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Morphological differentiation of Northern Morocco goat

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Abstract Data from 183 animals raised in 61 flocks were collected to investigate the morphological characteristics of the Northern Morocco goat. Nine zoometric measures and seven combined indices were obtained. Three zones were defined based on geo-climatic characteristics and environmental influences: Mediterranean, Atlantic and Dual. The morphological variables showed the absence of sexual dimorphism in the northern Morocco goat population. Measures were generally very similar (n.s. at $p<0.05$) for male and female, except shin girth was high in males compared with females. A few variables including height at withers, ear length, rump length, length led and ears index were significantly ($p < 0.05$) influenced by geographical area. Mahalanobis distances and Canonical analyses showed a greater distance between the most geographical separated subpopulations (Atlantic and Dual) and animals from these areas were the most heterogeneous. The stepwise procedure showed that length led, ear length, rump length and shin girth were the most discriminate variables between areas. Results suggest that the goat population of north Morocco, exhibiting different morphological variables by location, maybe due to the environmental adaptation or the differences in origin and recent influences by introgression or crossbreeding.

Keywords: Northern Moroccan goat, zoometric measurements, qualitative traits, environmental differentiation

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Introduction

Goat inventory in the north of Morocco is estimated to be 788,000 (Chentouf, 2014). This sector plays an important socio-economic role for the local population providing food and contributing with more than 70% of income in rural mountain communities (Chentouf et al., 2011). Exogenous and heterogeneous populations represent this livestock and no previous characterization of the goat population from the north of Morocco was carried out. This genetic resources showed some morphological resemblance to Spanish dairy goats breeds such as the Murciana-Granadina, the Malagueña or others Andalusian breeds (Tadlaoui Ouafi et al., 2002).

Characterization and inventory of the genetic resources are the first step to implement a strategy to genetic improvement (FAO 2010). The phenotypic characterization is broadened to include a description of the production environment that affects not only the natural environment, but also management practices and the different uses of animals. The study of the geographical distribution of breeds is also an integral part of phenotypic characterization (FAO, 2012).

The objective of this study was to differentiate morphologically the local goat population from the north of Morocco based on measurable and qualitative morphological traits by taking into account the possibility that this population is subdivided as a consequence of differences in geographic location, origin and breed influences. Results obtained from this characterization would provide useful information and contribute to ameliorate management practices and productivity in this population, and implement an improvement plan for milk production of the Moroccan goat.

Preliminary results of this study were communicated at the FAO seminar "Technology creation and transfer in small ruminant - Tangier" (El Moutchou et al., 2014).

Materials and methods

Sampling and location of populations

The sampled territory was divided into three main geographical areas according to climate conditions and environmental influences: sea and mountains) (Figure 1):

- Dual, covering the extreme northern part of Morocco influenced by the Mediterranean Sea and Atlantic Ocean with sub-humid climate (approximately latitude 13° 5′ N to 15°3′N) with 600-800mm/year precipitation;
- Mediterranean, occupying the north part of the country and undergoing a dual influence; Mediterranean Sea and the Rif mountain chain, with annual rainfall higher than 900mm;
- Atlantic, covering the northwest part of Morocco (latitude 9°3′N to 11°3′N) influenced by the Atlantic ocean with a semi-arid climate and rainfall 400-600mm/year.

In addition to climate influence, these areas were defined by considering the historical aspects of the Spanish and French occupation. With Spain in control of the Mediterranean and Dual areas, and France in the Atlantic area where imported goats could influence the local Moroccan goat population. Data were collected from 61 herds, 15 belonging to Dual, 22 to Mediterranean, and 24 to Atlantic. From each farm, 3 animals per herds were sampled, making a total of 45, 66 and 72 respectively in Dual, Mediterranean and Atlantic. In total 145 females and 38 males were selected and all of them were more than three years old.

Qualitative traits

Qualitative traits were registered: horns H (presence and absence), beard B, (presence and absence), wattles W (presence and absence), ear position EP (vertical, horizontal and dropped), cephalic profile CF (straight and convex), hairs length HL (long, short and medium), horns shape HS (arched and spiral), color pattern CP (black, white, red, roan, spotted, chamois and Swiss marked).

