



Qualitative and quantitative ethnobotanical assessment of *Zygophyllum gaetulum* Emb. & Maire: An emblematic medicinal plant of Saharan heritage

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Research

Abstract

Background: The Moroccan Saharan flora is a remarkable botanical heritage, distinguished by its exceptional adaptation to extreme desert conditions and its importance in traditional medicine. The present study aims to valorize the ethnopharmacological potential of *Zygophyllum gaetulum* Emb. & Maire, commonly known as “**agaaya**,” an emblematic species of the Moroccan Sahara, using a qualitative and quantitative ethnobotanical approach.

Methods: Ethnobotanical investigations were conducted among 56 local traditional medicine practitioners in the Rissani circle, Errachidia Province, Morocco, including herbalists and healers. Interviews were conducted using semi-structured questionnaires.

Results: The survey revealed that the plant is used in therapy by 57.14% of practitioners, mainly in the treatment of digestive disorders (53.19%), followed by dermatological disorders (29.79%) and endocrine and metabolic disorders (8.51%). The foliage (PPV = 0.610) and stems (PPV = 0.325) are the most recommended parts in powder form (78.13%). These preparations are generally administered orally (81.25%) or applied to the skin (68.75%). Quantitative analyses reveal the major importance of the plant in traditional pharmacopoeia given its significant use value (UV=0.839), its notable relative frequency of citation (RFC=0.5714), and its high cultural importance index (CI=0.839). Its therapeutic use is characterized by a high fidelity level (FL) for the treatment of digestive disorders (FL=78.125%).

Conclusions: This study reveals the role of *Zygophyllum gaetulum* Emb. & Maire in the traditional therapeutic practices of local communities and highlights its potential as a source of promising bioactive compounds for modern medicine. However, further research is needed to explore its therapeutic applications and safety.

Keywords: *Zygophyllum gaetulum* Emb. & Maire, Ethnopharmacology, Quantitative ethnobotany, Phytotherapy, Saharan medicinal plant, Rissani Circle, Morocco.

Background

Due to its indisputable plant wealth resulting from the heterogeneity of its habitats, landscapes, climatic and geological events, Morocco is endowed with remarkable biodiversity (Najem *et al.* 2019). In particular, the Moroccan desert, with its arid climate and extreme conditions, is home to fascinating flora that is perfectly adapted to its hostile environment. This often overlooked flora plays a crucial role in the balance of the desert ecosystem, providing food, shelter, and medicine to the region's indigenous population. In addition, the species that inhabit this arid environment are distinguished by their unique characteristics and traditional uses (Jamaledine *et al.* 2017).

One of the most emblematic species is *Zygophyllum gaetulum* Emb. & Maire or *Tetraena gaetula* [Emb. & Maire] Beier & Thulin, known as “*agaaya*” or “*el berraya*” in the local dialect, which is a xerophytic plant endemic to northwestern Africa and characteristic of Saharan flora (Janah *et al.* 2024, Plants of the World Online 2025). Its range extends mainly to Cape Verde, the Canary Islands, Morocco, Western Sahara, Mauritania, Senegal, Algeria, and Mali. In Morocco, *Z. gaetulum* is particularly concentrated in the regions of Drâa-Tafilalet, Tan-Tan, and Western Sahara, in arid and semi-arid bioclimates, and is resistant to saline soils (Janah *et al.* 2024, Plants of the World Online 2025). Indeed, this plant survives hostile conditions and thrives by concentrating bioactive compounds that have been exploited for generations in Saharan pharmacopoeia to relieve or treat hepatic, gastric, and dermatological disorders (Bellakhdar 1997).

It should be noted that studies on the ethnopharmacological use of *Z. gaetulum* are incomplete and fragmentary, or even non-existent in certain regions such as the Rissani circle in the province of Errachidia, which is distinguished by its strategic location at the crossroads between northern Morocco and the Sahara. This region has been home to a diverse population, including Amazighs, Muslim Arabs, Jews, and Saharans (Ben Brahim 2021). This human and cultural mix has contributed to a wealth of knowledge in phytotherapy, passed down orally through the generations (El Mansouri *et al.* 2011).

In this perspective, the present work focuses on documenting and valorizing the traditional ethnomedicinal uses of *Z. gaetulum* through a methodological approach combining qualitative and quantitative ethnobotanical investigations with holders of traditional knowledge and practices, which are unfortunately insufficiently documented.

Materials and Methods

Study area

The Rissani circle (Draa-Tafilalet Region, Errachidia Province) is located in the extreme southeast of Morocco, extending between latitudes 30°06' -31°39' N and longitudes 5°00' -3°36' W (Bammou *et al.* 2024). It is bounded by Algeria to the east, Tinghir Province to the west, the Erfoud Circle to the north, and Zagora Province to the south (HCP 2019). The study area (Fig. 1) comprises three caïdats and five communes: Bni M'Hamed Sijilmassa, Er-Rissani, Es-Sfalat, Et-Tous, Sidi Ali, and the municipality of Moulay Ali Cherif (Ben Tayeb & Er-rami 2019). The region has an arid and desert climate with a strong continental influence, with annual rainfall often limited to 120 mm, which limits surface water resources (Bammou *et al.* 2024, El Khoumsi *et al.* 2017). However, the Ziz and Ghrih valleys are vital water sources, providing irrigation for oases and replenishing groundwater (Ait Ali *et al.* 2024, El Mansouri *et al.* 2011).

From a biogeographical perspective, it belongs to the subdesert domain, characterized by steppe-type vegetation composed of xerophilous species, among which some are endemic, rare, and threatened (Benabid 2000, El Mansouri *et al.* 2011, Hammada 2007). The fauna, in turn, remains diverse, with the presence of rare and endemic North African species, illustrating the richness of the region's desert ecosystems (Alali & Benmohammadi 2013, La région de Drâa-Tafilalet 2015).

Data collection: Tools and procedures

This study focuses specifically on the plant *Z. gaetulum* and its ethnomedicinal use in the Rissani circle of the Errachidia province. The study is based on targeted ethnobotanical investigations carried out among 56 local practitioners of traditional medicine, including herbalists and traditional healers.

The survey was conducted in two phases, one from August to September 2023 and the other from February to March 2024. The approach used to collect data involved semi-structured interviews conducted using a questionnaire and the free listing technique, commonly used in ethnobotanical research and the social sciences (Miranda *et al.* 2007). At the same time, the field notebook technique was implemented, involving the use of audio recorders to collect information, with the prior consent of the participants. This methodological approach has the advantage of preserving all data (Najem *et al.* 2021). These

interviews, lasting an average of 20 minutes per person, were conducted in Darija (Moroccan Arabic dialect) to facilitate communication with the interviewees.

