) and 0.68 (Gengler *et al.*, 1997) between stature and thurl width were comparable and 0.76 (Harris *et al.*, 1992) was higher than present findings. Although, in positive direction as far this study but higher in

Table1. Genetic correlations and standard errors among linear type traits

	STA	CW	BD	ANG	RA	RW	RLS	RLRV	FA	FUA	RUH	CL	UD	TPRV	TLF	RUW	TW
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		.43	.64	.06	.10	.35	-.01	.02	-.09	.00	-.47	.16	-.18	-.03	.31	.38	.58
2	.05		.56	.07	-.13	.19	-.24	.22	-.11	-.02	-.66	.29	-.55	-.02	.35	.53	.60
3	.04	.05		.47	.07	.31	.05	.10	-.24	-.15	-.54	.30	-.59	-.12	.43	.62	.71
4	.07	.07	.06		.21	.10	.20	-.08	-.11	-.08	.03	.04	-.28	.01	.16	.29	.17.
5	.07	.07	.07	.08		.17	-.03	-.04	.07	-.17	.24	.04	-.01	-.02	.01	-.01	-.16
6	.06	.06	.06	.07	.07		.06	-.01	.02	.01	-.04	.13	-.13	-.09	.16	.22	.33
7	.06	.06	.07	.07	.07	.07		.00	.09	-.04	.20	-.08	.14	-.06	-.06	-.12	-.13
8	.06	.06	.07	.07	.07	.06	.07		-.03	-.07	-.21	.02	-.25	.04	.15	.24	.09
9	.06	.06	.06	.07	.07	.06	.07	.07		.04	.11	-.25	.19	-.05	-.13	-.21	-.21
10	.06	.07	.06	.07	.07	.06	.07	.06	.06		.01	-.32	.40	.40	-.06	-.17	.08
11	.06	.05	.05	.08	.08	.07	.07	.07	.07	.07		-.30	.47	-.01	-.33	-.48	-.68
12	.06	.06	.06	.07	.07	.06	.07	.06	.06	.06	.06		-.40	-.26	.20	.39	.28
13	.06	.05	.05	.07	.07	.07	.07	.06	.06	.06	.06	.06		.12	-.42	-.65	-.34
14	.06	.06	.06	.07	.07	.06	.06	.06	.06	.05	.07	.06	.06		-.14	-.13	-.03
15	.06	.06	.05	.07	.07	.06	.06	.06	.06	.06	.06	.06	.05	.06		.45	.39
16	.07	.07	.07	.09	.09	.08	.08	.09	.08	.08	.09	.07	.06	.08	.07		.51
17	.05	.05	.04	.07	.07	.06	.07	.07	.06	.06	.05	.06	.06	.06	.05	.05	

Note: Genetic correlations = above diagonal, Standard errors = below diagonal
Abbreviations: STA = Stature, CW = Chest width, BD = Body depth, ANG = Angularity, RA = Rump angle, RW = Rump width, RLS = Rear legs set, RLRV = Rear legs rear view, FA =Foot angle, FUA = Fore udder attachment, RUH = Rear udder height, CL = Central ligament, UD = Udder depth, TPRV = Teat placement rear view, TLF = Fore teat length, RUW = Rear udder width, TW = Thurl width.

