Multivariate Analysis of Morphometric Traits of Three Different Indigenous Cattle Populations from North East States of India

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ABSTRAK

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Penelitian ini dilakukan untuk membedakan 3 populasi sapi bagian Timur Laut India yaitu Tripura, Mizoram, dan Maniour berdasarkan sifat-sifat morfometrik menggunakan analisis pembeda canonical untuk melihat apakah mereka sama atau berbeda. Data terdiri dari 8 sifat morfometrik yang berbeda dari 383 sapi asli Tripura (136), Mizoram (71) dan Manipur (176). Sifat morfometrik berupa panjang tubuh, tinggi bagian punggung tertinggi, lingkar jantung, lingkar tembolok, lebar wajah, panjang telinga, panjang tanduk, dan panjang ekor tanpa sendi. Semua sifat morfometrik yang diamati memiliki perbedaan yang signifikan untuk semua populasi kecuali pada panjang tanduk. Nilai semua sifat pada sapi Tripura lebih rendah dibandngkan sapi Mizoram dan Manipur. Analisis pembeda bertahap menunjukkan bahwa tinggi bagian punggung tertinggi, panjang badan, panjang telinga, panjang ekor tanpa sendi, lingkat tembolok, and panjang wajah merupakan sifat yang paling berbeda diantara ketiga populasi sapi tersebut. Jarak Mahalanobis berpasangan antara populasi sapi Tripura dan Mizoram, Tripura dan Manipur, serta Mizoram dan Manipur adalah 9,72578, 5,72089 dan 4,65239 berturut-turut dan signifikan. Dendogram menunjukkan bahwa terdapat 2 kelompok, kelompok 1 terdiri dari sapi Manipur dan Mizoram serta kelpompok 2 adalah sapi Tripura yang di[isahkan secara jelas dari kelompok 1. Penempatan individu dari populasi yang berbeda dengan pengelompokkan validasi silang mengungkapkan bahwa 84,13% sapi Tripura, 82,09% sapi Mizoram, dan 79,87% sapi Manipur ditempatkan dengan benar di dalam populasi masing-masing. Berdasarkan pengamatan ini, kita tidak dapat menyimpulkan bahwa mereka adalah tiga bangsa yang berbeda. Tetapi, informasi saat ini, pada tiga populasi sapi tersebut dapat di dimanfaatkan dalam perancangan strategi-strategi yang tepat untuk managemen dan pelestarian sapi-sapi tersebut.

Kata Kunci: Sapi Asli, Sifat Morfometrik, Analisis Multivariate, Analisis Kelompok, Analisis Pembeda Kanonikal

ABSTRACT

Pundir RK, Singh PK, Sadana DK. 2015. Multivariate analysis of morphometric traits of three different indigenous cattle populations from North East states of India. JITV 20(2): 79-86. DOI: http://dx.doi.org/10.14334/jitv.v20i2.1162

In the present study an attempt has been made to differentiate three cattle populations of North East states of India i.e. Tripura, Mizoram and Manipur based on morphometric traits, using canonical discriminant analysis to see whether they are similar or distinct. Data consisted of eight different morphometric traits of 383 indigenous cows from Tripura (136), Mizoram (71) and Manipur (176). Morphometric traits included body length, height at withers, heart girth, paunch girth, face length, ear length, horn length and tail length without switch. All the morphometric traits under study differ significantly in these populations except horn length. All the traits, values were lower in Tripura cows than that of Mizoram and Manipur cows. The stepwise discriminant analysis showed that height at withers, body length, ear length, tail length without switch, paunch girth and face length were the most discriminating traits in these three cattle populations. The pair wise Mahalanobis distances between Tripura and Mizoram, Tripura and Manipur and Mizoram and Manipur were 9.72578, 5.72089 and 4.65239, respectively, and significant. The dendogram showed that there are two clusters; cluster one includes Manipur and Mizoram cows and cluster two Tripura cows those are clearly separated from cluster one. The Individual assignment of different cattle populations by the cross-validation classification revealed 84.13% of Tripura cows, 82.09% of Mizoram cows and 79.87% Manipur cows were assigned correctly into their respective population. Based on the present study we cannot conclude that they are three different distinct breeds. However, the present information on the three cattle populations could therefore be exploited in designing appropriate strategies for their management and conservation.

