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Research Article

Morphological characterization and ecotypic classification of olive varieties in Bordj Bou Arreridj, Algeria

Saad Ahmed [1,2*], Sebbane Nour ElHouda[1], Seghiri Abdel Madjid[3], Madani Djamila[1]

[1]Department of Agricultural sciences, Faculty of Sciences, University of M'sila, University Pole, Road Bordj Bou Arreridj, M'sila 28000, Algeria.
[2]Laboratory of Algerian Forests and Climate Change of the National Higher School of Forestry-Khenchela 40000, Algeria.
[3]Direction of agricultural services of Bordj Bou Areiridj, Venue H. Boumediene BBA, 34000 Bordj Bou Arreridj, Bordj Bou Arreridj, Algeria.

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***Corresponding author:**

E-mail:

Ahmed.saad@univ-msila.dz

Abstract

The aim of this research is to establish the phenotypic variation that exists in the olive varieties of *Olea europaea* L. in the Bordj Bou Arreridj region of Algeria. The study examined 18 olive varieties from 20 farms, focusing on the morphological characterisation of fruits, leaves, and endocarps using standard descriptors and precise measurement tools. Significant coefficients of variation were observed for the traits studied, indicating substantial differences among the varieties. The highest variability was found in fruit weight, with a coefficient of variation (CV) of 48.60%, while leaf length demonstrated the lowest CV at 9.77%. Principal Component Analysis (PCA) primarily distinguished three different ecotypic groups based on fruit and endocarp size and shape parameters. The Bray-Curtis similarity analysis revealed compositional similarities among some of the local variants, providing insights into their potential genetic relationships. Notably, the study reports the presence of the rare *Leucocarpa* variety, which had not been previously documented in Algeria. This discovery highlights the importance of thorough regional surveys in uncovering hidden biodiversity. The findings reveal a rich agro-morphological genetic variation in olive ecotypes in the region, which is valuable for genetic conservation efforts and breeding research. This diversity could potentially be exploited to develop cultivars with improved traits such as disease resistance, oil quality, or adaptation to specific environmental conditions.

Our classification enables targeted breeding, prioritized conservation, and optimized cultivation practices, supporting the development of resilient, locally-adapted varieties and the preservation of valuable genetic resources in the region's olive industry.

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1. Introduction

The olive tree (*Olea europaea* L.) is a valuable plant with evergreen fruit (Loumou & Giourga, 2003; Estruch et al., 2013). Indeed, over 12 million hectares of olive groves worldwide produce 2600 varieties for table and oil, with wide variability conserved at the World Olive Germplasm Bank (Rugini et al., 2016; Debbabi et al., 2022). Furthermore, olive is considered the most suitable and best-adapted crop to the Mediterranean environment, where it encompasses 80% of the worldwide olive tree area (Debbabi et al., 2022). Moreover, Olive farming plays an important role in the agricultural output and economic growth of many Mediterranean countries (Sansoucy, 1984). The cultivation of olives in Mediterranean regions also contributes to the preservation of biological diversity in rural areas and offers advantages in terms of social and economic aspects (Maesano et al., 2021).

In 2022, olive growing in Algeria occupied approximately 457.6 thousand hectares and produced around 822.97 thousand tons of olives with an average yield of 179.84 quintals per hectare (Food and Agriculture Organization Statistics., n.d.). Additionally, the production of olives in Algeria has expanded to several regions, following northern areas, due to increased demand for oil and government support programs (Acila et al., 2017).

By 1999, olive cultivation was mostly focused on a few 11 provinces. Nevertheless, after experiencing significant growth (Saad et al., 2023), Bordj Bou Arreirdj is now classified as part of the second phase of development, which began in 2008, and it has a prominent place in Algeria's olive oil sector, being at the sixth position in terms of national output. In 2020, the region's olive farming reached 26,330.5 hectares, generating 19,795.6 metric tonnes of olives. Notably, the agricultural area expanded from 21,544 hectares in 2012 to 26,385.5 hectares in 2020. Key olive-growing regions include the communes of Djaafra, Ouled Sidi Brahim, El Euche, and El Main (Direction of Agricultural Services of B.B.A, 2023).

Currently, the Algerian olive-tree variety comprises 138 introduced foreign varieties from Spain, Italy, or France, along with 36 indigenous varieties resulting from a long-standing selection process (Institut Technique de l'Arboriculture Fruitière et de la Vigne, 2023). Varietal identification is a critical step in managing genetic variation. Despite the arrival of genetic and biochemical technology, morphological characterisation remains used for varietal distinction and the identification of new genotypes (Titouh et al., 2021). Furthermore, this method has an important role in screening appropriate cultivars at a given location (Iqbal et al., 2019).

Additionally, the International Olive Council (IOC) has implemented a system of primary morphological characterisation to enhance the agronomic value and understanding of olive genetic resources (Barranco, 1994). Thus, morphological analysis of olive cultivars, revealing their significant variability in fruit, leaf, and endocarp shape and size, can effectively characterize and discriminate cultivars and establish phenological relationships (Barranco et al., 2000; Belaj et al., 2016; Blazakis et al., 2017).

