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Comparative Morphological, Nutritional, and Biochemical Analysis of *Myrtus communis* L. from Two Contrasting Habitats (Wadi al-Kuf and Wadi Azlifat) in Al-Jabal Al-Akhdar, Libya

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Abstract:

This study evaluated habitat-associated variation in the nutritional and morphometric characteristics of *Myrtus communis* L. across two habitats, Wadi al-Kuf and Wadi Azlifat, in Al-Jabal Al-Akhdar, Libya. Shoots, leaves, and fruits were collected in triplicate in summer 2023. Minerals (Ca, K, Na, and Mg), amino acids, leaf and fruit traits, and physicochemical fruit properties were analyzed. Crude protein was significantly higher in Wadi al-Kuf (5.805 ± 0.103 g/100 g d.w.) than in Wadi Azlifat (4.970 ± 0.386 g/100 g d.w.; $P = 0.022$), whereas carbohydrate content was significantly higher in Wadi Azlifat (14.960 ± 0.795 g/100 g d.w.) than in Wadi al-Kuf (6.273 ± 0.019 g/100 g d.w.; $P < 0.001$). Fat content was also significantly higher in Wadi Azlifat ($P = 0.002$), while moisture and ash did not differ significantly. Mineral concentrations were higher in Wadi Azlifat, with Ca reaching 3.132 mg/g d.w. compared with 1.631 mg/g d.w. in Wadi al-Kuf. Glutamic acid was the predominant amino acid, whereas methionine was least abundant. Fruit length was significantly greater in Wadi Azlifat (8.15 ± 0.51 mm) than in Wadi al-Kuf (7.22 ± 0.26 mm; $P = 0.048$), while seed number per fruit was significantly higher in Wadi al-Kuf (11.87 ± 2.53) than in Wadi Azlifat (2.47 ± 4.39 ; $P = 0.032$). Other fruit traits were not significantly different. Overall, the findings indicate habitat-associated morphological and biochemical variation in *M. communis*. Future studies should examine additional habitats and integrate soil and microclimatic variables to clarify the environmental drivers of this variation.

Keywords: Myrtle; Phytochemical composition; Phenotypic plasticity; Amino acids; Habitat variation.

تحليل مقارن للخصائص المورفولوجية والغذائية والبيوكيميائية لنبات الأس (*Myrtus communis* L.) من موطنين مختلفين (وادي الكوف، وادي أزليفات) في الجبل الأخضر، ليبيا

المستخلص: قُيِّمت هذه الدراسة التباين المرتبط الموئل الطبيعي في الخصائص الغذائية والمورفومترية (الشكلية) لنبات الميرسين (*Myrtus communis* L.) عبر بيئتين مختلفتين؛ هما: وادي الكوف ووادي أزليفات بمنطقة الجبل الأخضر في ليبيا. وقد جُمِعت عينات بثلاث مكررات من الأغصان والأوراق والثمار خلال صيف عام 2023. وقد شملت التحاليل تقدير العناصر المعدنية (الكالسيوم، البوتاسيوم، الصوديوم، والمغنيسيوم)، والأحماض الأمينية، وسمات الأوراق والثمار، بالإضافة إلى الخصائص الفيزيوكيميائية للثمار. وقد أظهرت النتائج أن نسبة البروتين الخام كانت أعلى معنوياً في وادي الكوف (5.805 ± 0.103 جم/100 جم وزن جاف) مقارنة بوادي أزليفات (4.970 ± 0.386 جم/100 جم وزن جاف؛ $P = 0.022$)، بينما كان محتوى الكربوهيدرات أعلى معنوياً في وادي أزليفات (14.960 ± 0.795 جم/100 جم وزن جاف) مقارنة بوادي الكوف (6.273 ± 0.019 جم/100 جم وزن جاف؛ $P < 0.001$). كما كان محتوى الدهون أعلى معنوياً في وادي أزليفات ($P = 0.002$)، في حين لم تسجل الفروق في الرطوبة والرماد أي دلالة إحصائية. وقد سُجِّلَت تركيزات أعلى للعناصر المعدنية في وادي أزليفات؛ حيث بلغ الكالسيوم 3.132 جم/جم وزن جاف مقارنة بـ 1.631 جم/جم وزن جاف في وادي الكوف. وقد كان حمض الجلوتاميك هو الحمض الأميني السائد، بينما كان الميثيونين الأقل وفرة. وعلى صعيد الصفات المورفولوجية، كان طول الثمرة أكبر معنوياً في وادي أزليفات (8.15 ± 0.51 مم) مقارنة بوادي الكوف (7.22 ± 0.26 مم؛ $P = 0.048$)، في حين كان عدد البذور لكل ثمرة أعلى معنوياً في وادي الكوف (11.87 ± 2.53) مقارنة بوادي أزليفات (2.47 ± 4.39 ؛ $P = 0.032$). ولم تظهر الصفات الأخرى للثمار فروقاً معنوية. وبشكل عام تشير هذه النتائج إلى وجود تباين مورفولوجي وبيوكيميائي مرتبط بالموئل الطبيعي لنبات الميرسين *M. K communis*. وتوصي الدراسة بإجراء أبحاث مستقبلية تتناول مواطن انتشار النبات وتدمج متغيرات التربة والمناخ الدقيق لتحديد سبب المرونة البيئية لهذا النبات.