Key Words: Indigenous Cattle, Morphometric Traits, Multivariate Analysis, Cluster Analysis, Canonical Discriminant Analysis

INTRODUCTION

North East states of India comprises of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura states (Figure 1 and 2). India had 190.9 million cattle heads in the year 2012 including 151.17 million indigenous and 39.73 million exotic and crossbreds (LC 2012). All these states has around 6.9% of total cattle population of the country. The proportion of indigenous and exotic cattle as compared to whole country was 8.19% and 2.28% in these states (Table 1). In this region, there is only one registered cattle breed known as Siri (Sikkim). Rest of the cattle in this region is known as known as *Desi* (non described). There is a need to characterize these cattle populations available in these states and observed similarity/dissimilarity with existing populations using multivariate techniques. If such populations are found distinct/unique, then register them as a distinct breed and if not, search a breed/ population where they can be merged or mixed.

Previous efforts on the phenotypic characterization of breeds of livestock have been restricted to the use of analysis of variance, whereas the current trends in livestock classification involve the use of multivariate statistical tools (Traore et al. 2008; Yakubu & Akinyemi 2010; Peter et al. 2012; Aziz & Al-Hur 2013). Univariate statistical analysis analyzes each variable separately and do not explain how the populations under investigations differ when all measured morphological traits are considered simultaneously (Dossa et al. 2007). Multifactorial discriminant analyses have been found to be more suitable in assessing variation within a population and can discriminate different population types when all measured morphological traits are considered jointly. Discriminate function analysis can be used not only as a means to explain differences among populations, but also to predict group membership for sampling entities of unknown membership. Discriminate analysis has been used for differentiating populations utilizing various morphological measurements simultaneously (Herrera et al. 1996; Capote et al. 1998; Zaitoun et al. 2005; Dossa et al. 2007; Martins et al. 2009; Yakubu et al. 2010a; Yakubu et al. 2010b; Yakubu et al. 2010c; Peter et al. 2012; Aziz & Al-Hur 2013). In the present study an attempt will be made to differentiate between three cattle populations of North East states of India i.e. Tripura, Mizoram and Manipur based on morphological traits, using canonical discriminant analysis to see whether they are distinct or similar.

Table 1. Cattle population (in thousands) in north east states in India in the year 2012

State	Cattle population	Indigenous cattle	Indigenous female	Exotic cattle
Arunachal Pradesh	463.76	440.53	248.67	23.23
Assam	10307.60	9911.70	5695.29	395.90
Manipur	263.84	219.54	133.80	44.31
Meghalaya	896.00	860.75	513.61	35.25
Mizoram	34.57	23.28	14.75	11.30
Nagaland	234.97	106.02	64.46	128.95
Sikkim	140.47	13.95	8.90	126.52
Tripura	948.79	815.69	502.89	133.31
Total	13290.00 (6.96%)	12391.46 (8.19%)	7182.37 (8.05%)	898.77 (2.28%)
India	190904.00	151172.00	89223.00	39731.00

Source: 19th LC 2012 (http://dahd.nic.in/dahd/WriteReadData/Livestock.pdf)

Figure 1. North East zone of India
Source: http://www.mapsofindia.com/states/

Figure 2. North East zone of India
Source: http://www.mapsofindia.com/states/

MATERIALS AND METHODS

Collection of data and location of study

Data consisted of 8 different morphometric traits of 383 indigenous cows from Tripura (136 from West, South, Gomti and Dhalai districts), Mizoram (71 from Champhai and Kolasib districts) and Manipur states (176 from Imphal East, Imphal west and Churachandpur districts) of the union of India. These indigenous cattle in all the three states were not described earlier and so far known as nondescript/desi. All the measurements were recorded by the same recorder to avoid between recorder effects. All the traits were recorded from the left side of the cows. The circumference measurements were taken from a tape while the other measures were taken by a measuring stick. Cows were reared through the extensive management system and originated from different herds in different states.

Measured traits

The recorded morphometric traits were body length (the distance from the point of the shoulder joint to the point of the pin bone), height at withers (the distance from the highest point of withers to the ground), heart girth (the circumference of the chest just behind the elbow joint), paunch girth (the circumference at paunch region just anterior to the hip joint), ear length (distance from the point of attachment of ear to the tip of the ear) face length(distance from between the horn site to the lower lip), horn length (distance from part of horn attachment to the tip of the horn) and tail length without switch (measured from the root of tail droop to the tip of the tail excluding switch). Physical traits like coat colour, body shape, face, horns, udder and tail characters were also recorded.

