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Morphological Characterization and Establishment of a DNA Biobank for Fantasia Horse Breeds (*Equus caballus*) in Algeria

Khedim R[1], Khalid F.Z[1], Berrais F[1], Benhammadi M[1], Azzi N[2], Gaouar S.B.S[1]

[1]*Applied genetic in agriculture, ecology and public health laboratory, SNV/STU Faculty, ABOU BEKR BELKAID UNIVERSITY, Tlemcen, Algeria;*
[2] *Department of Agronomic, Abou Bekr Belkaid University, Tlemcen, Algeria*

***Corresponding Author**: Semir Bechir Suheil GAOUAR, Applied genetic in agriculture, ecology and public health laboratory, Tlemcen, Algeria; **Email**: suheilgaouar@gmail.com
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Abstract
Equine genetic resources in Algeria are integral to the nation's cultural and economic heritage, particularly the Barbe and Arabe-Barbe breeds essential in traditional and equestrian activities. However, uncontrolled crossbreeding and poor documentation threaten their genetic integrity. This study aimed to characterize the morphometric and genetic diversity of equines from three Algerian regions—Tlemcen, Sidi Bel Abbès, and Relizane and to establish a DNA biobank for conservation. Morphometric analyses were conducted on 54 horses of various presumed origins, including both males and females over three years old. Twenty-six parameters, encompassing height, length, and circumferences, were measured using a hippometer and measuring tape. Data were analyzed using descriptive statistics, Principal Component Analysis (PCA), hierarchical clustering (HCA), and Analysis of Variance (ANOVA) with RStudio and SPSS software. Blood and hair samples were collected to identify each horse's origin and create a DNA biobank for future research. Results indicated significant regional variations, with Tlemcen horses showing the highest heights and robust builds, Sidi Bel Abbès horses exhibiting extended body lengths, and Relizane horses displaying lighter, agile morphologies. Sexual dimorphism was evident, and the Shannon-Weaver index highlighted substantial diversity among regions. This integrated approach provides critical insights into the phenotypic and genotypic variability of Algerian equines, underscoring the urgent need for sustainable management policies to preserve their biodiversity and ensure their long-term viability.
Keywords: *Equus caballus*, Fantasia horses, morphometric measurement, characterization.

Résumé :
Les ressources génétiques équines en Algérie constituent un élément essentiel du patrimoine culturel et économique du pays, notamment les races Barbe et Arabe-Barbe, fondamentales dans les activités traditionnelles et équestres. Cependant, leur intégrité génétique est menacée par le croisement non contrôlé et le manque de documentation. Cette étude vise à caractériser la diversité morphométrique et génétique des équidés de trois régions algériennes — Tlemcen, Sidi Bel Abbès et Relizane — et à établir une biothèque d'ADN en vue de leur conservation. Des analyses morphométriques ont été réalisées sur 54 chevaux d'origines présumées variées, comprenant des mâles et des femelles âgés de plus de trois ans. Vingt-six paramètres, incluant des mesures de hauteur, longueur et circonférences, ont été pris à l'aide d'une toise et d'un ruban métrique. Les données ont été analysées par statistiques descriptives, Analyse en Composantes Principales (ACP), classification hiérarchique ascendante (CAH) et Analyse de Variance (ANOVA) à l'aide des logiciels RStudio et SPSS. Des échantillons de sang et de poils ont été prélevés pour identifier l'origine des chevaux et créer une biothèque d'ADN pour les recherches futures. Les résultats révèlent des variations régionales significatives : les chevaux de Tlemcen présentent les plus grandes hauteurs et une morphologie robuste, ceux de Sidi Bel Abbès des corps allongés, et ceux de Relizane des morphologies plus légères et agiles. Un dimorphisme sexuel a été constaté, et l'indice de diversité de Shannon-Weaver a souligné une variabilité importante entre les régions. Cette approche intégrée fournit des informations essentielles sur la variabilité phénotypique et génotypique des équidés algériens, soulignant l'urgence de mettre en œuvre des politiques de gestion durable pour préserver leur biodiversité et garantir leur viabilité à long terme.
Mots-clés : *Equus caballus*, chevaux de Fantasia, mesure morphométrique, caractérisation.

Introduction
Agricultural biodiversity has evolved over thousands of years through human efforts to meet varying ecological and climatic challenges. The genetic variability within a species represents its evolutionary potential, enabling adaptation to environmental changes and resistance to emerging diseases. In Algeria, animal genetic resources, particularly equines, are a significant component of the country's natural heritage, with considerable economic, sociocultural, and ecological value. The equine sector holds a prominent place in the

history and economy of North Africa, contributing to sustainable development through landscape management, biodiversity preservation, and its unique relationship with humans, encompassing sports, cultural, and social activities.

