الجمهورية الجزائرية الديمقراطية الشعبية
PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
Ministry of Higher Education and Scientific Research
University of Mohamed Khider, Biskra
Faculty of Exact Sciences, Nature and Life Sciences
Department of Nature and Life Sciences

Order number:……

Series:……..

Thesis submitted in fulfillment of the requirements for the degree of

DOCTORATE OF SCIENCE

Special filed: Applied biology

Presented by: MOHAMMEDI Kenza

Entitled

Phenotypic characterization and growth performance of sheep populations in Northeastern Algeria

Jury

President	DEGHNOUCHE Kahramane	Professor	Mohamed Khider University, Biskra
Supervisor	LAIDI Ziane	Professor	Mohamed Khider University, Biskra
Examiners	TITAOUINE Mohamed	Dr., MCA	Mohamed Khider University, Biskra
	MEZIANE Toufik	Professor	Hadj Lakhdar University, Batna 1
	MAMMERI Adel	Dr., MCA	Mohammed. Boudiaf University, M'Sila
	GHRISSI Djellal	Dr., MCA	Mohamed Cherif Messaadia University, Souk-Ahras

2022/2023

ACKNOWLEDGEMENTS

It is with great pleasure that I reserve these lines as a sign of gratitude and deep recognition to all those who, directly or indirectly, have contributed to the realization and the culmination of this modest work.

First of all, I thank "Allah" the almighty, for having helped me and given me courage and strength in the most difficult and hardest moments I have gone through during the realization of my research activities.

I would like to thank Professor LAIADI Ziane, a researcher at the University of Biskra, for accepting to supervise my thesis and for helping me choose the path scientist that I am currently and Dr. TITAOUINE Mohamed for his guidance, his invaluable help; I hope that he accepts the expression of my gratitude.

I express my deep gratitude to Professor DEGHNOUCHE Kahramane, from Biskra University, for having accepted the presidency of the thesis jury.

Respectful tributes to the entire thesis jury who have accepted to give time to read and evaluate this work:

- *Dr. TITAOUINE Mohamed, Associated Professor at Biskra University;*
- *Professor MEZIANE Toufik, at Batna 1 University;*
- *Dr. MAMMERI Adel, Associated Professor at M'Sila university;*
- *Dr. GHRISSI Djellal, Associated Professor at Souk-Ahras University.*

I would also like to thank Mrs. MOKRANE H, Mrs. SOUICI S and the breeders at the ITDAS -Ain Ben Noui- and ITELV -Ain M'lila- for their help and the assistance they provided.

I would also like to thank everyone who contributed to this study, particularly Prof. MOUSSI Abdelhamid, Mrs. KOUAHLA G. and Mrs. ZEKRI W.

Special thanks go to my parents for their permanent, constant and above all, unfailing support, to my husband, for supporting me in the more difficult times, to my stepmother, the second mother of my children, to my sisters and brothers.

May all those who assisted me in carrying out this work find here the expression of my gratitude.

ملخص

تهدف هذه الدراسة إلى وصف الأغنام ظاهريًا في شمال شرق الجزائر ، لتحديد ديناميكية و اداء نمو الحملان في فترة ما قبل الفطام في هذه المنطقة ولتقييم تأثير الارتفاع على أداء نموالحملان. لهذا الغرض تم إجراء ثلاث تجارب. أجريت التجربة الأولى في ثماني مزارع حيث خضعت فيها مجموعه 160 نعجة لأربع قياسات كمية للجسم (طول الجسم، ارتفاع الكاهل، طول الذيل ووزن الصوف) و 9 سمات نوعية (طول الرأس، اتجاه الأذن، وجود القرن، طول الرقبة، امتداد الصوف، نسيج الذيل، شكل العينين، لون الرأس ولون الصوف). تشير النتائج إلى أن الأغنام في هذه المناطق تنتمي إلى سلالة أغنام أولاد جلال مع بعض الأنماط الظاهرية غير النقية، مما يشير إلى التكاثر العشوائي. تظهر قياسات الجسم قيم معامل تباين معتدل. تم الكشف عن ارتباطات واضحة بين ارتفاع الكاهل و طول الذيل (0.30) و طول الجسم و وزن الصوف (0.26). قسم التحليل الهرمي التجميعي قطعان الأغنام إلى ثلاث فئات.

أجريت التجربة الثانية في مزرعتين مؤسستين: ITDAS و ITELV حيث خضع 50 حيوانًا إلى 15 قياسًا للجسم: ارتفاع الكاهل، ارتفاع الظهر، ارتفاع الردف، عمق الصدر، طول الرأس، عرض الرأس، طول الأذن، عرض الأذن، عرض الصدر، عرض الردف، طول الجسم، محيط القلب ، محيط عظم الساق، طول الذيل ومحيط الذيل. أظهرت النتائج أن الأغنام المدروسة من سلالة أولاد جلال هي مجموعة متجانسة شكليًا مع تفوق، تقريبا كل قياسات الجسم، للذكور. تُظهر معاملات الارتباط أنه يمكن تقدير وزن الجسم عن طريق محيط القلب وحده أو بالاشتراك مع قياسات الجسم الأخرى مثل: محيط الذيل ، ارتفاع الكاهل ، طول الرأس ومحيط عظم الساق.

تقيم التجربة الثالثة ديناميكيات النمو وتأثير الارتفاع على مراحل النمو المختلفة لحملان أولاد جلال قبل الفطام. تم اختيار سبعة مواقع لهذه الدراسة. تم وزن تسعة وأربعين حملًا ولدوا احاديين في الربيع لنعاج متعددة، وتم حساب متوسط مكاسبهم اليومية في أعمار مختلفة (عند الولادة ، 30 يوم ، 60 يوم ، 90 يوم ، 120 يوم). أظهرت النتائج أن الحد الأقصى للنمو يحدث خلال الشهر الأول من حياة الحمل بمعدل 200 جرام / يوم. تم تسجيل ارتباطات موجبة ومعنوية عالية بين D 90 و D 120 (0.94) و D 60 و D 120 (0.88) و D 60 و D 90 (0.87) و D 30 و D 90 (0.77).فيما يتعلق بتأثير الارتفاع ، تُظهر الحملان المولودة في مناطق الارتفاعات المنخفضة أداء نمو أفضل من الحملان المولودة في مناطق الارتفاعات العالية، مما يؤكد أن سلالة اولاد جلال هي سلالة نموذجية من السهوب والسهول العالية.

الكلمات المفتاحية: الخصائص المظهرية ، أداء النمو ، تأثير الارتفاع. سلالة اولاد جلال، شمال شرق الجزائر.

Abstract

The presente study aims to characterize the sheep population phenotypically in Northeastern Algeria, to determine the growth dynamic and performance of pre-weaned lambs of this area and to assess the altitude effect on the growth performance. For this purpose, three experiments were performed. The first experiment was carried out in eight farms, in which a total of 160 ewes were subject to 4 quantitative body measurements (body length, withers height, tail length and wool weight) and 9 qualitative traits (head length, ear orientation, horn presence, neck length, wool extent, tail texture, eyes shape, head color and wool color). The results indicate that the sheep population in these areas belonged to the Ouled Djellal sheep breed with some atypic phenotypes, which refers to uncontrolled crossbreeding. Body measurements show moderate variation coefficient values. Clear correlations were revealed between withers height and tail length (0.30) and body length and wool weight (0.26). The Hierarchical Agglomerative Clustering analysis sub-divided the sheep population into three classes.

The second experiment was conducted on two institutional farms, ITDAS and ITELV, in which 50 adult animals were the subject of 15 body measurements: withers height, back high, rump high, chest depth, head length, head width, ear length, ear width, chest width, rump width, body length, heart girth, cannon circumference, tail length and tail circumference. The results reveal that the studied sheep of the Ouled Djellal breed is a morphologically homogeneous population with superiority, in almost body measurements, for males. The correlation coefficients show that body weight can be estimated by heart girth alone or combined with other body measurements such as tail circumference, withers height, head length and cannon circumference.

The third experiment evaluated the growth dynamics and the effect of altitude on different growth phases of pre-weaned Ouled Djellal lambs. Seven sites were chosen for this study. A total of 49 lambs were weighed. Their average daily gain was calculated at different ages (birth, D 30, 60, 90 and 120). The results show that maximum growth occurs during the lamb's first month of life at 200 g/day. Highly positive and significant correlations were recorded between D 90 and D 120 (0.94), D 60 and D 120 (0.88), D 60 and D 90 (0.87) and D 30 and D 90 (0.77). Concerning the altitude effect, lambs born in low altitude regions show a better growth performance than lambs born in high altitude regions which confirms that the Ouled Djellal breed is a typical breed of the steppe and the high plains.

Keywords: phenotypic characterization, growth performance, altitude effect, Ouled Djellal breed, Northeastern Algeria.

Résumé

La présente étude vise à caractériser phénotypiquement la population ovine du Nord-Est algérien, à déterminer la dynamique et la performance de croissance des agneaux pré-sevrés de cette zone et à évaluer l'effet de l'altitude sur la performance de croissance. À cet effet, trois expériences ont été réalisées. La première expérience a été réalisée dans huit fermes. Un total de 160 brebis ont été soumis à 4 mesures corporelles quantitatives (longueur du corps, hauteur au garrot, longueur de la queue et poids de la laine) et 9 caractères qualitatifs (longueur de la tête, orientation des oreilles, présence de la corne, longueur du cou, étendue de la laine, texture de la queue, forme des yeux, couleur de la tête et couleur laine). Les résultats indiquent que le cheptel ovin de ces zones appartenait à la race ovine Ouled Djellal avec quelques phénotypes atypique, due à des croisements non contrôlés. Les mesures corporelles montrent des valeurs de coefficient de variation modérées. Des corrélations claires ont été révélées entre hauteur au garrot et longueur de la queue (0,30) et longueur du corps et poids de la laine (0,26). La classification ascendante hiérarchique a subdivisé la population ovine en trois classes.

La deuxième expérimentation a été menée sur deux fermes institutionnelles : ITDAS et ITELV dans lesquels 50 animaux ont fait l'objet de 15 mensurations corporelles : hauteur au garrot, hauteur au dos, hauteur de la croupe, profondeur de la poitrine, longueur de la tête, largeur de la tête, longueur de l'oreille, largeur de l'oreille, largeur de la poitrine, largeur de la croupe, longueur du corps, tour de poitrine, circonférence du canon, longueur de la queue et circonférence de la queue. Les résultats révèlent que les ovins de race Ouled Djellal étudiés constituent une population morphologiquement homogène avec une supériorité, dans la plupart des mesures corporelles, pour les mâles. Les coefficients de corrélation montrent que le poids du corps peut être estimé par le tour de poitrine seul ou en combinaison avec d'autres mesures corporelles telles que la circonférence de la queue, la hauteur au garrot, la longueur de la tête et la circonférence du canon.

La troisième expérience évalue la dynamique de croissance et l'effet de l'altitude sur différentes phases de croissance d'agneaux Ouled Djellal pré-sevrés. Sept sites ont été choisis pour cette étude. Quarante-neuf agneaux nés simples au printemps de brebis multipares ont été pesés et leur gain moyen quotidien a été calculé à différents âges (à la naissance, J 30, 60, 90 et 120). Les résultats montrent que la croissance maximale se produit pendant le premier mois de vie de l'agneau à 200 g/jour. Des corrélations très positives et très significatives ont été enregistrées entre J 90 et J 120 (0,94), J 60 et J 120 (0,88), J 60 et J 90 (0,87) et J 30 et J 90 (0,77). Concernant l'effet d'altitude, les agneaux nés dans les régions de basse altitude montrent une meilleure performance de croissance que les agneaux nés dans les régions de haute altitude, ce qui confirme que la race Ouled Djellal est une race typique de la steppe et des hautes plaines.

Mots-clés : caractérisation phénotypique, performances de croissance, effet de l'altitude, la race Ouled Djellal, Nord-Est Algérie.

CONTENTS

BIBLIOGRAPHIC PART

PRACTICAL PART

List of Abbreviations

ADG	Average daily gain
ADG 1	Average daily gain between birth and D 30
ADG 2	Average daily gain between D 30 and D 60
ADG 3	Average daily gain between D 60 and D 90
ADG 4	Average daily gain between D 90 and D 120
ANOVA	Analysis of variance
BCS	Body condition score
BW	Body weight
CV	Coefficient of variation
FAO	Food and agriculture organization
Ha	Hectare
HAC	Hierarchical agglomerative clustering
ITDAS	Technical institute for the development of Sharan agronomy
ITELV	Technical institute of breeding
MCA	Multiple correspondence analysis
PCA	Principal component analysis
Q	Quintal
SD	Standard deviation
SE	Standard error
SPSS	Statistical package for social science
UAA	Useful agricultural area
WB	Weight at birth
W1	Weight at D 30
W2	Weight at D 60
W3	Weight at D 90
W4:	Weight at D 120

List of Figures

List of Tables

Introduction

Ovis aries (*Mammalia, Artiodactyla, Bovidae, Caprinae*), commonly called sheep, is one of humans' most valuable domestic animals. It is a highly adaptive and versatile species. Since they were domesticated in the Fertile Crescent around 11,000 years ago, sheep have spread throughout the various terrains of each inhabited continent, where they are exploited for a variety of uses, including the production of food (milk, fat, meat) and clothing (skin, wool) (Dwyer 2008). Sheep weigh between 25 Kg and 160 Kg depending on breed. They are reproductively mature at 4–8 months, gestation occurs over 5 months, and individuals can be expected to live for 10 or more years (Dwyer, 2008; Meadows, 2014).

Algeria, by its geographical position and its contrasting bioclimatic stages, represents a biodiversity hotspot. It is genuinely considered a reservoir of genetic diversity with local sheep breeds (Gaouar et al., 2017). Sheep breeding is considered an actual national wealth. It represents 80% of the total domestic animal production, with more than 28 million heads (Hadbaoui et al, 2020), of which about 60% (17 million heads) remain in the steppe zone (FAO, 2017). Consequently, sheep activity represents the "Tradition" in terms of breeding in Algeria, providing a livelihood for more than a third of the Algerian population (Chellig, 1992; Laoun et al, 2015).

Currently, twelve Algerian sheep breeds have been identified: Ouled Djellal, Rembi, Hamra, Berbere, Barbarine, D'man, Sidaou, Taadmit, Tazegzawet, Ifilene, Srandi and Daraa (Djaout et al et al, 2018) with undeniable qualities of sobriety, resistance, prolificity, productivity in meat, milk and wool and also the adaptability to arid, steppe and Saharan environments (Chellig, 1992; Gaouar et al., 2017). Ouled Djellal breed only represents 61% of the national sheep population (Zidane et al., 2015). This breed is subjected to the farmer's clear preference, which puts the other breeds in a very sensitive situation (Harkat et al., 2015). Although there are efforts made to characterize the Algerian authentic sheep genetic resources (Chellig, 1992; Belaib, 2012; Dekhili, 2014; Chekkal et al., 2015; Harkat et al., 2015; Laoun et al., 2015; Boubekeur et al., 2015; Djaout et al, 2015; Djaout et al, 2017; Belharfi et al., 2017; Afri-Bouzebda et al., 2018; El-Bouyahiaoui, 2021), these studies have not been yet extensive in covering the whole regions of Algeria.

Algerian sheep farming is primarily intended for producing red meat, providing an average of 150,000 tons annually, or 56% of national red meat production (Belhouadjeb, 2009). Culinary and religious habits mean that sheep meat consumption per year and capita precedes that of cattle (Djaout et al., 2017). However, sheep meat is still inaccessible to many middle- and low-income Algerian households (Deghnouche et al., 2018). Investigations carried out in the field have revealed that this regression is only a consequence of the interaction of several factors: rural exodus, drought and the traditional nature of livestock farming (Harkat and Lafri, 2007). As a result, red meat prices continue to rise and there is an excessive reliance on imports to fill the gap (Mouhous et al., 2014).

Sheep productivity is influenced by body weight and growth. A high birth weight gives the animal a good start in life and allows it to grow rapidly before and after weaning, predisposing it to better resistance to disease and to reach puberty and maturity quickly (Sulieman et al., 1985; Zidane et al., 2015). Several factors can influence lamb growth, whether genetic or non-genetic such as multiple births, dam age, and the sex of the lamb (Khama et al., 2022). However, to improve red meat production, it is necessary to understand and optimize these factors. In this global context, the main objectives of this study are to contribute to the phenotypic characterization of the sheep populations of North-East Algeria and to determine the growth performance of lambs in this area. The approach adopted in this study is the following:

- Morphobiometric description of the sheep populations in the study area through a multivariate discriminant analysis;
- Biometric description of the Ouled Djellal sheep breed in order to determine the homogeneity state, the sex effect and the significant correlations between the different body measurements of this breed in the study area;
- Evaluation of growth dynamic and performance of Ouled Djellal breed lambs in the pre-weaning period by measuring the birth weight, weight at typical ages and ADG at typical ages, although the determination of the effect of altitude on the growth performance.

Chapter 1. Taxonomy, origin and domestication of sheep

1. Taxonomic position

Sheep (*Ovis aries*) is an herbivorous mammal. It belongs to the order Artiodactyla (even-toed ungulate), suborder Ruminantia, infraorder *Pecora*, family *Bovidae* family, subfamily *Caprinae* subfamily and genus *Ovis*. (Fournier, 2006; Desbois, 2008). The classification of the genus *Ovis* is unclear and controversial. Nevertheless, six species of wild sheep and one species of domestic sheep are currently described (Geist, 1991; Grubb, 2005):

1. *Ovis orientalis* (O.o.): Mouflon, with a subspecies in Asia (*O.o.laristanica*) and one in Europe (*O.o.musimon*);
2. *Ovis ammon*: Argali, living in Central Asia, Tibet, China and Mongolia;
3. *Ovis vignei*: Urial. Ovis orientalis is sometimes considered synonymous with *O. vignei* (*Ovis orientalis vignei*) living in Asia minor;
4. *Ovis canadensis*: Bighorn in Canada and the United States of America;
5. *Ovis nivicola*: Snow sheep of Siberia;
6. *Ovis dalli*: Dall sheep (Thinhorn) of Alaska;
7. *Ovis aries*: Domestic sheep (modern breeds) nowadays.

Despite the differences in chromosome number, all these species can hybridize in captivity and produce fertile offspring (Vorontsov et al. 1972; Nadler et al. 1973).

Table 1. Taxonomy of domestic sheep

Taxom	**Members**
Kingdom	*Animalia*
Phylum	*Chordata*
Class	*Mammalia*
Order	*Artiodactyla*
Suborder	*Ruminantia*
Family	*Bovidae*
Subfamily	*Caprinae*
Genus	*Ovis*
Species	*Ovis aries*

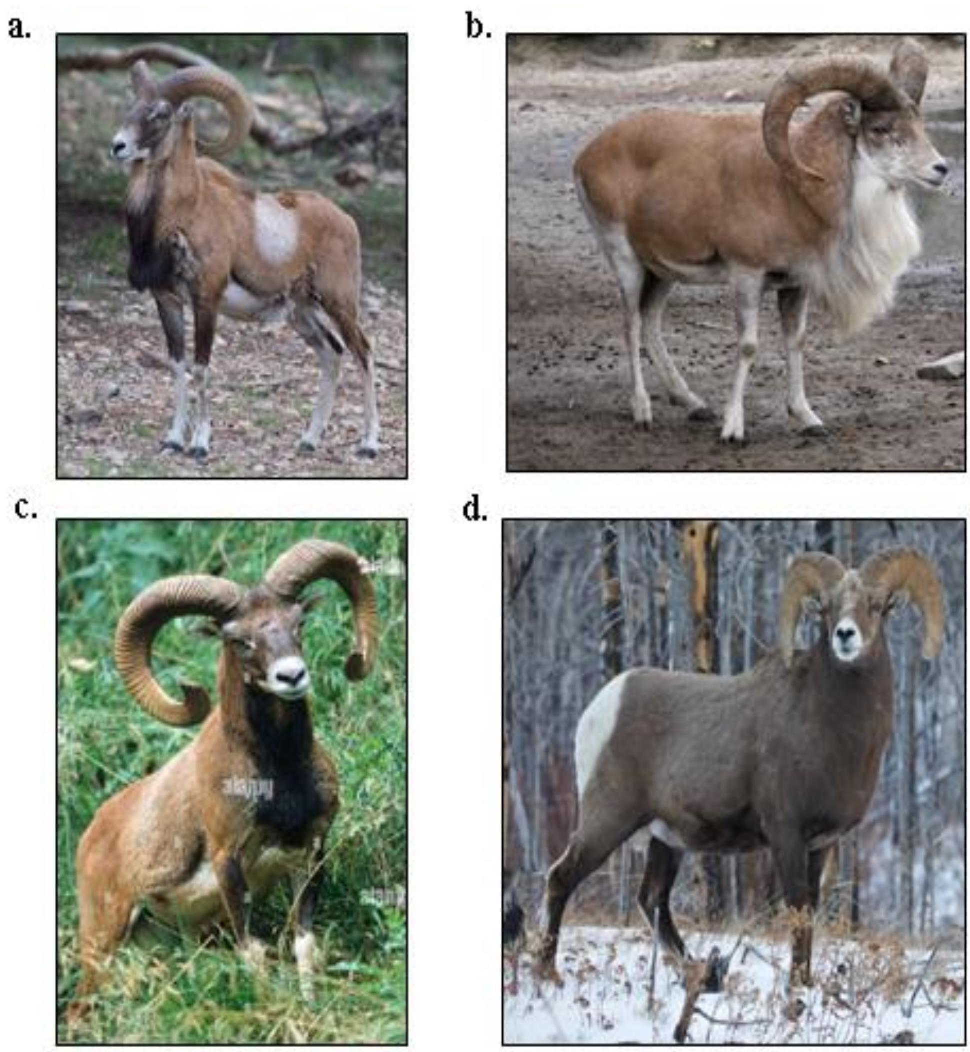


Figure 1. Photos of some wild sheep species. a. Asiatic mouflon (*Ovis orientalis*). b. Urial (*Ovis vignei*). c. Argali (*O. ammon*). d. Bighorn Sheep (*Ovis canadensis*)

2. Origin and distribution

The origin of sheep goes back to time immemorial. Sheep are integral to almost all mythologies and religions (Fournier, 2006). There is ongoing debate regarding which wild sheep species were domesticated to form *Ovis aries*, how often this process occurred, and to what extent subsequent introgression of wild animals has augmented modern domestic sheep (Meadows, 2014). According to Ryder, the origin of the modern domestic sheep remains uncertain. However, many wild and possibly ancestral species and subspecies exist (Ryder, 1983). Three major groups of Eurasian wild sheep, mouflon (*O. musimon/orientalis*, 2n = 54), urial (*Ovis vignei*, 2n = 58) and argali (*O. ammon*, 2n = 56), have been proposed as ancestors of the domestic sheep (2n = 54) or are believed to have contributed to specific breeds

(Hiendleder et al. 2002). Zeuner (1963) suggested that *Ovis aries* is descended from the urial currently found in central Asian countries and northern Iran extending up to Tibet and northern China (Zeuner, 1963; Abdurehman, 2019). The domestic forms subsequently spread throughout the Middle East and into Europe (Zeuner, 1963). Another line of domesticated sheep was believed to be derived from mouflon (*O. musimon* or *O. orientalis*) stock, which was brought into Europe and mixed with the urial derivatives (Hiendleder et al., 2002).

Based on the results of the analysis of mitochondrial (mt) DNA, the Asian mouflon (*O. orientalis*) is the most likely maternal ancestor of all domestic sheep (Meadows et al., 2011; Muigai and Hanotte, 2013). Sheep entered the African continent not long after their domestication in western Asia. Blench et al. (1999) postulated an African theory of origin for *Ovis aries* based primarily on rock art interpretations and osteological evidence from Barbary sheep (Blench et al., 1999). According to Epstein (1971), sheep were introduced into Africa in 3 waves of migration of precursor populations (thin-tailed, fat-tailed and fat-rumped sheep). The earliest sheep in Africa were thin-tailed and hairy, which were introduced to East Africa (Marshal, 2000). The second sheep introduction was fat-tailed sheep, which were introduced to North Africa (Ryder, 1983). The last wave of sheep introduction was composed of fat-rumped sheep introduced to East Africa (Epstein, 1971; Ryder, 1983; Abdurehman, 2019).

3. Domestication

3.1. Definitions

Bökönyi (1969) defined animal domestication as "*the capture and taming by man of animals of a species with particular behavioral characteristics, their removal from their natural living area and breeding community and their maintenance under controlled breeding conditions for profit.*" In 1992, Clutton-Brock gave an inclusive definition of the domesticated animal as "*a domesticated animal is one that has been bred in captivity, for purposes of subsistence or profit, in a human community that maintains complete mastery over its breeding, organization of territory and food supply*".

In 2012, Zeder defined the domestication of plant/animal as "*a sustained multi-generational mutualistic relationship in which humans assume some significant level of control over the reproduction and care of a plant/animal in order to secure a more predictable supply of a resource of interest and through which the plant/animal can increase its reproductive success over individuals not participating in this relationship*".

3.2. Place and period of sheep domestication

Sheep and goats were the first pastoral animals successfully domesticated (as a food resource) in the Old World (Zohary et al., 1998; Chessa, 2009). Both archaeological and genetic data shows that the oldest domestication centers of sheep and goat to have occurred in the Neolithic period, 9,000–8,000 years ago, in the Fertile Crescent, where many settlements have been discovered (Meadows et al., 2007; Rocha et al., 2011). Sheep were first reared for access to meat before human-mediated specialization for wool and milk commenced approximately 4000–5000 years ago (Kijas et al., 2012).

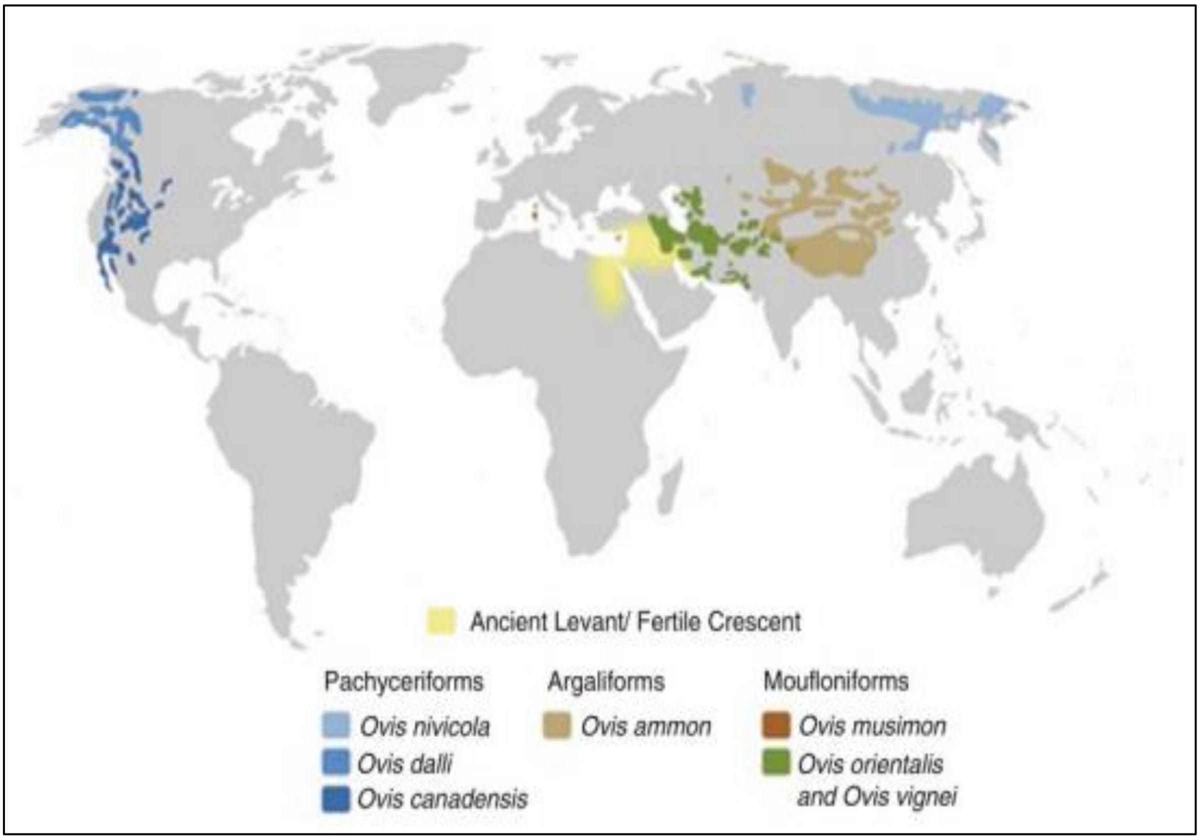


Figure 2. Natural global distributions of the seven wild *Ovis* species relative to the center of domestication (Fertile Crescent) **(**Meadows, 2014).

3.3. Modifications resulting from domestication

According to Zohary et al. (1998), the domesticated animals acquired new traits, and "*domestication syndromes*" appeared due to unconscious selection. This type of artificial selection isolates animals from their original wild environment and places them in a new (quite different) human-made environment. This shift in the ecology led automatically to drastic changes in selection pressures.

