



Ethnobotanical and Ethnopharmacological surveys of *Zygophyllum* species used in Moroccan traditional medicine

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Ethnobotany Research and Applications 35:14 (2026) - <http://dx.doi.org/10.32859/era.34.14.1-16>

Manuscript received: 23/05/2026 - Revised manuscript received: 27/06/2026 - Published: 01/07/2026

Research

Abstract

Background: *Zygophyllum* species are widely used in Moroccan traditional medicine, yet comprehensive documentation of their usage patterns across multiple regions remains limited. This ethnobotanical survey aimed to document and analyze the traditional uses, usage modalities, and therapeutic indications of four *Zygophyllum* species (*Zygophyllum gaetulum*, *Zygophyllum album*, *Zygophyllum cornutum*, and *Zygophyllum waterlotii*) across six Moroccan regions.

Methods: Semi-structured questionnaires were administered to 200 herbalists into Darija throughout five Moroccan regions (Marrakech, Casablanca, Rabat, Fez and Oujda). Data collected included sociodemographic characteristics, usage modalities, plant parts employed, preparation methods, administration routes, therapeutic indications, and outcomes. Ethnobotanical indices were calculated, and statistical associations were examined using chi-square tests.

Results: The study revealed a predominance of male respondents (96.0%) aged over 40 years, with cultural heritage (66.5%) as the primary knowledge source. Gastrointestinal disorders were the most cited indications, particularly irritable bowel syndrome (FC = 76) and gastric pain (FC = 70). Dried plant material (95.5%) harvested in spring (91.0%) was preferred, with grinding and infusion as the main preparation methods. Symptomatic relief was reported in 82.7% of cases, with only 5.6% reporting side effects. Plant parts value analysis showed branches as the most utilized part. Statistical associations ($p < 0.05$) revealed coherent traditional medical logic linking preparation methods, dosage, and treatment duration to therapeutic outcomes.

Conclusions: This study confirms the important role of *Zygophyllum* species in Moroccan traditional medicine, particularly for gastrointestinal disorders. The findings demonstrate strong concordance with pharmacological evidence and provide a foundation for future clinical and phytochemical investigations.

Keywords: Ethnobotany survey, *Zygophyllum*, medicinal plants, antidiabetic properties, gastrointestinal disorders, Morocco traditional medicine.

Background

Medicinal plants have played a vital role in the healthcare of humans in various civilizations and the empirical knowledge regarding these medicinal substances and their toxic potential has been transmitted by oral tradition (Latif & Nawaz 2026). Many useful drugs today, such as atropine, ephedrine and digoxin have been introduced as a result of investigations into indigenous remedies. Chemists still use plant-derived drugs as prototypes in their efforts to develop more effective and less toxic medicinal (Heinrich 2001). The genus *Zygophyllum* (family Zygophyllaceae) consists of approximately 150 species distributed in arid and semi-arid zones of Africa, Asia, the Mediterranean basin and Australia (Bourgou *et al.* 2017). These halophytic shrubs are well adapted to extreme environmental conditions like high salinity, drought and poor soil nutrition. *Zygophyllum* is a native of North Africa, especially Morocco, and various species of *Zygophyllum* have been used in traditional medicine for many centuries (Janah *et al.* 2024). Among these, *Zygophyllum gaetulum* (locally named “El Aggaya” or “El Berraya”), *Zygophyllum album*, *Zygophyllum cornutum* and *Zygophyllum waterlotii* are used in local traditional medicine. Morocco has a vast ethnopharmacological heritage, especially when considering its diversity of climatic zones and cultural crossroads, with hundreds of plant species traditionally used to treat a variety of ailments, from digestive disorders to metabolic diseases (Youssef *et al.* 2025).

In Moroccan traditional medicine, *Z. gaetulum* is used for stomach pain, eczema and dermatitis, and diabetes (Shawky *et al.* 2019, Janah *et al.* 2024). The plant is also traditionally used as an anti-inflammatory, antispasmodic and antidiarrheal agent (Capasso *et al.* 1998, Ait El Cadi *et al.* 2008, 2012). Phytochemical studies have revealed that the leaves are rich in saponins, terpenes, and sterols (Janah *et al.* 2024), and 33 compounds have been identified in fruits, leaves, and stem roots, mainly terpenoids, such as caryophyllene E, decanone, and bornylacetate (El Abdouni Khayari *et al.* 2017). Flavonoids and phenolic compounds have also been detected, adding to the diverse pharmacological activities of the genus (Mammas *et al.* 2025).

These traditional uses have been largely confirmed by recent pharmacological research. The antidiarrheal activity of *Z. gaetulum* was confirmed by the Ussing chamber technique (Ait El Cadi *et al.* 2008), and antispasmodic properties were demonstrated by isolation of saponins that reduce contractions in isolated guinea-pig ileum (Aquino *et al.* 2001). Anti-inflammatory properties have been recorded in animal models (Rimbau *et al.* 1999) and antidiabetic properties have been reported by inhibition of digestive enzymes with studies recording up to 61% reduction in blood glucose levels (Mnafgui *et al.* 2014, 2016). Other studies have reported antioxidant, antihyperlipidemic, antimicrobial and cytotoxic activities (Berzou *et al.* 2014, Bahlil *et al.* 2019, 2020, Bar *et al.* 2025). *Zygophyllum* species are widely used in Moroccan traditional medicine and scientific evidence for their pharmacological activities is increasing. However, detailed ethnobotanical data on their usage patterns, preparation methods and therapeutic outcomes in different regions of Morocco are still scarce. Most of the existing studies focused on specific regions, or specific diseases, leaving a gap in the holistic traditional knowledge regarding these plants. The absence of these surveys could lead to the loss of traditional knowledge, transmitted orally, and related to the *Zygophyllum* plant, due to the increasing rates of urbanization and modernization, which threaten traditional local knowledge transfer methods (Hseini & Kahouadji 2007, Belhaj *et al.* 2020).

The present study aims to document and analyze the traditional uses of four species of the genus *Zygophyllum* (*Z. gaetulum*, *Z. album*, *Z. cornutum*, and *Z. waterlotii*) in six Moroccan regions (Oujda, Rabat, Fez, Marrakech and Casablanca) based on the knowledge of 200 herbalists. In particular, this study aims to describe the sociodemographic profile of traditional practitioners; document the usage modalities, including plant parts, preparation methods, dosage, and administration routes; identify therapeutic indications and calculate ethnobotanical indices; analyze statistical associations between usage variables; and compare the results with existing literature to validate traditional knowledge. The present study contributes to the conservation and valorization of traditional medicinal knowledge in Morocco and provides a basis for future pharmacological investigations. The findings may also inform conservation strategies for these endemic plants and support their sustainable use in modern health care systems.