Zoometrics measurement

Nine zoometric measurements were carried out on goats according to FAO (2012) recommendations, including: Head length (HL), Height at withers (HW), Body length (BL), Rump length (RL), Length Led (LL), Height at Rump (HR), Chest depth (ChD), Shin Girth (SG), and Ear Length (EL). Additional combined indices related to the HW, ChD, BL, RL and EL were also calculated:

- Index of proportionality IPRO = BL * 100/HW,
- Index of relative chest depth IRCh = ChD* 100/HW,
- Longitudinal basin index ILB = RL * 100/HW,
- Index of the differences between the heights IDH =HR*100/HW,
- Ears index EI = EL * 100/HW,
- Auricular thoracic index IAT=EL/ChD,
- Index of substernal slenderness ISs= HW-ChD/HW.

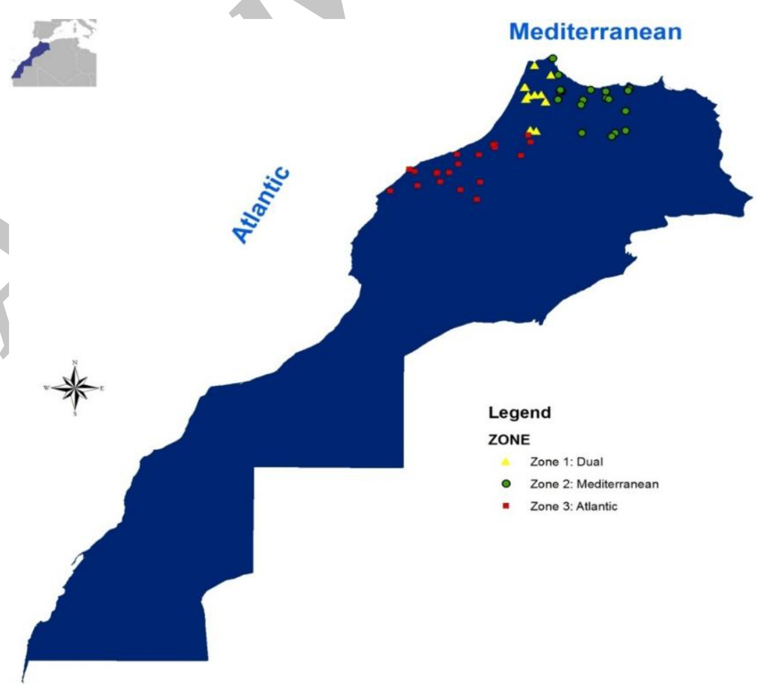

Figure 1. Dispersion of goats sampled. Geographic map illustrating the distribution of the 61 sampled herds. Each point represents one herds and different colors illustrate the limits of the main three zones [15herds in Zone1: Dual, 22 in Zone 2: Mediterranean and 24 in Zone3: Atlantic]

IRCh, EI, IAT and ISs are considered as indicators of adaptability to heat and arid environment as described by Bouzart et al. (1993) and Zeuh et al. (1997).

Statistical analysis

Frequencies of qualitative traits were calculated and the differentiation of qualitative traits affected by area and sex was measured by chi-square test (χ^2). Descriptive statistics for body measurements and indexes were calculated, considering the effect of sex and environmental areas testing significance by one-way ANOVA. The hypothesis of the possibility exchange of bloodstock between herds was assumed. The geographic and reproductive isolation of flocks are not complete and the herd effect within each zone must, therefore, be defined. The degree of homogeneity within the areas is noted by the coefficient of variation (Herrera et al., 2003).

The principal components analysis (PCA) were carried out to investigate the core structure of the trait to check when the traits could be reduced to uncorrelated dimensions. To determine the more discriminate morphological trait, a stepwise procedure was performed. Also, the relative importance of the morphometric variables in discrimination between the three areas was assessed using the level of significance, partial Lambda and F-statistics.

The discriminate ability of the lineal functions to identify the area of goats was indicated as the percentage of individuals correctly classified from the sampled generating the functions using split-sample validation (cross validation). In addition to the analysis of variance between the subpopulations, taking only the female data, a canonical analysis was used to derive canonical functions, a lineal combination of the quantitative variables that summarize variation and to obtain Mahalanobis distances between areas. All these analysis and graphs were carried out using Statistical 8.0 software package for Windows.