In response to the introduction of the animals into the anthropogenic environment, numerous adaptations vital to survival in the wild lost their fitness (Zohary et al., 1998). The variation range of certain traits within a domesticated species occasionally exceeds that in whole families or even orders (Digard, 2009; Trut et al, 2009). Modifications resulting from domestication concern morphology, physiology and behavior (Zohary et al., 1998; Naval-Sanchez et al., 2018)

3.3.1. Morphology

The most spectacular and obvious changes concern morphology, among which are the shape and size of the body (decrease in body size of both male and female animals) (Meadow, 1989; Hemmer, 1990), decrease in the head or brain size (Mignon-Grasteau et al, 2005), changes in the shape and angulation of the horns (including the absence of horns) (Bökönyi, 1977; Clutton-Brock, 1979), and the floppy ears, remarked only in domesticated sheep (Trut et al, 2009; Teletchea, 2019).

3.3.2. Physiology

Among the physiological changes observed in domesticated sheep are the changes in fat distribution patterns (such as fat-tail types) (Zohary et al., 1998). The activity of their reproductive system became enhanced and relatively uncoupled from the environmental photoperiod. They all acquired the capacity to reproduce in any season more often than once a year (Trut et al, 2009), and the frequency of carrying twins increased (Zohary et al., 1998).

3.3.3. Behavior

Behavior is probably the first to have been modified during domestication. Nevertheless, behavioral traits neither appeared nor disappeared during domestication but are the response thresholds that changed (Price, 1999). The behavioral changes initiated by the development of a lowered awareness of danger and reduced aggression resulted in the breakdown of the wild-type defense behavior (Zohary et al., 1998). More generally, mood, emotion, agnostic and affiliative behavior, as well as social communication, all have been modified in some way by domestication (Driscoll et al., 2009).

4. Morphology of domestic sheep

Morphology is the general exterior appearance of the sheep, which is distinctive enough to be recognized at first peek (Figure 3). Its body is corpulent and covered with a fleece called wool. Its head has a straight profile that is sometimes hooked, with pendulous or inclined ears (forward or backward) depending on the breed (Fournier, 2006; El Bouyahiaoui, 2017).

Most often, the male has a pair of horns, rarely four. The horns are strong, hollow, ringed, spiraled, or sometimes straight. In adults, the mouth has 32 teeth divided into 12 molars in the upper jaw, as many in the lower jaw and 8 incisors carried by the lower jaw (Fournier, 2006; El Bouyahiaoui, 2017). In the fore and hind limbs, only the two middle fingers, each consisting of three phalanges, rest on the ground. They are provided with hooves. The two lateral fingers are absent or rudimentary. The first phalanx is the pastern (Fournier, 2006; El Bouyahiaoui, 2017).

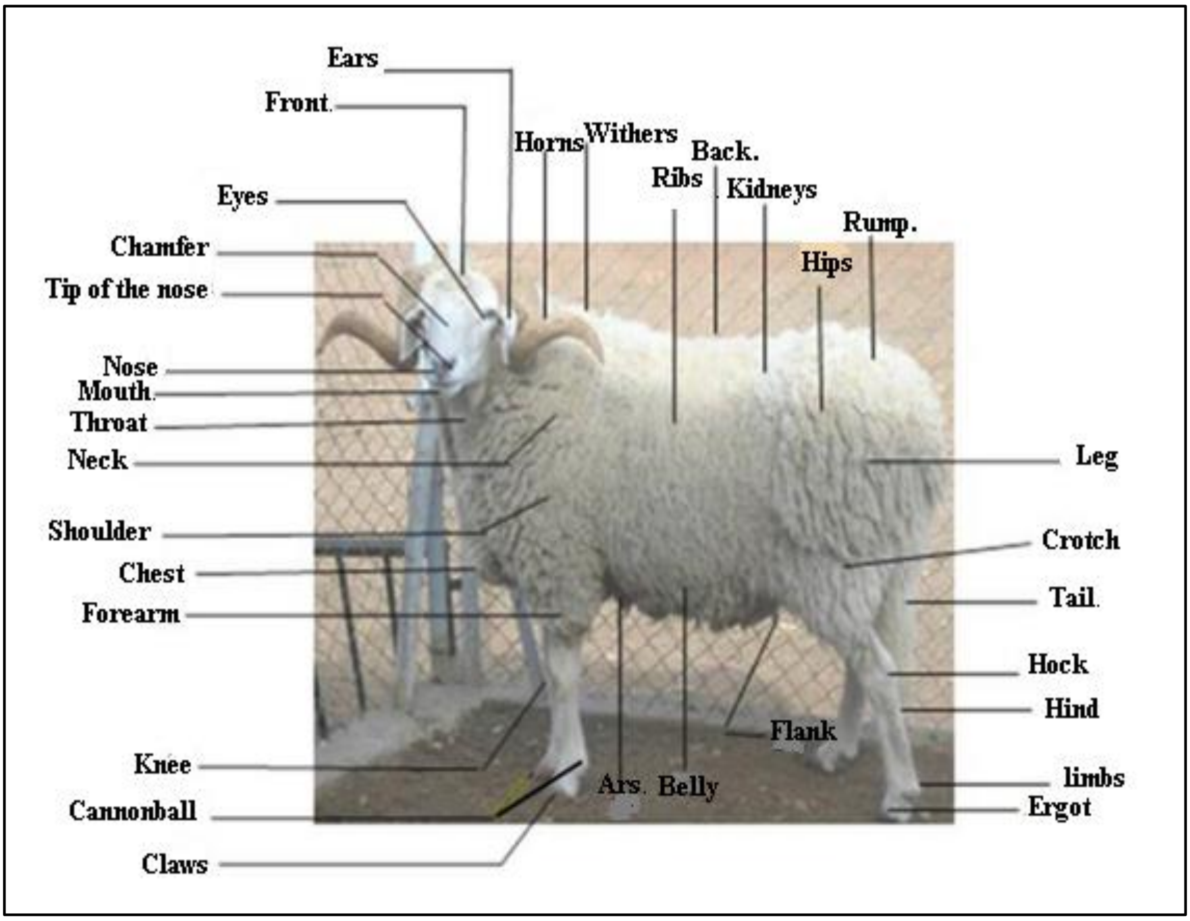


Figure 3. Sheep morphology (El Bouyahiaoui, 2017)

Chapter 2. Sheep breeds and breeding system in Algeria

1. Number of sheep heads

Algeria's livestock populations are difficult to assess due to the lack of reliable statistical data (El Bouyahiaoui, 2017). However, the latest figures show that the sheep herd is estimated at 28 723 994 head (MADR/DSASI, 2018). Goat breeding comes in second place with 4 900 000, cattle with 1 816 280 heads, and camels with 417 322 heads. National sheep numbers have shown a slight and steady improvement over the past decade, despite the continuing problems of drought, mortality due to lack of veterinary care, and the cultivation of rangeland (Figure 4) (Titaouine, 2015).

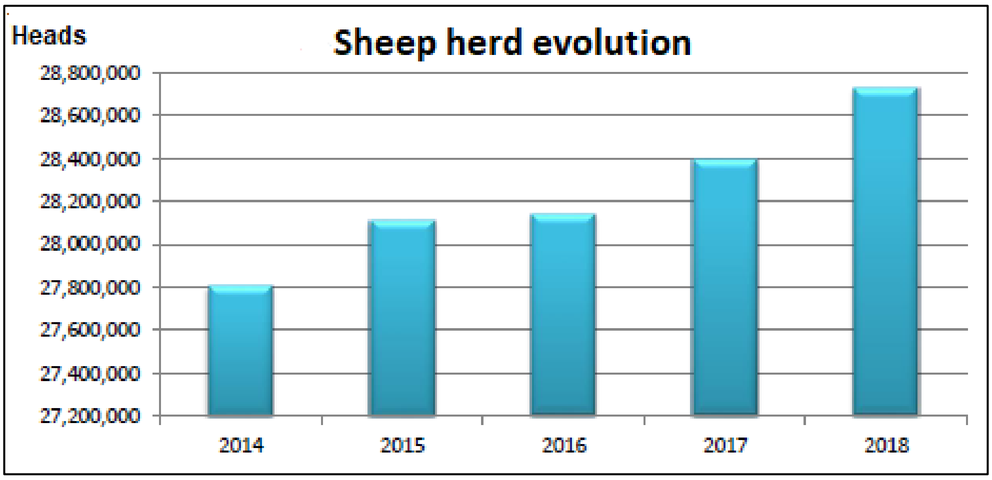


Figure 4. Sheep herd evolution from 2014 to 2018 (thousands of heads) (MADR/DSASI, 2018),

2. Sheep breeds in Algeria

The importance of sheep breeding in Algeria lies in the richness and diversity of its genetic resources (El Bouyahiaoui, 2017). After observing the evolution of their number, Chellig (1992) classified the sheep breeds into groups composed of 8 "breeds".

- Principal breeds: Ouled Djellal, Hamra, Rembi and Taâdmit
- Secondary breeds: D'Men, Sidaou, Berber and Barbarine

If this classification, according to numbers, was established based on certain phenotypic criteria established by Sagne (1950), Trouette (1929) and (Chellig, 1992), it seems outdated today because it is incomplete (Djaout et al., 2017). Since then, this population has undergone great changes in the number of breeds and their cradle. The number evolution has meant that the classification in order of numerical importance is as follows:

- **High-rated breeds:** Ouled Djellal, Hamra, Ifilène and Sidaou;
- **Limited numbers breeds:** Rembi, D'man, Taâdmit, Berbère, Barbarine, Tazegzawt, Srandi and Darâa (Djaout et al., 2017).

2.1. High-rated breeds

2.1.1. Ouled Djellal breed

a. Origin

Ouled Djellal breed, known as the white Arab breed (Trouette, 1929; Sagne, 1950 and Chellig, 1992), is the real sheep of the steppe, the most adapted to nomadism and walking. Historically, this breed would have been introduced by the Beni-Hilal, who came to Algeria in the 11th century from the Hijaz (Arabia) via High Egypt under the Caliph of the Fatimids (Sagne, 1950 and Chellig, 1992). It should be noted, however, that the sheep breeds of the Middle East and Asia are all Barbary fat-tailed breeds.

For this reason, according to Trouette (1929), the Ouled Djellal breed with fine tails and fine wool was introduced by the Romans, great wool lovers, in the fifth century from Taranto in Italy, where this type of sheep exists so far. It is also represented on the funerary steles of the ruins of Timgad, Batna (Chellig, 1992). However, it is by far the most important in numbers and the most interesting in productivity.

b. Phenotypic description

Individuals of the Ouled Djellal breed are robust and reach more than 80 cm in males and 74 cm in females. The average adult weight of the ram is between 80 and 140 Kg, compared to 55-75 Kg for ewes (Figure 5a) (Djaout et al., 2017).

- **Body:** the shape of its body is proportionate, its size is large, and its height is equal to the length of the trunk
- **Color:** skin, wool, legs and head are white
- **Head:** cephalic profile is convex, the ears long drooping; the animals are clods (Djaout et al., 2015), while Chellig, 1992 indicates in his description of this breed that

rams have spiral medium horns, which are absent in ewes (with a few exceptions, especially in the Djellalia variety).

- **Trunk**: long and fallen coast, wide chest, deep, straight back, the ample kidney cut in a "V".
- **Limbs**: flat legs, slender but well down, the limbs are robust.
- **Fleece**: often short, leaving bare the lower part of the neck, the head and the end of the limbs; the tail is slim (El Bouyahiaoui, 2017).

Table 2. Morphometric measurements of the Ouled Djellal sheep breed (Djaout et al., 2018)

Measurement	Male	Female
Body weight (Kg)	100.47	56.24
Total body length (cm)	118.13	104
Body length (cm)	102.6	84.89
Scapular-ischial length (cm)	96	80.83
Withers height (cm)	93.47	79.64
Heart girth (cm)	120.67	99.02
Chest depth (cm)	42.67	36.48
Paunch girth (cm)	129.2	108
Shoulder width (cm)	27.4	20.35
Hip width (cm)	27.33	21.73
Trochanter width (cm)	30.13	23.53
Ischia width (cm)	14.47	11.85
Pelvis length (cm)	33.33	28.03
Cannon perimeter (cm)	11.47	8.91
Cannon length (cm)	13.93	12.58

c. Varieties of the Ouled Djellal breed

Khelifi (1999) described two varieties of this breed: the high variety, a great walker, and a low variety, which evolves in the sub-Saharan rangelands. Harkat et al. (2015) described five varieties of Ouled Djellal: the Ouled Djellal, Mouidate, Safra, Baida and Hodnia. The varieties of the Ouled Djellal breed are:

- **A variety of Ouled Djellal** itself, or Djellalia, populates the regions of Biskra and Toughourt.
- **Variety of Ouled Naïl or Hodnia**: this variety occupies the region of Sétif, Constantine, Sidi Aïssa, Bousaâda, Batna and Oum-El-Bouaghi. It is called (Chaouiya, Naïlia). It is the most present variety on the Algerian territory.
- **Variety of "Samiïa"**: this variety occupies the region of Souamea at the level of the locality of Ouled Derradj, wilaya of M'Sila. It is characterized by a larger format than the Ouled Djellal breed, an adaptation to walking and wool that covers the animal's entire body. She is an excellent milkmaid. According to some breeders, this variety comes from a cross between the Ouled Djellal breed and the Rembi breed (Djaout et al., 2015).
- **Variety of Chellalia:** it is called "Safra" or "Chagra" (= yellow). It is the smallest type in size and the lightest; the wool is very fine. This type is found in Tiaret, Djelfa, Laghouat and Saïda regions. The head is light yellow, and thin limbs (Sagne, 1950; Chellig, 1992).

d. Distribution area

Ouled Djellal breed occupies most of the northern regions at the level of the steppe and is also resided north of the Sahara. However, recently, this breed has known an extension at the level of the tell, the steppe and the North of the Sahara (Figure 05), which has caused the narrowing of the distribution areas of the breeds: Hamra, Berber, Barbarine, Taâdmit, Rambi and D'man (Djaout et al., 2015).

2.1.2. Hamra breed

The Hamra breed called "Deghma"; it is called Beni-Ighil in Morocco (Moroccan High Atlas) (Djaout et al., 2017). It is highly appreciated for its rusticity but, above all, for the flavor and finesse of its flesh. The number of this breed has decreased considerably in recent years. This decrease is mainly due to the massive introduction, by breeders, of the Ouled Djellal breed in the cradle of this breed (Djaout et al., 2017).

Phenotypically, the Hamra breed has an ideal conformation of meat sheep. The latter is of medium size. The skin of the animals is brown, the mucous membranes black, the claws black, and the tongue blue. The wool is white, and the spirals are often streaked in black, of medium size in males and females are lumpy (Figure 5b) (Djaout et al., 2017).

2.1.3. Ifilène breed

The Ifilène breed originates from Mali, Niger and Nigeria (Uda breed), mainly exploited by the Tuareg population. This breed is high on legs, characterized by a hooked muzzle in both sexes, and long and drooping ears, unlike the Sidaou, which has short ears, a slender body, white, black or brown and sometimes a mixture of two colors. The animal is high-legged with long limbs and a medium tail, the ram has very voluminous spirally wound horns, and the ewes are lumpy. It is a hairy breed. Breeders appreciate its meat, unlike the meat of the Sidaou and D'man breed (Figure 5c) (Djaout et al., 2017).

2.1.4. Sidao breed

This breed is called Targuia because it is bred by the Tuaregs who live in the Sahara between Fezzan in Libya-Niger and southern Algeria in Hoggar-Tassili. It seems that the origin of the Targuia breed is Sudan (the Sahel). Its numbers have increased considerably due to the extension of its range throughout the Sahara. It can be estimated at more than one million heads (Djaout et al., 2017). The Sidaou sheep looks like a goat except that it has a long tail and a sheep's bleat; its color may be black, light straw or a mixture of the two colors. The males may have either no horns or small curved horns (Figure 5d) (Chelig, 1992).

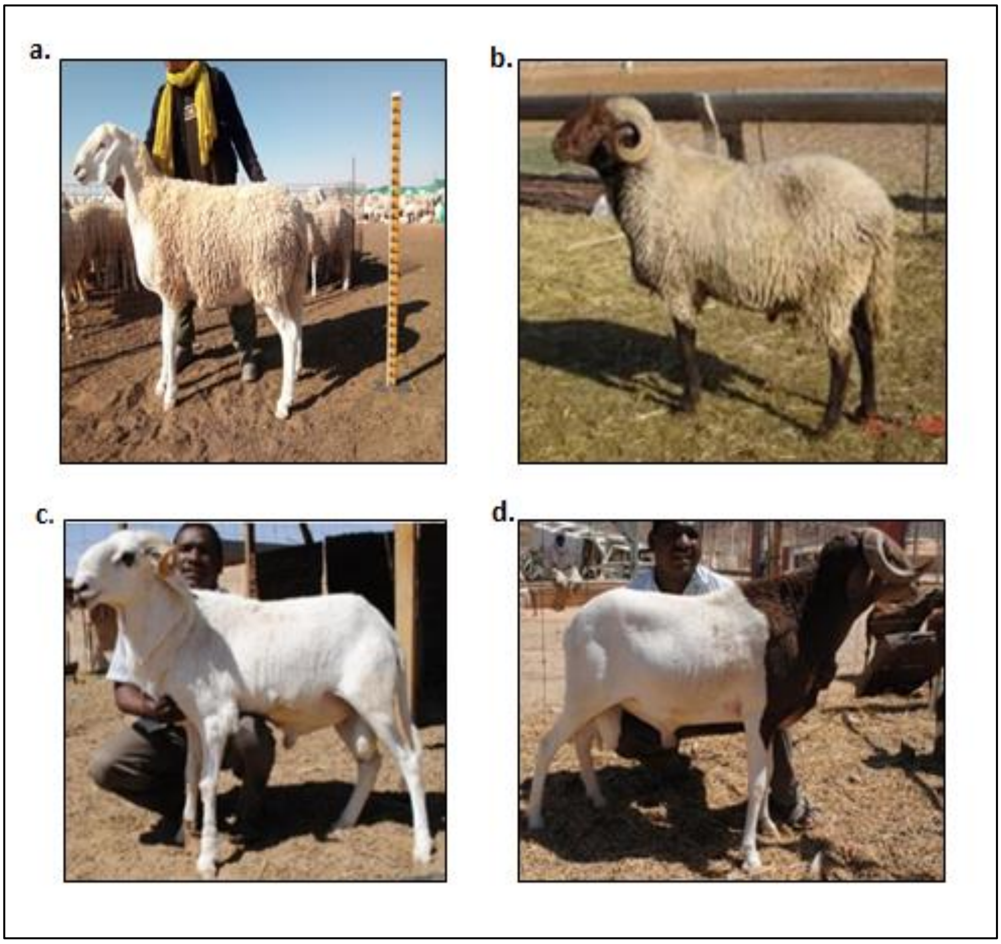


Figure 5. High-rated breeds in Algeria: a. Ouled Djellal ram. b. Hamra ram. c. Ifilène ram. d. Sidaou ram.

2.2. Limited numbers Breeds

2.2.1. Rembi breed

According to Trouette (1929), the Rembi sheep is probably the result of a cross between the Mouflon of Djebel Amour and the Ouled Djellal breed. This sheep is particularly adapted to the regions of Ouarsenis and the Tiaret mountains. The Rambi breed occupies the intermediate zone between the “Ouled Djellal” breed in the east and the Hamra breed in the west. It is limited in its range since it is found nowhere else (Chellig, 1992).

The Rembi sheep has practically the same morphological characteristics as the Ouled Djellal breed, except that it has a slightly more curved dorsal line and the legs and head are tawny or slightly greyish with medium-sized, hanging ears. The wool is white and covers the whole body up to the knees and hocks. Rams exhibit bulky, spiraling horns, and ewes may exhibit backward-sloping horns (Figure 6a) (Djaout et al., 2017).

2.2.2. D'man breed

It is a Saharan breed widespread in the oases of western Algeria and southern Morocco. The distribution of this breed extends from southwestern Algeria (Bechar, Tindouf, Adrar to Ouargla). The D'man ewe is very prolific. It can lamb twice a year, very often twins. The D'man ewe can have up to 5 lambs in a single litter (Chekal et al., 2015). The absence of horns, a long white tail and a white spot on the head distinguishes the D'man breed. The pendants can also be observed (Figure 6b) (Boubekeur et al., 2015).

2.2.3. Taâdmit breed

This breed is the product of crossbreeding between the Ouled Djellal breed and the Merino breed (Sagne, 1950). The focus of breeding this breed was primarily wool in addition to meat. A white head characterizes this breed with a hooked profile and voluminous horns in the male's long body. The animal is high on its legs. The fleece is extended, covering the forehead and descending to the hocks and sometimes to the knees. The wool is superfine to fine. The tail is long (Figure 6c) (Djaout et al., 2017).

2.2.4. Berbère breed

It is the oldest of the Algerian breeds, called "Azoulaï wool Berber", an endangered breed located in the mountains of Bouhadjar and Souk Ahras, in the region of El-Tarf, Annaba and at the Algerian-Tunisian borders and in Tlemcen. It is named "A'arbia" by breeders because they believe it to be the oldest of the Algerian breeds and native to this region (Djaout et al., 2017). It is a small animal with shiny white wool (Azoulaï), robust, generally white, brown, and can be black or a mixture of brown and white or black and white. The head is short, concave, and thin with medium, thin and horizontal ears. The wool is long and white, sometimes mixed with brown and black, not curly, widely hanging open fleece (Figure 6d) (Djaout et al., 2017).

2.2.5. Barbarine breed

This breed is found on the Tunisian border in the eastern erg (Oued Souf). Its extension area covers the east of the country of Souf to the Constantine plateaus up to the Tunisian borders. It is a mixed butcher breed and is reared for milk and wool (Chekal et al., 2015). This breed is remarkably adapted to the sandy desert and the great summer heat. The body of the Barbarine sheep is white except for the head and legs, which can be brown or black. The horns are developed in the male and absent in the female. The tail is large and can reach 3 to 4 Kg after fattening (Figure 6e) (Chellig, 1992).

2.2.6. Tazegzawt breed

The Bleue de Kabylie breed, or “Tazegzawt”, is a sheep typical of the mountains and the Soummam valley, perfectly adapted to the region’s natural conditions. (El Bouyahiaoui et al, 2015). The individuals of this race are uncolored; they have whitish skin with black pigmentation with bluish reflections around the eyes, at the level of the muzzle and the lower lobe of the ears. The head is long and elongated; the eyes are large and slightly bulging. The ears are long and drooping, the chest wide and deep, and well-marked in the male. The fleece is white; it covers the animal’s whole body, including the neck’s lower part, and goes down to the hocks. Tazegzawt females are all clods. Males can have varying-sized horns (Figure 6f) (El Bouyahiaoui et al., 2015).

2.2.7. Srandi breed

The Srandi breed, with its Sardi counterpart from Morocco, the Ripollesa breed from Spain and the French Causses-du-Lot breed, exists on Algerian territory, with a fairly large number in the regions near the Algerian-Moroccan borders. Its origin is not really defined (Djaout et al., 2017). It has a white head devoid of wool with black spots around the eyes, the muzzle of the tips of the ears, the legs and the level of the joints (knees and hocks). This phenotype gives it the name “breed with glasses” (Figure 6g) (Chikhi and Boujenane, 2005).

2.2.8. Darâa or black breed

This breed exists throughout the Algerian territory but in small numbers. It is characterized by an entirely black head and limbs (hence its name Darâa) with closed or semi-closed brown wool. The wool of this breed is used to make the Bernousse. The head is short and thin, the muzzle is straight, the limbs are thin, the tail is medium or long, and the horns are absent in females, but they may exist in males (Figure 6h) (Djaout et al., 2017).

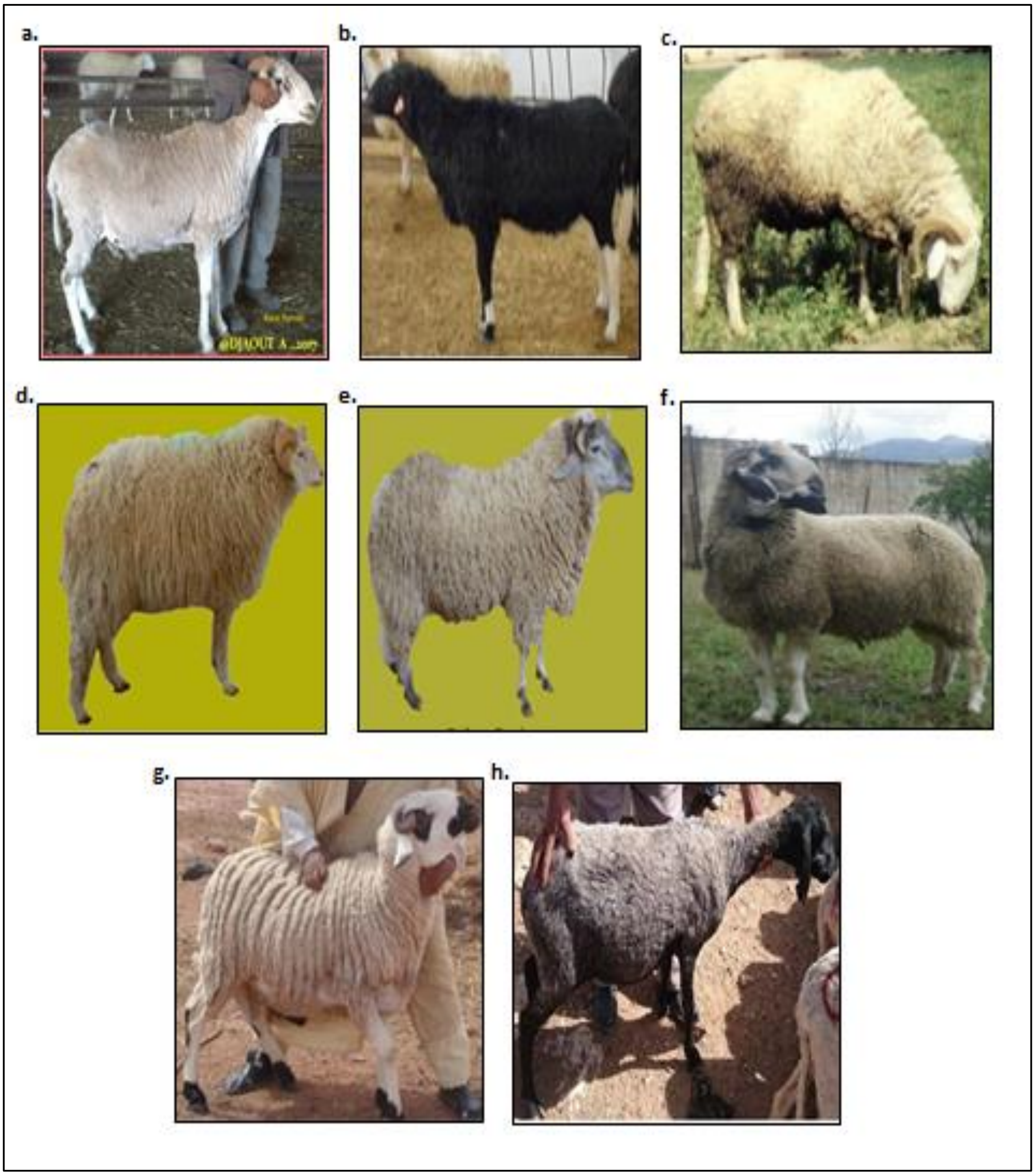


Figure 6. Limited breed numbers: a. Rembi ram. b. D'man ram. c. Taâdmit ram. d. Berbère ram. e. Barbarine ram. f. Tazegzawt ram. g. Srandi ram. h. Darâa ram.

