Biological Forum – An International Journal 11(2): 179-185(2019)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Application of Promax Rotated Principal Component Analysis of Diara Buffalo

Ramesh Kumar Singh[1*], Birendra Kumar[1], Rajesh Kumar[2], Santosh Kumar[3] and K.G. Mandal[4]
[1]Assistant Professor, Department of Animal Genetics and Breeding, BVC, Patna (Bihar), India.
[2]Assistant Professor (A.H.), Department of Agronomy, BAC, Sabour (Bihar), India.
[3]Assistant Research Officer, Institute of Animal and Production, (Bihar), India.
[4]Professor, Department of Animal Genetics and Breeding, BVC, (Bihar), India.

(Corresponding author: Ramesh Kumar Singh)*
(Received 27 July 2019, Accepted 07 October, 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT : Diara buffalo population of Bihar reared around banks of Ganga rivers are adapted to the agro-climatic and socio-economic conditions of the state under low-input management system. Principal Components Analysis (PCA) with promax rotation was applied on 20 biometric traits in 400 Diara buffalo to reduce data dimensionality and eliminate redundant variables. The Diara buffalo were observed similar in shape and size and homogeneousness in phenotypes. The phenotypic correlations were found mostly positive in high magnitude and significant correlations. After the application of Oblique rotation. The number of biometric traits to be recorded in Diara buffaloes (BH, NL, BLO, CG, PG, FL, EL, HL, TL and TLS) in PC1 were sufficient for ranking of animals. Hence, Principal Component Analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Keywords: Promax, Morphometric, Traits, Principal Component Analysis, Buffalo, Bihar.

INTRODUCTION

Diara buffalo population of Bihar reared around banks of Ganga rivers are fully adapted to the agro-climatic and socio-economic conditions of the state under low-input management system with respect to the scarcity of feeds and fodder in flood situation and resistance to various diseases. The Bihar had presented increasing trend of milk production from 2012 to 2017 and has produced 8.7 million Tones milk (BAHS, 2017). The buffalo milk 3.35 million Tonnes produced in Bihar contributed 4.1% milk to total milk 81.2 Million Tonnes produced by buffaloes in India. The average milk yield productivity of Buffalo reported to be 4.3 Kg/day in Bihar which is lower than national average 5.23 Kg/day of India (BAHS, 2017). The improvements in productivity required to ensure livelihood security of rural people. The phenotypic characterization of domestic animals consists of describing the morphometric traits of buffalo population which dyers from other groups (Canelon, 2005). The measurement of morphometric traits helps to study the individual shape and sizes to segregate them distinct genetic group. In addition, this characterization explore variation, comparison between and inside genetic groups and establishes the association between the animal's conformation and function. Body size and shape (conformation) are important traits in livestock animals. The data recording system is either lacking or in the initial stage in India. The pedigree and progeny information is limited and has not yet formed the basis for estimating reliable genetic parameters. Therefore, phenotypic information becomes imperative to clarify the relationship among morphometric traits (Ali *et al*., 1995). Body conformation by recording a minimum number of biometric traits which reduce the cost, labour and time is the need of the day. FAO have used height at withers (HT) as a prime indicator for their type (Simon and Buchenauer 1993). Analysis of variance and product moment correlations were widely used to characterize phenotypic and genetic relationships among traits in a breeding programme. The principal components analysis (PCA) is a multivariate technique that reduces the amount of originally-correlated variables into a smaller set of non-correlated variables while keeping most of the original variability and reducing the dimensionality to a new set of variables named principal components (PC) under the assumption of losing the least possible amount of information. When the original variables are highly correlated, the first PCs can explain most of the variation, thus allowing to eliminate redundant information (Meyer, 2007). The PCA allows lowering dimensionality of the variables, facilitating the interpretation of data in a few PC and identifying the type of relationship between the original variables (Agudelo-Gomez, 2015). It presents information about each morphometric variables in order of their merit. Buffalo morphometric traits can be used to predict the ability for commercial exploitation and when applied in breeding selection programs may contribute to creating an appropriate functional type. Therefore, the aim of this study was to reduce data dimensionality, eliminate redundant information and identify similarities using principal components analysis (PCA) with promax rotation.