Algeria hosts five major horse breeds: Barbe, Arabe-Barbe, Thoroughbred Arabian, English Thoroughbred, and French Trotter. Among these, the Barbe and Arabe-Barbe breeds, originating from North Africa's coastal regions, are integral to traditional cultural exhibitions like Fantasia and various equestrian sports. Despite their importance, the equine population faces genetic challenges due to uncontrolled crossbreeding, which threatens the genetic integrity of these breeds. According to the Algerian Ministry of Agriculture, the equine population in the country is estimated to be around 250,000 horses, with 90% consisting of Barb, Arabian-Barb, and Algerian Saddle horses (Berber et al., 2016). The remaining 10% includes Arabian horses, Thoroughbreds, and French Trotters (Berber et al., 2016).

For many domestic animals, including horses, breeds are cataloged in pedigree registers or "stud books," designed to maintain consistent traits such as size, morphology, and coat color over generations. However, many Algerian horses are not officially registered, and the limited number of recorded individuals exacerbates confusion between breeds and performance decline due to inbreeding.

In this context, sustainable genetic resource management is critical to mitigate the risks to indigenous genetic biodiversity. This requires identifying and characterizing equine breeds, particularly in regions such as Tlemcen, Sidi Bel Abbès, and Relizane. The present study aims to:

Identify and characterize equine breeds in the three regions, establishing strategies for conservation and sustainable management, as well as develop a comprehensive database of these breeds, serving as a foundation for improving and preserving Algeria's equine genetic heritage, ensuring its long-term sustainability.

Material and methodes:

The study was conducted across three regions in Northwestern Algeria (Figure 1): Tlemcen, Sidi Bel Abbès, and Relizane. In the Wilaya of Tlemcen, sampling sites included Ghazaouet, Beb El Assa, Nedroma, and Ain Fza. For Sidi Bel Abbès, data were collected from Telagh, Mezaourou, and Sidi Ali Benyoub. In Relizane, the study focused on the region of Yellel. These areas are characterized by diverse geographical and climatic conditions, contributing to the variability in equine morphology.

Figure 1. Representation of Sampling Areas on the Geographic Map of Algeria
1 : Tlemcen ; 2 : Sidi Bel-Abbès ; 3 : Relizane

A total of 54 horses (Tlemcen: N=29, Sidi Bel Abbes: N=19, Relizane: N=6), both males and females, all above three years of age and from different breeds were assessed, Morphometric measurements were performed (Table 1) using a measuring tape to record lengths and circumferences, while a hippometer was employed for height parameters. Each horse was positioned on a level horizontal plane for accurate measurements. Data collection emphasized precision and consistency to ensure the reliability of the morphometric analysis.

a. Height Measurements**:** Heights at the withers (HG) and croup (HC) were recorded using a hippometer. The cursor of the hippometer was positioned above the measurement point and lowered gently until it made precise contact with the most prominent part of the respective anatomical feature.

Anatomical Landmarks are shown in figure 2, a total of 11 anatomical reference points were marked on the horses using a marker (following Barone, 1980), including:

1. Point a: External occipital protuberance (top of the poll).
2. Point b: Anterior border of the atlas wing.
3. Point c: Tip of the scapula (shoulder blade).
4. Point d: Caudal part of the humeral greater tubercle (shoulder point).
5. Point e: Lateral aspect of the radial head (elbow region).
6. Point f: Distal radius (carpal joint region).
7. Point g: Head of the fourth metacarpal (distal carpal region).
8. Point h: Distal end of the metacarpus (fetlock).
9. Point i: Coxal tuberosity (hip angle).
10. Point j: Greater trochanter crest of the femur.
11. Point k: Tibial tuberosity (stifle region) .

These points were used to calculate key linear parameters such as scapulo-iliac length, total body length, and femoral and tibial lengths.

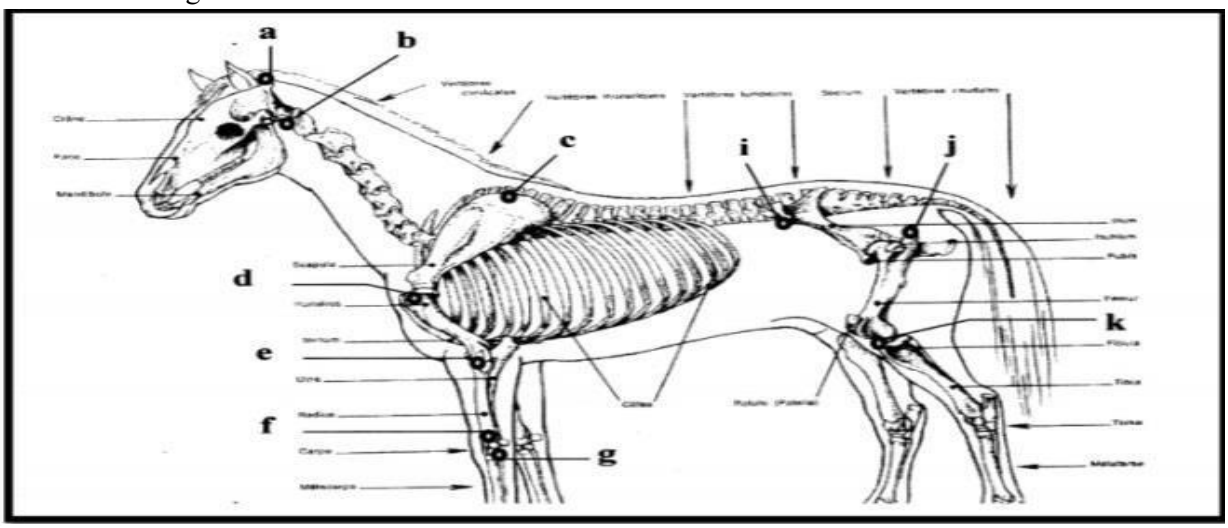

Figure 2. Landmarks defining the morphological parameters of the horse's length

Length and Circumference Measurements:

A measuring tape was used to determine body lengths, including the total body length, neck length, and lengths of limbs and other segments.