Statistical analysis

Means, standard errors and coefficients of variation of the different morphometric traits were calculated using General linear model PROC GLM (SAS 2009) with state effect. The DUNCAN's multiple range test was performed by all the means of different morphometric traits to see whether states are differ significantly or not. Stepwise discriminate procedure (SAS 2009) was applied using PROC STEPDISC to determine which morphological traits have more discriminant power than others. The relative importance of the morphometric variables in discriminating between the cattle populations was assessed using the level of significance, partial R2 and F-statistic. The CANDISC (SAS 2009) procedure was used to perform univariate and multivariate one-way analysis that

calculated the Mahalanobis distances between the three cattle populations. Based on the Mahalanobis distance matrix dendogram was created using PROC CLUSTER (SAS 2009) with Average Linkage Method. The ability of these canonical functions to assign each individual animal to its respective population calculated as the percentage of correct assignment to each cattle population using the DISCRIM (SAS 2009) procedure by Nearest Neighbour Discriminant Analysis. The cross-validation approach was used for assignment of individual to their respective population in which one individual is removed from the original matrix and the discriminant analysis is then performed from the remaining observations and used to classify the omitted individual. It also providesan unbiased estimate of error. The proportion of individuals correctly re-allocated is taken as a measure of the morphological distinctness of the population.

RESULTS AND DISCUSSIONS

Tripura, Mizoram and Manipur states are adjoining and located in eastern part of the country. In these states temperature ranged from 10°C to 32ºC. Rice is major crop and no green fodder was grown for animals. Annual rainfall is high more than 2000 mm. Animals were reared mainly on extensive system of management i.e. grazing from morning to evening. Physical traits recorded on these three cattle populations did not reveal significant differences as majority of traits were over lapping. Analysis of physical traits (frequencies) in these cattle population showed that they are differing in proportion of different physical traits, but there was not a single physical trait which can differentiate them strictly. In general animals were small in size with the cylindrical type of body. Animals were well built and compact with strong legs. The coat colour varied in different colours i.e. brown, black and grey/white but brown colour predominates. Dewlap and hump were small. The head was small. Face was short and concave. Ears were small to moderate in length and horizontal in orientation. The neck was short in length and thin. Horns were small, black or gray in colour. Orientation was outward and then upward. Hoofs were black. Muzzles were brown and black. Udder was small, not well developed and milk veins were not prominent. Sizes of fore and rear udder were small. Teats were small 5-12 cm long. Penis sheath flap was short and tucked up with the body. The tail was longer up to the hock with black, brown and white switch. Temperament was docile in all the cases. Cows of these three cattle populations are presented in Figures 3-5.

Descriptive statistics of the morphological traits of three different indigenous cows from three different states are given in Table 2. All the traits under study differ significantly in these populations except horn length. All the traits, values were lower in Tripura cows than that of Mizoram and Manipur cows. Manipuri and Mizoram cows differ significantly in body length, ear length and tail length without switch.

The considerable variation in body dimensions of the three cattle populations might not be unconnected with individual population potential and peculiarities. The minimum and maximum variability was observed in horn length and ear length, respectively. The estimates of body length obtained in the present study were in agreement with the reports of Pundir et al. (2013) in Uttara cows, Pundir et al. (2012) in Pithoragarh cows and Pundir et al. (2009) in Bargur cows. However, higher estimates of body length were observed by Singh et al. (2012) in Pullikumam cows, Pundir et al. (2011) in Kankrej cows and Pundiret al. (2007) in Kenkatha cows.The estimates of height at wither, heart girth and paunch girth were comparablewith the reports of Pundir et al. (2012; 2013). Higher estimates of height at wither were reported by Singh et al. (2012), Pundir et al. (2007; 2011).