Results

Phenotypic variability

Table1 shows the frequencies (%) and significant differences ($p < 0.05$) of the qualitative traits for each sex and zone. The hair length (HL) is predominantly long. The ears position is equitable between drooped or vertical in both sexes and varying from dropped in Atlantic, vertical in Dual, dropped and vertical in the Mediterranean area. Horns were mainly present, around 60%, in both sexes with arched horns in females (83%) while males were principally in spiral shape (67%). Mediterranean and Dual goats were mainly horned. In both sexes, three coat types were predominant: red, black dominant and spotted. The cephalic profile was mainly straight for both sexes and in the three subpopulations (more than 90%). Goatees were present in more than 60% and the wattles were absent in 70% of females and 56% of males.

The three environmental areas showed differences ($p < 0.05$) in five of eight qualitative traits studied (Table 1). The three subpopulations were statistically different from each other. Dual goats presented long hairs (86%), vertical ears (84%), arched horns (70%), an intermediate presence of wattles and goatee (about 50%). Atlantic animals had mainly dropped ears (78%), horns (44%) and goatee (75%). The Mediterranean group had intermediate values for all traits, with a high presence of wattles (81.8%). The predominant type of coat in the Mediterranean area was black (38%), while red was more common in the Atlantic and Dual (30% and 42%, respectively).

Descriptive statistics and analysis of variance by area and sex are presented in Table 2. Morphological traits were generally very similar (n.s. at $p<0.05$) for male and female.

The variable HW, EL, RL and EI were significantly ($p <0.05$) influenced by the geographical area. The HW showed extreme mean values in the Atlantic and Mediterranean areas (65.65 vs 62.54 cm, respectively). Mean value of EL (14.54 vs 16.65 cm) and RL (14.65 vs 16.34 cm) varied between Mediterranean and Atlantic respectively. The mean values of the index ISs were 1.18 (Dual) to 1.24 (Mediterranean). Measurements displayed a lack of homogeneity (CV > 9%) (Herrera et al., 2003) in the total population and within each area. The Atlantic subpopulation were the most homogeneous.

Discrimination by morphological traits

Table 3 presents the PCA analysis, four factors were necessary to explain 75% of the total variation between traits in females. All these traits were determinant of goat’s size. PC2 was loading principally by EL and combined index related to this measure (EI and IAT). SG is remarkable in PC3 and PC4.

The hypothesis that the measurements are equal in the three subpopulations was also tested using Wilk’s Lambda for the discrimination functions (Supplementary). We obtained a significant value ($p>0.05$) for three traits LL, RL and EI.

Differentiation between geographical subpopulations

Results of classification into each environmental area

Table 1. Frequencies (%) of qualitative traits by sex and environmental areas in the studied population

Traits	Sex		Environmental area			Test (χ2)	
	Male	Female	Mediterranean	Dual	Atlantic	Sex effect	Zone effect
Horns							
Absence	40.00	38.35	22.73 [a]	30.00[b]	56.25[c]	0.24 ns	11.05**
Presence	60.00	61.65	77.27	70.00	43.75		
Hair Length							
Long	68.00	81.06	72.73	86.00	76.56		
Medium	32.00	14.39	25.00	12.00	15.62	5.72 ns	6.64 ns
Short	0.00	4.55	2.27	2.00	6.25		
Ear Position							
Vertical	44.00	51.88	56.82[a]	84.00[b]	20.31[c]		
Horizontal	0.00	4.51	9.09	2.00	1.56	3.0 ns	48.53***
Dropped	56.00	43.61	34.09	14.00	78.13		
Horn Shape	33.33	82.93	73.52	71.43	82.15	14.42***	0.98 ns
Arched							
Spiral	66.67	17.07	26.47	28.57	17.85		
Coat Pattern							
White	8.00	8.27	6.81[a]	14.00[b]	4.68[c]		
Spotted	12.00	27.07	18.18	18.00	34.37		
Red	24.00	33.83	20.45	30.00	42.18		
Black	56.00	18.8	38.06	26.00	14.06	17.82**	24.44*
Swiss marked	0.00	5.26	9.09	6.00	0.00		
Chamois	0.00	6.02	6.81	6.00	3.12		
Roan	0.00	0.75	0.00	0.00	1.50		
Wattles							
Absence	56.00	70.68	81.81[a]	51.28[b]	75.00[c]	2.0 ns	9.79**
Presence	44.00	29.32	18.18	48.72	25.00		
Goatee							
Absence	32.00	35.34	36.36[a]	56.00[b]	25.00 [c]	0.1 ns	7.20*
Presence	68.00	64.66	63.63	54.00	75.00		
Cephalic Profile							
Straight	96.00	93.98	93.18	100.00	90.63	0.17 ns	5.77 ns
Convex	4.00	6.02	6.82	0.00	9.37		

