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Effect of agro-ecology and sex on adaptability of West African dwarf goats in the humid tropics

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Target Audience: *Animal breeders, Extension workers, Livestock Farmers, Corporate Ruminant Farms, Livestock policy makers.*

Abstract

To examine morphometric adaptability status of WAD goats, a survey of 227 male and female individuals over two ecological areas namely Osun and Ekiti was conducted in the humid tropics between May 2015 and June 2017. Five morphometric measurements recorded were Body weight (BWT), Heart girth (HGH), Diagonal trunk length (DTL), Height at withers (HWT), Height at the Rump (HRP) and seven derived morpho-structural index traits. Experimental design was Randomized complete block with factorial treatment design. Data collected on animals were analyzed using the General Linear Model Procedure and Tukey HSD test at p<0.05. Between ecological environments, TLI, BLI and DTL were significantly higher (P<0.05) in Osun goats, while WGI, HRP, BDI and HWT with least differences (0.18 to 0.70) evinced the most stable traits to ecological areas. High CV of 56.96 - 34.03 on BLI, BWT and WHI revealed a highly unselected population. Between sex, males demonstrated superior genetic ability for WHI, HGH and BWT at 30.45, 21.34 and 14.52%, while the females expressed greater genetic effects through WGI, BLI and TLI at 46.50, 12.82 and 5.70% expression. Ekiti goats demonstrated superiority in OBI (1.34) while males had higher OBI (99.03) than females (97.38). Interaction of sex by ecological area on DTL, TLI, OBI, BDI, BBI, LLI and BLI revealed that sexes elicit varying levels of adaptability.

Key words: *Adaptability, Analysis of variance, Morphometric measurements, Ecological area, goat breeding and improvement.*

Description of Problem

Small ruminants taken from one ecological niche to another demonstrate some degree of behavioural and performance adjustments to cope with the new agro-ecology in terms of nutrition, growth, and physical interaction with the ecology. Maladjusted animals could show many forms of adverse responses to a new environment such as stunted growth, abortion, sterility, ill-health, and finally death. Adaptability is important in West African dwarf goats since individual animals are reared under very wide range of ecological environments with diverse climatic conditions which are dictated by external factors. Adaptability is described as the ability of an animal to withstand adverse and extreme climatic conditions, adjust to and produce optimally in the environment in which it lives, or could refer to a reduced variation in performance across locations and ecological environments (1, 2) resulting from the ability of an individual to alter her responses to changing external and internal stimulating conditions. Research has also shown that individuals that are better adapted to a wide range of environments are most probably heterozygotes for traits of interest, and are thus

more favoured by selection process (3). A superior genotype, and thus, a better adapted individual could demonstrate higher adaptability and performance under maximum threshold of ambient conditions across seasons (2) and agroecology. The analysis of variance of genotypes under various agro-ecologies give estimates of variance between genotypes, variance between specific agroecology, and the variance attributable to interaction of genotypes with agro-ecology (4). Genotype x agroecology interaction indicates a change in the relative performance of a character of two or more genotypes measured under two or more agroecologies, and this interaction may involve changes in rank order, and in genetic, environmental and phenotypic variances between agroecologies (5). Therefore, adaptability study could give direction to specific attributes, relative individual/genotypic advantages, and possible regional, ecological and special attributes for breeding. In present study, five morphometric and seven morpho-structural index traits were employed to study adaptability among 227 surveyed individual WAD goats from Ekiti (Ikole and Ado) and Osun (Osogbo and Ilesa) ecological environments. The objective of study was to examine adaptability status of dwarf goats in south west environment.