MATERIAL AND METHODS

Study area. The body linear traits were collected with direct observations and measurements of Diara buffalo in breeding tract. The Diara buffaloes belonging to the breeding tract lies between 25°N and 26°N latitude and between 84°E and 90°E longitude in the middle Gangetic plains of India were taken into present study. Surveys were conducted in 3 districts of the Bihar state i.e. Patna, Ara and Buxar. Diara Buffaloes were randomly selected in a range from first to fifth parity on the basis of availability at farmers. Different body measurements of morphometric traits were recorded on 400 adult animals of Diara buffalo. All measurements were taken by measuring tape and recorded twice by the same recorder to minimize the error and to avoid between recorder effects. The body linear traits of Diara buffalo viz. Height at wither (HW) - Distance from the highest point of wither to the ground; Body length (BL) - Distance from the point of the shoulder joint to the point of the pin bone; Oblique Body length (BLO) - Distance from the point of the neck to the point of the pin bone; Heart girth (HG) - Circumference of the heart circumference around the chest; Paunch girth (PG) - Circumference around the chest; Leg length (LG) - Distance from the point of the shoulder joint to ground; Neck length (NL) - Distance from neck attachment to breast; Neck diameter (ND) - Girth of the neck from mid neck; Face length (FL) - Distance from between the horn site to the lower lip; Face width (FW) - Distance between front of both the eyes; Ear length (EL) - Distance from the point of attachment of ear to the tip of the ear; Horn Length (HL) - Distance between base to tip of horn; Horn Circumstance (HC) – Circumference at base of horn; Distance between horns (DBH) – Distance between two horns; Hip Bone Length (HBL) – Distance between hip point to ischia point; Hip Height (HBH) - Distance between hip point to ground; Pin Bone Length (PBL) - Distance between left and right pin bone point; Distance between Hip and Pin Bone (DHP) - Distance between Hip point to Pin point; Tail length (TL) - Distance between base of tail to tip of tail excluding Swiss hair length; Tail length (TLS) - Distance between base of tail to tip of tail including Swiss hair length were recorded and taken into study. Only adult buffalo were included in this study to prevent the effect of age and gender. The all measurements were taken by a measuring tape in upright animal standing on a level ground. The body measurements of morphometric traits in buffalo were measured in centimetres and always on the left side of the animals using measuring tape. The data were standardized for outliers. No specimens had missing measurements. Ethical approval was not necessary as animals were minimally manipulated. The data were standardized for any missing values and outliers.

Statistical analysis. The data collected were analysed using fixed effect model, by considering district effect as fixed so as to adjust the data for significant effect of district if any as per following statistical model (Harvey, 1987).

$$Y_{ij} = \mu + D_i + e_{ij}$$

where, Y_{ij} is the phenotypic observation for one of the 20 Biometric traits, μ is the overall mean; D_i is fixed effect of District, while e_{ij} is the random error associated with each record which is NID $(0, \sigma_e^2)$. The descriptive statistics Means and standard error were calculated. Peason's correlations (r) among different morphometric traits were estimated. When the recorded data of the biometric traits were correlated then data for the Principal Component Analysis (PCA) were generated using variance-covariance matrix.

Principle Component Analysis (PCA). The Bartlett's test of Sphericity and the KMO index (Kaiser-Mayer-Olkin) tests were computed to establish the variability. The KMO should be greater than 0.5 for statistical factor analysis to proceed; Bartlett's test if it is significant it means that the correlation matrix is not an identity matrix. The principal components are calculated through linear combinations of the morphometric variables. The absolute value of an eigenvector determines the importance of the traits in a principal component. Each eigenvector is calculated from an eigenvalue of the correlation matrix of the data, where the eigenvalues are related to the variance of each principal component (Rencher, 2002). PCA consists of transforming the set of original variables into a new set of variables which are linear functions of the original variables and independent of each other. Therefore, new variable is a principal component, calculated by linear combinations of the original variables with eigenvectors. The PCA was used to study the body conformation of the buffalo considering 20 body measurement traits. Rotation of principal factors was through the transformation of the factors to approximate a simple structure. Factor analysis using oblique (promax) rotation with power 3 employed for the rotation of the principal components matrix. Cumulative proportions of variance criterion were finally employed to determine the number of components to extract. Scree test was used to retain number of principal components which lies above the bended elbow of scree plot. Further, principal components to be retained based on its obtained Eigenvalue > 1 criterion (Kaiser, 1958). Each observed variable contributes one unit of variance to the total variance. If the eigenvalue is greater than 1, then each principal component explains at least as much variance as 1 observed variable. All analyses were performed using standard statistical and PCA procedure with different required packages available from R software.