Accurate varietal identification is essential for effectively managing genetic diversity and maximizing resource utilization. In olive tree research, while molecular and biochemical tools have advanced significantly, morphological characterization of olive fruits and stones remains a vital method for distinguishing between various varieties and identifying new genotypes (Titouh et al., 2021).

Numerous studies have addressed this topic, including several unpublished works such as Bentra and Boubeche (2016), Sarah et al. (2016), Diaf and Mekhalfia (2018), Bouzit and Djarboue (2023), Kouchit and Meharga (2023), and Lounis and Mihoub (2023). Bahlouli et al. (2023) recently published their work on this topic. Despite the extensive research on olive cultivation, there remains a lack of comprehensive studies focusing specifically on the phenotypic diversity of olive trees in the Bordj Bou Arreirdj region. While previous studies have explored varietal characteristics in other areas, the unique combination of local and introduced varieties in this region has not been thoroughly investigated. This study aims to fill that gap by providing a detailed evaluation of the morphological characteristics of these olive tree varieties.

Olive breeding research has seen significant advancements in recent years, particularly in the use of genomics-assisted breeding (GWAS) to identify loci associated with desirable fruit quality and oil composition, as well as in developing Verticillium wilt-resistant cultivars (Rallo et al., 2018). This research has underscored the importance of both traditional breeding techniques and modern biotechnology tools in olive breeding. This study focuses specifically on the phenotypic diversity of olive trees in the Bordj Bouarreirdj region of Algeria, which has a rich heritage of local and introduced varieties, aiming to provide a comprehensive evaluation of their morphological characteristics.

2. Materiel and methods

Bordj Bou Arreridj, situated in the eastern highlands of Algeria, is on the Algiers-Constantine axis at 36° North latitude and 4° 30′ East longitude. It is bordered on the north, east, west, and south by Bejaia, Setif, Bouira, and Msila. The region spans 3921 km² and has heights ranging from 302 to 1885 m. The highlands have three main zones: high plains, mountainous, and steppe zone (Miara et al., 2019). With a cold winter and a dry/hot summer, rainfall ranges between 300 and 600 mm/year. Bordj Bou Arreirdj's climate is semi-arid (Bendif et al., 2021).

This study characterized 12 distinct morphological traits of *Olea europaea* L. cultivars in the Bordj Bou Arreridj region of Algeria. The traits included leaf dimensions (length, width, length/width ratio), fruit parameters (length, width, length/width ratio, weight), and endocarp characteristics (length, width, length/width ratio, weight). Additionally, the study characterized the shapes of these plant parts following the standardized descriptors of the International Olive Council (IOC) (Barranco et al., 2000).

The research examined 18 olive varieties from 20 farms in the region (Figure 1) from December 8, 2023, to February 7, 2024, coinciding with the olive harvesting season. A systematic sampling approach was employed, selecting 10 trees randomly for each variety and collecting 10 fruits and leaves from each tree (Figure 2).

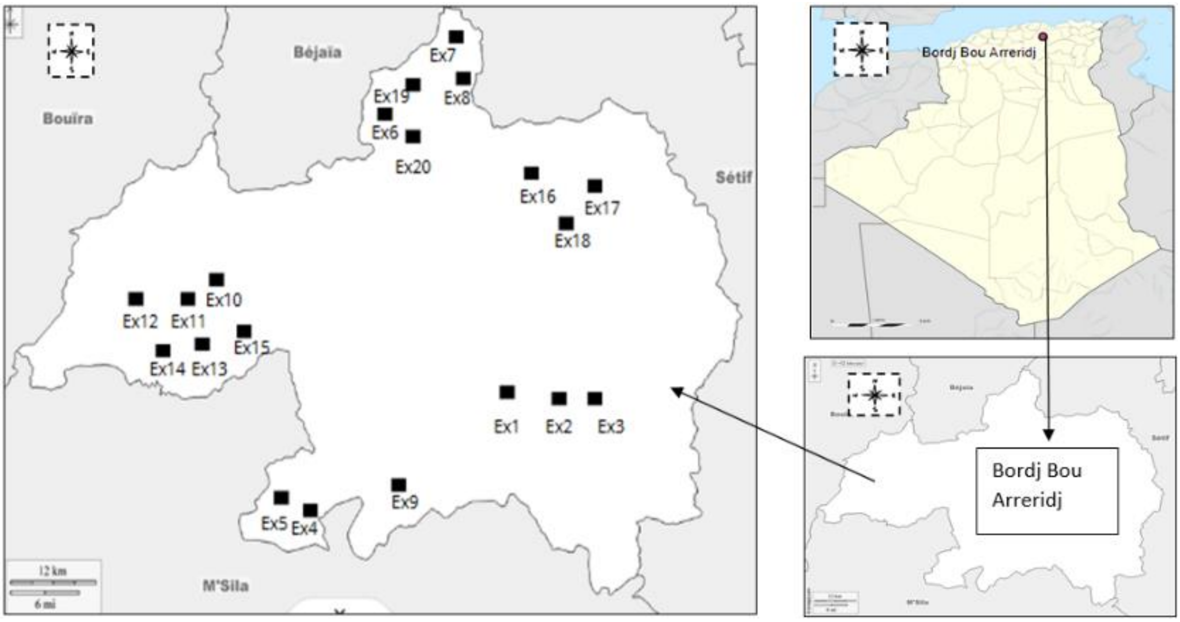

Figure 1. The location of the studied farms in the Bordj Bou Arreridj province.
Source: Adapted from www.d-maps.com.