Materials and Methods

Study area

The study was conducted in Morocco, a North Africa country borders by the Atlantic Ocean to the west, the Mediterranean Sea to the north, and Algeria to the east and southeast. Morocco covers a total area of approximately 716550 km² with a population of about 37400000 inhabitants (CIA, 2025). The country is characterized by diverse topographical and climatic conditions, including coastal areas, arid plains, and mountainous regions, which support a wide variety of medicinal plants species.

The ethnobotanical survey was carried out across five Morocco regions: Marrakech, Rabat and surrounding areas, Oujda and surrounding areas, Fez, and Casablanca (Table 1). These regions were selected based on their ecological diversity, cultural richness, and reputation as areas with active traditional medicine practitioners. Together, these regions account for more than 71% of Morocco's population and represent the country's diverse environmental and cultural landscapes, including the Rabat-Sale-Kenitra, Marrakech-Safi, Fez-Meknes, and the Casablanca-Settat regions (Metni *et al.* 2025).

Table 1. Description of the study area.

Region	Cities included	Area (km ²)	No. of Population	No. of respondents (n)
Oujda and surrounding	Oujda, Jerada, Berkane, Ahfir, Bni Drar	82,820	494,252	34
Rabat and surrounding	Rabat, Sale, Skhirate, Temara, Tamesna	18,194	5,130,000	62
Fez	Fez	3,570	1,256,000	46
Marrakech	Marrakech	2,625	4,890,000	40
Casablanca	Casablanca	20,394	7,690,000	18
Total	13 cities	107,117.5	19,460,252	200

Study Population and Data Collection

The study targeted traditional medicine practitioners and local informants knowledgeable about medicinal plants. Data were collected from January 1 to July 30, 2024, through semi-structured interviews conducted in Moroccan Arabic (Darija). Each interview lasted approximately 30 minutes and took place in markets, herbal shops, and villages (e.g., Bnidrare) to capture diverse traditional knowledge. Participation was voluntary and anonymous, with no financial compensation. Prior informed consent was obtained from all participants after explaining the study objectives.

The questionnaire was designed based on established ethnobotanical methodologies (Martin 2004, Cunningham 2001) and consisted of two sections:

Section 1: Sociodemographic information, including age, sex, education level, place of residence, and source of knowledge.

Section 2: Plant use data, including local names, plant parts used, preparation methods, administration routes, therapeutic indications, and treatment outcomes.

A total of 200 herbalists were interviewed to ensure data saturation. The results were cross-validated by comparison with published ethnobotanical studies from Morocco and other countries (Tardío & Pardo-de-Santayana 2008).

Botanical Identification

Zygophyllum species were identified using Moroccan botanical references including the *Moroccan Traditional Pharmacopoeia* (Bellakhdar 1997), *Practical Flora of Morocco* (Fennane 1999), and *Vascular Flora of Morocco* (Fennane *et al.* 2005). Voucher specimens were authenticated by Prof. Khamar Hamid, a botanist at the Scientific Institute of Rabat. Specimens were deposited in the Institute Herbarium and cross-referenced using the GBIF platform (<https://www.gbif.org>). The catalogue numbers are as follows: *Zygophyllum gaetulum* Emb. & Maire (234782-1), *Zygophyllum cornutum* Coss. (K005031691), *Zygophyllum waterlotii* Maire (RAB114683), and *Zygophyllum album* L. (RAB114759).

Data Analysis

Quantitative data were analyzed using Microsoft Excel 2019, Jamovi 2.6.44, and IBM SPSS Statistics (version 26.0). The following ethnobotanical indices were calculated:

Relative Frequency of Citation (RFC)

The ethnomedicinal data was assessed using a relative frequency citation (RFC) index (Vitalini *et al.* 2013):

$$\text{RFC} = \text{FC} / \text{N}$$

Where FC is the number of informants citing a specific use, and N is the total number of informants (Tardío & Pardo-de-Santayana 2008).

Plant Parts Value (PPV)

PPV assesses the preference for particular plant parts. The PPV was calculated using this formula:

$$\text{PPV} = (\text{number of use reports for a plant part} / \text{total use reports}) \times 100$$

Fidelity Level (FL)

FL measures the proportion of informants who use a plant species for the same ailment. FL index is estimated using the following formula:

$$\text{FL} = (\text{I}_p / \text{L}_u) \times 100$$

Where I_p is the number of informants citing a plant for a specific ailment, and L_u is the total number of informants citing the plant for any ailment (Sreekeesoon & Mahomoodally 2014).

Statistical associations between categorical variables were assessed using chi-square tests performed with IBM SPSS Statistics (version 26.0). The significance level was set at $p < 0.05$. A hierarchical clustering heatmap was generated using GraphPad Prism (version 10.0) to visualize the distribution of usage variables across demographic groups and therapeutic outcome categories.

Results and Discussion**Sociodemographic profile of users**

The analysis of the data showed that male users outnumbered female users by a very large margin (96% vs. 4%) (Table 2), which is statistically significant ($p < 0.001$). This indicates that traditional knowledge associated with *Zygophyllum* species is predominantly communicated by males in the study area. Similar results have been reported by El Ansari *et al.* (2025), who documented that *Z. gaetulum* is used by 57.14% of practitioners in the Moroccan Sahara, and by Hachi *et al.* (2016), who conducted an ethnobotanical survey in the Central Middle Atlas region identifying 76 medicinal plant species used for diabetes treatment. The gender imbalance can be attributed to socio-cultural factors, such as defined gender roles, which dictate the form and means of passing on traditional knowledge through restricted access and participation in traditional practice by gender (Powell *et al.* 2014).

Table 2. Sociodemographic distribution of respondents in the study area.

Variable	Category	Frequency (n)	Percentage (%)	P value
Gender	Women	8	4.0	<0.001
	Men	192	96.0	
Age	< 30 years	42	21.0	0.430
	30-40 years	47	23.5	
	40-50 years	54	27.0	
	> 50 years	57	28.5	
Education level	No formal education	105	52.5	0.480
	Primary school	37	18.5	
	Secondary school	37	18.5	
	University	21	10.5	
Source of knowledge	Cultural heritage	133	66.5	<0.001
	Personal experience	44	22.0	
	Literature research	23	11.5	
City	Marrakech	39	19.5	<0.001
	Casablanca	18	9.0	
	Rabat and surrounding	60	30.0	
	Fez	41	20.5	
	Oujda and surrounding	42	21.0	

Note: Percentages may not sum to 100 due to rounding.