RESULTS AND DISCUSSION

The effect of non-genetic factor District was investigated in the study and presented non-significant effect on all traits. It indicated that different morphometric traits across districts of Diara buffalo are similar in shape and size and not significantly different between each other. The mean statistics for themorphometric traits of Diara along with standard error has been shown in Table 1. Mean of biometric traits (cm) studied in Diara buffaloes were 121.75 ± 4.35 for BH, 113.16 ± 6.34 for BL, 123.66 ± 6.56 for BLO, 173.83 ± 10.03 for CG, 196.33 ± 11.72 for PG, 72.41 ± 2.31 for LG, 41.33 ± 2.23 for NL, 80.5 ± 4.97 for ND, 41.08 ± 1.84 for FL, 17.25 ± 0.69 for FW, 24.91 ± 1.25 for EL, 27.41 ± 3.33 for HL, 15.5 ± 1.60 for HC, 27.41 ± 1.49 for DBH, 41.58 ± 3.59 for HBL, 120.08 ± 4.01 for HBH,23.75 ± 2.08 for PBL, 36.08 ± 1.83 for DHP, 82.08 ± 4.14 for TL and 92.5 ± 4.4 for TLS. The means of biometric traits that Diara buffaloes were medium to larger in body size. Based on comparison of biometric traits, Diara buffalo are slightly smaller in height and length of Gojri buffaloes and Nilli Ravi buffaloes (Nivsarkar *et al*. 2000; Ahmad *et al.* 2013; Vohra *et al.*, 2015). This may due to poor management condition given to Diara Buffalo and harsh climatic condition of the region. The correlation coefficients between studied biometric traits are given in Table 2. Correlation coefficient estimated ranged between 0.20 (TL and HC) to 0.98 (TL and TLS) among various biometric traits. A total of 189 correlations (in all combinations) were estimated. Among these 147 correlations were significant and positive (Table 1 and 2). These correlations among all 147 correlations were moderate to high in magnitude. All other correlations were low to moderate in magnitude. The result is in agreement with the findings of phenotypic correlations with slight disagreements of Gojri buffalo where few correlations were negative (Vohra *et al.* 2015). The proportions of correlations (more than 75%) between measurements of biometric traits were positive and significant respectively in Kankrej cows (Pundhir *et al.* 2011) and local hill cattle (Tolenkhomba *et al*. 2013). The positive and significant (p<0.05/0.01) correlations among different biometric traits suggest high predictability among the different traits. Further, varying estimates of correlations in biometric traits could be attributed to the fact that postnatal growth does not take place proportionality in all tissue.

Table 1: Phenotypic Correlations among Morphometric Traits.

Trait	FW	EL	HL	HC	DBH	HBL	HBH	PBL	DHP	TL	TLS
FW	1										
EL	0.16	1									
HL	0.73**	0.55	1								
HC	0.31	0.55**	0.4	1							
DBH	0.63*	-0.08**	0.61	0.04	1						
HBL	0.74*	0.38**	0.93	0.39	0.49*	1					
HBH	0.81*	0.45**	0.88	0.29	0.67*	0.78**	1				
PBL	0.64*	0.58**	0.94*	0.24	0.5	0.83**	0.87**	1			
DHP	0.57	0.62**	0.91*	0.49	0.57	0.8**	0.77**	0.77**	1		
TL	0.57	0.56**	0.85	0.2	0.56	0.7*	0.88**	0.93**	0.75**	1	
TLS	0.48	0.44**	0.78	0.06	0.59*	0.61*	0.85**	0.86**	0.71*	0.98**	1

**<0.01; *<0.05

Table 2.

