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Influence of Breeds and Location on Phenotypic Variations among Nigerian Breeds of Goats

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ABSTRACT
The study was aimed at the influence of breeds and location on phenotypic variations among Nigerian goats. The study covered the North, North Central and South-South Zones of Nigeria. Seven hundred and twenty goats were monitored for the study, comprising 240 goats from each locations marked out for the study. Each study locations was extended to cover three local government areas and seven villages. Experimental design adopted was a 3x3 factorial. Body weights and conformation were measured with a 200 kg weighing scale and 100cm tape rule for quantitative traits. Phenotypic data collected were analysed using Generalized Linear Model (GLM) procedures of SPSS package. Pearson correlation coefficient (r) and regression analysis were computed. Results showed higher ($p<0.05$) average values were recorded in the Sahel goats, followed by Red Sokoto compared to WAD goats. Similar values ($p>0.05$) were obtained from goats from the Northern central and North zones though those from the South consistently recorded the lowest ($p>0.05$) values. The results indicated that live weight was positively and significantly ($p < 0.05$) correlated with most body parameters in male and female goats. For body weight determinations, body length (0.240, 0.328 and 0.991 R2 values for does) and body length (0.622, 0.791 and 0.800 R2 values for bucks) gave the best predictions. The breed and location had no significant effect on most of the traits measured. From the results, there was a distinct phenotypic difference among the goat populations relationship that existed between breeds (WAD, Red Sokoto and Sahel) and locations (South-South, North and North Central) goat's populations.

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INTRODUCTION

Globally, goat husbandry is practiced with goat products having a favorable image (Khorshidi-Jalali *et al*., 2019). The number of goats has increased globally, both in countries with high and low-income resources (Robinson *et al*., 2011). In developing countries, goats play an important socio-economic, nutritional, and cultural role in rural households (Bettencourt *et al*., 2015; Onzima *et al*., 2017). Traditional farmers own more than 80% of the goats raised in Nigeria. Goats provide products, such as fiber, milk, meat, and skin which made goats preferred option to alleviate poverty. Additionally, biomedical research uses goats as models (Kon *et al*., 2013; Faisal *et al*., 2013). Does are bred for milk, whereas bucks are bred for meat, making them multipurpose creatures.

Characterizations of farm animals are the primary footstep towards the utilization of the existing animal genetic resources, through either performance evaluation, phenotypic characterization and DNA or molecular characterization (FAO, 2010; Ambel and Bayou, 2022). Lack of information on characterization of genetic resource may lead to underutilization of

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that resource, its replacement and dilution through cross breeding despite their local adaptation to prevailing environmental constraints (Manzi *et al*., 2011, Ambel and Bayou, 2022). Breed characterization process is not exhaustive as different research works on characterizations had been executed by different authors (Tesfaye, 2009; Tesfaye, 2010; Grum, 2010; Halima *et al*., 2012; Halima *et al*., 2012b; Ambel and Bayou, 2022).

Despite the researches done, information on phenotypic characteristics of different indigenous goat population is still insufficient especially little was known regarding the phenotypic variability of goat genetic resource in this area (Ambel and Bayou, 2022). Live weight measurement is a fundamental tool to known animal performance for provides reliable and informative information for selection, feeding requirements, health management, and decision on selling price (Thiruvenkanden, 2005; Ambel and Bayou, 2022). Therefore, under field condition, linear body measurements of various body conformations are an important valuable instrument to estimate indirect way of live weight (Ambel and Bayou, 2022), and are helpful in developing suitable selection criteria and judging quantitative characteristics of meat. The objective of this study was to describe the morphological characteristics of WAD, Red Sokoto and Sahel breeds of goat.

MATERIALS AND METHODS

The Study Area

This experiment was carried out at the Faculty of Agriculture, Nasarawa State University, Keffi, Shabu – Lafia Campus. Lafia is located on latitude 08^0 35″ and longitude 08^0 33″. It is geographically located in Guinea Savanna Zone of North Central Nigeria. It has the mean maximum monthly temperature of 35.06^0 C and mean minimum monthly temperature of 20.16^0 C with a mean monthly relative humidity of 74%. The annual rainfall is about 168.90 mm (NIMET, Faculty of Agriculture, Lafia, 2022).

Experimental Animals and Experimental design

The study was arranged in a 3 x 3 factorial in a completely randomized design. This indicate that there are three breeds of goats (West African dwarf, Red Sokoto and Sahel), three agroecological zones (North, North Central and South South) and one state selected per zone. A total of 720 randomly sampled goats was used for the phenotypic study. This population comprised of 80 goats per zone and 80 goats per breed (40 males and 40 females).