Figure 3. Indigenous cattle of Tripura

Figure 4. Indigenous cattle of Manipur

Figure 5. Indigenous cattle of Mizoram

Table 2. Descriptive statistics of different morphometric traits (cm) in indigenous cows of NEH states

State	Overall (383)		Tripura (136)		Mizoram (71)		Manipur (176)	
Trait	Mean+S.E.	C.V.	Mean+S.E.	C.V.	Mean+S.E.	C.V.	Mean+S.E.	C.V.
Body lenght	101.14+0.46**	8.75	98.09+0.54^{c}	6.43	109.03+1.39^{a}	10.77	100.32+0.59^{b}	7.88
Height at wither	101.80+0.45**	8.81	93.39+0.44^{b}	5.52	106.92+0.84^{a}	6.67	106.22+0.51^{a}	6.48
Heart girth	132.45+0.72**	10.72	122.05+1.09^{b}	10.46	139.52+1.59^{a}	9.67	137.69+0.78^{a}	7.53
Paunch girth	136.89+0.82**	11.67	125.41+1.08^{b}	10.13	146.64+1.80^{a}	10.41	142.12+0.98^{a}	9.10
Ear length	19.26+0.13**	13.70	19.47+0.24^{b}	14.38	18.02+0.33^{a}	15.88	19.59+0.17^{b}	11.58
Face length	36.73+0.15**	8.63	35.30+0.20^{b}	6.71	36.15+0.37^{a}	8.82	38.06+0.23^{c}	8.02
Tail length without switch	71.20+0.38**	10.57	68.63+0.51^{a}	8.88	68.54+1.07^{a}	13.23	74.31+0.50^{b}	8.96
Horn length	11.34+0.26	4.37	10.87+0.50	5.20	11.01+0.42	31.90	11.85+0.38	41.01

Table 3. Summary of step wise selection of different traits in indigenous cows of of NEH states

Variable Entered	Partial R-Square	F Value	Pr>F	Wilks' Lambda	Pr< Lambda	Average Squared Canonical Correlation	Pr> ASCC
Height at wither	0.5114	180.06	<0.0001	0.488	<0.0001	0.255	<0.0001
Body length	0.1315	25.96	<0.0001	0.423	<0.0001	0.320	<0.0001
Eal length	0.1814	37.90	<0.0001	0.347	<0.0001	0.390	<0.0001
Tail length without switch	0.1112	21.33	<0.0001	0.308	<0.0001	0.432	<0.0001
Paunch girth	0.0852	15.84	<0.0001	0.282	<0.0001	0.451	<0.0001
Face length	0.0770	14.14	<0.0001	0.260	<0.0001	0.477	<0.0001

Similar estimation of face length and tail length without switch were obtained by Pundir et al. (2007; 2012; 2013). Higher estimates of both the traits were observed by Singh et al. (2012), Pundir et al. (2009; 2011). Comparable estimates of horn length to the present study was reported by Pundir et al. (2013) However, Pundir et al. (2007; 2009; 2011; 2012) and Singh et al. (2012) obtained higher estimates of the same trait.

The stepwise discriminate analysis showed that height at wither, body length, ear length, tail length without switch, paunch girth and face were the most discriminating variables between these three cattle populations (Table 3). Their respective partial R2 were 0.5114, 0.1315, 0.1814, 0.1112, 0.0852 and 0.0770, respectively, with high significant values (P<0.0001). The corresponding F values for these traits were 180.6, 25.96, 37.90, 21.33, 15.84 and 14.14, respectively and highly significant.

These six morphological variables obtained in the present study are more important and informative, and could be used to assign the three cattle populations into distinct populations, thereby reducing the errors of selection in future breeding and selection programmes. Similar to the present study, Yakubu et al. (2010a) also reported height at wither and face length most discriminating traits in two distinct cattle breeds. In an attempt to distinguish between brown and gray Bengal goats, Mukeherjee et al. (1979) reported significant differences between both breeds due to body length and chest circumference.

Herrera et al. (1996) employed discriminate analysis on several body measurements such as, shin circumference, chest girth, chest depth, rump length and width, and shoulder height to differentiate among five Spanish goat breeds. Zaitoun et al. (2005) applied discriminant analysis on 20 metrical variables to discriminate among different goat genetic groups.