Trait	BH	LG	NL	NC	BL	BLO	CG	PG	FL
BH	1								
LG	0.75**	1							
NL	0.91**	0.76*	1						
NC	0.9**	0.57**	0.75**	1					
BL	0.93**	0.6*	0.85**	0.94**	1				
BLO	0.93**	0.67*	0.86**	0.96**	0.97**	1			
CG	0.96**	0.66*	0.84**	0.96**	0.93**	0.97**	1		
PG	0.89**	0.52*	0.79**	0.94**	0.93**	0.96**	0.97**	1	
FL	0.88**	0.61*	0.86**	0.81**	0.9**	0.91**	0.89**	0.89**	1
FW	0.78**	0.58*	0.76**	0.72**	0.77**	0.84**	0.82**	0.82**	0.76**
EL	0.52	0.67*	0.66*	0.31	0.39	0.4	0.42	0.31	0.56
HL	0.9**	0.7*	0.9**	0.9**	0.91**	0.95**	0.91**	0.87**	0.9**
HC	0.5	0.45*	0.5^{ns}	0.24	0.48	0.39	0.37	0.33	0.66
DBH	0.64*	0.47*	0.42^{ns}	0.73**	0.63**	0.67**	0.65**	0.55**	0.41
HBL	0.81**	0.61*	0.8**	0.83**	0.85**	0.91**	0.86**	0.89**	0.89**
HBH	0.96**	0.75*	0.9**	0.9**	0.89**	0.92**	0.93**	0.88**	0.78**
PBL	0.84**	0.69*	0.89**	0.83**	0.86**	0.88**	0.83**	0.8**	0.76**
DHP	0.85**	0.65*	0.76**	0.86**	0.82**	0.85**	0.86**	0.79**	0.87**
TL	0.87**	0.7*	0.83**	0.86**	0.84**	0.84**	0.85**	0.77**	0.68**
TLS	0.81**	0.59*	0.73**	0.86**	0.78**	0.78**	0.8**	0.73**	0.57

**<0.01; *<0.05

The PCA was applied on 20 biometric traits of Diara Buffaloes. The value of KMO measure of sampling adequacy (MSA) was obtained as 0.907. This value fits with the acceptable threshold criterion of KMO (> 0.5) which permits to proceed with PCA analysis. The estimate of sampling adequacy KMO revealed the proportion of the variance in different biometric traits caused by the underlying components (Kaiser, 1958). The overall significance of the correlation matrix was tested with Bertlett's test of sphericity for the biometric traits (chi-square was 3575.5 p<0.01) was significant, it means correlation matrix is not an identity matrix and provided enough support for the validity of the factor analysis of data. Yakuba *et al*. (2009) reported in close agreement of our estimates of sampling adequacy were 0.90 and 0.92 in age groups of 1.5 to 2.4 years and 2.5 to 3.6 years, respectively in White Fulani cattle. However, Vohra *et al*. (2015); Pundir *et al*. (2011) reported lower estimates of sampling adequacy as 0.74 in Gojri buffalo and 0.891 in Kankrej cows, respectively. The percentages of the explained variances and cumulated variances for body morphometric traits are presented in Table no. 03. The results show that the first three components accounted for 90% of the total variance whose the eigenvalues were greater than 1(>1). The remaining seventeen PCs had lower variance. The second (PC_2) and third (PC_3) principal components accounted for 9% and 6%, respectively of the total variance while the remaining 17 PCs jointly accounted for 10% of the total variation.Another criterion for determination of number of component is scree plot that could be used to decide the actual number of component to be retained for analysis. Scree plot can depict various components and the component having eigenvalue up to the bent of elbow are usually considered. Three Principal Components above the bend or elbow are indicated in plot (Fig. 1) which suggest its retention for extraction. Based on above criteria, three components are appropriate for summarizing the data of biometric traits of Diara buffalo.

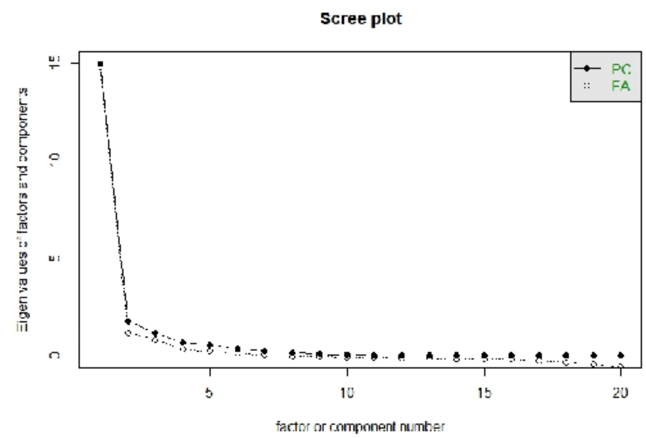

Fig. 1. Scree plot of components and eigenvalues for body morphometric traits of Diara buffalo.

