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RESEARCH ARTICLE

Comprehensive genetic analysis of linear type traits for characterization of the Sahiwal cattle in an organized herd

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Abstract: Sahiwal is one of the most important dairy cattle breeds of the Indian subcontinent. A holistic and balanced approach to selection and breeding strategies must be adopted to bring about desirable genetic improvement in livestock, including indigenous cattle. The inclusion of linear type traits for dairy cattle selection in any breed improvement program has not been carried out in India so far. Therefore, this study was taken up to characterize Sahiwal cattle, on the basis of linear type traits. Data was collected on adult Sahiwal cows up to their 10th parity, maintained at Institute herd of Indian Council of Agricultural Research- National Dairy Research Institute, Karnal, Haryana from 2006-2021. Data were analysed using Least Squares Maximum Likelihood (LSMLMW), considering a sire model for the present study. Parity, season and period of calving were taken as fixed effect and age at first calving as covariable. Sire or animal was considered as random variable. Least squares means of objective linear type traits *viz.,* stature was 125.97±0.68 cm, body length 136.58±1.01 cm, chest girth 173.04±1.14 cm, body depth 203.40± 1.39 cm, rump angle 14.50±0.39 cm, rump width 20.62±0.28 cm, udder depth 20.87±0.41 cm, rear udder height 18.38±0.33 cm, and teat length 6.16±0.24 cm. On the other hand, least square mean scores of subjective linear type traits (1-9 scale) viz. fore teat placement was 6.32±0.46, rear teat placement was 7.27±0.35, rear leg side view was 6.26±0.26, rear leg rear view was 6.28±0.27 score, foot angle 6.86±0.27, angularity 34.97±0.50-degree, central ligament 6.55± 0.39, fore udder attachment 5.91±0.32, fore teat placement 6.32±0.46, and rear teat placement was 7.27±0.35. Parity had a significant ($p<0.05$) effect on fore udder attachment and central ligament and teat length in Sahiwal cattle. Season of calving had the significant ($p< 0.05$) effect, observed in case of udder depth in Sahiwal cattle. Period of calving had a significant ($p<0.05$) effect on rump angle, udder depth, teat length, angularity and central ligament in Sahiwal cattle. Based on results of present study, it was observed that Sahiwal cattle establishes a balance between the scoring pattern of linear type traits, as the balance scoring of animals was desirable for better sustainability and production performance of a dairy cattle, on a longer run. Moreover, linear type traits have a better scope in selection process and genetic improvement programs that can be utilized as balanced and comprehensive approach for indigenous dairy cattle.

Keywords: Least-Squares Analysis, Linear type traits, LSMLMW, Sahiwal

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Introduction

India has a vast diversity of livestock species. According to 20th Livestock Census, India has 53.6 crores of total livestock population and 14.5 crores of cattle population (DAHD, 2019). Sahiwal, also known as Multani, is one of the most important indigenous breeds of milch cattle. Since many years, it has been observed that the selection of dairy sires in our country is mainly based on the production performance of their progenies, and this practice of sire evaluation is routinely followed till date in most of the dairy cattle breeding programmes. Many countries have moved towards more balanced selection objectives of dairy cattle by inclusion of previously underestimated and underrated traits like linear type traits, functional traits etc other than just the production traits (Miglior et al. 2005). This practice of sire selection is holistic, balanced and animal welfare oriented. Linear Type traits play an important role in selection, and breeding program of dairy cattle, which may enhance the reproductive performance of both sires and dams, which are the main contributors to involuntary culling. Linear type traits are the basis of all modern type classification systems, and are the foundation of all systems for describing the dairy cow. It has been found that selection only on the basis of production traits continuously has decreased the overall well-being of animal (Dadati et al. 1986). Scientists and animal breeders in the developed countries have

realized the important role of linear type traits towards the welfare of dairy cattle, but the application of such linear type traits is scanty in indigenous livestock breeding programs in our country. Hence, the present study was formulated with an objective to estimate various linear type traits in Sahiwal cattle and thereby, to characterize this prominent cattle breed of India.