Circumferences were measured for the chest, forearm, cannon (both anterior and posterior), knee, and fetlock using standard anatomical guides. Measurements were taken with the tape positioned perpendicular to the axis of the segment.

b. Weight Estimation**:**

Bodyweight was estimated based on the animal's chest circumference and total length. using the barymetric formula demonstrated by Caroll and Huntington (1988) :

$$\text{Body weight (kg)} = (\text{Chest circumference})^2 \times \text{Total length (cm)} / Y$$

- Y is a constant equal to 11877.4 cm^3/kg.

c. Body Indices**:**

Six body indices were calculated to assess morphological and functional traits (Marcq et al., 1951; Chabchoub et al., 2004; Nicks et al., 2006; Boujenane et al., 2008):

• Corpulence Index : Chest size (TP)/Height at the withers (HG) ;

- Body Profile Index :Height at the withers (HG)/ Total lenght (LT) ;
- Compactness Index : Live weight(PV)/Height at the withers (HG) ;
- Relative Body : Total lenght (LT) /Chest size (TP) ;
- Dactylo-Thoracic : Anterior Canon Ream (TCA)/Chest size (TP);
- Front Height Behind : Height at the withers (HG)/Height at the croup (HC)

The study of genetic biodiversity requires advanced statistical methods, leveraging high-throughput data analysis techniques and computational resources. Technological advances in bioinformatics have facilitated rapid processing of large datasets and enabled the extraction of diverse characteristics for population analysis. Three key software tools were used in this study: RStudio (FactoMineR, version 2.15.2), SPSS, and Microsoft Excel.

A comprehensive statistical approach was employed to analyze the dataset, beginning with descriptive statistics to summarize quantitative variables, revealing central tendencies and variability. Multivariate techniques were then applied to explore interactions among variables and identify systematic patterns within the studied populations. Principal Component Analysis (PCA) synthesized the dataset by reducing dimensionality while preserving essential variability, enabling the classification of individuals into homogeneous groups and revealing relationships among variables (Kouani et al., 2007). Hierarchical Cluster Analysis (HCA) further organized observations into nested partitions, facilitating the identification of both broader clusters and finer subdivisions, thereby enhancing the understanding of population variability (Roux, 2006). Analysis of Variance (ANOVA) assessed the effects of independent factors, such as locality, population type, and breed, on dependent variables, uncovering significant group differences and the influence of environmental and genetic factors (Ramousse, 1996). Additionally, the Shannon-Weaver diversity index (Shannon & Weaver, 1949) quantified biodiversity within the populations, offering a robust measure of ecological variability by evaluating diversity as the amount of information in the system. The formula for Shannon-Weaver diversity is calculated as follows:

$$H' = - \sum pi \, Log \, pi$$

- **S** is the total number of species
- **Pi** is the relative frequency of species **i** in the sample
- **nj** is the relative frequency of species **j** in the sampling unit
- **N** is the sum of the relative frequencies of all species in the sample

DNA Biobank Constitution

To enrich the existing DNA biobank at the Laboratory of Applied Genetics in Agriculture, Ecology, and Public Health (GenApAgie) at Tlemcen University, a comprehensive sampling protocol was established. Blood samples were collected using 4 mL syringes from the jugular vein of each animal, with the puncture site disinfected using cotton and alcohol. Each 4 mL blood sample was stored in EDTA-coated tubes labeled with the corresponding animal identification number and photography. Samples were transported in a cooler maintained at 0°C and stored at -20°C upon arrival at the laboratory. In addition, hair samples were collected for supplementary DNA extraction. These biological samples will support future molecular studies and contribute to expanding the biobank's resources.

Results:

Descriptive statistics

The morphometric analysis of equine ecotypes across the Tlemcen, Sidi Bel Abbes, and Relizane regions provided a detailed characterization of body measurements and indices. Descriptive statistics, including means, standard deviations, coefficients of variation, and indices, are presented in Table 1

a. Body Measurements

The analysis of height revealed that the mean heights at the withers and croup were 158.7 ± 6.39 cm and 157.94 ± 6.28 cm, respectively. The range for withers height spanned from 148 to 174 cm, while that for croup height extended from 147 to 172 cm, demonstrating moderate variability. Regarding body length, the average total body length was 176.33 ± 11.28 cm, whereas the scapulo-iliac length exhibited notable variability with a mean

of 134.22 ± 14.15 cm (CV = 10.55%), highlighting differences in body proportions within the population. In contrast, head length was more uniform, averaging 50.2 ± 3.45 cm.