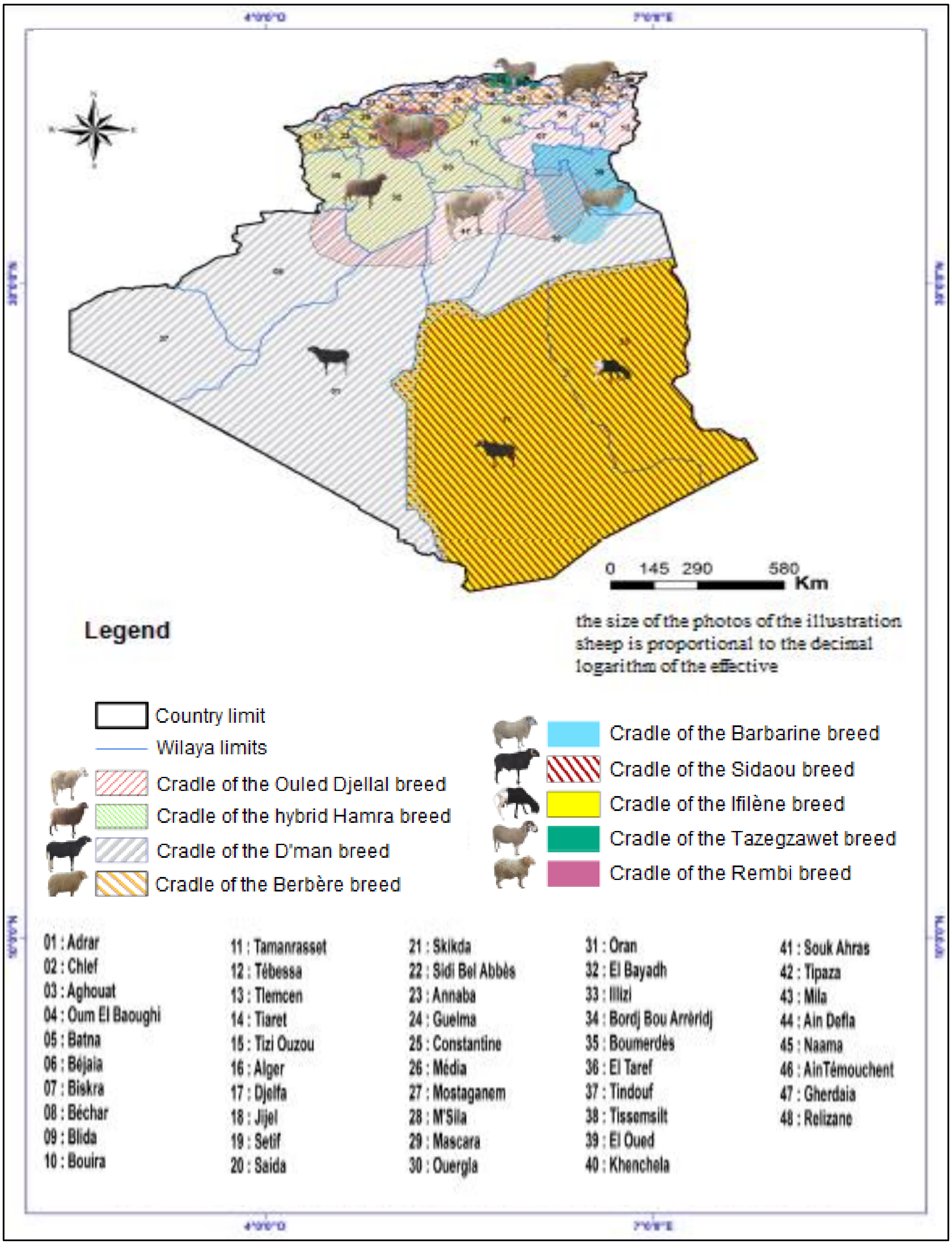


Figure 7. Distribution area of Algerian sheep breeds (Chekkal et al., 2015)

3. Breeding system

3.1. Definition

According to Lhoste (2001), the breeding system can be defined in a very general way as "*the combination of resources, animal species and techniques and practices implemented by a community or by a breeder, to meet its needs by valuing natural resources by animals*", or even more concisely and more generally, as "*a set of elements in dynamic interaction organized by man with a view to valuing resources through the intermediary of domestic animals*".

3.2. Types of breeding system

Production systems can be divided into different classes according to livestock management: extensive or intensive; the dominant speculation: meat or milk; dependence on the environment and in particular on food: integrated, aboveground or pastoral; location in relation to inhabited areas: urban, peri-urban or rural (Ben Abdallah, 2019). According to El Bouyahiaoui (2017), the main breeding systems encountered in Algeria are the extensive system (with two types: pastoral and agro-pastoral), the semi-intensive system and the oasis system.

3.2.1. Extensive system

Also known as open-air breeding, the sheep are raised freely in large spaces in this breeding mode. It is particularly the case in mountain pastures during the summer season. The herd is then guarded by a shepherd assisted by one or more dogs trained for this task. Feeding and watering use natural resources; hygienic conditions are much better than for animals raised in a closed room. Labor is reduced to a strict minimum (Fournier, 2006). In this breeding system, there are two subsystems:

- **Pastoral system**

This farming method practiced mainly by nomads is in marked decline. Similarly, ancestral nomadism made up of great transhumance (*âchaba* and *azaba*) tends to disappear, giving way to transhumance made of internal displacements, thus resulting in overgrazing of the steppe (El Bouyahiaoui, 2017).

- **Agro-pastoral system**

It is the association between cereal crops and breeding. Herd management is dominated by this system, conditioned by the influence of natural conditions (climate, type of vegetation or rainfall) and the ancestral knowledge of sheep management (El Bouyahiaoui, 2017). This system is distributed in the cereal regions and the irrigated perimeters. Although it is also extensive, it stands out thanks to its integration into agriculture, its less dependence on rangelands, and its zootechnical performances slightly better than those of the pastoral system (Rondia, 2006).

3.2.2. Semi-intensive system

With this method, the sheep are kept in an enclosed space by natural hedges or by a sufficiently high and solid fence to repel predators. A modest shelter allows the animals to take refuge in bad weather. It is imperative to provide artificial or natural water points and distribution devices for supplementary feeding (Fournier, 2006).

3.3.3. Oasis system

This system is mainly found in the country's south (in oases in general). The oasis maintains a balance of high-performance production systems with high-added value by combining several plants and animal productions. Thus, its productivity exceeds that of other sheep farming systems, with an average production of around 30 to 35 Kg live weight / zootechnical unit/year (zootechnical unit = 1 ewe lambed) (Rondia, 2006).

Chapter 3. Morphologic characterization and growth performances of sheep

1. Morphologic characterization of sheep

1.1. Concept of breed

The term "*breed*" is used in phenotypic characterization to identify distinct animal genetic resource populations as units of reference and measurement (FAO, 2012). FAO (1999) uses the following broad definition of the breed concept, which accounts for social, cultural and economic differences between animal populations, and which can therefore be applied globally in the measurement of livestock diversity: "*either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by a visual appraisal from other similarly defined groups within the same species or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity*".

1.2. Concept of population

In evolutionary biology, the concept of the population constitutes a starting point for studying the diversity of living organisms and the processes that produced it (Ewens, 1982). In genetics, a population is a group of individuals of the same species living in the same territory and reproducing sexually among themselves (De Rochambeau, 1990). A Mendelian population comprises individuals who can potentially mate or are related by kinship, marriage, or common ancestry. At a different level, the most extensive population is the species; since it determines the limits within which interbreeding is possible (Ewens, 1982).

1.3. Phenotypic characterization

Phenotypic characterization is a fundamental element of livestock management, with animals being all the more and better valued as they are well described. The phenotype is the description of an animal: external appearance, performance measured by control, and resistance to disturbing causes without knowing whether the variation of the phenomenon is due to the environment or heredity.

According to FAO (2012), the term "p*henotypic characterization of animal genetic resources (AnGR)*" generally refers to the process of identifying distinct breed populations and describing their external and production characteristics within a given production environment.

The definition given by FAO (2012) is broadened to include the description of the production environment. The term "*production environment*" is here taken to include not only the "*natural*" environment but also management practices and the uses to which the animals are put, as well as social and economic factors such as market orientation, niche-marketing opportunities and gender issues. Recording the geographical distribution of breed populations is considered an integral part of phenotypic characterization. There are two categories of phenotypic characteristics (Craplet et Thibier, 1984):

1.3.1. Qualitative traits

This category covers animals' external physical form, shape, color and appearance. These traits are recorded as discrete or categorical variables. Their discrete expression relates to the fact that they are determined by a small set of genes (FAO, 2012).

The qualitative traits given by FAO (2012) for sheep encompass:

- Sex: female, male (or castrated)
- Estimated age or dentition class
- Body hair coat color pattern: plain, patchy/pied, spotted
- Body hair coat color: black, dark red, light red, fawn, grey
- Body skin color: pigmented, not pigmented
- Fiber type:
    - hair sheep
    - wool sheep ·
        - coarse/carpet (about 100 microns) ·
        - medium wool (20 - 40 microns) ·
        - fine wool (about 15 microns)
- Hair length: medium (1–2mm); long (>2 mm)
- Horn presence (at flock level; separately for males and females): percent of polled animals, percent of horned animals
- Horn shape: scurs, straight, curved, spiral, corkscrew
- Horn orientation (at flock level, separately for males and females): lateral, obliquely upward, backward (also indicates if an animal is polled or if horns are loose or just stumps
- Ear orientation: erect, semi-pendulous, pendulous, carried horizontally

- Facial (head) profile: straight, concave, convex, ultra convex
- Ruff: absent, present
- Tail type: thin, fat rump, thick at base, fat
- Tail shape: cylindrical and straight, cylindrical and turned up at the end, bi-lobbed without appendage, broad without lobe
- Back profile: straight, slopes up towards the rump, slopes down from withers, dipped (curved)
- Rump profile: flat, sloping, roofy.

1.3.2. Quantitative traits

This category of traits covers the size and dimensions of animals' bodies or body parts, which are more directly correlated to production traits than qualitative traits are (FAO, 2012).

The quantitative variables applied for sheep are:

- Body weight (if spring balance or weighing bridge is available) with age specified
- Body size for adult males and females:
  - body length
  - height at withers
  - chest girth
  - chest depth
  - shoulder point width
  - rump length
  - rump width
  - head length
  - head width
  - shin circumference
  - horn length
  - ear length
  - tail length
  - hair/wool length (on the backline, at the rump) (FAO, 2012).

2. Growth performances

Growth is the increase in body mass (live weight) per unit of time; it represents the difference between what is built (anabolism) and what is destroyed (catabolism) in the body of the animal (Dudouet, 1997). Growth performances notably allow the identification, control and optimization of herd performances. According to Jean- Charles (2015), it allows us to know the genetic values of the herds and to conduct selection programs after that (Belkasmi, 2021).

2.1. Weight and average daily gain

Weighing lambs at key time points in production is a common practice employed for sheep. The average daily gain (ADG) is calculated from the weight and indicates the average growth rate expressed in g/d for given periods (Belkasmi, 2021). Average daily gain (ADG) in weight has been one of the most valuable traits. Higher ADG in sheep farming is essential from an economic point of view for higher production and reproduction, survivability and faster genetic improvement by decreasing generation interval and increasing replacement rate (Prakash et al., 2012; Gowane et al., 2015; Bansal et al, 2022).

2.2. Factors affecting lamb's growth

According to Belkasmi (2021), growth performances can be influenced by several factors, which are: the season, the body condition, the race, the age and parity of the ewe, the maternal behavior, the birth weight, the type of birth and the sex of the lamb.

2.2.1. The season

The change of season creates variability in pasture availability and nutritional characteristics (Belkasmi, 2021).

- **Autumn lambing** allows ewes to arrive in better condition at lambing despite losses during lactation. Food reserve composition period coincides with the high supply of pasture resources on spring pasture and grain harvest residues. Similarly, finishing lambs on grass can benefit their growth after weaning (Belkasmi, 2021).

- **Spring lambing** allows ewes to produce lambs with a higher weaning weight. However, the lambs are put to grass at the end of the grazing period, which can be restrictive for their growth (Chemmam et al., 2009).

2.2.2. Body condition

Lamb birth weight, growth to weaning and weaning weight can also be affected by ewe body condition score (BCS) in late pregnancy and lactation (Kenyon et al. 2014), although these effects have been inconsistent. Before lambing, greater BCS of the ewe has been shown to either not affect lamb birth weight (Al-Sabbagh et al. 1995) or have a positive effect (Molina et al. 1991). Similarly, lamb weaning weights have been reported to be unaffected by increased ewe BCS (Al-Sabbagh et al. 1995; Aliyari et al. 2012) or to show a positive effect (Sejian et al. 2009; Kenyon et al. 2012). It is possible that this inconsistency results from differences in ewe nutrition in late pregnancy and lactation (Corner-Thomas et al., 2015).

2.2.3. Breed

The breed influences the growth performances of lambs. In 2004, El Fadili showed that the breed of the rams affects fattening performance and carcass characteristics and significantly affects lambs' growth up to D 90. Chikhi and Boujenane (2005) showed that using rams of pure breeds allows lambs with good slaughter quality and improves sheep meat production. These variations between breeds are mainly due to factors related to their genetic variability and the difference between the regions they occupy (Belkasmi, 2021).

2.2.4. Age and parity

The age and the parity of the ewe can cause variations in lambs' growth performances. According to Baa et al. (2020), dams with a higher parity produced heavier lambs than primiparous dams. For the age, the authors found that older ewes give birth to heavier lambs than youngest ewes (Dekhili, 2003; Chniter et al., 2011; Zidane et al., 2015; Sveinbjörnsson et al., 2021). The low birth weight of lambs from young ewes is mainly because they are still growing during gestation and must share nutrients between their own needs and those of the fetus (Inyangala et al., 1992).

2.2.5. Maternal behavior

The maternal behavior develops from a mutual bond between mother and young under the influence of hormonal and peripheral somatosensory stimulation (Nowak and Poindron, 2006) during late gestation and during distension of the cervix and vagina during parturition (Xavier and Anthony, 2014). However, the predominant sensory modalities vary between species. According to Allouche et al. (2011), most Ouled Djellal ewes (75%) show overall good or average maternal behavior. The risk of mortality related to maternal behavior is 4 times higher for lambs of primiparous females than for lambs of multiparous females (Lecrivain and Ganeau, 1988; Belkasmi, 2021).

2.2.6. Birth weight

Birth weight is an important parameter affecting subsequent lamb growth (Belkasmi, 2021). A high birth weight allows the animal to start its life well and grow rapidly before and after weaning, predisposing it to better disease resistance and quickly reaching puberty and maturity (Sulieman et al., 1985; Zidane et al., 2015).

2.2.7. Type of birth

Lamb growth varies considerably with litter size. According to several authors, single lambs tend to have greater weights than twins (Chniter et al., 2011; Zidane et al., 2015; Deghnouche et al., 2018; Baa et al., 2020; Sveinbjörnsson et al., 2021; Tesema et al., 2022). This difference is due to the competition phenomenon of doubles during fetal life and the suckling period (Fraysse and Guitard, 1992).

2.2.8. Sex of the lamb

Lamb growth varies by sex; according to authors, male lambs are considerably heavier than female lambs (Chniter et al., 2011; Zidane et al., 2015; Deghnouche et al., 2018; Baa et al., 2020; Sveinbjörnsson et al., 2021; Tesema et al., 2022). This finding may be explained by sex-linked genes, conformational differences (neck muscles, head bones, overall skeleton), and in particular, the gradual advancement of the digestive organs of males (Bendiab and Dekhili, 2012).

Practical part

- **Presentation of the study area**

The study was carried out in the northeast region of Algeria, covering five provinces: Biskra, Ouled Djellal, Batna, M'Sila and Oum El Bouaghi.

1. Ziban Region (Biskra and Ouled Djellal Provinces)

1.1. Geographic location

The Ziban region is located in Algeria's center-east, at the Algerian Sahara's gates. It is a real buffer space between the North and the South, about 400 km southeast of the capital (Algiers). The total area of the Ziban region is 21671 km². Before 2019, the Ziban region was composed of one province Biskra. Now and after the new administrative division, it comprises two provinces, Biskra and Ouled Djellal.

Biskra province, with a superficies of approximately 10 000 km², is limited to the North by the wilaya of Batna, to the South by the wilayas of M'Ghair and El-Oued, to the East by the wilaya of Khenchela, to the Northwest by the wilaya of M'Sila and the West by the wilaya of Ouled Djellal (Figure 8). Ouled Djellal, covering an 11 410 km², is delimited to the North by the M'Sila Province, to the East by the Biskra Province and El M'Ghair Province, to the West by the Djelfa Province, and to the South by the Ouargla Province (Figure 8).

1.2. Geomorphology

The Ziban region is the transition between the atlas and the desert (Nouidjem et al., 2021). We go from a fairly high and rugged relief in the North to a plateau topography slightly inclined towards the South. The Ziban region's relief comprises four large geomorphological collections (Bakroune, 2021).

- Mountains are located in the North of the region. They are generally bare of any natural vegetation. The highest point is Djebel Taktiout, with an altitude of 1924 m.
- The plateaus are located largely west of the Ziban region. They extend over 1210848 ha (56% of the extent of the Ziban region). The vegetation of the plateaus is thin, constituted of the privileged sites.
- The plains extend in the East-West axis of the Ziban region and cover almost all the Daira of El-Outaya and Sidi-Okba and the commune of Doucen.

- The depressions are located in the southeast. They constitute a plate where very thin water bodies are formed, thus constituting the chotts, of which the most important is the Melghir chott, whose level may be less than 33 m below the sea (Bakroune, 2021).

1.3. Climate

Ziban is located in the Saharan bioclimatic zone (Menasra and Bouzaher, 2021). The climate of this region is desert-prone arid, and semi-arid, with a high temperature in summer reaching (48.8° C), in August and (1.6° C) in February. Due to the desertification phenomena, the summer is longer and hotter and the winter shorter and drier, with 139.8 mm/year of average rainfall (Bouzaher and Alkama, 2013).

1.4. Agriculture

With a total agricultural area (TAA) of 1652751 ha (74.84% of the total area of the wilaya), of which 185473 ha (8.62%) represents the useful agricultural area (UAA), Ziban zone is practically a leading agricultural region with thousands of hectares dedicated to market gardening, fruit and especially date palms (Table 3). The irrigated agricultural areas represent 62.25% of the UAA, approximately 11,455 ha (DPSB-Biskra, 2019).

Table 3. Distribution of crop production by area and production in the Ziban region (DPSB-Biskra, 2019).

	Area (ha)	**Production qx/ha**
Cereals	27334	996090
Cattle feed	1470	102555
Vegetables	21548	10206025
Fruit growing	51882	4913067
Viticulture	258	20180

2. Batna

2.1. Geographic location

The Batna province called the capital of the highlands, situated between the Tell Atlas in the North and the Saharan Atlas in the South, with the Chott el Hodna in the middle, constitutes a naturally protected passage between the South and North. It covers an area of approximately 12 038.76 km² (Kalla and Guettouche, 2017). The wilaya of Batna is limited to the north by the wilayas of Sétif and Oum El Bouaghi, to the west by the wilaya of M'Sila, to the east by the wilayas of Khenchela and Oum El Bouaghi and to the south by the wilaya of Biskra (Hannachi et al., 2016).

2.2. Geomorphology

The relief of the Batna region consists mainly of high plains of the Aurès mountain range and a portion of the Hodna basin. The mountainous form crosses the region from the East and West. A zone of plateaus is noticed in the northern part and between the mountain ranges (Hannachi et al., 2016).

2.3. Climate

A varied climate characterizes the Batna region, ranging from semi-arid in the North to arid in the South (Berkane and Yahiaoui, 2007). According to the variability of climate in this region, the climatic data of two different meteorological stations was retained, the station of the aerodrome of Batna in the North and the station of Chaâba in the South. These two stations are the most representative of the Batna region from the point of view of precipitation and temperature. The average annual rainfall is around 400 to 500 mm. February is the coldest month, with an average minimum temperature of 0.7°C. The hottest month is August, with an average maximum temperature of 30.2°C (Hannachi and Fenni, 2013).

2.4. Agriculture

The wilaya has an agro-pastoral vocation. Cereal growing is the main crop grown in the wilaya and whose area represents 38.08% of the agricultural area of the wilaya. Apiculture and aviculture are combined with sheep farming.

The apricot tree is especially present in the region of N'Gaous, and the olive tree and the apple tree in the region of Arris. A center for continental fishing is planned near the Koudiet Lamdouar barrage in Timgad, over 2,000 m. Apricots production is estimated at 500,000 quintals for the 2011 harvest, while olive production at over 186,000 quintals for the same year.
The exploited agricultural area increased from 70 000 hectares in 1962 to 422 000 ha in 2011. During the same period, irrigated areas increased from 1 500 ha to 50 000 ha and orchards from 700 ha to 21 000 ha. The agricultural sector employs 12,000 people in the wilaya. The Koudiet Lamdaouar barrage has a 70 million m^3 capacity.

3. M'Sila

3.1. Geographic location

It occupies a strategic position, in contact with the Tell and the Hodna basin and the heart of the Hauts-Plateaux. It has an area of 18,718 km^2 (Boudjelal et al., 2013). It is bordered by the wilayas of Medea, Bouira, Bordj-Bou-Arreridj and Setif to the North, Batna and Biskra to the East, Djelfa to the West and Ouled Djellal to the South (Figure 8).

3.2. Geomorphology

The territory of the wilaya constitutes a hinge zone between two large mountain ranges, the Saharan and the Tell Atlases. The geographical configuration of this region is characterized by the following:

- Mountains on either side of the Chott El-Hodna,
- A central region consisting essentially of plains and high plains,
- The Chott (Chott El-Hodna) in the center,
- An aeolian sand dune (Boudjelal, 2013).

3.3. Climate

M'Sila region has a continental climate with hot, dry summers and very cold winters (Boudjelal et al., 2013). Rainfall varies from 69 mm to 200 mm/per year, and the average annual temperature is between 13° C and 23° C, with extremes of -5° C in winter to 46° C in summer (Benikhlef et al., 2021).

3.4. Agriculture

M'Sila is a region with an agro-pastoral vocation, thanks to the importance of these courses. The territory of the region covers a total area of 1665271 ha distributed as follows (DSA M'Sila, 2017):

- The useful agricultural area is around 277592 ha, 15.25% of the territory of the wilaya;
- Rangelands and pastures occupy an area of 1029564 ha or 56.65% of the total agricultural area;
- Forests and alfa, covering an area of 349985 ha, or 19.26% of the territory of the wilaya;

- Finally, the unproductive lands with 170610 ha make up 09.39% of the total area.

4. Oum El Bouaghi

4.1. Geographic location

Oum El Bouaghi is a province of Algeria in the Aures region. Historically, it is part of the Chaouis region with the wilaya of Batna and the wilaya of Khenchela. Unlike the latter two, which make up the Aurès mountains, the wilaya of Oum El Bouaghi is at the heart of the plain Chaouia culture. Its area is estimated at 7638 km^2 (Elfegoun et al., 2017). It is delimited to the North by the wilaya of Guelma and wilaya of Constantine, to the Northeast by the wilaya of Souk Ahras, to the East by the wilaya of Tebessa, to the Northwest by the wilaya of Mila, to the West by the wilaya of Batna and to the South by the wilaya of Khenchla (Figure 8).

4.2. Geomorphology

The wilaya is located in contact with the Tell and the Aurès:

- To the North of the wilaya, we can distinguish the southern slopes of the Tell;
- In the center, the high plain, the altitude varies from 700 to 900 m and is dotted with small isolated mountain ranges that rise above, such as the Jebel Sidi Rgheiss (1 635 m above sea level), the Jebel Rherour (1 273 m), Jebel Amama (1 337 m), these form the eastern part of the Aurès;
- To the South, it is punctuated by endorheic depressions (Garet) or Sebkha (a salt lake). Garrets are less salty than Sebkhas;
- The highest point of the wilaya is Djebel Guerioun, 1 729 m above sea level.

4.3. Climate

The general climate is continental Mediterranean semi-arid. The summers are hot and dry, and the winters are cold and wet. The mean yearly rainfall is 350 – 400 mm in the North of the wilaya and 200 -250 in the South. The mean temperature is 32.6 °C in the summer and 9.3°C in the winter (Elfegoun et al., 2017).

4.4. Agriculture

The region of Oum El-Bouaghi is essentially characterized by agriculture and breeding. It is an area with an agro-silvo-pastoral vocation (Table 4). The useful agricultural area (UAA) represents 360885 Ha. This area is divided between the crops (cereal crops, fodder and vegetables) (ALIAT, 2017).

Table 4. Land distribution, crop production and animal numbers in the wilaya of Oum El Bouaghi (MADRP, 2015).

Wilaya	**General distribution of land**			**Vegetal production**				
Oum El Bouaghi	UAA (ha)	Land used for agriculture	Land not used for agriculture	Cereal production			Dry vegetable	Vegetables
				durum wheat	Common wheat	Barley		
	360885	360885	49796.36	636000	397600	1263150	1010	711808

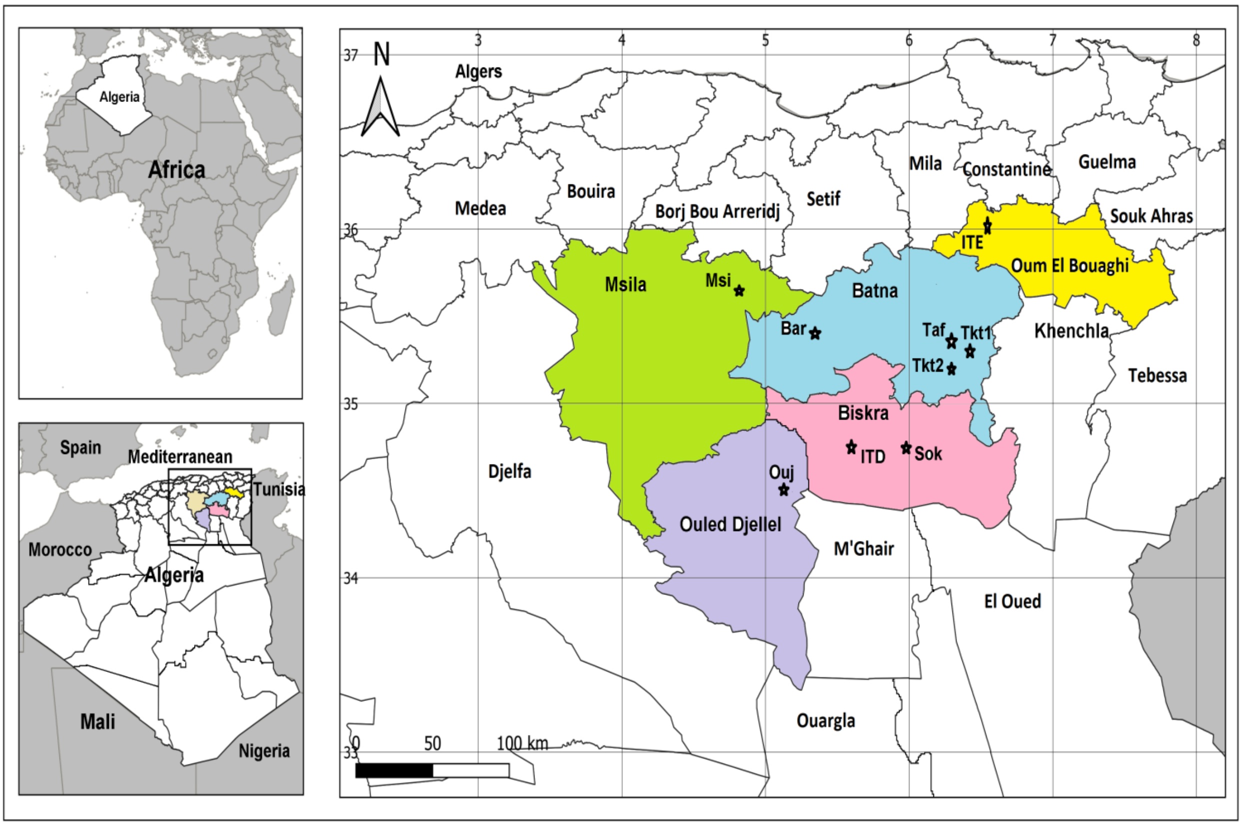


Figure 8. Map of the study area. Taf: Tafrent. Tkt1: Tkout 1. Tkt2: Tkhout 2. Bar: Barika. ITD: ITDAS. Sok: Sidi Okba. Ouj: Ouled Djellal. Msi: M'Sila.

Table 5. Geographic coordinates of each site of the studied area.

Province	**Site**	**Geographic coordinate**	
		Latitude	**Longitude**
Batna	**Tafrent**	35°15'48" N	6°30'13" E
	Tkout-1	35°08'02''N	6°18'05''E
	Tkout-2	35°10'45''N	6°21'58''E
	Barika	35°20'06''N	5°17'17''E
Biskra	**ITIDAS**	34°48'07''N	5°37'59''E
	Sidi Okba	34°44'03''N	5°51'56''E
Ouled Djellal	**Ouled Djellal**	34°21'15''N	5°06'33''E
M'Sila	**M'Sila**	35°44'53''N	4°31'07''E
Oum El Bouaghi	**ITELV Ain Mila**	35°51'35''N	6°29'27''E

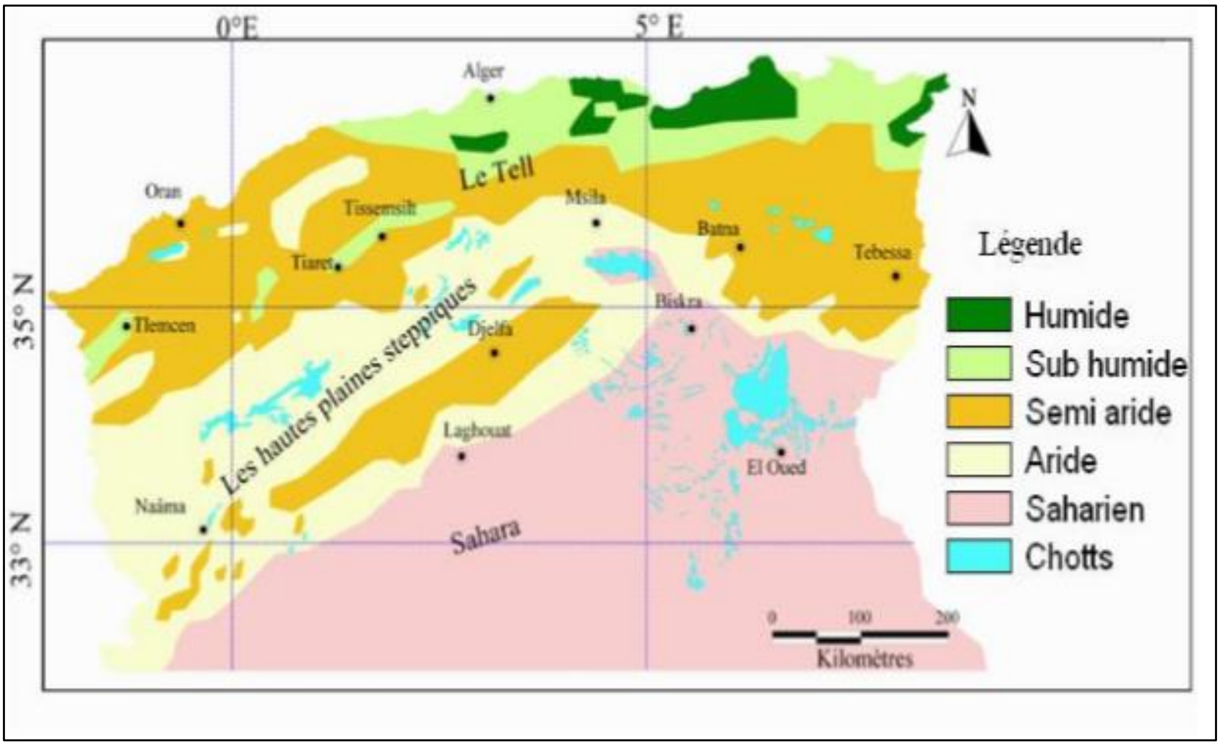


Figure 9. Bioclimatic map of Algeria (A.N.A.T, 2004)

Experiment 1. Phenotypic characterization of the sheep population of Northeast Algeria

1. Study framework

The study was carried out in four provinces: Batna, Biskra, Ouled Djellal and M'Sila. Eight farms were selected: four farms located in Batna (Tafrent, Tkout 1, Tkout 2 and Barika), two farms located in Biskra (ITDAS and Sidi Okba) and one farm located in Ouled Djellal and another one located in M'Sila (Table 5). All the chosen farms were private except for ITDAS (Institut Technique pour le Développement de l'Agronomie Saharienne - Technical Institute for the Development of Saharan Agronomy), an institutional farm.