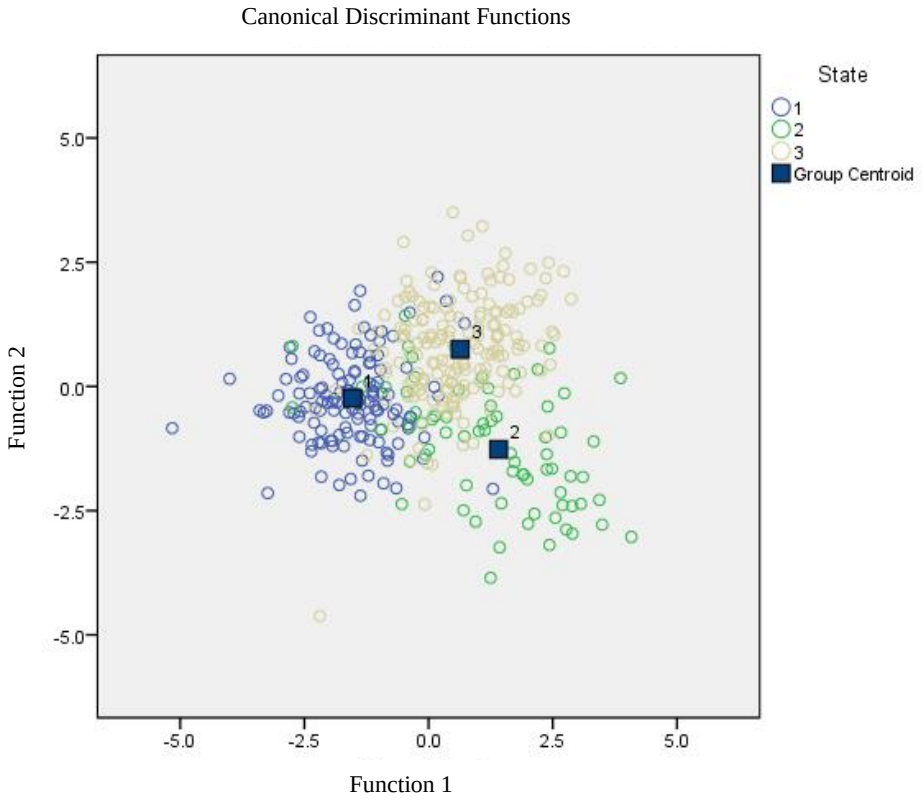

Figure 6. Canonical discriminiant functions of three indigenous cows populations (State 1 Tripura 2 Mizoram 3 Manipur)

In these studies, step-wise discriminant analysis was first applied to select the most important discriminator variables used for differentiation among breeds under study. The canonical discriminant function representation is shown in Figure 6 which revealed overlapping of these populations in the present study.The Mahalanobis distances between three cattle populations are given in Table 4. The pairwise distance Tripura and Mizoram, Tripura and Manipur and Mizoram and Manipur were 9.72578, 5.72089 and 4.65239, respectively, and highly significant (P<0.0001). Yakubu et al. (2010a) Observed Mahalanobis distance between the two cattle populations as 7.19 which was high and significant and indicated that that they belong to genetically different groups. Yakubu et al. (2010c) estimated Mahalanobis distance of 72.28 between West African Dwarf and Red Sokoto goats in Nigeria, indicating that there is considerable genetic variation between both breeds. Aziz & Al-Haur (2013) observed Mahalanobis distance of 0.55 between two lines of goat and between Ardi and each of Line1 and Line2 were 25.03 and 21.45, respectively.

The dendogram (Figure 7) based on the average linkage methodshowed that there are two clusters; cluster one includes Manipur and Mizoram cows and cluster two Tripura cows those are clearly separated from cluster one.

Table 4. Mahalanobis distances between three different populations of indigenous cows in North East States

State	Tripura	Mizoram	Manipur
Tripura	0	9.72578	5.72089
Mizoram	P<0.0001	0	4.65239
Manipur	P<0.0001	P<0.0001	0

In the lower triangular probability of significance is shown

The individual assignment to different cattle populations by the Cross-validation classification was given in table 5. The proportion of individuals correctly assigned to their respective population is considered as a measure of the morphological distinctness of the population.High values of error 0.158, 0.179 and 0.201 were observed for Tripura, Mizoram and Manipur cattle populations, respectively. The reason for this misclassification may be a high degree of intermingling these populations as they are from the adjoining states. The high morphological distances between the cattle populations coupled with high correct assignment to source populations is an indication that they belong to different populations. But there was no distinct physical trait which could differentiate these populations.