Linear measurements for other anatomical features provided further insights into variability. For instance, the neck length was 87.67 ± 12.08 cm, and the forearm length was 40.67 ± 4.12 cm, both indicating moderate variability across individuals. Circumferential measurements revealed a chest circumference averaging 180.46 ± 10.57 cm, while the anterior cannon circumference demonstrated greater uniformity at 24.69 ± 1.83 cm. These results suggest a consistent pattern in segmental proportions, reflecting the population's morphological stability.

b. Body Indices

The calculated body indices further emphasized the balanced morphology and functional conformation of the studied ecotypes. The profile body index averaged 0.89 ± 0.046, while the compactness index was 3.04 ± 0.44, underlining a well-proportioned physique. Similarly, the dactylo-thoracic index (0.13 ± 0.01) and the relative body index (0.97 ± 0.06) underscored the harmonious development of the population. Finally, the estimated live body weight ranged widely from 332 to 653 kg, with a mean of 487.07 ± 77.73 kg, indicating variability in overall size and robustness.

Table 1. Descriptive statistics

Abbreviation	Parameters	Mean (n =54)	Sd	Variance	Mini	Max
	Height (cm)					
HG	at the withers	158.7	6.39	40.89	148	174
HC	at the croup	157.94	6.28	39.45	147	172
	Lenght (cm)					
LT	Total	176 .33	11.28	127.24	152	204
LSH	scapulo-iliac	134.22	14.15	200.47	109	181
LTe	head	*50.2*	3.45	11.93	45	59
AIY	distance between the internal angles of the eyes	20 .39	1.39	1.94	18	24
LE	Neck	87.67	12 .08	145.92	66	116
LEp	shoulder	74.76	15.07	227.2	45	98
LB	arm	37.3	6.27	39.34	27	48
LAB	forearm	40.67	4.12	16.98	32	48
LC	canon	27.13	4.43	19 .62	20	34
LI	illiac	48 .94	5	25.03	39	57
LCe	thigh	65.04	9.72	94.48	50	80
	Circumference (cm)					
TP	Chest size	180.46	10.57	111.93	150	201
TAB	forearm	45.94	1.89	3.6	42	50
Ttg	knee	32.98	2.37	5.64	28	38
TB	cannon bone	28.3	2.15	4.62	24	34
TCA	Anterior Canon Ream	24.69	1.83	3.35	20	28
TCP	Posterior Canon Tower	22.85	1.74	3.03	20	27
	Index					
(HG/LT)	Body Profile Index	0.89	0.05	0.002	0.8	1.01
(PV/HG)	Compactness Index	3.04	0.44	0.197	2.07	3.88
(TP/HG)	Corpulence Index	1.13	0.05	0.004	0.96	1.24
(TCA/TP)	Dactylo-Thoracic	0.13	0.01	0	0.1	0.17
(LT/TP)	Relative Body	0.97	0.06	0.004	0.85	1.16
(HG/HC)	Front Height Behind	1	0.01	0	0.98	1.02

Live weight (kg)	487.07	77.73	6042.1	32	653

Sexual Dimorphism in Morphometric Traits

The analysis of morphometric traits revealed evidence of sexual dimorphism in the equine population studied. with significant variations identified in five out of 26 parameters ($p < 0.05$). as detailed in Table 2. Using the Mann-Whitney test. differences between males and females were evaluated. highlighting sex-related morphological distinctions.

Table 2. Mean values of different parameters in males and females

Abbreviation	Parameters	Mean Males (n =38)	Mean Females (n =16)	Signification (P < 0.05)
	Height (cm)			
HG	at the withers	158.87	158.31	NS
HC	at the croup	158.08	157.63	NS
	Lenght (cm)			
LT	Total	175.79	177.63	NS
LSH	scapulo-iliac	131.84	139.88	*
LTe	head	50.08	50.5	NS
AIY	distance between the internal angles of the eyes	20.32	20.56	NS
LE	Neck	86.29	90 .94	NS
LEp	shoulder	73.42	77.94	NS
LB	arm	37.47	36.88	NS
LAB	forearm	40.68	40 .63	NS
LC	du canon	26.53	28 .56	NS
LI	de l'illium	49.68	47.19	NS
Lce	thigh	65.53	63.88	NS
	Circumference (cm)			
TP	Chest size	180.18	181.13	NS
TAB	forearm	45.63	46.69	*
TG	knee	33.47	31.81	*
TB	cannon bone	28.53	27.75	NS
TCA	Anterior Canon Ream	24 .68	24.69	NS
TCP	Posterior Canon Tower	23.03	22.44	NS
	Index			
(HG/LT)	Body Profile Index	0.9	0.88	NS
(PV/HG)	Compactness Index	3.02	3.12	*
(TP/HG)	Corpulence Index	1.12	1.13	NS
(TCA/TP)	Dactylo-Thoracic	0.13	0.13	NS
(LT/TP)	Relative Body	0.97	0.97	NS
(HG/HC)	Front Height Behind	1	0.93	*
	Live weight (kg)	483 .34	495.94	**NS**

For body measurements. males tended to exhibit greater dimensions in several traits. such as scapulo-iliac length (131.84 ± 14.15 cm in males versus 139.88 ± 14.15 cm in females. $p < 0.05$). forearm circumference (45.63 ± 1.89 cm in males versus 46.69 ± 1.89 cm in females. $p < 0.05$). and knee circumference (33.47 ± 2.37 cm in males versus 31.81 ± 2.37 cm in females. $p < 0.05$). Conversely. females showed higher mean values in the compactness index (PV/HG: 3.12 ± 0.44 in females versus 3.02 ± 0.44 in males. $p < 0.05$).