Table 1: ANOVA mean square values for morphometric and structural index traits of West African Dwarf (WAD) goats in Ekiti and Osun States of South-west Nigeria

SV	Df	BWT	DTL	HGH	HWT	HRP	TLI	OBI	BDI	BBI	WGI	BLI	WHI
Model	3	<0.001	0.0001	0.0001	0.0001	0.0001	<0.0001	0.0007	<0.0001	0.0003	<0.0001	<0.0001	<0.0001
EA	1	316.72^{a}	5279.34^{a}	60.93	26.81	2.02	22673.57^{a}	99.34^{d}	11.08	70.25	31.88	13599.31^{a}	1412.45^{b}
Sex	1	5307.70^{a}	1534.57^{c}	5951.37^{a}	1459.39^{a}	1782.98^{a}	5520.81^{b}	151.23^{c}	3775.62^{a}	3201.29^{a}	3775.62^{b}	17475.10^{b}	14299.51^{a}
EAxSex	1	38.79	1051.68^{d}	52.70	9.79	36.45	7685.89^{a}	93.34^{d}	344.48^{a}	981.21^{a}	91.87	2725.17^{b}	259.07
Error	223	58.30	229.28	66.97	37.92	29.41	532.79	23.33	207.28	198.10	147.09	401.11	174.60
RMSE		7.64	15.14	8.18	6.16	5.42	23.08	4.83	14.40	14.07	12.13	20.03	13.21
Mean		17.95	78.76	54.16	44.57	43.75	176.53	98.42	121.83	123.83	-21.83	145.48	38.83
CV		42.55	19.22	15.11	13.82	12.39	13.08	4.91	11.82	11.37	-54.24	13.77	34.03
R^2		0.296	0.130	0.285	0.152	0.220	0.261	0.074	0.100	0.081	0.102	0.306	0.280

Notes: BWT=Body weight, DTL=Diagonal trunk length, HGH=Heart girth, HWT=Height at the withers, HRP=Height at the rump, TLI=Trunk length index, OBI=Overbuilding index, BDI=Body depth index, BBI=Body breadth index, WGI=Withers girth index, BLI=Body length index, WHI=Weight height index, Significant levels: a<0.0001; b<0.001; c<0.01; d<0.05. Parameteric values under each trait with different superscripts are significant within the model, EA=Ecological area.

Materials and Methods

Study area: The survey was conducted between May 2015 and June 2017, on two hundred and twenty-seven free-ranging and scavenging WAD goats, consisting of 124 males and 103 females, in Osogbo and Ilesa in Osun State; and in Ado and Ikole in Ekiti State. The GPS coordinates are 7^0 46^I 0N, 4^0 36^I 0E, 328m; 7^0 37^I 0N, 4^0 44^I E, 377m; 7^0 37^I 15 N, 5^0 13^I 17E, 411.7m; and 7^0 47^I 53N, 5^0 30^I 52E, 508m respectively. All locations are in the humid tropical forest environment.

Morphometric Traits: Five basic morphometric measurements on body weight (kg) and linear body dimensions (cm) were recorded on each animal namely Body weight (BWT), Heart girth (HGH), Diagonal trunk length (DTL), Height at withers (HWT), Height at the Rump (HRP) as described by various researchers (6 - 17). Body weight was measured with a field, portable, digital, electronic scale (model: WH-A08, made in China, Patent No:201030634194.3) of 50 kg capacity, hung on a tripod stand, while linear measurements were taken with a tape rule and thread. All measurements were taken in the morning before animals were fed.

Morpho-structural Index Traits: From above body traits, various morpho-structural index traits were derived as in Formulars 1-7:

Trunk length index (Shape) (TLI) = (DTL/HWT)*100 ----------(1)
Overbuilding Index (OBI) = (HRP/HWT)*100 ----------(2)
Body Depth Index (BDI) = (HGH/HWT)*100 ----------(3)
Body Breadth Index (BBI) = (HGH/HRP)*100 ----------(4)
Withers-Girth Index (WGI) = (HWT - HGH)/HWT*100. This index could be used to examine variation in post-natal fore-quarter development in WAD goat ----------(5)

Table 2: Effect of ecological environment on Least Square Means and Standard deviation of morphometric and structural index traits of WAD goats in Ekiti and Osun states of South-West Nigeria