2. Materials and methods

2.1. Animals

A total of 160 ewes aged from 2 to 6 years, as determined by dentition (Wilson and Durkin, 1984), were sampled, and 20 ewes were randomly selected from each farm. The selected animals were raised under semi extensive system, while the ITDAS animals were reared under a semi-intensive system.

2.2. Herds Conduct in the private farms

2.2.1. Feeding management

The feeding of the animals is essentially based on fallow grazing in autumn during the lambing of the ewes (for the period from September to November), grazing on cereal stubble in summer (during the period from June to the end of August) and grazing on the meadows in spring (during March at the end of May).

2.2.2. Reproduction

The mode of mating is free. Reproduction is ensured by the male present permanently in the herd. The choice of the male is based on their size and weight.

2.2.3. Prophylaxis

The animals have undergone sanitary and prophylactic treatments against Clostridial toxi-infections and internal and external parasites.

2.3. Morpho-biometric characterization

The morphological profiling was established based on certain qualitative (ordinal) and quantitative (biometric) characters.

2.3.1. Qualitative characters

A total of 9 qualitative body characteristics were studied: head length, ear orientation, horn presence, neck length, wool extent, tail texture, eyes shape, head color and wool color (Table 6).

Table 6. Qualitative measures adopted for ewes' characterization.

Qualitative Variables	Symbol	Trait type	Coding	Reference
Head length	HL	Long Short	HL.1 HL.2	(FAO, 2012)
Head color	HC	White Black Mix	HC.1 HC.2 HC.3	(Harka et al., 2015)
Eyes shape	ES	Bulge Not bulge Big Small	ES.1 ES.2 ES.3 ES.4	(Belaib, 2012)
Ear orientation	EO	Horizontal Semi-horizontal Drooping	EO.1 EO.2 EO.3	(FAO, 2012)
Horn presence	H	Presence Absence	H.1 H.2	(FAO, 2012)
Neck length	NL	Long Short	NL.1 NL.2	(Harkatet al., 2015)
Tail texture	TT	Slim Fat Average	TT.1 TT.2 TT.3	(Belaib, 2012)
Wool extent	WE	Total Partial	WE.1 WE.2	(Harkatet al., 2015)
Wool color	WC	White Black Mix	WC.1 WC.2 WC.3	(FAO, 2012)

2.3.2. Quantitative characters

Quantitative measurements were: body length, withers height, tail length and wool weight (Table 7). Except for the variable of wool weight, the body measurements were taken using a measurement stick and metric tape (Figure 10). Measurements were taken in the morning before releasing the animals for grazing.

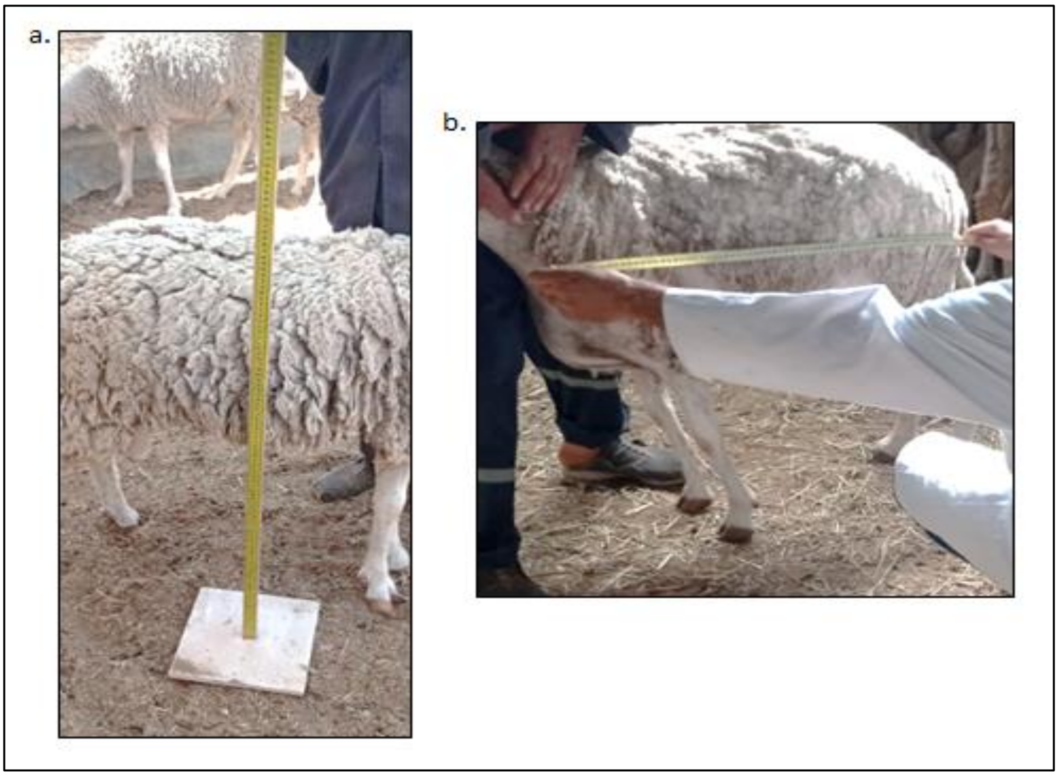


Figure 10. Tools used for biometric measurements **(**Personal photos).

a. Measurement stick. b. Metric tape

Table 7. Quantitative measures adopted for ewes' characterization.

Quantitative variables	Symbol	Definition	Reference
Body length	BL	Distance from the base of the tail to the base of the neck	(FAO, 2012)
Withers height	WH	Height from the top of the withers to the ground	(FAO, 2012)
Tail length	TL	Distance from the point of attachment of the tail to the tip	(FAO, 2012)
Wool weight	WW	Weight of wool measured after shearing the animal	(Chellig, 1992)

2.4. Statistical analysis

The methods used in this experimental study are the classic procedures of elementary descriptive statistics (calculation of the minimum, maximum, mean, standard deviation, and coefficient of variation plus plots of histograms and mustache box). In addition, multidimensional statistical data analysis techniques were applied, such as Multiple Correspondence Analysis (MCA), Principal Component Analysis (PCA) and Hierarchical Agglomerative Clustering (HAC). These tests were processed by R software version 2.15.0.

- MCA is the method of data analysis devoted to processing tables crossing individuals with more than two qualitative variables. In our study, the individuals are the 160 ewes, and the variables are the qualitative characters and the "Herd".
- PCA is a data analysis technique that allows the processing of large tables crossing individuals and quantitative characters. Its principle is to reduce the number of variables that may be too large at the start. It represents a sort of basis for other methods of statistical analysis. In our case, the individuals are the farms, and the characters are the quantitative morphological variables. Each farm is defined by four values representing the means of the BL, WH, TL and WW measurements taken on the 20 selected ewes from the same farm. The 8 farms, therefore, form a set of points in a four-dimensional space, impossible to visualize. PCA makes it possible to project these points into a plane (in 2 dimensions) called the factorial plane.
- Agglomerative clustering is the most common type of hierarchical clustering used to group objects in clusters based on their similarity. In our study, the purpose of this test is to highlight the similarities between the herds and group them according to their proximity from the point of view of quantitative morphology.

3. Results and discussion

3.1. Qualitative characters

3.1.1. Frequencies of qualitative traits

The frequencies of the qualitative traits were expressed by percentage (Table 8). The results obtained show that the sheep populations had, in most, a long white head (93% and 80% respectively), bulge eyes (86%), a semi-horizontal ear (67%), 98% of these populations had no horns, 72% have a long neck, 83% had a fat tail, the wool is white and covers the whole body (95% and 60% respectively).

Table 8. Percentage (%) of ewes according to qualitative traits.

Qualitative trait	Trait type	%
Head length	Long	80
	Short	20
Ear orientation	Horizontal	1
	Semi-horizontal	67
	Drooping	32
Horn	Presence	2
	Absence	98
Neck length	Long	72
	Short	28
Wool extent	Total	60
	Partial	40
Tail texture	Fat	83
	Slim	11
	Average	6
Eyes shape	Bulge	86
	Not bulge	9
	Big	4
	Small	1
Head color	White	93
	Black	6
	Mix	1
Wool color	White	95
	Black	4
	Mix	1

According to the results from table 8, the sheep population in the studied region belonged approximately to the Ouled Djellal breed described by Chellig (1992). Some variability was noted in the sheep population, like the ear orientation, the height percentage was recorded for the semi-horizontal shape (67%) compared to the drooping shape (32%), which has ear orientation the characteristic of Ouled Djellal sheep (Harkat et al., 2015),

The reasons for the presence of such phenotypic variabilities can be summed up in the absence of state intervention and monitoring, the breeders are left to their own devices, and consequently, breeding has become disorganized, the reproductions are not mastered, and the crossings are done in an anarchic way between the different regions of the country.

3.1.2. Multiple Correspondence Analysis

Figure 11 shows the results of the MCA, where we note some extreme points in the left part. This finding seems compatible with reality. Indeed, these extreme points correspond to rare modalities (not characteristic of the Ouled-Djellal breed) such as ES.4 for the small eyes, H.1 for the presence of horns, WC.2 and WC.3 for the non-white colors of the wool, and HC.2 for the black color of the head.

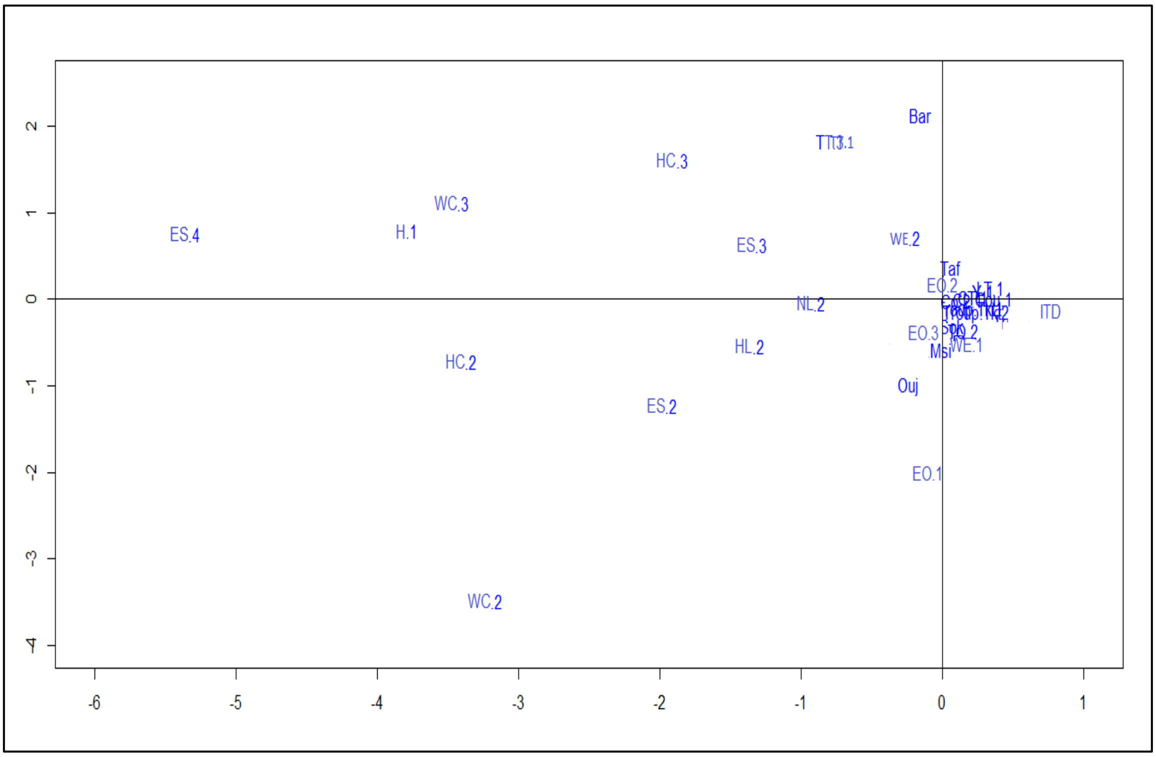


Figure 11. Projection of the modalities of the qualitative variables.

3.2. Quantitative characters

3.2.1 Statistical analysis by farm

Table 9 lists the overall mean, min, max, standard deviation and coefficient of variation of the quantitative measurements for each farm. Figure 12 shows the concentrations per herd of the different quantitative traits around the medians. We see concentrations that vary from one herd to another, particularly a very high concentration of wool weight in M'Sila and Ouled Djellal. On the other hand, it can also be seen that the herd of the ITDAS in Biskra presents the greatest body lengths, that the biggest body heights characterize the herd of Tkout-2 farm, that the ewes with longer tails are in Ouled Djellal and that the Barika farm is the one that offers more wool.

Table 9. Descriptive statistics for body measurements of studied sheep population given by farm

		Tafrent	Tkout 1	Tkout 2	M'Sila	Barika	Ouled Djellel	ITDAS	Sidi Okba
BL	Min (cm)	66.10	65.10	73.30	72.40	72.40	70.20	76.30	72.00
	Max (cm)	71.70	73.10	80.20	78.30	77.40	78.20	84.20	78.60
	Mean(cm)	69.12	69.38	76.55	75.37	75.08	74.54	78.88	76.06
	SD	1.44	2.20	1.68	1.35	1.40	1.98	2.11	1.69
	CV (%)	02.08	3.17	2.19	1.79	1.86	2.66	2.67	2.22
WH	Min (cm)	72.90	71.20	74.30	70.30	68.80	70.30	71.30	67.00
	Max(cm)	77.20	75.30	84.20	78.30	74.30	78.20	75.30	75.60
	Mean(cm)	74.92	73.81	80.12	72.98	71.22	74.49	73.04	72.86
	SD	1.29	1.23	2.22	1.67	1.52	1.97	1.29	2.17
	CV (%)	1.72	1.67	2.77	2.29	2.13	2.64	1.77	2.98
TL	Min(cm)	33.00	29.00	31.10	30.00	29.10	35.10	30.20	27.00
	Max(cm)	37.30	33.90	34.50	35.20	34.00	41.00	34.30	34.40
	Mean(cm)	35.11	31.23	32.91	32.45	31.84	38.22	32.09	32.44
	SD	1.36	1.25	1.04	1.61	1.63	1.63	1.15	1.97
	CV (%)	3.87	4.00	3.16	4.96	5.12	4.26	3.58	6.07
WW	Min (Kg)	1.40	1.20	1.70	1.80	1.60	1.50	1.20	1.60
	Max (Kg)	1.70	1.50	2.00	2.30	2.80	2.00	1.80	2.00
	Mean(Kg)	1.56	1.35	1.85	2	2.32	1.95	1.33	1.86
	SD	0.08	0.08	0.08	0.09	0.29	0.15	0.18	0.1
	CV (%)	5.13	5.93	4.32	4.50	12.50	7.69	13.53	5.38

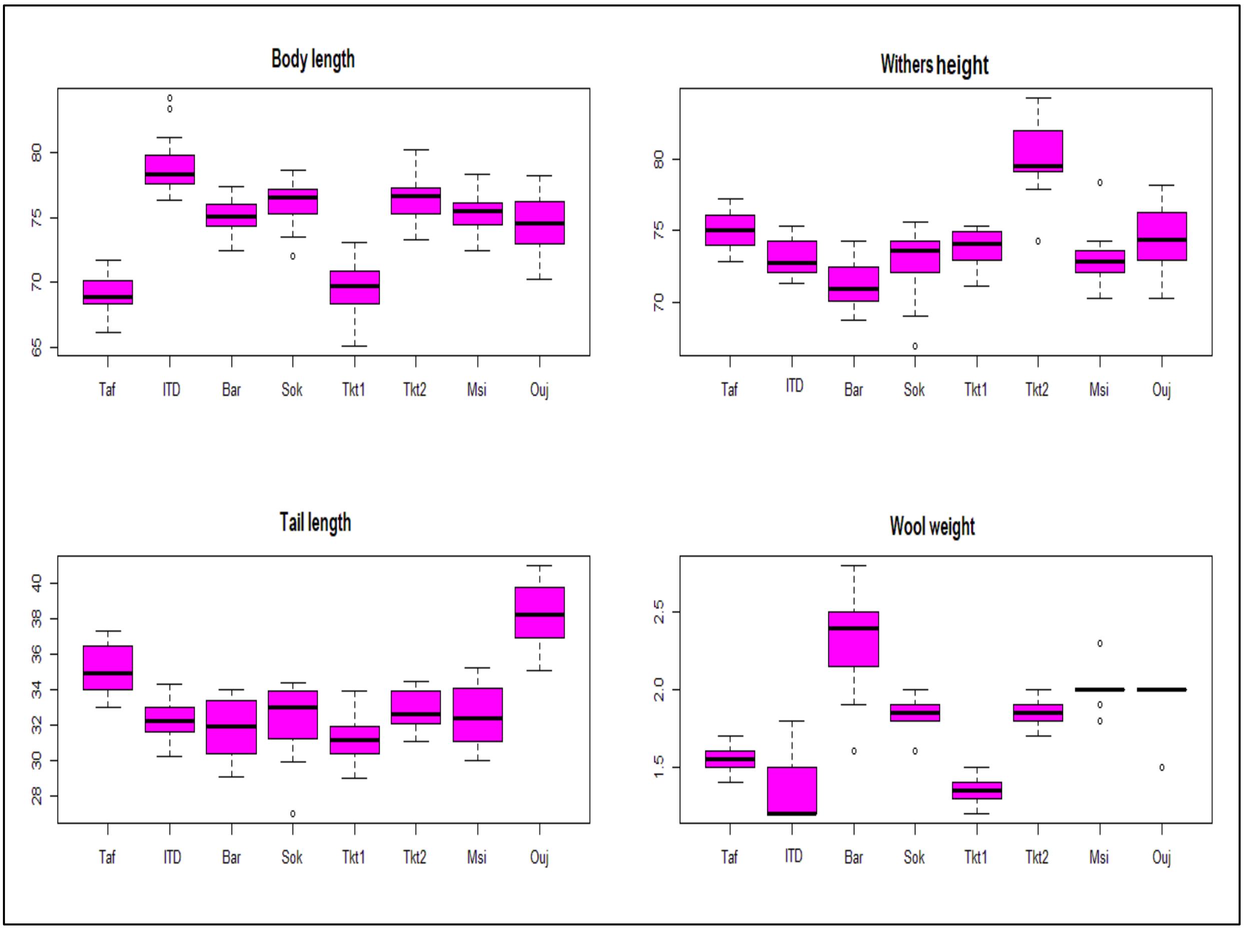


Figure 12. The concentration of quantitative variables for sampled 160 ewes.

3.2.2. Global statistical analysis

The descriptive statistics of the quantitative measurements for the eight farms are shown in table 10. The entire sheep population studied has an average body length of 74.37 cm, an average withers height of 74.18 cm, an average tail length of 33.29 cm and an average wool weight of 1.78 Kg.

Table 10. Descriptive statistics for body measurements of the global sheep population.

	Min	Max	Mean	SD	CV (%)
Body length (cm)	70.98	77.71	74.37	1.73	2.33
Withers high (cm)	70.76	77.30	74.18	1.67	2.25
Tail length (cm)	30.56	35.58	33.29	1.46	4.38
Wool weight (Kg)	1.50	2.01	1.78	0.13	7.37

The results are listed in Table 10. The body length value found in this study is higher (74 cm) than the value recorded by Chellig in 1992 (67 cm). The measurements of BL and WH are almost the same, which indicates that the sheep populations had a square body. The values of BL and WH found in this study were lower than those recorded by Harkat et al. (2015) (114.08 and 80.13 cm, respectively) and Afri-Bouzebda et al. (2018) (90 and 85 cm, respectively) for Ouled Djellal sheep breed, Laoun et al. (2015) (107.6 cm and 77.32 cm respectively) and Afri-Bouzebda et al. (2018) (76.8 and 77.2 cm respectively) for Rembi sheep breed and Dekhili (2014) (103.4 and 79.2 cm respectively) for the sheep population in North-East of Algeria.

In contrast, the values of these two measurements observed in this study were higher than those recorded by Chellig (1992) for Hamra (70 and 67 cm respectively), Berbère (64 and 60 cm respectively), Barbarine (65 and 64 cm respectively) sheep breed and lower also than those recorded by Kandoussi et al. (2021) for the Blanche de Montagne sheep breed in Morocco. The value of BL found in this study was lower than that reported by Khaldi et al. (2011) for the sheep breeds in the Southern-East of Tunisia, whereas the value of WH was higher than those recorded by the same author.

The sheep population had a higher value for TL than those reported by Kandoussi et al. (2021) for the Blanche de Montagne sheep breed in Morocco (31.1 cm). In contrast, a lower value for TL was found compared to those recorded by Harkat et al. (2015) (43 cm) and Dekhili (2014) (38.9 cm) on the same breed. For WW, the results are almost similar to those recorded by Chellig (1992) (1.7 Kg). The coefficients of variation calculated on all the measurements ranged from 2.25 to 7.37%. These values were lower than those of Dekhili (2014) and Harkat et al. (2015). The highest variation was observed for WW (7.37%), which could be important for selection and improvement.

3.2.3. Correlation between body measurements

The correlations between body measurements registered in this study varied from -0.07 to 0.30 (Table 11). The highest correlations were observed between WH and TL (0.30). This result was in concordance with the results obtained by Boubekeur et al. (2015) for the D'man sheep breed in Algeria, Severin et al. (2019) for the Djallonké sheep breed in Ivory Coast and Akbar et al. (2021) for Thalli sheep breed in Pakistan which they recorded 0.20, 0.37 and 0.25 respectively.

A weak correlation was registered between BL and WH (0.15), which was in concordance with the results of Severin et al. (2019) and Anila and Luan (2021) for the Bardhoka sheep breed in Albania (0.24 and 0.13, respectively). In other studies, a negligible correlation between these two body measurements was recorded by Khargharia et al. (2015) for the Assam Hill goat in eastern Himalayan India (0.06), and a moderate correlation was recorded by Bello-Ibiyemi et al. (2017) for the Dwarf sheep in West Africa (0.67). A strong correlation was recorded by Akbar et al. (2021) (0.84). A negligible correlation was recorded between BL and TL (0.01) compared to those recorded by Boubekeur et al. (2015), Severin et al. (2019) and Akbar et al. (2021), where they found a weak correlation between these parameters (0.27, 0.29 and 0.20 respectively), which indicate the independence of these measurements.

Table 11. Pearson's correlation coefficients between body measurements of the studied ewes. BL: body length, WH: withers height, TL: tail length, WW: wool weight

	BL	**WH**	**TL**	**WW**
BL	**1**			
WH	0.15	**1**		
TL	0.01	0.30	**1**	
WW	0.26	- 0.07	0.14	**1**

3.2.4. Classification of studied sheep population

The hierarchical agglomerative clustering resulting from PCA permits determining three classes (Figure 13). The first class comprises M'Sila, Barika, Sidi Okba and ITIDAS. The second class comprises Tafrent and Tkout-1, and the third class of Tkout-2 and Ouled Djellal. The subdivision of the sheep population into three classes may refer to the difference in the type of vegetation, climate (Whannou et al., 2021) and altitude among these regions (Harkat et al., 2015). Several studies have confirmed the effect of environmental factors on the morphology of sheep (Gizaw et al., 2007; Ahozonlin et al., 2020). The grouping of the Tkout-2 and Ouled Djellal sheep population in the same class (class 3), although they belong to different ecological zones, seems to reflect the height practice of crossbreeding of Tkout-2 sheep population with the Ouled Djellal sheep breed, which consumers more demand for his physical characteristics and meat quality.

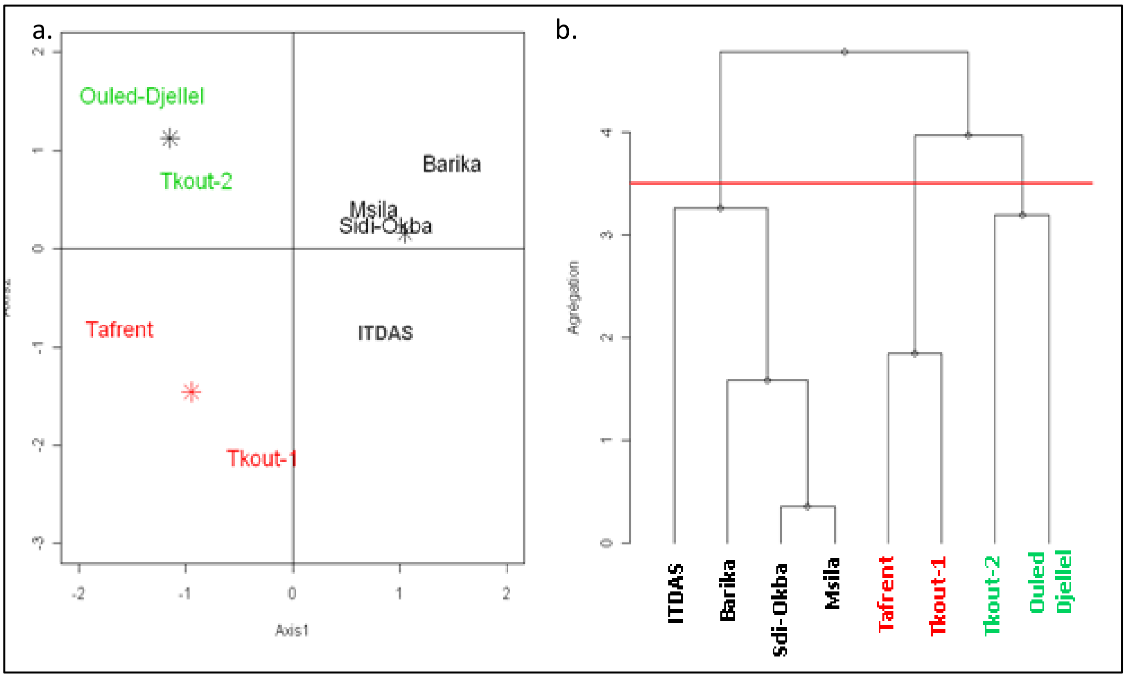


Figure 13. PCA factorial plan and classification tree of the 8 sites according to quantitative measurements. (a) PCA factorial plan; (b) Classification tree.

Table 13 summarizes the means per class of quantitative morphometric variables. The animals of the third class have the highest values for most of the morphometric variables WH, TL and WW, the animals of the second class have the average values for WH and TL and the lowest values for BL and WW, and the animals of the first class have the biggest values of BL, the average values of WW and the lowest values of WH and TL.

Table 12. Means of morphometric traits per class. BL: body length, WH: withers height, TL: tail length, WW: wool weight.

Class	BL (cm)	WH (cm)	TL (cm)	WW (Kg)
1	76.35	72.52	32.20	1.88
2	69.25	74.36	33.17	1.46
3	75.54	77.31	35.56	1.90

4. Conclusion

The description of the quantitative and qualitative characteristics indicates that the sheep population of the North-East of Algeria belongs to the Ouled Djellal sheep breed with some variabilities due to the effect of uncontrolled crossings between local breeds. The results show moderate variation coefficient values for body measurements of the studied population, with the highest value reported for WW (7.37%). The correlation analysis revealed the presence of a clear correlation between WH and TL (0.30) and BL and WW (0.26). According to body measurements, the HAC analysis subdivided the sheep population into three classes, which may refer to the effect of environmental factors.

Experiment 2. Barymetric characterization of the Ouled Djellal sheep breed reared in Northeast Algeria

1. Study framework

The study was conducted on two institutional farms: ITDAS (Institut Technique pour le Développement de l'Agronomie Saharienne - Technical Institute for the Development of Saharan Agronomy) located in Ain Ben Noui (Biskra) and ITELV (Institut Technique d'élevage - Technical Institute of breeding) located in Ain M'lila (Oum El Bouaghi Province) (Table 5) during the period from April to July 2022.

1.1. Presentation of the institutions

1.1.1. Presentation of the ITDAS

The Technical Institute for the Development of Saharan Agronomy "ITDAS" was created by decree N° 86 - 117 of 06/05/86 and modified by Decree N° 87 - 55 of 24/02/1987, fixing the headquarters in Biskra. Its main mission is to take charge of the various agricultural development programs in the Saharan zones.