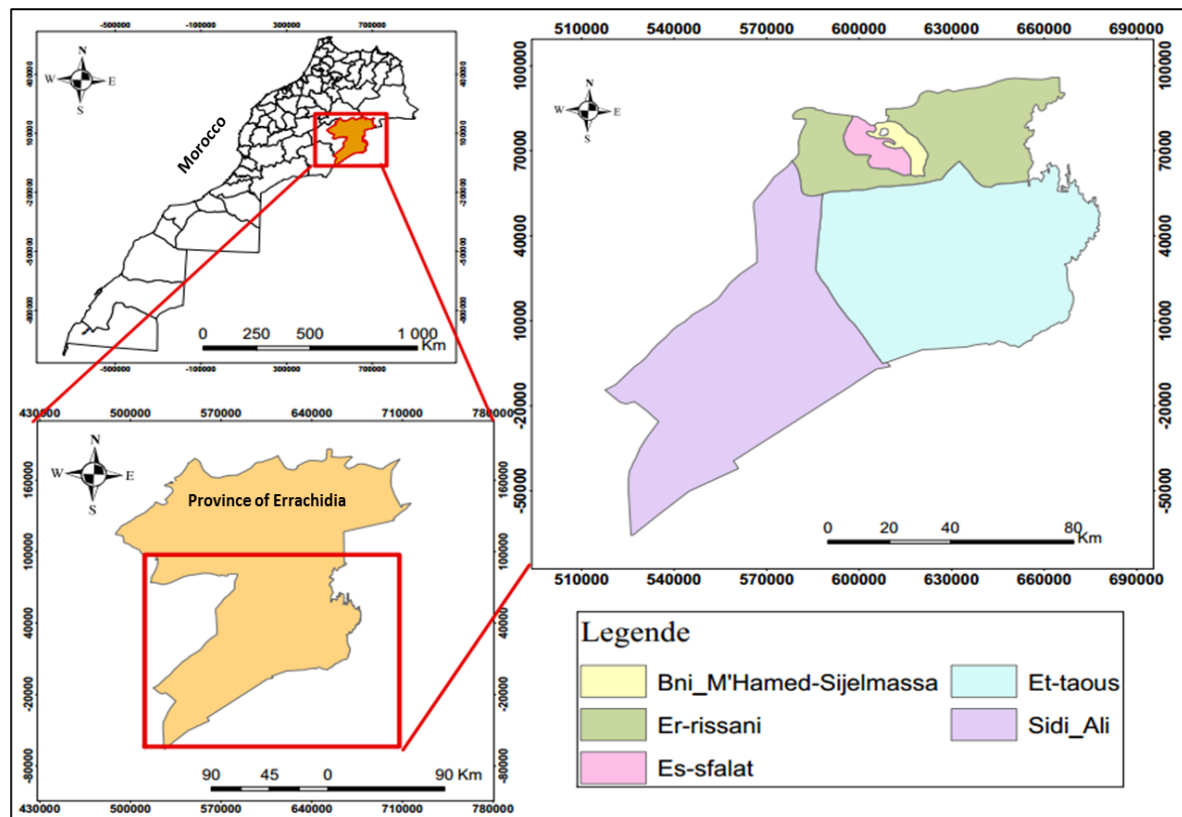


Figure 1. Map of the study area in the Rissani Circle (Province of Errachidia, Morocco), showing the five communes where the ethnobotanical survey was conducted

At the beginning of each interview, we obtained oral consent and agreement from each interviewee to participate in the survey. All respondents were informed that the purpose of the research is purely

academic and not commercial. They were also informed that their responses will be published anonymously and that they have the right to withdraw their information at any time during the survey.

This qualitative survey combined both open-ended and closed-ended questions. This allowed informants to express themselves freely while remaining within a predefined thematic framework. The questionnaire, inspired by previous work, addressed three key dimensions: (1) sociodemographic information about the respondents (age, gender, occupation, family situation, level of education, etc.), (2) specific ethnobotanical knowledge (local plant names, parts used, methods of preparation and administration), and (3) therapeutic applications and possible adverse effects (Appendix 1).

Target population and sampling method

The total population of traditional practitioners is not officially recorded in the studied region. Given this constraint, an approach combining different sampling methods was adopted. With regard to herbalists, their total number was established at 29 individuals, all of whom were included in the survey (exhaustive sampling) (Razafindrasoa *et al.* 2025). For traditional healers, mostly women practicing informally, the snowball sampling method made it possible to reach 27 individuals until data saturation (Aribou & Amrani 2023, Vignigbé *et al.* 2024). This adapted methodological approach enabled circumventing the lack of a complete census while providing a representative view of traditional practices.

Inclusion and exclusion criteria

Inclusion criteria

With regard to respondents, only indigenous practitioners from the Rissani circle who practice traditional herbal medicine were interviewed. These individuals were born and raised in the study area and are widely recognized and respected by the local population. They volunteered to participate in the survey and agreed to answer all questions on the questionnaire

honestly. This choice allowed us to focus on traditional local knowledge in the study area. With regard to plants, this study focused solely on the medicinal plant *Z. gaetulum*, which is used exclusively by local practitioners for therapeutic purposes.

Exclusion criteria

Other types of traditional medicine practitioners, such as druggists, tolbas, fqihs, syaddins, and non-indigenous actors of traditional herbal medicine, were excluded from this study. In addition, users and consultants from the general population who commonly use this plant were not interviewed. Furthermore, other aromatic and medicinal plants used for therapeutic purposes, as well as those used in magic and witchcraft practices, were excluded from the study.

Collection and identification of the plant species studied

The plant *Z. gaetulum* (Fig. 2) was collected in May 2024 in the Rissani region, Er-Rachidia province, located in southeastern Morocco, at geographical coordinates 31.267783° north latitude and -4.270501° east longitude, at an altitude of 763.50 meters. The harvested plant was then dried, numbered, and preserved according to standard methodological procedures (Jain 1964) (Appendix 2). Its taxonomic identification in the field was carried out with the help of local practitioners and verified at the “Environment and Valorization of Microbial and Plant Resources” laboratory of the Faculty of Sciences of Meknes, Moulay Ismail University, by Professor Laila NASSIRI. This verification was based on the vascular plant identification manuals “Flore pratique du Maroc” (Fennane *et al.* 2007) and the online database *Plants of the World Online* (Plants of the World Online 2025).

Z. gaetulum is a perennial chamaephyte species (50 cm) recognizable by its suffrutescent and pubescent habit, with a ligneous base and young shoots covered with whitish trichomes (Fennane *et al.* 2007, Janah *et al.* 2024). Its bifoliate leaves, borne on a petiole, have two succulent leaflets typical of plants adapted to aridity (Fig. 2) (Fennane *et al.* 2007, Janah *et al.* 2024). The plant is most easily identified by its distinctive capsular fruits: the mature capsule has a lower part that is significantly longer than its five apical lobes, which measure between 1 and 3 mm (Fennane *et al.* 2007). Although flowering mainly occurs in spring, it can sometimes occur in autumn, demonstrating its ecological plasticity (Bellakhdar 1997, Fennane *et al.* 2007).

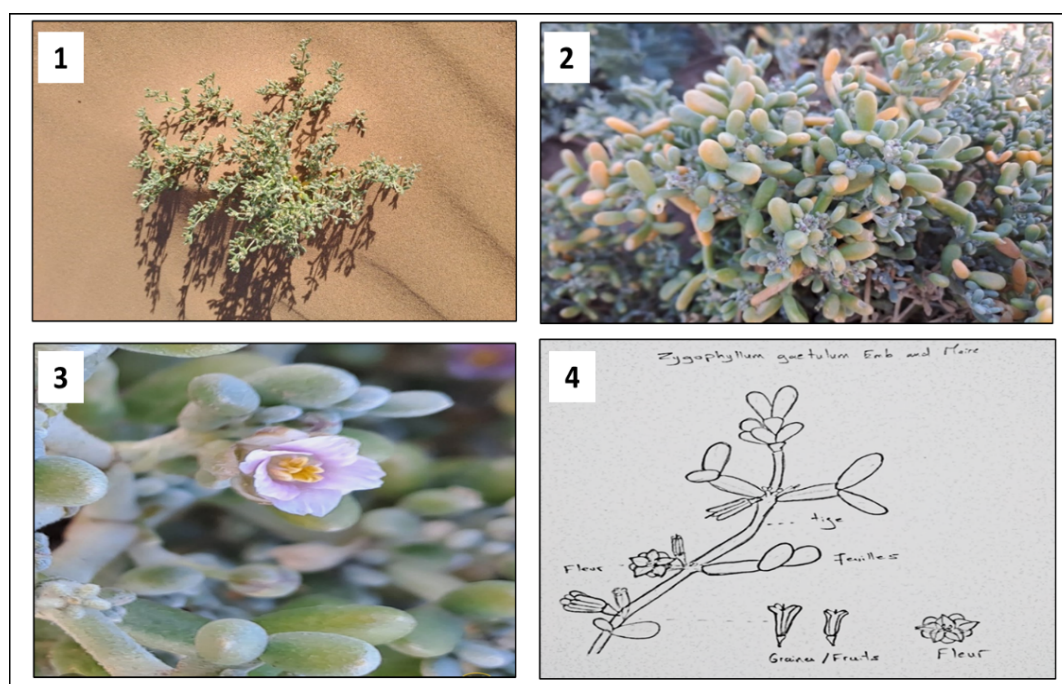


Figure 2. Morphological characteristics of the *Zygophyllum gaetulum* Emb. & Maire plant: (1) general view of the whole plant, (2) leaves, (3) flower and (4) botanical illustration

Statistical analysis of data

The collected data were entered and analyzed using Excel 2021 and IBM SPSS Statistics 26 software. Descriptive and quantitative analysis methods, such as Fisher's exact test for samples with fewer than 5 observations and the chi-square test, were used. Results with p-values less than or equal to 0.05 were considered statistically significant.