User age did not show a statistically significant difference in the distribution throughout age brackets ($p = 0.430$), with approximately 21% of users being younger than 30 years old, 23.5% between 30 and 40 years, 27% between 40 and 50 years, and almost 28.5% older than 50 years. Overall, this balanced age bracket distribution provides indications of intergenerational continuity of using and transmitting traditional knowledge. However, the higher number of traditional knowledge users older than 50 years old raises an important question regarding the future preservation of traditional knowledge. Most of the traditional knowledge is held by the older generation and this heritage is vulnerable to extinction if proper intergenerational transmission methods are not employed (Powell et al. 2014, Voeks & Leony 2004).

Educational level analysis showed that more than half of the users (52.5%) had no formal education, 18.5% had primary education or secondary education and only 10.5% had university-level education (Table 2). In this variable no statistically significant difference was found ($p = 0.480$), which indicates that formal education is not a determining factor in the possession or use of this knowledge. This profile is in accordance with several ethnobotanical studies carried out in Morocco, which report that the holders of traditional knowledge are mainly people with low education levels or illiteracy (Hachi et al. 2016, El Ansari et al. 2025). The situation showed that traditional knowledge was passed on mainly by word of mouth and by practical experience. The most important source of knowledge was cultural heritage (66.5%), personal experience (22.0%) and literature research (11.5%; $p < 0.001$). Sharing of collective knowledge is a characteristic of traditional systems, but means of transmission (oral communication and practical demonstrations) are very transitory so this knowledge is more vulnerable to rapid social change like urbanization (Martínez-Alier & Muradian 2015, Voeks & Leony 2004).

The distribution of respondents across the five sample regions was significantly different ($p < 0.001$) with the highest proportion of herbalists (30.0%) from Rabat and surrounding areas and the lowest (9.0%) from Casablanca (Table 1). This pattern fits with regional variation in the conservation and use of ethnobotanical knowledge on *Zygophyllum*. The increased representation from Rabat can be attributed to the proximity of rural and peri-urban areas, where traditional phytotherapy is still practiced despite the process of urbanization. Conversely, the lower representation of Casablanca might be explained by the strong urbanization and industrialization phenomena where traditional practices are fading in favor of modern medicine (Powell et al. 2014, Chaachouay et al. 2019). El Ansari et al. (2025) also reported the regional variation in the use of *Z. gaetulum* in Moroccan Sahara.

Usage modalities of *Zygophyllum* species

Plant Parts Used and Plant Parts Value (PPV)

The present study found that 55.5% of respondents use whole plant or branches, and 44.5% use only aerial parts, with a statistically significant difference ($p < 0.001$) (Table 3). This result is further confirmed by the Plant Parts Value (PPV) where branches had the highest PPV (0.72) followed by aerial parts (0.60) whereas other parts had a considerably lower PPV (0.15) (Fig. 1). This is different from the report by El Ansari et al. (2025) who found that foliage (PPV = 0.610) and stems (PPV = 0.325) were the most recommended parts for *Z. gaetulum* in the Moroccan Sahara which might indicate regional variations in traditional knowledge. Branches are possibly preferred because they are abundant and accessible, whereas aerial parts are rich in biologically active compounds such as flavonoids, tannins and alkaloids (Harborne & Harborne 1998, Pandey & Rizvi 2009). Phytochemical analyses by El Abdouni Khayari et al. (2017) showed that different plant parts have different essential oil profiles. Total phenolic and flavonoids content of various extracts of *Z. gaetulum* was also quantified by Mammass et al. (2025) and methanolic extracts showed the highest antioxidant activity.

Table 3. *Zygophyllum* usage modalities (N = 200) in the study area.

Variable	Category	Frequency (n)	Percentage (%)	P value
Plant part	Aerial parts	89	44.5	<0.001
	Other (branches, whole plant)	111	55.5	
Plant form	Dried plant	191	95.5	<0.001
	Fresh plant	9	4.5	
Harvest period	Spring	182	91.0	<0.001
	Other	18	9.0	
Therapeutic Outcome	Complete Remission	34	17.3	<0.001
	Symptomatic Relief	163	82.7	
Side Effects	Yes	11	5.6	<0.001
	No	187	94.4	

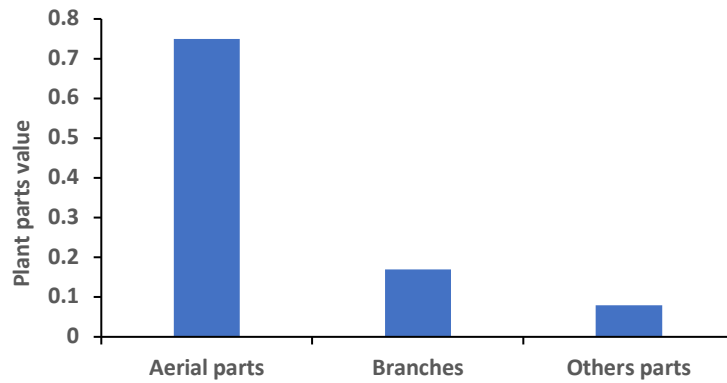


Figure 1. Plant parts value (PPV) of different *Zygophyllum* species used in traditional medicine.

Preparation methods and plant condition

The most common method of preparation was grinding (54%) followed by infusion (27.5%) and all other methods (18.5%) ($p < 0.001$) (Table 4). This agrees with the results of El Ansari et al. (2025) who reported powder form to be used in 78.13% of preparations. Grinding is the best method for extraction of active compounds especially, lipophilic compounds and infusion is the best method for extraction of hydrophilic active ingredients (Dai & Mumper 2010, Azwanida 2015). The almost exclusive use of dried plant material (95.5%) indicates a consolidated practice to maintain stability of active compounds and facilitate preservation (Belhaj et al. 2020). The majority of respondents - 63% use a teaspoon, the rest 33% use a tablespoon ($p < 0.001$). Oral administration was the most common route (94%), with topical or other routes rarely used (6%). This is in contrast to El Ansari et al. (2025) who reported 68.75% of topical application for dermatological conditions. The difference may be due to the difference in therapeutic indications; the present sample was mainly presenting for treatment of gastrointestinal disorders, for which oral administration is more logical, while dermatological disorders do require topical treatment.