Indices further emphasized morphological differences. For instance. the height ratio (HG/HC) was significantly higher in males (1.00 ± 0.01) compared to females (0.93 ± 0.01. $p < 0.05$). reflecting proportional differences between front and rear heights. Although males generally exhibited slightly greater heights at the withers and croup (158.87 ± 6.39 cm and 158.08 ± 6.28 cm. respectively). these differences were not statistically significant ($p > 0.05$).

Comparison of Parameters Between the Sampled Classes and Horse Breeds Studied

The hierarchical cluster analysis (HCA) grouped the sampled horses into three distinct classes. which correspond to the Arab-Barb (Class 01). Barb (Class 02). and Anglo-Barb (Class 03) breeds based on field observations during sampling (Figure .1). To validate these classifications. we compared the morphometric parameters of the sampled horses to established data for purebred Arabians (El Beji. 1972). Thoroughbreds (Legault. 1977). and Barbs (Benhamadi et al.. 2016).

Table 3. Comparison of parameters between the samples classes and horse breeds studied

Lenghts (cm)	**mean values Barbe (Benhamadi et al. 2016)**	**mean values (PSA) (legaultr.J.1 977)**	**mean values Class 01**	**mean values Classe 02**	**mean values Class 03**
Total	160	162.93	173.7	177.1	170.8
Scapulo-iliac	118.2	109.41	132.7	137.7	124.8
Neck	62.8	80.56	87.39	89.39	83.2
Circumference (cm)	**mean values Barbe (Benhamadi et al. 2016)**	**mean values of the Barb standard**	**mean values Class 01**	**mean values Class 02**	**mean values Class 03**
Chest size	175.5	> 170	178.4	179.2	180.2
Anterior Canon Ream	19.8	> 18	24.58	25.22	23.4
Lenghts (cm)	**mean values (PSA) (legaultr.J.1 977)**	**mean values (PSA). (Benhamadi et al. 2016)**	**mean values Class 01**	**mean values Class 02**	**mean values Class 03**
shoulder	46.98	54.4	74.35	78.11	65.2
arm	33.39	32.62	36.55	38.89	36.2
forearm	45.36	36.91	40.39	41.22	40.4
canon	25.93	25.93	26.77	28.44	24.6
Illiac	37.40	37.40	48.45	49.67	49.4
thigh	45.79	45.79	66.16	63.56	63.4

Key body measurements and indices demonstrated notable differences across the three classes and the referenced purebreds (Table 3). For example. total body length was highest in Class 02 (177.1 cm) and lowest in Class 03 (170.8 cm). compared to 162.93 cm in Thoroughbreds and 160.0 cm in Barbs. Scapulo-iliac length also varied. with Class 02 showing the greatest mean (137.7 cm). exceeding the Barb standard (118.2 cm) and Thoroughbred mean (109.41 cm). In the other hand . chest girth was most pronounced in Class 03 (180.2 cm) and lowest in Class 01 (178.4 cm). both surpassing the standard Barb value (175.5 cm). Foreleg cannon circumference ranged from 23.4 cm in Class 03 to 25.22 cm in Class 02. with all classes exceeding the Barb standard of 19.8 cm. In limb measurements. the sampled horses also showed distinctive traits. For instance. shoulder length in Class 02 (78.11 cm) significantly exceeded the values for purebred Arabians (46.98 cm) and Barbs (54.40 cm). Similarly. ilium length in Class 02 (49.67 cm) surpassed the standards for both Barb (37.40 cm) and Thoroughbred breeds (37.40 cm). Height at withers (HG) and height at croup (HC) for Class 3 were comparable to the Barbe horse standard and the Purebred Arabian (PSAr) but lower than those of the Thoroughbred (PSA). while Class 2 exceeded PSAr values but remained below PSA. Length-related traits. including total length (LT). scapulo-iliac length (LSH). and neck length (LE). were greater across all classes compared to the Barbe and PSA horses. with LE in Class 3 closest to the PSA standard.