reveal that Dual and Atlantic individuals were the best classified in their source populations (75.0% and 72.4% respectively), whilst only 27.3% of the Mediterranean goats were correctly classified. The values for CAN1 and CAN2 for each individual by geographical areas were plotted in Figure 2. The animals of the three sub-populations were heterogeneous and dispersed across the axis and the dual subpopulation is located in an intermediate distribution between the Mediterranean and Atlantic area. The ANOVA results (Table2) showed significant differences only in LL measure ($p<0.05$) across the three geographical areas.

The greater Mahalanobis distance was detected between the most geospatially separated areas, Atlantic and Mediterranean with a value of 1.5776 ($p<0.005$). The Dual area showed very similar and intermediate values with Mediterranean (1.2387) and Atlantic areas (1.2258).

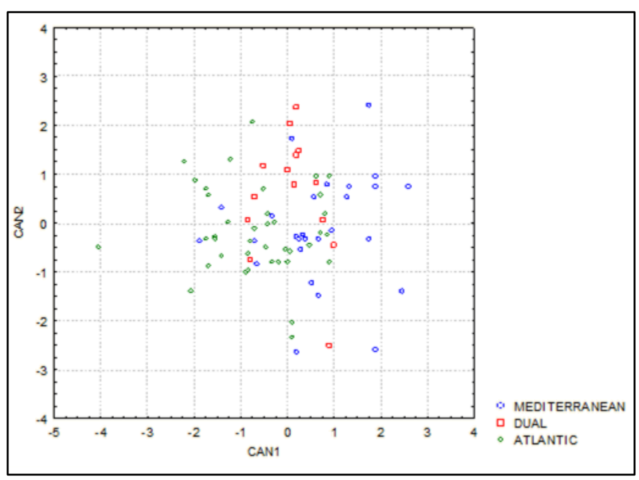

Figure 2. Bi-dimensional represenetion of the canonical variables associated to the individuals sampled (female only) in each environmental area in northern Morocco using morphostructural variables

Table 2. Means of lineal body measurements (in cm) with their standard error (SE) and coefficient variation (CV) of northern Morocco goat population