Ecological Area	BWT (kg)	DTL (cm)	HGH (cm)	HWT (cm)	HRP (cm)	TLI (cm)	OBI (cm)	BDI (cm)	BBI (cm)	WGI (cm)	BLI (cm)	WHI (kg/cm)
Ekiti	16.48^{b}	74.41^{b}	53.26	44.00	43.37	168.62^{b}	98.88	121.70	123.17	-22.28	137.67^{b}	35.96^{b}
± SD	9.21	18.34	8.39	7.27	6.50	30.31	5.39	12.64	1.12	12.64	26.76	15.62
Osun	18.87^{a}	84.19^{a}	54.31	44.70	43.56	188.87^{a}	97.54	121.25	124.30	-22.46	155.41^{a}	41.06^{a}
± SD	8.77	10.58	5.78	11.02	5.62	13.42	4.29	17.75	1.17	12.90	14.60	15.08
Pr > t	0.0207	0.0001	0.4014	0.3412	0.7934	<0.0001	0.0402	0.8174	0.5521	0.8174	0.0049	0.0049
EE diff.	2.39	**9.78**	1.05	0.70	0.19	**20.25**	1.34	0.45	1.13	0.18	**17.74**	5.10

Notes: BWT=Body weight, DTL=Diagonal trunk length, HGH=Heart girth, HWT=Height at the withers, HRP=Height at the rump, TLI=Trunk length index, OBI=Overbuilding index, BDI=Body depth index, BBI=Body breadth index, WGI=Withers girth index, BLI=Body length index, WHI=Weight height index, Values with different superscripts under traits are significantly different, EA diff=Ecological area difference.

Table 3: Effect of Sex on Least Square Means and Standard deviation of morphometric and structural index traits of WAD goats in Ekiti and Osun states of South-west Nigeria

SEX	BWT (kg)	DTL (cm)	HGH (cm)	HWT (cm)	HRP (cm)	TLI (cm)	OBI (cm)	BDI (cm)	BBI (cm)	WGI (cm)	BLI (cm)	WHI (kg/cm)
Does	12.77^{b}	76.67^{b}	48.60^{b}	41.78^{b}	40.62^{b}	183.74^{a}	97.38^{b}	116.74^{b}	119.93^{b}	-17.96^{a}	156.46^{a}	30.45^{b}
±SD	4.07	9.97	7.15	4.21	3.85	2.02	0.46	17.02	17.08	12.51	15.58	8.89
Bucks	22.57^{a}	81.94^{a}	58.97^{a}	46.92^{a}	46.30^{a}	173.75^{b}	99.03^{a}	126.21^{a}	127.54^{a}	-26.02^{b}	138.67^{b}	46.53^{a}
±SD	9.75	19.69	8.94	7.37	6.43	2.67	0.46	11.75	11.24	11.75	25.82	16.29
Pr > t	<0.0001	<0.0103	<0.0001	<0.0001	<0.0001	<0.0015	<0.0116	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sexual Diff.	9.80	5.27	10.37	5.14	5.68	9.99	1.65	9.47	7.61	8.06	**17.79**	**14.16**

Notes: BWT=Body weight, DTL=Diagonal trunk length, HGH=Heart girth, HWT=Height at the withers, HRP=Height at the rump, TLI=Trunk length index, OBI=Overbuilding index, BDI=Body depth index, BBI=Body breadth index, WGI=Withers girth index, BLI=Body length index, WHI=Weight height index. Values with different superscripts under traits are significantly different.

Table 4: Effect of environment by sex on least square means of morphometric and structural index traits of WAD goats in Ekiti and Osun states of South-west Nigeria