Table 4. Complete cross-tabulation of *Zygophyllum* usage variables (preparation method, dosage, application method, time of application, duration of use, and therapeutic outcomes).

	Modalities (n=200)	Preparation method			Dosage		Application method	
		infusion % (n=55)	Grinding % (n=108)	Other % (n= 37)	Teaspoon % (n= 126)	Tablespoon % (n= 74)	Oral % (n= 188)	Other % (n= 12)
Education level	No formal	58.2	47.2	59.5	54.0	50.0	53.7	33.3
	formal	41.8	52.8	40.5	46.0	50.0	46.3	66.7
Source of knowledge	Cultural heritage	72.7	66.7	56.8	67.5	64.9	67.6	50.0
	Personal experience	12.7	24.1	29.7	21.4	23.0	22.3	16.7
	Literature research	14.5	9.3	13.5	11.1	12.2	10.1	33.3
Dosage	Teaspoon	60.0	66.7	56.8	-	-	64.4	41.7
	Tablespoon	40.0	33.3	43.2	-	-	35.6	58.3
Application method	Oral	98.2	94.4	86.5	96.0	90.5	-	-
	Other (topical, etc.)	1.8	5.6	13.5	4.0	7 9.5	-	-
Time of application	Morning	76.4	75.0	81.1	77.8	74.3	79.3	33.3
	Random	23.6	25.0	18.9	22.2	25.7	20.7	66.7
Duration use	Until healing	81.8	78.7	70.3	77.0	79.7	76.6	100.0
	Other (fixed period)	18.2	21.3	29.7	23.0	20.3	23.4	0.0
Type of use	Irritable Bowel	27.3	36.1	54.1	31.7	45.9	38.3	16.7

Outcomes	Syndrome							
	IBS							
	Other gastric pain	40.0	34.3	18.9	38.9	23.0	35.1	0.0
	Other disease	32.7	29.6	27.0	29.4	31.1	26.6	83.3
	Complete recovery	13.0	14.0	33.3	13.6	23.6	16.8	25.0
Preparation method	Partial progress	87.0	86.0	66.7	86.4	76.4	83.2	75.0
	Infusion	-	-	-	26.2	29.7	28.7	8.3
	Grinding	-	-	-	57.1	48.6	54.3	50.0
	Other method	-	-	-	16.7	21.6	17.0	41.7

Table 4 (Continued). Complete cross-tabulation of *Zygophyllum* usage variables (preparation method, dosage, application method, time of application, duration of use, and therapeutic outcomes).

	Modalities (n=200)	Time of application		Duration use		Outcomes	
		Morning% (n= 153)	Random% (n= 47)	Until healing % (n= 156)	Other % (n= 44)	Complete recovery % (n= 34)	Partial progress % (n= 163)
Education level	No formal	51.6	55.3	50.6	59.1	50.0	52.8
	formal	48.4	44.7	49.4	40.9	50.0	47.2
Source of knowledge	Cultural heritage	66.0	68.1	66.0	68.2	55.9	69.3
	Personal experience	22.9	19.1	21.2	25.0	29.4	20.9
	Literature research	11.1	12.8	12.8	6.8	14.7	9.8
Dosage	Teaspoon	64.1	59.6	62.2	65.9	50.0	66.3
	Tablespoon	35.9	40.4	37.8	34.1	50.0	33.7
Application method	Oral	97.4	83.0	92.3	100.0	91.2	94.5
	Other (topical, etc.)	2.6	17.0	7.7	0.0	8.8	5.5
Time of application	Morning	-	-	75.6	79.5	88.2	74.2
	Random	-	-	24.4	20.5	11.8	25.8
Duration use	Until healing	77.1	80.9	-	-	67.6	80.4
	Other (fixed period)	22.9	19.1	-	-	32.4	19.6
Type of use	Irritable Bowel Syndrome	41.8	21.3	32.7	52.3	67.6	30.1
	IBS						
	Other gastric pain	30.1	42.6	37.2	18.2	2.9	39.3
	Other disease	28.1	36.2	30.1	29.5	29.4	30.7
Outcomes	Complete recovery	19.9	8.7	14.9	25.6	-	-
	Partial progress	80.1	91.3	85.1	74.4	-	-
Preparation method	Infusion	27.5	27.7	28.8	22.7	20.6	28.8
	Grinding	52.9	57.4	54.5	52.3	44.1	56.4
	Other method	19.6	14.9	16.7	25.0	35.3	14.7

Mode and Timing of Administration, Duration of Use, and Harvest Period

The majority of consumers take the remedy orally (94%) because of its historical use for gastrointestinal problems (Table 4). Most users (76.5%) prefer to take the remedy in the morning, which may be due to better pharmacodynamic efficacy due to biological rhythms (Chaachouay et al. 2019). As for duration, 78% of users continue utilization until they heal, which speaks of a pragmatic approach (Barros et al. 2012). Moreover, 91% of users prefer to harvest the plant in spring when the concentrations of active compounds are at their peak (Omidian et al. 2007). The optimal composition of essential oils was

confirmed by El Abdouni Khayari et al. (2017) as the spring harvest. No significant differences were observed in administration timing by education level or source of information. In terms of duration of use by ailment, users with irritable bowel syndrome (IBS) used the remedy for longer (52.3%) than those with other gastric pain conditions (37.2%) ($p = 0.026$), suggesting protocols adapted to chronic conditions (Table 4). Duration until healing as a stopping rule refers to the fact that the treatment is generally patient-guided approach characteristic of traditional phytotherapy in Morocco (Boufous et al. 2017).

Main Therapeutic Indications and Reported Outcomes

The most common reasons for using *Zygophyllum* species are IBS (31.67%) and gastric pain (29.17%) (Tables 4, 5). This together account for the majority of indications for gastrointestinal diseases. Reported clinical outcome was 82.7% of users with symptom relief and 17.3% reported complete healing ($p < 0.001$) (Table 3). The low rate of side effects (5.6%) shows excellent patient tolerance. The significant relation between the preparation method and the clinical result ($p = 0.018$) demonstrated the impact of use modalities on therapeutic results. Interestingly, the complete healing was higher among users of other preparation methods (33.3%) than among users of infusion (13.0%) or grinding (14.0%). These results highlight the high empirical knowledge of traditional pharmacopoeia, adapted in terms of plant part selection, preparation methods and doses, from extensive knowledge of *Zygophyllum* species properties.

