

## Assessment of Phenotypic Traits in West African Dwarf Goats in Cross River State

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### Abstract

A study was conducted to evaluate the phenotypic differentiation of qualitative traits in West African Dwarf goat in Cross River State. The study areas covered were Cross River North, Central and South. A total of 630 goats (252 bucks and 378 does) were sampled for the study, comprising of 210 goats from each location marked out for the study. Each study location was extended to cover three local government areas comprising of and seven villages. Experimental animals were weighed using a 200kg scale while body parts were measured using a 100cm measuring tape. Data on traits measured (body weight, body length, height at wither, rump height, width, length, heart girth, sternum, chest depth, paunch girth, cannon bone length, cannon bone circumference, sacral pelvic width, shoulder width, ear length, head length, head width, neck length and tail length) were analyzed using SPSS Version 22. The result showed higher ( $p < 0.05$ ) average values were recorded for goats from the Central compared to those from other zones in the state. Similar values were obtained for goats in the Northern and Southern zones of state although those in the South consistently recorded the lowest ( $P > 0.05$ ) values. For bodyweight determination in both bucks and does, hearth girth had the best prediction of 0.398, 0.639 and 0.169  $R^2$  value and 0.979, 0.914 and 0.981  $R^2$  values, respectively. From the results, there were distinct phenotypic differences among relationships that existed between goat populations in the northern central and southern zones.

**Keywords:** linear body measurement, phenotypic, traits, correlation, West African Dwarf goats

## Évaluation des caractères phénotypiques qualitatifs et quantitatifs chez les chèvres naines d'Afrique de l'Ouest dans l'État de Cross River

### Résumé



Une étude a été menée afin d'évaluer la différenciation phénotypique des caractères qualitatifs chez la chèvre naine d'Afrique de l'Ouest dans l'État de Cross River. Les zones d'étude couvraient le nord, le centre et le sud de l'État de Cross River. Au total, 630 chèvres (252 boucs et 378 chèvres) ont été échantillonnées pour l'étude, soit 210 chèvres provenant de chaque site sélectionné pour l'étude. Chaque site d'étude a été étendu pour couvrir trois zones administratives locales comprenant sept villages. Les animaux expérimentaux ont été pesés à l'aide d'une balance de 200 kg, tandis que les parties du corps ont été mesurées à l'aide d'un mètre ruban de 100 cm. Les données relatives aux caractéristiques mesurées (poids corporel, longueur du corps, hauteur au garrot, hauteur de la croupe, largeur, longueur, circonférence thoracique, sternum, profondeur de la poitrine, circonférence abdominale, longueur du canon, circonférence du canon, largeur du bassin sacro-pelvien, largeur des épaules, longueur des oreilles, longueur de la tête, largeur de la tête, longueur du cou et longueur de la queue) ont été analysées à l'aide du logiciel SPSS version 22. Les résultats ont montré que des valeurs moyennes plus élevées ( $p < 0,05$ ) ont été enregistrées pour les chèvres de la zone centrale par rapport à celles des autres zones de l'État. Des valeurs similaires ont été obtenues pour les chèvres des zones nord et sud de l'État, bien que celles du sud aient systématiquement enregistré les valeurs les plus faibles ( $p > 0,05$ ). Pour la détermination du poids corporel chez les boucs et les chèvres, la circonférence thoracique a donné les meilleurs résultats de prédiction, avec des valeurs  $R^2$  de 0,398, 0,639 et 0,169, et des valeurs  $R^2$  de 0,979, 0,914 et 0,981, respectivement.

Les résultats ont mis en évidence des différences phénotypiques marquées entre les relations existant entre les populations de chèvres des zones nord, centre et sud.

**Mots-clés:** mesures corporelles linéaires, phénotypiques, caractères, corrélation, chèvres naines d'Afrique de l'Ouest

## **Introduction**

Goats (*Capra hircus*) are important livestock in rural communities of Nigeria. They are referred to as poor person's bank with the widest ecological distribution among other common ruminant species (Bitto, 2008). About 80% of the goat populations in Nigeria are owned by traditional farmers, and they contribute significantly to the livelihood of resource-poor farmers in developing country like Nigeria (Kurnianto *et al.*, 2013). Goats have high multiplication rate as compared to large ruminants as a result of their short reproductive cycle, which is the best possible way to alleviate poverty. The goat flock in Nigeria is dominated by the West African Dwarf (WAD) goat populations and has developed certain valuable genetic traits such as ability to perform better under low input conditions and climatic stress, tolerance to infectious diseases and parasites as well as heat stresses (Kosgey and Okeyo, 2007). As a result, they are able to cope with the stressful nature of the very large lands in the region. They are also rugged animals and are important reservoirs of useful genes. Their morphological and production characteristics within a given production environment differ and have important socio-cultural and economic values in Nigeria (FAO, 2012); consequently, majority of the farmers have specific consideration and choices for goat coat colours and body sizes. In Nigeria, white coat coloured goat is more preferred (Abba and Igbokwe, 2015). Irrespective of the afore-mentioned merits, the local goat genetic resources were seen as less productive, consequently, subject to replacement and crossbreeding with foreign goat breeds (Halima *et al.*, 2012a) and some goat breeds introduced at different periods by a different organization. In designing appropriate breeding and utilization programs, understanding the adapted goat genetic resources is important for designing appropriate breeding and utilization programs. Characterization of livestock breeds