Data collection and management

Quantitative traits : Body weight (BW) and thirteen morphological traits such as 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. Measurements of length and girth were taken using measuring tape while weight of the individual animal were measured using suspended weighing scale with 50 kg capacity with 0.2 kg precision. “Weights were recorded in the morning by the same person to avoid human error” (FAO, 2012). Graduated ruler was used to take height measurement (Womack, 2005).

Data analyses

Phenotypic variation

The qualitative traits were computed utilizing SPSS (Version 2020). Hierarchical cluster was examined utilizing quantitative traits and dendrogram was built dependent on separation between goat populations utilizing unweighted pair-group technique to aggregate the goat populations into their morphological similarity, which was examined on SPSS software. After cluster examination, Pearson correlation coefficient (r) values for the goat populations was additionally registered utilizing same programming to assess the connection between body measurement traits. Moreover, regression analyses were used to predict body weights.

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RESULTS AND DISCUSSION

Effects of breeds on phenotypic traits of goats

The results of the impacts of breed on phenotypic traits of goats (Table 1) showed that body weight, length, height at withers, heart girth, paunch girth, chest depth, rump height, rump length, rump width, neck length, ear length, head length, head width, "cannon bone circumference, cannon bone length, sacral pelvic width", shoulder width and tail length were influenced ($p<0.05$) by breed. Body weight was higher ($p<0.05$) for Sahel goat (23.30 kg) although not different from Red Sokoto goat (22.63 kg) but the WAD goat had the lowest (17.74 kg). Body weight values in Sahel weigh highest (20.833kg), compared to Red Sokoto (17.697 kg) and WAD (18.367 kg). Although Red Sokoto had similar body traits, their slightly lower weight compared to Sahel goats could be linked to differences in body frame and muscle distribution (Aliyu *et al*., 2023). These differences could arise from genetic makeup, environmental adaptation, and feeding efficiency, supporting earlier observations by Fajemilehin *et al*. (2018) and Ogunlade *et al*. (2022).

Body length was highest (53.51 cm) for Sahel goat although not different ($p>0.05$) from Red Sokoto (50.24 cm) while WAD goats (45.52 cm) had the lowest ($p<0.05$). The shorter stature of WAD goats agrees with reports by (Adebayo *et al*., 2021; Fadun *et al*., 2022). The range value of 43.53 – 60.68 cm were recorded HAW with the highest recorded for Sahel, followed by Red Sokoto while WAD was least. The result agrees with Abdullahi *et al*. (2022) and Ibrahim *et al*. (2023), who reported that Sahel goats are tall, long-legged, and adapted to semi-arid areas, whereas WAD goats are smaller and suited to humid zones. Heart and paunch girths obtained were higher for Sahel goat (69.63 and 80.27 cm), followed by RS (67.55 and 79.48 cm) and WAD with corresponding values of 62.25 and 71.41 cm.

The result agrees with reports by Yusuf *et al*. (2022) that Sahel and Red Sokoto goats possess good chest development, contributing to their milk-meat dual purpose potential. Rump height ranged between 55.66 and 41.15 cm with the highest recorded for Sahel while the least was recorded for WAD goat. The range values of 11.53 cm to 14.46 cm were recorded for rump length. Sahel goats (14.46 cm) had significantly ($p<0.05$) higher value for rump length although not different ($p>0.05$) from 14.01 cm recorded for RS goats while WAD (11.53 cm) had the least ($p<0.05$). Rump width was higher ($p<0.05$) for Sahel goats (16.14 cm) followed by RS (15.73 cm) although not different from the value obtained for Sahel while the least was recorded for WAD goats (9.59 cm). Neck and ear length were significantly higher for Sahel goats while the lowest was recorded for WAD goats.

The results indicate that Sahel goats have a larger skeletal and muscular frame, which favors meat production potential, while WAD goats are better adapted for smallholder systems with lower feed inputs. This agreed with the observations made by Ogunlade *et al*. (2022) and Ewuola *et al*. (2020), who reported that body depth and rump length are positively associated with meat yield potential in goats. Head length and head width followed same trend with Sahel goats recording the highest values while WAD recorded the lowest. The result align with breed descriptions, where Sahel goats are recognized for long drooping ears and elongated heads (Ngere *et al*., 2011; Adesina *et al*., 2023). Cannon bone circumference was significantly ($p<0.05$) higher (9.88 cm) for Sahel but not different from the 9.23 cm recorded for RS goats while the lowest was recorded for WAD (7.01 cm). Statistically similar values were obtained for Sahel and RS goats in terms of CBL (15.43 cm) and (14.72 cm) but different from 11.03 cm recorded for WAD.