Table 2. Phenotypic correlations and standard errors among linear type traits

		STA	CW	BD	ANG	RA	RW	RLS	RLRV	FA	FUA	RUH	CL	UD	TPRV	TLF	RUW	TW
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	STA		.35	.50	.02	.13	.27	.01	.04	-.08	.00	-.30	.14	-.16	-.02	.27	.26	.45
2	CW	.04		.42	.06	-.07	.14	-.15	.18	-.10	-.01	-.42	.23	-.39	-.01	.30	.29	.43
3	BD	.04	.04		.52	.10	.20	.03	.09	-.17	-.12	-.38	.22	-.44	-.10	.35	.22	.55
4	ANG	.02	.05	.03		.15	.06	.10	-.04	-.05	-.07	-.02	.02	-.15	-.01	.11	-.05	.07
5	RA	.05	.05	.05	.04		.13.	.02	-.02	.03	-.11	.13	.04	-.06	-.03	-.01	-.02	-.09
6	RW	.05	.05	.05	.05	.05		.04	-.01	.02	.01	-.10	.09	-.08	-.06	.13	.06	.23
7	RLS	.05	.05	.05	.04	.05	.05		.00	.07	-.03	.14	-.08	.07	-.04	-.04	-.04	-.09
8	RLRV	.05	.05	.05	.05	.05	.05	.05		-.02	-.05	-.15	.01	-.19	.05	.12	.12	.06
9	FA	.05	.05	.05	.05	.03	.05	.05	.05		.01	.05	-.19	.12	-.03	-.11	-.12	-.16
10	FUA	.05	.05	.05	.05	.05	.05	.05	.05	.05		-.01	-.26	.29	.38	-.04	-.08	.06
11	RUH	.04	.04	.04	.04	.04	.05	.05	.05	.05	.05		-.17	.25	-.03	-.22	-.03	-.44
12	CL	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05		-.32	-.21	.17	.25	.23
13	UD	.05	.04	.04	.04	.05	.05	.05	.05	.05	.04	.04	.04		.09	-.36	-.48	-.27
14	TPRV	.05	.05	.05	.05	.05	.05	.05	.05	.05	.04	.05	.05	.05		-.12	-.08	-.04
15	TLF	.05	.05	.04	.05	.05	.05	.05	.05	.05	.05	.05	.05	.04	.05		.29	.33
16	RUW	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.03	.04	.04		.26
17	TW	.04	.04	.03	.05	.05	.05	.05	.05	.05	.05	.04	.05	.04	.05	.05	.04	

Note: Phenotypic correlations (above diagonal) and standard errors below diagonal
Abbreviations: STA = Stature, CW = Chest Width, BD = Body Depth, ANG = Angularity, RA = Rump Angle, RW = Rump Width, RLS = Rear Legs Set, RLRV = Rear Legs Rear View, FA = Foot Angle, FUA = Fore Udder Attachment, RUH = Rear Udder Height, CL = Central Ligament, UD = Udder Depth, TPRV = Teat Placement Rear View, TLF = Teat, Length Front, RUW = Rear Udder Width, TW = Thurl Width.

magnitude, correlation between chest width and body depth 0.80 (Harris *et al.*, 1992) and 0.93 (Lawstuen *et al.*, 1987; Vanraden *et al.*, 1990) were reported. Correlation of magnitude 0.72 (Vanraden *et al.*, 1990) was in the same range as for this study and 0.95 (Harris *et al.*, 1992) was higher than current study between chest width and thurl width. Correlations between body depth and angularity in medium range 0.39 to 0.60 (Wiggans *et al.*, 2004; Harris *et al.*, 1992; Gengler *et al.*, 1997 and Foster *et al.*, 1988) were not very different from present study. Correlations higher than of current study 0.63 (Klei *et al.*, 1988) and 0.73 of (Lawstuen *et al.*, 1987) of body depth with rump width were reported. The correlation between body depth and thurl width 0.71 to 0.82 (Vanraden *et al.*, 1990; Harrris *et al.*, 1992 and Gengler *et al.*, 1997) were in line with those of the current study. Genetic correlation higher than present study between body depth and thurl width 0.91 (GeGroot *et al.*, 2002), 0.82 (Gengler *et al.*, 1997), comparable to present study 0.78 (Harris *et al.*, 1992) were reported.