الكلمات المفتاحية: نبات الميرسين؛ التركيب الكيميائي النباتي؛ المرونة الظاهرية؛ الأحماض الأمينية؛ التباين البيئي.



INTRODUCTION

Myrtus communis L. a prominent member of the (Myrtaceae) family, has been a cornerstone of Unani phytotherapy since the era of ancient Greece. This shrub represents a fundamental component of the Mediterranean Maquis and maintains an extensive geographical distribution spanning the Mediterranean basin and the Middle East (**Bouzabata, et al., 2023**). Myrtle is a perennial evergreen shrub characterized by its resilience and ability to propagate through both seeds and stem cuttings. In the Mediterranean region and North Africa, the plant is known by several vernacular names, reflecting its cultural and medicinal importance; it is commonly referred to as "Al-As", "Hamulas", and sometimes "Rayhan" in certain local dialects (**Yadegarinia et al., 2006**). It has been utilized for centuries to treat various ailments; however, this extensive use has led to a noticeable decline in its natural habitats and population density (**Alhadead and Almesmari, 2021**). The fruit production of *Myrtus communis* within natural populations is significantly influenced by climatic and environmental conditions. This often results in inconsistent fruit quality and quantity, failing to meet the industrial requirements for specific volume and qualitative standards (**Salim et al., 2024**). Research indicates that variations in ecological parameters including thermal conditions, moisture accessibility, and elevation significantly influence fruit morphology, secondary metabolite concentrations, and total biomass. In particular, environmental stress associated with lower altitudes, increased temperatures, and arid conditions has been linked to an accumulation of flavonoids and phenolic constituents (**González-de-Peredo et al., 2019**). Consequently, conservation programs are essential for planning the effective exploitation of species facing rising biomass demands, particularly in light of increasing environmental pressures and anthropogenic exploitation (**Medda and Mulas, 2022**). This deterioration necessitates the implementation of sustainable management and conservation programs to ensure the species' survival and prevent the loss of its genetic diversity. This is particularly critical in ecologically sensitive regions like Al-Jabal Al-Akhdar, where numerous rare plant species face increasing threats from unsustainable human activities (**Santos et al., 2020; Tilman et al., 2014**). Within the Al-Jabal Al-Akhdar ecosystem, *M. communis* is classified as a high-priority woody species currently facing a heightened risk of local extinction. This vulnerability is primarily driven by intensifying anthropogenic disturbances, including unregulated overgrazing, premature livestock foraging, and the illicit harvesting of woody biomass for fuel and charcoal. These pressures are further compounded by the expansion of agricultural frontiers into native rangelands and the increasing frequency of severe drought episodes (**Al-Zani, 2002**). Although *Myrtus communis* L. has been investigated for its ecological, phytochemical, and nutritional properties, the relationship between habitat variation and the integrated expression of morphological, nutritional, and biochemical traits remains insufficiently characterized of Al-Jabal Al-Akhdar, Libya. Most available information addresses individual aspects of the species rather than examining morphological traits together with proximate composition, mineral elements, and amino acid profiles within contrasting habitats. Consequently, it remains unclear whether local habitat conditions are associated with coordinated variation in the phenotype and biochemical composition of *M. communis*. Addressing this gap is important for understanding the ecological plasticity of the species and for assessing how habitat conditions may influence its nutritional characteristics. Accordingly, this study compared the morphological, nutritional, and biochemical attributes of *M. communis* growing in Wadi al-Kuf and Wadi Azlifat, with the aim of identifying habitat-associated variation in these traits. The present study aims to investigate the impact of eco-geographical variation on the phytochemical, nutritional, and morphometric profiles of *Myrtus communis* L. (Myrtaceae) in two habitats within Libya's Al-Jabal Al-Akhdar region: Wadi al-Kuf and Wadi Azlifat.

MATERIALS AND METHODS

The plant material of *Myrtus communis* L. (Myrtaceae) was collected during the vegetative stage

in the summer of 2023. Samples were obtained from two distinct natural habitats within the Al-Jabal Al-Akhdar region: Wadi al-Kuf and Wadi Azlifat (**Figure 1**).

Site Description and Climatic Parameters:

Climatic data for the study sites during the year 2023 were collected to characterize the environmental conditions of *Myrtus communis* L. habitats in Wadi al-Kuf and Wadi Azlifat. Wadi al-Kuf is characterized by a higher cumulative annual rainfall of 468.9 mm, with maximum precipitation concentrated during the winter months (110.0 mm in January and 114.1 mm in February). The mean monthly temperatures at this site ranged from 10.1°C in February to 26.0°C in July. In contrast, Wadi Azlifat recorded a lower annual rainfall of 441.2 mm, marked by a sharper decline in precipitation during the spring and summer periods and a prolonged dry season. The mean monthly temperatures ranged from 7.98°C in February to a summer peak of 24.98°C in August.