Morphometric analyses were performed using high-precision instruments: a Balance Kern PCB 1000-2 (maximum capacity 1 kg, resolution ±0.01 g) for weight measurements and a 150 mm Mono Bloc Insize stainless hardened calliper (precision ±0.02 mm) for linear measurements., assessing parameters like weight, length, width, shape, symmetry, apex, and base characteristics. Qualitative traits were evaluated using standardized descriptors from the Catalogue of Algerian Olive Varieties (Institut Technique de l'Arboriculture Fruitière et de la Vigne, 2023).

Figure 2. Plant materials used (leaves, fruits and endocarps).

Qualitative data analysis included cladistic diagrams, while quantitative analyses, including one-way ANOVA, principal component analysis (PCA), and Bray-Curtis analysis, were conducted using PAST software (Hammer & Harper, 2001). Radar charts for data visualization were created using Microsoft Excel.

3. Results and discussion

We observed 18 distinct varieties of olive trees throughout our examination, which notably contradicts the previous statement from Direction of Agricultural Services of B.B.A (2023) that the Bordj Bou Arreridj area only contained three species, distributed as follows: *Chemlal*: 75 %; *Azeradj*, 22.5 %; and *Sigoise*, 3 %.

Among the 18 types discovered, it is important to highlight that the 15 are unique to the area, reflecting the rich local legacy of olive production. These indigenous varieties include *Aghenfas, Aguenau, Ronde of Miliana, Aidel, Chamlal, Sigoise, Hamra, Abani, Bouchouk Guergour, Bouchouk Soummam, Aberkane, Azeradj, Limli, Aouragh, and Aghchren of Titest.*

In addition to the indigenous varieties, three imported ones: *Arbequina, Sevillana*, and *Leucocarpa* have also been cultivated. Notably, *Arbequina* and *Sevillana* are of Spanish origin. Interestingly, our investigation found the *Leucocarpa* variety, which is lacking from the existing Algerian inventory. Moreover, *Leucocarpa* olives are a rare, ancient variety characterized by their unique ivory-white color when ripe, found primarily in Greece and parts of Italy, with distinct pomological features including broad foliage and small, oval fruits (Monselise, 1986; Zemmeli et al., 2023). The discovery of *Leucocarpa* in Bordj Bou Arreridj expands the local genetic pool, offering unique breeding opportunities for market-niche varieties, while its adaptability outside its typical habitat provides valuable research prospects, emphasizing the need for priority conservation and official registration in Algeria's olive inventory.

The existence of 15 indigenous and 3 introduced olive varieties in Bordj Bou Arreridj underscores the significance of safeguarding local genetic diversity for biodiversity, adaptation, and cultural heritage, while simultaneously addressing the potential threats of genetic erosion from non-native varieties through balanced in-situ and ex-situ conservation strategies. However, the lack of systematic information on local olive germplasm hinders the effective utilization of ancient genetic material and inadvertently promotes the use of well-documented foreign varieties, underscoring the urgent need for comprehensive characterization and conservation efforts of indigenous cultivars (Emmanouilidou et al., 2018).

According to the final report, "Molecular characterization of olive varieties in Algeria," our findings account for 10.34 % of the total genetic heritage of the olive tree in our country. Within our collection, 13 varieties have a dual purpose, and five are intended for the production of olive oil.

3.1 Qualitative Characters

In terms of the fruit shape, we can distinguish three different groups: First, the group of ovoid shapes (OFS) is composed of eight varieties. Secondly, the group of spherical shapes (SFS) is composed of six varieties. Finally, the group of elongated shapes (EFS) is composed of four varieties, as shown in the distribution of olive varieties by fruit shape in Table 1 (Observations confirmed with IOOC descriptors).

Table 1. Distribution of samples according to fruit shape

(OFS) Ovoid Fruit Shape	**(EFS) Elongated Fruit Shape**	**(SFS)spherical Fruit Shape**
Hamra; Aguenau; Sevillana; Sigoise; Azeradj; Aberkane; Arbequina; Aghchren of titest;	*Aghenfase; Bouchouk soummam; Aidel; Ronde of miliana.*	*Chamlal ; Limli ; Bouchouk guergour ; Aouragh ; Abani ; Leucocarpa.*

The cladogram in Figure 3 demonstrates the classification of olive tree varieties according to the morphological characteristics of their fruit, specifically weight and shape. The FMW (Medium Fruit Weight) group is the most extensive and variegated, which includes varieties such as *Aidel*, *Aouragh*, and *Sigoise*. It shows a wide range of fruit shapes Ovoid, Elongated, and Spherical, which underscores the variability of medium-weight olive fruit.