using their morphological traits differences is the first step towards the utilization of the available animal genetic resource (AnGRs) (Muhammed *et al.*, 2012). Morphometric measurements have been used to assess the characteristics of different breeds of animals, and could provide direct information on the suitability of animals for selection (Martins *et al.*, 2009; Yakubu *et al.*, 2010) and for more characterization studies using modern molecular procedures. Body weight and linear body measurements are pertinent parameters to describe growth (Henry *et al.*, 2014). Okpeku *et al.* (2011a) stated that body measurements in addition to body weight, can give a complete description of an individual or a population. In breed classification and identification, phenotypic characteristics are of great importance. Determination of differences in morphological traits is the first step of the characterization of local genetic resources (Okpeku *et al.* 2011b). In the report of Gebrekiros *et al.* (2016) linear body measurements may be used as selection criteria for improvement of meat production in goat while Muhammed *et al.* (2012) uses linear body measurements for prediction of body weight in goat. Linear body measurements and its indices estimated from different combinations of conventional and non-conventional body parameters provide the superior guide to weight in addition to the use as indicators of type and function in domestic animals (Okpeku *et al.* 2011b). The desired body conformation in the production of meat animal, is such a complicated character that slight progress has been made in reducing it to a single bodily measurement which can be taken on the live animal. Body size (g/kg) and linear body parts have become pertinent parameters to describe growth. Okpeku *et al.* (2011) stated that body measurements in addition to body weight, can give a complete description of an individual or a population. In breed classification and identification, phenotypic characteristics are of great importance. For characterization of local

genetic resources, differences in morphological traits needs to be established (Okpeku *et al.* 2011b). In the report of Gebrekiros *et al.* (2016) measurements of body parts may be employed as selection standards for improving meat quality in goat while Muhammed *et al.* (2012) predicted goat's body weight using linear body parameters. This study therefore attempts to assess the phenotypic expression of qualitative and quantitative characters in West African dwarf goat in Cross River State.

## **Materials and Methods**

### ***Study Area***

The experiment was carried out using goat populations in three administrative zones of Cross River State in Nigeria namely, North, Central and South. The local governments that made up North included: Yala (lies between Latitude 6°35'35"N8°38'01"E and Longitude 6.59306°N 8.63361°E) (Simon, 2010), Obudu (lies on Latitude 6°40'0"N9°10'0"E and Longitude 6.67°N 9.17°E) and Ogoja (lies between Latitude and Longitude ) (Etiosa, 2006). Central include: Abi (6°50'00"N7°14'00"E6.83°N 7.23°E), Ugep (5°48'N8°05'E5.800°N 8.083°E) and Ikom (lies between Latitude 5°57'40"N 8°42'39"E and Longitude 5.96°N 8.71°E) Local government Areas (NIPOST, 2012), while those in the South include: Akpabuyo (lies between latitude 4° 5' and 5° 40' and longitude 8° 25' and 8° 32 East), Odukpani (5° 7' 0" North, 8° 20' 0" East) and Calabar South Local Government Areas.

### ***Management of the Experimental Animals***

The animals were managed under the traditional extensive system, with little or no provision for shelter in the day and night. They grazed during the day on natural pasture containing forages such as gamba grass (*Andropogon gayanus*), stylo (*Stylosanthes gracilis*) and leucaena (*Leucaena leucocephala*). Occasionally, feed supplements such as cassava and yam peels, cereal offal and crop residues were provided prior and/or after grazing of natural pastures.

### ***Data Collection and Management***

Qualitative traits measured were sex, coat color pattern, coat color type, horn presence and horn shape which were documented using visual assessment of the appearance on the goat types and body measurements. A total of 27 peasant associations, 3 per local government were selected randomly and used for the interview. Fourteen morphological characters (quantitative traits) including body weight (BW), body length (BL), height at withers (HAW), rump height (RH), rump width (RW), rump length (RL), heart girth (HG), sternum height (SH), chest depth (CD), paunch girth (PG), cannon bone length (CBL), cannon bone circumference (CC), sacral pelvic width (SPW), and shoulder width (SW) were recorded from 630 goats. Measuring tape was used to take the length and girth measurements and weight of the individual animal was measured using suspended weighing balance having 200 kg capacity with 0.2 kg precision in the morning by the same person to avoid human error and effect of feeding and watering on the animal's size (FAO, 2012). Height measurements were taken using graduated stick. Prior to taking measurements of various parameters, the animals were restrained and guarded to remain stable.

### ***Statistical analysis***

The qualitative traits were computed utilizing SPSS version 22 programming. Data were subjected to one way analysis of variance for assessing effect of location on body parameters while significant means were separated using Duncan's Multiple Range Test. Pearson correlation coefficient (r) values for the goat populations were additionally registered utilizing same programming to assess the connection between body measurement traits. Moreover, regression analyses were used to predict body weights.

### ***Statistical Model***

"The following model was used for the estimation of body weight from linear body measurements.

$$Y_j = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \epsilon_j$$

Where:  $Y_j$  = the dependent variable (body weight);  $\alpha$  = the regression intercept;  $X_1, X_2, \dots, X_n$  are the explanatory traits (BC, BL, HW, CG, CW, RL, PW, HL, EL and SC);  $\beta_1, \beta_2, \dots, \beta_n$  are partial regression coefficients of the traits;  $\epsilon_j$  = the residual random error”