Traits	Males				Females															
	Total				Total				Dual area				Mediterranean area				Atlantic area			
	N	Mean	CV	SE	N	Mean	CV	SE	N	Mean	CV	SE	N	Mean	CV	SE	N	Mean	CV	SE
HL	18	19.5^{A}	12.97	0.5981	70	19.5^{A}	13.95	0.3256	25	19.4^{a}	11.65	0.4526	12	19.4^{a}	12.23	0.6848	33	19.6^{a}	16.26	0.5559
HW	25	64.0^{A}	11.95	1.5297	133	64.1^{A}	9.27	0.5157	37	63.4^{a}	13.07	1.3643	39	62.5^{ab}	7.34	0.7346	57	65.6^{ac}	6.89	0.5989
BL	21	61.1^{A}	11.81	1.5747	83	61.0^{A}	9.83	0.6589	28	61.6^{a}	10.46	1.219	14	58.6^{a}	11.54	1.8094	41	61.4^{a}	8.68	0.8331
RL	20	15.5^{A}	17.19	0.596	81	15.6^{A}	13.99	0.2434	27	15.2^{a}	13.7	0.4015	15	14.6^{ab}	13.09	0.4952	39	16.3^{ac}	13.34	0.3491
LL	21	40.4^{A}	15.53	1.3691	86	40.4^{A}	11.76	0.5125	28	42.2^{a}	10.19	0.8131	14	39.1^{b}	12.53	1.3109	44	39.6^{c}	11.97	0.7153
HR	21	67.7^{A}	10.25	1.5144	87	67.8^{A}	7.66	0.5572	28	68.8^{a}	8.17	1.0629	15	65.8^{a}	6.4	1.0871	44	67.8^{a}	7.56	0.7742
ChD	21	29.9^{A}	10.87	0.7116	87	29.8^{A}	9.38	0.3006	28	30.2^{a}	11.59	0.6621	15	28.3^{a}	10.27	0.7525	44	30.1^{a}	6.87	0.3127
SG	25	8.24^{A}	13.23	0.2182	133	7.69^{A}	9.32	0.0622	37	7.63^{a}	9.22	0.1157	39	7.60^{a}	11.7	0.1425	57	7.79^{a}	7.47	0.0771
EL	25	15.0^{A}	14.55	0.4377	133	15.7^{A}	15.3	0.2093	37	15.7^{a}	16.46	0.4256	39	14.5^{ab}	16.23	0.3779	57	16.6^{ac}	11.71	0.2583
IPRO	21	96.3^{A}	8.19	1.7225	83	93.6^{A}	8.38	0.8608	28	94.2^{a}	7.63	1.3581	14	92.6^{a}	9.83	2.4353	41	93.5^{a}	8.53	1.2458
IRCh	21	47.3^{A}	8.48	0.877	87	45.8^{A}	7.63	0.3751	28	46.2^{a}	9.4	0.8213	15	45.1^{a}	10.15	1.1826	44	45.8^{a}	5.12	0.3543
ILB	20	24.5^{A}	16.729	0.9185	81	24.0^{A}	13.53	0.3611	27	23.2^{a}	12.77	0.5708	15	23.2^{a}	11.19	0.6711	39	24.8^{a}	14.1	0.5615
IDH	21	106.7^{A}	5.31	1.2387	87	104.0^{B}	4.88	0.5442	28	105.2^{a}	4.59	0.9128	15	104.4^{a}	2.98	0.8028	44	103.1^{a}	5.48	0.8521
EI	25	23.5^{A}	12.41	0.5857	133	24.7^{A}	15.8	0.3388	37	25.1^{a}	19.22	0.7943	39	23.2^{ab}	15.74	0.5866	57	25.4^{ac}	12.25	0.413
IAT	20	0.50^{A}	12.8	0.0143	87	0.54^{A}	15.85	0.0091	28	0.52^{a}	15.74	0.0155	15	0.53^{a}	22.85	0.031	44	0.55^{a}	13	0.0108
ISs	21	1.13^{A}	15.5	0.0381	87	1.19^{A}	14.71	0.0188	28	1.18^{a}	15.42	0.0344	15	1.24^{a}	23.2	0.0744	44	1.19^{a}	9.53	0.017

Table 3. Eigen values, factor pattern and communality of lineal body measurements and combined index of the three goat subpopulations of Northern Morocco.

Traits	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
HL	-0.55	-0.41	0.19	-0.13	-0.47	0.48	-0.18	0.03	-0.01
HW	-0.84	-0.18	0.12	0.16	-0.11	-0.15	0.32	-0.25	-0.16
BL	-0.85	0.22	0.17	-0.16	0.15	-0.15	-0.14	0.25	-0.19
RL	-0.59	0.41	0.23	-0.27	0.40	0.38	0.22	-0.07	0.09
LL	-0.48	0.39	-0.43	0.55	0.07	0.27	-0.20	-0.04	-0.04
HR	-0.81	-0.25	-0.17	0.24	-0.08	-0.11	0.32	0.21	0.17
ChD	-0.79	-0.11	0.20	0.01	0.12	-0.29	-0.43	-0.14	0.15
SG	-0.43	-0.09	-0.74	-0.51	-0.02	-0.05	-0.02	-0.06	-0.01
EL	-0.11	0.80	0.07	-0.10	-0.55	-0.15	0.04	-0.02	0.06
*IPRO	-0.22	0.42	0.09	-0.37	0.30	-0.03	-0.46	0.56	-0.08
*IRCh	-0.09	0.03	0.13	-0.18	0.26	-0.19	-0.84	0.07	0.35
*ILB	-0.13	0.54	0.16	-0.39	0.49	0.48	0.05	0.08	0.21
*IDH	0.06	-0.11	-0.44	0.12	0.04	0.07	0.01	0.72	0.50
*EI	0.38	0.78	-0.03	-0.17	-0.41	-0.03	-0.12	0.11	0.16
*IAT	0.38	0.72	-0.09	-0.06	-0.50	0.03	0.26	0.07	-0.02
*ISs	0.07	-0.03	-0.12	0.22	-0.27	0.14	0.84	-0.08	-0.33
Eigen value	3.80	1.30	0.93	0.77	0.74	0.61	0.53	0.20	0.13
Explained variance (%)	42.20	14.40	10.36	8.59	8.17	6.73	5.88	2.25	1.42
Cumulative variance (%)	42.20	56.60	66.96	75.55	83.72	90.45	96.33	98.58	100