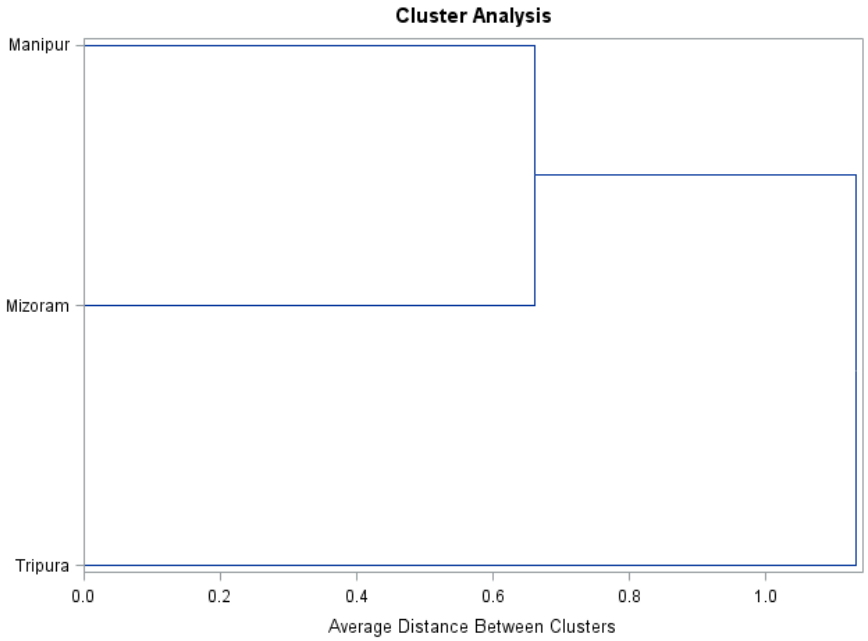

Figure 7. Dendogram showing similarity/distinctness in three indigenous cows populations

Table 5. Percent of individual cows classified in to different populations of north east states

Population	Tripura	Mizoram	Manipur	Total
Tripura	106	7	13	126
	(84.13)	(5.56)	(10.32)	(100)
Mizoram	4	55	8	67
	(5.97)	(82.09)	(11.94)	(100)
Manipur	13	18	123	154
	(8.44)	(11.69)	(79.87)	(100)
Error level	0.158	0.179	0.201	0.158
Priors	0.333	0.333	0.333	

Yakubu et al. (2010a) reported that 85.48% of Bunaji cattle and 96.55% of Sokoto Gudali classified into their source population assigned correctly by the Nearest Neighbour Discriminant Analysis. Aziz & Al-Haur (2013) observed 100% assignment of Ardi animals into their genetic group and percentages of animals assigned in Line1 and line2 were 86.10 and 42.55, respectively. The use of multivariate discriminant analyses therefore could be successfully used in morphometric differentiation. Similar reports on goats (Dossa et al. 2007; Yakubu et al. 2010a; Yakubu et al. 2010b; Yakubu et al. 2010c), sheep (Traore et al. 2008; Yakubu & Akinyemi 2010), cattle (Ndumu et al. 2008) and buffalo (Johari et al. 2009) respectively were observed.

CONCLUSION

In the present study correct assignment of individual animals to their respective population ranged from 80 to 84% but we could not get a physical /discontinuous trait which can distinct these populations may be due to intermingling. Canonical discriminiantanalysis also showed that these three indigenous cow populations were overlapping, so we cannot conclude that they are distinct breeds.

REFERENCES

Aziz MMA, Al-Hur FS.2013. Differentiation between three Saudi goat types using size free Canonical discriminant analysis. Emir J Food Agric. 25:723-735.

Capote J, Delgado JV, Fresno M, Camacho ME, Molina A.1998. Morphological variability in the Canary goat population. Small Rumin Res. 27:167-162.

Dossa LH, Wollny C, Gauly M. 2007.Spatial variation in goatpopulations from Benin as revealed by multivariate analysisof morphological traits. Small Rumin Res. 73:150-159

Herrera M, Rodero E, Gutierrez MJ, Pena F, Rodero JM. 1996. Application of multifactorial discriminant analysis in the morphostructural differentiation of Andalusian caprine breeds. Small Rumin Res. 22:39-47.