Quantitative analysis of ethnobotanical data

The data collected were used to calculate various quantitative indices, including use value (UV), relative frequency of citation (RFC), fidelity level (FL), cultural importance index (CI), and plant part value (PPV).

Use value (UV)

Use value (UV) is a quantitative method used to assess the relative importance of a plant. It is calculated using the following formula (Vitalini *et al.* 2013):

$$UV = \sum_{i=1}^{I=N} U_i / N$$

Where, U_i is the number of mentions of use reported by each informant i for the species; N is the total number of informants interviewed.

Relative frequency of species citation (RFC)

The relative frequency of citation (RFC) shows the local importance of the specie and it is given by the following formula (Vitalini *et al.* 2013):

$$RFC = FC / N$$

Where, FC is the number of informants using the species; N is the total number of informants interviewed in the study. The relative frequency of citation varies from 0 to 1; when it is close to 0, it means that none of the respondents referred to this plant as useful, and when it is close to 1, it indicates that this plant is considered useful by almost all respondents (Tardío & Pardo-de-Santayana 2008).

Fidelity level (FL)

The Fidelity level (FL) is used to assess the extent to which a particular species is specifically used to treat a given disease (Nawash *et al.* 2013); it is calculated using the following formula (Nawash *et al.* 2013):

$$FL (\%) = (N_p / N) \times 100$$

Where, N_p is the number of informants who reported using the species to treat a disease; N is the number of informants who mentioned the species for any use.

A high FL indicates high use of the plant species for a particular condition, while a low FL indicates a wide range of medicinal uses but with low frequency for each condition (Yaseen *et al.* 2015).

Cultural Importance Index (CI)

The Cultural Importance Index (CI) was used to assess the value of the species (Singh *et al.* 2019). It is calculated using the following formula (Pardo-de-Santayana *et al.* 2007):

$$CI = \sum_{i=1}^{i=Nu} UR_i / N_t$$

Where, UR_i is the number of citations of use of the species for different categories of use (i can range from a single use to all uses recorded.); N_t is the total number of participants surveyed

Use value of plant parts (PPV)

The value of plant parts (PPV) is calculated using the following formula (Najem *et al.* 2022):

$$PPV = RU \text{ of plant part} / \text{Total RU}$$

Where, RU corresponds to the total number of uses reported for all plant parts; RU of the plant part corresponds to the number of uses reported for a specific part of the plant.

The highest PPV value indicates the plant part most commonly used by respondents (Najem *et al.* 2022).

Results and Discussion

Qualitative ethnobotanical study

Sociodemographic data

A total of 56 participants selected for this study took part in the survey, representing a participation rate of 100%. 33 were men and 23 were women. Among them, 32 practitioners (57.14%) reported using the medicinal plant under study, *Z. gaetulum*, with 50% men and 50% women, giving a sex ratio of 1. Although the numbers are equal, a notable difference appears when these figures are related to the total number of individuals of each sex. Nearly 70% of women mentioned the plant, while less than half of men (48.48%) cited it. This result suggests that, proportionally, the plant *Z. gaetulum* is better known or used by women. Indeed, women play a central role in the domestic and family sphere. They use aromatic and medicinal plants to treat common ailments within the household, making them the guardians of ancestral knowledge related to the therapeutic use of plants (Chaachouay *et al.* 2019, Pourchez 2014).

These results are consistent with those obtained by other researchers in the Tafilalet region (El Rhaffari & Zaid 2002) and in the Saharan province of Tata (Abouri *et al.* 2012). However, another study conducted in the Meknes-Tafilalet region reported that men were more active than women in herbal medicine, except that in this case, the respondents were mainly herbalists and druggists (Bammou *et al.* 2015). On the other hand, there have been reports of increased participation by women in marketing medicinal plants, particularly through the creation of associations, cooperatives, and specialized pharmacies (Bammou *et al.* 2015, Najem *et al.* 2019). This finding highlights the importance of involving women in initiatives to develop and promote traditional medicine in the Rissani circle to strengthen and preserve this ancestral knowledge (Najem *et al.* 2020a).

The citation rate for the plant *Z. gaetulum* varies according to the age of practitioners. It is lower among those aged 20 to 40, reaches its highest level in those aged 40 to 60, and then slightly decreases among practitioners over 60. This progression suggests that knowledge or use of the plant may be linked to long experience accumulated over time (Najem *et al.* 2020a), particularly among practitioners aged 40-60 years, who constitute the largest group. Although age can be an indicator of experience, analyzing seniority in practice provides a better understanding of the possible influence of experience on knowledge of the plant being studied.

Thus, practitioners with more than 30 years of experience were the ones who cited the plant most frequently, suggesting that ethnobotanical knowledge tends to be acquired and reinforced over years of practice (Mehdioui & Kahouadji 2007). These observations are consistent with other studies highlighting that experience and age play a crucial role in the knowledge and use of medicinal plants (Daoudi *et al.* 2015, Eddouks *et al.* 2017).

While ethnomedical knowledge is accumulated with age and experience, young people need to become involved in this field to prevent the potential erosion of this ancestral knowledge and ensure its preservation through intergenerational transmission (Najem *et al.* 2019).

The practice of traditional medicine in the Rissani circle varies according to the level of education. The citation rate of *Z. gaetulum* is highest among illiterate practitioners, followed by those with a primary school level. These results highlight that knowledge and use of this particular plant have been reported among practitioners trained through oral tradition, outside of academic settings (Elachouri *et al.* 2021, Lefrioui *et al.* 2024). However, the presence of practitioners with a level of education shows that this knowledge can also be enriched by external contributions (Diabagate *et al.* 2025).

The lower rate among academics could be explained by a lack of interest in traditional knowledge or a preference for more standardized approaches. However, their contribution could help promote this plant and herbal medicine locally (Najem *et al.* 2020a).

This diversity of educational profiles highlights the importance of an inclusive approach to transmitting and promoting local traditional knowledge, particularly around certain emblematic plants often ignored by traditional academic training (Elachouri *et al.* 2021, Gopalkrishnan 2021).

Analysis of the data obtained showed that the citation rate for the plant studied varies according to the practitioners' specialty. It is higher among traditional practitioners compared to herbalists. This may be explained by the nature of their role, which is often based on oral transmission and the targeted use of local plants for healing purposes (Awoke *et al.* 2024).

The analysis of factors influencing the indigenous knowledge of the practitioners surveyed about the plant *Z. gaetulum* revealed non-significant results. Knowledge was not dependent on gender, age, educational level, specialty, or years of experience ($p > 0.05$) (Table 1).