The identified three components could explain cumulative percentage of variance of 90%. First component accounted for 75% of the variation. It was represented by significant positive high loading of BLO, BH, CG, HL, BL, HBH, NC, PG, NL, PBL, FL, TL, HBL and DHP. First component seemed to be explaining the maximum of general body conformation in Diara Buffaloes. The second component (PC2) explained 9% of total variance with high loading of distance between EL and HC. The third component (PC3) explained 6% of total variance with high loading of distance between FW and HC. Vohra *et al.* (2015) used factor analysis with promax rotation revealed 4 components which explained about 70.86% variation which is slightly lower to our finding but the total variation with first component explained 31.45% of total variation and was represented by significant positive high loading of height at wither (HW), BL, FL, FW, HL and CG in Gojri buffalo. In Egyptian buffalo bull Shahin *et al*. (1993) reported that most of the common variability (88%) in body dimensions could be accounted for by components representing general size, body depth and height and head width. Tolenkhomba *et al*. (2013) used factor analysis with promax rotation revealed 6 components which explained about 69.77% which is slightly lower to our finding but the total variation with first component explained 21.93% of total variation and was represented by significant positive high loading of height at wither, BL, heart girth, PG, and EL in local cattle of Manipur.

The proportion of total variance explained by first component was more in this study (75%) compared to by Tolenkhomba *et al*. (2013); Vohra *et al*. (2015). Yakubu *et al*. (2009) extracted 2 factors in the age group of 2.5 to 3.6 years explained 86.47% of the total variation by studying the 14 morphostructural traits of White Fulani cattle. These differences indicate that each population has its own characteristics. The selection criteria should be determined taking into account the specificity of population or breed.

Table 3: Variance and Proportion of variances explained by Principal Components for morphometric traits of Diara buffalo.

Variance Name	PC1	PC2	PC3
SS loadings	14.99	1.76	1.18
Proportion Var	0.75	0.09	0.06
Cumulative Var	0.75	0.84	0.9
Proportion Explained	0.84	0.1	0.07
Cumulative Proportion	0.84	0.93	1

The proportion of total variance explained by the first component was more in present investigation compared to earlier study Assam hill cattle (21.93%) and in Gojri buffalo (31.45) (Vohra *et al*. 2015) but lowered than those reported White Fulani cattle. The second component explained 9% of total variance with high loading of EL and HC. The proportion of total variance explained by the second component was less in present investigation compared to earlier study 17.15% in Gojri buffalo (Vohra *et al.,* 2015).

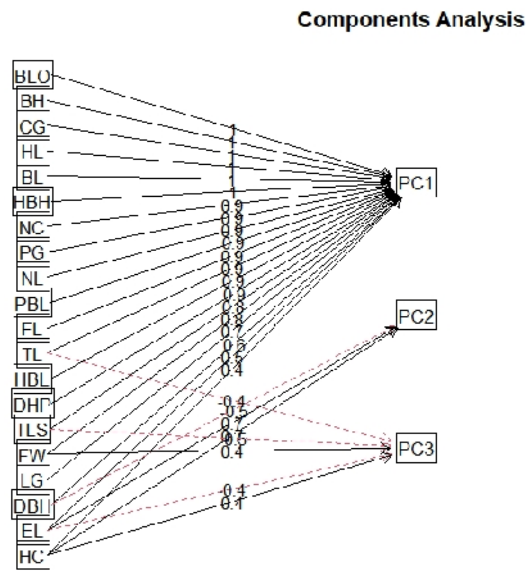

Fig. 2. Diagram of the Two Factor Loading (Solution) for Biometric traits of Diara buffalo.

Promax Rotation of Principle Components. The identified three components after oblique rotation i.e. Promax could explain cumulative percentage of variance of 90%. First component accounted for 52% of the variation. It was represented by significant positive high loading of FW, PG, DBH, BLO, NC, CG, BL and HBL. First component seemed to explain length, height and depth of Diara buffalo. The second component explained 11% of total variance with high loading of EL and HC, traits. Vohra *et al.* (2015) used factor analysis with promax rotation revealed 4 components which explained about 70.86% which is slightly lower to our finding. The first component after Promax rotation explained 31.45% of total variation and was represented by significant positive high loading of height at wither (HW), BL, FL, FW, HL and CG in Gojri buffalo (Vohara *et al*. 2015). It is lower than the first component value of promax rotation obtained in Diara buffaloes. Tolenkhomba *et al.* (2013) used factor analysis with promax rotation revealed 6 components which explained about 69.77% which is slightly higher to our finding but the total variation with first component explained 21.93% of total variation and was represented by significant positive high loading of height at wither, BL, heart girth, PG, and EL in local cattle of Manipur. However, Yakubu *et al.* (2009) extracted two factors each explaining 86.47% of the total variation in White Fulani bulls.