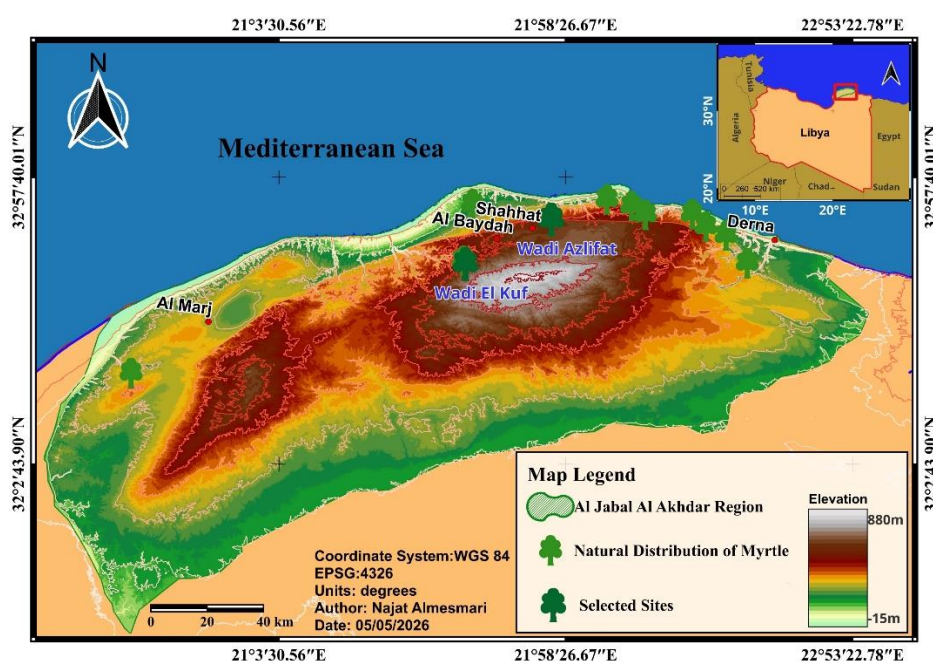


Figure 1. Distribution of *Myrtus communis* L. and location study in the Al-Jabal Al-Akhdar region: Wadi al-Kuf and Wadi Azlifat

General Phytochemical Analysis of *Myrtus communis*

To evaluate the nutritional profile of *Myrtus communis*, pulverized vegetative samples collected from Wadi al-Kuf and Wadi Azlifat were subjected to a comprehensive biochemical screening. The percentages of moisture and ash were determined in accordance with the **AOAC (1999)** protocols, specifically utilizing methods 930.15 and 942.05, respectively.

For mineral quantification (mg/g), the concentrations of essential minerals specifically Magnesium (Mg), Calcium (Ca), Potassium (K), and Sodium (Na) were measured using an Atomic Absorption Spectrometer (SHIMADZU 6650 AA). Sample preparation for this analysis followed the dry ashing technique as established by **Egan et al. (1981)**. The proximate composition of the samples was further evaluated by determining crude fats, crude protein, and total carbohydrates. Total lipid content was measured gravimetrically following a Soxhlet extraction process utilizing hexane as the solvent. Crude protein content was estimated via the Kjeldahl method, where the total nitrogen concentration was multiplied by a standard conversion factor of 6.25. Finally, total carbohydrate fractions were

derived by difference, subtracting the combined percentages of moisture, ash, lipids, and proteins from the total weight (100%) according to the approach described by **Judprasong et al. (2013)**.

Estimation of total amino acids

Amino Acid Profiling: The total amino acid distribution of *M. communis* was quantified using an automated Amino Acid Analyzer (Model: AAA400). The analytical procedure was conducted in accordance with the methodology established by **Csomòs and Simon-Sarkadi (2002)**. Prior to analysis, the plant samples underwent a stabilization process involving initial freezing, followed by controlled dehydration in a convection oven. The drying process was maintained at a constant temperature of 45°C over a duration of seven days to preserve the integrity of the amino acid constituents and prevent thermal degradation.

Acid Hydrolysis: For sample purification, a designated mass of the pulverized matrix was initially defatted by overnight immersion in diethyl ether, effectively removing lipids, pigments, and interfering lipophilic contaminants. Subsequent to de-oiling, approximately 0.3g of the treated tissue was hydrolyzed with 10mL of 6 N hydrochloric acid (HCl) in a hermetically sealed tube, followed by a 24-hour incubation in a convection oven at 110°C. Once incubated, the resulting hydrolysates were quantitatively transferred into porcelain dishes, where the acid was evaporated to dryness using a water bath at 50-60°C. Residual HCl was completely eliminated by repeating a cycle of adding 5mL of distilled water and re-evaporating twice. The obtained residue was then redissolved in 10mL of distilled water and clarified through a 0.45 µm membrane filter. To achieve higher purity, the filtrate was concentrated under vacuum via rotary evaporation, undergoing a final re-hydration and drying phase. Ultimately, the purified extracts were reconstituted in 1mL of 0.2N sodium citrate buffer pH and stored in sealed vials under cryogenic conditions prior to automated chromatographic analysis.

Separation of amino acids by amino acid analyzer

Chromatographic Separation and Detection: The processed extracts were introduced into the automated Amino Acid Analyzer. The separation of individual amino acids was achieved through ion-exchange chromatography, governed by specific pH gradients. Following separation, the analytes underwent post-column derivatization with ninhydrin for colorimetric detection. Spectrophotometric Quantification: The reaction yield varies based on the amino acid structure:

Primary alpha amino acids: These react to form a complex purple pigment, which is monitored at a maximum absorbance of 570 nm. **Secondary amino acids (e.g., Proline):** Due to their cyclic structure, these produce a distinct yellow derivative, with quantification performed at an absorbance maximum of 440 nm.