## Results and discussion

### *Qualitative characteristics of WAD goat assessed*

The frequency and percentages of qualitative traits of north, central and Southern goat populations are presented in Table 1. Whole coat colour patterns observed showed 47.6% plain, 40.5% patchy and 11.9% spotted in the north; 64.3% plain, 35.7% patchy and 4.8% spotted in the central; and 48.6% plain, 40.0% patchy and 11.9% spotted in South goat populations. Plain dark or light brown coat colour (59.1%) were the common coat colours found among bucks and doe goat populations in the north while white coat color were common in the central (61.0%) and South (40.0%) goat populations. White marked with spots of different colours (brown or light brown or black), uniform black and light red colour goats were present with little and diverse frequencies in the studied populations. Nevertheless, some coat colours showed small frequencies in the population examined; this study revealed a wide range of coat colours within the study area. These results were in line with earlier findings by Grum (2010) and Halima *et al.* (2012b) who differently reported a wide range of coat colours for Ethiopian goat populations. Horn was present in all the goats examined. In horned goats, the straight, curved and spiral shapes of horns were observed. However, straight horn shaped goats appeared in the following frequencies of 93.8%, 73.8% and 66.2% in North, Central and South populations, respectively. Visual assessment showed that goats from the three locations were different (Figure 1), this could be attributed to geographical diversity. The different coat colours in the studied populations were equally

represented. The goats had predominantly three coat colour patterns with plain coat colour being the most frequent across all goat populations. Seven coat colour types were observed with dark red/brown in the north while white was predominant in the central and south. The dominant occurrence of dark red/brown and white colours obtained is in agreement Hassen *et al.* (2012) and Birteeb and Lomo (2015) who observed brown, white, black with the most frequent coat colour being white with spots (20.7%), followed by brown with patches (17.5%) and brown (15.4%). There were variations in coat colour pattern with plain having the highest percentage followed by patchy and spotted among goat populations sampled. The variation in coat colour pattern observed is in agreement with Robertshaw (2006) who reported different coat patterns in the goat populations with 36.1% as spotted, 32.4% patchy and 30.4% plain for the various coat colours observed.

### *Effects of location on phenotypic traits of does*

The results of the impacts of location on phenotypic traits of does (Table 2) that body weight, length, rump width, heart girth, cannon bone circumference, sacral pelvic width, ear and neck lengths were influenced ( $P < 0.05$ ) by location while height at wither, rump height, rump length, sternum length, chest depth, paunch girth, cannon bone length, shoulder width, head length, head width and tail length of does were not influenced by the location. Body weight was higher ( $P < 0.05$ ) for does from south (35.16 kg) whereas does from the north (34.40 kg) and central (34.36 kg) recorded similar ( $P < 0.05$ ) values. Body length was highest (53.18 cm) for does from the central although not different ( $P > 0.05$ ) from those from north (52.20 cm) while does from the south (51.99 cm) recorded the lowest ( $P < 0.05$ ) values. The value range of 12.25 cm to 13.09 cm was recorded for rump width. Does from the central (13.09 cm) had significantly ( $P < 0.05$ ) higher value for rump width although not different ( $P > 0.05$ ) from 12.71 cm recorded for does from the north while those from the south (12.25 cm) had the least ( $P < 0.05$ )

value. Heart girth was higher ( $P < 0.05$ ) for does from south (65.34 cm) followed by those from the north (63.94 cm) although not different from the value obtained for does from the central (64.03 cm). Cannon bone circumference was significantly ( $P < 0.05$ ) higher (8.50 cm) for does from central Cross River State. Similar values were obtained for goats in north (8.04 cm) and south (8.20 cm) Cross River State. The value range of 7.69 cm to 8.69 cm was obtained for sacral pelvic width. Does from the north (8.69 cm) recorded the highest although not different from those in the south (8.10 cm) and central (7.69 cm). Higher ear length (8.80 cm) was obtained in northern does while those in central (8.47 cm) and (8.34 cm) were similar. The value range of 16.72 to 17.15 cm was obtained for neck length across the different study locations. Values obtained for does in Cross River north (17.15 cm) was significantly ( $P < 0.05$ ) higher than 16.72 cm recorded for does in Cross River north although not different ( $P > 0.05$ ) from the 16.98 cm obtained for those in Cross River south. Comparisons of averages of traits between populations revealed that Cross River South does had significantly ( $P < 0.05$ ) higher weight with an average of  $35.16 \pm 1.59$  kg and measuring highest heart girth ( $65.34 \pm 2.85$  cm) among the different populations. It was observed from the results of the study that goats in Cross River south when compared with Cross River North and Cross River Central does, differed ( $P < 0.05$ ) in eight (body weight, length, rump width, heart girth, cannon bone circumference, sacral pelvic width, ear and neck lengths) of the twenty measured traits. However, withers height, rump height and its length, sternum length, chest depth, paunch girth, canon bone length, shoulder width, tail length, head length and width were similar. Hence, the implication of the result is that, differences between North, Central and South does population were small even though majority of the characteristics obtained in Central does were higher although height at wither, rump height, chest depth, sacral pelvic girth, shoulder width,

ear length, head and tail lengths were slightly higher for does in the North. Mean body weight, body length, withers height and chest girth for WAD does recorded in this study for all locations were not comparable to those reported by Akpa *et al.* (2009), Okpeku *et al.* (2011b), Samuel and Salako (2008). The differences may be attributed to variation in age of animals used in various studies compared. According to Yakubu *et al.* (2010), phenotypes are the expression of genetic characteristics, influenced by the condition of the environment as such; this interaction can bring about phenotypic variations.