In light of this.. indices are shown in table 4. The body index (HG/LT) values for Classes 1. 2. and 3 were 0.908. 0.903. and 0.917. respectively. indicating a mediolineal structure and confirming adherence to the international Barbe horse standard. Weight parameters. such as live weight (PV) for Classes 1. 2. and 3 (467.2 kg. 480.9 kg. and 469 kg. respectively) and chest girth (TP) values. were consistent with the Algerian Barbe standard. indicating a voluminous thorax and robust limb structure. Compactness (PV/HG) and corpulence (TP/HG) indices for Classes 1. 2. and 3 were 2.963. 3.001. and 2.998 kg/cm. and 1.132. 1.121. and 1.153. respectively. which were higher than those of the Arabe-Barbe. Anglo-Arabe. and Barbe horses but lower than the Demi-Selle Normand. highlighting the horses' proportional build. functional efficiency. and adaptability for various equestrian purposes.

Table 4. Comparison between the indices of the 3 classes

Index		Classe 01	Classe 02	Classe 03
(HG/LT)	Body Profile Index	*0.908*	0.903	0.917
(PV/HG)	Compactness Index	2.963	3.001	2.998
(TP/HG)	Corpulence Index	1.132	1.121	1.153
(TCA/TP)	Dactylo-Thoracic	*0.138*	0.14	0.129
(LT/TP)	Relative Body	0.975	0.989	0.947
(HG/HC)	Front Height Behind	0.997	1.004	0.997

Table 5. Comparison of the average horse measurements between the three sampled areas

Parameters		**mean Tlemcen n=29**	**mean Sidi Bel Abbes n=19**	**mean Relizane n=6**	**Signification (P < 0.05)**
	Height (cm)				
HG	at the withers	159.75	159.1	152.32	*
HC	at the croup	159.31	158	151.16	*
	Lenght (cm)				
LT	Total	176.62	178.36	158.5	**NS**
LSH	scapulo-iliac	130.55	141.1	130.16	*
LTe	head	50.65	50.47	47.16	**NS**
AIY	distance between the internal angles of the eyes	20.41	20.26	20.66	**NS**
LE	Neck	85.93	93.89	76.33	**
LEp	Shoulder	72.06	80.36	70	**NS**
LB	arm	37.03	39.57	31.33	*
LAB	forearm	41.1	41.47	36	*
LC	canon	25.62	30	25.32	**
LI	illiac	51.24	47.15	43.5	**
LCe	thigh	70.86	59.1	55.66	***
	Circumference (cm)				
TP	Chest size	181.1	180.36	177.66	**NS**
TAB	forearm	45.48	46.89	45.16	**NS**
TG	knee	33.03	33.52	31	**NS**
TB	cannon bone	28.34	28.68	26.83	**NS**
TCA	Anterior Canon Ream	24.34	25.47	23.83	**NS**
TCP	Posterior Canon Tower	22.51	23.63	22	**NS**
	Index				
(HG/LT)	Body Profile Index	0.9	0.88	0.9	**NS**
(PV/HG)	Compactness Index	3.06	3.08	2.95	**NS**
(TP/HG)	Corpulence Index	1.12	1.12	1.16	**NS**
(TCA/TP)	Dactylo-Thoracic	0.13	0.13	0.12	**NS**
(LT/TP)	Relative Body	0.97	0.98	0.94	**NS**
(HG/HC)	Front Height Behind	0.96	1	1	**NS**
	Live weight (kg)	490	493	450	**NS**

Comparison of Average Morphometric Measurements of Horses Between the Tlemcen. Sidi Bel Abbes. and Relizane Regions.

In comparing the average body measurements of horses from the Tlemcen. Sidi Bel Abbes. and Relizane regions (Table 10). significant differences were observed across the three populations for 9 out of the 26 parameters studied. Specifically. parameters such as height at withers (HG). height at croup (HC). scapulo-iliac length (LSH). arm length (LB). and forearm length (LAB) showed significant differences ($P < 0.05$). More pronounced distinctions were found for neck length (LE). cannon length (LC). iliac length (LI). and thigh length. with highly significant differences ($P < 0.01$ to $P < 0.0001$). Notably. horses from Tlemcen exhibited greater values for HG. HC. LI. and LCE compared to those from Sidi Bel Abbes and Relizane. In contrast. horses from Sidi Bel Abbes had a longer and broader head. as well as greater values for LSH. LE. LB. LAB. and LC. when compared to those from Tlemcen and Relizane. These differences may be attributed

to environmental factors and distinct breeding practices. The size and morphology of horses vary depending on whether they are raised in coastal plains. mountainous regions. or semi-desert areas. with temperature and rainfall influencing vegetation and. consequently. animal development. Additionally. selective breeding pressures in these regions have impacted measurable traits directly (Tamzali. 1989; Kadri. 2006).

Comparison of Shannon and Weaver Diversity Index for the Three Studied Regions

The Shannon and Pielou diversity indices for the three regions. based on the studied traits. are presented in Table 6. The Pielou index (PI) reflects the evenness of the Shannon Diversity Index (SDI) across regions (Legendre & Legendre. 1979).