Table 1. Socio-demographic characteristics of informants

Variables	Categories	Citation rate (%)	P-values
Sex	Men	48.48	0.097
	Wives	69.56	
Speciality	Traditional Healers	66.67	0.131
	Herbalists	48.27	
	≤20	0.00	
Age	]20-40]	33.33	0.128
	]40-60]	67.65	
	≥60	46.15	
	Nothingness	66.67	
Educational level	Primary	57.14	0.324
	Secondary	46.66	
	Academic	25.00	
	≤10	50.00	
Years of experience	]10-20]	57.14	0.920
	]20-30]	66.66	
	]30-40]	66.66	
	≥40	50.00	

Traditional use of the plant *Z. gaetulum* and therapeutic indications

Parts used and methods of preparation of the plant *Z. gaetulum*

The results of this study show that the leaves are the part recommended by all practitioners using *Z. gaetulum* to prepare their recipes. The stems, especially the leafy stems, are also used, while the flowers and roots are only used occasionally (Fig. 3). The diversity of traditional uses associated with a plant reflects its importance in local pharmacopoeias and suggests specific therapeutic potential for its different parts (Badou *et al.* 2019). These results are confirmed by several studies in other regions (Abouri *et al.* 2012, El Rhaffari & Zaid 2002).

Furthermore, the use of *Z. gaetulum* in powder form is the most common (Fig. 4); this could be explained by the ease of preparation and use of the powder, as well as its long shelf life. The powder allows for flexible administration, whether by ingestion, external application, or mixing with other substances. Studies conducted in another region confirm these results and thus reinforce the validity and reliability of the justifications presented (Ghourri *et al.* 2012).

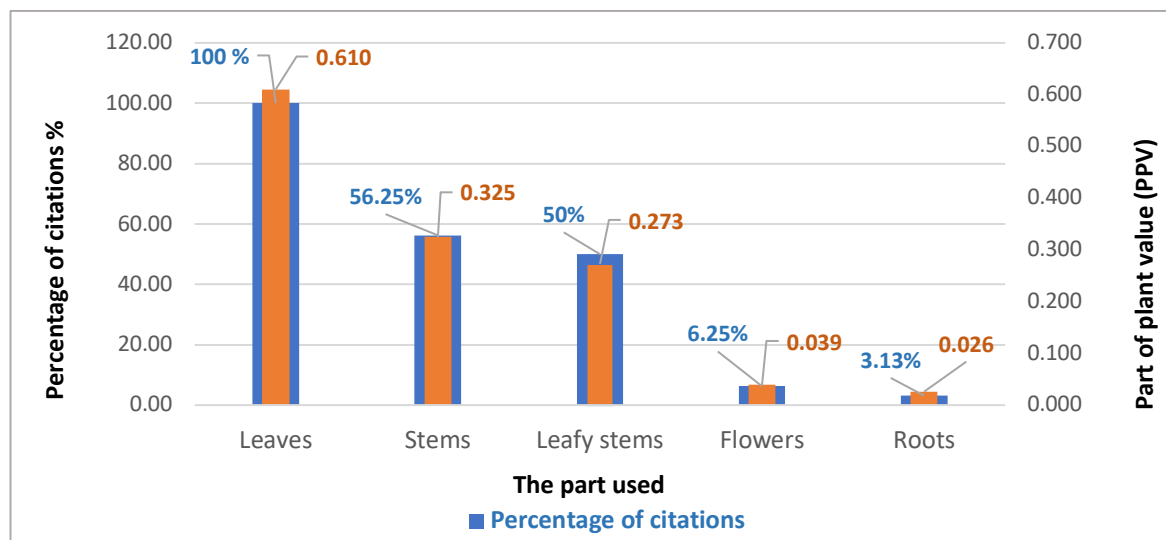


Figure 3. Frequency of use of different parts of the *Z. gaetulum* plant as recommended by the surveyed practitioners, along with the Part of Plant Value (PPV) index indicating the relative importance of each part.

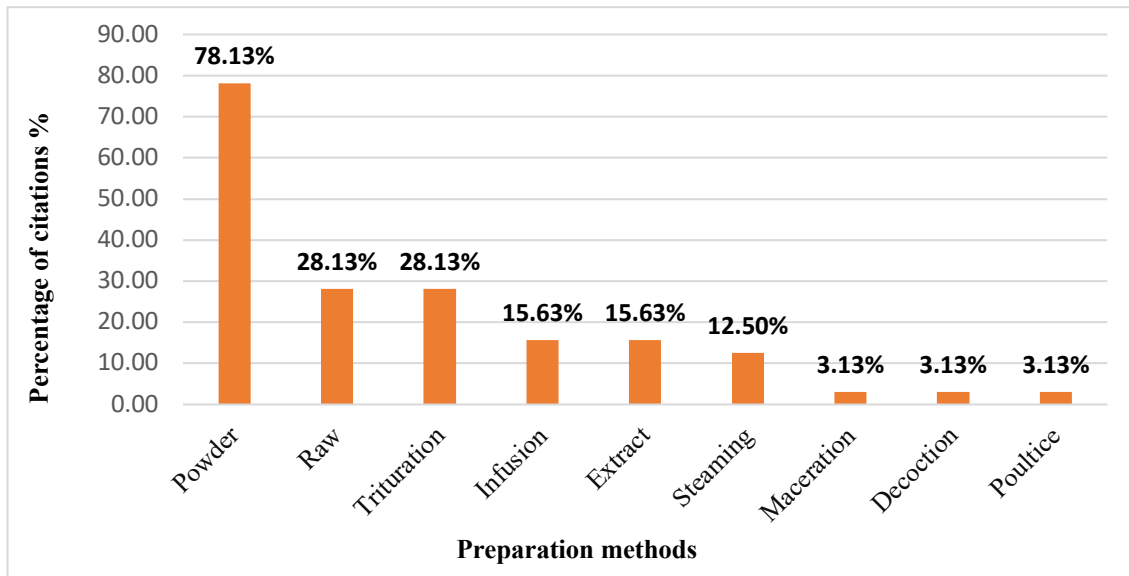


Figure 4. Frequency of the different methods of preparation of *Z. gaetulum* recommended by the practitioners surveyed

Routes of administration

Analysis of the results obtained reveals that the oral route is by far the most commonly used, accounting for more than three-quarters of administration methods (Fig. 5 and Appendix 3). This is explained by the ease of use, acceptability, and systemic absorption of active substances via this route. It is also related to the most common methods of preparation, namely powder with water, trituration (juice), and infusion, respectively (Fig. 4). The cutaneous route ranks second, highlighting the importance of local applications, particularly for the treatment of dermatological conditions. The ophthalmic route, although a minority, remains an interesting option, often in the form of drops. Several ethnobotanical studies conducted by different researchers in the same area or in other study areas have reported that the oral route is the most common mode of administration for medicinal plants, which is consistent with our results (Abouri *et al.* 2012, El Rhaffari & Zaid 2002).

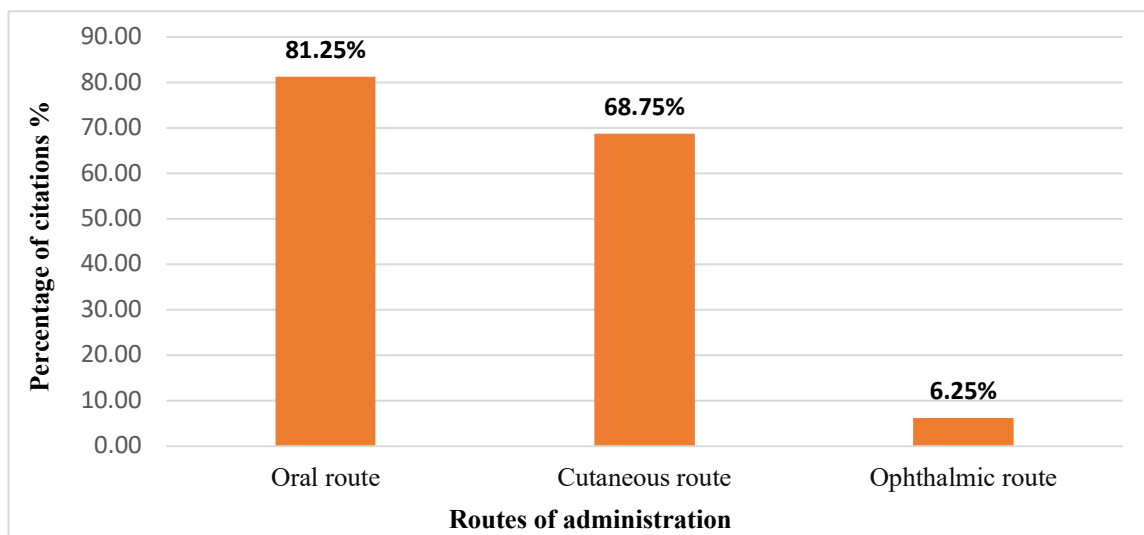


Figure 5. Frequency of the different routes of administration of *Z. gaetulum* recommended by the practitioners surveyed