Table 5. Therapeutic indications of *Zygophyllum* species in the study area.

Use category	Disease/Condition	FC	RFC	FL (%)
Digestive disorders	Gastric pain	70	0.2917	29.17
	Irritable Bowel Syndrome (IBS)	76	0.3167	31.67
	Intestinal pain	8	0.0333	3.33
	Diarrhea	6	0.0250	2.50
	Abdominal bloating	5	0.0208	2.08
	Gastroesophageal reflux	4	0.0167	1.67
	Gastric/duodenal ulcer	4	0.0167	1.67
Hair and scalp disorders	Bacterial scalp infection	5	0.0208	2.08
	Hair disorders (loss, dandruff)	7	0.0292	2.92
Skin diseases	Eczema	4	0.0167	1.67
	Skin burn	3	0.0125	1.25
	Skin infections	6	0.0250	2.50
Gynecological disorders	Infertility (women)	4	0.0167	1.67
	Dysmenorrhea	5	0.0208	2.08
	Childbirth support	3	0.0125	1.25
	Intimate hygiene/uterine infections	4	0.0167	1.67
	Abortion inducer	2	0.0083	0.83
Metabolic disorders	Diabetes	6	0.0250	2.50
	Cancer	3	0.0125	1.25
	Hypercholesterolemia	5	0.0208	2.08
Neurological conditions	Migraine	6	0.0250	2.50
	Inflammations	7	0.0292	2.92
	Fever	8	0.0333	3.33
Toxicological conditions	Snakebite	2	0.0083	0.83
	Hepatitis	5	0.0208	2.08

FC: Frequency of citation; RFC: Relative frequency of citation; FL: Fidelity level.

Hierarchical Clustering Heatmap of Usage Variables

A hierarchical clustering heatmap was generated to visually explore the relationships between usage variables and user groups (Fig. 2). The heatmap displays percentage values of 13 usage variables, including preparation methods (grinding, infusion, other preparation), administration route (oral, other), dosage (teaspoon, tablespoon), treatment duration (until healing, other duration), application time (morning, random), and therapeutic outcomes (complete recovery, partial progress). Rows are eight user groups (no formal education, formal education, personal experience, cultural heritage, literature research, digestive problems, other gastric pain, and other diseases). The color intensity is expressed in percentage values; red (80%) for higher frequencies, orange/yellow (40-60%) for intermediate values and blue (0-20%) for lower

frequencies. The dendrograms (clustering trees) on the left and top show the similarity relationships between the rows (user groups) and columns (usage variables) respectively.

The dendrogram shows two main groups of user groups. The first cluster is cultural heritage and no formal education, showing that traditional knowledge transmitted by oral tradition correlates with similar usage patterns. The second cluster includes formal education, personal experience and literature research, which implies that formal education and written sources have an influence on preparation preferences. A further subcluster is formed by digestive problems and other diseases with condition-specific usage patterns.

The column dendrogram shows that infusion, morning application and oral administration are clustered together, confirming that these modalities are often used together. Complete recovery closely follows the time until healing, indicating a strong positive correlation between the time for treatment until symptom resolution and the success of treatment. Partial progress, on the other hand, is associated with random timing of application and other preparation techniques. Cultural heritage and no formal education indicate higher frequencies of infusion (72.7% and 58.2%, respectively) and oral administration (67.6% and 53.7%), while literature research indicates higher frequencies of grinding (52.8%) and alternative application methods (33.3%). The maximum complete recovery was obtained with until healing duration (100%) and infusion (13.0-33.3%), while partial progress was more prevalent than most other variables.

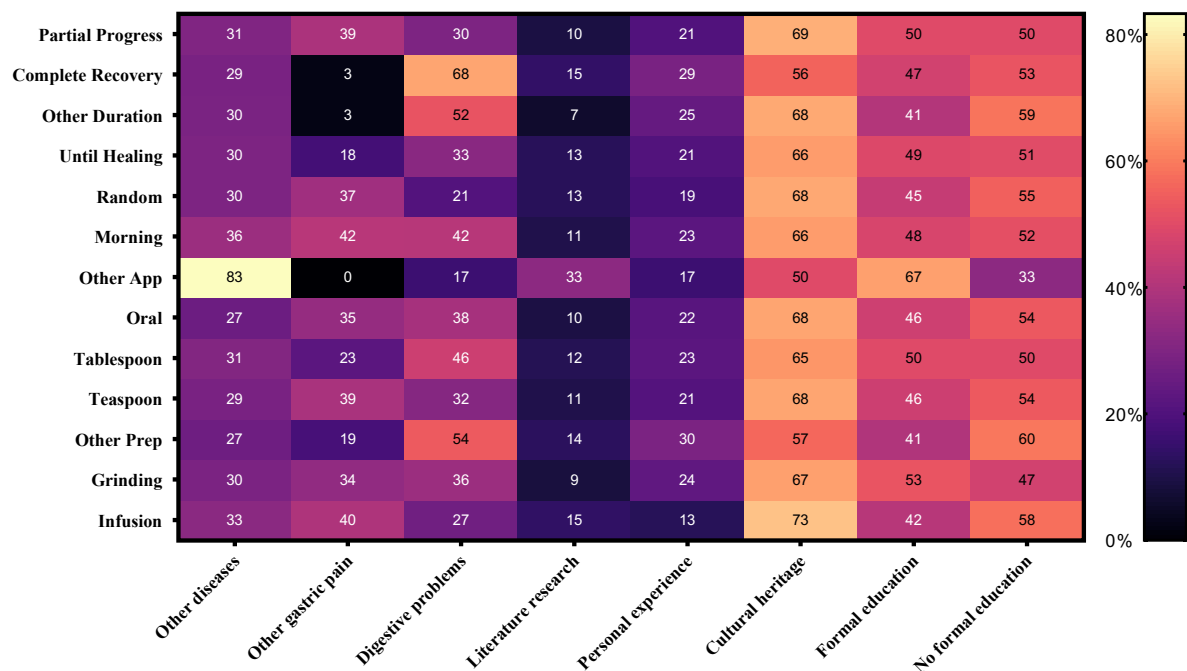


Figure 2. Hierarchical clustering heatmap illustrating the distribution of *Zygophyllum* usage variables across user groups (n = 200). Color intensity represents percentage values, with red (80%) indicating higher frequencies and blue (0%) indicating lower frequencies. Rows represent user groups; columns represent usage variables (preparation methods, dosage, administration route, application time, duration of use, and therapeutic outcomes). The dendrograms (trees) on the left and top indicate similarity relationships between user groups and variables, respectively, based on hierarchical clustering with complete linkage and Euclidean distance.