Fruit Morphometric and Physical Parameters: For each studied wadi, plant populations were sampled by selecting five representative trees per site. physical and morphometric parameters were evaluated using random fruit samples in three replicates. Fruit weight was measured using a high-precision electronic balance, and the average weight of 100 fruits (g) was recorded. Fruit volume cm³ was determined via the standard water displacement method for irregular shapes.

Chemical and Quality Analysis:

pH Determination: The pH of the fruit was measured after thoroughly homogenizing ripe fruits using an electric blender. A representative sample of the resulting pulp was tested using a calibrated pH meter.

Total Soluble Solids (T.S.S): The concentration of total soluble solids was estimated. All aforementioned measurements were conducted in accordance with the standard methods of the **AOAC**

(2000).

Biometric Traits of Fruits and Leaves:

Fruit Parameters: Length and width of the fruit, fresh and dry weight, number of seeds per fruit, total fruit and seed weight (Figure 2a).

Leaf Parameters: Leaf length, leaf width, and total leaf area. The selection of these specific traits to evaluate the diversity of *M. communis* is a robust and effective tool for studying variations in leaf and fruit morphology (Figure 2b & 2c). The characterization list was implemented according by (Nour et al., 2023).

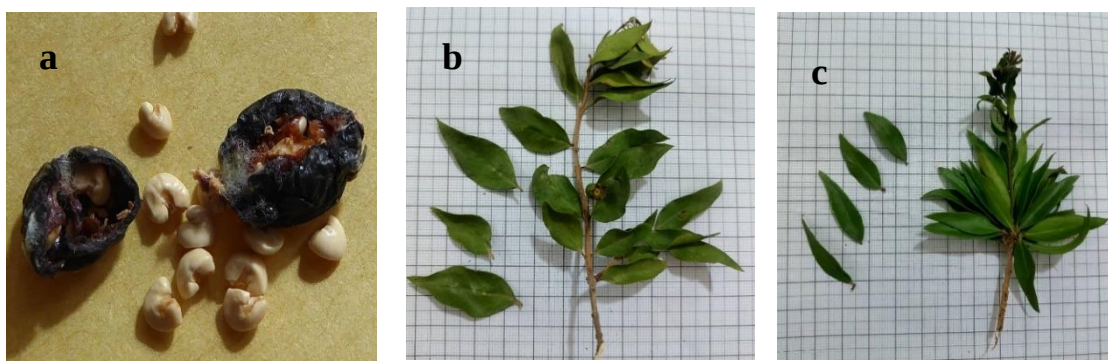


Figure 2. The number of seeds per fruit (a), Ecological Habitat: Wadi Al-Kuf (b) and Ecological Habitat: Wadi Azlifat (c).

Statistical Analysis: A Completely Randomized Design (CRD) with a single factor (habitat) was employed for this study. All plant samples (leaves, fruits) were collected in triplicates ($n = 3$) during a single sampling season from two distinct eco-habitats: Wadi Al-Kuf and Wadi Azlifat. Data were expressed as Mean $\pm$ Standard Deviation (Mean $\pm$ SD). Statistical comparisons between the two study sites across all morphological, biochemical, and physicochemical parameters were evaluated using an Independent Samples t-test. Differences were considered statistically significant at $P \leq 0.05$, whereas values with $P > 0.05$ were designated as statistically non-significant. All statistical analysis computations were executed using SPSS software.

RESULTS AND DISCUSSION

The proximate composition of *Myrtus communis* L. shoot powder differed between Wadi al-Kuf and Wadi Azlifat, although the magnitude and statistical significance of the differences varied among the measured components (Table 1). Moisture content was 9.600 ± 0.173 g/100 g in Wadi al-Kuf and 9.760 ± 0.971 g/100 g in Wadi Azlifat, with no statistically significant difference between the two habitats ($P = 0.793$). Similarly, ash content did not differ significantly between Wadi al-Kuf (26.000 ± 1.732 g/100 g) and Wadi Azlifat (25.400 ± 0.361 g/100 g; $P = 0.588$).

In contrast, fat content was significantly higher in Wadi Azlifat (0.190 ± 0.026 g/100 g) than in Wadi al-Kuf (0.077 ± 0.000 g/100 g; $P = 0.002$). Protein content also differed significantly between the two habitats, being higher in Wadi al-Kuf (5.805 ± 0.103 g/100 g d.w.) than in Wadi Azlifat (4.970 ± 0.386 g/100 g d.w.; $P = 0.022$). The most pronounced difference was observed in carbohydrate content, which was significantly higher in Wadi Azlifat (14.960 ± 0.795 g/100 g d.w.) than in Wadi al-Kuf (6.273 ± 0.019 g/100 g d.w.; $P < 0.001$).

Regarding mineral composition, calcium was the most abundant element in both habitats. The concentrations of Ca, K, Na, and Mg were numerically higher in Wadi Azlifat than in Wadi al-Kuf, with Ca concentrations of 3.132 and 1.631 mg/g d.w., respectively. Likewise, K, Na, and Mg concentrations were 0.4861, 0.3641, and 0.1242 mg/g d.w. in Wadi Azlifat compared with 0.248, 0.185, and 0.053 mg/g d.w. in Wadi al-Kuf, respectively. These mineral differences are presented descriptively because replicate-level measurements for the mineral variables were not available for statistical testing.