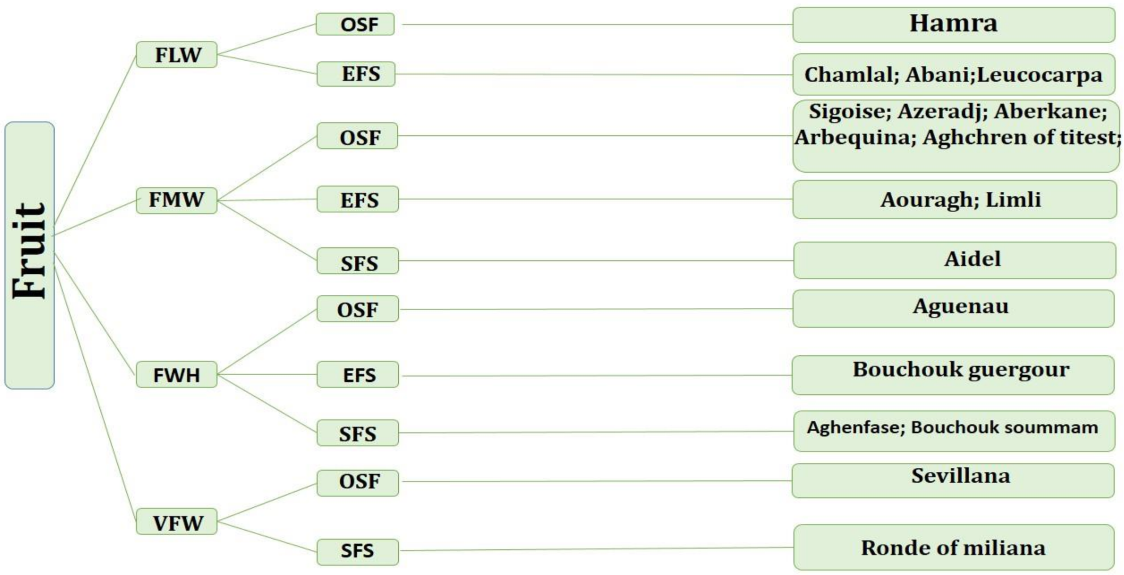

Figure 3. Cladogram of the studied trees based on the morphological characterization of olive fruits.

Note: FWH: Fruit Weight High. FLW: low Fruit weight. VFW: Very High Fruit Weight. FMW: medium Fruit Weight. OFS: Ovoid Fruit Shape. EFS: Elongated Fruit Shape. SFS: spherical Fruit Shape.

There were four distinct groups categorized by endocarp shape: the first group consisted of a single variety with an ovoid shape; the second group comprised a single variety with a spherical shape; the third group, with an elliptical shape, included 11 varieties; and the final group contained seven varieties with an elongated shape (Table 2) (Observations confirmed with IOOC descriptors).

Table 2. The distribution of the samples according to the shape of the endocarp.

Spherical endocarp shape(SES)	Ovoid endocarp shape(OES)	Elliptical endocarp shape (EES)	Elongated endocarp shape(EES’)
Aghenfase	*Arbequina*	*Chamlal ; Azeradj ; Sigoise ; Hamra ; Aguenau ; Aouragh ; Aghchre of titest ; Aidel ; Sevillana ; Leucocarpa.*	*Limli ; Aberkane ; Bouchouk guergour ; Bouchouk soummam ; Abani ; Ronde of miliana.*

The grouping in Figure 4 demonstrates the differences in stone weight and shape among olive tree varieties. The MEW (Medium Endocarp Weight) cluster is the primary group in this cladogram. It encompasses a diverse array of olive trees, including *Arbequina*, *Chemlal*, and *Sigoise*, which exhibit a variety of stone morphologies, including Ovoid (OES), Elliptical (EES), and Elongated (EES'). The medium-weight category's diversity indicates a wide range of adaptations among these varieties, making it the most variable and significant cluster in the investigation.

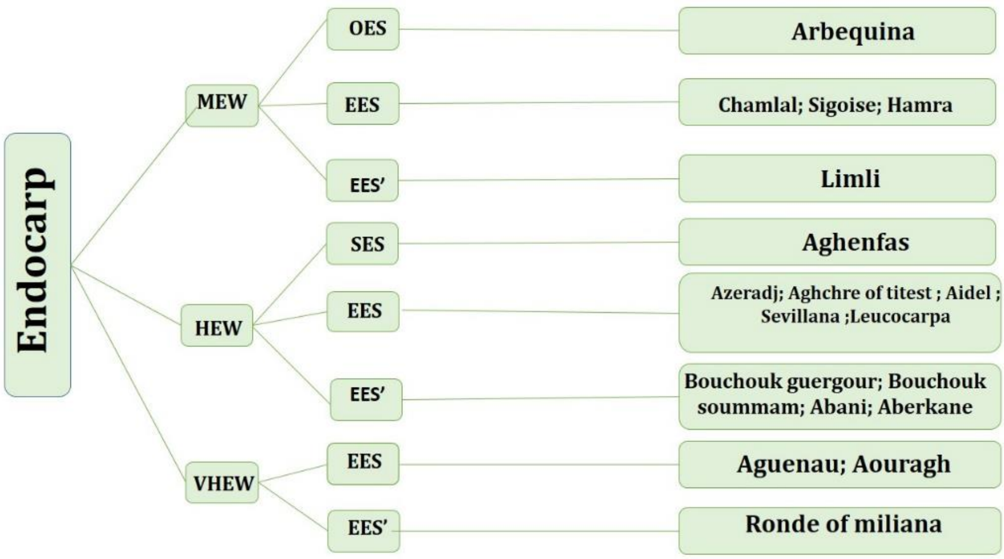

Figure 4. Cladogram of the trees studied according to the pomological characterization of the olive endocarp.