The range of 6.24 – 8.84 cm was obtained for sacral pelvic width. Sahel goats recorded the highest (8.84 cm) followed by RS goats (8.36 cm) and WAD (6.24 cm). Higher shoulder width (14.26 cm) was obtained in Sahel and RS goats (14.08 cm). The range value of 7.74 to 10.71 cm was obtained for tail length. Value obtained for Sahel goat (10.71 cm) is significantly ($p<0.05$) higher than the 7.74 cm recorded for WAD although not different ($p>0.05$) from the 10.15 cm obtained for RS goats.

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Table 1: Effect of breed on linear body measurements of goats

	Breeds				
Parameter	**WAD**	**Red Sokoto**	**Sahel**	**SEM**	**p-value**
BW (kg)	17.74[b]	22.63[a]	23.30[a]	0.353	<0.001
BL (cm)	45.52[b]	50.24[a]	53.51[a]	0.532	<0.001
HAW (cm)	43.53[b]	57.99[a]	60.68[a]	0.548	<0.001
HG (cm)	62.25[b]	67.55[a]	69.63[a]	0.459	<0.001
PG (cm)	71.41[b]	79.48[a]	80.27[a]	0.542	<0.001
CD (cm)	25.71[b]	29.24[a]	31.61[a]	0.566	0.024
RH (cm)	41.15[b]	54.14[a]	55.66[a]	0.529	<0.001
RL (cm)	11.53[b]	14.01[a]	14.46[a]	0.192	<0.001
RW (cm)	9.59[b]	15.73[a]	16.14[a]	0.177	0.008
NL (cm)	11.62[b]	15.28[a]	16.11[a]	0.189	<0.001
EL (cm)	8.85[b]	11.47[a]	12.75[a]	0.156	<0.001
HDL (cm)	10.05[b]	16.18[a]	17.17[a]	0.199	<0.001
HDW (cm)	8.62[b]	10.52[a]	11.13[a]	0.126	<0.001
CBC (cm)	7.01[b]	9.23[a]	9.88[a]	0.098	<0.001
CBL (cm)	11.03[b]	14.72[a]	15.43[a]	0.198	<0.001
SPW (cm)	6.24[b]	8.36[a]	8.84[a]	0.11	0.030
SW (cm)	10.06[b]	14.08[a]	14.26[a]	0.144	<0.001
TL (cm)	7.74[b]	10.15[a]	10.71[a]	0.127	0.052

SEM: standard error of mean, [a,b]: mean with different superscript on the same row differ significantly @ p<0.05, 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, HDL=Head Length, HDW=Head Width, NL=Neck Length, TL=Tail Length, WAD=West African dwarf

Effect of locations on linear body measurements of goats

The results showed (Table 2) that body weight, body length, height at wither, heart girth, paunch girth, chest depth, rump length, rump width, neck length, ear length, head length, head width, cannon bone circumference, cannon bone length, sacral pelvic width, shoulder width, and tail length were not significantly influenced ($p > 0.05$) by location while rump height was significantly ($p < 0.05$) influenced by the location of goats. Goats from South-South had numerically higher ($p > 0.05$) body weight (21.36 kg), rump width (13.99 cm) and neck length (14.51 cm).

Body length (49.86 cm), height at withers (54.30 cm), heart girth (66.36 cm), paunch girth (77.36 cm), rump length (13.45 cm, head length (14.50 cm), head width (10.11 cm), CBC (8.74 cm), CBL (13.78 cm), SPW (7.88 cm), SW (12.84 cm) and tail length (9.61 cm) was recorded for goats in north central while goats from the north were highest ($p>0.05$) in chest depth (29.83 cm), rump height (55.01 cm) $p<0.05$), ear length (11.73 cm).

The results of quantitative variation indicated higher average values for most of the traits in the north central goats, differences observed with goats from the North and south-south showed no differences ($p>0.05$) for majority of the traits measured but rump height showed differences ($p<0.05$) between the goats. Majority of the linear body measurements for south-south goats had lower ($p<0.05$) while those in Northern and North central had higher values.

Comparisons of averages of traits between populations showed that North goats showed significantly ($p<0.05$) higher rump height an average of 55.01 cm. Contrarily, some of these traits were similar (withers height, rump height and its length, chest depth, paunch girth, canon bone length, shoulder width, tail length, head length and width). Hence, the implication of the result is that,

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differences between South-south, North, and North central population were not different even though majority of the characteristics obtained in North-central. Mean body weight, length of the body, 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 for the studies. According to Yakubu *et al*. (2010), "phenotypes are the expression of genetic characteristics, influenced by the condition of the environmental; and differences in genetics and environment may affect phenotypic difference".