1.1.2. Presentation of the ITELV Ain M'lila

In 1999 on February 13, under decree 99/42, the two ITEBO institutions (technical institute of cattle and sheep farming) and ITPE (technical institute for small livestock farming) were grouped into a single entity called the Technical Institute for breeding (ITELV). The ITELV of Ain M'lila specializes in producing future Ouled Djellal broodstock and operates according to a selection program in seven wilayas at the level of pilot farms.

2. Materials and methods

2.1. Animals

A total of 50 adult animals had a mean age of 3.95 ± 1.86 years, including 36 females and 14 males. They were subjected to body measurements. Table 13 lists the distribution of the number of animals in the ITDAS and ITELV.

Table 13. Distribution of animals' numbers in the ITDAS and ITELV.

	Number	
	Male	**Female**
ITDAS	2	11
ITELV	12	25

2.2. Herds conduct

2.2.1. Feeding management

- **At ITDAS**

Farm animals are brought out to pasture twice a day (once in the morning, a second in the evening). They are housed in a sheepfold at night and have access to fresh and clean water twice daily. The natural pastures consisted of a mixture of Stipa tenacissima, Amplelodesma tenax and Artemisia herba alba, and annual meadows composed of various types of grass (predominance of Cynodon dactylon, Melilotus sulcata and Vicia monantha). The animals received the same supplementation of commercial grain concentrate and good-quality hay. The amount of concentrate given differed according to the body condition score.

- **At ITELV**

ITELV produces part of its feed from its annual harvest (grain barley, alfalfa hay, oat hay and straw). The semi-intensive mode influences the feed program for the sheep. The food ration is made according to the season and the physiological stage of the animals, and it is given according to the availability of fodder and the supply of concentrated feed. The food calendar is divided according to the months of the year. It is based on fallow grazing in autumn (September-November), grazing on meadows in spring (March-May) and grazing on stubble and cereal residues in summer (June-August) with a supplement of 500g throughout the year.

A supplement of 30% is added during flushing and steaming-up. It consists of concentrated feed and good quality oat or barley hay. During mating, rams also benefit from a concentrated feed supplement of 500 to 800 grams plus good quality hay. At birth, milk is the main food of lambs during the first month of their life. From the second month, the lambs had at their disposal barley hay, a progressive supply of alfalfa hay and concentrated food, and the ration was adjusted according to the growth of the lambs.

2.2.2. Prophylaxis

- **At ITDAS**

Antiparasitic treatments are carried out regularly for the animals. They have been dewormed 4 times a year with anthelmintics and are systematically vaccinated against the most known diseases of the region, which are of origin: viral (sheep pox), bacterial (enterotoxaemia) and small ruminant plague.

- **At ITELV**

At the ITELV Farm, an internal deworming is done before each mating, and an external deworming is applied each summer with general bathing of the animals with organophosphates. The sheep were vaccinated against brucellosis in 2017, sheep pox depending on the vaccine availability, immunization against Clostridial toxi-infections from 2 months for first-age lambs and vaccination against the small ruminant plague. Vitamin supplementation is given to the animals in the different physiological stages of production (growth-lactation).

2.3. Barymetric characterization

Overall, 16 biometric variables were applied to the studied animals. Withers height (WH), back heigh (BH), rump heigh (RH) and chest depth (CD) measurements were made using a measurement stick. Head length (HL), head width (HW), ear length (AL), ear width (EW), chest width (CW), rump width (RW), body length (BL), heart girth (HG), cannon bone circumference (CC), tail length (TL) and tail circumference (TC) were taken with a tape measure (Table 14).

Due to the malfunctioning of livestock weighing in both consulting institutes, the value of body weight (BW) was predicted using a CREVAT formula proposed by Djaout et al. (2018). The CREVAT formula permits estimating the body weight of the Ouled Djellal sheep breed using simple linear body measurement of heart girth (HG in meters): $BW = 57.9\ HG^3$ (The partial R^2 for HG is 0.8584) (Djaout et al., 2018).

Table 14. Body measurements used in this study.

Measurement	Abbreviation	Definition
Head length	HL	Distance between the upper limit of the forehead to the tip of the nose (Harkat et al., 2015)
Head width	HW	Maximum distance between zygomatic arches (Harkat et al., 2015)
Ear length	EL	Distance from the base to the tip of the right ear, along the dorsal surface (Harkat et al., 2015)
Ear width	EW	the maximum distance at the middle of the ear (Kandoussi et al., 2021)
Body length	BL	Distance from the base of the tail to the base of the neck (Djaout et al., 2018)
Chest width	CW	The maximum intercostal diameter just behind the elbows (Kandoussi et al., 2021)
Rump width	RW	the maximum distance between the left and right hurls (Kandoussi et al., 2021)
Heart girth	HG	the perimeter of the chest just behind the front legs and the withers (Kandoussi et al., 2021)
Chest depth	CD	The distance from the brisket between the front legs to the withers (Kandoussi et al., 2021)
Tail length	TL	Distance from the point of attachment of the tail to the tip (Djaout et al.,2018)
Tail circumference	TC	The circumference of the base of the tail
Cannon bone circumference	CC	the smallest circumference of the cannon bone of the foreleg (Kandoussi et al., 2021)
Withers height	WH	Height from the top of the withers to the ground
Back height	BH	Height at the middle of the back (Popoola, 2015).
Rump height	RH	Height from the top of the rump to the ground (Harkat et al., 2015)
Body weight	BW	Live weighing

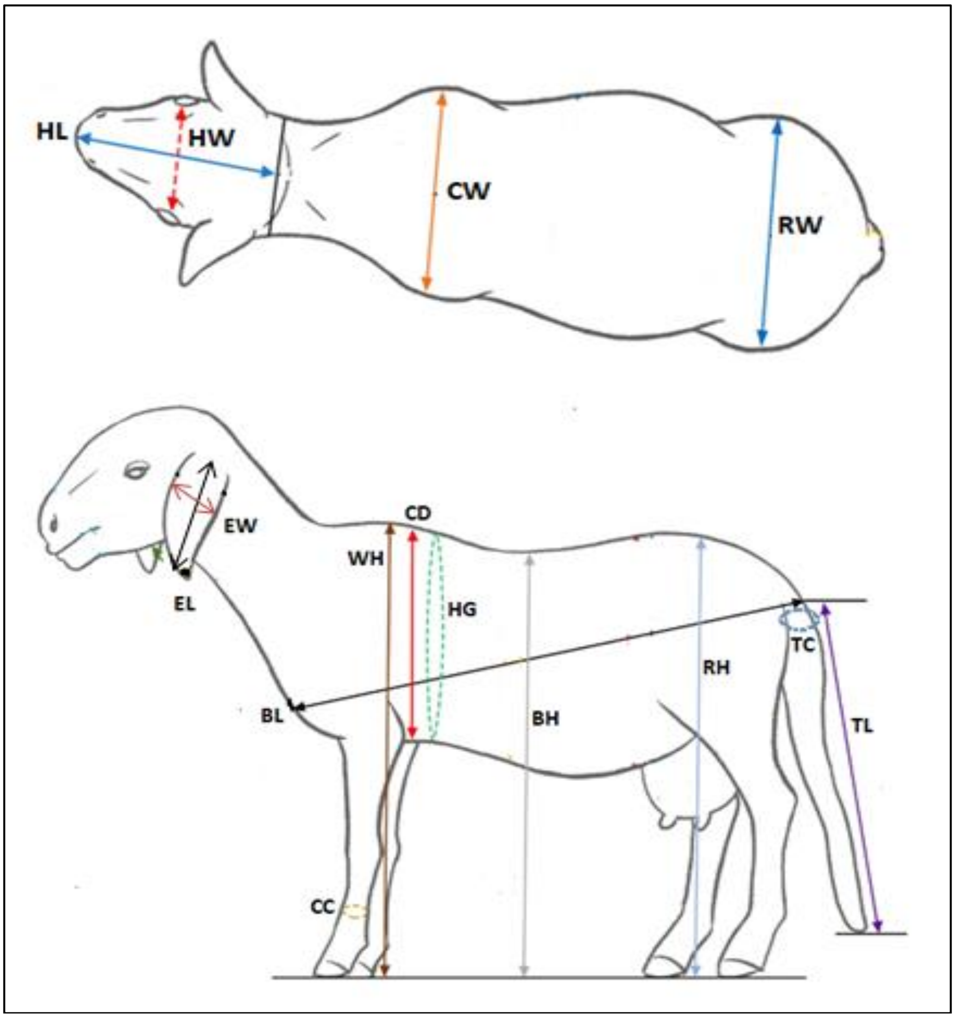


Figure 14. Position of body measurements. WH: withers height, BH: back heigh, RH: rump heigh, CD: chest depth, HL: head length (HL), HW: head width, EL: ear length, EL: ear width, CW: chest width, RW: rump width, BL: body length, HG: heart girth, CC: cannon bone circumference, TL: tail length and TC: tail circumference.

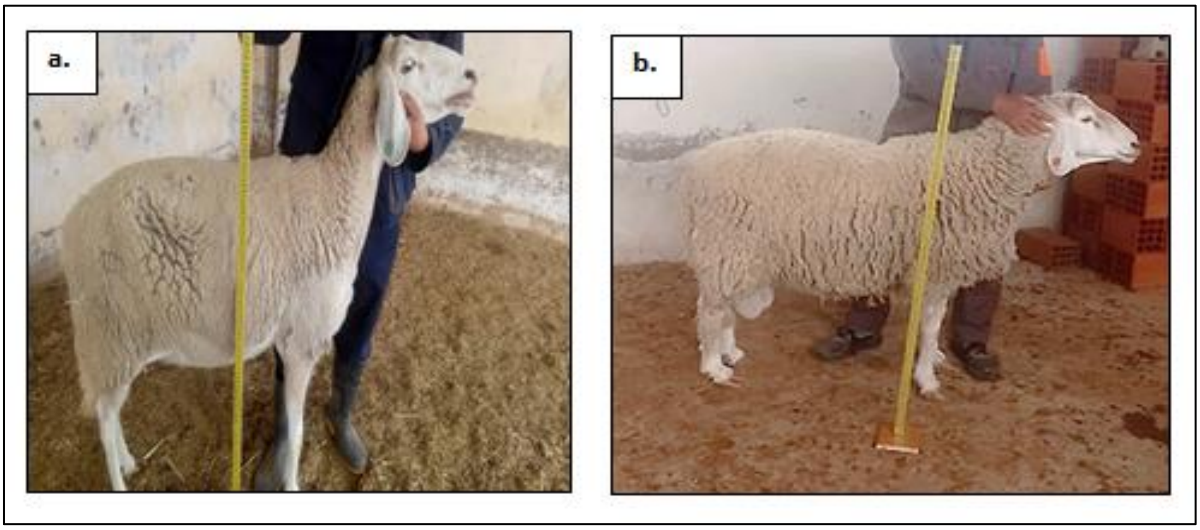


Figure 15. Photos of ram and ewe of Ouled Djellal breed taken in the ITDAS. a. Ram, b. Ewe (Personal photos).

2.4. Statistical analysis

The biometric data were processed using descriptive statistics (mean, standard deviation and coefficient of variation). ANOVA test was used to determine the influence of sex on the body measurements then data were subject to Pearson's correlation coefficient to determine the degree of a linear relationship between morphometric measurements. The statistical analyses were performed with the SPSS software, version 25.

3. Results and discussion

3.1. Body measurements analysis

Table 15 lists descriptive statistics of body measurements for combined and individual males and females and the significance level between them.

Table 15. Descriptive statistics of the morphological traits of the studied animals

	Male			Female			All			Significance level	
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)		
BW	70.86	23.55	33.23	54.58	10.30	18.87	59.14	16.65	28.16	0.001	**
HL	26.39	2.40	9.11	24.83	1.28	5.16	25.27	1.79	7.09	0.005	**
HW	16.32	0.82	5.04	13.72	1.21	8.82	14.45	1.62	11.19	0.0001	***
EL	17.86	1.80	10.09	18.00	1.54	8.53	17.96	1.60	8.89	0.780	NS
EW	8.75	0.78	8.89	8.94	0.54	6.09	8.89	0.62	6.94	0.322	NS
BL	99.14	8.42	8.49	85.61	6.03	7.05	89.40	9.08	10.16	0.0001	***
CW	20.29	4.23	20.86	17.61	2.05	11.62	18.36	3.04	16.53	0.004	**
RW	17.29	2.67	15.46	20.50	1.80	8.76	19.60	2.52	12.83	0.0001	***
HG	105.93	11.06	10.44	97.69	6.12	6.26	100.00	8.55	8.55	0.002	**
CD	41.71	4.53	10.86	38.31	2.40	6.27	39.26	3.46	8.81	0.001	**
TL	40.86	4.57	11.19	38.04	4.54	11.93	38.83	4.68	12.05	0.055	NS
TC	16.36	2.50	15.28	13.08	1.73	13.22	14.00	2.45	17.50	0.0001	***
CC	11.29	1.49	13.20	10.28	0.85	8.26	10.56	1.15	10.85	0.004	**
WH	83.29	5.95	7.15	80.44	3.07	3.82	81.24	4.22	5.19	0.031	*
BH	78.29	4.30	5.50	77.93	3.51	4.51	78.03	3.71	4.75	0.765	NS
RH	81.79	4.59	5.62	78.89	2.92	3.70	79.70	3.66	4.59	0.01	*

*** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$), NS- Non significant

WH: withers height, BH: back heigh, RH: rump heigh, CD: chest depth, HL: head length (HL), HW: head width, EL: ear length, EL: ear width, CW: chest width, RW: rump width, BL: body length, HG: heart girth, CC: cannon bone circumference, TL: tail length and TC: tail circumference.

According to the results summarized in Table 15, the average body weight (BW) of the Ouled Djellal breed studied was 59.14 ± 16.65 Kg with the highest coefficient of variation (28.16%), which explains the remarkable diversity of the weight among the animals studied. Similar findings were registered by Dekhili (2014) and Djaout et al. (2018) for the same breed which they recorded the highest coefficient of variation for BW, (34.3%) and (29.98%), respectively.

The heads of the Ouled Djellal animals were longer than wide (25.27±1.79 vs. 14.45±1.62 cm). The ears were long (17.96±1.60cm) and wide (8.89±0.62 cm). These results were identical to the finding of Belharfi et al. (2017) for the same breed, Djaout et al. (2014) for the Rembi breed and El-Belyahiaoui et al. (2021) for the Tazagzawt breed.

The body length (BL) was 89.40±9.08 cm. This measurement showed that the animals studied were more elongated than Hamra, Barbarine, Srandi, Daraa, Tazagzawt (Belharfi et al., 2017) and D'man breeds (Boubekeur et al., 2015) and less elongated than Ouled Djellal breed studied by Harkat et al. (2015) and Djaout et al. (2018) and Rembi breed (Laoun et al., 2015).

Withers height (WH), back height (BH), and rump height (RH) were found as 81.24±4.22 cm, 78.03± 3.71cm, and 79.70±3.66 cm, respectively. These showed that this animal was more in height than the Barbarine breed and lower than Hamra, Srandi, Daraa and Ouled Djellal breeds studied by Belharfi et al. (2017). In addition, these values showed that the back line of the Ouled Djellal breed studied was slightly sloping down from the back. Harkat et al. (2015) reported similar findings for the same breed, while El-Belyahiaoui et al. (2021) reported that the Tazagzawt breed presented a straight dorsal line following the equality between the wither's height and the rump height.

The animals had a developed thoracic cavity; the chest depth (CD) was 39.26±3.46 cm, and the heart girth (HG) was 100± 8.55 cm. The chest of these animals was more developed than Srandi and Tazagzawt breeds and less developed than Barbarine studied by Belharfi et al. (2017) and Ouled Djellal breed studied by Djaout et al. (2018). The chest width (CW) and the rump width (RW) are 18.36± 3.04 cm and 19.60±2.52 cm. the results showed that these animals were less large than Ouled Djellal breed studied by Harkat et al. (2015) and Tazagzawt breed (El-Belyahiaoui et al., 2021).

The circumference of the cannon bone (CC) was 10.56±1.15 cm which was greater than that of the Rembi (Djaout et al. 2015), Ouled Djellal, Srandi, Barbarine, Hamra, Darra and Tazagzawt breeds (Belharfi et al. 2017) while it was below than that of Ouled Djellal breed studied by Djaout et al. (2018). The tail length (TL) of the animals studied was 38.83±4.68, which is shorter than Ouled Djellal breed reported by Harkat et al. (2015) and the D'man breed (Boubekeur et al., 2015).

3.2. Effect of sex on body measurements

The body weight of male and female sheep was 70.86±23.55 and 54.58±10.30 Kg, respectively. The body weight was significantly ($p<0.001$) higher in males. The higher mean of body weight observed in males than females might be due to males' relatively large physical features due to natural hormonal variations (Popoola, 2015). The same estimate was found, for the same breed, by Djaout et al. (2018), whether Chellig (1992) reported a higher weight in females compared to males.

The head width, body length and tail circumference were higher in males than females, with a very high significant difference ($p<0.001$). The head length, chest width, heart girth, chest depth and cannon bone circumference highly differ between sexes ($p<0.01$). Weathers height significantly differed ($p<0.04$) between males and females, and the value of all mentioned characters was higher in males. Similar estimates were found by Belharfi et al. (2017) about Ouled Djellal, Hamra, Barbarine, Srandi, Daraa, and Tazagzawt breeds, Djaout et al. (2018) about the Ouled Djellal breed, Khaldi et al. (2011) about three Tunisian breeds and Kandoussi et al. (2021) about the Blanche de Montagne breed.

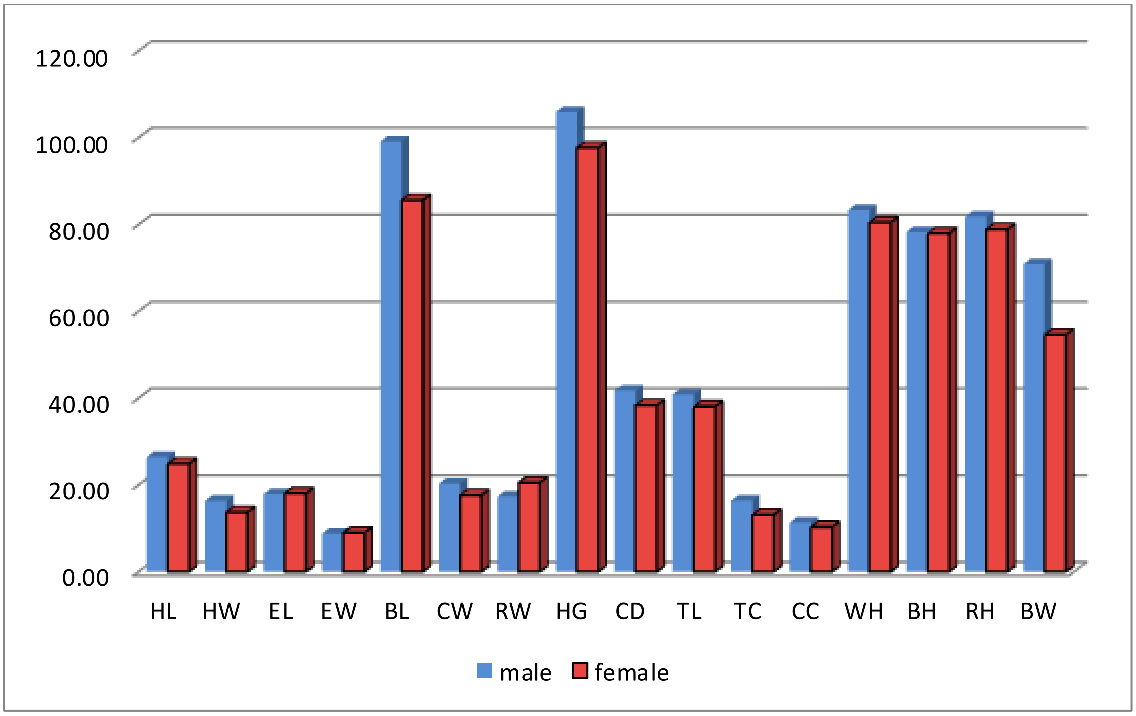


Figure 16. Differences in body measurements between males and females. WH: withers height, BH: back heigh, RH: rump heigh, CD: chest depth, HL: head length (HL), HW: head width, EL: ear length, EL: ear width, CW: chest width, RW: rump width, BL: body length, HG: heart girth, CC: cannon bone circumference, TL: tail length and TC: tail circumference.

3.3. Correlation Between body measurements

The correlation is one of the most common and useful statistics that describes the degree of relationship between two variables (Anila and Luan, 2021). The total correlation coefficients among all biometric measures for all animals are presented in Table 16. According to the results obtained, 71.66 % of the correlation coefficients were positive and significant, 55.83 % of these correlation coefficients were significant at the level of p<0.01 and 15.83 % at the level of p<0.05, indicating a strong morphological harmony of the breed. Stojiljkovic et al. (2015) concluded that positive correlation values among morphometric measurements indicate a balanced physical development and adaptation of the sheep breed to environmental conditions through evolution.

Only 7.5% of the correlation coefficients were negative between HW and ear EL, HW and EW, HW and RW, BL and RW, TL and RW, TC and RW, CD and EL, BH and EL and BL and EL.

The highest correlations were observed between BW and HG (0.99), BW and TC (0.83) and HG and TC (0.82). High correlations were observed between body length and all the other morphometric measurements (p<0.01) except with ear length, ear width and rump width.

Body weight was significantly correlated with all morphometric measurements except with rump width and tail length, in which the highest was, in addition to heart girth, tail circumference (0.83), withers height (0.77), head length (0.77) and cannon bone circumference (0.76). Several authors (Djaout et al., 2018; Anila and Luan, 2021) concluded that BW could be predicted from HG alone or in combination with other body measurements, which would be practical use under field conditions with reasonable accuracy.

Table 16. Pearson's correlation coefficients between body measurements of the studied sheep.

	HL	HW	EL	EW	BL	CW	RW	HG	CD	TL	TC	CC	WH	BH	RH	BW
HL	1															
HW	0.271	1														
EL	0.411**	-0.222	1													
EW	0.508**	-0.149	0.539**	1												
BL	0.508**	0.563**	-0.069	0.114	1											
CW	0.522**	0.463**	0.346*	0.278	0.535**	1										
RW	0.011	-0.226	0.016	0.287*	-0209	0.204	1									
HG	0.758**	0.258	0.369**	0.480**	0.568**	0.511**	0.066	1								
CD	0.430**	0.565**	-0.146	0.095	0.563**	0.462**	0.139	0.633**	1							
TL	0.299*	0.318*	0.026	0.177	0.474**	0.320*	-0.091	0.256	0.266	1						
TC	0.698**	0.464**	0.243	0.439**	0.642**	0.489**	-0106	0.826**	0.590**	0.340*	1					
CC	0.701**	0.340*	0.208	0.407**	0.659**	0.592**	0.171	0.742**	0.509**	0.298*	0.698**	1				
WH	0.689**	0.374**	0.120	0.426**	0.647**	0.581**	0.303*	0.732**	0.723**	0.362**	0.674**	0.712**	1			
BH	0.242	0.187	-0.026	0.300*	0.427**	0.319*	0.346*	0.345*	0.472**	0.116	0.286*	0.327*	0.663**	1		
RH	0.456**	0.503**	0.108	0.310*	0.619**	0.671**	0.193	0.531**	0.672**	0.359*	0.585**	0.591**	0.760**	0.668**	1	
BW	0.779**	0.289*	0.344*	0.500**	0.594**	0.524**	0.094	0.990**	0.647**	0.267	0.834**	.0768**	0.770**	0.386**	0.556**	1

** ($p<0.01$), * ($p<0.05$)

WH: withers height, BH: back heigh, RH: rump heigh, CD: chest depth, HL: head length (HL), HW: head width, EL: ear length, EL: ear width, CW: chest width, RW: rump width, BL: body length, HG: heart girth, CC: cannon bone circumference, TL: tail length and TC: tail circumference.

4. Conclusion

The barymetric study of the Ouled Djellal sheep breed permits us to conclude that:

- This breed is a morphologically homogeneous population;
- There is a sex dimorphism in which all body measurements, except ear length, ear width, tail length and rump height, were significantly higher in males than females;
- The body weight can be estimated by heart girth alone or in combination with other body measurements such as tail circumference, withers height, head length and cannon bone circumference.

Experimental 3. Growth dynamics and altitude effect on growth performance of Ouled Djellal lambs during the pre-weaning period.

1. Study framework

Seven sites (Tafrent, Tkout 1, Tkout 2, Barika, M'Sila, ITDAS and Ouled Djellal) (Table 5), distributed in four provinces (Batna, Biskra, Ouled Djellal and M'Sila), were chosen for the study of the growth performance of pre-weaned Ouled Djellal breed lambs.

2. Materials and methods

2.1. Animals

The study was conducted on 49 lambs of the Ouled Djellal breed, 7 of which were taken from each site (Tafrent, Tkout 1, Tkout 2, Barika, M'Sila, ITDAS and Ouled Djellal). These lambs were born singles from multiparous ewes (aged from 2 to 6 years) during the spring seasons. During the first month of the lamb's life, the mother's milk represents the main source of nutrition. From the second month, the lambs follow their mothers to the pasture until 4 months, when they will be weaned (see Experimental 1).

Table 17. Lamb studied.

Region	**Site**	**Altitude (m)**	**Number of studied lambs**	**Total**
High altitude	Tafrent	1400	7	21
	Tkout 1	1000	7	
	Tkout 2	1200	7	
Low altitude	Barika	450	7	28
	M'Sila	500	7	
	ITDAS	120	7	
	Ouled Djellal	250	7	

2.2. Growth parameters

Growth is assessed by monthly weighing of fasted lambs from birth to 4 months, as mentioned by Okere et al. (2011) and Titaouine (2015), to characterize the various phases of the growth of the lambs. The weight measurements were done using a 30 Kg portable scale. The measured weights are:

- Weight at birth (WB)
- Weight at D 30 (W1)
- Weight at D 60 (W2)
- Weight at D 90 (W3)
- Weight at D 120 (W4)

The average daily gains (ADGs) between these weights were calculated:

- Average daily gain between birth and D 30 (ADG 1)
- Average daily gain between D 30 and D 60 (ADG 2)
- Average daily gain between D 60 and D 90 (ADG 3)
- Average daily gain between D 90 and D 120 (ADG 4)

The criterion ADG1 (birth-D 30) is an indicator of the milk value of the mother, while the growth between D-30-60 was used as a criterion characterizing the precocity of the lamb and its growth abilities (El Bouyahiaoui, 2017).

2.3. Statistical analyses

Data were analyzed statistically for Min, Max, Mean, Standard Error and Standard Deviation. Pearson's correlation coefficient was calculated to assess the relationship between birth weight and weight at typical ages on hand and between the values of average daily gain on the other hand. In addition, an ANOVA test was applied to evaluate the effect of altitude on the different growth phases of lambs. The statistical analyses were performed with the SPSS software, version 25. Histograms were plotted using Excel.

3. Results and discussion

3.1. Statistical analysis by farm

3.1.1. Weight parameter

Table 17 presents the mean weight of typical lambs' ages on each consulted farm. Figure 17 shows that the highest birth weight and weight at D 30 were recorded in Ouled Djellal farm (3.90 and 10.79 Kg, respectively), while the lowest birth weight was recorded in Tkout 1 (3.19 Kg), the highest weight at D 60 was in Barika (16.01 Kg), the highest weight at D 90 was in M'Sila (19.10 Kg) and the highest weight at D 120 was registered for Barika lambs (25.71 Kg). The lowest weight at D 30, D 60, D 90 and D 120 were registered for Tafrent lambs (8.13, 10.66, 13.71 and 16.79 Kg, respectively).

Table 18. Average weight at the typical age of lambs from each farm.