Contrary to the present study, higher genetic correlations with positive direction between fore udder attachment and udder cleft 0.18 to 0.63 for Holstein Friesian, 0.45 to 0.50 for Jersey cows (Visscher and Goddard, 1995), were reported. Almost double in magnitude than present study, correlations from 0.75 to 0.87 between fore udder attachment and udder depth 0.87 (Vij *et al.*, 1990), 0.77 (Lawstuen *et al.*, 1987), 0.75 (Foster *et al.*, 1988 (Meyer *et al.*, 1987) and 0.54 comparable to this study (Harris *et al.*, 1992) were reported. Correlations between fore udder attachment and front teat placement 0.57 to 0.67 (Misztal *et al.*, 1992), 0.60 (Schaeffer *et al.*, 1985), 0.59 (Lawstuen *et al.*, 1987), 0.57 higher than present study, were reported (Visscher and Goddard, 1995). Estimates between fore udder attachment and front teat placement were comparable to this study. The values varied from 0.36 to 0.47(Meyer et al., 1987). Genetic correlation of udder cleft with rear udder width 0.40 (Lawstuen *et al.*, 1987), 0.41 (Misztal *et al.*, 1992) 0.42 (Klei *et al.*, 1988) were comparable to present study. Correlation between udder cleft and rear udder height 0.48 (Misztal *et al.*, 1992), 0.73 (Vij *et al.*, 1990) were higher than present study with opposite signs. Although, comparable in magnitude but with opposite direction genetic correlations were reported between udder support and udder depth 0.47 (Lawstuen *et al.*, 1987), 0.63 (Vij *et al.*, 1990) and 0.00 (Brotherstone, 1994; Klei *et al.*, 1988). Contrary to the present findings positive correlation of more than 0.70 in magnitude was reported between rear udder height and rear udder width (Misztal *et al.*, 1992; Harris *et al.*, 1992; Lawstuen *et al.*, 1987a; Foster *et al.*, 1988; Schaeffer *et al.*, 1985; Brotherstone, 1994 and Gengler *et al.*, 1997; Wiggans *et al.*, 2004). The genetic correlations between udder depth and rear udder height 0.37 (DeGroot *et al.*, 2002) was comparable and 0.19 was lower than the present study (Gengler *et al.*, 1997). Genetic correlations between udder depth and rear udder width 0.48 (DeGroot *et al.*, 2002) was of similar magnitude but in opposite direction to that found in present study whereas correlations were lower than current study findings although, in the same direction -0.17 (Gengler *et al.*, 1997) and -0.24 (Harris *et al.*, 1992).

Yet the correlations were lower Although having the same direction than present study in magnitude between body depth and udder depth -0.10- to -0.40 (Wiggans *et al.*, 2004; Gengler *et al.*, 1997 and Foster *et al.*, 1988), (Lawstuen *et al.*, 1987) and contrary to the present study zero correlation (Vanraden *et al.*, 1990) and higher with positive direction 0.75 (DeGroot *et al.*, 2002) was reported. Genetic correlations were comparable between thurl width and rear udder width 0.56 (Gengler *et al.*, 1997), 0.40 (Vanraden *et al.*, 1990) and lower than present study 0.35 (DeGroot *et al.*, 2002). Although comparable in magnitude but with opposite direction correlation 0.62 (DeGroot *et al.*, 2002) was reported between strength and udder depth. Genetic correlation 0.31 between stature and rear udder width were comparable (Wiggans *et al.*, 2004 and Vanraden *et al.*, 1990) and 0.33 (Gengler *et al.*, 1997), lower -0.04 to 0.22 (Foster *et al.*, 1988; Schaeffer *et al.*, 1985; Lawstuen *et al.*, 1987); 0.22 (Thompson *et al.*, 1983) and higher 0.55 (DeGroot *et al.*, 2002). Correlations between rear udder width and strength were comparable 0.44 to 0.51 (Thompson *et al.*, 1983; Gengler *et al.*, 1997; DeGroot *et al.*, 2002), lower in magnitude than current study from 0.13 to 0.36 (Schaeffer *et al.*, 1985; Foster *et al.*, 1988; Lawstuen *et al.*, 1987; Wiggans *et al.*, 2004). Rear udder width had lower correlation with body depth 0.17 to 0.34 (Foster *et al.*, 1988; Wiggans *et al.*, 2004; Vanraden *et al.*, 1990; Lawstuen *et al.*, 1987) and estimates were in consensus to present findings 0.53 (Gengler *et al.*, 1997) and 0.60 (DeGroot *et al.*, 2002).