Therapeutic Indications of *Zygophyllum* Species by Disease Category

Gastrointestinal Disorders

The most common reasons for using *Zygophyllum* were gastrointestinal disorders. Irritable bowel syndrome (IBS) was the most cited condition (FC = 76, FL = 31.67%) followed by gastric pain (FC = 70, FL = 29.17%). Other gastrointestinal ailments were intestinal pain (FC = 8), diarrhea (FC = 6), abdominal bloating (FC = 5) and gastroesophageal reflux disease (FC = 4) (Table 5). This dominance is consistent with traditional knowledge recorded across North Africa. *Z. gaetulum* is known for its stomach pain relieving properties and is one of the commonly used plants for the treatment of digestive disorders (Janah *et al.* 2024). Digestive disorders were the main indication for the use of *Z. gaetulum* in the Moroccan Sahara, accounting for

53.19% of all citations (El Ansari *et al.* 2025). Scientific evidence supports the use of *Z. gaetulum* for its gastrointestinal effects. According to Aquino *et al.* (2001), the antispasmodic effect of *Z. gaetulum* roots was studied using electrically-stimulated guinea pig ileum models; a dose-dependent inhibition of electrically-induced contraction was noted, with bioassay-guided isolation of a novel saponin called zygophyloside N, along with three known quinovic acid glycosides (Capasso *et al.* 1998).

The anti-diarrheal activity of *Zygophyllum* species was also confirmed experimentally by Atta & Mouneir (2004) who investigated the anti-diarrheal activity of *Z. album* species in castor oil-induced diarrhea models. Mnafigui *et al.* (2016) also demonstrated that the essential oil of *Z. album* significantly alleviated the symptoms of diarrhea in alloxan-induced diabetic rats. The anti-diarrheal activity of *Z. gaetulum* was confirmed by Ait El Cadi *et al.* (2008) using the Ussing chamber method. This finding provides a mechanistic basis for the traditional use of *Zygophyllum* species for diarrheal conditions. The phytochemical basis for these effects has been characterized by El Abdouni Khayari *et al.* (2017) and Janah *et al.* (2024) who showed that the leaves are rich in saponins especially bisdesmosidic triterpene saponins, terpenes, and sterols. These saponins are known to possess surfactant properties that may alter intestinal transit. Some terpenoids possess an antispasmodic activity on smooth muscle providing a mechanistic basis for the traditional use in gastric pain and spasm of the digestive tract.

Hair and Scalp Disorders

Zygophyllum is used to treat hair disorders such as alopecia or dandruff (FC = 7, FL = 2.92%) and bacterial scalp infections (FC = 5, FL = 2.08%) (Table 5). The antimicrobial effects of the *Zygophyllum* species are well known. *Z. gaetulum* extracts exhibit significant antibacterial activity against *Escherichia coli*, which was related to the total phenolic and flavonoid content (Mammass *et al.* 2025). Similarly, *Z. simplex* saponifiable fraction showed a strong antibacterial activity against *Pseudomonas aeruginosa*, confirming the traditional use for scalp infections (Bar *et al.* 2025). The chemical constituents such as flavonoids and phenolic compounds help in improving the scalp health.

Dermatological Disorders

Another major category of traditional indications in this study was dermatological conditions like skin infections (FC = 6, FL = 2.50%), eczema (FC = 4, FL = 1.67%), and burns (FC = 3, FL = 1.25%) (Table 5). These uses are in line with the traditional knowledge reported in the literature. *Z. gaetulum* is recognized for its traditional application in the management of eczema and dermatitis (Janah *et al.* 2024). Dermatological disorders were the second most common indication of *Z. gaetulum* in the Moroccan Sahara, as reported by El Ansari *et al.* (2025), accounting for 29.79% of citations. The study validated the use of the species traditionally against eczema and dermatitis which is quite in line with the findings of the present study.

Recently, dermatological applications have largely been supported by scientific validation. Bar *et al.* (2025) studied the lipoidal fractions of *Zygophyllum simplex* in a rat model of *Pseudomonas aeruginosa* infected burn. The saponifiable fraction exhibited the most potent antibacterial activity and significantly stimulated wound healing as evidenced by decreased bacterial load, faster wound closure, increased collagen deposition and restored histoarchitecture. Immunohistochemically. The results suggest the prospect of *Zygophyllum* species in therapy and support the traditional use of these species for skin diseases. Mammass *et al.* (2025) further validated the antibacterial potential of *Z. gaetulum* extracts. The high concentrations of tannins and saponins aid in tissue repair and infection control.

Gynecological and Reproductive Disorders

The traditional uses of *Zygophyllum* for gynecological conditions include: treatment of female infertility (FC = 4, FL = 1.67%); treatment of dysmenorrhea (FC = 5, FL = 2.08%); support during childbirth (FC = 3, FL = 1.25%); intimate hygiene and prevention of uterine infections (FC = 4, FL = 1.67%); and abortion-related uses (FC = 2, FL = 0.83%) (Table 5). These applications are based on the antimicrobial and anti-inflammatory effects of the plant. However, some of these uses require further scientific validation.

Metabolic Disorders: Diabetes Mellitus and Hypercholesterolemia

Diabetes mellitus was cited with moderate frequency (FC = 6, FL = 2.50%), while hypercholesterolemia was also documented (FC = 5, FL = 2.08%) (Table 5). The prominence of *Zygophyllum* species for metabolic disorders in Moroccan traditional medicine is well-documented. Boufous *et al.* (2017) identified *Z. gaetulum* among the six plant species with the highest use values (UV = 0.44) in Zagora province, specifically documented for use against diabetes. Hachi *et al.* (2016) and Benkhniqie *et al.* (2014) documented *Zygophyllum* species among medicinal plants used for diabetes treatment in the Central Middle

Atlas and Al Haouz-Rhamna regions, respectively. Similarly, Janah et al. (2024) identified *Z. gaetulum* as one of the frequently employed plants for managing diabetes in Moroccan folk medicine.