Materials and Methods

Source of Data

The present study was conducted on the Sahiwal herd maintained at Livestock Research Centre (LRC), ICAR-National Dairy Research Institute, Karnal, Haryana. Linear type traits of 185 live adult cows belonging to the Sahiwal breed were recorded for the present study. Stature (STAT), Body length (BL), Chest girth (CG), Body Depth (BD), Angularity (ANG), Rump Angle (RA), Rump Width (RW), Rear Legs Rear View (RLR), Rear Legs Set-Side View (RLS), Foot Angle (FA), Fore Udder Attachment (FU), Front Teat Placement (TP), Teat Length (TL), Udder Depth (UD), Rear Udder Height (RUH), Central Ligament (CL), Rear Teat Placement (RTP) were recorded on each of the Sahiwal cows. To define Sahiwal breed on the basis of linear type traits, all these type traits were scored and measured as per the guidelines of International committee for Animal Recording, (2018) and National Dairy Development Board, (2017). Type traits can basically be classified into two broad categories with respect to their pattern of assessment *viz.* subjective assessment (for which no dimensions are made) and objective assessment (which can be measured by dimensions or unit). Fore udder attachment, front and rear teat placements, foot angle, rear legs side view and rear leg rear view are the traits that depend on subjective assessment on a scale of 1-9; while other traits like stature, body length, chest girth, body depth, rump angle, rump width, teat length, udder depth and rear udder height depend on objective assessment through measurement. For those traits which depend on subjective assessment, scoring was carried out through visual observations of live animals. For traits which depend on objective assessment, scoring was completed through actual measurement of traits (in centimeters). Stature, Body length, Chest girth, Body Depth, Rump Angle, Rump Width, Teat Length, Udder Depth, Rear Udder Height, were measured in centimeters. Angularity (Degree), Rear Legs Rear View, Rear Legs Side View, Foot Angle, Fore Udder Attachment, Front Teat Placement, Central Ligament, Rear Teat Placement were recorded subjectively on a 1-9 scale, while a score of 5 was considered being the intermediate value.

Instruments for Measurement Stature, Body length, Chest girth, Body Depth, Rump Angle, Rump Width, Teat Length, Udder Depth, Rear Udder Height, were measured using a rewindable, 5m long metal tape with a precision of 1.00 mm and a wooden flat strip was used for leveling. Angularity was measured using a wooden device with a protector to measure the angle of openness of the ribs. Rear Legs Rear View, Rear Legs Side View, Foot Angle, Fore Udder Attachment, Front Teat Placement, Central Ligament, and Rear Teat Placement were given scores on the basis of visual observation on a scale of 1 to 9, with 5 being the intermediate score.

Data Structure

To ensure the proper normalisation, the data set was standardized using mean ±2×standard deviation for each trait. The records of the animals with normal lactation were considered for this study. The records with less than 100 kg of lactation yield were discarded. The records of the adult Sahiwal cows with known pedigree were taken for the present study. Experimental and pregnant animals were also excluded from the study. Abortion, stillbirth and other pathological conditions which affected the lactation yield were considered as abnormalities and hence such records were not taken into consideration. The non-genetic factors *viz*; season of calving (4 levels) and period of calving (2 levels), parity of animal (4 levels) were classified into subclasses to assess the effects of non-genetic factors on different traits in order to get a precise estimate of genetic parameters of different traits under study. Age at first calving was taken as covariate.