Note: Spherical endocarp shape (SES). Ovoid endocarp shape (OES). Elliptical endocarp shape (EES). Elongated endocarp shape (EES’). Medium endocarp weight (MEW). High endocarp weight (HEW). Very high endocarp weight (VHEW).

Based on the leaf shape as shown in Table 3, the varieties were categorized into two distinct groups: the first group, characterized by an elliptical-lanceolate shape, comprises 13 varieties, while the second group, featuring a lanceolate shape, encompasses 05 varieties (observations confirmed with IOOC descriptors).

Table 3. The distribution of the samples according to the leaf shape.

ELLIPTICAL-LANCEOLATE SHAPE (ELL)	LANCEOLATE SHAPE (LLS)
Aghenfas; Arbequina; Ronde Of Miliana; Aguenau; Aidel; Chamlal; Sigoise; Hamra; Abani; Bouchouk Guergour; Bouchouk Soummam; Aberkane; Leucocarpa.	*Sevillana; Limli; Aouragh; Azeradj; Aghchre of titest.*

Figure 5 shows how different olive varieties differ in leaf morphology. In this cladogram, the main group is the ELL (Elliptical-Lanceolate shape) cluster. It has a wide range of olive ecotypes, like *Chemlal*, *Aidel*, and *Arbequina*, with leaves that are Medium Length (MLL) and Width (MLW) and Low Length (LLL) and Width (LLW). This is the most significant and diverse cluster among the other groups.

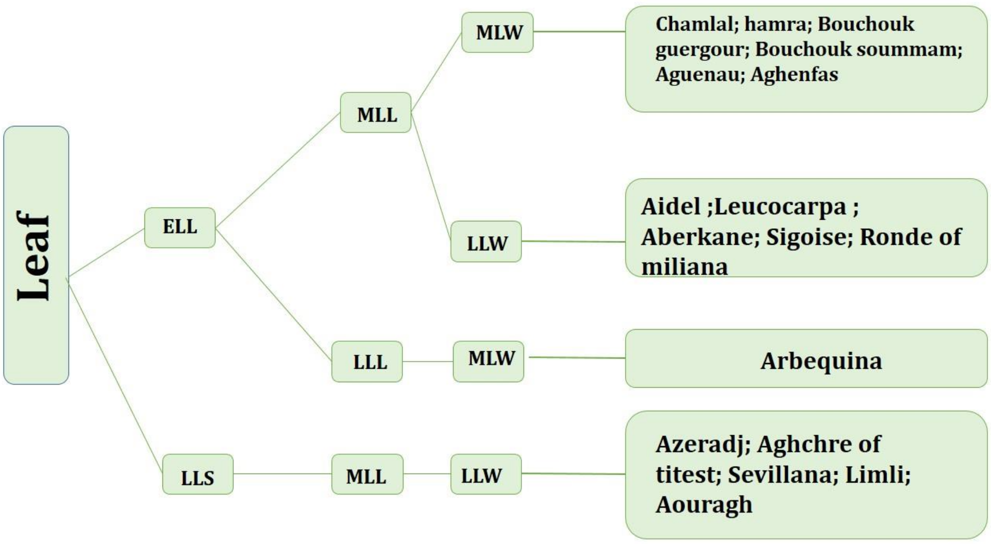

Figure 5. Cladogram of the trees studied according to the pomological characterization of olive leaves.

Note: Low width (LLW). Medium width (MLW). Low length (LLL). Medium length (MLL). Elliptical-lanceolate shape (ELL). Lanceolate shape (LLS).

Koubouris et al. (2018); Sarwar et al. (2023); Yogurtcu et al. (2022) observed significant variations in leaf size and form across several olive cultivars, influenced by genetic and environmental factors. Koubouris et al. (2018) specifically noted that under water stress reduced leaf size (length and width), with the extent varying by cultivar.

3.2 Quantitative characters

3.1.1 Comparative study of varieties

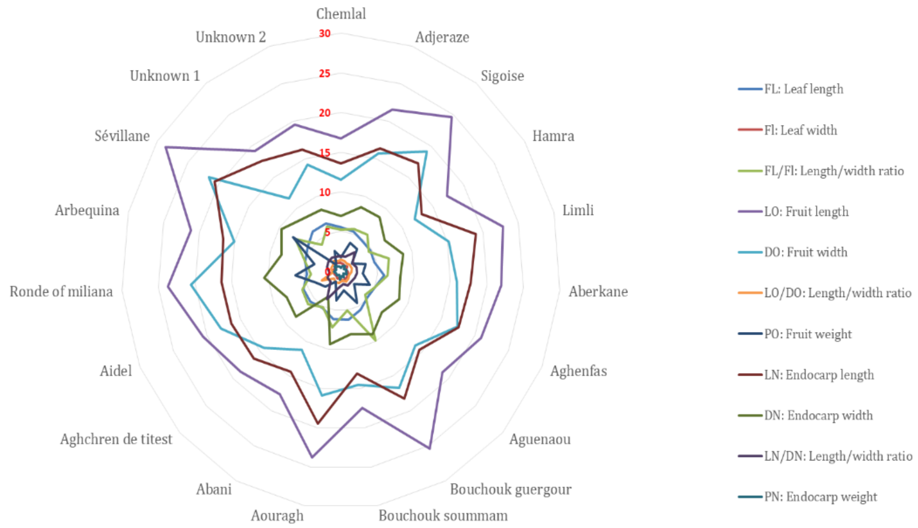

Figure 6. Radar Chart Comparing Leaf and Fruit Characteristics.