Treated disorders

The survey conducted in the Rissani circle revealed that *Z. gaetulum* is used in the therapeutic recipes of 57.14% of participants, mainly to treat gastric disorders, followed by dermatological conditions and, to a lesser extent, endocrine and metabolic disorders (Fig. 6 and Appendix 3). This could be explained by practitioners' in-depth knowledge of the therapeutic properties of this plant for these types of conditions (Bellakhdar 1997). These results are consistent with previous specific studies (El Abdouni Khayari *et al.* 2017, Shawky *et al.* 2019), which have also documented its traditional use in the treatment of these pathologies. Furthermore, general studies on medicinal and aromatic plants (MAPs) confirm that *Z. gaetulum* is

recognized for these traditional uses, thus following a common trend observed for many MAPs (Afrokh *et al.* 2023, Idm'hand *et al.* 2020).

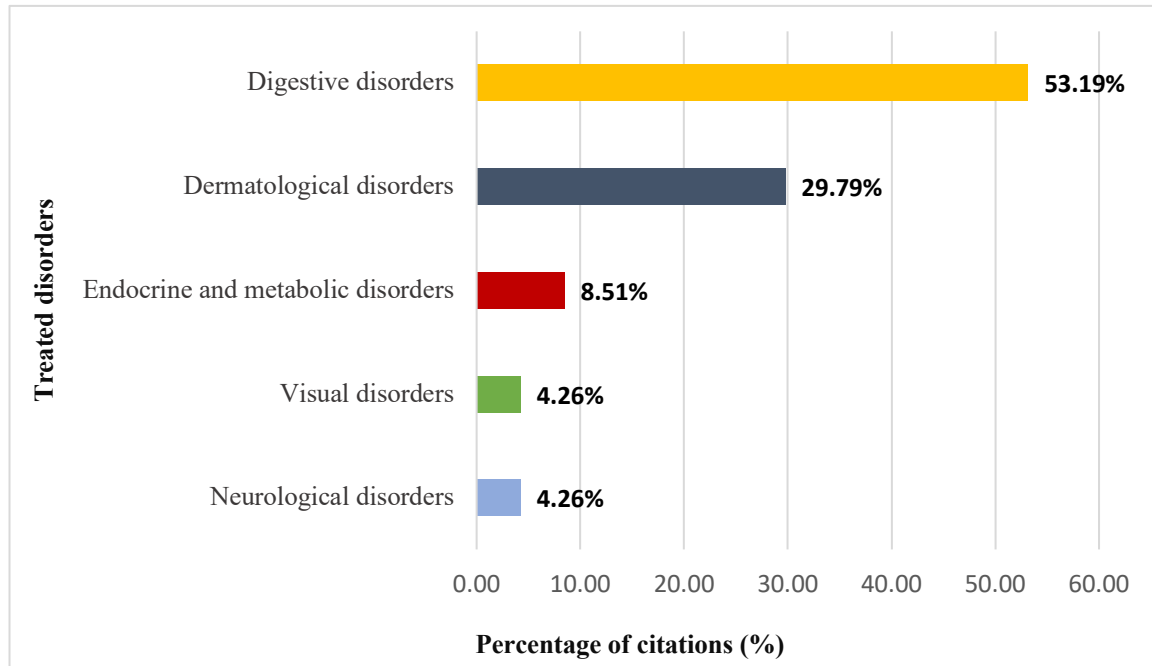


Figure 6. Disorders treated by *Zygophyllum gaetulum* Emb. & Maire in the Rissani circle according to the practitioners surveyed

Associations of *Z. gaetulum* with other plants

The results of the study show that practitioners use the plant *Z. gaetulum* alone in 53% of treatments, with a significant predominance for dermatological conditions (85.7%, p -value = 0.005). These data confirm its efficacy as monotherapy for targeted pathologies (dermatological, ophthalmological, and metabolic) and the practicality of its isolated use (Chaachouay *et al.* 2020, El Rhaffari & Zaid 2002). However, 47% of treatments are based on mixtures of plants (Table 2), with a significant frequency for digestive disorders (64%, p -value = 0.007). There are several reasons for this tendency to combine plants. First, practitioners believe that these combinations aim to create a synergistic effect, thereby potentiating the action of *Z. gaetulum* (Mukherjee *et al.* 2021). Plants can act together to enhance each other's beneficial effects, as demonstrated by several ethnobotanical studies (Abouri *et al.* 2012, El Haouari *et al.* 2018).

In traditional medicine, plants are classified as "hot" or "cold" based on their effects on the body. This concept, derived from the sensory and empirical experience of their properties, also aims to restore the balance of the "humors" (Pottier 1971). Hot plants produce a warming effect and are used to treat "cold" conditions, such as rheumatism or influenza. Conversely, cold plants have a cooling effect and are employed for "hot" conditions, such as fever (Pottier 1971).

Combining plants of opposing properties allows practitioners to moderate their effects and reduce the risk of side effects (El Rhaffari & Zaid, 2002). For example, in the treatment of gastric disorders the irritating effects of a hot plant can be counterbalanced by a cold plant like *Z. gaetulum* or other cooling plants. This approach illustrates the synergy and complementarity of traditional remedies. It is based on knowledge passed down through generations (El Rhaffari & Zaid, 2002).

Table 2. Medicinal and aromatic plants associated with *Z. gaetulum* for the Preparation of traditional remedies

Scientific names	Vernacular name	Family	Part used	Methods of preparation	Disorders treated
<i>Acacia raddiana</i> Savi	talh	Fabaceae	Resin	Powder	Digestive disorders
<i>Ammodaucus leucotrichus</i> Coss.	kamoun soufi, nsoufa	Apiaceae	Seeds	Powder Infusion	Digestive disorders