Statistical Analysis

The Sahiwal breeding data were analyzed by Least Squares Maximum Likelihood (LSML) approach by using the Computer software package LSMLMW (Harvey, 1990). The effect of non-genetic factors (period of calving, season of calving, parity and AFC) was estimated using fixed effect model for linear type traits in Sahiwal cattle. The model was used with the assumption that different components being fitted into the model were linear, independent and additive. The following fixed effect model was considered to estimate the effect of non-genetic factors on the linear type traits in Sahiwal cattle.

$$\mathbf{Y_{ijkl} = \mu + S_i + P_j + L_k} + b\,(X_{ijkl} - \bar{X}) + \mathbf{e_{ijkl}}$$

where,

Y_{ijkl} = linear type traits of l^{th} animal calved in i^{th} season and j^{th} period and of k^{th} parity

μ = Population mean

S_i = Effect of i^{th} season of calving (i=1,2,3,4)

P_j = Effect of j^{th} period of calving (j=1,2)

Lk = Effect of k^{th} parity of animals (k=1,2,3,4)

X_{ijkl} = Age at first calving corresponding to Y_{ijkl}

b = Regression of variable on age at first calving

$\bar{X}$ = Average age at first calving

e_{ijk} = Random error associated with observation, assumed to NID $(0, \sigma^2_e)$

Duncan's multiple range test as modified by Kramer (1957) was used for testing differences among least squares means.

Results and Discussion

To define Sahiwal breed on the basis of linear type traits, all these type traits were scored and measured as per the guidelines of ICAR (2018) and NDDB (2017). The least squares mean of 17 linear type traits of Sahiwal cattle with their standard error were presented in the Table 1. Sahiwal cattle can be defined as a breed of dairy cattle having average stature of 125.97±0.68 cm, average body length of 136.58±1.01, chest girth of 173.04±1.14 cm, body depth of 203.40± 1.39 cm, rump angle of 14.50±0.39 cm and rump width of 20.62±0.28 cm. The average score of rear leg rear view, rear leg side view, foot angle, udder depth, rear udder height, fore udder attachment, teat length, front teat placement and rear teat placement 6.28±0.27, 6.26±0.26, 6.86±0.26,20.87±0.41 cm,18.46±0.33 cm, 5.91±0.32 score, 6.16±0.24 cm, 6.32±0.46 score,

Table 1 Least-Squares Means (LSM), Standard Error (SE) and Range of Linear Type Traits

Sr	Trait	LSM ± SE	Range	Interpretation
1	Stature (cm)	125.97 ± 0.68	116-134	Intermediate stature
2	Body Length (cm)	136.58 ± 1.01	115-155	Moderate body length
3	Chest Girth (cm)	173.04 ± 1.14	151-194	Intermediate chest girth
4	Body Depth (cm)	203.40 ± 1.39	168-242	Moderately strong body
5	Rump Angle (cm)	14.50 ± 0.39	8-22	High rump angle
6	Rump Width (cm)	20.62 ± 0.28	16-26	Intermediate rump width
7	Udder Depth (cm)	20.87 ± 0.41	14-37	Intermediate udder depth
8	Teat Length (cm)	6.16 ± 0.24	2-18	Moderate teat length
9	Rear Udder Height (cm)	18.46 ± 0.33	12-29	Intermediate rear udder
10	Angularity (angle in degree)	34.99 ± 0.51	20-45	Intermediate
11	Rear Leg Rear View (score;1-9 scale)	6.28 ± 0.27	1-9	Intermediate to high
12	Rear Leg Side View (score;1-9 scale)	6.26± 0.26	1-9	Intermediate to high
13	Foot Angle (score;1-9 scale)	6.86 ± 0.26	1-9	Intermediate to high
14	Fore Udder Attachment (score;1-9 scale)	5.91± 0.32	1-9	Moderate attachment
15	Front Teat Placement (score;1-9 scale)	6.32± 0.46	1-9	Centrally placed in majorityCases.
16	Central Ligament (score;1-9 scale)	6.55 ± 0.39	1-9	Intermediate to stronger central ligament
17	Rear Teat Placement (score;1-9 scale)	7.27 ± 0.35	1-9	Centrally and closely placed rear teats