The pharmacological evidence for antidiabetic activity is extensive. Mnafgui et al. (2014) demonstrated that *Zygophyllum album* ethanol extract decreased α -amylase activity in serum, pancreas, and intestine of alloxan-induced diabetic rats by 40%, 45%, and 46%, respectively, leading to a 61% reduction in blood glucose levels. Mnafgui et al. (2016) further reported that the essential oil inhibited α -amylase activity by 43-38%, leading to a 60% reduction in serum glucose levels, while also improving lipid disorders through inhibition of pancreatic lipase (47%) and exerting antihypertensive effects through ACE inhibition (25%). In the present study, the traditional use of *Z. cornutum* for diabetes mellitus was also reported. This result is supported by a number of pharmacological studies. Zaakane (2017) demonstrated that the aqueous extract at 10% significantly reduced hyperglycemia in alloxan-induced diabetic mice with histological improvement of pancreatic β -cells. The *Z. cornutum* infusion extract had the highest total phenolic content and antioxidant and anti-inflammatory effects, as reported by Harchaoui et al. (2025). Touaibia & Abdellali (2025) showed that the methanol extract had a high DPPH radical scavenging activity, which was correlated with the high contents of phenolic and flavonoids.

El Ghouli et al. (2012) demonstrated antihyperglycemic, antihyperlipidemic and antioxidant activities of aqueous extract of *Z. album* in streptozotocin-induced diabetic mice with respect to hypercholesterolemia and cardiovascular protection. As shown by Ghouli et al. (2013), ethanolic extract significantly reduced plasma glucose, cholesterol, triglycerides, LDL and VLDL levels while increased HDL. Berzou et al. (2014) investigated the effects of aqueous extract of *Z. gaetulum* in rats fed with high-cholesterol diet and showed that plasma total cholesterol and LDL levels were 1.5 and 2.4 times lower, respectively, and HDL levels were 50% higher compared to untreated hypercholesterolemic rats. The extract reduced lipid peroxidation in plasma by 76% and increased antioxidant enzyme activities in different tissues. Bahlil et al. (2019) found that the aqueous extract lowered glycemia by 15% and increased insulinemia by 28%, and improved Homeostasis Model Assessment of Insulin Resistance by 19% in hypercholesterolemic-diabetic rats, with a significant reduction in lipid peroxidation and an increase in antioxidant enzyme activities. Further, Bahlil et al. (2020) demonstrated that the aqueous extract of *Z. album* reduces protein oxidation and preserves endothelial function in hypercholesterolemic-diabetic rats, suggesting cardiovascular benefits.

Cancer

Promising anticancer properties of *Zygophyllum* species have been reported in some scientific investigations (Table 5). Cancer was cited with relatively low frequency (FC = 3, FL = 1.25%). El-Attar et al. (2019a, 2019b) showed that extracts of *Z. album* have significant cytotoxic activity against human liver cancer and lung carcinoma cell lines and are selectively toxic to cancer cells without affecting normal cells. Abdelhameed et al. (2022) also reported that *Z. album* extracts, especially formulated as silver nanoparticles, showed potent cytotoxicity against lung and prostate cancer cell lines. The relatively low citation frequency for cancer in the present study likely reflects lower prevalence compared to more common conditions.

Neurological Disorders, Inflammation, and Fever

Reported uses for *Zygophyllum* include treatment of migraines (FC = 6, FL = 2.50%), inflammation (FC = 7, FL = 2.92%), and fever (FC = 8, FL = 3.33%) (Table 5). The anti-inflammatory properties have been experimentally validated. Boukemara (2016) demonstrated that *Z. gaetulum* extracts inhibited xylene-induced ear edema in mice by 45% at 300 mg/kg, attributing this effect to inhibition of reactive oxygen species production by neutrophils. Rimbau et al. (1999) evaluated aqueous, ethanol, and chloroform extracts of *Z. gaetulum* for anti-inflammatory activity using mouse ear edema induced by arachidonic acid and rat subplantar edema induced by carrageenan, confirming significant anti-inflammatory activity. Harchaoui et al. (2025) reported that *Z. cornutum* infusion extract possesses anti-inflammatory effects superior or equal to reference drugs, with acute toxicity tests confirming innocuity. Rouibi et al. (2018) evaluated the anti-inflammatory activity of *Z. cornutum* aqueous extract using the carrageenan-induced paw edema method, demonstrating 58.56% edema inhibition compared to 56.25% for Diclofenac. The presence of antioxidants and anti-inflammatory compounds such as flavonoids and phenolics supports these therapeutic uses.

Toxic and Infectious Conditions

The use of *Zygophyllum* for snakebites (FC = 2, RFC = 0.0083, FL = 0.83%) and hepatitis (FC = 5, RFC = 0.0208, FL = 2.08%) indicates traditional use for severe health problems (Table 5). However, limited research has established connections between *Zygophyllum* and these conditions. The antimicrobial properties documented by Mammass et al. (2025) and Bar et al. (2025) may support the treatment of infectious components, but dedicated studies on snakebite neutralization and hepatoprotective effects are needed. These uses represent important research gaps requiring further investigation.

Plant Part Selection Across Usage Variables

Analysis of plant part selection by demographic and usage variables showed that the aerial parts were most frequently used among all levels of education (from 62.5% to 69.0%), but the differences were not statistically significant ($p = 0.835$) (Table 6). This lack of statistically significant association suggests that the traditional knowledge of which parts to use is preserved consistently across the educational levels and is not influenced by formal education.

Source of knowledge showed a non-significant trend ($p = 0.269$) with cultural heritage associated with highest aerial part use (70.4%) and literature research associated with highest whole-plant use (22.2%). This tendency may be due to the fact that written sources are more accurate in suggesting specific parts of plants whereas oral tradition emphasizes the use of whole plants. These findings are consistent with the reports of other ethnobotanical surveys of Zygophyllaceae in which traditional knowledge is mainly transferred through oral communication within the indigenous communities (Ahmed 2021). The predominance of gastrointestinal indications (IBS, gastric pain) in the present study may favor the use of branches while the higher foliage use documented by El Ansari et al. (2025) may be related to the higher proportion of dermatological indications (29.79%) in that study.

No statistically significant association was found between time of application ($p = 0.447$), type of use ($p = 0.979$) and therapeutic outcome ($p = 0.394$). The lack of significant associations indicates shared traditional knowledge and not individual variation. The non-significant association of the therapeutic outcome with the choice of plant part ($p = 0.394$) showed that traditional practitioners consider the aerial parts and the branches as equally effective. The similarity of plant part selection across most variables suggests that the traditional knowledge on the use of *Zygophyllum* is shared and not individually varying with the characteristics of the users. The phytochemical literature supports this uniformity, as El Abdouni Khayari et al. (2021) showed that different parts of the plant contained diverse but complementary bioactive compounds and each part contributed to the overall therapeutic profile.