SEX		DOES		BUCKS		AVERAGE		
Environment		EKITI± SD	OSOGBO± SD	EKITI± SD	OSOGBO± SD	MEAN	SD	CV
Body Trait	N	53	50	74	50	227	-	-
BWT, kg	227	11.99±3.90	13.55±4.12	20.96±10.08 ^{b}	24.19±8.98 ^{a}	17.95	9.04	42.55
DTL, cm	227	73.96±11.01 ^{b}	79.37±7.92 ^{a}	74.87±22.22 ^{b}	89.00±10.77 ^{a}	78.76	16.12	19.22
HGH, cm	227	48.56±5.41	48.63±8.69	57.96±7.95	59.99±10.20	54.16	9.61	13.82
HWT, cm	227	41.22±3.98	42.34±4.40	46.78±8.18	47.06±6.06	44.57	6.64	15.11
HRP, cm	227	40.12±3.84	41.13±3.83	46.61±6.68	45.99±6.09	43.75	6.13	12.39
TLI, cm	227	179.51±24.55 ^{b}	187.98±14.06 ^{a}	157.73±30.91 ^{b}	189.77±12.83 ^{a}	176.53	26.67	13.08
OBI, cm	227	97.40±3.59	97.36±5.61	100.35±6.10 ^{a}	97.71±2.35 ^{b}	98.42	4.98	4.91
BDI, cm	227	118.21±12.62 ^{a}	115.27±20.75 ^{b}	125.19±11.90	127.24±11.53	121.83	15.08	11.82
BBI, cm	227	121.47±13.21 ^{a}	118.39±20.41 ^{b}	124.87±10.75 ^{b}	130.21±11.28 ^{a}	123.83	14.58	11.37
BLI, cm	227	152.12±16.18 ^{b}	160.79±13.70 ^{a}	127.32±28.09 ^{b}	150.03±13.57 ^{a}	145.48	23.89	-56.96
WGI, cm	227	-18.21±1.73 ^{a}	-15.27±2.93 ^{b}	-25.19±1.38	-27.24±1.63	-21.83	15.08	13.77
WHI, kg/cm	227	28.99±1.21	31.89±1.24	42.92±1.96 ^{b}	50.14±2.06 ^{a}	38.83	15.47	34.03
Mean	**227**	**73.11±8.44** ^{b}	**76.79±8.97** ^{a}	**75.03±12.18** ^{b}	**82.01±8.11** ^{a}	**76.86**	**13.61**	**11.26**

Notes: BWT=Body weight, DTL=Diagonal trunk length, HGH=Heart girth, HWT=Height at the withers, HRP=Height at the rump, TLI=Trunk length index, OBI=Overbuilding index, BDI=Body depth index, BBI=Body breadth index, WGI=Withers girth index, BLI=Body length index, WHI=Weight height index. Values with different superscripts within sexes are significant at p<0.01 level

Body length Index (BLI): (DTL/HGH)*100: When index is >90% animal is longigline; 86-88% is medigline, while less than 85% is brevigline (18, 19) ----------(6)

Weight-Height Index (WHI) = (BWT/HWT)*100 ----------(7)

The experimental design used was Randomized complete block with factorial treatment design (RCBD). Fixed factor was Sex while the Random factor was Location. The experimental model was of the form:

$Y_{ijk} = \mu + S_i + L_j + SE_{ij} + \varepsilon_{ijk}$

Where Y_{ijk} = Body weight and linear body responses in Sex $_i$, location $_j$ and animal $_k$.

μ = overall mean of the population

S_i = the fixed effect of Sex $_i$ of an animal (male and female; where i =1, 2)

E_j = the random effect of Ecological area $_j$ of an animal (Ekiti and Osun, where i =1, 2)

SE_{ij} = interactive effect of Sex $_i$ and Ecological area $_j$.

ε_{ijk} = random error associated with record in Sex i, Ecological area j and Animal k.

The data collected on animals from the field were analyzed using the General Linear Model Procedure (PROC GLM) to evaluate the significance of sources of variation affecting characters (ANOVA), Least square means procedures (LSMEANS) and Tukey HSD test were conducted at $p<0.05$ to differentiate between paired sources of variation. All analyses were done with SAS software 8.0 (20).

Results

Table 1 showed the mean square values, CVs and R^2 for sources of variation for morphometric and structural index traits of WAD goats in the surveyed locations. It revealed significant values ($p<0.05$) between locations in BWT, DTL, TLI, OBI, BLI and WHI; significant ($p<0.05$) differences between sexes for all traits; and significant differences ($p<0.05$) for interaction of EA X Sex on DTL, TLI, OBI, BDI, BBI, LLI and BLI. The CVs for BWT, LLI, WHI and DTL ranged from 19.22-65.96, while CVs for HGH, HWT, HRP, TLI, BDI, BBI and BLI ranged from 11.77 to 15.11, while OBI posted CV of 4.91.

