

Autecology and Soil Characteristics of Native *Capparis spinosa* L. in the Cyrenaica Region, Libya

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البيئة الذاتية وخصائص التربة لنبات القبار الشوكي (*Capparis spinosa* L.) المحلي في منطقة برقة، ليبيا

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Abstract

Capparis spinosa L. (caper) is a medicinal and aromatic plant of significant economic and ecological value, well-adapted to the Mediterranean basin's harsh environments. This study investigated the geographical distribution, ecological requirements, and associated soil characteristics of native *C. spinosa* populations in the Cyrenaica region of northeastern Libya. Field surveys were conducted at nine distinct sites representing the region's diverse ecology, from coastal plains to semi-arid interiors. At each site, plant presence was recorded, and soil samples were collected from the rhizosphere and analyzed for key physicochemical properties (pH, electrical conductivity (EC), and macronutrients). The results confirmed the wide distribution of *C. spinosa* across an elevational gradient (13-380 m a.s.l.) and its occurrence in a variety of habitat. Soil analyses revealed significant variations in properties across sites, with pH ranging from slightly acidic to slightly alkaline (6.50-8.15) and EC showing high variability (1.45-46.30 dS/m), particularly in coastal sites like La'thrun, indicating salinity tolerance. Nutrient levels (N, P, Ca, Mg) also varied considerably. One-way ANOVA indicated no significant difference in the combined soil measurement means across the sites ($p > 0.05$), suggesting the plant's broad edaphic tolerance. The plant's resilience in arid and semi-arid conditions underscores its ecological importance for soil conservation and combating desertification. This research provides a foundational scientific basis for the conservation, sustainable utilization, and potential cultivation of this valuable native resource in Cyrenaica.

Keywords: *Capparis spinosa*; Geographical Distribution; Soil Properties; Ecological Requirements; Conservation.

المخلص:

يعد نبات القبار الشوكي (*Capparis spinosa* L.) من النباتات الطبية والعطرية ذات القيمة الاقتصادية والبيئية الكبيرة، وهو متكيف بشكل جيد مع الظروف البيئية القاسية لحوض البحر الأبيض المتوسط. هدفت هذه الدراسة إلى التحري عن التوزيع الجغرافي والاحتياجات البيئية وخصائص التربة المرتبطة بالعشائر المحلية لنبات القبار الشوكي في منطقة برقة

بشمال شرق ليبيا. أجريت مسوحات ميدانية في تسعة مواقع متميزة تمثل التنوع البيئي للمنطقة، الممتد من السهول الساحلية إلى المناطق الداخلية شبه القاحلة. في كل موقع، تم تسجيل وجود النبات وجمع عينات تربة من منطقة انتشار الجذور (rhizosphere) وتحليلها لتحديد خصائصها الفيزيوكيميائية الرئيسية (درجة الحموضة، والتوصيل الكهربائي، والعناصر الغذائية الكبرى). أكدت النتائج الانتشار الواسع لنبات القبار الشوكي عبر تدرج ارتفاعي (13-380 مترًا فوق مستوى سطح البحر) وتواجده في مواطن متنوعة. أظهرت تحليلات التربة تباينات كبيرة في الخصائص بين المواقع، حيث تراوحت درجة الحموضة بين الحمضية الخفيفة والقلوية الخفيفة (6.50-8.15)، وأظهر التوصيل الكهربائي تباينًا عاليًا (1.45-46.30 ديسي سيمنز/م)، وخاصة في المواقع الساحلية مثل لاثرون، مما يشير إلى تحمل النبات للملوحة. كما تباينت مستويات العناصر الغذائية (النيتروجين، الفوسفور، الكالسيوم، المغنيسيوم) بشكل كبير. أشار تحليل التباين الأحادي (One-way ANOVA) إلى عدم وجود فرق معنوي في متوسطات قياسات التربة مجمعة عبر المواقع ($p > 0.05$), مما يشير إلى التحمل البيئي الواسع للنبات. إن مرونة النبات في الظروف القاحلة وشبه القاحلة تؤكد أهميته البيئية في الحفاظ على التربة ومكافحة التصحر. يوفر هذا البحث أساسًا علميًا راسخًا للحفظ والاستخدام المستدام والزراعة المحتملة لهذا المورد المحلي القيم في برقة.

الكلمات المفتاحية: قبار شوكي، توزيع جغرافي، خصائص التربة، احتياجات بيئية، حفظ.