<i>Artemisia cina</i> O. Berg	chih lkhriissi	Asteraceae	Leafy stem	Powder	Digestive disorders
<i>Artemisia herba alba</i> asso	chih	Asteraceae	Leafy stem	Powder Infusion	Digestive disorders
<i>Brocchia cinerea</i> (Delile) Vis.	gertoufa, kamona	Asteraceae	Aerial part	Powder	Digestive disorders
<i>Carthamus tinctorius</i> L.	asfour-zaafour	Asteraceae	Stamens	Powder	Digestive disorders
<i>Carum carvi</i> L.	qerwiya	Apiaceae	Seeds	Powder Infusion	Digestive disorders
<i>Ceratonia siliqua</i> L.	elkharoub	Fabaceae	Fruit	Powder	Digestive disorders
<i>Chamaecrista absus</i> (L.) H.S.Irwin & Barneby	habba sawdae	Fabaceae	Seeds	Powder Infusion	Digestive disorders
<i>Chamaemelum nobile</i> (L.) All.	babounj	Asteraceae	Flowers	Powder	Digestive disorders
<i>Cuminum cyminum</i> L.	kamoun	Apiaceae	Seeds	Powder	Digestive disorders
<i>Cyperus rotundus</i> L.	tara	Cyperaceae	Tuberous rhizomes	Powder	Digestive disorders
<i>Foeniculum vulgare</i> Mill.	besbas	Apiaceae	Seeds	Powder Infusion	Digestive disorders
<i>Glycine max</i> subsp. <i>max</i>	soja	Fabaceae	Seeds	Powder	Digestive disorders
<i>Hordeum vulgare</i> L.	dechicha, che'ir, tahin	Poaceae	Seeds	Powder Cooked	Digestive disorders
<i>Lavandula stoechas</i> L.	lhalhal	Lamiaceae	Aerial part	Powder	Digestive disorders
<i>Lawsonia inermis</i> L.	henna	Lythraceae	Leaves	Powder Poultice	Digestive and dermatological conditions
<i>Lepidium sativum</i> L.	hab erchad	Brassicaceae	Seeds	Powder	Digestive disorders
<i>Linum usitatissimum</i> L.	zeri'at lketan	Linaceae	Seeds	Powder	Digestive disorders
<i>Mentha pulegium</i> L.	fliyou	Lamiaceae	Leaves	Powder	Digestive disorders
<i>Myrtus communis</i> L.	rihanne	Myrtaceae	Leaves	Powder	Digestive disorders
<i>Nigella sativa</i> L.	sanouj	Ranunculaceae	Seeds	Powder	Digestive disorders
<i>Pennisetum typhoides</i> (Burn.) Stapf et Hubb.	illan	Poaceae	Seeds	Powder	Digestive disorders
<i>Pimpinella anisum</i> L.	hbbat hlawa	Apiaceae	Seeds	Powder	Digestive disorders
<i>Punica granatum</i> L.	rmane	Lythraceae	Fruit peels	Powder Infusion	Digestive disorders
<i>Ricinus communis</i> L.	kharwae	Euphorbiaceae	Seeds	Powder	Digestive disorders
<i>Rosa centifolia</i> L.	elward	Rosaceae	Flowers	Extract	Dermatological conditions
<i>Rosmarinus officinalis</i> L.	azir	Lamiaceae	Leafy stems	Powder	Digestive disorders

<i>Tamarix aphylla</i> (L.) H.Karst.	dlaya, adba	Tamaricaceae	Resin	Powder	Digestive and dermatological conditions
<i>Tetraclinis articulata</i> (Vahl) Mast.	aarar	Cupressaceae	Leafy stems	Powder	Digestive disorders
<i>Thymus satureioides</i> Coss.	zukni	Lamiaceae	Aerial part	Powder	Digestive disorders
<i>Thymus vulgaris</i> L.	za'atar	Lamiaceae	Aerial part	Powder	Digestive disorders
<i>Trigonella foenum graecum</i> L.	lhalba	Fabaceae	Seeds	Powder Infusion	Digestive disorders
<i>Ziziphus lotus</i> (L.) Lam.	nebg, assidr	Rhamnaceae	Fruit	Powder Infusion	Digestive disorders

Distribution according to dose used, dosage regimen, and duration of treatment

Analysis of the information gathered from practitioners regarding usual doses shows that they are approximate, even random. Thus, the most commonly administered or recommended dose is a spoonful (Fig. 7 (A) and Appendix 3). Practitioners probably find this measurement practical and sufficiently accurate for preparing remedies based on this plant. A handful is the second most commonly used type of dose, particularly for preparing remedies with a significant frequency for the treatment of dermatological conditions ($p < 0.001$). This predominance can be explained by the fact that these are external applications, requiring a large quantity to cover the entire affected area, and where the risk of overdose is considered negligible. As for the pinch, it is the least used. Indeed, this dose is mainly reserved for hot or toxic plants, where very small quantities are necessary to avoid adverse effects. The use of precise doses remains marginal, suggesting that most practitioners do not rely on exact measurements. The adoption of precise doses may be more common among practitioners with formal training or access to specific measuring tools (Hewson 2015).

The relative results for dosage regimen and duration of treatment are shown in Fig. 7 (B) and (C), respectively. Analysis of the results shows that the vast majority of preparations are taken once a day. This simple, once-daily dosage probably promotes patient adherence to treatment. However, the duration of use is mainly “until recovery”. This predominance shows that practitioners adapt the duration of treatment according to the clinical progress of each patient, rather than setting standard durations. Overall, these investigations have led to the conclusion that practitioners take a pragmatic and individualized approach to the dosage, duration of use, and dose of the plant *Z. gaetulum*. They strike the right balance between giving patients choice and ensuring safe use, demonstrating their concern to tailor treatments as closely as possible to the needs and constraints of each patient, while ensuring good tolerance.

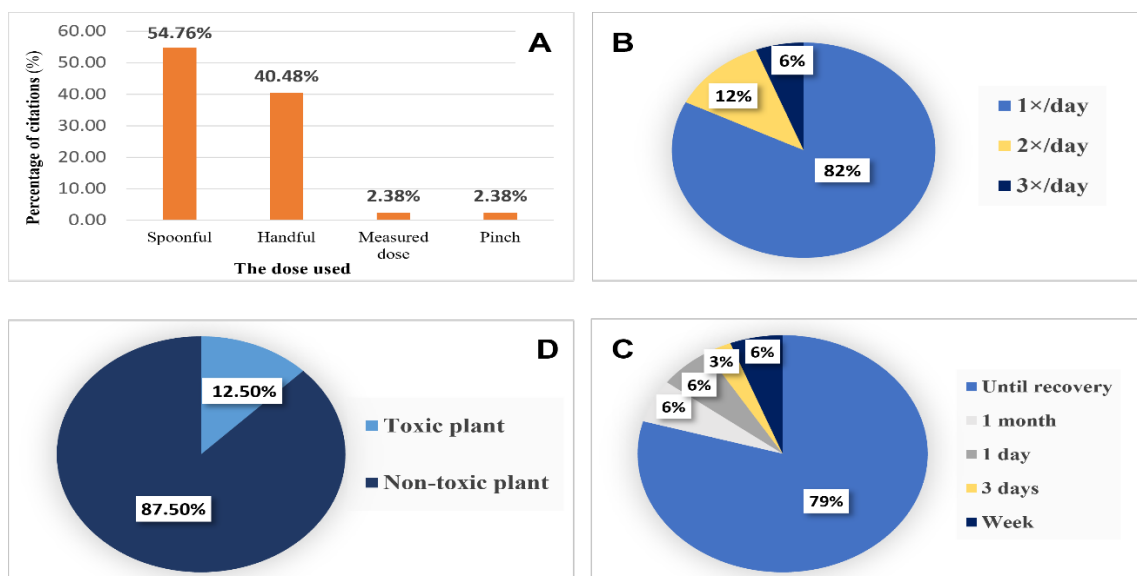


Figure 7. Characteristics of traditional uses of the *Z. gaetulum* plant reported by practitioners. (A) Frequency of doses used. (B) Dosage regimen commonly used. (C) Duration of treatment. (D) Frequency of toxicity reports among practitioners.

However, a major criticism of traditional medicine is the lack of standardization of doses, which represents a significant risk. Indeed, as toxicity is often dose-dependent, an overdose can lead to unintentional poisoning (Hammiche *et al.* 2013). As Paracelsus pointed out in the 16th century: “Everything is poisonous and nothing exists without toxicity; only the dosage makes a thing not a poison” (Fourneret 2010). Thus, the lack of dosage precision is a major challenge, which can lead to adverse effects or therapeutic ineffectiveness (Najem *et al.* 2020b).

Toxicity

During this ethnobotanical investigation, 12.5% of practitioners surveyed reported the toxicity of *Z. gaetulum* (Fig. 7 (D) and Appendix 3). Although the majority considered it generally safe, this proportion remains significant and warrants careful attention.

This perception may be influenced by several factors, including dosage and duration of use, errors in preparation or administration, lack of knowledge about the chemical properties of the plants, and the oral transmission of knowledge, which can introduce inaccuracies (Najem *et al.* 2019). These factors suggest that the adverse effects reported by some practitioners are often related to inappropriate usage conditions rather than the plant itself (Najem *et al.* 2020c).

