Biological Forum – An International Journal **11(2): 186-191(2019)**

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

Production Performance and Body Morphometric Measurements in Diara Buffaloes of Bihar India

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 02 August 2019, Accepted 10 October, 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT : Morphometric measurements of 20 traits of 400 Diara buffaloes of Bihar, India were recorded and used in analysis for phenotypic characterisation. Means and standard error were estimated for production, reproduction and morphometric traits of Diara buffalo. Peason's correlations (r) among different morphometric traits were estimated and used for Principal Component Analysis (PCA). Lactation milk yield (Kg), Daily Milk Yield (Kg), Lactation length (days), Peak yield (Kg), Dry period (days), Calving interval (months), Age at first service (months), Age at first calving (months) and Service period (days) were estimated to be 1450.87 ± 28.12, 4.9 ± 0.4, 301.67 ± 12.87, 9.65 ± 0.33, 89.87 ± 4.25, 14.4 ± 0.13, 34.86 ± 0.78, 46.27 ± 0.63 and 131.31 ± 3.06, respectively. The 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. Correlation coefficient estimated ranged between 0.20 (TL and HC) to 0.98 (TL and TLS) among various biometric traits. Among all estimated phenotypic correlation, these 147 correlations were significant and positive. The positive and significant (p<0.05/0.01) correlations among different biometric traits suggest high predictability among the different traits. The first three PC explained 90 % of the original variance of 20 body linear traits of Diara buffalo. The first (PC1) second (PC2) and third (PC3) principal components accounted for 75%, 9% and 6% of the total variance, respectively. The traits represented in first PCs can be used in selection criteria and presented reduction in dimensionality of explanatory variables.

Keywords – Morphometric, Production, Diara, Buffaloes, Bihar.

INTRODUCTION

India harbors all the recognized and high milk producing breeds of buffalo of the world. More than half of the total buffalo population of India is classified as non-descript in the lack of characterization efforts. Similarly, the buffalo population of Bihar state of India placed under non-descript type in absence of systematic efforts of characterization. The buffalo in Bihar accounts for nearly 48% of the total milk production in the state (BAHS, 2017). This indicates that buffaloes in Bihar are efficient milk producers and an important Animal Genetic Resource for augmenting milk production in the state. Buffaloes are distributed throughout the length and breadth of the state but the area under South and North Gangetic plains of Bihar is densely populated with clusters of buffalo, phenotypically homogenous in certain characteristics, popularly known as Diara buffalo. They are well adapted to submerged condition of land in rainy season with water of the river Ganga. These buffalo are fully adapted to the agro-climatic and socio-economic conditions of the state under low-input management system in the Taal and Diara area of the river Ganges, Sone and Gandak. These populations of Diara buffalo required genetic improvement for augmenting milk production. Assessment of variability present in a population is vital and it is a basic component for working out conservation strategies and for designing genetic improvement programs for a particular population. The phenotypic characterization of domestic animals consists of describing the exterior traits of each group, differing from other groups when considered as a whole (Canelón, 2005). This characterization included the biometric measurements of sample animals body structure. The biometric body traits can be studied by using measurements with appropriate instruments which are called morphometric traits. Morphometric measurement allows identification of the individual conformation, allowing the racial characterization and classification of the population. In addition, this characterization allows the comparison between and within genetic groups and establishes the association between the animal's conformation and function. These traits also contribute to the selection process in identifying the superior animals (Carvalho *et al*., 2010). The estimates of morphometric traits and correlations are reported scanty in literature (Espinosa-Núnês *et al*., 2011; Johari *et al*., 2009; Vohra *et al*., 2015; Mirza *et al.*, 2015; Dhillod *et al*. (2017) which required for formulation of genetic improvement programmes. As reported by Agudelo-Gómez *et al*. (2015) the body measurements of female buffaloes and their correlations can aid in predicting the potential and aptitudes of these animals. There is some association between the body measurements, the productive and reproductive traits in buffaloes (Thomas and Chakravarty 2000; Espinosa-Núnês *et al*., 2011; Kern *et al*., 2014) and in cattle (Wenceslau *et al*., 2000; Lagrotta *et al*., 2010). Productive and Reproductive traits are economically important for sustainable productivity and profitability from buffalo.