Table 2: Effect of locations on linear body measurements of goats

	Zones				
Parameters	**South-South**	**North**	**North-Central**	**SEM**	**P-value**
BW (kg)	21.36	21.21	21.10	0.353	0.202
BL (cm)	49.64	49.77	49.86	0.532	0.119
HAW (cm)	54.02	53.87	54.30	0.548	0.101
HG (cm)	65.09	66.14	66.36	0.459	0.475
PG (cm)	76.70	77.10	77.36	0.542	0.236
CD (cm)	29.04	29.83	27.70	0.566	0.410
RH (cm)	47.87^{b}	55.01^{a}	48.06^{b}	0.529	<0.001
RL (cm)	13.17	13.37	13.45	0.192	0.151
RW (cm)	13.99	13.67	13.81	0.177	0.656
NL (cm)	14.51	14.20	14.30	0.189	0.104
EL (cm)	10.58	11.73	10.76	0.156	0258
HDL (cm)	14.43	14.48	14.50	0.199	0.472
HDW (cm)	10.09	10.07	10.11	0.126	0.758
CBC (cm)	8.67	8.70	8.74	0.098	0.118
CBL (cm)	13.65	13.74	13.78	0.198	0.358
SPW (cm)	7.76	7.79	7.88	0.11	0.258
SW (cm)	12.78	12.78	12.84	0.144	0.098
TL (cm)	9.42	9.56	9.61	0.127	0.088

SEM: standard error of mean, ^{a,b}: mean with different superscript on the same row differ significantly @ p<0.05, 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, HDL=Head Length, HDW=Head Width, NL=Neck Length, TL=Tail Length

Breed x location interaction on linear body measurements

Descriptive statistics of the morphometric characters of the interaction between locations (South-South, North and North Central) and breeds (WAD, RS and Sahel) of goats in this study are presented in Table 3. The body parameters of Sahel goats were significantly (p<0.05) higher than those of their WAD counterparts although not different from RS across the locations. This is in line with the report of Yakubu *et al*. (2011) who reported smaller body parameters for WAD goats against RS goats. This was conspicuous in the small body stature of WAD goats and the large body size and leggy nature of RS goats.

This variation is often related to behavioural or ontogenetic differences. Adaptation involves natural selection of those characters that improve the chance for survival and reproduction of individuals (Daramola and Adeloye 2009, Yakubu *et al*., 2011). Local environments vary in selecting for different characters in different areas. Heterogeneity

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between populations could be due to considerable genetic differences between WAD, RS and Sahel goats as well as environmental factors. The morphological variation may reflect the level of adaptation of these two populations to the specific conditions of their regions of origin (Yakubu *et al*., 2011).

The present pattern of morphometric variation strongly indicates an eco-geographical trend of population differentiation along the north–south gradient of the country. This is not quite unexpected considering the natural habitat and geographical spread of RS (mainly in the northern axis) and WAD (largely in the southern axis) goats in Nigeria.

This is consistent with the report of West-Eberhard (2005) and Yakubu *et al*. (2011) that environmental induction can jump start adaptive evolution by immediately producing a population of phenotypic variants upon which selection can act. Then if the phenotypic variance is partly due to genetic variation among individuals, adaptive evolution in response to selection can occur.