Experimental data indicate that the toxicity of *Z. gaetulum* strongly depends on the route of administration, with oral use generally considered safe (El Youbi *et al.* 2012, Skim *et al.* 1998).

From a public health perspective, these findings highlight the importance of standardizing dosages and preparation methods in traditional medicine. Non-standardized practices can increase the risk of adverse effects, particularly among vulnerable users. It is therefore essential to promote safe practices and raise awareness among practitioners to minimize potential health risks (Najem *et al.* 2024).

Quantitative analyses

Use value (UV) of the plant *Z. gaetulum*

Quantitative analysis of use value (UV) made it possible to assess the relative importance of *Z. gaetulum* in the practices of practitioners in the region studied. The use value recorded in our study is $UV = 0.8393$. This result positions the plant as a species of high importance within the local pharmacopoeia (Appendix 3). It clearly exceeds the values reported in other regions of Morocco: Tarfaya province, where the UV is 0.09 (Idm'hand *et al.* 2020), and the Al Haouz-Rehamna region, where it is 0.026 (Benkhniue *et al.* 2023). However, it remains lower than that recorded in the Fez-Meknes region, where the UV reaches 1 (Mechchate *et al.* 2020). This result highlights the strong recognition and traditional use. Such a value justifies the implementation of in-depth studies, in particular biochemical and pharmacological analyses to identify their active ingredients, with the aim of developing therapeutic alternatives (Najem *et al.* 2020a).

Relative citation frequency (RCF)

The relative citation frequency (RCF) ranges from 0 to 1 (Yaseen *et al.* 2015). The higher the value and the closer it is to 1, the more widely recognized the plant is as useful by participants (Tardío & Pardo-de-Santayana 2008). The plant *Z. gaetulum* has an RCF of 0.5714, which means that it was cited by just over half of the informants. This value indicates significant dissemination, although it does not reflect unanimous adoption by all practitioners, due to its therapeutic properties and availability (Janah *et al.* 2024, Najem *et al.* 2021).

Cultural Importance Index (CI)

The Cultural Importance Index (CI) measures the importance of the plant in the culture of the region (Shaheen *et al.* 2017). The higher its value, the more it means that this species is well known, frequently used, and shared among members of this community (Tardío & Pardo-de-Santayana 2008). It is important to note that the total value of the CI is mathematically identical to that of the UV, although their calculation methods differ (Shaheen *et al.* 2017). The quantitative ethnobotanical study revealed that the cultural importance index (CI) value of the plant studied is high, with a score of 0.839.

Analysis of the Level of Fidelity (FL) by Therapeutic Use

The analysis of the fidelity level (FL) highlights a marked specialization of the studied plant in certain therapeutic uses. A high FL indicates a significant use of the plant species for a specific treatment, whereas a low index reflects a diversity of medicinal applications but with a rare occurrence for each ailment (Yaseen *et al.* 2015). The species studied, *Z. gaetulum*, has an exceptionally high level of fidelity for the treatment of digestive disorders (Table 3), indicating that this application constitutes the main therapeutic indication of the plant in local traditional medicine.

In second place, dermatological conditions highlighted its therapeutic relevance in this area. In contrast, endocrine and metabolic disorders, neurological disorders, and ophthalmic disorders showed significantly lower levels of fidelity, suggesting secondary or marginal uses. Studies conducted in other regions of Morocco have also revealed high levels of fidelity for the plant *Z. gaetulum* for digestive disorders.

Indeed, an FL of 37% was reported in the province of Tarfaya (Idm'hand *et al.* 2020), while it was 44% in Errachidia (Eddouks *et al.* 2017). With regard to diabetes, which is classified as an endocrine and metabolic disorder, a fidelity level of 100% was recorded, indicating a highly targeted and widely shared use of the plant for this purpose (Mechchate *et al.* 2020).

Table 3. Fidelity Level (FL) by therapeutic use concerning the medicinal plant *Z. gaetulum* in the Cercle of Rissani, Province Errachidia

Disorders	Np	N	FL (%)
Digestive disorders	25	32	78.125
Endocrine and metabolic disorders	4	32	12.500
Neurological disorders	2	32	6.250
Ophthalmic disorders	2	32	6.250
Dermatological disorders	14	32	43.750

The use value of the part of the plant Z. gaetulum (PPV)

In the Rissani circle, practitioners use different parts of the plant *Z. gaetulum* to make traditional remedies (Fig. 3). Analysis of the PPV (Part of Plant Value) index indicates a very high value for the leaves. This predominance can be explained by the fact that the leaves are the centers of photochemical reactions and reservoirs of derived organic matter, thus providing the majority of alkaloids, glycosides, and essential oils (Salhi *et al.* 2010). In addition, they are easy and quick to harvest, limiting the impact on the survival of the plant (Bhat *et al.* 2013), making them a practical choice for practitioners (Salhi *et al.* 2010). Furthermore, during field trips, it was noted that the leaves are the most readily available and most commonly sold part of the *Z. gaetulum* plant among herbalists. The other parts of the plant are less sought after: stems come in second place, followed by leafy stems, flowers and roots, with the latter being used only marginally.

Conclusion

The ethnobotanical study in the Rissani Circle, Errachidia Province, on the endemic plant *Z. gaetulum*, which is notable for its importance in the treatment of several ailments, revealed that this plant, although still little studied scientifically, occupies a privileged place in local practices, as evidenced by its high use value (UV = 0.839) and its high frequency of citation (RFC = 0.5714) by practitioners. Oral knowledge about *Z. gaetulum* highlights its therapeutic potential but also the need to scientifically validate its properties. Indeed, the gap between its ancestral use and pharmacological evidence remains to be bridged. This plant could therefore represent a promising source of active ingredients for modern applications, particularly in the treatment of digestive and dermatological conditions. Furthermore, with a view to sustainable development, it would be essential to implement conservation strategies to preserve this plant resource while regulating its exploitation. Finally, this work contributes to the preservation of local knowledge and opens up avenues for future research into the rational exploitation of *Z. gaetulum*, combining respect for traditions and scientific innovation. It calls for multidisciplinary collaboration to transform this empirical knowledge into concrete applications for the benefit of local communities and public health.

Declarations

List of abbreviations: Cultural Importance Index: CI; Fidelity Level: FL; Medicinal and aromatic plants: MAP; Use value of plant parts: PPV; Relative Frequency of Citation: RFC; Statistical Package for the Social Sciences: SPSS; Use Value: UV

Ethics approval and consent to participate: All participants provided informed consent after being fully informed of the purpose of the study.

Consent for publication: Not applicable.

Availability of data and materials: The data generated during this study are not available in public repositories.

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revising the manuscript. K.B. contributed to writing and revising the manuscript. L.N. supervised and conceived the study, and contributed to writing and revising the manuscript.

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Survey on the plant *Zygophyllum gaetulum* Emb. & Maire

Date.....

Region.....

Commune.....