Johari S, Kurnianto E, Sutopo S, Hamayanti WA. 2009. Multivariate analysis on phenotypic traits of body measurementin swamp buffalo (*Bubalus bubalis*). J Indones Trop Anim Agric. 34:289-294.

[LC] Livestock Census. 2012. Animal Husbandry Statistics. Department of Animal husbandry and Dairying, MoA, GOI, New Delhi.

Martins CEN, Quadros SAF, Trindade JPP, Quadros FLF,Costa JHC, Raduenz G. 2009. Shape and function in Braford cows: The body shape as an indicative of performance and temperament. Arch Zootec. 58:425-433.

Mukeherjee DK, Singh CSP, Mishra HR. 1979. A note on some phenotypic parameters in grey and brown Bengal goats. Indian J Anim Sci. 49:671-671.

Ndumu DB, Baumung R, Hanotte O, Wurzinger M, OkeyoMA, Jianlin H, Kibogo H,Solkner J. 2008. Genetic andmorphological characterization of the Ankole Longhorn cattle in the African Great Lakes region. Genet Sel Evol. 40:467-490.

Peter TB, Peters SO, Yakuba AA, Michael OO. 2012. Multivariate characterisation of the phenotypic traits of Djallonke and Sahel sheep in Northern Ghana. Trop Anim Health Prod. http://dx.doi.org/10.1007/s11-250-012-02114.

Pundir RK, Singh PK, Prakash B, Ahlawat SPS. 2007. Characterization and evaluation of Kenkatha breed in its native tract. Indian J Anim Sci. 77:177-180.

Pundir RK, Kathiravan P, Singh PK, Manikhandan VA. 2009. Bargur cattle: status, characteristics and performance. Indian J Anim Sci. 79:681-685.

Pundir RK, Singh PK, Singh KP, Dangi PS. 2011. Factor analysis of biometric traits of kankrej cows to explain body. Asian Aust J Anim Sci. 24:449-456.

Pundir RK, Singh PK, Sharma D, Saini A, Singh CV, Prakash B. 2012. Hill cattle of Pithoragarh district of Uttarakhand. Indian J Anim Sci. 82:1591-1593.

Pundir RK, Singh PK, Neelkant, Sharma D, Singh CV, Prakash B. 2013. Uttara- A new cattle germ plasm from Uttarakhand hills. Indian J Anim Sci. 83:51-58.

[SAS] Statistical Analysis System. 2009. Statistical Analysis System User's guide: Release 9.2. SAS Institute, Inc., Cary, NC, USA.

Singh PK, Pundir RK, Kumarasamy P, Vivekanandav P. 2012. Management and physical features of migratory Pullikulam cattle of Tamilnadu. Indian J Anim Sci. 82:15287-90.

Traore A, Tamboura HH, Kabore A, Royo LJ, Fernandez I, Alvarez I, Sangare M, Bouchel D, Poivey JP, Francois D, Sawadogo L, Goyache F. 2008. Multivariate analyses on morphological traits of goats in Burkina Faso. Arch Tierz Dummerstorf. 6:588-600.

Yakubu A, Akinyemi MO. 2010. An evaluation of sexual size dimorphism in Uda sheep using multifactorial discriminant analysis. Acta Agriculturae Sci Section A. 60:74-78.

Yakubu A, Idahor KO, Haruna HS, Wheto M, Amusan S. 2010a. Multivariate analysis of phenotypic differenciation in Bunaji and Sokoto Gudali Cattle. Acta Agriculturae Solvenica A. 96:75-80.

Yakubu A, Salako AE, Imumorin IG. 2010b. Multivariate analysis of spatial patterns of morphological traits in West African Dwarf goats in three agro-ecological zones of Nigeria. J Appl Anim Res. 38:257-260.

Yakubu A, Salako AE, Imumorin IG, Ige AO, Akinyemi MO. 2010c. Discriminant analysis of morphometric differentiation in the West African Dwarf and Red Sokoto goats. S Afr J Anim Sci. 40:381-387.

Zaitoun IS, Tabbaa MJ, Bdour S.2005. Differentiation of native goat breeds of Jordan on the basis of morphostructural characteristics. Small Rumin Res. 56:173-182.