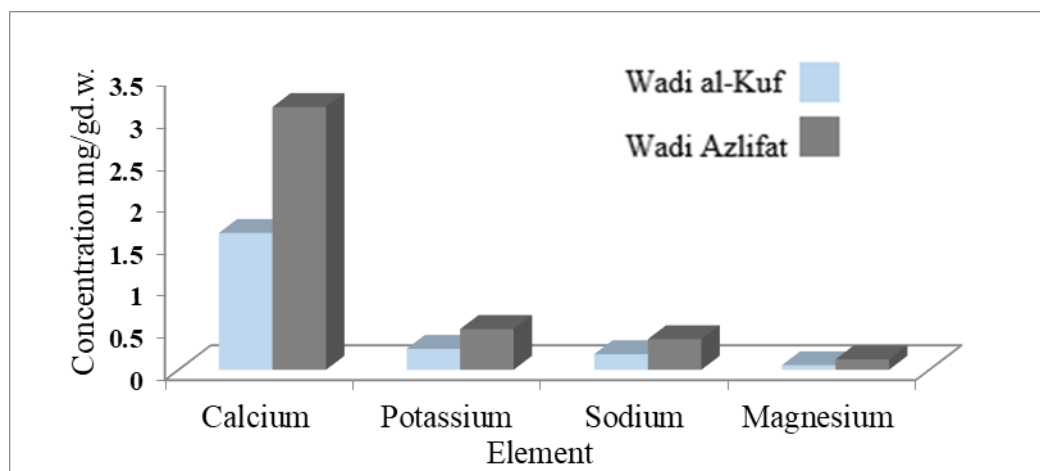


Figure3. Concentration (mg/g) of some elements in Wadi al-Kuf and Wadi Azlifat of *Myrtus communis* L. shoot powder.

Table 1. Nutritive content (g/100g d.w.) in Wadi al-Kuf and Wadi Azlifat *Myrtus communis* L. shoot powder.

Content	Wadi al-Kuf	Wadi Azlifat	P-value
Moisture *	9.600 ± 0.173 ^a	9.760 ± 0.971 ^a	0.793
Ash	26.000 ± 1.732 ^a	25.400 ± 0.361 ^a	0.588
Fat	0.077 ± 0.000 ^a	0.190 ± 0.026 ^b	0.002
Protein	5.805 ± 0.103 ^a	4.970 ± 0.386 ^b	0.022
Carbohydrate	6.273 ± 0.019 ^a	14.950 ± 0.795 ^b	<0.001

*Moisture content is calculated in terms of g/100 g fresh weight

Values are presented as mean ± SD (n = 3). Different superscript letters within the same row indicate significant differences between habitats at P < 0.05. Moisture content is expressed on a fresh-weight basis, whereas ash, fat, protein, and carbohydrate contents are expressed on a dry-weight basis.

Estimation of essential amino acids

Wadi al-Kuf and Wadi Azlifat were used for quantitative analysis of amino acid profile. Shoot samples of *Myrtus communis* L. from Wadi al-Kuf and Wadi Azlifat were used for the quantitative analysis of the amino acid profile (Figure 4). Results revealed Glutamic acid (GLU) was the most abundant amino acid in both habitats, reaching 0.015 mg/g d.w. in Wadi al-Kuf and 0.011 mg/g d.w. in Wadi Azlifat. Arginine (ARG) content was identical in both sites at 0.005 mg/g d.w.

Furthermore, the concentrations of Aspartic acid (ASP), Histidine (HIS), Phenylalanine (PHA), Alanine (ALA), Leucine (LEU), Proline (PRO), Lysine (LY), Tyrosine/Tryptophan (TRY), and Serine

(SER) ranged between 0.011 and 0.004 mg/g d.w. in Wadi al-Kuf, whereas in Wadi Azlifat they ranged between 0.009 and 0.003 mg/g d.w.

A notable variance was observed in Methionine (METH), which recorded the lowest concentration in Wadi Azlifat at 0.001 mg/g d.w., while reaching 0.005 mg/g d.w. in Wadi al-Kuf. Additionally, Glycine (GLY), Isoleucine (ISOL), Threonine (THREO), and Valine (VAL) in Wadi al-Kuf all shared the same modest value of 0.003 mg/g d.w., whereas their corresponding values in Wadi Azlifat were 0.002 mg/g d.w.