Table 2 displayed the effect of ecological area on the least square means (LSM) of body traits of WAD goats in the surveyed locations. This shows significant differences ($p<0.0001$-0.0049) between Ekiti and Osun goats in BWT, DTL, TLI, BLI and WHI in favour of Osun goats (2.39 – 20.25); and in OBI ($P<0.04$) in favour of Ekiti goats (1.34). The traits -TLI, BLI and DTL among all others gave the highest mean square values (Table 1). The standard deviation (SD) for DTL, TLI, BLI and WHI among Ekiti goats ranged between 15.62 – 30.31, while SD among Osun goats for BDI, LLI and WHI ranged 15.08 – 17.75. The SD on BBI, OBI, HRP, HGH were low (1.12 – 8.39).

Table 3 reveals the effect of sex on morphometric traits LSM. Between does and bucks, all body traits were significantly ($P<0.0116$-0.0001) higher in bucks except TLI, WGI and BLI which were significantly ($P<0.0015$-0.0001) higher in does. This confirmed sexual dimorphism between sexes in relation to respective traits. Differences between sexes obtained were 1.65-14.16 and 8.06-17.79 in favour of Bucks and Does respectively. SD for BDI, BBI, LLI, and BLI ranged between 15.58 – 17.02 among Does while SD for DTL, BLI and WHI ranged between 16.29 – 25.82. In both sexes, SD was low on OBI and TLI (0.46-2.67). Between sexes, BWT, DTL, HGH, HWT, HRP, OBI, BDI, BBI and WHI parameters were higher in bucks; while TLI, WGI and BLI parameters were higher in the does.

Table 4 shows the result of sex by ecological area (Sex X EA) interaction on morphometric and structural traits of WAD goats. Within Does, there were significant ($P<0.05$) differences between Ekiti and Osun ecological areas on DTL, TLI, BDI, BBI, BLI and WGI. Osun Does revealed higher mean parametric values on DTL, TLI, BLI, WGI while Ekiti Does had higher values on BDI and BBI traits respectively. SD for Ekiti Does were 24.55 and 16.18 for TLI and BLI; while BBI and BDI recorded SD of 20.75 and 20.41 for Osun Does. Within Bucks, there were significant ($p<0.05$) differences between ecological areas on BWT, DTL, TLI, OBI, BBI, BLI and WHI. Osun Bucks had higher parametric means on all traits except OBI in Ekiti Bucks which was significantly ($p<0.05$) higher (100.35 vs 97.71). Higher SD values were obtained for DTL, TLI and BLI (22.22 – 30.91) for Ekiti Bucks whereas all SD for Osun Bucks' traits were below 14.00. Average parametric trait values revealed higher SD for TLI and BLI (26.67 and 23.89), and lower SD for OBI, HRP and HWT (4.98, 6.13 and 6.64) respectively. Mean CV values were higher for

BLI, BWT, WHI (56.96, 42.55 and 34.03); medium for DTL, HWT (19.22 and 15.11) and low for OBI (4.91).