1. Introduction

Medicinal plants have been used since ancient times to manage health and treat diseases due to their health-promoting effects and bioactive compounds [1]. According to the World Health Organization [2], approximately 80% of the world's population relies primarily on traditional medicine. In China, an estimated 30-50% of total medical consumption comes from traditional medicine preparations [2]. About 90% of Germans reported using natural remedies for specific health purposes [3]; hence, there is an increasing use and popularity of traditional medicine in both developing and industrialized countries, indicating a robust global market for traditional medicine. The global herbal drug market has exceeded 60 billion US dollars annually and continues to grow steadily [4].

Natural products such as medicinal and aromatic plants have been used as traditional remedies due to their remarkable therapeutic properties. *Capparis spinosa* (caper) is one of the most important medicinal plants in Iranian, Chinese, Unani, Ayurvedic, and Greco-Arab medical systems. Phytochemicals identified in this plant include fats, flavonoids, alkaloids, saponins, tannins, lignin, glucocapparin, (6S)-hydroxy-3-oxo- α -ionone glucosides, and polyphenols. *Capparis spinosa* possesses anthelmintic, cytotoxic, anti-inflammatory, anti-arthritis, antioxidant, antimicrobial, cardiovascular, anti-chondrogenic, anti-diabetic, hypolipidemic, anti-allergic, antihistaminic, immunomodulatory, anticancer, and hepatoprotective activities [5]. Caper can be recommended for further clinical trials to evaluate its clinical efficacy and safety in modern pharmaceutical sciences by considering its chemical constituents [6]. Therefore, medicinal plants such as *Capparis spinosa* continue to play a major role in healthcare systems.

C. spinosa is one of the most important economic species in the Capparidaceae family, which has a wide diversity of about 40-50 genera and 700-900 species. Capparidaceae is known to be closely related to the cabbage family (Cruciferae), which is rich in glucosinolates and flavonoids [7]. *C. spinosa* is also known as caper, wild cucumber (in China), Cappero (in Italy), Alaf-e-Mar (in Persian), and Alcaparro (in Spain) [8].

C. spinosa is a perennial dicotyledonous shrub that can grow up to 1 meter in height and has extensive root systems. It is native to the Mediterranean basin and is widely distributed from Morocco to the Crimean Peninsula, Armenia, and Iran [9]. Many countries, such as Greece, Italy, Spain, and Turkey, produce it on a large scale. For example, Spain and Turkey produce approximately 1000 and 4500 tons of *C. spinosa* annually, respectively [10].

Few articles have reviewed some of the chemical constituents and health benefits of *C. spinosa* in different aspects, including its sustainability. Therefore, the aim of our work was to summarize and review the phytochemicals. The primary mediating functions of medicinal herbs in traditional herbal sciences in countries such as Iran, China, India, and Japan have received considerable attention in recent years. Traditional medicine, which relies heavily on herbs, still supports primary healthcare for a larger number of people worldwide compared to conventional or Western medicine, and it is culturally acceptable and readily available even in modern times [11].

The caper bush (*Capparis spinosa* L., Capparidaceae) is a deciduous winter species distributed in the Mediterranean, Europe, Africa, Asia, and Australia. The small flower buds, known as capers, are highly favored as a food spice, and different parts of the plant are used in the manufacture of medicines and cosmetics. This drought-tolerant perennial plant has a positive impact on the environment and is used in landscaping and erosion control along highways, steep rocky slopes, and fragile semi-arid

ecosystems. Caper is low in flammability and may play a role in reducing wildfires [12]. The caper bush is a perennial shrub 30 to 50 cm tall. Its roots can range from 6 to 10 meters in length. The fruit (caper) is oval or sub-oval and has a thin skin. The fruit bursts when ripe, revealing numerous seeds embedded in its pale red pulp. The seeds range from 3 to 4 mm in width, are gray-brown in color, and are reniform. This study discusses the chemical composition, cultivation and production, food processing uses, functional and health benefits, and quality issues of caper. The caper bush (*Capparis spinosa* L., Capparidaceae) has been introduced as a specialized crop in some European countries over the past four decades. The economic importance of capers has led to a significant increase in both cultivated area and production levels during the late 1980s. The main production areas in harsh environments are found in Morocco, southeastern Iberian Peninsula, Turkey, and the Italian islands of Pantelleria and Salina. This species has developed special mechanisms to survive in Mediterranean conditions, and its introduction into semi-arid lands may help prevent the disruption of the balance of these fragile ecosystems [13].