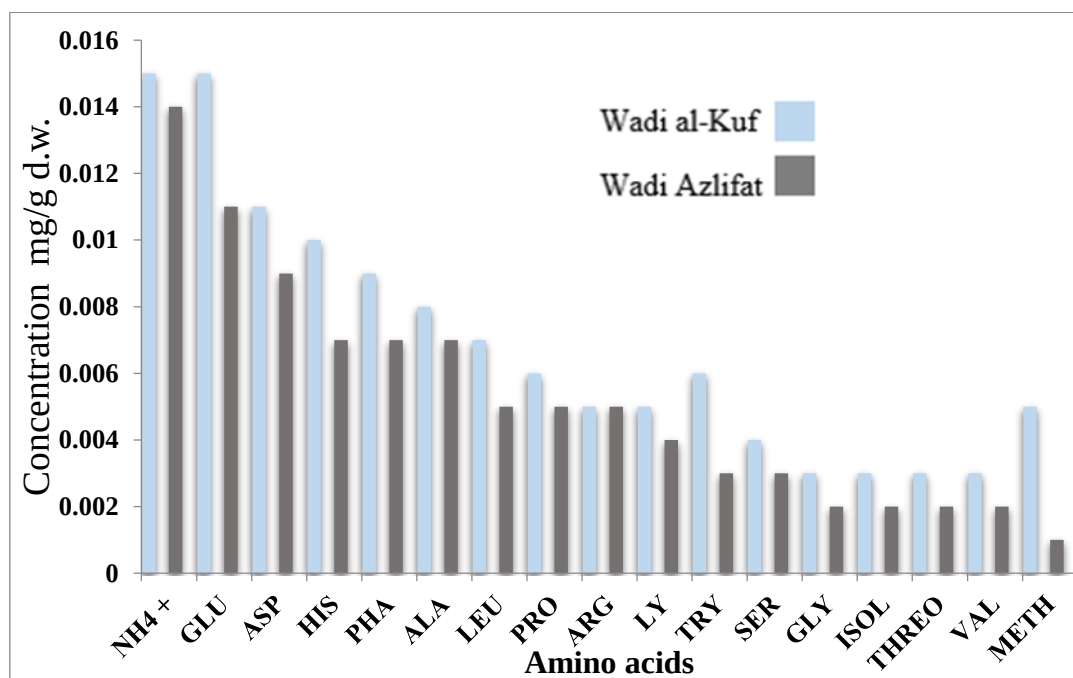


Figure 4. Comparative estimation of the concentration of NH₄⁺ and sixteen essential amino acids (Wadi al-Kuf) and (Wadi Azlifat) *Myrtus communis* shoot powder.

The phytogeographical data presented in Figure 1 confirms that *Myrtus communis* L. is strategically distributed across various ecological niches within the Al-Jabal Al-Akhdar region. The significant variations observed in the chemical and nutritional profiles between Wadi al-Kuf and Wadi Azlifat underscore the "Phenotypic Plasticity" of this species in response to localized environmental

1.Mineral Dynamics The chemical analysis (Figure 3) revealed a pronounced accumulation of minerals in *Myrtus communis* L. shoots from Wadi Azlifat, where Calcium (Ca) levels were nearly **double** (3.132 mg/g d.w.) compared to those recorded in Wadi al-Kuf (1.631 mg/g d.w.). Similarly, higher concentrations of Potassium (K), Sodium (Na), and Magnesium (Mg) were observed in Wadi Azlifat (0.4861, 0.3641, and 0.1242 mg/g d.w., respectively) relative to Wadi al-Kuf (0.248, 0.185, and 0.053 mg/g d.w., respectively). According to **Messaoud et al. (2021)**, mineral uptake in Mediterranean shrubs is highly localized, reflecting the immediate lithology of the habitat. High Ca and Mg levels are often associated with the plant's structural integrity and its ability to maintain physiological functions under the arid conditions typical.

2. Primary Metabolites: Stress Response and Nutritional Value A notable divergence was observed

in the composition (Table 1). The significantly higher protein content in Wadi al-Kuf (5.805 g/100g) may be attributed to the relatively more humid and sheltered environment of the valley, which supports robust nitrogen assimilation. In contrast, the substantial increase in carbohydrate content in Wadi Azlifat (4.970 g/100g) likely represents an osmotic adjustment. As noted by **Fadhel et al. (2022)**, plants in exposed or mineral-heavy habitats often accumulate soluble sugars to maintain turgor pressure and mitigate the effects of summer heat stress.

3. Amino Acid Profile and Metabolic Adaptation The quantitative analysis of ammonium (NH_4^+) and sixteen amino acids (Figure 4) further supports the metabolic differentiation between the two studied habitats. Overall, higher total amino acid concentrations were recorded in *Myrtus communis* shoots from Wadi al-Kuf compared to Wadi Azlifat, which strongly aligns with the elevated crude protein levels observed in Wadi al-Kuf. Among the analyzed amino acids, Glutamic acid (GLU) emerged as the most abundant amino acid in both habitats (0.015 mg/g d.w. in Wadi al-Kuf and 0.011 mg/g d.w. in Wadi Azlifat), which is consistent with its central role as a key precursor for nitrogen assimilation, metabolic pathways, and stress-related signaling (**Zhao et al., 2023**). A notable variation was observed in Methionine (METH) concentration, which showed a substantially lower level in Wadi Azlifat (0.001 mg/g d.w.) compared to Wadi al-Kuf (0.005 mg/g d.w.). This marked reduction in Wadi Azlifat may suggest its rapid metabolic consumption and conversion into stress-response metabolites, such as ethylene, or a limited availability of sulfur in that specific habitat.

4. Ecological Resilience The timing of the collection during the vegetative stage in summer is a critical factor. The Mediterranean climate forces *M. communis* to reconfigure its chemical signature to survive. While Wadi Al-Kuf offers a microclimate that favors protein and amino acid synthesis, Wadi Azlifat drives the plant toward a mineral and carbohydrate-rich profile. These findings align with the global understanding of *M. communis* as an exceptionally adaptable species, capable of modifying its nutritional and phytochemical composition to thrive in diverse Mediterranean microenvironments (**Alhadead et al., 2025**).