Communality. The communality ranged from 0.99 (PG) to 0.68 (DBH) for all the 20 different morphometric traits. The obtained communality indicated that bulk portion of variance has been accounted for by the component solution. For BH, NL, BLO, CG, PG, FL, EL, HL, TL and TLS of their variance has been captured by three PCs. These traits possess more than 90 % communality being of same sign, the PC1seems to explain major portion of variation of Diara buffalo. Tolenkhomba *et al.* (2013) reported communality ranged from 0.59 (body length) to 0.85 (hind girth) in local bulls of Manipur. Similar estimates of communality (ranged from 0.79 to 0.93) were observed by Yakubu *et al*. (2009) in White Fulani cattle.

The inter-factor correlations between two components were positive and significant (0.65) between first and third components in Diara buffaloes. The application of Oblique characters (PC1) derived from the PCA can be more reliable in predicting body size compared to the use of the original body measurements. The three extracted factors determine the source of shared variability to explain body conformation in Diara buffaloes. These first PC could be exploited in the evaluation and comparison of animals and thus provide an opportunity to select the animals based on a small group of traits rather than on isolated traits. Our results suggest that the present PCA provided a means for a reduction in the number of biometric traits to be recorded in Diara buffaloes (BH, NL, BLO, CG, PG, FL, EL, HL, TL and TLS) which could be used in ranking programs as a mean to explain the body conformation. The results suggest that principal component analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Table 4: Component Matrix or Standardized loading of different Promax Rotated Component for Morphometric traits of Diara buffalo.

Traits	RC1	RC3	RC2	Communalities
BH	0.68	0.31	0.14	0.95
LG	0.14	0.62	0.2	0.68
NL	0.43	0.47	0.26	0.9
NC	0.85	0.23	-0.13	0.95
BL	0.82	0.14	0.12	0.93
BLO	0.86	0.15	0.08	0.99
CG	0.83	0.18	0.06	0.96
PG	0.92	0.01	0.07	0.92
FL	0.71	0	0.5	0.97
FW	1.01	-0.27	0.14	0.81
EL	-0.49	0.91	0.48	0.97
HL	0.63	0.37	0.12	0.94
HC	0.16	-0.2	0.96	0.87
DBH	0.9	-0.04	-0.38	0.7
HBL	0.79	0.05	0.22	0.83
HBH	0.67	0.41	-0.07	0.93
PBL	0.4	0.67	-0.08	0.91
DHP	0.52	0.34	0.22	0.81
TL	0.34	0.81	-0.23	0.97
TLS	0.34	0.83	-0.41	0.95

Table 5: Total Variance and Proportions of Variances explained by Promax Rotated Components for morphometric traits of Diara buffalo.

Variances	RC1	RC3	RC2
SS loadings	10.43	5.23	2.27
Proportion Variance	0.52	0.26	0.11
Cumulative Variance	0.52	0.78	0.9
Proportion Explained	0.58	0.29	0.13
Cumulative Proportion	0.58	0.87	1

Table 6: Correlation between Promax Components.

Components	RC1	RC3	RC2
RC1	1	0.65	0.31
RC3	0.65	1	0.44
RC2	0.31	0.44	1

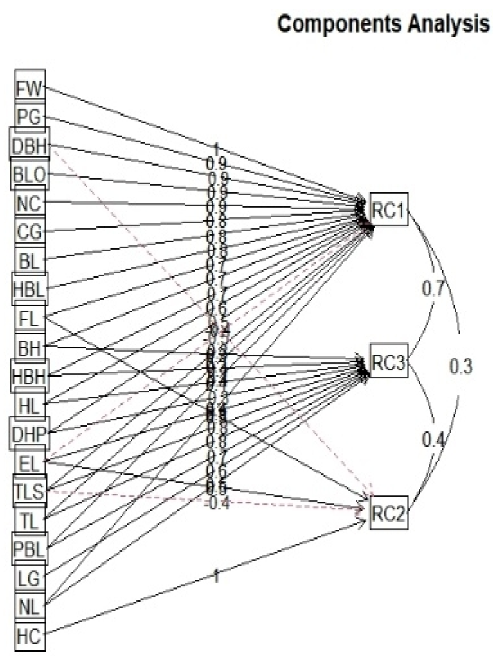

Fig. 3. Diagram of the Two Promax Rotated Component Loading (Solution) for Biometric traits of Buffalo of Kosi Region.