Discussion

Between ecological areas, individuals could not be removed from their ecologies, therefore adaptability could be evaluated best based on difference between the two ecological areas for each trait. Traits that recorded least ecological differences were regarded as conferring better adaptability on individuals in the entire environment of study, while individuals and groups with higher mean values were regarded as better adapted to own ecological area. This principle revealed, in order of magnitude, that WGI, HRP, BDI and HWT with least differences (0.18 to 0.70) evinced least variability (most stability) among traits examined. These traits also revealed least mean square (MS) values of 31.88, 2.02, 11.08 and 26.81 between agro ecologies respectively. WAD goat population was better adapted to entire environment on WGI, HRP, BDI and HWT. Likewise, Osun goats demonstrated superiority on TLI, BLI, DTL and WHI (20.25, 17.74, 9.78 and 5.10) above Ekiti goats, as these traits were highly differentiated in favour of Osun goats. Ekiti goats demonstrated superiority in OBI (1.34). Thus, ecological populations were better adapted in respective traits because of their superior tropical adaptability in respective traits (21). These differences between ecological populations opens up a selection window for improvement and development of Trunk, Breadth and Length along with associated traits such as meatiness (BWT) in WAD goat. Between sexes, male genetic superiority was profoundly expressed on WHI, HGH and BWT at 30.45, 21.34 and 14.52%, while female genetic effects were expressed on WGI, BLI and TLI at 46.50, 12.82 and 5.70% expression levels above males. Traits that demonstrated the least difference between sexes was OBI (1.65), with males giving higher OBI (99.03) than females (97.38) values. The results of present study differ slightly from that of Fajemilehin and Salako (15) who reported significant ($P < 0.05$) sex influence on body weight and body linear measurements of WAD in the forest zone, as females consistently showed superiority. It was also reported that sex had significant effect ($p< 0.05$) on all body parameters considered in Kogi WAD goat (22). The significant values obtained on interaction of EA by SEX on DTL, TLI, OBI, BDI, BBI, LLI and BLI revealed that sexes elicit different responses in ecological areas. Within Does between agro-ecologies, the medium SD on BLI and TLI (Ekiti) and; BDI and BBI (Osun) suggested that these traits were highly sensitive to the agroecology; while the low SD on WHI, WGI, OBI, HRP, HWT and BWT indicating low sensitivity to agroecology, and thus making them useful for phenotypic characterization of WAD Does. Within Bucks between agro-eclogies, the high SD on BLI and TLI (Ekiti) implied high sensitivity of traits to the environment, while the low SD on WHI, WGI and DTL (Ekiti and Osun) suggested also useful traits for phenotypic characterization of Bucks. The high average SD on BLI, TLI and to a lesser extent DTL meant that traits were highly sensitive to the humid hot environment; while the low SD on OBI, HRP and HWT revealed that traits were stable (lowly variable) and could be utilized for characterization of WAD goats in hot humid environments. This recommendation of traits for phenotypic characterization was further corroborated by MS values from ANOVA for traits (93.34, 36.45 and 9.79) respectively. BWT and HGH which recorded overall SD below ten units (9.04 and 9.61) and low mean square (MS) values of 38.79 and 52.70 could also be used for secondary characterization purposes based on MS values. SD values between agroecology (1.17 – 15.08) and Sexes (0.46 – 25.82) in study were higher than 1.12 – 7.71 reported by

(14) on immature Uda sheep in South-west Nigeria. OBI and HGH in Does; HRP and HWT in Bucks which demonstrated least parametric differences between ecological environments were considered as most stable traits. Adaptability in this study was viewed in terms of the capacity of the animals to match or fit the environment (21). Sex by ecological area interaction (Sex X EA) enables analysis of the adaptability of sexes to ecological environments. Based on this, adaptability status of WAD in study area could best be measured with highly sensitive traits of BLI, TLI and DTL that demonstrated high SD. The high CV of 56.96, 42.55 and 34.03 on BLI, BWT and WHI revealed that WAD goats in the environment were highly unselected with regards to BLI, BWT and WHI; while opportunity also exist for selection based on DTL and HWT. The CV results of 4.91 – 56.96 in present work were comparable to 10.44 – 84.07 reported on body measures by (23); but higher than the low CV value range of 1.58 - 9.65 obtained on goat on Creole goats (18), Andalusian caprine breeds (24), sheep (25), horses (26, 27) which represented highly uniform and selected populations. The capacity of an individual to adapt to dynamic agroecological conditions during her lifetime and the capacity of a population to adapt to its environment over many generations through genetic, phenotypic and structural changes would measure adaptability. This work studied adaptability in relation to biometric performance using a one-stop data across environments. By utilizing biometric data, a wide range of functional capabilities such as disease and parasite resistance, survivability, longevity, heat/cold tolerance, behavioural and metabolic adaptation to variations in food supply, fearfulness, fertility and fecundity were being expressed in surveyed animals over generations, time and space (21).

Conclusion and Applications

1. WAD sexes could be differentiated morphologically between ecological niches with OBI.
2. WAD breed in the South-west environment are highly unselected, possessing high potential for phenotypic improvement on BLI, BWT, WHI, DTL and HWT respectively.
3. Osun Bucks demonstrated higher adaptability to ecology than Ekiti Bucks.

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