	Tafrent	Tkout 1	Tkout 2	Barika	M'Sila	ITDAS	Ouled Djellal
Weight at birth	3.63	3.19	3.20	3.57	3.59	3.81	3.90
Weight at D 30	8.13	9.24	9.14	9.46	10.59	9.37	10.79
Weight at D 60	10.66	13.30	13.61	16.01	15.71	12.84	14.16
Weight at D 90	13.71	15.20	17.93	18.89	19.10	17.57	18.41
Weight at D 120	16.79	19.66	21.51	25.71	23.49	22.84	23.63

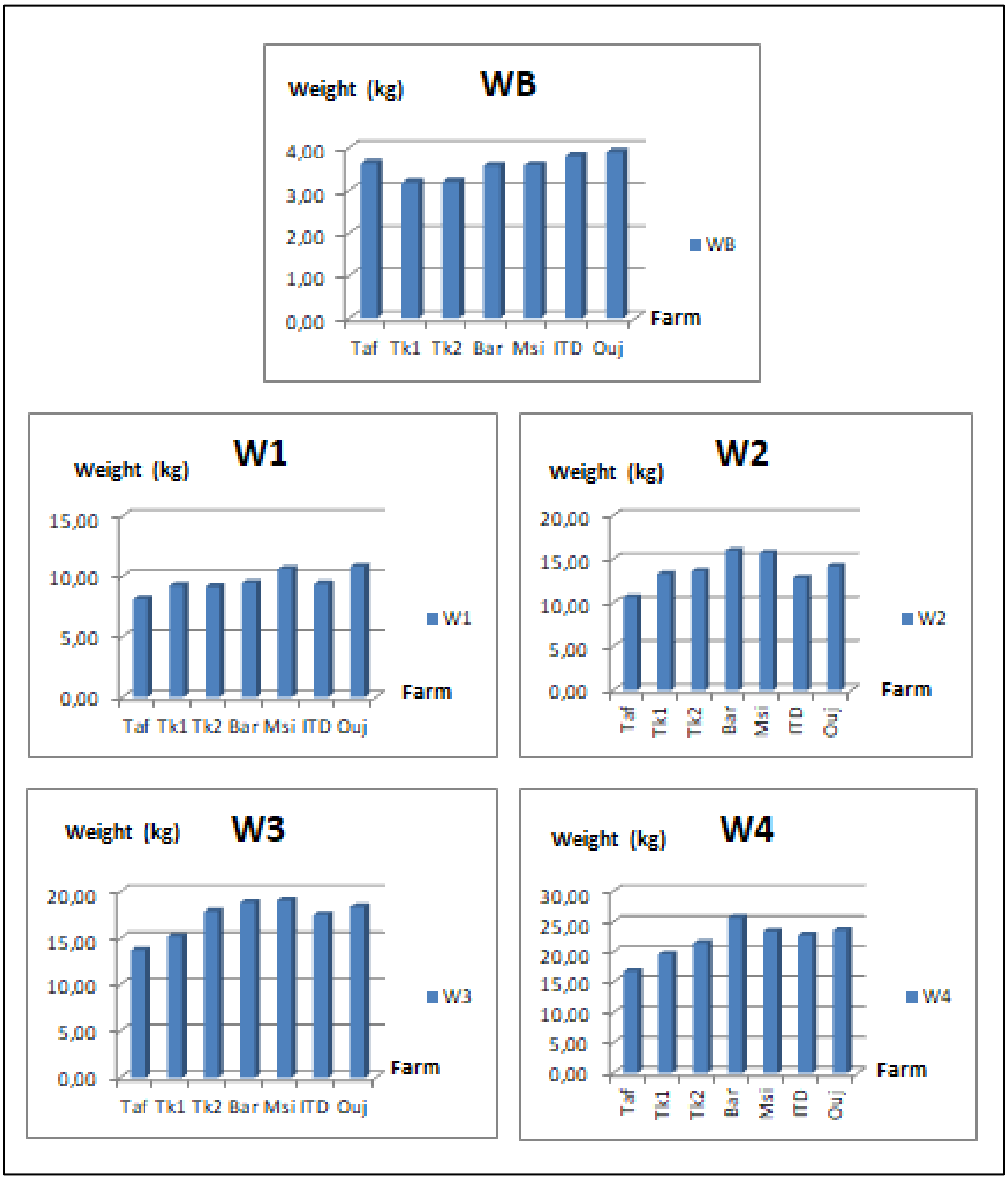


Figure 17. Histograms show the weight at typical ages for each site: birth weight (WB), D 30 (W1), D 60 (W2), D 90 (W3) and D 120 (W4). Taf: Tafrent. Tkt1: Tkout 1. Tkt2: Tkhout 2. Bar: Barika. ITD: ITDAS. Ouj: Ouled Djellal. Msi: M'Sila.

3.1.2. Average daily gain parameter

The mean of the average daily gain of each farm is listed in Table 18. The highest ADG 1 was remarked in M'Sila and Ouled Djellal farms, the highest ADG 2 and ADG 4 were remarked in Barika farm, and the highest ADG 3 was found in ITDAS. The lowest ADG 1, ADG 2 and ADG 4 were registered in Tafrent farm, and the lowest ADG 3 was found in Tkout 1.

Table 19. Mean of average daily gain (ADG) of each farm.

ADG (g/d)	Tafrent	Tkout 1	Tkout 2	Barika	M'Sila	ITDAS	Ouled Djellal
ADG1	150	200	200	200	230	180	230
ADG2	80	140	150	220	170	110	110
ADG3	100	60	140	100	110	160	140
ADG4	100	150	120	230	150	180	170

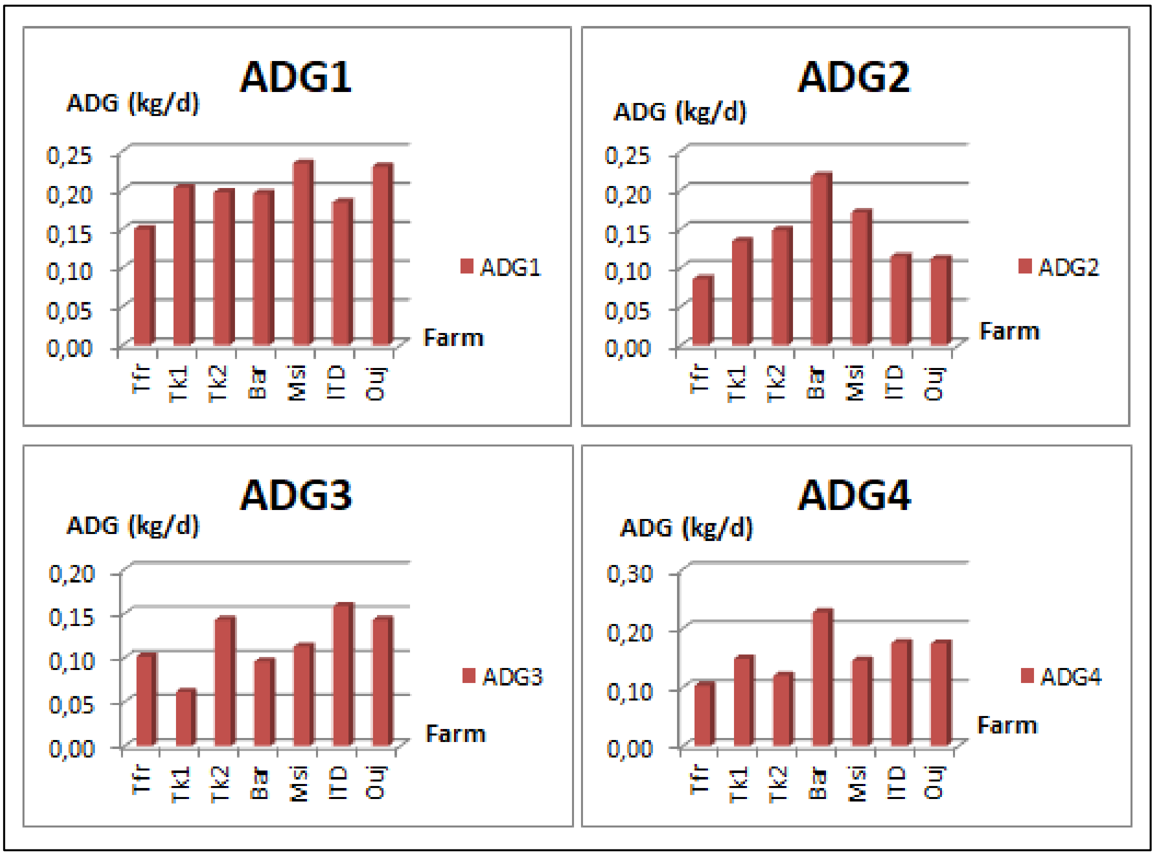


Figure 18. Histograms show the average daily gain (ADG) for each site: ADG1 (birth-D 30), ADG2 (D 30-60), ADG3 (D 60-90) and ADG4 (D 90-120). Taf: Tafrent. Tkt1: Tkout 1. Tkt2: Tkhout 2. Bar: Barika. ITD: ITDAS. Ouj: Ouled Djellal. Msi: M'Sila.

3.2. Global statistical analysis

3.2.1. Weight parameter

The studied lambs were born with an average weight of 3.56 Kg, reaching 9.53 Kg at D 30, 13.76 Kg at D 60, 17.26 Kg at D 90 and 17.26 Kg at D 120 (Table 19). The result obtained for the weight at birth in this study was almost similar to those obtained by Chellig (1992) for the lamb of the same breed (3.5 Kg), Benyounes et al. (2013) for the lamb of the Ouled Djellal and Taadmit breed (3.64 and 3.55 Kg respectively) and Ziani and Khaled (2016) for Hamra breed (3.57 Kg). Several studies reported superior birth weight values for lambs of the Ouled Djellal breed born in autumn. Deghnouche et al. (2018), Djellal et al. (2015), Smaali and Boukazoula (2019), and Boussena et al. (2020) recorded values of 4.19, 5.54, 4.38 and 4.5 Kg, respectively. The same results were found by Benchohra et al (2013), who registered a value of 4.20 Kg at birth for the lamb of the Rembi breed.

The birth weight obtained was higher than the value reported by Zidane et al. (2015) for the Ouled Djellal breed lamb and Kerfal et al. (2005) for the D'man breed lamb (3.04 and 2.6 Kg, respectively). The difference in the weight at birth observed, whether within the same sheep breed or between different breeds, can be explained by the ability of WB to be influenced by genotypic factors (Khama et al, 2022) and productive factors such as the sex of the lamb, type of birth, age and parity of the ewe, season and year of birth. Research done on this subject has shown that male lambs and lambs born single are considerably heavier than female lambs and lambs born doubles (Chniter et al., 2011; Zidane et al., 2015; Deghnouche et al., 2018; Baa et al., 2020; Sveinbjörnsson et al., 2021; Tesema et al., 2022). Older ewes give birth to heavier lambs than youngest ewes (Dekhili, 2003; Chniter et al., 2011; Zidane et al., 2015; Sveinbjörnsson et al., 2021). Lambs born from multiparous ewes are heavier at birth than lambs from primiparous ewes (Baa et al., 2020). Moreover, the weight at birth can differ according to the year of birth (Dekhili, 2003; Djellal et al., 2015; Tesema et al., 2022). For the season of birth, Chniter et al. (2011) found that lambs born in spring were heavier than those born in autumn, whereas Dekhili (2003) found the opposite.

Table 20. Global descriptive statistics of body weight on Kg.

Variable	Minimum (Kg)	Maximum (Kg)	Mean (Kg)	Std. Error	Std. Deviation
Weight at birth	3.19	3.90	3.56	0.10	0.27
Weight at 30 d	8.13	10.79	9.53	0.34	0.91
Weight at 60 d	10.66	16.01	13.76	0.68	1.81
Weight at 90 d	13.71	19.10	17.26	0.77	2.03
Weight at 120 d	16.79	25.71	21.95	1.11	2.95

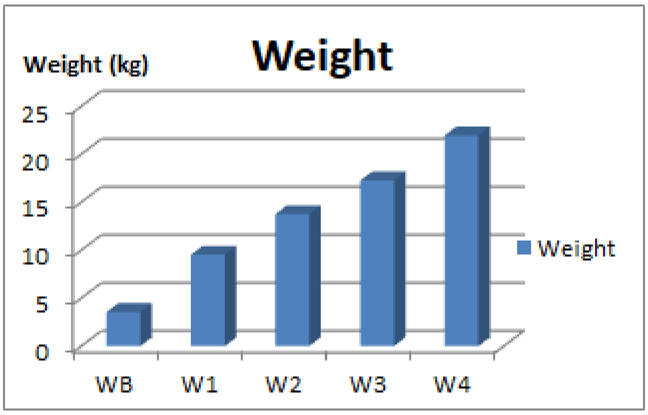


Figure 19. Global average weights of lamb. WB: weight at birth, W1: weight at D 30, W2: weight at D 60, W3: weight at D 90, W4: weight at D 120.

3.2.2. Average daily gain parameter

The average daily gain recorded in this study was 200 g/d for ADG1, 140 g/d for ADG2, 120 g/d for ADG3 and 160 g/d for ADG4 (Table 20). This result indicates that the maximum growth occurred in the first D 30 of lamb life, which could be explained by the sufficient milk supply given by ewes to lambs. The high decrease in average daily gain noted after the first month of lamb's life was closely related to the transitional phase from suckling to grazing, which enters the lambs in a competition situation for feed. The slight increase in average daily gain remarked after D 90 of age might be due to the adaptation of lambs to feeding practice. This finding is in concordance with those reported by Zidane et al. (2015) and Baa et al. (2020) for Ouled Djellal breed lamb and Chniter et al. (2011) and Boubakeur et al. (2019) for the D'man breed lamb. However, Boujenane and Kerfal (1992) reported a low daily gain from 10 to D 30 of age.

Table 21. Global descriptive statistics of average daily gain (ADG, g/d).

Variable	Minimum (g/d)	Maximum (g/d)	Mean (g/d)	SE	SD
ADG1	150	230	200	0.01	0.03
ADG2	90	220	140	0.02	0.04
ADG3	60	160	120	0.01	0.03
ADG4	100	230	160	0.02	0.04

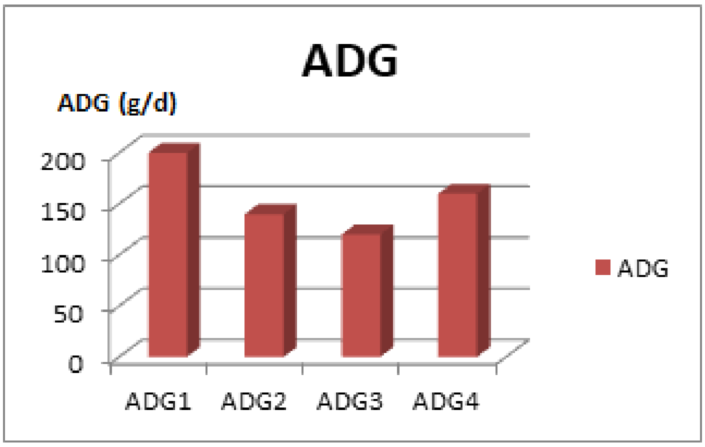


Figure 20. Global means of average daily gain of lambs. ADG1: birth-D 30, ADG2: D 30-60, ADG3: D 60-90, ADG4: D 90-120.

3.3. Correlation between parameters

3.3.1. Weight parameter

Correlation coefficients among birth weight and weight at D 30, 60, 90 and 120 ranged between -0.002 and 0.94 (Table 21). Highly positive and significant correlations can be noted between weight at D 90 and 120 (0.94), between weight at D 60 and 120 (0.88), between weight at D 60 and 90 (0.87) and between weight at D 30 and 90 (0.77). Moreover, correlation coefficients are low but positive between birth weight with weight at D 30, weight at D 90, and weight at D 120 (0.38, 0.24 and 0.31, respectively). In contrast, Deghnouche et al. (2018) reported a significant correlation between weight at birth and the mean weights observed at D 10, 20, 30 and 90 (0.56, 0.57, 0.54 and 0.63, respectively).

Table 22. Pearson correlations of body weights of Ouled Djellal breed lambs.

	WB	W1	W2	W3	W4
WB	1	0.382	-0.002	0.243	0.314
W1		1	0.719	0.773*	0.710
W2			1	0.873*	0.886**
W3				1	0.943**
W4					1

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).
WB: weight at birth, W1: Weight at D 30, W2: weight at D 60, W3: weight at D 90, W4: weight at D 120

3.3.2. Average daily gain parameter

The correlation coefficients among ADG1, ADG2, ADG3 and ADG4 ranged between -0.21 and 0.63 (Table 22). A moderate correlation was found between ADG1 and ADG2 (0.41) and ADG2 and ADG4 (0.63). The rest of the correlations were weak to negligible except for ADG2 and ADG3, which was negative (-0.21). Compared to the study of Deghnouche et al. (2018) on the same breed of lamb, a significant correlation (P= 0.002) was found between ADG at D 30 and ADG at D 90 (0.64).

Table 23. Pearson correlation among the values of the average daily gain (ADG).

	ADG1	ADG2	ADG3	ADG4
ADG1	1	0.417	0.081	0.362
ADG2		1	-0.213	0.631
ADG3			1	0.072
ADG4				1

3.4. Aanalysis of variance of weights and gains

Figures 21 and 22 show the effect of altitude on the growth performance of Ouled Djellal lambs in the pre-weaning period. Lambs born in low-altitude regions have bigger body weights and average daily gain values than those born in high-altitude. Lenfant (1973) found that the reduction in birth weight observed in high-altitude regions may be explained by intrauterine growth retardation caused by hypoxia. A significant ($p < 0.05$) difference can be noted in W3 and W4, which confirms the description of several authors for the Ouled Djellal breed, who were unanimous in classifying it as a real steppe sheep and the most adapted to nomadism (Kerboua et al, 2003).

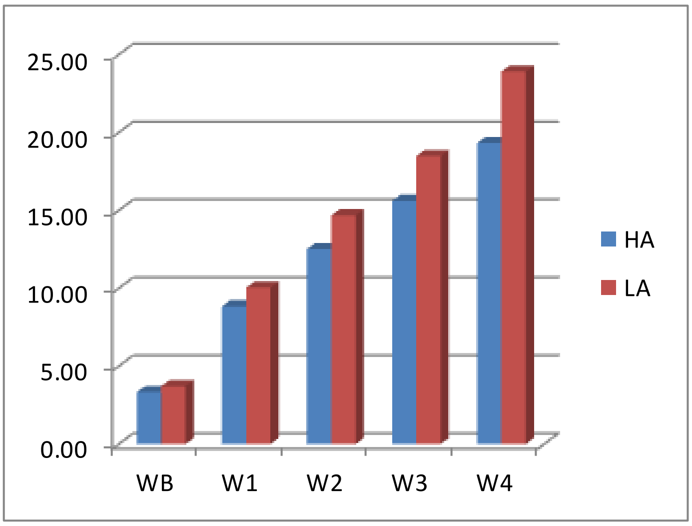


Figure 21. Difference of lambs' weights at typical ages (Kg) between high altitude and low altitude regions, HA: high altitude, LA: law altitude, WB: weight at birth, W1: weight at D 30, W2: weight at D 60, W3: weight at D 90, W4: weight at D 120.

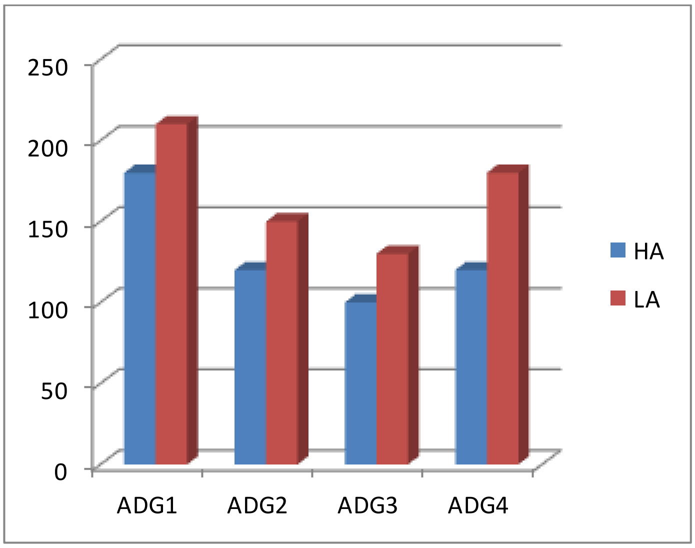


Figure 22. Difference in Average Daily Gain (ADG, g/d) between high altitude and low altitude region, HA: high altitude, LA: law altitude, ADG1: birth-D 30, ADG2: D 30-60, ADG3: D 60-90, ADG4: D 90-120.

Table24. Results of the analysis of variance of body weights

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
WB	Between Groups	0.244	1	0.244	5.927	0.059
	Within Groups	0.206	5	0.041		
	Total	0.450	6			
W1	Between Groups	2.534	1	2.534	5.271	0.070
	Within Groups	2.404	5	0.481		
	Total	4.938	6			
W2	Between Groups	7.974	1	7.974	3.395	0.125
	Within Groups	11.742	5	2.348		
	Total	19.715	6			
W3	Between Groups	14.211	1	14.211	6.738	**0.048**
	Within Groups	10.545	5	2.109		
	Total	24.756	6			
W4	Between Groups	36.235	1	36.235	11.357	**0.020**
	Within Groups	15.952	5	3.190		
	Total	52.187	6			

4. Conclusion

This experiment studied the growth dynamics and the effect of altitude on different growth phases of pre-weaned Ouled Djellal lambs from northeastern Algeria. The findings indicate that:

- during the pre-weaning period, the maximum gain weight of the Ouled Djellal lamb occurred in the first D 30;
- the highest and most significant correlation coefficients were recorded between W3 and W4, W2 and W4, W2 and W3 and W1 and W3;
- lamb born in low altitude regions has a better growth performance than a lamb born in high altitude regions, with a significant difference in W3 and W4.

General conclusion

This study aimed to contribute to the phenotypic characterization of sheep populations in northeastern Algeria, to determine the dynamics and growth performance of pre-weaned lambs in this region and to evaluate the effect of altitude on growth performance. In the first part of the study, the result of the quantitative and qualitative characteristics indicates that the sheep population of this area belongs to the Ouled Djellal sheep breed with some variabilities due to the effect of uncontrolled crossbreeding among local breeds. The variation coefficient of the body measurement shows moderate values for the body. The highest reported value for WW is 7.37%. The correlation analysis revealed the presence of a clear correlation between WH and TL (0.30) and BL and WW (0.26). According to body measurements, the HAC analysis sub-divided the sheep population into three classes, which may refer to the effect of environmental factors.

The Ouled Djellal sheep breed is typical of the steppe and high plateaus. Its presence in the mountain region (Aures) means that this breed circulates in different national territories, which confirms the good adaptation of this breed to harsh environmental conditions. Moreover, the geographical expansion of this breed leads to a reduction of their body size, resulting from crossbreeding with other local sheep breeds, thus contributing to the problem of marginalization or, worse, the extinction of other breeds.

In the second part of the study, the barymetric study's result reveals that the sheep of the Ouled Djellal breed is a morphologically homogeneous population with superior, in almost body measurement, for males. Pearson's correlation coefficients show that body weight can be estimated by heart girth alone or combined with other body measurements such as tail circumference, withers height, head length and cannon bone circumference. Therefore, further molecular characterization is recommended to back up the present finding. Using a combination of phenotypic and genetic tools will help to develop effective conservation and improvement programs.

The results of the third part of the study indicate that the maximum gain weight of pre-weaned Ouled Djellal lambs occurred in the first month of lamb life. Pearson's correlation coefficient analysis shows that the highest and most significant correlation coefficients were recorded between D 90 and D 120 (0.94), D 60 and D 120 (0.88), D 60 and D 90 (0.87) and D 30 and D 90 (0.77). Analysis of variance of weights and gains revealed that lambs born in low altitude regions have a better growth performance than lambs born in high altitude regions, with a significant difference in D 90 and D 120. This result confirms that Ouled Djellal breed is a steppe and high plain breed par excellence. Therefore, to have a good knowledge of the growth performance of this breed, it is necessary to study the other factors, genetic or not, which can influence the growth dynamic.

References

Abdurehman, A. (2019). Origin, domestication, current status, trend, conservation and management of sheep genetic resource in Africa with specific reference to Ethiopia. *Adv Life Sci Technol*, 71, 8-14.

Afri-Bouzebda, F., Djaout, A., Bouzebda, Z., Belkhiri, Y. (2018). Barymetry of five Algerian sheep breeds. *Livestock Research for Rural Development*, 30(4),1-14.

Ahozonlin, M.C., Dossa, L.H., Dahouda, M., Gbangboche, A.B. (2020). Morphological divergence in the West African shorthorn Lagune cattle populations from Benin. *Tropical Animal Health and Production*, 52(2), 803-814.

Akbar, M.A., Javed, K., Faraz, A., Waheed, A. (2021). Principal Component Analysis of Morphometric Traits Explain the Morphological Structure of Thalli Sheep. *Pak J Zool*, 54(1), 207-212. https://dx.doi.org/10.17582/journal.pjz/20200220060257.

Aliat, T. (2017). Doctorate Thesis. Les écosystèmes humides des hautes plaines orientales algériennes Biodiversité : Préservation et Valorisation.Ferhat Abbas University, Setif 1. 116p.

Aliyari, D., Moeini, M.M., Shahir, M.H., Sirjani, M.A. (2012). Effect of body condition score, live weight and age on reproductive performance of Afshari ewes. *Asian Journal of Animal and Veterinary Advances*, 7, 904–909.

Allouche, L., Belkasmi, F., Madani, T., Semara, L., and Mouffok, C. (2011). Effect of the maternal behavior of the Ouled Djellal ewe in the presence of the shepherd on the growth, mortality and neonatal behavior of the lambs, *Rencontres Recherches Ruminant*, 18, 104.

Al-Sabbagh, T.A., Swanson, L.V., Thompson, J.M. (1995). The effect of ewe body condition at lambing on colostral immunoglobulin-g concentration and lamb performance. *Journal of Animal Science*, 73, 2860–2864.

A.N.A.T. (2004). National Agency for Spatial Planning. Bioclimatic map of Algeria.

Anila, H., Luan, H. (2021). Body measurements of Bardhoka sheep breed from Albania. *Acta Biologica Turcica*, 34(3), 122-127.

Baa, A., Bara, Y., Laalam, L.B. and Bensbaa, W. (2021). Factors influencing the growth of Ouled Djellal "Hodna type" lambs in the wilaya of Setif (Algeria). *Livestock Research for Rural Development*, 32.

Bakroune, N. (2021). Doctorate thesis. L'entomofaune des céréales dans la région de Biskra. Ecologie des populations des principaux bioagrésseurs. Mohamed Khider University, Biskra, 141p.

Bansal, G. K., Kumar, V., Nagda, R. K., & Hada, R. (2022). Factors affecting average daily gain in Sonadi sheep. *Indian Journal of Small Ruminants*, 28(1), 20-23.

Belaib, I. (2012). Magisterium thesis: Morphological characterization of sheep herds in the Sétif region. Ferhat Abbas University, Setif 1, 160 p.

Belharfi, F. Z., Djaout, A., Ameur, A. A., & Gaouar, S. B. S. (2017). Barymetric characterization of Algerian sheep breeds in Western Algeria. *Genetics & Biodiversity Journal*, 1(2), 31-41.

Belkasmi, F. (2021). Doctorate thesis: Modeling of reproduction, growth and productivity performances of sheep farming in the semi-arid region of Algeria : Case study of "Yehia Ben Aichouche farm". Ferhat Abbas University, Setif 1, 106 p.

Benchohra, M., Amara, K., Hemida, H., Kalbaza, A.Y. and Aggad, H., (2013). Assessing dairy potential and lamb growth performance in Algerian Rembi sheep. *Livestock Research Rural Development*, 25.

Bendiab, N., Dekhili, M. (2012). Factors influencing the growth of lambs in northeastern Algeria. *Agriculture Review*, 04, 03-04.

Benikhlef, R., Aoun, K., Boudrissa, A., Ben Abid, M., Cherif, K., Aissi, W., Benrekta, S., Boubidi, S.C., Späth, G.F ,Bouratbine, A., Sereno, D., & Harrat, Z. (2021). Cutaneous Leishmaniasis in Algeria; Highlight on the Focus of M'Sila. *Microorganisms*, 9(5), 962.

Belhouadjeb, F.A. (2009). Magisterium thesis: Analyse de la compétitivité de la filière ovine algérienne :Cas des éleveurs de la wilaya de Djelfa. National Superior School of Agronomics (ENSA) El-Harrach – Algiers, 114p.

Berkane, A., Yahiaoui, A. (2007). Erosion in the Aurès. Drought, 18 (3), 213-6.

Benyounes, A., Rezaiguia, M., Lamrani, F. (2013). Effect of lambing season on lamb mortality in Ouled Djellal and Taâdmit sheep breeds reared in northeastern Algeria. Agriculture, 4, 5-9.

Blench, R., Kevin C.M. (1999). The Origins and Development of African Livestock. Routledge. ISBN 1-84142-018-2.

Bökönyi, S. (1969). The Domestication and Exploitation of Plants and Animals. *Ucko, P. J., & Dimbleby, G.W. (Eds.).* London: Duckworth.

Bökönyi, S. (1977). The animal remains from four sites in the Kermanshah Valley, Iran: Asiab, Sarab, Dehsavar and Siahbid. *Oxford: British Archaeological Reports, Supplementary Series*, 34.

Boubekeur, A., Benyoucef, M.T., Lounassi, M., Slimani, A., Amiali, M. (2015). Phenotypic characteristics of algerian d'man sheep breed in adrar oases. *Livestock Research for Rural Development*, 27(7):1–6.

Boudjelal, A., Henchiri, C., Sari, M., Sarri, D., Hendel, N., Benkhaled, A., & Ruberto, G. (2013). Herbalists and wild medicinal plants in M'Sila (North Algeria): An ethnopharmacology survey. *Journal of ethnopharmacology*, 148(2), 395-402.

Boudjelal, A. (2013). Doctorate thesis: Extraction, identification and determination of the biological activities of some active extracts of spontaneous plants (Ajuga iva, Artemisia herba alba and Marrubium vulgare) from the region of M'Sila, Algeria. Badji Moktar University, Annaba, 60p.

Boujenane, I. and Kerfal, M. (1992). Estimation de la production laitiere des brebis D’man. *Al Awamia* 78, 145-155.

Boussena, S., Dahmane, A., Zerrougui, S., Hireche, S. and Bouaziz, O. (2020). Relationship between body and testicular measurements in Ouled Djellal lambs before puberty. *Livestock Research for Rural Development*, 32.

Bouzaher, S. L., & Alkama, D. (2013). The requalification of the palm trees of Ziban as a tool for sustainable planning. *Procedia-Social and Behavioral Sciences*, 102, 508-519.