Acknowledgements. We are very much thankful to state Veterinary officers for assisting us in collection of data in field at farmer's houses.

Conflict of Interest. None.

REFERENCES

Agudelo-Gómez, D., Pineda-Sierra, S., & Cerón-Muñoz, M. F. (2015). Genetic evaluation of dual-purpose buffaloes (*Bubalus bubalis*) in Colombia using principal component analysis. *PloS one*, **10**(7): e0132811.

Ahmad, N., Abdullah, M., Javed, K., Khalid, M. S., Babar, M. E., Younas, U., & Nasrullah (2013). Relationship between Body Measurements and Milk Production in Nili-Ravi Buffaloes Maintained at Commercial Farms in Peri-Urban Vicinity of Lahore. *Buffalo Bull*, **32**(2): 792-795.

Ali, A. K. A., Al-Enazi, M., Hayes, E., & Al-Saidy, M. (1995). Phenotypic factor and image analysis of type traits of Holstein cows in the Masstock Saudi herds. *J. King Saud Univ. Agric. Sci.*, **7**(2): 143-161.

BAHS (Basic Animal Husbandry Statistics) (2017). Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Govt. of India, New Delhi.

Canelón, J. L. (2005). Phenotypic characteristics of the Criollo horse: observations in the Apure State. *Arch Zoot*, **54**: 217-220.

Harvey, W. R. (1987). Least squares analysis of data with unequal subclass numbers ARS H-4. *USDA, Washington DC*.

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika* **23**: 187–200.

Meyer, K. (2007). Multivariate analyses of carcass traits for Angus cattle fitting reduced rank and factor analytic models. *Journal of Animal Breeding and Genetics*, **124**(2): 50-64.

Nivsarkar, A. E., Vij, P. K., & Tantia, M. S. (2000). Animal genetic resources of India: Cattle and Buffalo. Directorate of information and publications of Agriculture, ICAR, New Delhi, India

Pundir, R. K., Singh, P. K., Singh, K. P. & Dangi, P. S. (2011). Factor analysis of biometric traits of Kankrej cows to explain body conformation. *Asian-Australasian Journal of Animal Sciences*, **24**(4): 449-456.

Rencher, A. C. (2002). Methods of multivariate analysis. 2nd ed. New York: Wiley-Inter-Science; 2002. p. 361–404.

Simon, D. L., & Buchenauer, D. (1993). Genetic diversity of European livestock breeds. Results of monitoring by the EAAP Working Group on Animal Genetic Resources.

Shahin, K. A., Soliman, A. M., & Moukhtar, A. E. (1993). Sources of shared variability for the Egyptian buffalo body shape (conformation). *Livestock Production Science*, **36**(4): 323-334.

Tolenkhomba, T. C., Singh, N. S., & Konsam, D. S. (2013). Principal component analysis of body measurements of bulls of local cattle of Manipur, India. *Indian J. Anim. Sci.*, **83**(3): 281-284.

Vohra, V., Niranjan, S. K., Mishra, A. K., Jamuna, V., Chopra, A., Sharma, N., & Jeong, D. K. (2015). Phenotypic characterization and multivariate analysis to explain body conformation in lesser known buffalo (*Bubalus bubalis*) from North India. *Asian-Australasian Journal of Animal Sciences*, **28**(3): 311-317.

Yakubu, A., & Ayoade, J. A. (2009). Application of principal component factor analysis in quantifying size and morphological indices of domestic rabbits. *Int. J. Morphol.*, **27**: 1013-1017.

How to cite this article: Singh, R.K., Kumar, B., Kumar, R., Kumar, S. and Mandal, K.G. (2019). Application of Promax Rotated Principal Component Analysis of Diara Buffalo. *Biological Forum – An International Journal*, *11*(2): 179-185.