Morphological Characteristics and Biomass Distribution:

The fruits of *Myrtus communis* L. from both studied habitats (Wadi Al-Kuf and Wadi Azlifat) were characterized by a globose (rounded) morphology, consisting of a fleshy pericarp (pulp) and spiral-shaped seeds. Analysis of fruit composition was conducted to evaluate the relative biomass distribution between the seeds and the surrounding pericarp tissues. As presented in Table 2, noticeable variations were observed between specimens from both wadis, particularly regarding fruit length, fresh fruit weight, pulp mass, and seed count ($P \leq 0.05$). Conversely, certain traits, such as the weight of 100 seeds ($4.53 \pm 0.46\text{g}$ in Wadi Al-Kuf vs. $4.47 \pm 1.04\text{g}$ in Wadi Azlifat) and fruit width, showed no statistically significant differences ($P > 0.05$), indicating a stable seed mass despite habitat induced variations in total seed production per fruit.

Table 2. Morphological characteristics of *Myrtus communis* L. from both studied habitats (Wadi Al-Kuf and Wadi Azlifat)

Fruit Characteristics	Means $\pm$ SD		P-value	Significance
	Wadi Al-Kuf	Wadi Azlifat		
Fruit Length (mm)	7.22 ± 0.26	8.15 ± 0.51	0.048	Significant
Fruit Width (mm)	5.76 ± 0.43	5.85 ± 0.27	0.774	NS
Length/Width Ratio	1.26 ± 0.08	1.39 ± 0.03	0.058	NS

Fresh Fruit Weight (g)	0.25 ± 0.03	0.31 ± 0.05	0.149	NS
Dry Fruit Weight (g)	0.09 ± 0.01	0.12 ± 0.02	0.081	NS
Number of Seeds per Fruit	11.87 ± 2.53	2.47 ± 4.39	0.032	Significant
Seed Weight per Fruit (g)	0.05 ± 0.01	0.05 ± 0.02	1.000	NS
Weight of 100 Seeds (g)	4.53 ± 0.46	4.47 ± 1.04	0.833	NS
Pulp Weight (g)	0.20 ± 0.02	0.25 ± 0.04	0.125	NS
Pulp-to-Seed Ratio	3.71 ± 0.12	4.90 ± 0.92	0.090	NS

Values are presented as mean ± SD (n = 3). Statistical analysis was performed using Student's independent two-sample *t*-test at $P < 0.05$. **SD**: Standard Deviation; **NS**: Not Significant ($P \geq 0.05$).

Bold P-values indicate statistically significant differences between habitats.

The morphological characteristics of *Myrtus communis* L. fruits from the two studied habitats are presented in Table 2. Overall, several differences were observed between Wadi Al-Kuf and Wadi Azlifat; however, only some of these differences reached statistical significance. Fruit length was significantly higher in Wadi Azlifat (8.15 ± 0.51 mm) than in Wadi Al-Kuf (7.22 ± 0.26 mm; $P = 0.048$). In contrast, fruit width was similar between Wadi Azlifat (5.85 ± 0.27 mm) and Wadi Al-Kuf (5.76 ± 0.43 mm; $P = 0.774$). The length-to-width ratio was numerically higher in Wadi Azlifat (1.39 ± 0.03) than in Wadi Al-Kuf (1.26 ± 0.08), although the difference was not statistically significant ($P = 0.058$).

Fresh and dry fruit weights were also higher in Wadi Azlifat (0.31 ± 0.05 and 0.12 ± 0.02 g, respectively) than in Wadi Al-Kuf (0.25 ± 0.03 and 0.09 ± 0.01 g, respectively); however, neither fresh fruit weight ($P = 0.149$) nor dry fruit weight ($P = 0.081$) differed significantly between habitats. A significant difference was observed in the number of seeds per fruit, which was substantially higher in Wadi Al-Kuf (11.87 ± 2.53) than in Wadi Azlifat (2.47 ± 4.39 ; $P = 0.032$). In contrast, seed weight per fruit was identical in mean value between the two habitats (0.05 ± 0.01 and 0.05 ± 0.02 g; $P = 1.000$).

The weight of 100 seeds showed very similar values between Wadi Al-Kuf (4.53 ± 0.46 g) and Wadi Azlifat (4.47 ± 0.04 g), with no significant difference ($P = 0.833$). Similarly, pulp weight was higher in Wadi Azlifat (0.25 ± 0.04 g) than in Wadi Al-Kuf (0.20 ± 0.02 g), but the difference was not statistically significant ($P = 0.125$). The pulp-to-seed ratio was also numerically higher in Wadi Azlifat (4.90 ± 0.92) than in Wadi Al-Kuf (3.71 ± 0.12), although this difference was not statistically significant ($P = 0.090$).

Table 3. Chemical properties of *M. communis* fruits (pH, EC, and TDS) in the studied habitats (Wadi Al-Kuf and Wadi Azlifat)

Parameter	Wadi Al-Kuf	Wadi Azlifat	P-value
pH	5.44	4.80	<0.05
Electrical Conductivity (EC)	2382 μ S/cm	1875 μ S/cm	<0.05
Total Dissolved Solids (TDS)	1525 ppm	1200ppm	<0.05

Values represent means of triplicate determinations ($n = 3$). Differences between habitats were evaluated using Student's independent t -test ($P < 0.05$).