Chekkal, F., Benguega, Z., Meradi, S., Berredjouh, D., Boudibi, S., Lakhdari, F. (2015). Guide to the phenotypic characterization of Algerian sheep breeds. *CRSTRA edition*. 53p.

Chellig, R. (1992). Algerian sheep breeds. *Ben aknoun University Publications Office*.

Chemmam, M., Moujahed, N., Ouzrout, R., & Kayouli, C. (2009). Performance variations in the "Ouled Djellel" ewe on pasture in the South-East of Algeria: Effects of season and supplementation. *Livestock Research for Rural Development*, 21(6).

Chessa, B., Pereira, F., Arnaud, F., Amorim, A., Goyache, F., Mainland, I., ... & Palmarini, M. (2009). Revealing the history of sheep domestication using retrovirus integrations. *Science*, 324(5926), 532-536.

Chikhi, A., & Boujenane, I. (2005). Fattening performance and carcass characteristics of Boujaad and Sardi lambs in Morocco. *Ele Vét*, 58(4), 267-272.

Chniter, M., Hammadi, M., Khorchani, T., Krit, R., Lahsoumi, B., Sassi, M.B. and Hamouda, M.B. (2011). Phenotypic and seasonal factors influence birth weight, growth rate and lamb mortality in D’man sheep maintained under intensive management in Tunisian oases. *Small Ruminant Research*, 99, 166-170.

Clutton-Brock, J. (1979). The mammalian remains from the Jericho Tell. *Proc. Prehist. Soc.* 45: 135-157.

Clutton-Brock, J. (1992). The process of domestication. *Mammal review*, 22(2), 79-85.

Corner-Thomas, R. A., Hickson, R. E., Morris, S. T., Back, P. J., Ridler, A. L., Stafford, K. J., & Kenyon, P. R. (2015). Effects of body condition score and nutrition in lactation on twin-bearing ewe and lamb performance to weaning. *New Zealand journal of agricultural research*, 58(2), 156-169.

Craplet, C. and Thibier, M. (1984). Le Mouton, *Vigot (eds), Paris*, 568p.

D.A.S. (2017). Directorate of agricultural services of the wilaya of M'Sila. Statistics office.

Dekhili, M. (2003). Relationship between the birth weight of lambs (Ouled-Djellall) and the weaning rate at 90 days. *Renc. Rech. Ruminants*, 10, 116.

Dekhili, M. (2014). A morphometric study of sheep reared in North-East Algerian. *Archivos de zootecnia*, 63(244), 623-631.

Djaout, A., Afri-bouzebda, F., Bouzebda, Z., Routel, D., Benidir, M., Belkhiri, Y. (2015). Morphological characterization of the Rembi sheep population in the Tiaret area (West of Algeria). *Indian Journal of Animal Sciences*, 85 (4), 386–391. http://epubs.icar.org.in/ejournal/index.php/IJAnS/article/view/47821

Djaout, A., Afri-Bouzebda, F., Chekal, F., El-Bouyahiaoui, R., Rabhi, A., Benidir, M., Ameur Ameur, A., Gaouar, S.B.S. (2017). Biodiversity state of Algerian sheep breeds. *Genetics and Biodiversity Journal*, 1(1), 11–26.

Djaout, A., Afri-Bouzebda, F., Bouzebda, Z., Benidir, M., & Belkhiri, Y. (2018). Application of linear body measurements for predicting live weight in Ouled Djellal breed. *Indian Journal of Animal Sciences*, 88(8), 966-971.

Djellal, F., Kadi, S.A., Mouhous, A., and Berchiche, M. (2015). Effect of birth season and sex on growth before weaning of lambs of the Ouled Djellal breed (Algeria). In Seminar of the Subnetworks on Nutrition and on Production Systems of the FAO-CIHEAM Network for Research and Development in Sheep and Goats.

Deghnouche, K., Cherif, B.N., and Boukhalfa, H.H. (2018). Evaluation Of Growth Performance Of Ouled Djellal Lambs By Sex And Litter Size In A Semi-Arid Region Of Algeria. *Comm. Appl. Biol. Sci, Ghent University*, 83, 84-87

Desbois, A.C.M. (2008). Doctorate thesis: Contribution to the study of an Irish breed: the Galway sheep, 72p.

Digard, J-P. (2009). Man and domestic animals. Fayard: Anthropology of a Passion, 325 p

DPSB-Biskra. (2019). Directorate of programming and budget monitoring of the wilaya of Biskra (2019) Monograph of the wilaya of Biskra, Algeria, 203 p.

Driscoll, C.A., MacDonald, D.W., O'Brien, S.J. (2009). From wild animals to domestic pets, an evolutionary view of domestication. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 9971-9978

Dudouet, C. (1997). La production d mouton. *France Agricole Editions*, 2nd edition, 287 p

Dwyer, C.M. (2008). Environment and the sheep, in C.M. Dwyer (ed.) The welfare of sheep: Dordrecht, *Springer*, 41-79.

El Bouyahiaoui, R., Arbouche, F., Ghozlane, F., Moulla, F., Belkheir, B., Bentrioua, A., Hidra, H., Mansouri, H., IguerOuada, M., Bellahreche, A. and Djaout, A. (2015). Distribution and phenotype of the Blue sheep breed of Kabylia or Tazegzawt (Algeria). *Livestock Research for Rural Development* 27 (10).

El Bouyahiaoui, R. (2017). Doctorate thesis: Morphogenetic characteristics and zootechnical performances of the “TAZEGZAWT” sheep breed endemic to Kabylia, National Superior School of Agronomics (ENSA) El-Harrach – Algiers, 174p

El Fadili, M. (2004). Factors of variation and crossbreeding performances of the Boujâad sheep breed. I. Reproductive traits, viability and pre-weaning growth. *Awamia*, 111, 101-116.

Elfegoun, M. C. B., Gharbi, M., & Kohil, Z. M. K. (2017). Bovine piroplasmosis in the provinces of Skikda and Oum El Bouaghi (Northeastern Algeria): Epidemiological study and estimation of milk yield losses. Journal of animal breeding and veterinary medicine in tropical countries, 70(3), 105-110.

Epstein, H. (1971). The origin of domestic animals of Africa. Vol. 2. New York, USA: *Africana Publication Corporation*

Ewens, W. J. (1982). On the concept of the effective population size. Theoretical Population *Biology*, 21(3), 373-378.

FAO (Food and Agriculture Organization). (1999). The global strategy for the management of animal genetic resources: executive brief. Initiative for Domestic Animal Diversity, ISBN: 92-5-104267-5, Rome, 46p

FAO. (2012). Phenotypic characterization of animal genetic resources. FAO animal production and health guidelines., No. 11. Rome, 134p.

FAO. (2017). sheep flock statistics 1961–2017. FAOSTAT online statistical databases, updated on: 20 December 2018, [8 octobre 2019]. http://www.fao.org/faostat/fr/ [Google Scholar]

Fournier, A. (2006). Sheep farming, Editions Artémis, France.

Fraysse, J.L., Guitard, J.P. (1992). Produce sheep meat. Editions France Agricole, Paris, 220p.

Gaouar, S. B. S., Lafri, M., Djaout, A., El-Bouyahiaoui, R., Bouri, A., Bouchatal, A., ... & Da Silva, A. B. (2017). Genome-wide analysis highlights genetic dilution in Algerian sheep. *Heredity*, 118(3), 293-301.

Geist, V. (1991). On the taxonomy of giant sheep (Ovis ammon Linnaeus, 1766). *Can. J. Zool*, 69: p. 706–723.

Gizaw, S., Van-Arendonk, J.A., Komen, H., Windig, J.J, Hanotte, O. (2007) Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Animal Genetics*, 38(6), 621-628.

Gowane, G.R., Prince, L.L.L., Lopes, F.B., Paswan, C. and Sharma, R.C. (2015). Genetic and phenotypic parameter estimates of live weight and daily gain traits in Malpura sheep using Bayesian approach. *Small Ruminant Research* 128, 10-18

Grubb, P. (2005). Order Artiodactyla, in Mammal Species of the World: A Taxonomic and Geographic Reference, D.E. Wilson, Reeder, D.M., *Editor. Johns Hopkins University Press*. p. 267-722.

Hadbaoui, I, Senoussi H, Huguenin J. Feeding methods for sheep flocks in the Algerian steppe, M'Sila region: practices and trends. Cah Agric. 2020; 29(28). https://doi.org/10.1051/cagri/2020027.

Hannachi, A., & Fenni, M. (2013). Floristic and ecological study of crop weeds in the Batna region. *Agriculture,* 4(1), 24-36

Hannachi, A., Gharzouli, R., Tabet, Y. D., & Daoud, A. (2016). Wastewater reuse in agriculture in the outskirts of the city Batna (Algeria). *Journal of Fundamental and Applied Sciences,* 8(3), 919-944.

Harkat, S., and Lafri, M. (2007). Effet des traitements hormonaux sur les paramètres de reproduction chez des brebis «Ouled-Djellal». Saad Dahlab Blida University (Algeria): Mail of Knowledge, 08, 125-132.

Harkat, S., Laoun, A., Benali, R., Outayeb, D., Ferrouk, M., Maftah, A., Da Silva, A., Lafri M. (2015). Phenotypic characterization of the major sheep breed in Algeria. *Revue Méd. Vét*., 166, 5-6, 138-147.

Hemmer, H. (1990). Domestication: the decline of environmental appreciation. 1st edition. *Cambridge: Cambridge University Press.*

Hiendleder, S., Kaupe, B., Wassmuth, R., & Janke, A. (2002). Molecular analysis of wild and domestic sheep questions current nomenclature and provides evidence for domestication from two different subspecies. Proceedings of the Royal Society of London. Series B: *Biological Sciences,* 269(1494), 893-904.

Inyangala, B. A. O., Rege, J. E. O., & Itulya, S. (1992). Growth traits of the Dorper sheep. I. Factors influencing growth traits.

Jean-Charles. (2015). Performance monitoring of suckler sheep. Agriculture room.

Kalla, I.M., & Guettouche, M.S. (2017). Using geomatics for assessing vulnerability to cutaneous leishmanisais. Application to the wilaya of Batna (Algeria). *GEOMATE Journal*, 13(40), 9-15.

Kandoussi, A., Petit, D., Boujenane, I. (2021). Morphologic characterization of the Blanche de Montagne, an endemic sheep of the Atlas Mountains. *Tropical Animal Health and Production*, 53(1),1-8.

Kenyon, P.R., Morris, S.T., Hickson, R.E., Stafford, K.J., West, D.M. (2012). Nutritional restriction of triplet-bearing ewes and body condition score has minimal impacts. *New Zealand Journal of Agricultural Research*, 55, 359–370.

Kenyon, P.R., Maloney, S.K., Blache, D. (2014). Review of sheep body condition in relation to production characteristics. *New Zealand Journal of Agricultural Research*, 57, 38–64

Kerboua, M., Feliachi, K., Abdelfettah, M., Ouakli, K., Selhab, F., Boudjakdji, A., Takoucht, A., Benani, Z., Zemour, A., Belhadj, N., Rahmani, M., Khecha, A., Haba, A. and Ghenim, H. (2003). National report on animal genetic resources: Algeria. Ministry of Agriculture and Rural Development, National Commission AnGR, 1-46.

Kerfal, M., Chikhi, A. and Boulanouair, B. (2005). Productive potential of the D'Man breed at the INRA Experimental Domain at Er-Rachidia In: Boulanouar B., Kradi C. (Eds.). Proceedings of the International Symposium on the Sustainable Development of Oasis Systems. INRA Morocco, 350-358. http://webagris.inra.org.ma/doc/ouvrages/oasis2005/oasis350-358.pdf.

Khaldi, Z., Haddad, B., Souid, S., Rouissi, H., Gara, A.B., Rekik, B. (2011) Phenotypic charaterisation of the sheep population in south-west Tunisia. *Animal Genetic Resources*, 49:1-8.

Khama, R. K., Alston-Knox, C., Pethick, D.W. and Gardner, G.E. (2022). Sire Breed, Litter Size, and Environment Influence Genetic Potential for Lamb Growth When Using Sire Breeding Values. *Animals*, 12(4), 501.

Khargharia, G., Kadirvel, G., Kumar, S., Doley, S., Bharti, P.K, Das, M. (2015). Principal component analysis of morphological traits of Assam Hill goat in Eastern Himalayan India. *Journal of Animal & Plant Sciences*. 25(5).

Khelifi, Y. (1999). Sheep and goat production in the Algerian steppe zones. In: Rubino R. (ed.), Morand-Fehr P. (ed.).Systems of sheep and goat production: Organization of husbandry and role of extension services. Mediterranean Options: Series A. Mediterranean Seminars; n. 38. P, 245-247.

Kijas, J.W., Lenstra, J.A., Hayes, B., Boitard, S., Porto Neto, L.R. et al. (2012). Genome-wide analysis of the world's sheep breeds reveals high levels of historic mixture and strong recent selection. *PLoS Biology*, 10 (2), e1001258

Laoun, A., Harkat, S., Benali, R., Yabrir, B., Hakem, A., Ranebi, D… Lafri M. (2015). Phenotypic characterization of the Rembi sheep breed from Algeria. *Animal productions and animal products*. Review of breeding and veterinary medicine of tropical countries. 2015; 68(1):19-26.

Lenfant, C., (1973). High altitude adaptation in mammals. *American Zoologist*, 13, 447-456.

Lhoste, Ph. (2001). The study and diagnosis of breeding systems. Training workshop for DMC agronomists Madagascar, 32 p.

MADRP, (2015). Ministry of Agriculture and Rural Development and Fisheries “national statistics».

MADR/DSASI., 2018. Agricultural Statistics Serie B. Ministry of Agriculture and Rural Development / Department of Agricultural Statistics and Information Systems, Algiers, Algeria

Marshal, F. (2000). The origins and spread of domestic animals in East Africa. In: Blench, R.M. and MacDonald, K.C. (eds), The origins and development of African livestock: Archaeology, genetics, linguistics and ethnography. *London, UK: University College London Press*. pp. 191–218.

Meadow, R. (1989). Osteological evidence for the process of animal domestication. *In The walking larder:* patterns of domestication, pastoralism and predation: 80-90.

Meadows, J. R. S., Cemal, I., Karaca, O., Gootwine, E., & Kijas, J. W. (2007). Five ovine mitochondrial lineages identified from sheep breeds of the Near East. *Genetics*, 175, 1371–1379.

Meadows, J. R. S., Hiendleder, S., & Kijas, J. W. (2011). Haplogroup relationships between domestic and wild sheep resolved using a mitogneome panel. *Heredity*, 106, 700–706

Meadows, J.R.S. (2014). Sheep: Domestication. In: Smith, C. (eds) Encyclopedia of Global Archaeology. *Springer, New York, NY.* 6597-6600p. https://doi.org/10.1007/978-1-4419-0465-2_2215

Menasra, A., & Bouzaher, S. (2021). GIS tools for landscape character assessment: case of Ziban region in Algeria. *Geomatics, Landmanagement and Landscape*, 4, 19-29.

Mignon-Grasteau, S., Boissy, A., Bouix, J., Faure, J-M., Fisher, A.D., Hinch, G.N., et al. (2005). Genetics of adaptation and domestication in livestock. *Livestock Production Science*, 93, 3-14

Molina, A., Gallego, L., Perez, J.I., Bernabeu, R. (1991). Growth of Mancha race lambs according to the physical condition of the ewes the lambing period the type of birth and gender. *Advances in Food and Animal Improvement*, 31, 198–202

Mouhous, A., Chibane, F., Segheir, S., Brabez F and Kadi, S.A. (2014). Feeding strategies and main expenses in sheep breeding in mountainous area of Tizi-Ouzou (Algeria). Mediterranean Options, Series A, 109, p. 713-716. http://om.ciheam.org/om/pdf/a109/a109.

Muigai, A. W., & Hanotte, O. (2013). The origin of African sheep: archaeological and genetic perspectives. *African Archaeological Review*, 30(1), 39-50.

Nadler, C. F., Hoffmann, R. S., & Woolf, A. (1973). G-band patterns as chromosomal markers, and the interpretation of chromosomal evolution in wild sheep (Ovis). *Experientia*, 29(1), 117-119.

Naval-Sanchez, M., Nguyen, Q., McWilliam, S., Porto-Neto, L. R., Tellam, R., Vuocolo, T., & Kijas, J. (2018). Sheep genome functional annotation reveals proximal regulatory elements contributed to the evolution of modern breeds. *Nature communications*, 9(1), 1-13.

Nowak, R., Poindron, P. (2006). From birth to colostrum: early steps leading to lamb survival. *Reproduction Nutrition Development*, 46(4), 431-446.

Nouidjem, Y., Hadjab, R., Khammar, H., Merouani, S and Bensaci E. (2021). Diversity, Ecology and Therapeutic Properties of Plants. *J Biores Manage*., 8(1) : 29-39

Okere, C., Bradley, P., Bridges, E.R., Bolden-Tiller, O., Ford, D. and Paden, A. (2011) Relationship among body conformation, testicular traits and semen output in electro-ejaculation pubertal Kiko goat bucks. *Journal of Agricultural and Biological Science*, 6, 43-48.**)**

Prakash, V., Prince, L.L.L., Gowane, G.R. and Arora, A.L. (2012). Pre-weaning average daily gain and Kleiber ratios in Malpura sheep. *Indian Veterinary Journal,* 89, 63-65.

Popoola, M. A. (2015). Original Research Article Zootechnical Index Analysis of West African Dwarf Rams in Southwestern Nigeria. *Agricultura Tropica et Subtropica*, 48(21), 24-29.

Price, E.O. (1999). Behavioral development in animals undergoing domestication. *Applied Animal Behaviour Science*, 65, 245-271

Rocha, J., Chen, S., & Beja-Pereira. (2011). Molecular evidence for fat-tailed domestication. *Tropical Animal Health and Production*, 43, 1237–1243

Rondia, P., (2006). Aperçu de l'élevage ovin en Afrique du Nord. Filière Ovine et Caprine n°18, octobre 2006.

Ryder, M. L. (1983). Sheep & Man. (Duckworth, London)

Sagne, J. (1950). Pastoral Algeria. Its origins, its formation, its past, its present, its future. Fontana Printing, 27 p.

Sejian, V., Maurya, V.P., Naqvi, S.M.K., Kumar, D., Joshi, A. (2009). Effect of induced body condition score differences on physiological response, productive and reproductive performance of Malpura ewes kept in a hot, semi-arid environment. *Journal of Animal Physiology and Animal Nutrition*, 94, 154–161.

Severin, K.G., Cyrille, K.N., Etienne, L.N,. Yves, E.J., Charles, D.G., Mamadou, S., Valentine, Y.G.C. (2019). Primary morphological characterization of West African dwarf (Djallonk) ewes from Cote dIvoire based on qualitative and quantitative traits. *International Journal of Genetics and Molecular Biology*, 11(2), 16-28. https://doi.org/10.5897/IJGMB2019.0170.

Smaali, S. and Boukazoula, F. (2019). The effect of body condition and weight of Ouled Djellal ewes on the growth of the lambs in an accelerated lambing farm. *Livestock Research for Rural Development*, 31.

Stojiljkovic, M., Stevanovic, O., Ivanov, S., Drobnjak, D., Urosevic, M., & Trailovic, R. (2015). Morphometrical characterisation of the Karakachan sheep from Stara planina, Serbia. *Bulgarian Journal of Agricultural Science*, 21(6), 1278-1284.

Sulieman, A.H, Ali, H.O. and El Jack, E.E. (1985). Investigations on characteristics of shugor, Dubasi and Watish ewe lambs at first lambing at el Huda sheep research station. *World Review animal Production*, 21, 55–58.

Sveinbjörnsson, J., Eythórsdóttir, E. and Örnólfsson, E. K. (2021). Factors affecting birth weight and pre-weaning growth rate of lambs from the Icelandic sheep breed. *Small Ruminant Research*, 201, 106420.

Teletchea, F. (2019). Animal domestication: A brief overview. *IntechOpen. ISBN. 978-1-83881-133-4. 170p.* DOI: 10.5772/intechopen.86783

Tesema, Z., Deribe, B., Lakew, M., Getachew, T., Tilahun. M., Belayneh, N. and Bishaw, M, (2022). Genetic and non-genetic parameter estimates for growth traits and Kleiber ratios in Dorper× indigenous sheep. *Animal*, 16, 100533.

Titaouine, M. (2015). Doctorate thesis: Approche de l'étude zootechnico-sanitaire des ovins de race ouled djellal dans l'est algérien, évolution des paramètres biochimiques et hématologiques en fonction de l'altitude. Hadj Lakhdar University, Batna. 100p

Trouette, M. (1929). The Algerian breeds. Sheep Congress, Paris 9, 10,11 Dec 1929. 299-302.

Trut, L, Oskina, I., Kharlamova, A. (2009). Animal evolution during domestication: The domesticated fox as a model. *BioEssays*, 31:349-360

Vorontsov, N. N., Korobitsyna, K. V., Nadler, C. F., Hofman, R., Sapozhnikov, G. N. & Gorelow, J. K. (1972). Chromossomi dikich baranow i proiskhzhdenie domashnikh ovets. Priroda, *Moscow* 3, 74–82.

Whannou, H.R.V., Afatondji, C.U., Ahozonlin, M.C., Spanoghe, M., Lanterbecq, D., Demblon, D… Dossa LH. (2021). Morphological variability within the indigenous sheep population of Benin. *PloS one*, 16(10). https://doi.org/10.1371/journal.pone.0258761.

Wilson, R.T., Durkin, J.W. (1984). Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. *Livestock Production Science*, 11(4), 451-455.

Xavier, M. and Anthony, J. (2014). Behaviour, conduct and animal welfare. Edition Quae, CTA, Gembloux agricultural press, pp52-60.

Zeder, M. A. (2012). The broad spectrum revolution at 40: resource diversity, intensification, and an alternative to optimal foraging explanation. *Journal of Anthropological Archaeology* 31: 241-64.

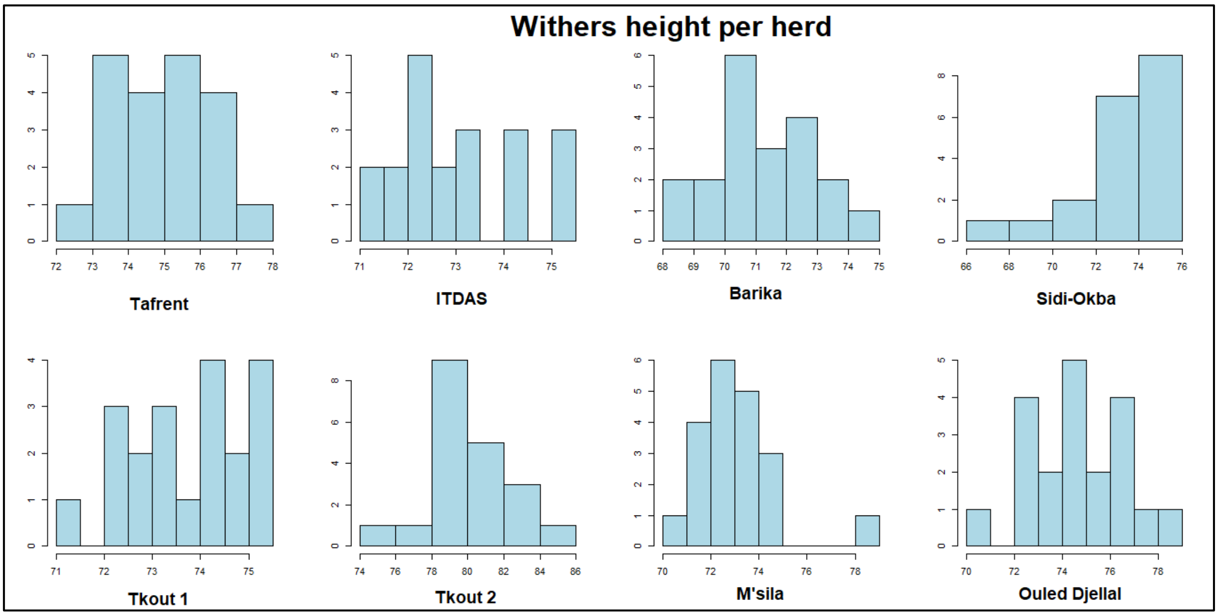
Zeuner, F. E. (1963). A history of domesticated animals. 1st edition, *London: Hutchinson*.

Zidane, A., Niar, A. and Ababou, A. (2015). Effect of some factors on lamb's growth performances of the Algerian Ouled Djellal breed. *Livestock Res Rural Develop*, 27. http://www.lrrd.org/lrrd27/7/zida27126.html

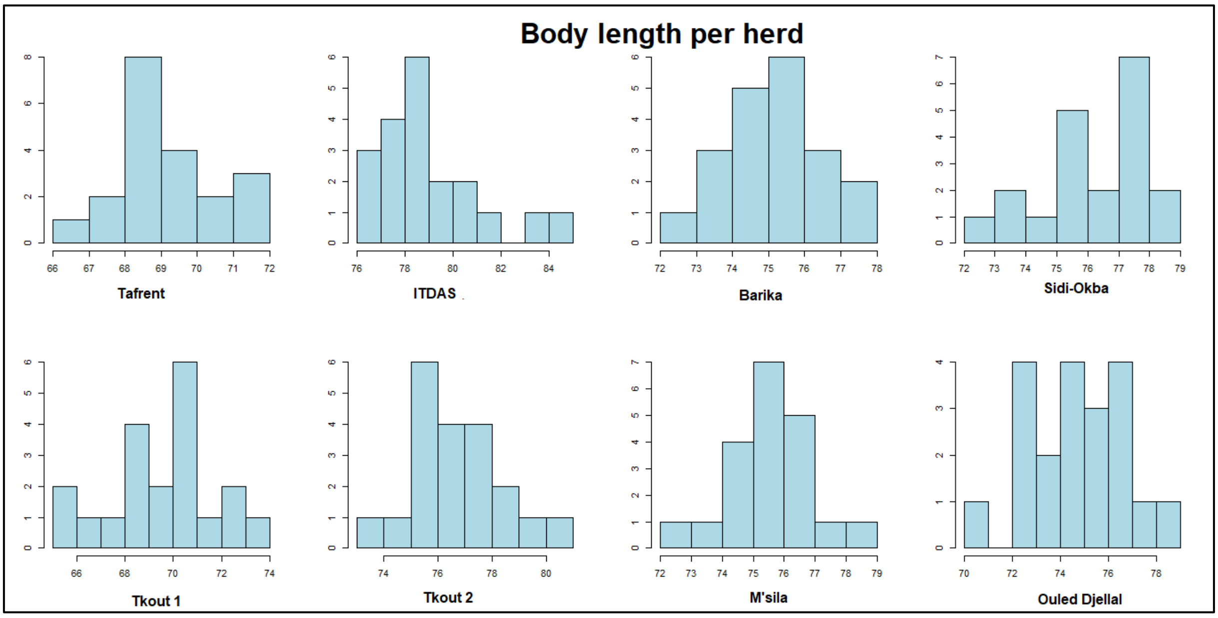
Ziani, K., and Khaled, M.B. (2016). Partial substitution of barley for corn: effect on "Hamra" lamb growth performance, carcass and meat characteristics. *Tropical animal health and production*, 48, 517-524.

Zohary, D., Tchernov, E., & Horwitz, L. K. (1998). The role of unconscious selection in the domestication of sheep and goats. *Journal of Zoology*, 245(2), 129-135.