Table 2 Effect of non-genetic factors on linear type traits in Sahiwal cattle

Sr	Traits	Parity	Season of calving	Period of calving
1	Stature	NS	NS	NS
2	Body Length	NS	NS	NS
3	Chest Girth	NS	NS	NS
4	Rump Width	NS	NS	NS
5	Rump Angle	NS	NS	S*
6	Udder Depth	NS	S*	S*
7	Rear Udder Height	NS	NS	NS
8	Teat Length	S*	NS	S*
9	Angularity	NS	NS	S*
10	Rear Leg Rear View	NS	NS	NS
11	Rear Leg Side View	NS	NS	NS
12	Foot Angle	NS	NS	NS
13	Fore Udder Attachment	S*	NS	NS
14	Front Teat Placement	NS	NS	NS
15	Central Ligament	S*	NS	S*
16	Rear Teat Placement	NS	NS	NS
17	Body Depth	NS	NS	NS

S* significant at $p<0.05$

and 7.27±0.35 score, respectively. The significant effect of various non-genetic factors on linear type traits were listed in the (Table 2).

Average linear type traits scores in Sahiwal cattle

During measurement of linear type traits, a wide variability in stature (116-134) of animals was observed with the average 125.97±0.68 cm. Chest girth was measured as the circumference around the chest at the proximal end of chest, while body depth was measured around the circumference of last ribs towards attachment of abdomen. The average score for chest girth and body depth were 173.04±1.14 cm and 203.40 ± 1.39 cm in Sahiwal cattle, respectively.

Angularity was measured as an angle made by last rib of the body to an imaginary line drawn perpendicular to the ground, and a wedge-shaped body indicates good milking ability of animal. The average score for angularity in Sahiwal cattle was 34.99±0.51 degree that depicted that Sahiwal breed is intermediate in angularity. Rump angle was measured as a distance between two imaginary lines drawn: one straight from hip bone in long axis of spine and the other one on long axis of pin bone. Mean estimate for rump angle was 14.50 ± 0.39 cm in Sahiwal cattle. There should be a little difference in levels of hip and pin bones, and there was very little difference in levels of hip and pin bones in Sahiwal as compared to Holstein Friesian (NDDB, 2017), it may be because of this reason, indigenous breeds have lesser reproductive or calving related difficulties like dystocia than most of exotic breeds. Godara et al. (2015) reported similar observations (5.55±0.47 score) in Tharparkar cattle (n=149) on a 1-9 scale of measurement. Rump width was measured as the distance between two pin bones. Mean estimate for rump width was 20.62±0.28 cm in Sahiwal cattle, indicating intermediate to wider pelvic area. This trait indicates the capacity of pelvis of cattle which is a fine indicator of calving ease. Udder depth was measured as the distance between the attachments of udder on the abdominal wall to the lowest portion of udder up to the level of hock joint, by a measuring scale. Pendulous and deep udders were scored least, as they were more prone to injury and damage. In present study, average udder depth was 20.87±0.41 cm, indicating intermediate depth, and shallow udder in Sahiwal cattle. Deep udders are more prone to mastitis and damage (Rogers, 1993). So, during selection procedures, a balance must be established, between deep udders and shallow udders. The mean estimate of teat length was 6.26±0.24 cm, which suggested that Sahiwal has medium to long teats. Rear udder height in Sahiwal cow was measured as the distance in centimetres from the lower tip of vulva to the point of attachment of udder of the animal. Mean estimate for rear udder height was 18.46 ± 0.33 cm in Sahiwal breed, indicating low to intermediate rear udder height.

On 1-9 points scale, average score for rear legs side view was 6.26±0.26 in Sahiwal cow, and rear leg rear view was scored as 6.28±0.27, indicating intermediate to higher score in Sahiwal, depicting the proper direction and alignment of hind feet in Sahiwal cattle, to bear and support the weight of the animal. Foot angle was the angle between the imaginary line drawn at level of hoof wall to the ground. It should be steep not flat, since flat foot is not desired as it causes walking difficulties and it can't bear the weight of animal, leading it susceptible to hoof injury. Average score for foot angle was 6.86±0.26 points, indicating intermediate to moderate angle and well-formed feet. Dubey et al. (2014); Godara et al. (2015); Khan and Khan (2015) reported similar observations in Sahiwal, Tharparkar and Sahiwal (n=310) cattle, respectively. Fore udder attachment indicates