The genetic correlations between primary and experimental linear type traits were not very different from the present study (Short *et al.*, 1991; Lawstuen *et al.*, 1987). Genetic correlations between stature and rear udder height 0.22 to 0.52, chest width and rear udder height 0.17 to 0.29, between body depth and rear udder height 0.24 to 0.48 and between thurl width and rear udder height with positive sign were not in consensus to the present study (DeGroot *et al.*, 2002; Gengler *et al.*, 1997; Harris *et al.*, 1992). Genetic correlations of teat length with stature 0.33 (Gengler *et al.*, 1997), 0.32 (Harris *et al.*, 1992), chest width 0.32 (Gengler *et al.*, 1997) and body depth 0.35 were comparable. Genetic correlation higher than the current study 0.52 between chest width and teat length (Harris *et al.*, 1992) and lower than present study 0.28

between body depth and teat length (Gengler *et al.*, 1997) were reported. Genetic correlation between chest width and central ligament and body depth and central ligament were in the same range as for this study (DeGroot *et al.*, 2002; Gengler *et al.*, 1997; Harris *et al.*, 1992). Genetic correlations between thurl width and udder depth lower in magnitude than present findings but of the same direction -0.16 (Gengler *et al.*, 1997), -0.24 (Harris *et al.*, 1992) and higher in magnitude with opposite direction 0.55 (DeGroot *et al.*, 2002) were reported.

The phenotypic correlations among linear type traits are presented in Table 2.

More than a few studies have reported phenotypic correlations among linear type traits. In general, correlations were not very different than those found in the current study. Correlations were higher than the present study and were in medium range between stature and strength 0.49 (Thompson *et al.*, 1983; Lawstuen *et al.*, 1987; Misztal *et al.*, 1992), 0.51 (Klassen *et al.*, 1992; Gengler *et al.*, 1997), 0.53 (Wiggans *et al.*, 2004), 0.56 (Vanraden *et al.*, 1990) and 0.60 (DeGroot *et al.*, 2002). Estimates were comparable to the present study 0.31 (Klei *et al.*, 1988), but were lower than found in the current study 0.21 (Meyer *et al.*, 1987), 0.22 (Schaeffer *et al.*, 1985) and 0.25 (Brotherstone, 1994). Correlations in medium range (0.42 to 0.54) between stature and body depth were very different from the present study (Gengler *et al.*, 1997; Meyer *et al.*, 1987; Brotherstone, 1994; Wiggans *et al.*, 2004 and Misztal *et al.*, 1992). Correlations were slightly higher 0.60 (DeGroot *et al.*, 2002; Lawstuen *et al.*, 1987 and Vanraden *et al.*, 1990) and lower than present study, estimate was 0.29 (Klei *et al.*, 1988) between stature and body depth. Estimates between stature and thurl width were comparable to the present finding 0.40 to 0.44 (Vanraden *et al.*, 1990; DeGroot *et al.*, 2002; Gengler *et al.*, 1997) and lower estimates were 0.28 (Klei *et al.*, 1988) and 0.32 (Klassen *et al.*, 1992). Correlation was comparable 0.42 between strength and body depth (Meyer *et al.*, 1987). More than a few studies have reported estimates in medium to high range (0.52-0.77), but higher than the present findings (Klei *et al.*, 1988; Brotherstone, 1994; Gengler *et al.*, 1997; Misztal *et al.*, 1992; Wiggans *et al.*, 2004; Lawstuen *et al.*, 1987; Vanraden *et al.*, 1990; DeGroot *et al.*, 2002). Estimates were comparable 0.36-0.47 between strength and thurl width (Misztal *et al.*, 1992; Klassen *et al.*, 1992; Vanraden *et al.*, 1990 and DeGroot *et al.*, 2002). Estimate was higher than current study 0.70 (Gengler *et al.*, 1997). Correlations were lower than current study, between body depth and angularity 0.20 (Klei *et al.*, 1988), 0.21 (DeGroot *et al.*, 2002), 0.33 (Gengler *et al.*, 1997). Correlation was lower with negative signs -0.15 (Meyer *et al.*, 1987) which was not in agreement with the present study. As for the present study, correlation was in medium range i.e 0.40 (Foster *et al.*, 1988). Phenotypic correlation between body depth and thurl width ranged from 0.48 to 0.57 (Harris *et al.*, 1992; Gengler *et al.*, 1997; DeGroot *et al.*, 2002) and were not very different from present findings.