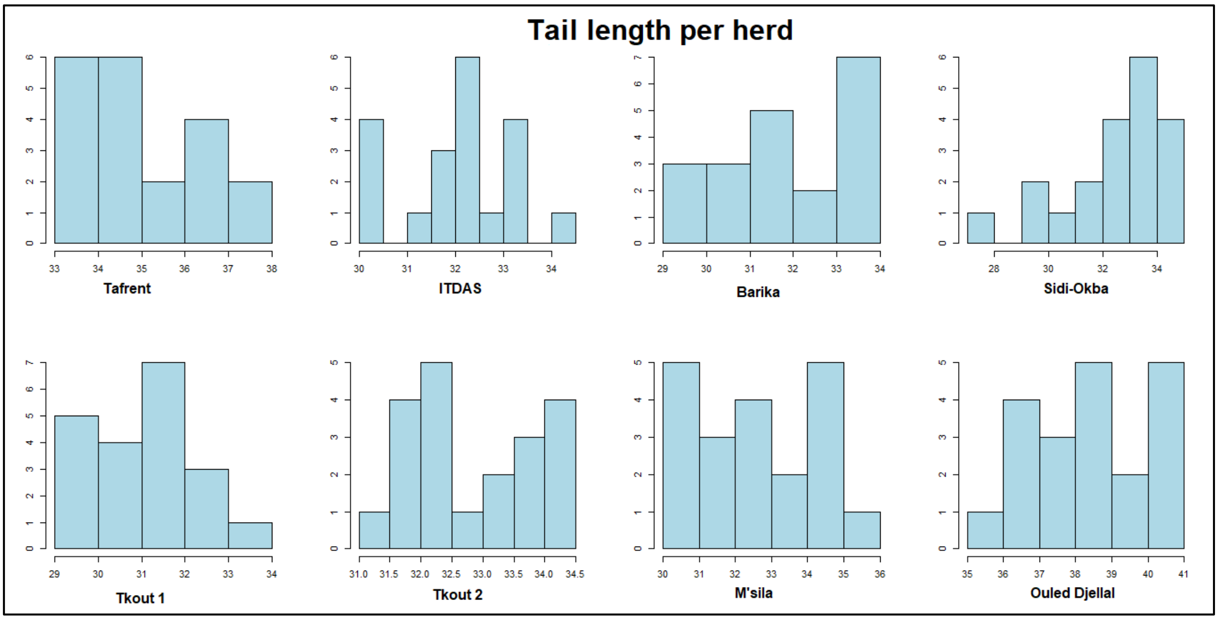
Annex 1. Number of withers height per herd



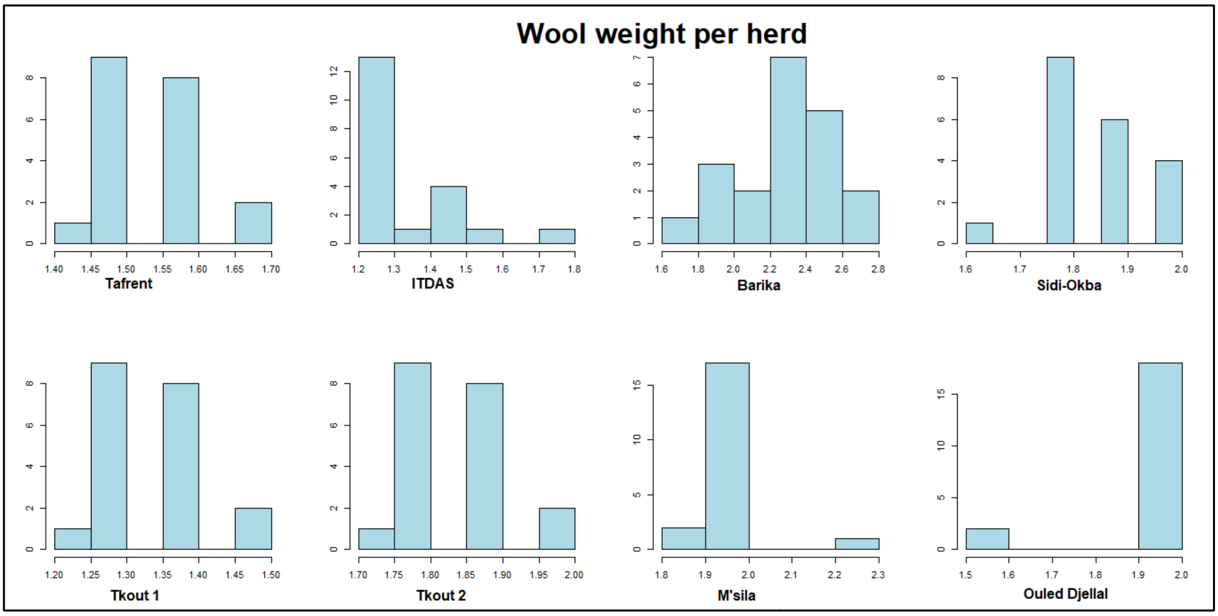
Annex 2. Number of body length per herd



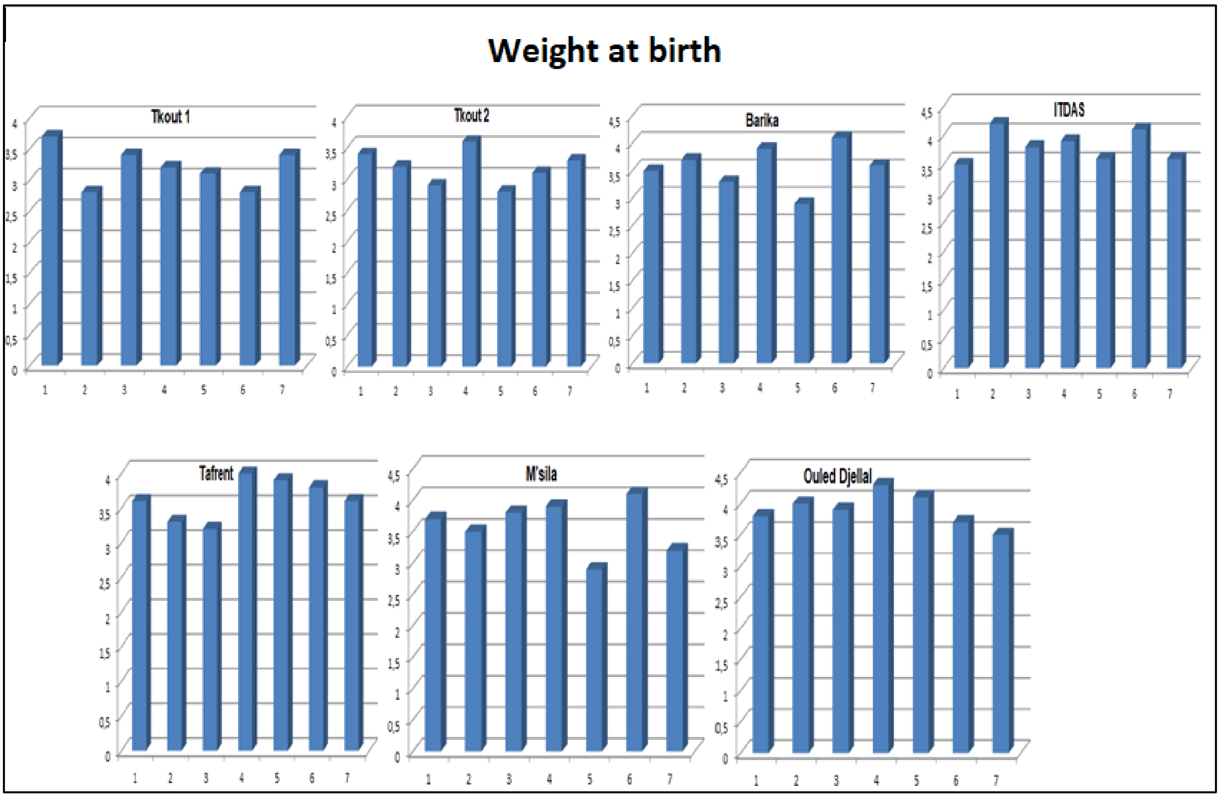
Annex 3. Number of tail length per herd



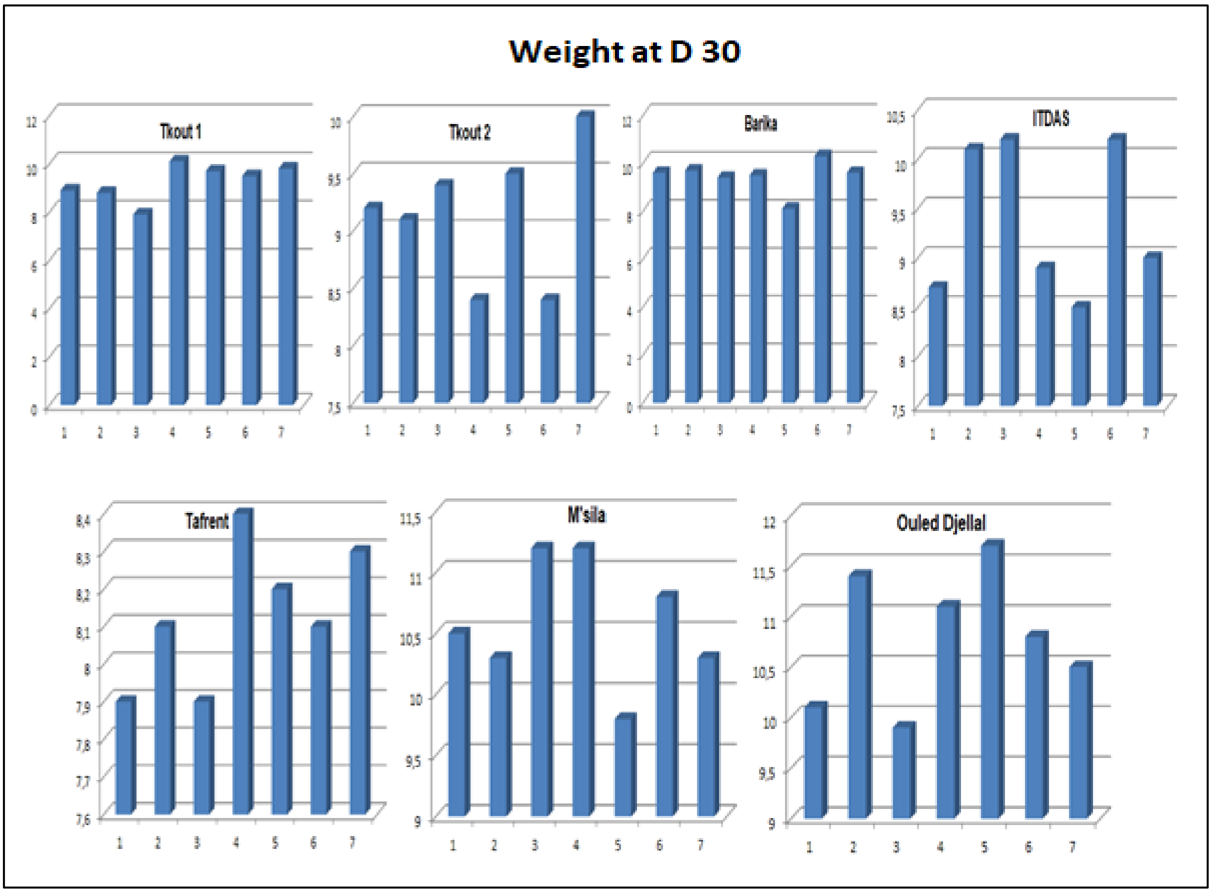
Annex 4. Number of wool weight per herd



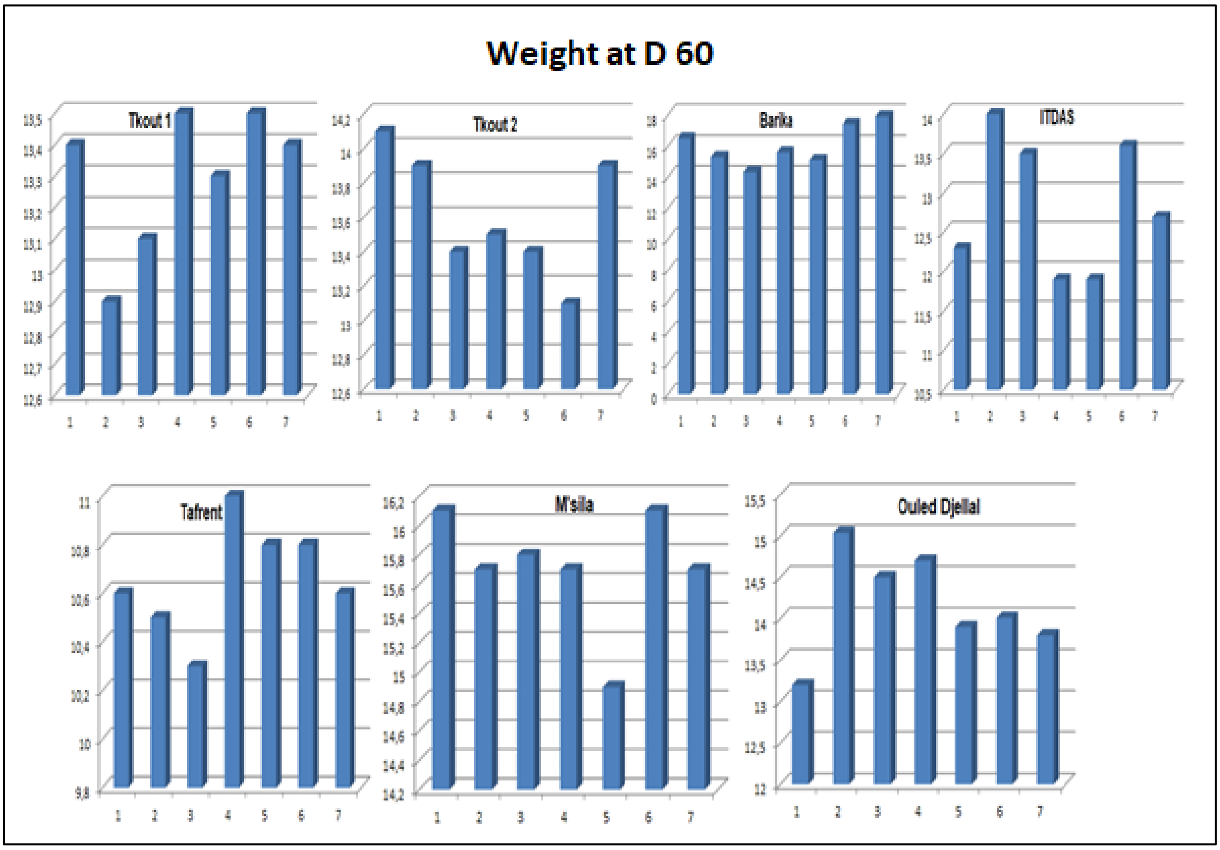
Annex 5. Number of weight at birth per herd



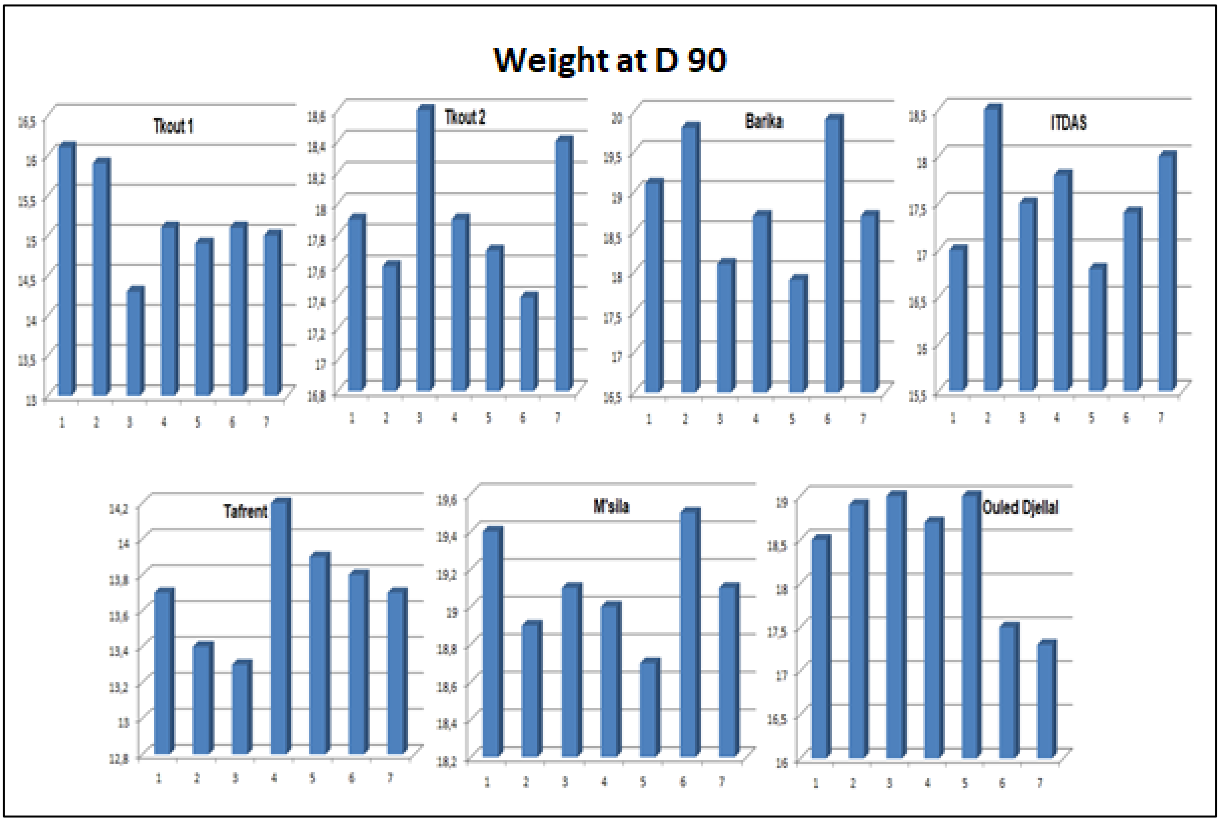
Annex 6. Number of weight at D 30 per herd



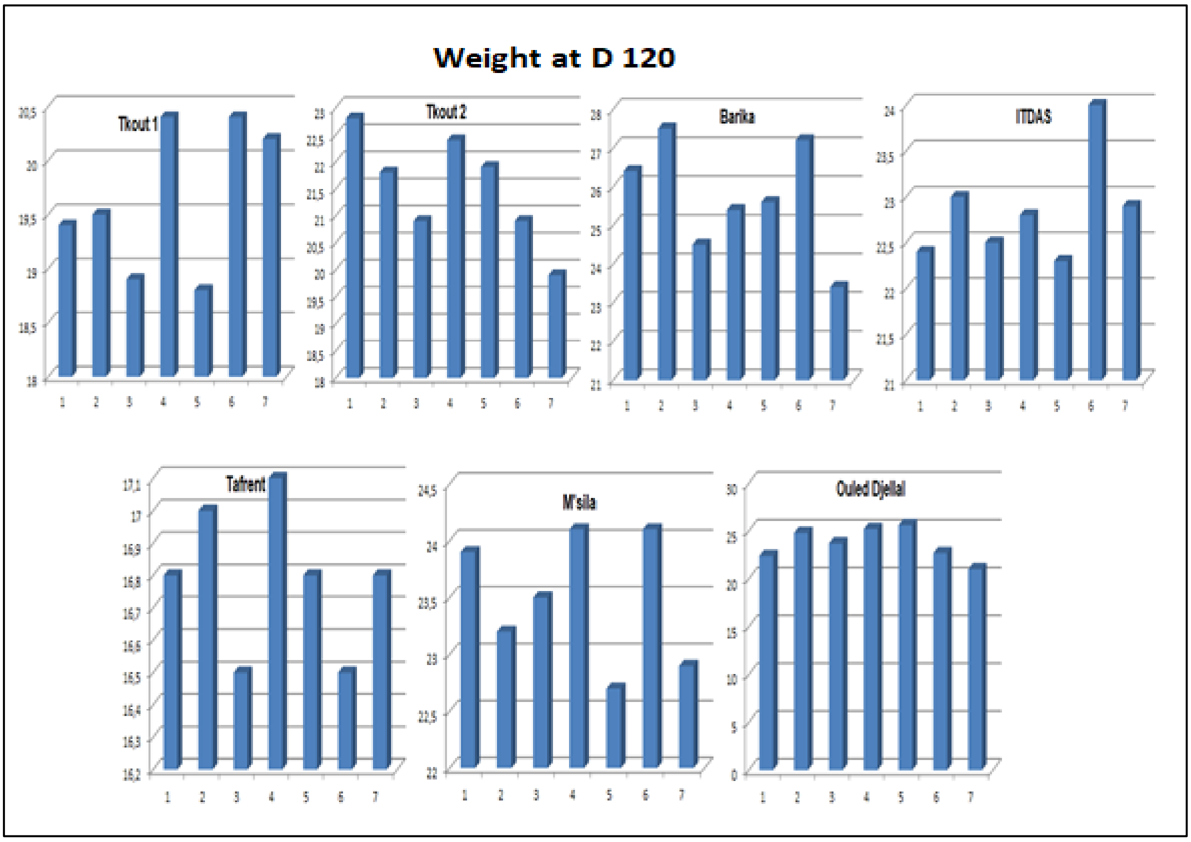
Annex 7. Numberof weight at D 60 per herd



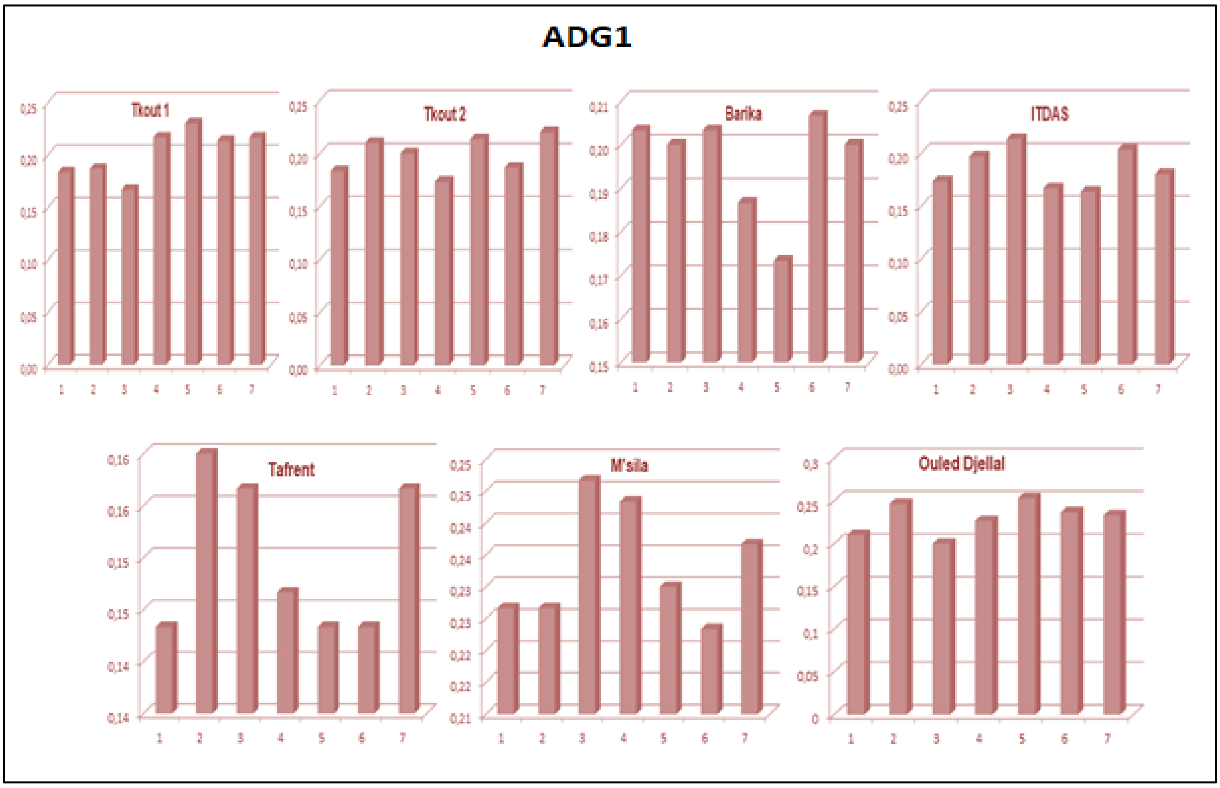
Annex 8. Number of weight at D 90 per herd



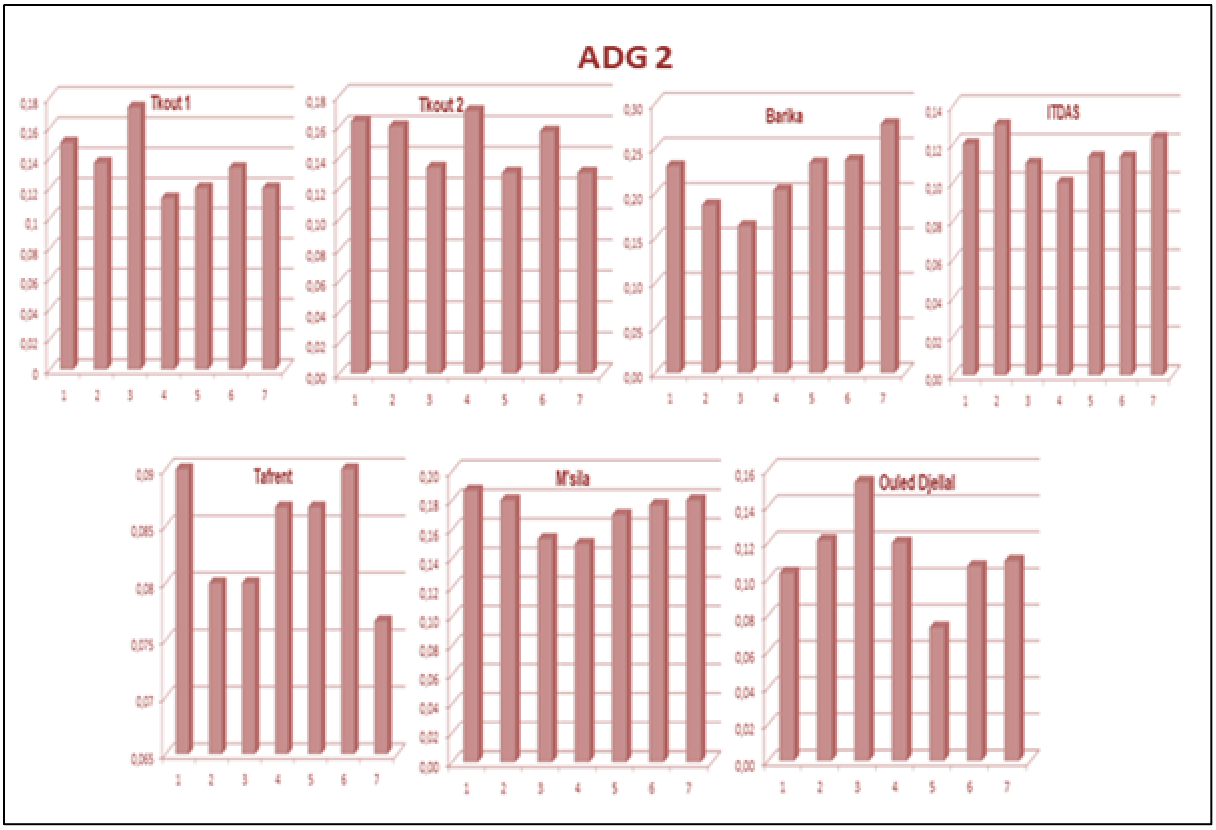
Annex 9. Number of weight at D 120 per herd



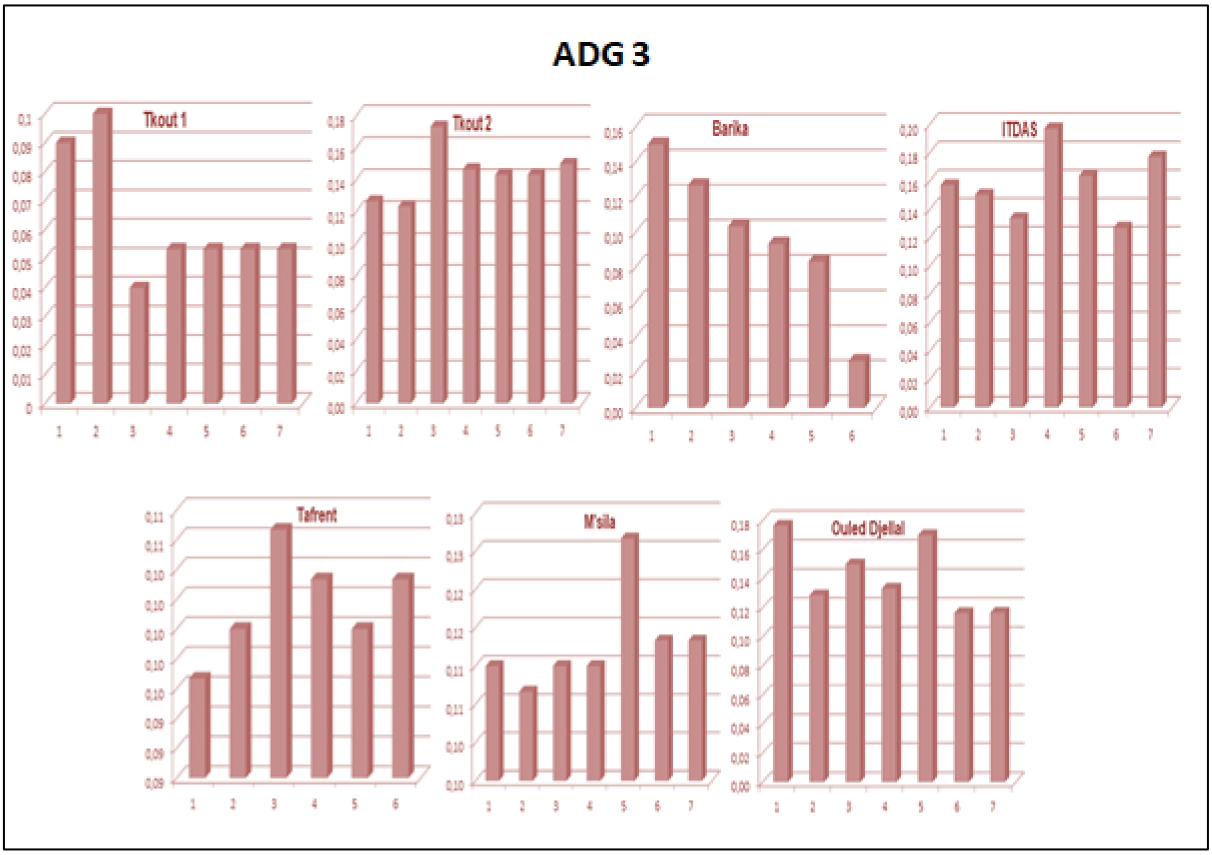
Annex 10. Number of average daily gain between weight at birth and D 30 per herd



Annex 11. Number of average daily gain between D 30 and D 60 per herd



Annex 12. Number of average daily gain between D 60 and D 90 per herd



Annex 13. Number of average daily gain between D 90 and D 120 per herd