Table 3 Least-Squares Means and influence of parity on linear type traits

Traits	Overall (185)	Parity1 (64)	Parity 2 (30)	Parity 3 (30)	Parity 4 (61)
Stature	125.97±0.68	126.42 ±1.17	126.96 ± 1.1	125.99 ± 1.1	124.37± 1.17
Body Length	136.58±1.01	136.72 ± 1.9	137.40 ± 1.9	135.46 ± 1.9	134.62 ± 1.9
Chest Girth	173.04±1.14	174.17 ± 2.3	176.9 ± 2.2	171.11 ± 2.3	168.9 ± 2.3
Body Depth	203.40± .39	203.2 ± 2.98	203.7 ± 2.97	202.10 ± 3.0	202.8 ± 3.0
Rump Angle	14.50 ± 0.39	13.91 ±0 .77	14.15 ± 0 .76	14.15 ±0 .66	15.4 ± 0.77
Rump Width	20.62 ± 0.28	20.98 ± 0 .49	21.02± 0.49	20.25± 0 .50	19.70 ± 0 .49
Udder Depth	20.87 ± 0.41	20.12 ± 1.0	20.11 ± 1.04	21.46 ± 1.06	21.46 ± 1.06
Teat Length	6.16± 0.24	4.49^{a} ± 0. 58	6.41^{b} ± 0 .58	7.41^{c} ± .58	7.61^{c} ± 0 .58
Rear Udder Hight	18.46± 0.33	18.78 ± .88	17.37±0 .88	18.74 ±0.88	18.73±0 .88
Angularity	34.99± 0.51	36.10 ±1.3	34.12 ± 1.3	33.10 ± 1.3	35.11 ± 1.3
Rear Leg Rear View	6.28± 0.27	7.47 ±0 .70	6.41± 0 .75	5.47 ± 0 .72	5.24 ±0 .72
Rear Leg Side View	6.26± 0.26	6.45 ± 0 .67	5.45 ± 0 .11	6.45 ±0 .32	6.45 ± 0 .55
Foot Angle	6.86 ± 0.26	7.32 ± 0 .22	6.32 ± 0 .55	7.32 ± 0 .44	6.32 ±0 .61
Fore Udder Attachment	5.91± 0.32	6.92^{b} ± 0 .85	6.96^{b} ±0.85	5.92^{a} ± .85	5.98^{a} ±0 .85
Front Teat Placement	6.32± 0.46	6.87 ± 0 .83	6.87 ±0 .83	5.87 ± 0.83	6.87 ± 0 .83
Central Ligament	6.55 ± 0.39	8.02^{d} ± 0 .82	7.32^{c} ± 0.74	6.13^{b} ±.78	4.73^{a} ± 0.77
Rear Teat Placement	7.27 ± 0.35	7.91 ± 0 .74	7.31 ± 0.67	7.31 ± 0 .67	6.31 ± 0.67

Values with different superscript differ significantly at $p<0.05$, Figures in parenthesis is number of observations

Table 4 Least-Squares means and influence of Season of calving on linear type traits