Table 6. Comparison of the Shannon-Weaver diversity index for the three sampled areas

Parameters	**Shannon Index**	**Tlemcen n=29**	**Bel Abbes n=19**	**Relizane n=6**
	Height (cm)			
HG	at the withers	1.436	1.298	0.669
HC	at the croup	1.446	1.235	0.737
	Lenght (cm)			
LT	Total	1.44	1.275	0.787
LSH	scapulo-iliac	1.428	1.298	0.601
LTe	head	1.443	1.338	0.787
AIY	distance between the internal angles of the eyes	1.303	1.421	0.876
LE	Neck	1.448	1.235	0.719
LEp	shoulder	1.444	1.258	0.601
LB	arm	1.428	1.362	0.737
LAB	forearm	1.414	1.362	0.826
LC	canon	1.453	1.355	0.995
LI	illiac	1.44	1.333	0.737
LCe	thigh	1.442	1.235	0.719
	Circumference (cm)			
TP	Chest size	1.437	1.252	0.737
TAB	forearm	1.438	1.377	0.787
TG	knee	1.468	1.327	0.965
TB	cannon bone	1.221	1.351	0.838
TCA	Anterior Canon Ream	1.381	1.416	0.956
TCP	Posterior Canon Tower	1.269	1.408	0.995
	Live weight (kg)	1.428	1.252	0.601
Mean		**1.41**	**1.31**	**0.78**

In Tlemcen. the highest diversity (1.453) is found for Canon Length (LC). while in Sidi Bel Abbes. the highest diversity (1.421) is for Distance Between Internal Angles of the Eyes (AIY). In Relizane. the peak diversity (0.995) is observed for both Canon Length (LC) and Posterior Canon Circumference (TCP). These traits likely involve genes with minimal impact on the organism. possibly due to accumulated mutations (Benhamadi et al.. 2016).

The lowest diversity is observed for Cannon Circumference (1.221) in Tlemcen. Croup Height (HC). Neck Length (LE). and Thigh Length (1.235) in Sidi Bel Abbes. and Scapulo-iliac Length (LSI). Neck Circumference (LEP). and Live Weight (PV) (0.601) in Relizane. These traits are likely influenced by genes with significant physiological effects. shaped by environmental factors (Benhamadi et al.. 2016).

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was conducted on the studied quantitative traits (Figure 3.1). The analysis showed that these variables showed 55.8% of the two axes total inertia. which is relatively average (Figure 3.1). the result highlights that certain parameters. such as Thoracic Abdominal Balance (TAB) and

Inter-Eye Angle Length (AIY). are statistically non-informative as they are positioned too close to the center of the PCA plot.

The remaining traits are grouped into three distinct clusters (arranged from top to bottom):

- Group 1 includes only Iliac Length (LI) and Crest Length (LCE).
- Group 2 consists of Withers Height (HG). Chest Perimeter (TP). Croup Height (HC). Thigh Length (LTE). Chest Depth (TG). Total Length (LT). Body Weight (poids en kg). and Thoracic Breadth (TB).
- Group 3 comprises Arm Length (LAB). Inter-Eye Angle Length (AIY). Forearm Length (LB). Neck Perimeter (LEP). Posterior Canon Circumference (TCP). Anterior Canon Circumference (TCA). Scapulo-Humeral Length (LSH). Neck Length (LE). and Neck Perimeter (LEP).

These positive correlations among traits suggest a shared genetic control. with these traits responding similarly to environmental factors.

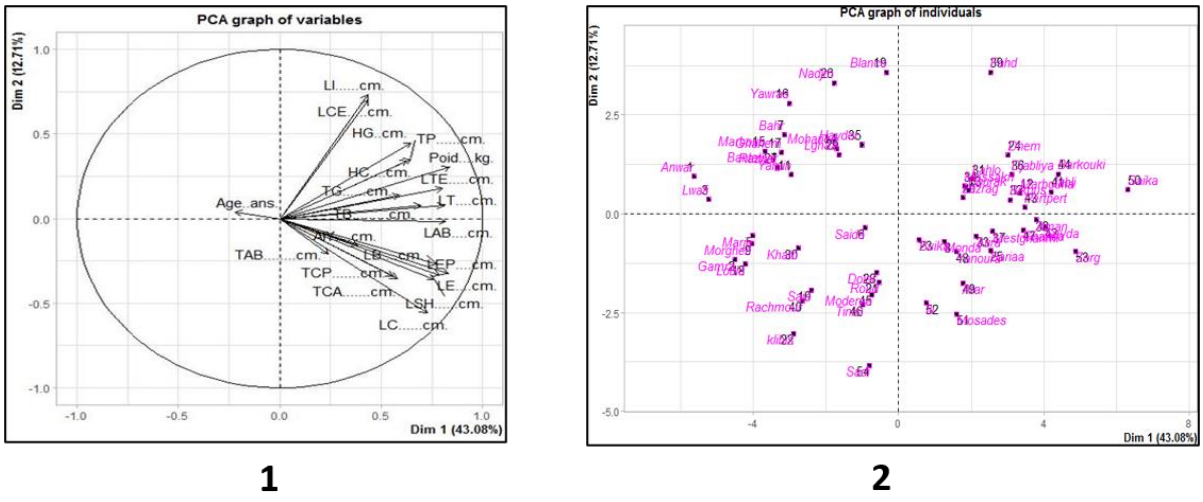

Figure 3. Graphical presentation of principal component analysis
1: Body measurements correlations; 2 : The distribution of individuals