Capparis spinosa is native to the Mediterranean, Southern Europe, North Africa, and the Arabian Peninsula. Records of the occurrence of this species have been made in the following countries: Morocco, Portugal, Spain including the Balearic Islands, France (including Corsica), Italy (including Sardinia and Sicily), Croatia (islands), Albania, Greece (islands, including Crete), Turkey, Ukraine (Crimea), Georgia, Armenia, Azerbaijan, Uzbekistan, Tajikistan, northern Pakistan, India (near Srinagar), Afghanistan, Iran, Oman, Yemen (including Socotra), Saudi Arabia, Iraq, Syria, Lebanon, Jordan, Cyprus, Egypt, Libya, Tunisia, and Algeria. Despite the extensive global literature on the pharmacological and phytochemical profiles of *Capparis spinosa* L., empirical research regarding its ecological boundaries, edaphic requirements, and rhizosphere soil dynamics within North African ecosystems, particularly in the Cyrenaica region of northeastern Libya, remains remarkably scarce. Previous studies in the region have mostly focused on general botanical surveys or regional flora checklists without systematically quantifying the specific soil physicochemical parameters (such as pH, electrical conductivity, and macronutrient availability) that dictate the survival and distribution of native populations.

To bridge this critical knowledge gap, this study provides the first comprehensive quantitative analysis evaluating the ecological distribution, elevation gradients, and rhizosphere soil characteristics of native *C. spinosa* across nine distinct micro-habitats in Cyrenaica, ranging from hyper-saline coastal plains to semi-arid interior valleys. By defining the precise edaphic tolerance limits and environmental resilience of this species, this research not only fills a geographical and ecological void in the Mediterranean caper literature, but also establishes a foundational scientific basis for conserving local genetic resources, restoring degraded habitats, and promoting sustainable agro-ecological cultivation in fragile semi-arid regions.

2. Botanical Classification of Capparis Species

Capparis spinosa belongs to the Capparaceae family, which encompasses approximately 45 genera and 600 species. This family exhibits a high degree of diversity, with species distributed across various regions of the world, reflecting their ability to adapt to diverse environmental conditions. In Libya, three primary species of *Capparis* are identified. The most widespread is *Capparis spinosa*, which is distributed across various regions within the country. This species includes two subspecies: *Subsp. spinosa* and *Subsp. Orientalis* [14]. *Subsp. orientalis* further comprises two varieties: *orientalis*, the most prevalent in the Green Mountain region, thriving in diverse environments and used in various culinary and medicinal applications; and *kruegeriana*, endemic to Libya, highlighting the country's unique biodiversity and natural heritage.

These diverse *Capparis* species contribute to the region's biodiversity and play a vital role in the ecosystem by providing food and shelter for various organisms. *Capparis spinosa* L. is a perennial shrub characterized by a prostrate or hanging growth habit, typically reaching 50-100 cm in height. Its twigs are initially pubescent but become glabrous with age. A key diagnostic feature is the presence of stipular spines, which are 4-5 mm long, flattened, and have a recurved (hooked) apex.

The leaves are simple, alternate, and fleshy when fresh, becoming leathery with age. The petiole is 1-4 mm long. The leaf blade is highly variable in shape, ranging from ovate, obovate, broadly elliptic to suborbicular, measuring 1.3-3 cm in length and 1.2-2 cm in width. The leaf base is rounded, and the apex can be acute, obtuse, or retuse, but is characteristically tipped with a small spine.

Flowers are solitary in the upper leaf axils and are showy and symmetrical. The pedicel is 2-6 cm long, elongating up to 9 cm in fruit. The calyx is zygomorphic, with sepals measuring 1.5-2 cm in length. The petals are dimorphic; the anterior two are white with a clawed base, while the posterior two are

yellowish-green and thicker. The stamens are numerous, approximately 80, with unequal filaments 2-4 cm long and anthers 2-3 mm long. The ovary is ellipsoid (3-4 mm) and glabrous [11].



Figure 1. Morphology OF *Capparis spinosa* L.

The fruit is an ellipsoid to oblong-obovoid berry, measuring 1.5-4 cm in length and 0.8-1.8 cm in width. It is dark green when dry and features 6-8 longitudinal ridges. The fruit is dehiscent, splitting open at maturity. Each fruit contains 40-60 seeds, which are reddish-brown, reniform to globose in shape, 3-4 mm in diameter, and have a smooth surface. The flowering period is June-July, with fruiting occurring in August-September

3. The Importance of *Capparis spinosa* in CYRINYCA

This research highlights the significance of *Capparis spinosa* (caper), a medicinal plant with deep cultural and economic roots in many societies. The study aims to investigate the distribution, utilization, and potential benefits of this plant in CYRINICA Libya.