Correlations between fore udder attachment and front teat placement 0.31 (Meyer *et al.*, 1987), 0.35 (Schaeffer *et al.*, 1985), 0.38 Klassen *et al.*, 1992), 0.40 (Lawstuen *et al.*, 1987) and 0.41 (Thompson *et al.*, 1983) were comparable to current study. Lower than current study estimates were 0.26 (Brotherstone, 1994) and 0.27 DeGroot *et al.*, 2002). Contrary to present study results, correlation between rear udder height and rear udder width were in medium to high range 0.49 to 0.76 with positive direction (Schaeffer *et al.*, 1985; Klei *et al.*, 1988; Wiggans *et al.*, 2004; Foster *et al.*, 1988; DeGroot *et al.*, 2002; Misztal *et al.*, 1992; Vanraden *et al.*, 1990; Gengler *et al.*, 1997; Lawstuen *et al.*, 1987; Thompson *et al.*, 1983). Correlations of udder cleft with udder depth 0.47 (DeGroot *et al.*, 2002) and 0.54 (Thompson *et al.*, 1983) were higher than present study. Phenotypic correlations between udder depth and fore teat length were lower in magnitude -0.08 to -0.15 (Harris *et al.*, 1992; Gengler *et al.*, 1997; DeGroot *et al.*, 2002) but in the same direction as for this study.

Lower correlations between chest width and udder depth 0.00 (Vanraden *et al.*, 1990), -0.06 (Meyer *et al.*, 1987) and teat length with chest width 0.07 (Meyer *et al.*, 1987) and of body depth with teat length 0.10 (Meyer *et al.*, 1987), 0.20 (DeGroot *et al.*, 2002) and of body depth and udder depth -0.10 (Meyer *et al.*, 1987) were lower than current findings. Correlations were lower than current study with opposite signs (0.20) between strength and rear udder height (Thompson *et al.*, 1983). Correlations 0.18 (Thompson *et al.*, 1983) lower in magnitude and 0.55 (Vij *et al.*, 1990) higher than current study between stature and rear udder height with positive signs were reported. Phenotypic correlation between body depth and rear udder height were lower in magnitude than present findings with positive signs (Harris *et al.*, 1992; Gengler *et al.*, 1997; DeGroot *et al.*, 2002). Correlation between fore teat length and thurl width was higher in the present study than reported by Harris *et al.* (1992), Gengler *et al.* (1997) and DeGroot *et al.* (2002).

CONCLUSIONS

High genetic correlations between some of body traits indicated that selection for one trait will bring change in other correlated traits. Feet and legs traits showed very low or negative genetic correlation with body traits and among themselves. Genetic correlations among udder traits were in low to medium range. Rear udder height, for example, showed negative genetic correlation with stature, chest width and body depth. Thus, care is needed to avoid deterioration among undesirably negatively associated traits. This information should, however, be considered preliminary because of smaller data set.

REFERENCES

Bhatti, A.A., M.S. Khan, Z. Rehman, A.U. Hyder and F. Hassan. 2007. Selection of Sahiwal bulls on pedigree and progeny. Asian-Aust. J. Anim. Sci. 20: 12-18.

Brotherstone, S. 1994. Genetic and phenotypic correlations between linear type traits and production traits in Holstein-Friesian dairy cattle. Anim. Prod. 59: 183-187.

Dahiya, S.P. 2005. Linear functional type traits for reproductive efficiency in Hariana cows. Indian J. Anim. Sci. 75: 524-527.

Dahiya, S.P. 2005a. Appraisal of linear type traits for reproductive efficiency in Sahiwal cows. Indian J. Anim. Sci. 75: 945-948.

DeGroot, B.J., J.F. Keown, L.D. Van Vleck and E.L. Marotz. 2002. Genetic parameters and responses of linear type, yield traits and somatic cell scores to divergent selection for predicted transmitting ability for type in Holsteins. J. Dairy Sci. 85: 1578-1585.

Foster, W.W., A.E. Freeman, P.J. Berger and A. Kuck. 1988. Linear type trait analysis with genetic parameter estimation. J. Dairy Sci. 71: 223-231.

Gengler, N., G.R. Wiggans, J.R. Wright, H.D. Norman and C.W. Wolfe. 1997. Estimation of (Co) Variance components for Jersey type traits using a repeatability model. J. Dairy Sci. 80: 1801-1806.