HL: Head length, HW: Height at withers, BL: Body length, RL: Rump length, LL: Length led, HR: Height at rump, ChD: Chest depth, SG: Shin Girth, EL: Ear Length, IPRO: Index of proportionality, IRCh: Index of Relative chest depth, ILB: Index longitudinal basin, IDH: Index the differences between the heights, EI: Ears index, IAT: Index auricular thoracic, ISs: Index of sous-sternal slenderness

Discussion

The qualitative traits support the presence of a large variability amongst and within areas, probably due to a high degree of admixture in this population. The goat population studied was especially variable in the coat color, although this variability was greater in females than males. The studied goats, in both sexes and in all areas, presented mainly a straight profile (>94%), may be due to a similarity in origin. Herrera et al. (1996) concluded that the head profile is the most important to determine a different racial origin of the populations, and Capote et al. (1998) used horn shape and cephalic profile to differentiate the Canary goat population.

The results of X^2 comparison test between geographical areas support the initial hypothesis of the presence of distinct subpopulations within this population. We found variability in horn shape with a marked effect of geographical localization. Also, a great difference in wattle presence between geographical zones was detected. As reported by Leng et al. (2010), the presence of high incidence of wattles can be a result of adaptation more than selection for this trait, but the role of wattle for adaptation is not well known. Dossa et al. (2007), for north Benin goats, found differences in the frequency of qualitative traits between different vegetation zones, but in our case, with northern Morocco goat population, the differences between the environmental areas were not very clear.

The morphological traits between sexes showed a lack of sexual dimorphism. This could be a result of a delayed sexual maturation of males during the growth period and may be influenced by food conditions (Polák and Frynta, 2009). Limitations in food quantity and quality may affect linear body measurements (Kadim et al., 2006). The high coefficients of variation in the majority of measures indicated the presence of disorganized crossing (Chacón et al., 2011). Mavule et al. (2013) reported that the head length shows scarce variability due to its close association with cranial bone, and the large variation shown by the higher standard deviation in some measurements is a result of the absence of selection, or the body parts are affected more by the environment than other factors.

ANOVA data showed significant differences only in LL measure (p<0.05) across the three geographical zones. These results are in agreement with Macciotta et al. (2002) and Capote et al. (1998).

In the present study, a significant difference between animals raised under conditions of less rain, Atlantic, and the other two areas was detected, and the tallest (HW) animals were located in the Atlantic subpopulation, this could be the result of selection practices in this area.

Compared with other Moroccan breeds, the northern goat population is higher (HW) with shorter (BL) than the Draa breed, higher and almost the same length as the Atlas; and higher and longer than Barcha and Ghazzalia (Ibnelbachyr et al., 2015). Boujenane et al. (2016) in Barcha and Atlas breeds found higher values in HW and BL than those reported by Ibnelbachyr et al. (2015) for the same breeds and other Moroccan goat breeds. Authors explained these differences by the period when the measurements were taken.

The PC1 showed that a high animal is also usually long in body. The Second PC describes a subgroup of animals with variation in EL. The HW, EL, HR and EI were the most important traits that differentiate the Mediterranean subpopulation from the Atlantic subpopulation. EL and LL were very important to discriminate globally the three areas. The finding in the present paper on the use of EI to discriminate between goat populations is consistent with the study of earlier authors on goats from Cameroon and Chad (Bourzat et al., 1993; Zeuh et al., 1997). The best discriminate function model used in this study included only three morphological measures (RL, LL, and EI) out of the nine measurements and the pre-selected seven index, indicating that taking basic measurements consistently was more important than acquiring numerous additional measurements. Dossa et al. (2007) reported similar results.

Also, the measurements that are low at discrimination are those significantly affected by the environment (Zaitoun et al., 2005). Yokoo et al. (2010) suggested the inclusion of lineal dimensions in breeding programs because such traits were easily measured and less affected by environmental variations.

The large classification errors obtained using discriminate analyses did not give statistical support to separate this population into three different breeds.

The Mahalanobis distance (1.238 and 1.576) suggesting low differentiation between Mediterranean subpopulation and the other two. Based on the Mahalanobis distance, Yakubu et al. (2011) reported an important genetic variation between West African Dwarf and Red Sokoto goat breeds, also Boujenane et al. (2016) suggest morphological differences between Barcha and Atlas breeds.