The chemical analysis of *Myrtus communis* L. fruit juice (Table 3) revealed significant variations ($P < 0.05$) in pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) between the two studied habitats, providing key insights into the physiological and biochemical status of the fruits:

Fruit Acidity (pH): Fruit juice from Wadi Al-Kuf exhibited a significantly higher pH value (5.44) compared to Wadi Azlifat (4.80; $P < 0.05$), indicating that fruits from Wadi Azlifat are distinctly more acidic. This increased acidity represents a typical physiological response to the drier, more exposed environmental stress in Azlifat, where plants tend to synthesize and accumulate organic acids to facilitate osmoregulation.

Ionic Strength & Soluble Content (EC & TDS): Conversely, Wadi Al-Kuf registered significantly higher values ($P < 0.05$) for both Electrical Conductivity (2382 $\mu\text{S}/\text{cm}$ vs. 1875 $\mu\text{S}/\text{cm}$ in Azlifat) and Total Dissolved Solids (1525 ppm vs. 1200 ppm in Azlifat). The elevated EC directly reflects a higher concentration of free ionic species and mineral electrolytes, while the higher TDS underlines a greater overall accumulation of soluble solids, aligning with the observed higher protein and amino acid levels in the same site.

Overall, these physicochemical variations confirm that while Wadi Azlifat yields fruits with a sharper, more acidic profile suited for drought adaptation, Wadi Al-Kuf produces fruits with higher overall nutrient density, greater ionic strength, and a less acidic flavor profile.

Leaf Morphological Traits: Mean Leaf Length and Width: Specimens from Wadi Al-Kuf exhibited significantly greater dimensions, with a mean length and width of 31.42 mm $\times$ 13.00 mm, compared to those from Wadi Azlifat, which measured 26.67 mm $\times$ 10.22 mm. These findings suggest that the more humid environmental conditions in Wadi Al-Kuf promote the development of larger leaf surfaces, potentially enhancing photosynthetic efficiency.

Specimens from Wadi Al-Kuf exhibited significantly longer and wider leaves compared to those from Wadi Azlifat. These results are in alignment with the findings of **Messaoud and Chen (2011)**, who noted that plants in humid environments tend to develop larger leaf surface areas to maximize photosynthetic efficiency. Conversely, plants in arid or xeric habitats typically produce smaller and narrower leaves as an adaptive strategy to minimize water loss through transpiration.

Conversely, the leaf length-to-width ratio was higher in Wadi Azlifat (2.61) compared to Wadi Al-Kuf (2.42), indicating a more elongated leaf morphology in the arid habitat. This observation supported by **Taïbi et al. (2016)**, who identified this ratio as a key indicator of plant adaptation to environmental stress

CONCLUSIONS

This study demonstrates significant habitat-associated variations in the biochemical, nutritional, physicochemical, and morphometric characteristics of *Myrtus communis* L. between Wadi al-Kuf and Wadi Azlifat in Al-Jabal Al-Akhdar, Libya:

Nutritional Profile Variations: Specimens from Wadi Azlifat exhibited significantly higher accumulation of carbohydrates (14.950 ± 0.795 g/100g d.w., $P < 0.001$) and crude fat (0.190 ± 0.026 g/100g d.w., $P = 0.002$), alongside higher overall mineral concentrations (particularly Calcium, reaching > 3.0 mg d.w.).

Conversely, Wadi al-Kuf specimens showed significantly higher crude protein content (5.805 ± 0.103 g/100g d.w., $P = 0.022$) as well as generally higher concentrations across most analyzed amino acids, with Glutamic acid (GLU) being the predominant amino acid and Methionine (METH) the least abundant in both habitats.

Fruit Physicochemical Properties: Fruits harvested from Wadi al-Kuf exhibited higher values across all evaluated physicochemical parameters compared to Wadi Azlifat, including pH (5.44 vs. 4.80), Electrical Conductivity ($2382 \mu\text{S}/\text{cm}$ vs. $1875 \mu\text{S}/\text{cm}$), and Total Dissolved Solids (1525 ppm vs. 1200 ppm). This indicates a lower acidity and a higher concentration of ionic and soluble solids in the fruits of Wadi al-Kuf.

Morphometric Fruit Adaptations: Morphological evaluation revealed distinct structural trade-offs between habitats: Wadi Azlifat produced significantly longer fruits (8.15 ± 0.51 mm, $P = 0.048$), whereas Wadi al-Kuf produced fruits with a significantly higher seed count per fruit (11.87 ± 2.53 , $P = 0.032$).

Other traits (fruit width, fresh/dry weight, seed weight, and pulp-to-seed ratio) showed no statistically significant differences ($P > 0.05$).

Overall Implication: These findings confirm strong physiological and morphological plasticity in *M. communis* in response to localized environmental and microclimatic conditions.

Wadi Azlifat provides conditions more favorable for carbohydrate storage, lipid synthesis, and mineral accumulation, whereas Wadi al-Kuf favors protein synthesis, higher fruit ion concentration (EC and TDS), and reproductive investment via higher seed yield per fruit.

Future Recommendations: Future research should incorporate soil physical/chemical analysis and microclimatic variables across additional geographic sites to clarify the environmental drivers behind these physicochemical, nutritional, and phenotypic variations, facilitating potential conservation and commercial exploitation of *M. communis*.

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