A. Problem Statement:

The study seeks to address the following questions:

1. How is *Capparis spinosa* utilized as a food and medicinal plant in the region?
2. What threats does this plant face, and is it at risk of extinction?
3. Where is *Capparis spinosa* distributed in the study area, and how is its distribution changing?

B. Importance of the Study:

This research is significant for several reasons:

- **Filling a knowledge gap:** It addresses a topic that is understudied in the region, particularly regarding the medicinal and economic potential of *Capparis spinosa*.
- **Conservation:** The study highlights the need to conserve this valuable plant species and its associated biodiversity.
- **Economic development:** By exploring the potential economic benefits of *Capparis spinosa*, the research can contribute to the development of sustainable livelihoods in the region.
- **Public health:** The study can contribute to a better understanding of the health benefits associated with the consumption of *Capparis spinosa* and promote its use in traditional and modern medicine.

C. Objectives of the Study:

The primary objectives of this study are to:

- Assess the distribution and abundance of *Capparis spinosa* in the Barqa region.
- Evaluate the environmental factors influencing the growth and distribution of this plant.
- Explore the potential medicinal and nutritional benefits of *Capparis spinosa*.

- Develop strategies for the conservation and sustainable utilization of this valuable plant resource.

4. Study Area

A. Geographical Location and General Characteristics

- This study focuses on a group of selected sites located in the eastern region of Libya. These sites were precisely identified based on several scientific criteria, most notably: the abundance and distribution of the caper plant (*Capparis spinosa*), the diversity of natural environments in which it grows, and the extent to which various climatic factors influence its life cycle and distribution pattern.
- The data gathered from these specific sites is expected to provide accurate and comprehensive information regarding the ecological status of the caper plant in this part of Libya, thereby enhancing the scientific understanding of its botanical characteristics and environmental requirements.
- The targeted areas possess significant ecological and economic importance, underscoring the need for in-depth study. The objective of selecting these sites is not limited to collecting accurate data reflecting the plant's actual distribution; it also extends to understanding the natural and anthropogenic challenges facing its growth and sustainability in each area. By analyzing this information, effective strategies can be developed to conserve this important plant resource and promote its sustainable use in the future, especially in light of climate change and increasing environmental pressures.

B. Sampling Site Selection

Sampling points were carefully selected to represent the targeted areas based on multiple criteria, including plant abundance, habitat diversity, and the ecological and economic importance of the regions. Figure 2 provides a visual representation of the study area, illustrating the specific geographic coordinates from which data and samples were collected.

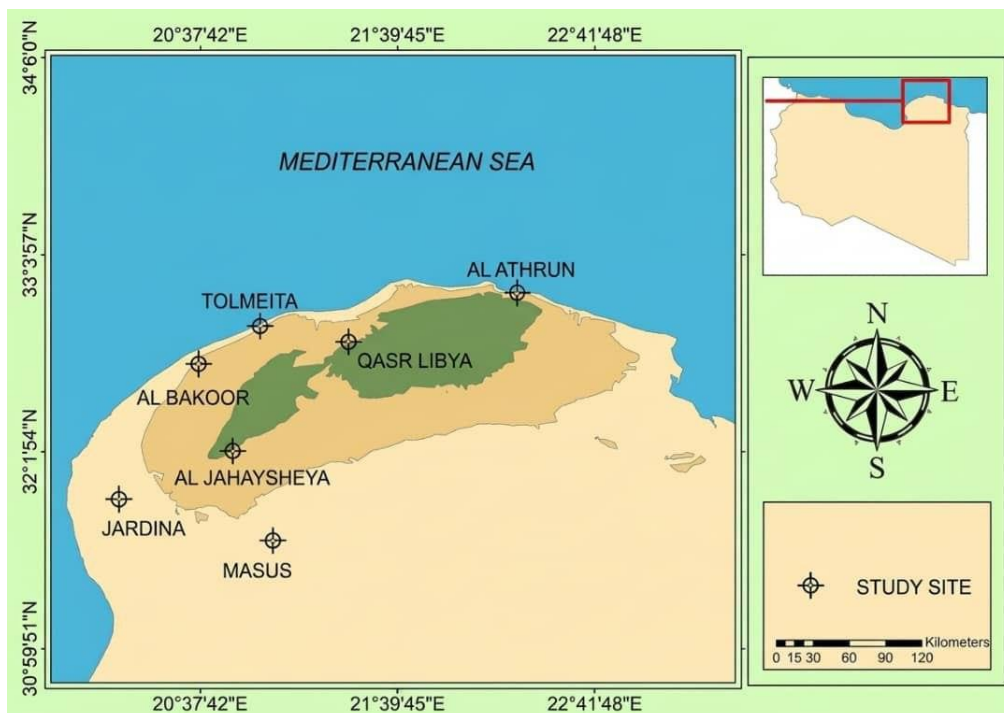


Figure 2. Map of Distribution Sites of *Capparis spinosa* in Cyrenaica, Northeastern Libya.