#### ***Effects of location on phenotypic traits of bucks***

The results (Table 3) showed that body weight, rump width, rump length, heart girth, chest depth, paunch girth, cannon bone length, cannon bone circumference, sacral pelvic width, shoulder width, head length, head width, neck length and tail length were influenced ( $P < 0.05$ ) by location while body length, height at wither, rump height, sternum length and ear length were not significantly ( $P > 0.05$ ) influenced by the location of bucks. Bucks in Cross River north (29.65 kg) and south (29.86 kg) had similar body weight ( $P > 0.05$ ) which were higher ( $P < 0.05$ ) when compared with those obtained in central (28.94 kg). value ranges for rump width (10.08 – 11.72 cm), rump length (15.89 – 17.03 cm), heart girth (57.27 – 58.69 cm), paunch girth (66.48 – 69.28 cm) and cannon bone length (9.54 – 10.78 cm) were similar for bucks in Cross River north and south but significantly ( $P < 0.05$ ) different from values obtained from those in Cross River central. Cannon bone circumference (7.53 – 8.34 cm), shoulder width (9.18 – 9.91 cm), head length (15.32 – 16.69 cm), head width (8.04 – 8.47 cm), neck length (15.68 – 17.39 cm) and tail length (9.32 – 9.82 cm) were higher ( $P < 0.05$ ) for bucks in Cross River central while those in Cross River north and south were significantly ( $P < 0.05$ ) lower. The results of quantitative variation indicated higher average values for most of the traits in the Southern bucks, differences observed

within bucks from the North showed no differences ( $P>0.05$ ) for majority of the traits measured but sacral pelvic width and neck length showed differences ( $P<0.05$ ) between the bucks. Majority of the linear body measurements for Central bucks had lower ( $P<0.05$ ) values, while those in Northern and Southern Cross River had higher values. The mean values of body length, height at withers, rump height, sternum length and ear length in the three populations were not significantly ( $P>0.05$ ) different (Table 3). The range of 28.94 – 29.86kg body weight obtained across the location falls within the range of  $22.94\pm 0.47$  and  $30.02\pm 0.78$  kg reported by Hassan and Ciroma (1992) but higher than average of 12.8kg, the range of  $15.37\pm 0.38$  and  $18.99\pm 0.3$  6kg and  $20.06 \pm 0.07$  kg respectively reported by Akpa *et al.* (2009), Okpeku *et al.* (2011b) and Samuel and Salako (2008). Body length obtained in this study were in agreement with the findings of Samuel and Salako (2008), Akpa *et al.* (2009) and Okpeku *et al.* (2011b) although lower than those reported by Hassan and Ciroma (1992), Yakubu *et al.* (2010) and Oseni and Ajayi (2014) for WAD and Red Sokoto breeds of goat. Height at withers values obtained in this study (39.21 – 39.93 cm) is slightly lower than the 44.5 – 48.55 cm and 43.87 cm respectively reported by Birteeb and Lomo (2015) and Oseni and Ajayi (2014) in WAD goat. The variation values obtained may be attributed to age of the goats, nutrition as well as location of the experiment.

#### ***Pearson's correlation coefficients of quantitative traits***

The phenotypic relationships between body weight and other phenotypic measurements from WAD goat in the north are presented in Table 4. Coefficients of relationship between the body weight and linear body characteristics studied ranges from strong (0.989) to low (-0.175) for northern Cross River goats (Table 4). From Central Cross River, the correlation coefficient ranged between -0.24 (SW and CBL) to 0.956 (BW and HG) (Table 5) while the range of -0.337

to 0.991 coefficient of correlation was obtained for southern (Table 6) Cross River goats. Most measurements (BL, HAW, RH, HG and PG) showed positive correlation with body weight. This implied that, when one or more of these traits except SPW is selected, the live body weight of these goats may increase. Live body weight and heart girth had the highest correlation coefficient in bucks and does populations. Though, for Southern bucks, chest girth with height at wither as well as body weight had higher correlation coefficient. The correlation between body weight and chest girth was positive ( $p<0.01$ ) in bucks and does but bucks recorded higher values compared with does in sampled population. Relationships observed between body weight and linear body measurements suggested that in selection for improvement, selecting individual traits for improvement will improve another. In another study, Tesfaye (2008) “revealed the highest relationship between are body weight and chest girth for sheep”. The phenotypic correlations of body weight with body length and heart girth found in the present investigation for both bucks and does are in concordance with the results of Khan *et al.* (2006) and Pesmen and Yardimci (2008). Tsegaye *et al.* (2013) reported higher correlation between body weight and heart girth, height at withers and rump height, but lower values between body weight and body length and rump length across the locations compared to the results of the present investigation. Positive and highly significant correlations in the present investigation would be useful for predicting body weight in WAD goat as reported by Salako (2006). The high phenotypic correlations between heart girth and body weight indicate that selection for heart girth will favour the selection for body weight. This implied that the positive correlations expressed by some of the evaluated traits indicated that selection and improvement of one trait will lead to a corresponding improvement in the other trait (s) (Halilu *et al.*, 2018).