The demand of products of buffalo milk is on rise for its flavor and healthy food to human. The understanding of variation of production and Reproduction traits is essential to improve production levels by forming suitable breeding strategies (Lopes *et al.*, 2008). The phenotypic information on conformation traits becomes imperative when pedigreed phenotypic information on productive and reproductive traits unavailable to enhance the productivity of animals (Yakubu and Ayoade 2009). Analysis of variance and product moment correlations are widely used to characterize phenotypic and genetic relationships among traits in a breeding program (Yakubu *et al.*, 2011). However, principal component analysis is a more refined technique for analyzing data on linear body measurements and performances (Posta *et al.*, 2007). Principal components are linear combinations of the original traits and are estimated in such a way that the first principal component can explain the largest percentage of the total phenotypic variance. This paves way for the explanation and identification of trait groups, which can allow a quantitative measure for animal conformation with fewer parameters. The resulting principal components or loading may decrease the dimension of the explanatory variables. Diara buffalo required to be characterized and documented for exploring the variability of traits and need to be identified important morphometric traits to formulate improvement and conservation programme. The present investigation explores the variation of productive and reproductive traits and to identify the redundant morphometric traits with principal component analysis to aid buffalo selection programs.

MATERIAL AND METHODS

Place of research. 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. The data was collected from 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. Performance traits like lactation yield, daily milk yield, lactation length, peak yield, dry period, calving interval, age at first calving, age at first service and service period were collected by conversing with the farmers from the surveyed villages. Different body measurements and physical characteristics were recorded on 400 adult animals of different sex during the period of years 2017 - 2019. 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 morphometric traits of Diara buffalo (buffalo 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. 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 morphometric 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 $(0, \sigma_e^2)$. Means and standard error were calculated. Peason's correlations (r) among different morphometric traits were estimated. When the recorded data of the morphometric traits were highly correlated then data for the Principal Component Analysis (PCA) were generated using variance-covariance matrix.

Principle Component Analysis (PCA). The data is further checked for sample adequacy using Bartlett's Sphericity and the KMO index (Kaiser-Mayer-Olkin) tests for checking of data suitability for Principle Component Analysis (PCA). Principal Component Analysis (PCA) which reduces the dimensionality of a data set was used. The PCA can explain relationships between different body morphometric traits in a better way. The derived variables in PCA called principal components are linear combinations of the observed variables. The PCA equation as follows

$$PC_p = a_{1p}X_1 + a_{2p}X_2 + \ldots + a_{np}X_n$$

Where PCp is the weighted combination of the n observed variables that accounts for the most variance in the original set of variables Where, X was observed variables; a is a matrix of eigenvectors (weights). The second principal component is the linear combination that accounts for the most variance in the original variables under the constraint that it's orthogonal (uncorrelated) to the first principal component. Each subsequent component maximizes the variance accounted for while at the same time remaining uncorrelated with all previous components. Theoretically, you can extract as many principal components as there are variables. 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 the statistical analyses were implemented using algorithms available in R software.

RESULTS AND DISCUSSION

The descriptive statistics for all the production and reproduction performances of Diara buffalo was presented Table no 01 along standard error. Diara buffaloes are moderate milk producers and normally give four to nine litres of milk daily. The average peak yield was obtained 9.65 Kg per day. The average daily milk yield was 4.9 ± 0.4 Kg as reported by the farmers. The length of lactation varied from 210 to more than 340 days with an average of 301.6±10.3 days. The lactation milk yield varied from 1008.4±95.7 to 1635.6±112 litres with a mean of 1450.87±28.7 Kg. Diara buffaloes have relatively long productive life spans as demonstrated by animals with more than five calvings commonly found in the villages. Age at first calving and calving interval was estimated to be 46.27 ± 0.63 months and 14.4 ± 0.13 months, respectively. The dry period, average age at first service and service period was estimated to be 89.87±4.25 days, 34.86±0.78 months and 131.31±3.06 days. The different traits estimated above are in agreement with Chandran *et al*. (2015) in Diara Buffalo. These findings suggest that Diara buffalo appeared as moderate performer for production and reproduction traits.