The position of the Mediterranean subpopulation supports the hypothesis of the influence from the Spanish breed through the Strait of Gibraltar. This does not necessarily reject past influences of Southwest Asiatic goats, nor later influences of several cultures (Phoenician, Roman, Arabs, Berbers, Ottomans) (Pereira et al., 2009; Benjelloun et al., 2011; Benjelloun et al., 2015)..

A significant proportion of cross-classification errors between the Mediterranean area (27%) and the other two confirm the introgression. The transhumance or human migration between the Mediterranean and Atlantic areas could explain this gene introgression.

Animals from the Dual area showed intermediate values in the majority of morphometric measurements, suggesting that this area may be considered as a great crossbred zone (Dossa et al., 2007). The farming system and production purpose had an important effect on the morphostructure of goat breeds (Gonzalez-Martinez et al., 2014; Rodero et al., 2015). Also Traoré et al. (2008) have attributed the cause of large misclassifications of introgression across breeds to the farming targets.

The lower misclassification errors of the Atlantic area may be an indicator of more uniformity and more homogeneity of this population.

Benjelloun et al. (2015) reported that northern goats were slightly more diverse than Draa and Black of Atlas goat, and displayed a higher assignment probability to one distinct cluster. This supports the hypothesis of an influence of Iberian gene flows through the Strait of Gibraltar in the North of Morocco and the presence of uncontrolled breeding strategies in agricultural extensive systems.

The goats from north Morocco showed a great heterogeneity whose current structure cannot be totally understood by only taking into consideration their territorial distribution. The reason for this could be attributed to the absence of selection plans and the uncontrolled mounts, the intense admixture between exotic breeds and local Moroccan populations.

Conclusion

Clear differences between the three suggested subpopulations were absent and an intense mixture through the geographical areas was detected. The Mediterranean area showed more morphological variability possibly due to the multiple migratory flows through the Strait of Gibraltar. Dual area had an intermediated position between Atlantic and the Mediterranean. The Atlantic subpopulation was the most homogeneous and differentiated group.

The most important factors of the high variability and low geographic differentiation found in Northern Morocco goat seem to be the lack of selection, crossing and introgression from other exotic breeds. This research can be important and an urgent call to change the management practices, avoid inbreeding and indiscriminate crossbreeding to preserve these local genetic resources. A genetic characterization of this population was conducted using microsatellite markers and a study on the phylogenetic relationships with Spanish breeds was also conducted (articles in press).

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Supplementary table. Summary of discriminatory analysis of morphometric characteristics

Traits	Wilks' Lambda	Partial Lambda	F-remove	p-level	Toler.	1-Toler. (R-Sqr)
HL	0.661	0.966	0.923	0.404	0.724	0.276
HW	0.649	0.985	0.395	0.676	0.289	0.711
BL	0.663	0.964	1.003	0.374	0.243	0.757
RL	0.720	0.888	3.343	0.043	0.539	0.461
LL	0.738	0.866	4.102	0.022	0.742	0.258
HR	0.639	1.000	0.004	0.996	0.298	0.702
ChD	0.642	0.996	0.116	0.890	0.347	0.653
SG	0.676	0.946	1.525	0.227	0.836	0.164
EL	0.704	0.908	2.698	0.077	0.757	0.243
IPRO	0.752	0.982	0.641	0.530	0.429	0.571
IRCh	0.780	0.947	2.000	0.143	0.039	0.961
ILB	0.790	0.934	2.488	0.090	0.628	0.372
IDH	0.753	0.981	0.687	0.507	0.974	0.026
EI	0.809	0.913	3.390	0.039	0.004	0.996
IAT	0.802	0.920	3.067	0.053	0.003	0.997
ISs	0.779	0.948	1.966	0.147	0.013	0.987

HL: Head length, HW: Height at withers, BL: Body length, RL: Rump length, LL: Length led, HR: Height at rump, ChD: Chest depth, SG: Shin Girth, EL: Ear Length, IPRO: Index of proportionality, IRCh: Index of Relative chest depth, ILB: Index longitudinal basin, IDH: Index the differences between the heights, EI: Ears index, IAT: Index auricular thoracic, ISs: Index of sous-sternal slenderness