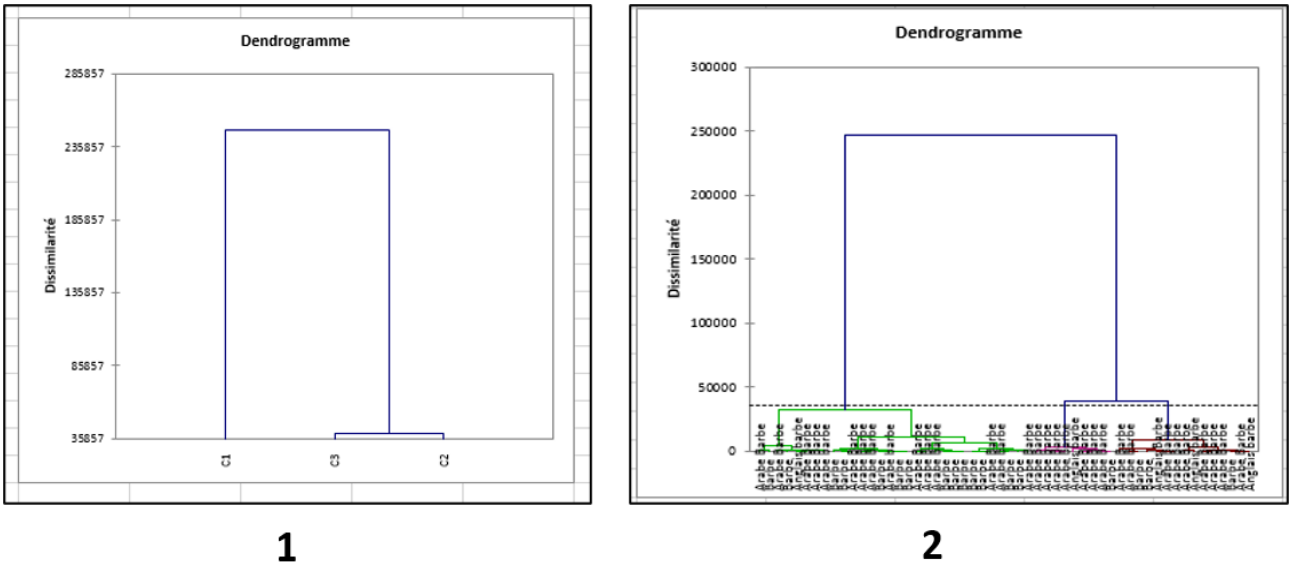

Figure 4. Graphical representation of hierarchical clustering
1: Per group distribution; 2: Distribution by individual

Furthermore. the PCA (Figure 3.2) and hierarchical clustering (Figures 4.1 and 4.2) reveal a subdivision of the studied population into three major groups. independent of the animals' geographical location. This indicates that while environmental conditions and livestock management practices in Tlemcen. Sidi Bel Abbes. and Relizane are broadly similar. significant heterogeneity exists within the livestock populations across these regions.

Conclusion

Animal genetic resources are vital for the economic. nutritional. environmental. and sociocultural development of a country. In Algeria. equine genetic resources represent a significant part of our national heritage. with profound economic and sociocultural importance. Understanding the genetic diversity of Algerian horse breeds is crucial for the formulation of long-term conservation and management strategies for indigenous breeds.

this study represents a foundational effort to characterize the equine population associated with Fantasia through field surveys. morphometric assessments. and the establishment of a DNA biobank. The results reveal significant regional and morphometric diversity across equines sampled from Tlemcen. Sidi Bel Abbès. and Relizane. The Shannon-Weaver index demonstrated moderate to high levels of diversity across regions. likely influenced by both genetic and environmental factors. Moreover. the study identified three distinct morphometric classes. with Classes (01) and (02) closely aligning with the Barbe horse standard. while Class (03) exhibited traits shared with both the Barbe and Arabe-Barbe horses. These findings highlight the predominance of the Barbe horse. renowned for its suitability in Fantasia games. However. the results also expose substantial interbreeding and a lack of breed standardization. posing a risk to Algeria's equine genetic heritage.

This study involved the morphometric characterization of 54 horses of uncertain origin. both male and female. through 26 parameters analyzed using PCA and HCA techniques. Males demonstrated greater structural robustness. with higher height at the withers. thoracic perimeters. and croup lengths. while females displayed finer proportions and higher compactness indices. Regional differences were significant; Tlemcen horses exhibited greater height and robust builds. Sidi Bel Abbès horses had longer body lengths and strides. and Relizane horses displayed lighter frames optimized for agility.

Additionally. the inclusion of genetic sampling through blood and hair roots has enabled the establishment of a comprehensive DNA biobank. which will serve as a biological repository for future investigations. These findings provide a critical baseline for understanding Algeria's equine genetic diversity and call for immediate conservation efforts. Integrating molecular analysis into this framework will be essential to preserve and manage these invaluable genetic resources effectively through targeted conservation and management initiatives.

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