### ***Prediction of body weight from linear body measurements***

Tables 7 and 8 summarize the results of regression analysis from the goat studied. Heart girth (Table 7) accounted for 97.9, 91.4 and 98.1 % of differences in body weights respectively, in goats from northern, central and southern Cross River State. When cannon bone circumference and body length traits were added to heart girth, these accounted to 98.0 and 91.9 % of the differences in body weight. The model is more accurate with increase in other variables. The prediction model including heart girth may be suitable for predicting body weight of WAD goats in the study area. The stepwise multiple regression and models for the prediction of body weight using individual linear body measurements for bucks are shown in Table 8. Heart girth accounted for 39.8 % of differences observed in body weight in goats from the northern CRS. The precision of the mathematical equation increased to 45.6 % when rump width is included in the model. Heart girth of goats from central accounted for 63.9 % of differences in body weight. Precision of mathematical equation is 68.5 % when sternum height is included in the model. In the south, heart girth accounted for 16.9 % of differences in body weight. Precision of mathematical equation is 22.6 % when ear length is included in the mathematical equation was increased to 29.6 % when ear length and head width were included in the model. Heart girth was of great importance in predicting live body weight as shown by stepwise multiple regression analysis in the goat populations studied. Although the extent of improvement differed in bucks and does population, the addition of more linear body measurements to heart girth improved the precision of the forecast model ( $R^2$ ) in this study. Results of this study is in line with earlier findings with sheep and goats (Hulunim, 2014) “who variously reported greater coefficient of determination ( $R^2$ ) in body weight prediction models with heart girth as independent variable”. This author also stated that “heart girth was

described to be effective compared to other measurements such as height at wither and body length”. Live body weight of does was predicted with better precision ( $R^2$ ) when compared with bucks in the studied populations, when heart girth was the first variable explaining great difference. The  $R^2$  value was higher for Southern does than those in North and Central while higher  $R^2$  values were obtained for Central bucks followed by Northern bucks and Southern bucks recorded the lowest value. Based on coefficient of determination ( $R^2$ ), the value of  $R^2$  will always increase with addition of more independent variables to the regression model. The results of this study showed that, some independent factors do not improve  $R^2$  value when added in the mathematical equations. Although, produces smaller standard error of estimate (SEE) to show better goodness fit of the mathematical equations. Although the additional increase of some traits was little,  $R^2$  improvement gotten when more than one of the measured traits was combined showed that more than combination of two traits, instead of one can precisely evaluate weight. However, Grum (2010), Tesfaye (2008) and Hulunim (2014), reported that considering more factors under broad administration conditions will be strange because of cost and precision issues. Therefore, heart girth alone will be a better estimator of live weight under extensive management conditions.

### ***Conclusion and recommendations***

There were distinct phenotypic differences among relationships that existed between goat populations in the northern, central and southern locations. There was a high, positive and significant correlation between the measured traits (body weight and heart girth) for all does in the goat populations ( $r = 0.96 - 0.99$ ) and height at withers and rump height ( $r = 0.89 - 0.92$ ) for bucks. Thus, it would be useful to include performance data into characterization studies to understand which locations have comparative advantages within an agro-ecological zone. Linear estimations could be useful in estimating

live body weight where weighing scales are not promptly accessible.

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**TABLE 1**  
**Qualitative characteristics of WAD goat assessed**

Traits	Class	North			Central			South		
		Doe N (%)	Buck N (%)	Total N (%)	Doe N (%)	Buck N (%)	Total N (%)	Doe N (%)	Buck N (%)	Total N (%)
Coat pattern	Plain	61 (58.1)	39 (37.1)	100 (47.6)	75 (71.4)	60 (57.1)	135 (64.3)	44 (41.9)	58 (55.2)	102 (48.6)
	Patchy	30 (28.6)	55 (52.4)	85 (40.5)	25 (23.8)	50 (47.6)	75 (35.7)	39 (37.1)	45 (42.9)	84 (40.0)
	Spotted	14 (13.3)	11 (10.5)	25 (11.9)	5 (4.8)	5 (4.8)	10 (4.8)	23 (21.9)	2 (1.9)	25 (11.9)
Coat colour type	White	11 (10.5)	20 (19.0)	31 (14.8)	60 (57.1)	68 (64.8)	128 (61)	33 (31.4)	51 (48.6)	84 (40.0)
	Dark red/brown	43 (41.0)	30 (28.6)	73 (34.8)	5 (4.8)	3 (2.9)	8 (3.8)	4 (3.8)	2 (1.9)	6 (2.9)
	Black	15 (14.3)	2 (1.9)	17 (8.1)	1 (1.0)	0	1 (0.5)	6 (5.7)	2 (1.9)	8 (3.8)
	Light red	35 (33.3)	13 (12.4)	48 (22.9)	3 (2.9)	5 (4.8)	8 (3.8)	8 (7.6)	4 (3.8)	12 (5.7)
	White and brown	12 (11.4)	8 (7.6)	20 (9.5)	20 (19.0)	12 (11.4)	32 (15.2)	8 (7.6)	2 (1.9)	10 (4.8)
	White and black	7 (6.7)	8 (7.6)	15 (7.1)	6 (5.7)	5 (4.8)	11 (5.2)	20 (19.0)	32 (30.5)	52 (24.8)
	White and light brown	27 (25.7)	24 (22.9)	51 (24.3)	10 (9.5)	12 (11.4)	22 (10.5)	26 (24.8)	12 (11.4)	38 (18.1)
Horn	Present	105 (100.0)	105 (100.0)	210 (100.0)	105 (100.0)	105 (100.0)	210 (100.0)	105 (100.0)	105 (100.0)	210 (100.0)
	Absent	0	0	0	0	0	0	0	0	0
Horn shape	Straight	102 (97.1)	95 (90.5)	197 (93.8)	70 (66.7)	85 (81.0)	155 (73.8)	62 (59.0)	77 (73.3)	139 (66.2)
	Curved	2 (1.9)	10 (9.5)	12 (5.7)	32 (30.5)	19 (18.1)	51 (24.3)	40 (38.1)	7 (6.7)	47 (22.4)
	Spiral	1 (1.0)	0	1 (0.5)	3 (2.9)	1 (1.0)	4 (1.9)	3 (2.9)	21 (20.0)	24 (11.4)