Table 1: Production and Reproduction Performances of Diara buffalo.

Traits	Production
Lactation milk yield (Kg)	1450.87 ± 28.12
Daily Milk Yield (Kg)	4.9±0.4
Lactation length (days)	301.67 ± 12.87
Peak yield (Kg)	9.65 ± 0.33
Dry period (days)	89.87±4.25
Calving interval (months)	14.4±0.13
Age at first service (months)	34.86±0.78
Age at first calving (months)	46.27±0.63
Service period (days)	131.31±3.06

The effect of non-genetic factor District was investigated in the study and presented non-significant effect on all traits. It indicates that different morphometric traits across districts of Diara buffalo are similar and not significantly different between each other. The mean and standard error of 20 morphometric traits of adult Diara buffalo are presented in Table 2.

The 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 obtained results are in agreement with Chandran *et al*. (2015). 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.

Table 2: Least squares means of different body linear traits of Diara buffalo.

Sr. No.	Parameters	Code	Mean ± SE
1.	Height at wither (cm)	BH	121.75 ± 4.35
2.	Body length Horizontal (cm)	BL	113.16 ± 6.34
3.	Body length Oblique (cm)	BLO	123.66 ± 6.56
4.	Heart girth (cm)	CG	173.83 ± 10.03
5.	Paunch Girth (cm)	PG	196.33 ± 11.72
6.	Leg (cm)	LG	72.41 ± 2.31
7.	Neck Length (cm)	NL	41.33 ± 2.23
8.	Neck Circumstance (cm)	ND	80.5 ± 4.97
9.	Face Length (cm)	FL	41.08 ± 1.84
10.	Face Width (cm)	FW	17.25 ± 0.69
11.	Ear Length (cm)	EL	24.91 ± 1.25
12.	Horn Length (cm)	HL	27.41 ± 3.33
13.	Horn Circumstance (cm)	HC	15.5 ± 1.60
14.	Distance between horns (cm)	DBH	27.41 ± 1.49
15.	Hip Bone Length (cm)	HBL	41.58 ± 3.59
16.	Hip Height (cm)	HBH	120.08 ± 4.01
17.	Pin Bone (cm)	PBL	23.75 ± 2.08
18.	Distance between Hip and Pin Bone (cm)	DHP	36.08 ± 1.83
19.	Tail length (cm)	TL	82.08 ± 4.14
20.	Tail Length up switch to Switch (cm)	TLS	92.5 ± 4.4

Correlation coefficient. The phenotypic correlation coefficients between studied biometric traits are given in Table 3 (a) and 3 (b). 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 3 a & b). 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 in Diara buffalo with slight disagreements of Gojri buffalo where few correlations were negative (Vohra *et al.* 2015).The positive and significant ($p<0.05/0.01$) correlations among different biometric traits suggest high predictability among the different traits.

Table 3 (a): Phenotypic Correlations among Biometric Traits.