Gilmour, A.R., B.J. Gogel, B.R. Cullis, S.J. Welham and R. Thompson. 2007. ASReml User Guide (Version 2.0), VSN International Ltd., Hemel Hempstead, HP11ES, UK.

GOP (Government of Pakistan) Livestock Census 2006. Punjab Province, Statistics Division, Agricultural Census Organization.

Harris, B.L., A.E. Freeman and E. Metzger. 1992. Genetic and phenotypic parameters for type and production in Guernsey dairy cows. J. Dairy Sci. 75: 1147-1153.

ICAR, 2003. International Agreement of Recording Practices (approved on 30 May, 2002). International Committee for Animal Recording. Rome.

Khan, M.S. 2007. Research efforts for conservation and development of Sahiwal breed. Proceedings of National Workshop on Sahiwal Cattle "Development of Indigenous Resources–The Sahiwal Cattle Breed", April14, 2007. Deptt. Animal Breeding and Genetic, University of Agriculture, Faisalabad.

Klassen, D.J., H.G. Monardes, I. Jairath, R.I. Cue and J.F. Hayes. 1992. Genetic correlations between lifetime production and linearized type in Canadian Holsteins. J. Dairy Sci. 75: 2272-2282.

Klei, L., E.J. Pollak and R.L. Quaas. 1988. Genetic and environmental parameters associated with linearized type appraisal scores. J. Dairy Sci. 71: 2744-2752.

Lawstuen, D.A., L.B. Hansen and L.P. Johnson. 1987. Inheritance and relationships of linear type traits for age groups of Holsteins. J. Dairy Sci. 70: 1027-1035.

Meyer, K., S. Brotherstone, W.G. Hill and M.R. Edwards. 1987. Inheritance of linear type traits in dairy cattle and correlations with milk production. Anim. Prod. 44: 1-10.

Misztal, I., T.J. Lawlor, T.H. Short and P.M. VanRaden. 1992. Multiple-trait estimation of variance components of yield and type traits using an animal model. J. Dairy Sci. 75: 544-551.

Patterson, L.D. and R. Thompson. 1971. Recovery of inter-block information when block sizes are unequal. Biometrika 58: 545-554.

Rupp, R. and D. Boichard. 1999. Genetic parameters for clinical mastitis, somatic cell score, production, udder type traits and milking ease in first lactation Holsteins. J. Dairy Sci. 82: 2198-2204.

Schaeffer, G.B., W.E. Vinson, R.E. Pearson and R.G. Long. 1985. Genetic and phenotypic relationships among type traits scored linearly in Holsteins. J. Dairy Sci. 68: 2984-2988.

Talbott, C.W. 1994. Potential to increase milk yield efficiency in tropical countries. Ph. D. Thesis, Department of Animal Science, North Carolina State University, Raleigh, USA.

Thomas, C.L., W.E. Vinson, R.E. Pearson and H.D. Norman. 1985. Components of genetic variance and covariance for linear type traits in Jersey cattle. J. Dairy. Sci. 68: 2989-2994.

Thompson, J.R., A.E. Freeman, D.J. Wilson, C.A. Chapin, P.J. Berger and A. Kuck. 1981. Evaluation of a linear type program in Holsteins. J. Dairy Sci. 64: 1610-1617.

Thompson, J.R., K.L. Lee, A.E. Freeman and L.P. Johnson. 1983. Evaluation of a linearized type appraisal system for Holstein cattle. J. Dairy Sci. 66: 325-331.

Vanraden, P.M., E.L. Jensen, T.J. Lawlor and D.A. Funk. 1990. Prediction of transmitting abilities for Holstein type traits. J. Dairy Sci. 73: 191-197.

Vij, P.K., D.S. Balain, M. George and A.K. Vinayak. 1990. Linear type traits and their influence on milk production in Tharparkar cattle. Indian J. Anim. Sci. 60: 845-852.

Visscher, P.M. and M.E. Goddard. 1995. Genetic parameters for milk yield, survival, workability and type traits for Australian dairy cattle. J. Dairy Sci. 78: 205-220.

Wiggans, G.R., N. Gengler and J.R. Wright. 2004. Type trait (Co) variance components for five dairy breeds. J. Dairy Sci. 87: 2324-2330.