Table 3: Locations x breed interaction on linear body measurements of goats

Parameters	SS			North			NC			SEM	p-value
	WAD	RS	SH	WAD	RS	SH	WAD	RS	SH		
BW (kg)	18.16^{b}	22.55^{a}	23.36^{a}	17.85^{b}	22.48^{a}	23.29^{a}	17.21^{b}	22.85^{a}	23.24^{a}	0.612	<0.001
BL (cm)	45.11^{b}	50.31^{a}	53.49^{a}	45.98^{b}	50.21^{a}	53.12^{a}	45.48b	50.19^{a}	53.91^{a}	0.922	<0.001
HAW (cm)	43.14^{b}	58.33^{a}	60.59^{a}	43.79^{b}	57.22^{a}	60.61^{a}	43.65^{b}	58.41^{a}	60.83^{a}	0.949	<0.001
HG (cm)	60.01^{b}	66.09^{a}	69.17^{a}	60.46^{b}	68.23^{a}	69.74^{a}	60.27^{b}	68.32^{a}	69.97^{a}	0.795	<0.001
PG (cm)	71.30^{b}	78.76^{a}	80.04^{a}	71.42^{b}	79.84^{a}	80.05^{a}	71.51^{b}	79.84^{a}	80.73^{a}	0.940	<0.001
CD (cm)	25.58^{b}	30.15^{a}	31.39^{a}	25.83^{b}	31.79^{a}	31.87^{a}	25.73^{b}	25.79^{a}	31.58^{a}	0.981	0.003
RH (cm)	34.02^{b}	54.16^{a}	55.44^{a}	54.68^{b}	54.38^{a}	55.98^{a}	34.75^{b}	53.87^{a}	55.55^{a}	0.916	<0.001
RL (cm)	11.08^{b}	13.85^{a}	14.58^{a}	11.86^{b}	14.09^{a}	14.17^{a}	11.66^{b}	14.08^{a}	14.62^{a}	0.333	<0.001
RW (cm)	9.85^{b}	15.97^{a}	16.14^{a}	9.54^{b}	15.34^{a}	16.12^{a}	9.39^{b}	15.88^{a}	16.17^{a}	0.306	<0.001
NL (cm)	11.85^{b}	15.56^{a}	16.11^{a}	11.37^{b}	15.17^{a}	16.06^{a}	11.63^{b}	15.12^{a}	16.15^{a}	0.328	<0.001
EL (cm)	7.22^{b}	11.64^{a}	12.87^{a}	11.63^{b}	11.05^{a}	12.51^{a}	7.69^{b}	11.71^{a}	12.88^{a}	0.270	<0.001
HDL (cm)	10.08^{b}	16.12^{a}	17.08^{a}	10.03^{b}	16.20^{a}	17.20^{a}	10.04^{b}	16.22^{a}	17.23^{a}	0.345	<0.001
HDW (cm)	8.62^{b}	10.50^{a}	11.15^{a}	8.60^{b}	10.51^{a}	11.11^{a}	8.64^{b}	10.54^{a}	11.14^{a}	0.219	<0.001
CBC (cm)	7.02^{b}	9.21^{a}	9.79^{a}	7.00^{b}	9.23^{a}	9.88^{a}	7.01^{b}	9.24^{a}	9.97^{a}	0.170	<0.001
CBL (cm)	11.02^{b}	14.35^{a}	15.58^{a}	11.07^{b}	14.83^{a}	15.32^{a}	11.00^{b}	14.97^{a}	15.38^{a}	0.343	<0.001
SPW (cm)	6.22^{b}	8.19^{a}	8.87^{a}	6.26^{b}	8.35^{a}	8.77^{a}	6.23^{b}	8.53^{a}	8.88^{a}	0.197	<0.001
SW (cm)	10.02^{b}	14.10a	14.21^{a}	10.09^{b}	14.02^{a}	14.23^{a}	10.08^{b}	14.11^{a}	14.33^{a}	0.250	<0.001
TL (cm)	7.57^{b}	10.14^{a}	10.55^{a}	7.79^{b}	10.16^{a}	10.74^{a}	7.85^{b}	10.15^{a}	10.84^{a}	0.220	<0.001

SEM: standard error of mean, ^{a,b}: mean with different superscript on the same row differ significantly @ p<0.05, 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, HDL=Head Length, HDW=Head Width, NL=Neck Length, TL=Tail Length, SS: South-South, NC: North Central, WAD: West African dwarf, RS: red Sokoto, SH: Sahel

Phenotypic Correlation

West African Dwarf goat

The data on the relationships between live weight and linear body parameters for males and females WAD goats are presented in Tables 4. The results indicated that live weight was positively and significantly (p < 0.05) correlated with most body parameters in male and female WAD goats except CBC in female goats. Higher and significant correlation values were recorded for body weight vs heart girth (0.989), HAW vs RH (0.995), rump height vs body length (0.767),

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height at withers vs body length (0.695), BL vs BW (0.455), BL vs HG (0.452), RH vs RW (0.562), rump W vs HG, PG and CBL (0.584, 0.516 and 0.576), RL vs CD and CBL (0.613 and 0.509) and PG vs SW (0.461) in males, while in females, higher and significant value was recorded for body weight vs body length (0.512), HAW (0.488), RH (0.494), heart girth (0.653), CD (0.485) and PG (0.651); Body length had significant correlation with HAW (0.645), RH (0.728), HG (0.761), CD (0.698), PG (0.734) and CBL (0.605) respectively. Phenotypic values were higher in male WAD goats than the females.

Red Sokoto goats

Relationships between live weight and body parameters as revealed by phenotypic correlation are presented in Tables 5. The results showed that, the values were within the range of -0.242 to 0.968 for male and -0.185 to 0.891 for female, thus live weight was positively and significantly ($p < 0.05$) correlated with the linear body trait. However, highest correlation coefficient was recorded for body weight and heart girth (0.968), followed by 0.881, 0.867 and 0.779, respectively for BL vs. HAW, HAW vs. RH and BL vs. RH. While in female the highest was recorded for RH and HAW (0.891) followed by RW vs. PG (0.726), BL vs. RH (0.701), HG vs. RW (0.692), BL vs. HAW (0.687) and RW vs. RL (0.626).