Traits	Overall (185)	Winter (48)	Summer (39)	Rainy (59)	Autumn (39)
Stature	125.97±0.68	126.56± 0.98	124.47 ± 1.0	124.68 ± 1.0	128.07± 1.0
Body Length	136.58±1.01	134.71 ± 1.6	135.52 ± 1.6	135.91 ± 1.6	138.17± 1.6
Chest Girth	173.04±1.14	172.81 ± 1.9	171.32 ± 0.9	170.01± 1.1	175.80 ± 1.9
Body Depth	203.40± 1.39	200.67 ± 2.4	203.17± 2.4	200.63 ± 2.9	206.13±0 .49
Rump Angle	14.50 ± 0.39	14.89± 0 .65	14.83 ± 0 .65	13.81 ± 0 .65	14.74 ± 0 .65
Rump Width	20.62 ± 0.28	20.86 ± 0 .42	20. 71 ± 0 .42	20. 91± 0 .42	20.18± 0 .42
Udder Depth	20.87 ± 0.41	20.32^{a} ±0.83	$20. 11^{a}$±0.83	22.88^{b}±0.83	20.37^{a}± 0 .83
Teat Length	6.16± 0.24	5.83 ± 0 .46	6.53± 0 .49	6.25 ± 0 .49	6.16± 0 .49
Rear Udder Hight	18.46± 0.33	18.09 ± 0 .70	17.52 ± 0 .70	18.52 ± 0 .70	18.02 ± 0.70
Angularity	34.99± 0.51	35.68 ±0.91	33.91± 0 .91	33.24 ± 0 .91	34.18± 0 .91
Rear Leg Rear View	6.28± 0.27	6.08 ± 0.48	5.77± 0.48	6.90± 0 .48	6.28± 0.48
Rear Leg Side View	6.26± 0.26	6.01 ± 0.46	5.41± 0.46	6.72 ± 0 .46	6.19± 0 .46
Foot Angle	6.86 ± 0.26	6.97 ± 0.46	6.85± 0 .46	6.69± 0 .46	6.99 ± 0 .46
Fore Udder Attachment	5.91± 0.32	6.18 ± 0 .57	5.16 ± 0.57	6.09 ± 0 .57	5.31 ± 0 .57
Front Teat Placement	6.32± 0.46	6.31 ± 0 .62	6. 01± 0 .62	6. 40 ± 0.62	6.32 ± 0 .62
Central Ligament	6.55 ± 0.39	7. 70 ± 0 .58	6.10 ± 0.58	5. 07 ± 0 .58	6. 70 ± 0 .58
Rear Teat Placement	7.27 ± 0.35	7.67 ± 0 .52	7.64 ±0 .52	7. 77 ± 0 .52	7. 07 ± 0.52

Values with different superscript differ significantly at $p<0.05$, Figures in the parenthesis were the number of observations

Table 5 Least-Squares means and influence of Period of calving on linear type traits

Traits	Overall (n=185)	2017-2019 (n=63)	2020-2021 (n=122)
Stature	125.97±0.68	125.46 ± 0.84	126. 08 ±0.84
Body Length	136.58±1.01	134.94 ± 1.38	137. 89 ± 1.38
Chest Girth	173.04±1.14	173.23±1.64	172. 43 ± 1.64
Body Depth	203.40± 1.39	203.27±2.1	202.87 ± 2.1
Rump Angle	14.50 ± 0.39	14.15^{a} ± 0 .57	$14. 86^{b}$ ± 0.57
Rump Width	20.62 ± 0.28	20.22 ±0 .37	20.47 ± 0.37
Udder Depth	20.87 ± 0.41	19.28^{a} ±0 .66	22.86^{b}± 0 .66
Teat Length	6.16± 0.24	5.67^{a} ± 0.36	$6. 55^{b}$± 0 .36
Rear Udder Hight	18.46± 0.33	18.05 ± 0 .55	18. 03 ± 0 .55
Angularity	34.99± 0.51	35.78^{b} ± 0 .75	34.71^{a}± 0.75
Rear Leg Rear View	6.28± 0.27	5.78 ± 0 .40	6. 26 ± 0 .40
Rear Leg Side View	6.26± 0.26	5.92 ± 0.38	6.42 ± 0.38
Foot Angle	6.86 ± 0.26	6.56 ± 0 .38	7. 78 ± 0 .38
Fore Udder Attachment	5.91± 0.32	6.06 ± 0 .47	5. 77 ± 0 .47
Front Teat Placement	6.32± 0.46	6.41 ± 0 .55	6. 46 ± 0 .55
Central Ligament	6.55 ± 0.39	6.55^{b}± 0 .50	$6. 17^{a}$± 0 .50
Rear Teat Placement	7.27 ± 0.35	7.28± 0 .451	7.80 ± 0.451