C. Description of Sampling Sites

A total of nine distinct sites were selected for field surveys and sample collection. Table 1 presents the geographic coordinates, elevation, and general climatic characteristics of each sampling location.

Table 1. Geographic Coordinates and Characteristics of Sampling Sites.

Site No.	Site Name	Geographic Coordinates (N)	Geographic Coordinates (E)	Elevation (m a.s.l.)	Temperature Regime
1	Jardina	31°85'136" N	20°40'92" E	66	Relatively High
2	Wadi Masus (Messous Valley)	31°41'3125" N	21°03'2057" E	115	High
3	Al Jaheishiyah	32°2'40" N	20°44'30" E	280	High
4	Al Khuruba (Carob)	31°86'0853" N	21°14'871" E	330	High
5	Ain Boutraba (Bu Atraba)	32°14'080" N	20°11'92" E	13	Moderate
6	Al Bakour (Albacore)	32°53'263" N	20°58'71" E	338	Moderate
7	Qasr Libya	32°45'294" N	21°24'536" E	387	Moderate
8	La'thrun (Lathron)	32°52'24" N	22°16'40" E	52	Moderate
9	Al Kuwayfiah (Kuwaifia)	31°45'988" N	20°56'08" E	13	Moderate

Detailed Site Descriptions:

- **La'thrun (Lathron):** Located in a narrow coastal plain between the Akhdar Mountains and sandy beaches at coordinates 32.68261°N and 21.341217°E. The area experiences a relatively moderate Mediterranean **climate, with an elevation of approximately 52 meters above sea level.**
- **Qasr Libya:** Situated along the coastal region of the Jebel Akhdar (Green Mountain) at 32°45'294" N and 21°24'536" E. The elevation is approximately 436 meters, characterized by a moderate climate and relatively high annual rainfall compared to surrounding areas.
- **Ain Boutraba (Bu Atraba):** Located in a coastal area interspersed with valleys at 32°14'080" N and 20°11'92" E. The elevation is approximately 13 meters above sea level. The climate is moderate with low humidity due to its proximity to the sea. The soil is predominantly red clay (Terra rossa) and supports a rich diversity of plant species.
- **Al Bakour (Albacore):** A coastal mountainous region located at 32°53'263" N and 20°58'71" E, with an elevation of approximately 338 meters. The climate is moderate with moderate humidity levels. The soil is red clay, rich in nutrients, supporting a dense and diverse plant community.
- **Al Kuwayfiah (Kuwaifia):** Located on the coastal strip at 31°45'988" N and 20°56'08" E, with an elevation of approximately 13 meters. The climate is moderate with some relative humidity. The soil is clayey, and *C. spinosa* populations are primarily found growing on rocky outcrops.
- **Al Khuruba (Kharouba):** A semi-arid region located at 31°86'0853" N and 21°14'871" E, with an elevation of approximately 330 meters. The climate is characterized by very hot summers and relatively high humidity due to low annual rainfall. The soil is sandy and supports some drought-tolerant shrubs and annual plants.
- **Wadi Masus (Messous Valley):** A semi-arid region located at 31°41'3125" N and 21°03'2057" E. It is a dry area with high temperatures and low rainfall, at an elevation of approximately 120 meters. The soil is sandy and supports sparse vegetation consisting of shrubs and annuals.
- **Al Jaheishiyah:** A semi-arid region located at 32.05355°N and 20.81579°E. The area experiences very high temperatures with relatively high humidity, at an elevation of approximately 280 meters. The vegetation is sparse, consisting primarily of annual plants and shrubs.
- **Jardina (Gardenia):** A rocky region located at 31°85'136" N and 20°40'92" E. It is a relatively dry area with high temperatures and humidity levels, at an elevation of approximately 66 meters above sea level.

D. Vegetation Cover Characteristics

The vegetation cover in the study area varies significantly across the different sites, reflecting the underlying environmental gradients. Table 2 summarizes the nature and type of vegetation observed at each sampling location.

Table 2. Vegetation Cover Characteristics at Sampling Sites.