Table 4 and Figure 6 provide the morphological analysis of 18 olive varieties, revealing notable diversity in the studied traits. Leaves show an average length of 5.38 cm (± 0.12) and a length/width ratio of 5.75 (± 0.33). Fruits measure, on average, 21.16 mm (± 0.76) in length and 15.80 mm (± 0.71) in width, with a mean weight of 3.42 g (± 0.39).

Endocarps display an average length of 16.56 mm (± 0.51) and width of 8.29 mm (± 0.35), weighing 0.73 g (± 0.05).

The study reveals significant variability in olive cultivation and breeding coefficients. Fruit weight (CV = 48.60%) shows significant diversity in fruit size, suggesting potential end-uses from table olives to oil production. Breeders can use this diversity to develop cultivars tailored to market demands or improve fruit uniformity. Leaf length (CV = 9.77%) is relatively low, suggesting a conserved trait across varieties. Breeders can focus on other leaf traits or use this stability as a baseline for stress-tolerant varieties. The length/width ratios of leaves and fruits (CV ≈ 24.70%) offer opportunities for both growers and breeders. Growers can use these ratios as visual characteristics for variety identification and breeders can develop cultivars with specific fruit or leaf shapes. Endocarp characteristics, particularly weight, are relevant for oil production, with smaller, lighter endocarps preferred for higher flesh-to-pit ratios, potentially increasing oil yield. Breeders can focus on these traits to develop improved oil-producing cultivars.

Table 4. Descriptive statistics of morphological characters.

	Fl	FL	FL/Fl	LO	DO	LO/DO	PO	LN	DN	LN/DN	PN
Sum	18.0	96.76	103.58	380.8	268.5	26.41	61.54	298.01	140.96	38.41	13.08
Mean	1.00	5.38	5.75	21.16	15.80	1.47	3.42	16.56	8.29	2.13	0.73
Std. error	0.04	0.12	0.33	0.76	0.71	0.09	0.39	0.51	0.35	0.13	0.05
Variance	0.03	0.28	2.02	10.51	8.54	0.13	2.76	4.62	2.08	0.30	0.04
Coeff. var	18.1	9.77	24.69	15.32	18.50	24.72	48.60	12.99	17.37	25.88	27.46

Note: Fl: Leaf width FL: Leaf length FL/Fl: Length/width ratio LO: Fruit length DO: Fruit width LO/DO : Length/width ratio PO: Fruit weight LN: Endocarp length DN: Endocarp width LN/DN: Length/width ratio PN: Endocarp weight.

Table 5. The results related to the one-way analysis of variance (variety) of the different characters.

Variable	Source of Variation	D.f	F-test	p-value
FL	Variety	17	2.6923	0.0079
	Error	72		
Fl	Variety	17	4.7619	< 0.001
	Error	72		
FL/Fl	Variety	17	3.8462	< 0.001
	Error	72		
LO	Variety	17	15.3846	< 0.001
	Error	72		
DO	Variety	17	11.5385	< 0.001
	Error	72		
LO/DO	Variety	17	16.9231	< 0.001
	Error	72		
PO	Variety	17	20.7692	< 0.001
	Error	72		
LN	Variety	17	12.3077	< 0.001
	Error	72		
DN	Variety	17	7.6923	< 0.001
	Error	72		
LN/DN	Variety	17	18.4615	< 0.001
	Error	72		
PN	Variety	17	14.6154	0.0000
	Error	72		

Note: df (Degrees of Freedom), F-test (F statistic), p-value (probability value).

As indicated in Table.6, the analysis of variance revealed significant differences among olive cultivars for most morphological traits examined ($p < 0.05$). Fruit characteristics exhibited the highest variability, with fruit weight ($F = 20.7692$, $p < 0.0001$) and fruit shape (LO/DO ratio, $F = 16.9231$, $p < 0.0001$) showing the most pronounced differences. Endocarp traits, particularly shape (LN/DN ratio, $F = 18.4615$, $p < 0.0001$), also displayed significant variability. Leaf traits showed less variation, with leaf length ($F = 2.6923$, $p = 0.0079$) being the least variable among significant characteristics. Leaf width was the only trait not showing significant differences among cultivars ($F = 4.7619$, $p > 0.05$). This pattern of variability indicates strong differentiation in reproductive structures and relative conservation of vegetative features among olive cultivars, reflecting the complex interplay of selective pressures in olive domestication and breeding.

Figure 7, illustrates the application of principle component analysis (PCA), a statistical method that transforms a collection of potentially interrelated variables into a new set of variables devoid of correlations (Ranjan & Saha, 2024). The morphological characters of 18 olive cultivars demonstrated a notable organization of pomological variation in the examined area. Two primary axes, F1 and F2, which accounted for 64.92% of the variability, mostly explained the entire variability. Specifically, F1 contributed 49.23% and F2 contributed 15.69%. F1 had a significant correlation with fruit size and weight, leaf length, and endocarp width, but F2 was mainly associated with fruit length.