Table 4: Pearson's correlation coefficients for bucks (below diagonal) and does (above diagonal) form WAD goats

	BW	BL	HAW	RH	RW	RL	HG	CD	PG	CBL	CBC	SPW	SW	EL
BW	1.000	0.512*	0.488*	0.494*	0.118	0.125	0.653*	0.485*	0.651*	0.418	-0.046	0.246	0.311	0.222
BL	0.455*	1.000	0.645*	0.728**	0.115	0.176	0.761**	0.698*	0.734**	0.605*	0.098	0.429	0.344	0.344
HAW	0.381	0.695*	1.000	0.929**	0.344	0.586*	0.545*	0.556*	0.553*	0.272	0.265	0.395	0.658*	0.638*
RH	0.352	0.767**	0.995**	1.000	0.365	0.518*	0.578*	0.585*	0.563*	0.288	0.288	0.408	0.645*	0.566*
RW	0.016	-0.114	-0.034	0.562*	1.000	0.232	0.577*	0.659*	0.604*	0.139	0.467*	0.142	0.245	0.291
RL	0.100	0.043	-0.065	0.275	0.443	1.000	0.422	0.109	0.269	0.448	0.076	-0.136	0.058	0.579*
HG	0.989**	0.452*	0.336	0.383	0.584*	0.381	1.000	0.545*	0.870**	0.500*	-0.022	0.345	0.244	0.433
CD	0.192	0.129	0.005	0.192	0.139	0.613*	0.200	1.000	0.682*	0.434	0.343	0.354	0.367	0.165
PG	0.410	0.312	0.341	0.343	0.516*	0.425	0.433	0.312	1.000	0.751**	-0.111	0.554*	0.144	0.401
CBL	0.142	0.319	0.200	0.288	0.576*	0.509*	0.131	-0.041	0.077	1.000	-0.202	0.566*	-0.088	0.232
CBC	0.071	-0.065	0.070	0.025	-0.160	-0.123	0.101	0.400	0.171	-0.387	1.000	-0.254	0.422	0.113
SPW	0.188	0.391	0.210	0.371	0.369	0.245	0.171	-0.032	0.251	0.413	-0.378	1.000	0.098	0.339
SW	0.167	0.019	0.344	0.312	-0.069	-0.122	0.175	0.444	0.461*	-0.287	0.409	0.098	1.000	0.498*
EL	0.123	0.226	0.448	0.437	0.065	-0.088	0.144	0.228	0.261	-0.017	0.145	0.365	0.408	1.000

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) for Red Sokoto goats

	BW	BL	HAW	RH	RW	RL	HG	CD	PG	CBL	CBC	SPW	SW	EL
BW	1.000	0.324	0.150	0.154	0.020	0.091	0.802**	0.131	0.311	0.015	0.032	0.255	0.009	0.021
BL	0.452*	1.000	0.687*	0.701**	-0.086	0.063	0.489*	0.534*	0.661*	0.408	0.434	0.117	0.322	0.275
HAW	0.478*	0.881**	1.000	0.891**	0.291	0.272	0.033	0.634*	0.377	0.244	0.454*	-0.172	0.418	0.441
RH	0.550*	0.779**	0.867**	1.000	0.414	0.518*	0.233	0.511*	0.408	0.217	0.481*	-0.058	0.345	0.423
RW	0.055	0.153	0.320	0.427	1.000	0.626*	0.692*	0.366	0.726**	0.304	0.352	0.256	-0.087	0.162
RL	0.015	0.051	0.400	0.425	0.436	1.000	0.294	0.228	0.224	0.171	-0.185	-0.108	0.133	0.047
HG	0.968**	0.515*	0.527*	0.587*	0.418	0.432	1.000	0.114	0.534*	0.254	0.177	0.243	0.012	0.187

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	BW	BL	HAW	RH	RW	RL	HG	CD	PG	CBL	CBC	SPW	SW	EL
CD	0.368	0.197	0.278	0.275	0.056	0.087	0.387	1.000	0.465*	0.465*	0.462*	0.131	0.354	0.312
PG	0.501*	0.535*	0.488*	0.479*	0.463*	0.515*	0.524*	0.332	1.000	0.568*	0.295	0.152	0.231	0.314
CBL	0.223	0.132	0.095	0.165	0.605*	0.187	0.199	0.241	0.323	1.000	0.122	0.334	0.101	0.135
CBC	0.252	0.177	0.254	0.243	0.004	0.149	0.267	0.332	0.211	-0.214	1.000	-0.095	0.656*	0.555*
SPW	0.078	0.043	0.032	0.056	0.354	0.016	-0.084	0.100	0.154	0.376	-0.154	1.000	-0.145	-0.126
SW	0.203	0.234	0.387	0.291	0.003	0.242	0.214	0.321	0.273	-0.242	0.618*	-0.012	1.000	0.485*
EL	0.305	0.112	0.254	0.155	0.128	0.190	0.074	0.041	0.101	-0.200	0.534*	0.165	0.592*	1.000