Site No.	Site Name	Nature of Vegetation Cover	Vegetation Type
1	Al Jaheishiyah	Very sparse	Shrubs and some annual plants
2	Wadi Masus	Moderate	Desert plants and herbaceous perennials
3	Qasr Libya	Dense	Trees, shrubs, perennial herbs, and coastal plants
4	Jardina	Moderate	Trees, shrubs, and perennials
5	La'thrun	Dense	Diverse Mediterranean vegetation types
6	Al Bakour	Dense	Diverse Mediterranean vegetation types
7	Boutraba	Dense	Diverse Mediterranean vegetation types
8	Al Khuruba	Moderate	Desert plants, perennial herbs, and some shrubs
9	Al Kuwayfiyah	Moderate	Coastal plants, perennial herbs, and annual herbs

5. Materials and Methods

A. Field Survey and Sample Collection

Field surveys were conducted at the nine distinct sites described above to collect data and samples of *Capparis spinosa*. These sites were strategically chosen to represent the diverse ecological conditions found in the eastern region of Libya. At each site, the following data and materials were collected:

- **Plant Samples:** Samples of leaves, stems, flowers, fruits, and seeds were collected for subsequent laboratory analysis.
- **Soil Samples:** Soil samples were collected from the rhizosphere of *C. spinosa* plants at a depth of approximately 10 cm. Samples were placed in labeled, sealed plastic bags for transport.
- **Geographic Coordinates:** The exact location of each sampling point was recorded using a Global Positioning System (GPS) device.



Figure 3. Sampling.

- **Environmental Data:** Qualitative data on climate, soil type, topography, and vegetation cover were recorded for each site.

B. Soil Sampling and Preparation

Nine soil samples were collected from the various locations within the study area. Sampling sites were selected to ensure representativeness of the overall area, and site areas were approximated using Google Earth imagery. Collected soil samples were transported to the laboratory for processing and analysis. In the laboratory, soil samples were air-dried at room temperature, gently crushed, and sieved through a 2 mm mesh to remove gravel, plant debris, and other large particles. A subsample of each sieved soil was then used for subsequent chemical analyses.

C. Soil Chemical Analysis

Soil chemical analyses were conducted at the Faculty of Science, Omar Mukhtar University, Benghazi, and at Al Qimah Laboratory, Benghazi. The following parameters were analyzed:

- **Soil pH:** Measured in a 1:2.5 soil-water suspension using a calibrated pH meter.
- **Electrical Conductivity (EC):** Determined in a saturated soil paste extract using a conductivity meter. Total Dissolved Solids (TDS) were subsequently calculated from EC measurements.
- **Total Nitrogen:** Determined using the Kjeldahl digestion method followed by quantification using a spectrophotometer.



Phosphorus: Available phosphorus was extracted and measured using a spectrophotometer.

Figure 4. Soil Sampling and Preparation.

- **Elemental Analysis:** For other elements (Ca, Mg, CO_3 , HCO_3 , Cl), a 1-gram subsample of each air-dried soil was weighed into a digestion tube. A mixture of concentrated nitric acid (HNO_3) and hydrochloric acid (HCl) was added, and the samples were digested using a block digester. The resulting digests were diluted with distilled water and analyzed using appropriate standard methods.

D. Quality Assurance and Quality Control (QA/QC)

To ensure the accuracy and reliability of the analytical results, standard quality assurance and quality control procedures were followed. These included:

- **Calibration:** All instruments (pH meter, EC meter, spectrophotometer) were calibrated daily using standard solutions.
- **Blanks:** Method blanks were analyzed alongside samples to monitor for contamination.
- **Duplicate Analysis:** A subset of samples was analyzed in duplicate to assess analytical precision.
- **Standard Reference Materials:** Where available, certified reference materials were analyzed to verify the accuracy of the analytical methods.

E. Data Analysis

The collected data were compiled and analyzed using appropriate statistical methods. Descriptive statistics (mean, standard deviation, standard error) were calculated for all measured parameters. A one-way Analysis of Variance (ANOVA) was employed to test for significant differences in soil properties and plant characteristics among the different sampling sites. All statistical analyses were performed using SPSS software (Version 28)

6. Results

A. Geographical Distribution and Vegetation Cover

Capparis spinosa exhibited a wide geographical distribution within the study area, thriving at elevations ranging from 13 to 380 meters above sea level. This distribution demonstrates the species' adaptability to diverse environmental conditions. The plant was recorded in various habitats, including semi-arid and arid regions, as well as mountainous, coastal, and lowland areas. The vegetation cover in the study area was characterized by a Mediterranean-type flora, consisting of grasses, shrubs, and trees adapted to the region's climate. The dominant vegetation varied across different sites, influenced by factors such as soil type, topography, and rainfall patterns.