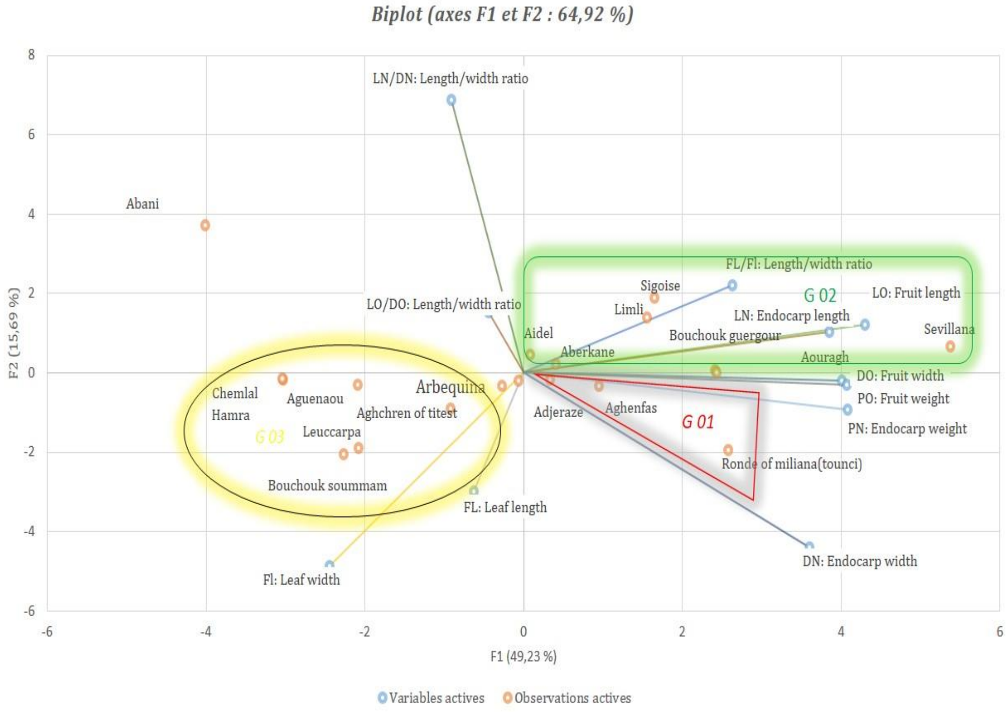

Figure 7. Principal Component Analysis: Projection of Variables on the Factor Plane 1-2

Three separate ecotypic groupings were found based on the use of PCA and morphological data.

1 *The large fruit and large endocarp ecotype*: includes varieties such as *Ronde of Miliana* (Tounci), *Adjeraze*, and *Aghenfas*. These types are known for their large and heavy fruits, as well as their large endocarps.

2 *Elongated fruit and elongated endocarp ecotype:* Including cultivars like *Sigoise*, *Limli*, and *Sevillana*, defined by high length-to-width ratios in fruits and endocarps, sometimes accompanied by elongated leaves.

3 *Tiny fruit, short endocarp, and small leaf ecotype*: Encompassing cultivars such as *Chemlal*, *Hamra*, and *Aguenaou*, characterized by tiny fruits, endocarps, and frequently short leaves.

These results show the enormous morphological variation among olive cultivars in the area, suggesting possible responses to diverse environmental circumstances and production approaches. Ecotypic groupings offer a structured framework for future research on olive cultivation, allowing for targeted investigation into genetic, physiological, and agronomic aspects. Understanding these groups, helps develop efficient strategies for cultivar improvement and adaptation to specific conditions or market needs. They also inform practical decisions, allowing growers to select varieties best suited to their conditions and production goals.

3.3 Correlation between qualitative and quantitative traits

Significant relationships between qualitative and quantitative traits of olive varietals are found in the study. Fruit shapes, endocarp shapes, leaf shapes, and overall morphology are all correlated with quantitative measurements. Elongated fruit shapes (EFS) and spherical fruit shapes (SFS) show higher length/width ratios, while ovoid fruit shapes (OFS) fall between these extremes. Leaf shapes, elliptical-lanceolate and lanceolate, show variability but generally lower ratios. Fruit weight also correlates with morphological traits, with FWH (Fruit Weight High) varieties having larger endocarps and the FMW (Medium Fruit Weight) group showing the most diversity. These correlations offer a more nuanced understanding of olive morphological diversity and enable more precise selection basedon comprehensive form and specific dimensional criteria. The study also highlights the complex interplay between different morphological traits, suggesting potential genetic or developmental links.

3.4 Analysis of ecotypic groupings of olive varieties based on agronomic and Environmental data

The analysis identifies three primary ecotypic categories of olive varietals based on agronomic and environmental data. *(1) large fruit and large endocarp*, located in elevated regions characterised by cooler climates and enhanced water accessibility; (2) elongated fruit and elongated endocarp, suited for moderate soil and moisture conditions, likely exhibiting greater drought resistance; and (3) small Fruit, small endocarp, and small leaf, adapted to diverse environments, including severe mountainous terrains and elevated plateaus. These classifications illustrate the olive trees' adaptation to local environmental conditions, soil characteristics, and agricultural practices, showcasing the varieties resilience and adaptability to diverse ecosystems.