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

Sahel goats

Correlation coefficient of body parameters of male and female Sahel goats are summarized in Tables 6. The results showed body weight was positively correlated ($p < 0.05$) with the linear body measurement studied in both sexes except for RH, CBC, SW and EL for female goats. Highest correlation coefficient was observed for body weight and heart girth (0.998) in male and lowest was observed for SPW (0.010). Correlation between body parameters were also positive exception of BL vs. CBC (-0.032), HAW vs. CBC (-0.001), RL vs. SPW (-0.143), CD vs. SPW (-0.148) and EL (-0.101), PG vs. CBC (-0.012), CBL vs. CBC (-0.295), SW (-0.187) and EL (-0.156) and CBL vs. SPW (-0.234) that showed negative correlation coefficients. In female, live weight was also positively correlated with all the linear body parameters except with RH, CBC, SW and EL. The Sahel goats had correlation coefficient of -0.294 to 0.998 for male goats while -0.612 to 948 was recorded for females.

The positive and significant phenotypic correlation between most body parameters and live weight agreed with the reports of other researchers carried out with goats in similar climatic conditions (Shuaibu *et al*., 2020) who reported that the correlation coefficients observed between body weight and linear body measurements were generally moderate to high and significant. This also agreed with the work of Bedada *et al.* (2019) who reported coefficient of 0.91, 0.96, 0.93, 0.79 and 0.45 between the body weight and length, chest girth, wither height, pelvis width and ear length in males, and with corresponding values of 0.84, 0.87, 0.71, 0.83 and 0.41 in females, respectively.

Table 6: Pearson's correlation coefficients for bucks (below diagonal) and does (above diagonal) for Sahel goats

	BW	BL	HAW	RH	RW	RL	HG	CD	PG	CBL	CBC	SPW	SW	EL
BW	1.000	0.012	0.112	-0.164	0.321	0.201	0.421	0.178	0.224	0.314	-0.372	0.012	-0.014	-0.331
BL	0.223	1.000	0.698*	0.599*	-0.253	-0.212	0.334	0.102	0.398	-0.112	0.173	0.261	0.364	0.472*
HAW	0.242	0.689*	1.000	0.948**	-0.009	-0.077	-0.001	0.013	0.072	-0.263	0.344	0.454*	0.572*	0.752**
RH	0.257	0.588*	0.846**	1.000	0.585*	0.235	-0.072	-0.035	-0.045	-0.274	0.384	0.412	0.544*	0.691*
RW	0.046	0.019	0.245	0.311	1.000	0.257	0.463*	0.622*	0.453*	0.383	0.208	0.434	0.357	0.389
RL	0.106	0.069	0.281	0.255	0.352	1.000	0.251	0.361	0.300	0.237	0.196	0.159	0.108	0.154
HG	0.998**	0.214	0.245	0.244	0.413	0.433	1.000	0.292	0.798**	0.425	-0.372	0.131	0.051	0.232
CD	0.264	0.056	0.041	0.022	0.091	0.063	0.274	1.000	0.223	0.095	0.161	-0.212	0.402	-0.074
PG	0.197	0.168	0.188	0.178	0.419	0.581*	0.205	0.092	1.000	0.391	-0.424	0.301	-0.011	-0.192
CBL	0.045	0.174	0.145	0.132	0.222	0.201	0.066	0.224	0.256	1.000	-0.612*	0.322	-0.192	-0.421
CBC	0.077	-0.032	-0.001	0.128	0.164	0.303	0.068	0.156	-0.012	-0.295	1.000	-0.233	0.482*	0.491*
SPW	0.010	0.387	0.578*	0.445	0.073	-0.143	0.001	-0.148	0.137	0.278	-0.234	1.000	0.201	0.274

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	BW	BL	HAW	RH	RW	RL	HG	CD	PG	CBL	CBC	SPW	SW	EL
SW	0.141	0.044	0.134	0.214	-0.113	0.165	0.135	0.196	0.175	-0.187	0.573*	0.100	1.000	0.513*
EL	0.022	0.351	0.549*	0.550*	0.227	0.304	0.014	-0.101	0.195	-0.156	0.361	0.480*	0.524*	1.000

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 $P<0.01$

Similarly, Ijomanta (2012) found a low, positive, and significant relationship between Red Sokoto goat morphometric traits. The correlations found in this study were generally higher than those found in previous studies by Okpeku *et al*. (2011), Pesmen and Yardimci (2008), and Khan *et al*. (2006). Pesmen and Yardimci (2008) found the strongest correlation between live weight and heart girth.