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

$^{**}<0.01$; $^{*}<0.05$

Further, varying estimates of correlations in morphometric traits could be attributed to the fact that postnatal growth does not take place proportionality in all tissue categories or body regions within those tissue categories. PCA was performed using values of 20 body linear traits of Diara buffalo. The obtained eigenvalues and variance proportions for the principal components (PC) of 20 body linear traits are presented in Table 4. The first three PCs had eigenvalues greater than one, and explained 90 % of the original variance of 20 body linear traits of Diara buffalo. The obtained 3 PCs presented their usefulness to reduce dimensionality. The remaining 17 PCs had lower variance (10%). The first (PC1), second (PC2) and third (PC3) principal components accounted for 75%, 9% and 6% of the total variance, respectively, while the remaining PCs jointly accounted for 10% of the total variation. The morphometric traits BH, NL, NC, BL, BLO, CG, PG, FL, HL, HBH, PBL and TL had high loading in first PCs. These traits reflect height, length and diameter of Diara buffalo.

Table 3 (b): Phenotypic Correlations among Biometric 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

In similar study, Vohra *et al*. (2015) obtained 4 PCs explaining 70% of the total variance after analyzing 13 morphometric traits of Gojri buffalo. In present study, the first Principal Component (PC1) explaining 75% of bulk of total variation. It suggesting that PC1 could be used in evaluation and comparison of morphometric traits and for selection of animals. According to the report by Val and Ferraudo (2008), the first two PCs comprised 70.33% of the total variation of six traits associated with meat production and one trait associated to breeding in Nellore cattle. Three PCs accounted for 100% of the additive genetic variance of nine traits associated with meat production in Nellore cattle (Boligon *et al.*, 2013). Oliveira et al. (2014) evaluated seven productive and two reproductive traits of buffaloes in Brazil concluding that a reduced rank model with 3 or 4 PCs was sufficient to explain the largest percentage of the additive genetic variance for all the traits. According to the results of this study, Diara buffaloes were medium to larger in body size and moderate in production. The positive and significant ($p<0.05/0.01$) correlations among different biometric traits exist which suggest high predictability among the different traits. In PCA analysis, the first three PC explained 90% of the original variance of 20 body linear traits of Diara buffalo. The first (PC1) second (PC2) and third (PC3) principal components accounted for 75%, 9% and 6% of the total variance, respectively. The Principal Component showed its usefulness in reduction of dimensionality of data. The first principal components (PC1) is sufficient to describe structure and size of Diara buffalo. This first principal components (PC1) have high loading of the morphometric traits BH, NL, NC, BL, BLO, CG, PG, FL, HL, HBH, PBL and TL. These traits can be used as selection criteria and resulted into reduction of explanatory variables.

Table 4: Eigenvalues and variance proportions for the principal components (PC) of the genetic values of Diara Buffalo.

PC	Eigenvalues	variance proportions	Cumulative variance proportions
PC1	14.99	0.75	0.75
PC2	1.76	0.09	0.84
PC3	1.18	0.06	0.9
PC4	0.67	0.03	0.93
PC5	0.52	0.03	0.96
PC6	0.36	0.02	0.97
PC7	0.22	0.01	0.98
PC8	0.16	0.01	0.99
PC9	0.08	0	1
PC10	0.05	0	1
PC11	0.02	0	1
PC18	0	0	1
PC17	0	0	1
PC12	0	0	1
PC13	0	0	1
PC15	0	0	1
PC16	0	0	1
PC19	0	0	1
PC20	0	0	1

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.

Boligon, A. A., Bignardi, A. B., Mercadante, M. E. Z., Lôbo, R. B., & Albuquerque, L. G. (2013). Principal components and factor analytic models for birth to mature weights in Nellore cattle. *Livestock Science*, **152**(2-3), 135-142.

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.

Carvalho, G. M. C., Almeida, M. J. O., Azevêdo, D. M. M. R., Araújo Neto, R. B., Leal, T. M., Monteiro, F. C., & Lima Neto, A. F. (2010). Phenotypic characterization of the hard foot cattle of Northeastern of Brazil. *Boletim Pesq Desenv*, **93**, 9-23.

Chandran, P. C., Pandian, S. J., Dey, A., Kamal, R., & Kumari, R. (2015). Production and reproduction performances of Diara buffaloes in the Gangetic basin of Bihar. *The Indian Journal of Animal Sciences*, **85**(7): 770-773.