B. Soil Analysis

Soil samples were collected from nine different sites and analyzed for various physicochemical properties. The results revealed significant variations in soil characteristics across the study area. Key findings include:

- **Soil pH:** Values ranged from slightly acidic to slightly alkaline, indicating a diversity of soil conditions.
- **Electrical Conductivity (EC):** EC values varied, reflecting differences in soil salinity levels across the sites.

- **Nutrient Content:** The concentrations of essential nutrients such as nitrogen (N), phosphorus (P), and others varied among the sampling sites, with levels generally influenced by soil type and vegetation cover.

Table 3. One-Way ANOVA Results for Soil Properties Across Sites

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.	Statistical Decision
Between Groups	5053	5	1011	1.62	0.17	Accept Null Hypothesis
Within Groups	29931	48	624			
Total	34984	53				

Table 4. Descriptive Statistics for Soil Physicochemical Properties.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
PH	6	7.56	0.61	0.25	6.93	8.20	6.50	8.15
EC	6	9.64	17.99	7.34	-9.24	28.51	1.45	46.30
Ca	6	33.83	64.84	26.47	-34.21	101.88	3.00	166.00
Mg	6	6.17	6.11	2.50	-0.25	12.58	1.00	18.00
Co2	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO3	6	7.00	5.40	2.21	1.33	12.67	4.00	18.00
CL	6	15.79	17.49	7.14	-2.56	34.14	4.00	47.25
N	6	0.39	0.07	0.03	0.31	0.46	0.30	0.50
P	6	35.45	20.48	8.36	13.96	56.94	14.00	70.00
Total	54	12.87	25.69	3.50	5.86	19.88	0.00	166.00

C. Statistical Analysis

To test the hypotheses regarding differences in plant characteristics across different sampling sites and between different analytical parameters, a one-way ANOVA was conducted using SPSS version 28. Prior to conducting the ANOVA, the normality assumption was assessed using the Shapiro-Wilk test.

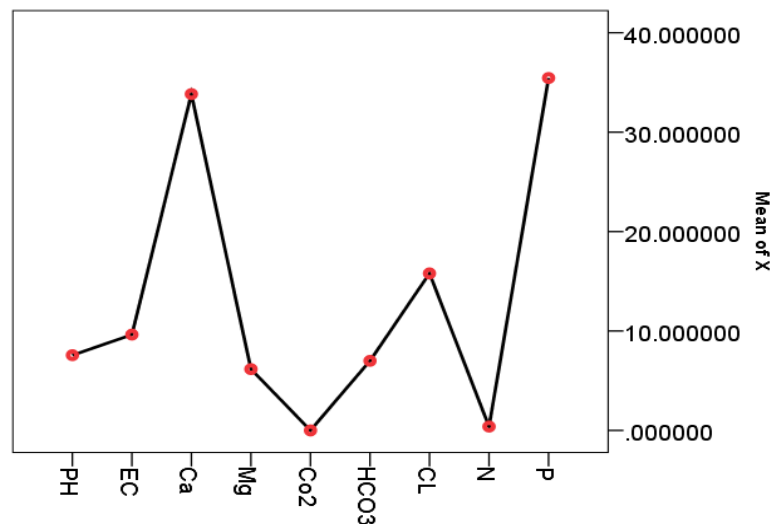


Figure 5. Descriptive Statistics for Soil Physicochemical Properties.

- **Normality Test:** The Shapiro-Wilk test was employed to assess the normality of the data distribution. The null hypothesis (H_0) stated that the data were normally distributed. The results of the Shapiro-Wilk test indicated that the data met the assumption of normality ($p > 0.05$), justifying the use of parametric tests.

Table 5. Descriptive Statistics for *Capparis spinosa* Parameters by Site.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Al Khuruba	9	5.47	6.43	2.14	.5	10.4	.0	20.5
Jardina	9	6.98	7.97	2.66	.9	13.1	.0	25.3
Al Jaheishiyah	9	12.83	22.09	7.36	-4.2	29.8	.0	70.0
Boutraba	9	7.69	14.65	4.88	-3.6	19.0	.0	46.2
Masus	9	10.41	12.43	4.14	.9	20.0	.0	36.7
La'thrun	9	33.83	52.72	17.57	-6.7	74.4	.0	166.0
Total	54	12.87	25.69	3.50	5.86	19.88	0.00	166.00

D. Hypothesis Testing

- **Hypothesis 1 (H_{01}):** There is no significant difference in the mean values of the measured parameters among the different sampling sites.
- **Hypothesis 2 (H_{02}):** There is no significant difference in the mean values of the measured parameters based on the type of analysis.
- **ANOVA Results:** A one-way ANOVA was conducted to compare the mean values of the measured parameters across the different sampling sites. The results showed no statistically significant difference in the mean values among the sites ($F(5, 48) = 0.650$, $p = 0.66 > 0.05$), indicating that the plant characteristics were statistically similar across the different locations.
- **Post-hoc Analysis:** As the ANOVA result was not significant, post-hoc tests (e.g., Tukey's HSD) were not required.