3.5 Assessment of Varietal Relationships Using Bray-Curtis Similarity Analysis

Table 6 illustrates the high compositional similarities (pair values > 0.95) between four pairs of local olive varieties: *Adjeraze-Aberkane* (0.97), *Adjeraze-Aghenfas* (0.97), and *Aghenfas-Arbequina* (0.97). Conversely, modest similarities (values < 0.80) are detected between *Chemlal-Sevillana* (0.76), *Hamra-Sevillana* (0.76), and *Abani-Sevillana* (0.74), with Sevillana presenting as a very separate variant.

High compositional similarities between certain olive varieties, such as Adjeraze-Aberkane, Adjeraze-Aghenfas, and Aghenfas-Arbequina, have significant implications for genetic relationships and breeding strategies. These similarities suggest genetic closeness, potential for misidentification, limited genetic gain, and conservation of traits, diversification needs, and evolutionary insights. However, The Bray-Curtis similarity analysis has limitations. Alternative methods like Molecular Marker Analysis, Phylogenetic Analysis, and Functional Trait Analysis offer deeper insights into genetic relationships, population structure, and diversity. Integrating these methods with Bray-Curtis analysis can provide a more comprehensive understanding of olive variety genetic relationships.

Table 6. Bray-Curtis Similarity Matrix for 18 Olive Varieties

	Chemlal	**Adjeraze**	**Sigoise**	**Hamra**	**Limli**	**Aberkane**	**Aghenfas**	**Aguenaou**	**Bouchouk guergour**	**Bouchouk soummam**	**Aouragh**	**Abani**	**Aghchren de titest**	**Aidel**	**Ronde of miliana**	**Arbequina**	**Sévillane**
Adjeraze	0.89																
Sigoise	0.84	0.94															
Hamra	0.97	0.89	0.84														
Limli	0.86	0.96	0.94	0.86													
Aberkane	0.88	0.97	0.94	0.87	0.97												
Aghenfas	0.87	0.97	0.95	0.87	0.95	0.95											
Aguenaou	0.94	0.93	0.88	0.95	0.90	0.91	0.92										
Bouchouk guergour	0.82	0.93	0.93	0.82	0.94	0.94	0.93	0.86									
Bouchouk soummam	0.94	0.92	0.86	0.95	0.88	0.91	0.90	0.95	0.85								
Aouragh	0.84	0.95	0.94	0.83	0.97	0.96	0.93	0.88	0.95	0.87							
Abani	0.94	0.86	0.82	0.93	0.83	0.85	0.84	0.91	0.79	0.90	0.81						
Aghchren de titest	0.92	0.96	0.91	0.91	0.93	0.95	0.94	0.96	0.90	0.95	0.92	0.89					
Aidel	0.88	0.97	0.94	0.87	0.93	0.95	0.96	0.91	0.91	0.90	0.92	0.85	0.94				
Ronde of miliana	0.81	0.92	0.94	0.82	0.90	0.90	0.93	0.86	0.90	0.85	0.90	0.78	0.88	0.91			
Arbequina	0.89	0.99	0.93	0.90	0.95	0.96	0.97	0.94	0.92	0.92	0.93	0.87	0.96	0.96	0.91		
Sévillane	0.76	0.87	0.90	0.76	0.89	0.88	0.88	0.80	0.91	0.79	0.91	0.74	0.84	0.86	0.91	0.85	
Leucocarpa	0.92	0.91	0.87	0.92	0.90	0.92	0.91	0.93	0.86	0.91	0.89	0.89	0.93	0.90	0.85	0.92	0.80

4. Conclusion

Based on this extensive investigation of olive diversity in Bordj Bou Arreridj, substantial agro-morphological variation occurs among the 18 recognised types, including 15 indigenous and 3 foreign cultivars. The study indicated three separate ecotypic groupings based on fruit and endocarp characteristics: large-fruited types (e.g., *Ronde of Miliana*), elongated types (e.g., *Sigoise*), and small-fruited types (e.g., *Chemlal*). While fruit shape exhibited substantial diversity, leaf features revealed relative retention, indicating steady adaptation to local environments. The finding of the uncommon *Leucocarpa* variation, previously unreported in Algeria, underscores the necessity of continuing investigation of local genetic resources. This result has important ramifications for breeding operations and future market diversification. Principal component analysis and Bray-Curtis similarity evaluations indicated tight correlations between specific local variations, suggesting possible genetic links that deserve further exploration. The demonstrated morphological flexibility, notably in fruit traits, gives opportunity for selective breeding programs targeting both oil and table olive output. This work lays a platform for future research approaches, including genetic analysis, environmental interaction investigations, and agronomic performance assessments. Further research should concentrate on molecular characterisation, functional genomics, and phenomics to corroborate morphological results and comprehend variety adaptability across varied climatic circumstances. Such thorough knowledge will be vital for conservation policies and the sustainable development of the region's olive sector, eventually contributing to both economic prosperity and agricultural variety.

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Author's declaration and contribution

The authors declare no conflicts of interest. From concept creation and methodological refinement to data collection, analysis, paper draughting, critical review, project supervision, and showcasing a thorough team effort, author contributions were various and significant.

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