Dhillod, S., Kar, D., Patil, C. S., Sahu, S., & Singh, N. (2017). Study of the dairy characters of lactating Murrah buffaloes on the basis of body parts measurements. *Veterinary World*, **10**(1): 17-21.

Espinosa-Nunez, Y., Ponce-Ceballos, P., Capdevila-Valera, J., Riera-Nieves, M., & Nieves-Crespo, L. (2011). Udder morphobiometric in milk buffaloes from west herds of Cuba. *Revista Cientifica-Facultad DE Ciencias Veterinarias*, **21**(6), 533-538.

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

Johari, S., Kurnianto, E., Sutopo, S., & Hamayanti, W. A. (2009). Multivariate analy I on phenotypic trait of body measurement in swamp buffalo (*Bubalus bubalis*). *Journal of the Indonesian Tropical Animal Agriculture*, **34**(4): 289-294.

Lagrotta, M. R., Euclydes, R. F., Verneque, R. D. S., Santana Júnior, M. L., Pereira, R. J., & Torres, R. D. A. (2010). Relationship between morphological traits and milk yield in Gir breed cows. *Pesquisa Agropecuária Brasileira*, **45**(4): 423-429.

Lopes, C. R. D. A., Barbosa, S. B. P., Pereira, R. G. D. A., Santoro, K. R., & Lira, A. V. D. (2008). Eficiência reprodutiva e influência de fatores de meio e de herança sobre a variação no peso ao nascer de bubalinos no estado de Rondônia. *Revista Brasileira de Zootecnia*, **37**, 1595-1600.

Mirza, R. H., Javed, K., Akhtar, M., Rauf, M., Dilshad, S. M. R., Khan, M. A., & Tipu, M. A. (2015). Genetic and phenotypic correlation of somebody measurements with milk yield in Nili Ravi buffaloes of Pakistan. *J Anim Health Prod.*, **3**(1): 1-5.

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.

Oliveira, D. P., Barros, C. C., Neto, F. R. A., Lourenco, D. A. L., Hurtado-Lugo, N. A., & Tonhati, H. (2014). Principal Components for Reproductive and Productive Traits in Buffaloes from Brazil. 10th World Congress of Genetics Applied to Livestock Production. Vancouver, pp. 3–5.

Posta, J., Komlosi, I., & Mihok, S. (2007). Principal component analysis of performance test traits in Hungarian Sporthorse mares. *Archives Animal Breeding*, **50**(2): 125-135.

Thomas, P. R., & Chakravarty, A. K. (2000). Canonical correlation analysis for studying the association of breeding efficiency and breeding values with growth and reproductive traits of Murrah buffaloes. *Indian Journal of Animal Research*, **34**(2): 100-103.

Val, J. E., Ferraudo, A. S., Bezerra, L. A. F., Corrado, M. P., Lôbo, R. B., Freitas, M. A. R., & Paneto, J. C. C. (2008). Alternativas para seleção de touros da raça Nelore considerando características múltiplas de importância econômica. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, **60**, 705-712.

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.

Wenceslau, A. A., Lopes, P. S., Teodoro, R. L., Verneque, R. S., Euclydes, R. F., Ferreira, W. J., and Silva, M. A. (2000). Estimate of genetic parameters of conformation traits, milk production and age at first calving in dairy Gyr breed cows. *Rev Bras Zoot*. **29**(1): 153–158.

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.

Yakubu, A., Salako, A. E., & Abdullah, A. R. (2011). Varimax rotated principal component factor analysis of the zoometrical traits of Uda sheep. *Archivos de zootecnia*, **60**(231): 813-816.

How to cite this article: Singh, R.K., Kumar, B., Kumar, R., Kumar, S. and Mandal, K.G. (2019). Production Performance and Body Morphometric Measurements in Diara Buffaloes of Bihar India. *Biological Forum – An International Journal*, **11**(2): 186-191.