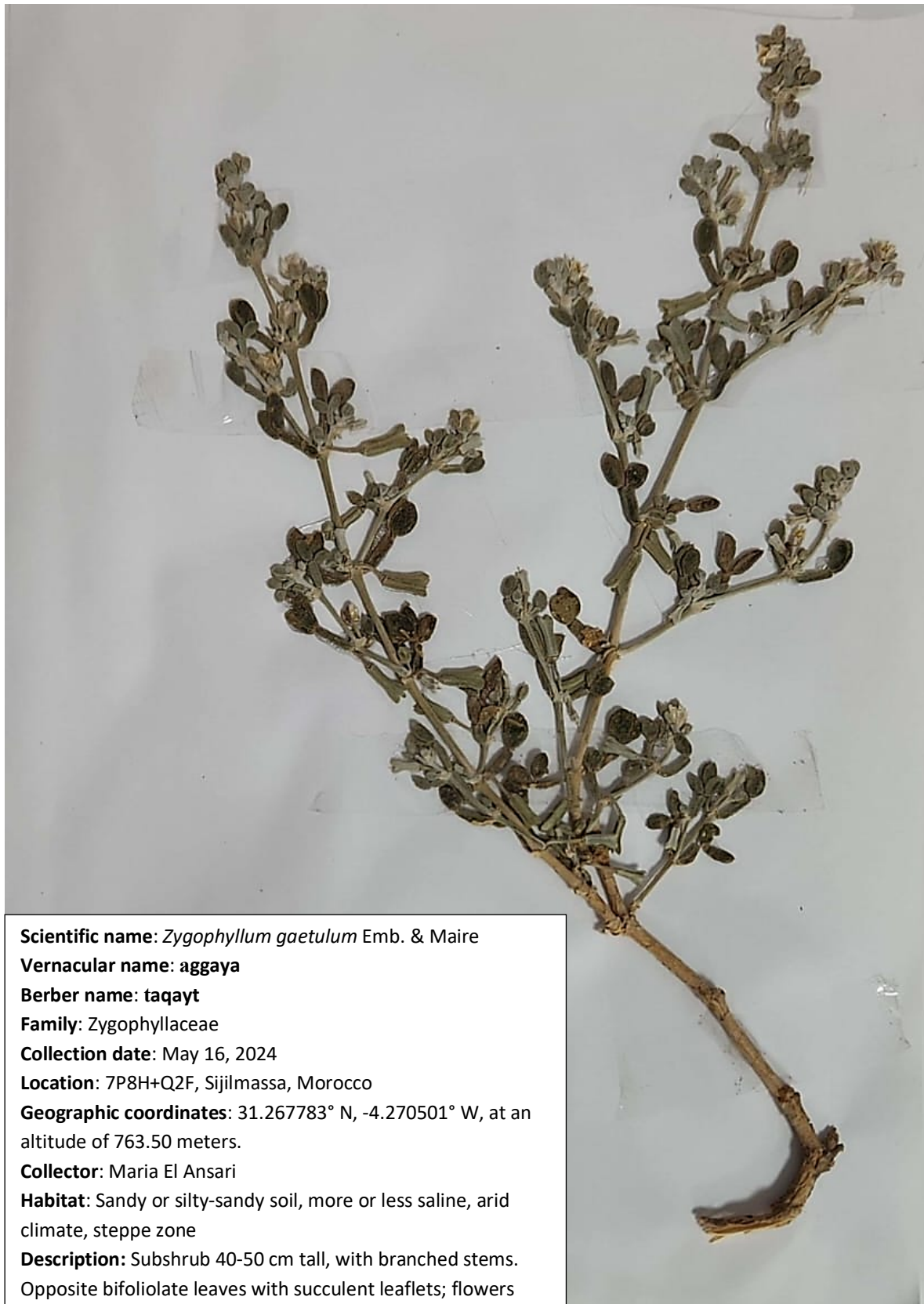
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Location : Nomadic	ksar	Village	City
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Traditional medicine	Modern medicine
1. Herbal medicine 2. Acupuncture 3. Meditation 4. Yoga 5. Chiropractic 6. Massage therapy 7. Herbal supplements 8. Traditional Chinese medicine 9. Indian Ayurveda 10. Japanese Kampo	1. Pharmaceuticals 2. Surgery 3. Chemotherapy 4. Radiation therapy 5. Immunotherapy 6. Gene therapy 7. Stem cell therapy 8. Organ transplantation 9. Artificial intelligence 10. Telemedicine

Rubric	Content
Local name (Arabic / Amazigh)	—
Status (<i>wild / cultivated</i>)	—
Location	Mountain (a), forest (b), rangeland (c), cultivated land (d), others
Abundance	Very rare (a), rare (b), uncommon (c), common (d)
Harvesting season	Summer, Spring, Autumn, Winter, All year round
Traditional use	Therapeutic (a), cosmetic (b), food (c), other (d): culinary, artisanal, pastoral, ornamental, beekeeping
Type of disease / indication	<i>td</i> : digestive disorders, <i>r</i> : respiratory disorders, <i>d</i> : dermatological disorders, <i>ug</i> : urogenital disorders, <i>em</i> : endocrine and metabolic disorders, <i>im</i> : immunological disorders, <i>oa</i> : osteoarticular disorders, <i>o</i> : eye disorders, <i>sorl</i> : oral and dental disorders, <i>sn</i> : neurological disorders, <i>cv</i> : cardiovascular disorders
Form (dry / fresh)	Dry plant (dp), fresh plant (fp)
Part used	Root (a), stem (b), leaf (c), flower (d), fruit (e), bark (f), whole plant (l)
Mode of preparation	Infusion (a), decoction (b), poultice (c), maceration (d), fumigation (e), rubbing (f), raw (h), cooked (i), powder (k), essential oil (l), extract (m), vegetable oil (n), steaming (o)
Dose used	Spoonful (a), pinch (b), handful (c), precise dose (d)
Combination with other plants / ingredients	Yes / No + details if yes
Other ingredients added to the preparation	(for exemple :honey, sugar, oil, salt...)
Mode of administration	Oral (a), massage (b), rinsing (c), inhalation (d), gargle (e), other (f)
Time of use	On an empty stomach (a), before meals (b), after meals (c), before sleeping (d)
Posology	Once/day, twice/day, three times/day, other
Duration of use	1 Day, 1 Week, 1 Month, Until recovery
Perceived efficacy	Disease progression (a), improvement (b), recovery (c), ineffective (d), toxic (e)
Source of information	Herbalist (a), family (b), pharmacist (c), physician (d), media (e), personal experience (f), book (g), traditional practitioner (h)

Appendix 2: Herbarium voucher of *Zygophyllum gaetulum* Emb. & Maire

Scientific name: *Zygophyllum gaetulum* Emb. & Maire

Vernacular name: aggaya

Berber name: taqayt

Family: Zygophyllaceae

Collection date: May 16, 2024

Location: 7P8H+Q2F, Sijilmassa, Morocco

Geographic coordinates: 31.267783° N, -4.270501° W, at an altitude of 763.50 meters.

Collector: Maria El Ansari

Habitat: Sandy or silty-sandy soil, more or less saline, arid climate, steppe zone

Description: Subshrub 40-50 cm tall, with branched stems. Opposite bifoliate leaves with succulent leaflets; flowers

Appendix 3: Comprehensive Monographic Profile of *Zygophyllum gaetulum* Emb. & Maire

Category	Element	Data
Botanical presentation	Scientific name	<i>Zygophyllum gaetulum</i> Emb. & Maire or <i>Tetraena gaetula</i> [Emb. & Maire] Beier & Thulin
	Berber Name	Taqayt
Systematic	Arabic Name	Agaaya
	Reign	Plantae
	Phylum	Streptophyta
	Class	Magnoliopsida
	Order	Zygophyllales
	Family	Zygophyllaceae
	Gender	<i>Zygophyllum</i>
Localization	Collection site	The Dra Tafilalet area, Errachidia Province, Rissani, Morocco
	GPS coordinates	31.267783°N, -4.270501°E
	Altitude	763.50 m
Weighted uses	Disorders treated	Digestive disorders, Dermatological disorders
	Part used	Leaves
	Preparation	Powder
	Method of administration	Oral/Cutaneous
Quantitative parameters	Dosage	1 Spoonful /day, Until recovery
	RFC (<i>Relative Citation Frequency</i>)	0.5714
	UV (<i>Use Value</i>)	0.839
	FL (<i>Level of Fidelity</i>)	78.125% (Digestive Disorders), 43.750% (Dermatological Disorders)
	CI (<i>Cultural Importance Index</i>)	0.839
	PPV (<i>Plant part value</i>)	0.610 (Leaves)
Security	Toxicity	12.50% (in high dose)