**TABLE 2: Effects of location on phenotypic traits of does**

Traits	North			Central			South		
	Mean	CV (%)	SD	Mean	CV (%)	SD	Mean	CV (%)	SD
BW	34.40 <sup>b</sup>	4.74	1.63	34.36 <sup>b</sup>	5.49	1.89	35.16 <sup>a</sup>	1.59	4.52
BL	52.20 <sup>ab</sup>	8.20	4.28	53.18 <sup>a</sup>	9.77	5.19	51.99 <sup>b</sup>	4.51	8.67
HAW	43.66	7.94	3.46	43.17	8.81	3.80	43.24	4.24	9.94
RH	46.80	7.14	3.34	46.45	9.11	4.23	45.98	3.97	8.63
RW	12.71 <sup>a</sup>	11.18	1.42	13.09 <sup>a</sup>	14.38	1.88	12.25 <sup>b</sup>	1.64	13.43
RL	17.43	7.44	1.30	17.59	10.18	1.79	17.42	1.77	10.18
HG	63.94 <sup>b</sup>	4.60	2.94	64.03 <sup>b</sup>	5.20	3.32	65.34 <sup>a</sup>	2.85	4.36
Sternum	19.68	6.89	1.36	19.61	7.72	1.51	19.80	1.40	7.09
CD	13.77	67.24	9.26	13.05	5.24	1.49	12.91	1.67	4.99
PG	73.53	5.77	4.25	73.58	11.45	3.85	73.18	3.65	12.92
CBL	11.03	13.02	1.44	11.01	14.49	1.60	11.09	1.68	15.20
CBC	8.04 <sup>b</sup>	13.02	1.05	8.50 <sup>a</sup>	12.36	1.05	8.20 <sup>b</sup>	1.03	12.62
SPW	8.69 <sup>a</sup>	19.22	1.67	7.69 <sup>c</sup>	14.89	1.15	8.10 <sup>b</sup>	1.60	19.71
SW	10.30	16.39	1.69	10.10	16.65	1.68	10.10	1.55	15.37
EL	8.80 <sup>a</sup>	11.00	0.97	8.47 <sup>b</sup>	12.53	1.06	8.34 <sup>b</sup>	1.23	14.81
HL	16.92	13.97	2.36	16.61	15.82	2.63	16.87	2.71	16.15
HDW	8.58	10.27	0.88	8.58	9.91	0.85	8.42	1.02	12.12
NL	16.72 <sup>b</sup>	9.10	1.52	17.15 <sup>a</sup>	8.98	1.54	16.98 <sup>ab</sup>	1.44	8.47
TL	10.08	14.46	1.46	9.87	13.20	1.30	9.83	1.38	14.05

BW= Body Weight, BL=Body Length, HAW=Height at Wither, RH=Rump height, RW=Rump Width, RL=Rump Length, HG=Heart Girth, CD=Chest Depth, PG=Paunch Girth, CBL= Cannon Bone Length, CBC=Cannon Bone Circumference, SPW=Sacral Pelvic Width, SW=Shoulder Width, EL=Ear Length, HL=Head Length, HDW=Head Width, NL=Neck Length, TL=Tail Length, SD=Standard Deviation and CV=Coefficient of Variations

Different superscripts for mean on the same row showed significant ( $P < 0.05$ ) differences.

**TABLE 3: Effects of location on phenotypic traits of bucks**

Traits	North			Central			South		
	Mean	CV (%)	SD	Mean	CV (%)	SD	Mean	CV (%)	SD
BW	29.65 <sup>a</sup>	4.55	0.17	28.94 <sup>b</sup>	6.04	0.22	29.86 <sup>a</sup>	4.72	0.18
BL	48.17	10.23	0.61	47.16	10.14	0.59	46.46	9.62	0.56
HAW	39.72	9.85	0.48	39.93	7.76	0.38	39.21	10.80	0.53
RH	42.92	10.06	0.53	42.96	7.00	0.37	42.04	10.15	0.53
RW	11.72 <sup>a</sup>	12.98	0.19	10.08 <sup>b</sup>	12.13	0.16	11.34 <sup>a</sup>	11.27	0.16
RL	16.60 <sup>a</sup>	11.06	0.23	15.89 <sup>b</sup>	11.71	0.23	17.03 <sup>a</sup>	9.05	0.19
HG	58.36 <sup>a</sup>	5.35	0.38	57.27 <sup>b</sup>	6.31	0.44	58.69 <sup>a</sup>	4.21	0.31
Sternum	18.55	9.82	0.22	18.56	12.72	0.29	19.20	8.47	0.20
CD	12.36 <sup>ab</sup>	11.88	0.18	11.88 <sup>b</sup>	14.26	0.21	12.69 <sup>a</sup>	13.13	0.21
PG	68.81 <sup>a</sup>	8.24	0.70	66.48 <sup>b</sup>	8.66	0.71	69.28 <sup>a</sup>	5.66	0.49
CBL	10.78 <sup>a</sup>	16.32	0.22	9.54 <sup>b</sup>	11.43	0.13	10.50 <sup>a</sup>	12.63	0.17
CBC	7.53 <sup>b</sup>	10.18	0.09	8.34 <sup>a</sup>	12.23	0.13	7.84 <sup>b</sup>	12.22	0.12
SPW	8.34 <sup>a</sup>	17.47	0.18	7.18 <sup>b</sup>	6.35	0.06	7.42 <sup>b</sup>	13.78	0.13
SW	9.18 <sup>b</sup>	14.38	0.16	9.91 <sup>a</sup>	15.52	0.19	9.39 <sup>b</sup>	15.30	0.18
EL	8.67	14.43	0.14	8.39	13.25	0.14	8.00	17.11	0.17
HL	15.32 <sup>b</sup>	15.32	0.29	16.69 <sup>a</sup>	13.83	0.28	15.65 <sup>b</sup>	17.34	0.34
HDW	8.34 <sup>ab</sup>	12.32	0.13	8.47 <sup>a</sup>	11.77	0.12	8.04 <sup>b</sup>	9.84	0.10
NL	15.68 <sup>c</sup>	11.03	0.21	17.39 <sup>a</sup>	8.28	0.18	16.41 <sup>b</sup>	8.32	0.17
TL	9.36 <sup>b</sup>	13.67	0.16	9.82 <sup>a</sup>	13.86	0.17	9.32 <sup>b</sup>	12.74	0.15