the strength of attachment of the udder to the abdominal floor of a cow. It should be tight and strong, loose attachment of udder is not desirable. The average score for fore udder attachment was 5.91 ± 0.32 points in Sahiwal which was intermediate to slightly higher in range. Other udder traits like front and rear teat placement and their positions were examined and scores were given to each cow; closer the front teats, higher the score was allocated. Rear teats should be closer to central axis of cattle and close together, which indicates better placement of teats for easy milking, good appearance and less susceptibility to mastitis. Mean scores for front and rear teat placement were 6.32 ±0.46 and 7.27±0.35, respectively indicating central positions of teats in Sahiwal breed. Central ligament indicates strength of ligamental attachment of udder of cattle. Tight ligament attachment makes udders less susceptible to mastitis, and other udder related disorders. Average score for central ligament was 6.65 ± 6.60, indicating a medium to higher score in Sahiwal.

Effect of non-genetic factors

Effect of parity

Least squares mean of 17 linear type traits scores based on parity of Sahiwal cows were presented in Table 3. Parity had a significant ($p<0.05$) effect only on fore udder attachment and central ligament

and teat length in Sahiwal cattle on the other hand other traits revealed no significant effect of parity in Sahiwal cows. Thompson et al. (1983) reported parity as a significant effect for all linear type traits in Holstein cattle. Lucas et al. (1984) reported significant effect of parity on fore udder attachment and udder depth in crossbreed cattle, similar to the present study. Least squares mean of teat length increased from first parity to fourth parity in a linear fashion in Sahiwal cattle. Marinov et al. (2015) reported significant effect of parity on teat length in Holstein cattle. Least squares mean of fore udder attachment was decreased from second to third parity, indicating, fore udder attachment loosened with increase in parity in Sahiwal cattle. Constant decrease in least square means of central ligament was observed from first to fourth parity, indicating, weakening or loosening of central ligament of Sahiwal cattle with increase in parity number.

Effect of season of calving

Season of calving was having the significant ($p< 0.05$) effect on udder depth in Sahiwal cattle while, other traits revealed no significant effect of season of calving in Sahiwal cows (Table 4). Udder depth in rainy season (22.82 ±0.83) was found significantly higher than other seasons *viz*., winter, summer and autumn. However, there was no significant difference between winter and summer season in Sahiwal.

Effect of period of calving

Period of calving had a significant ($p<0.05$) effect on different linear type traits viz., rump angle, udder depth, teat length, angularity and central ligament in Sahiwal cattle (Table 5). While, other traits revealed non-significant effect of period of calving in Sahiwal cows. Least squares mean of rump angle (14.86±0.57), udder depth (22.86±0.66) and teat length (6.55±0.36) were significantly higher ($p<0.05$) in 2020-21 year of calving in Sahiwal cows. While, LSM score of angularity (35.78±0.75) and central ligament (6.55±0.50) were significantly ($p<0.05$) higher in 2017-19 years of calving in Sahiwal cattle.

Conclusions

Based on the observations of the present study, it is concluded that Sahiwal cattle have established a balance between the scoring patterns of linear type traits, as the balance scoring of dairy animal for linear type traits is desirable for better sustainability and production performance. Dairy cattle exhibiting a proper balance in linear type traits should be recommended for future breeding. Sahiwal cattle is a breed of intermediate stature, medium to long body, wide and strong chest and intermediate body depth. It was observed that Sahiwal, being one of the most prominent indigenous cattle may have a better scope in the selection process and genetic improvement programs for linear type traits. Results in the present study, focused on the fact that incorporation, scoring and recording of linear type traits should be initiated at organized herds in different other indigenous breeds with larger sample size for efficient observations. This would provide more reliable estimates for inclusion of linear type traits in the selection criteria of the Indian dairy cattle.

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