In general, the correlation results between linear measurements and body weights in this study agreed with those reported in the literature by Shresthra *et al*. (1984), Brown *et al*. (1973), and Jeffery and Berg (1972). The positive and highly significant correlation found between body weight and other parameters suggests that any of these variables or their combinations would provide a good estimate for predicting live weight in goats in Nigeria's derived savannah zone. The lack of correlation and non-significance confirms the traits' unsuitability for body weight prediction.

Positive correlation indicates that both body measurements in pairs can be considered for live weight improvement at the same time, as previously asserted by Buvanendran *et al*. (1980), Raymond *et al*. (1982), Hassan and Ciroma (1992) and Fajemilehin and Salako (2008). 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".

Prediction of body weight from linear body measurements

Table 7 and 8 summarize the results of regression analysis from the goat studied for does. Body length (Table 8) accounted for 99.1, 57.3 and 50.2 % of differences in body weights respectively, for Sahel, Red Sokoto and WAD goats. When paunch girth was added to body length, these accounted to 59.4 % of the differences in body weight. The model is more accurate with increase in other variables. The prediction model including paunch girth may be suitable for predicting body weight of Red Sokoto 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 9. Body length accounted for 62.2, 79.1 and 80.0 % of differences observed in body weight in goats across WAD, Red Sokoto and Sahel breeds. The precision of the mathematical equation increased from 79.1 to 80.8 and 81.7 % when HAW and RH was included in the model for Red Sokoto goats. Body length Sahel goats accounted for 80.0 % of differences in body weight. Precision of mathematical equation is 81.4, 82.4 and 83.2 % when SPW, CBC and RW were included in the model.

Body length 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 body length improved the precision of the forecast model (R2) 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 (R2) in body weight prediction models with heart girth as independent variable". These authors also stated that "body length in addition to heart girth was described to be effective compared to other measurements such as height at wither".

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Live body weight of bucks was predicted with better precision (R^2) when compared with does in the studied populations, when body length was the first variable explaining great difference. The R^2 value was higher for Sahel bucks than those of Red Sokoto and WAD goats while higher R^2 values were obtained for Sahel does followed by Red Sokoto bucks and WAD 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, body length alone will better estimation of live body weight under extensive management conditions.

Table 7: Regression of body weight on other body traits for does

Population	Equation	Intercept	Regression coefficients		R	R^2	R^2 change	SEE	Significant
		α	β1	β2					
WAD	BL	2.584	0.898		0.502	0.240	0.240	0.469	0.029
RS	BL	3.462	0.358		0.573	0.328	0.328	0.537	0.000
	BL+PG	0.848	0.351	0.040	0.594	0.353	0.025	1.514	0.036
Sahel	BL	-0.970	0.553		0.991	0.981	0.981	0.219	0.000

WAD= West African dwarf goat, RS= Red Sokoto goat, BL=Body Length, PG= paunch girth, R= regression coefficient, R^2 =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^2	R^2 change	SEE	Significant
		α	β1	β2	β3	β4					
WAD	BL	-5.699	0.654				0.622	0.350	0.350	2.127	0.014
RS	BL	-7.403	0.562				0.791	0.626	0.626	2.108	0.000
	BL+HAW	-8.345	0.525	0.056			0.808	0.652	0.027	2.040	0.000
	BL+HAW+RH	-7.154	0.518	0.150	-0.106		0.817	0.667	0.014	2.005	0.000
Sahel	BL	-8.956	0.600				0.800	0.641	0.641	2.368	0.000
	BL+SPW	-3.781	0.552	-0.343			0.814	0.663	0.022	2.303	0.000
	BL+SPW+CBC	-6.6652	0.532	-0.339	0.475		0.824	0.679	0.017	2.256	0.000
	BL+SPW+CBC+RW	-4.659	0.519	-0.224	0.612	-0.267	0.832	0.693	0.013	2.217	0.000

WAD= West African dwarf goat, RS= Red Sokoto goat, BL=Body Length, HAW=Height at wither, RH= rump height, SPW= sacral pelvic width, CBC=Cannon Bone Circumference, RW= rump width, R= regression coefficient, R^2 =coefficient of determination, SEE=standard error of estimate,

CONCLUSION

From the results, there was a distinct phenotypic difference among the goat populations relationship that existed between breeds (WAD, Red Sokoto and Sahel) and locations (South-South, North and North Central) goat's populations. There was a high, positive and significant correlation between the measured traits

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(body weight and heart girth) for all bucks in the goat populations (r = 0.968 - 0.998) and height at withers and rump height (r = 0.891 - 0.995) for does. Body length 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 body length improved the precision of the forecast model (R^2) in this study.

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