BW= Body Weight, BL=Body Length, HAW=Height at Wither, RH=Rump height, RW=Rump Width, RL=Rump Length, HG=Heart Girth, CD=Chest Depth, PG=Paunch Girth, CBL= Cannon Bone Length, CBC=Cannon Bone Circumference, SPW=Sacral Pelvic Width, SW=Shoulder Width, EL=Ear Length, HL=Head Length, HDW=Head Width, NL=Neck Length, TL=Tail Length, SD=Standard Deviation and CV=Coefficient of Variations

Different superscripts on the mean values on the same row showed significant ( $P < 0.05$ ) different.

**TABLE 4**

**Pearson's correlation coefficients for bucks (below diagonal) and does (above diagonal) from Northern Cross River**

	BW	BL	HAW	RH	HG	STH	PG	CBL	CBC	SPW	SW	EL
BW	<b>1.00</b>	0.52*	0.48*	0.49*	0.63*	0.48*	0.61*	0.41*	-0.06	0.24	0.31	0.22
BL	0.41*	<b>1.00</b>	0.64*	0.72**	0.76**	0.69*	0.73**	0.60*	0.09	0.42*	0.34	0.34
HAW	0.35	0.69*	<b>1.00</b>	0.92**	0.54*	0.55*	0.53*	0.27	0.26	0.39	0.65*	0.63*
RH	0.37	0.76**	0.95**	<b>1.00</b>	0.57*	0.58*	0.53*	0.28	0.28	0.40*	0.64*	0.56*
HG	0.99**	0.42*	0.36	0.38	<b>1.00</b>	0.54*	0.80**	0.50*	-0.02	0.35	0.24	0.43*
STH	0.17	0.27	0.25	0.24	0.20	<b>1.00</b>	0.62*	0.43*	0.34	0.34	0.36	0.16
PG	0.43	0.31	0.34	0.34	0.43*	0.31	<b>1.00</b>	0.75**	-0.11	0.54*	0.14	0.40*
CBL	0.14	0.39	0.20	0.28	0.13	-0.04	0.07	<b>1.00</b>	-0.20	0.56*	-0.08	0.23
CBC	0.07	-0.06	0.07	0.02	0.10	0.40	0.17	-0.37	<b>1.00</b>	-0.24	0.42*	0.13
SPW	0.18	0.39	0.31	0.37	0.17	-0.03	0.25	0.43*	-0.37	<b>1.00</b>	0.09	0.39
SW	0.16	0.09	0.34	0.31	0.17	0.44*	0.46*	-0.28	0.40*	0.09	<b>1.00</b>	0.49
EL	0.13	0.26	0.44*	0.43*	0.14	0.28	0.26	-0.07	0.14	0.35	0.40*	<b>1.00</b>

BW= Body Weight, BL=Body Length, HAW=Height at Wither, RH=Rump height, HG=Heart Girth, STH=Sternum Height, PG=Paunch Girth, CBL= Cannon Bone Length, CBC=Cannon Bone Circumference, SPW=Sacral Pelvic Width, SW=Shoulder Width and EL=Ear Length

\*significant at P < 0.05

\*\*significant at P<0.01

**TABLE 5**

**Pearson's correlation coefficients for bucks (below diagonal) and does (above diagonal) from Central Cross River**

	BW	BL	HAW	RH	HG	STH	PG	CBL	CBC	SPW	SW	EL
BW	<b>1.00</b>	0.32	-0.10	0.15	0.80**	-0.13	0.31	0.01	0.03	0.25	-0.09	0.02
BL	0.42*	<b>1.00</b>	0.68*	0.70**	0.48*	0.53*	0.66*	0.40*	0.43*	0.11	0.32	0.27
HAW	0.47*	0.81**	<b>1.00</b>	0.89**	0.03	0.63*	0.37	0.24	0.45*	-0.17	0.41*	0.44*
RH	0.50*	0.77**	0.86**	<b>1.00</b>	0.23	0.51*	0.40*	0.21	0.48*	-0.05	0.34	0.42*
HG	0.96**	0.51*	0.52*	0.58*	<b>1.00</b>	0.11	0.53*	0.25	0.17	0.24	0.01	0.18
STH	0.36	0.19	0.27	0.27	0.38	<b>1.00</b>	0.46*	0.45*	0.46*	0.13	0.35	0.31
PG	0.50*	0.53*	0.48*	0.47*	0.52*	0.33	<b>1.00</b>	0.56*	0.29	0.15	0.23	0.31
CBL	0.22	0.12	0.09	0.16	0.19	0.24	0.32	<b>1.00</b>	0.12	0.33	0.10	0.13
CBC	0.25	0.17	0.25	0.24	0.26	0.33	0.21	-0.21	<b>1.00</b>	-0.09	0.65*	0.55*
SPW	-0.07	0.03	0.03	0.05	-0.08	0.10	0.15	0.37	-0.15	<b>1.00</b>	-0.14	-0.16
SW	0.20	0.24	0.38	0.29	0.21	0.32	0.27	-0.24	0.61*	-0.02	<b>1.00</b>	10.45*
EL	0.30	0.12	0.25	0.15	0.07	0.04	0.10	-0.20	0.53*	0.15	0.59*	<b>1.00</b>