Table 6. Plant part used by demographic and usage variables in the study area.

Variable	Category	Aerial parts (%)	Branches (%)	Other parts (%)	p-value
Education level	No formal	68.2	17.0	14.8	0.835
	Primary	69.0	20.7	10.3	
	Secondary	65.0	33.3	1.7	
	University	62.5	20.8	16.7	
Source of knowledge	Cultural heritage	70.4	19.2	10.4	0.269
	Personal experience	65.2	21.7	13.0	
	Literature research	55.6	22.2	22.2	
Dosage	Teaspoon	60.0	20.0	20.0	0.256
	Tablespoon	65.8	26.3	7.9	
Application method	Oral	72.2	16.7	11.1	0.965
	Infusion	60.6	45.5	0.0	
Time of application	Morning	68.0	14.2	10.3	0.447
	Evening	60.2	30.1	9.7	
Duration of use	Until healing	75.5	14.2	10.3	0.340
	One week	60.2	30.1	9.7	
Type of use	Digestive problems	70.6	17.6	11.8	0.979
	Eczema	66.7	22.2	11.1	
	Diabetes	60.0	20.0	20.0	
Outcome	Complete /Partial	17.3/82.7	-	-	0.394

Safety Profile and Toxicological Considerations

The low rate of side effects reported in the present study suggests good tolerability of *Zygophyllum* preparations under traditional conditions of use. Acute toxicity tests performed by Harchaoui et al. (2025) confirmed the innocuousness of *Z. cornutum* extracts. Similarly, Mnafigui et al. (2014) studied the effects of *Z. album* ethanol extract in rats and reported not only efficacy but also protection of pancreatic β -cell structure and function, without any reported acute toxicity in the 30-day study period.

More alarming are findings by Haroun & Abualghaith (2015) who showed concentration-dependent mutagenic effects of *Zygophyllum simplex* in *Allium cepa* and *Vicia faba* root tip assays, where higher concentrations (40% extracts) induced

mitotic and meiotic aberrations. The results emphasize the importance of correct dosages and warn against consuming too much. The difference between the low incidence of reported side effects in traditional use and the mutagenic effects observed at high concentrations in plant models underlines the importance of dose in determining safety outcomes.

Study Limitations and Research Gaps

There are a few limitations to note. The sample was largely male, which may not be representative of traditional knowledge holders. The cross-sectional design is limited to usage patterns at one point in time and causality cannot be established. No studies were found for *Z. waterlotii*, which is an important gap in research. Future research should focus on clinical trials, standardization of the extract and comprehensive toxicological evaluation.

Conclusion

This ethnobotanical study is a review of the traditional uses of 4 *Zygophyllum* species (*Z. gaetulum*, *Z. album*, *Z. cornutum* and *Z. waterlotii*) in 6 Moroccan regions among 200 herbalists. The results confirm that these plants are still in the Moroccan folk medicine. The study reveals that the traditional knowledge of *Zygophyllum* species is predominantly transmitted through cultural heritage and is held by older male respondents with low formal education, thus emphasizing the urgent need for documentation before the potential erosion of knowledge due to urbanization and modernization. The modalities of use are characterized by a preference for dried plant material collected in spring, prepared principally by grinding or infusion, and administered orally, with treatment usually maintained until healing. The low rate of side effects reported indicates good tolerability under traditional use conditions.

The analysis of the plant parts value showed that the most used plant part was the branches followed by aerial parts. No significant correlation was found between the plant part selections and demographic and usage variables suggesting that traditional knowledge is consensual among user groups. The statistical associations revealed consistent traditional medical logic, where preparation methods, dosage, application time and treatment duration were significantly associated with therapeutic outcomes. The close agreement between the traditional uses reported in this study and the pharmacological evidence from the literature supports the empirical basis of *Zygophyllum* preparations. These plants have been proven through many preclinical studies to possess antispasmodic, antidiarrheal, antidiabetic, antihyperlipidemic, anti-inflammatory and wound healing properties, thus offering scientific rationale for their continued therapeutic use. While *Z. gaetulum*, *Z. album* and *Z. cornutum* have attracted increasing scientific interest, *Z. waterlotii* is not investigated in the literature and represents an important research gap. Future studies should focus on clinical trials to test efficacy and safety in human populations, phytochemical standardization of extracts, complete toxicological evaluation and ethnopharmacological studies on *Z. waterlotii*. Conservation strategies for these endemic species are also suggested for their sustainable use in Moroccan traditional medicine.

Declarations

List of abbreviations: RFC: Relative Citation Frequency, FC: Citation Frequency, N: Total Number of herbalists, PPV: Plant Part Value, FL: Fidelity Level, Ip: Number of citations of the species used to treat a particular disease, Lu: total number of citations of the species used for all diseases. IBS: Irritable bowel syndrome, DPPH: 2,2-diphenyl-1-picrylhydrazyl.

Ethics approval and consent to participate: The data were collected in accordance with ethical standards, ensuring confidentiality, anonymity, and informed consent. All participants were fully informed about the purpose of the study prior to data collection.

Consent for publication: Not applicable

Availability of data and materials: The data from this study have not been deposited in public repositories.

Competing interests: The authors declare no conflicts of interest.

Funding: This research was funded by the PASS (PhD-Associate Scholarship) program of the National Centre for Scientific and Technical Research (CNRST), Morocco.

Author contributions: **M.K.E.B.** Study design, conduction of ethnobotanical surveys, active participation in structuring the methodology, manuscript writing, data analysis, and interpretation. **H.B.** Data analysis, interpretation, methodology development, manuscript writing, Review and editing, and interpretation. **M.Q.** Data analysis, contribution to methodology. **S.B.** Investigation, writing of the original draft, methodology, and formal analysis. **B.S.** Review and editing, methodology, formal analysis, and drafting. **A.D.** Review and editing, methodology, formal analysis, and drafting. **A.C.H.** Investigation, writing of the original draft, methodology, and formal analysis. **H.B.** Study design and supervision, contribution to methodology, manuscript refinement, and review editing. All authors read, reviewed, and approved the final version of the manuscript.

Acknowledgements

The authors thank Pr. Hamid Khamar from the Botanical Department of the Scientific Institute of Rabat, Morocco, for plants authentication.

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