7. Discussion

A. Soil Analysis and Plant Growth

The soil analysis revealed significant variations in physicochemical properties across the study sites, which likely influence the growth, distribution, and physiological performance of *Capparis spinosa*. The highest electrical conductivity (EC) was observed in the Lathrun region, indicating elevated salinity levels. This is likely attributable to the site's proximity to the coast and the associated influence of saline groundwater or sea spray. In contrast, the lowest EC values were recorded in the Qasr Libya and Al Kuwayfiah regions, suggesting lower salinity stress and potentially more favorable conditions for plant growth.

Soil pH also varied among the sites, with Qasr Libya exhibiting the highest value. The elevated pH in this region may be attributed to the prevalence of calcareous parent material and the accumulation of organic matter, which can contribute to increased soil alkalinity. The relatively lower pH values observed in other regions may be influenced by factors such as higher rainfall leaching, specific vegetation cover, or different parent material composition.

Nutrient availability, as indicated by the concentrations of nitrogen, phosphorus, and other elements, varied considerably among the sampling sites. The highest levels of phosphorus were found in the Al Kuwayfiah and Al Jaheishiyah regions. This may be due to the accumulation of organic matter and subsequent nutrient mineralization over time. The lower phosphorus levels in other regions could be attributed to factors such as leaching, erosion, or higher rates of plant uptake.

B. Implications for Plant Growth

The observed variation in soil properties has direct implications for the growth and distribution of *Capparis spinosa*. For instance, plants growing in soils with high salinity levels (e.g., Lathrun) may experience physiological stress, potentially leading to reduced growth rates, lower biomass accumulation, and altered physiological function. Conversely, plants growing in soils with optimal nutrient levels and favorable pH (e.g., Al Kuwayfiah) are likely to exhibit enhanced growth performance.

8. Further Research

Further research is needed to fully understand the relationship between soil properties and the growth and distribution of *Capparis spinosa*. This may involve conducting more detailed soil analyses, including the determination of micronutrients and heavy metals. Additionally, plant tissue analysis can provide insights into the uptake of nutrients by the plant.

9. Recommendations

This study proposes several recommendations to conserve and promote the *Capparis spinosa* plant:

- **Governmental Support:** The Libyan government should prioritize biodiversity conservation, with a particular focus on the *Capparis spinosa* plant.
- **Scientific Research:** Given its unique characteristics and potential, *Capparis spinosa* should be the subject of more intensive scientific research.
- **Protected Areas:** Establish protected areas specifically for *Capparis spinosa* and other endangered plant species.
- **Soil Research:** Conduct in-depth soil research to better understand the plant's soil requirements and its role in soil conservation.
- **Ornamental Cultivation:** Promote the cultivation of *Capparis spinosa* as an ornamental plant due to its aesthetic appeal.
- **Food Industry Partnerships:** Collaborate with food industries to incorporate *Capparis spinosa* into various food products, given its nutritional value.
- **Pharmaceutical Research:** Partner with pharmaceutical companies to investigate the plant's medicinal properties and potential pharmaceutical applications.
- **Traditional Medicine Integration:** Work with traditional medicine practitioners to document and validate the plant's traditional uses.
- **Arid Land Cultivation:** Encourage the cultivation of *Capparis spinosa* in arid regions to combat desertification and promote sustainable land use.

10. Conclusion

This study aimed to investigate the geographical distribution, ecological requirements, and soil characteristics associated with *Capparis spinosa* in study area. The findings of this research highlight the significant role of this species in the local ecosystem and its adaptability to a wide range of environmental conditions.

The results indicate that *C. spinosa* exhibits a broad geographical distribution, thriving in diverse habitats ranging from coastal regions to mountainous areas. Soil analysis revealed significant variations in physicochemical properties across the sampling sites, suggesting that the species can tolerate a wide range of soil conditions. The plant's ability to thrive in arid and semi-arid environments, as demonstrated by its presence in regions with limited rainfall and high temperatures, underscores its resilience and ecological importance.

The study also highlights the potential of *C. spinosa* for various applications, including food, medicine, and conservation. Its deep root system and tolerance to drought make it a valuable species for soil conservation and combating desertification.

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