BW= Body Weight, BL=Body Length, HAW=Height at Wither, RH=Rump height, HG=Heart Girth, STH=Sternum Height, PG=Paunch Girth, CBL= Cannon Bone Length, CBC=Cannon Bone Circumference, SPW=Sacral Pelvic Width, SW=Shoulder Width and EL=Ear Length

\*significant at P < 0.05

\*\*significant at P<0.01

**TABLE 6**  
**Pearson's correlation coefficients for bucks (below diagonal) and does (above diagonal) from Southern Cross River**

	BW	BL	HAW	RH	HG	STH	PG	CBL	CBC	SPW	SW	EL
BW	<b>1.00</b>	-0.02	-0.11	-0.16	0.41*	0.17	0.24	0.31	-0.37	0.01	-0.04	-0.33
BL	0.22	<b>1.00</b>	0.69*	0.59*	0.33	0.10	0.39	-0.11	0.17	0.26	0.36	0.47*
HAW	0.24	0.68*	<b>1.00</b>	0.91**	-0.00	0.01	0.07	-0.26	0.34	0.45*	0.57*	0.75**
RH	0.25	0.58*	0.84**	<b>1.00</b>	-0.07	-0.03	-0.04	-0.27	0.38	0.41*	0.54*	0.69*
HG	0.99**	0.21	0.24	0.24	<b>1.00</b>	0.29	0.79**	0.42*	-0.37	0.13	0.05	0.23
STH	0.26	0.05	0.04	0.02	0.27	<b>1.00</b>	0.22	0.09	0.16	-0.21	0.40*	-0.07
PG	0.19	0.16	0.18	0.17	0.20	0.09	<b>1.00</b>	0.39	-0.42*	0.30	-0.01	-0.19
CBL	0.04	0.17	0.14	0.13	0.06	0.22	0.25	<b>1.00</b>	-0.61*	0.32	-0.19	-0.42*
CBC	0.07	-0.03	-0.00	0.12	0.06	0.15	-0.01	-0.29	<b>1.00</b>	-0.23	0.48*	0.49*
SPW	-0.01	0.38	0.57*	0.44*	0.00	-0.14	0.13	0.27	-0.23	<b>1.00</b>	0.20	0.27
SW	0.14	0.04	0.13	0.21	0.13	0.19	0.17	-0.18	0.57*	0.10	<b>1.00</b>	0.51*
EL	0.02	0.35	0.54*	0.50*	0.01	-0.10	0.19	-0.15	0.36	0.48*	0.52*	<b>1.00</b>

BW= Body Weight, BL=Body Length, HAW=Height at Wither, RH=Rump height, HG=Heart Girth, STH=Sternum Height, PG=Paunch Girth, CBL= Cannon Bone Length, CBC=Cannon Bone Circumference, SPW=Sacral Pelvic Width, SW=Shoulder Width and EL=Ear Length

\*significant at P < 0.05

\*\*significant at P<0.01

**TABLE 7**  
**Regression of body weight on other body traits for does**

Population	Equation	Intercept	Regression coefficients		R	R <sup>2</sup>	R <sup>2</sup> change	SEE	Significant
		A	β1	β2					
North	HG	-0.611	0.548		0.989	0.979	0.979	0.237	0.000
	HG+CBC	-0.313	0.549	-0.052	0.990	0.980	0.001	0.232	0.000
Central	HG	-0.328	0.542		0.956	0.914	0.914	0.557	0.002
	HG+BL	-0.242	0.567	-0.032	0.959	0.919	0.006	0.540	0.000
South	HG	-0.970	0.553		0.991	0.981	0.981	0.219	0.000

BL=Body Length, HG=Heart Girth, CBC=Cannon Bone Circumference, R= regression coefficient, R<sup>2</sup>=coefficient of determination, SEE=standard error of estimate,

**TABLE 8**  
**Regression of body weight on other body traits for bucks**

Population	Equation	Intercept	Regression coefficients			R	R <sup>2</sup>	R <sup>2</sup> change	SEE	Significant
		A	β1	β2	β3					
North	HG	13.744	0.273			0.631	0.398	0.398	1.054	0.000
	HG+RW	14.957	0.20	0.259		0.675	0.456	0.057	1.010	0.000
Central	HG	6.767	0.387			0.800	0.639	0.639	1.058	0.000
	HG+STH	9.091	0.398	-0.159		0.828	0.685	0.045	0.997	0.004
South	HG	16.013	0.236			0.411	0.169	0.169	1.305	0.000
	HG+EL	19.913	0.204	-0.255		0.476	0.226	0.057	1.269	0.000
	HG+EL+HDW	16.448	0.204	-0.300	0.480	0.544	0.296	0.70	1.221	0.000

HG=Heart Girth, STH = Sternum Height, EL = Ear length, HDW = head width, R= regression coefficient, R<sup>2</sup>=coefficient of determination, SEE=standard error of estimate



