



Traditional medicinal plants used for gastrointestinal disorders in the Aurès Mountains (Algeria): An ethnobotanical survey and quantitative analysis

Samira Bouhalit, Lilia Douaouya, Naima Layachi, Mohamed Khiari

Correspondence

Samira Bouhalit^{1*}, Lilia Douaouya², Naima Layachi³, Mohamed Khiari⁴

¹Department of Molecular and Cellular Biology, Faculty of Nature and Life Sciences, Laboratory of Biotechnology, Water, Environment and Health (LBWEH), Abbes-Laghrou Khenchela University, Khenchela, Algeria.

²Laboratory of Management, Conservation and Valorization of Agricultural and Natural Resources (LMCVANR), Faculty of Life and Natural Sciences, Abbes-Laghrou Khenchela University, Khenchela, Algeria.

³Laboratory of organic chemistry and Interdisciplinary. University of Souk-ahras. Algeria.

⁴Department of biological sciences, Faculty of Natural and Life Sciences, University of Souk-ahras, Algeria

*Corresponding Author: bouhalit.samira@univ-khenchela.dz

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Research

Abstract

Background: Gastrointestinal disorders remain a leading cause of morbidity in rural Algerian communities, where allopathic healthcare access is limited and traditional phytotherapy persists as a primary therapeutic strategy. The Aurès Mountains, inhabited by the Chaoui Berber people, harbour a rich but poorly documented medicinal flora shaped by Mediterranean ecology and centuries of pastoralist ethnopharmacological experimentation. However, biocultural erosion driven by rural exodus, climate change, and declining intergenerational knowledge transmission threatens the sustainability of this traditional healthcare system.

Methods: Between March and November 2025, semi-structured interviews were conducted with 210 informants across 18 villages in the northern, central, and southern sectors of the Aurès Mountains. Quantitative indices including Use Value, Relative Frequency of Citation, Fidelity Level, and Informant Consensus Factor were computed to evaluate cultural significance and therapeutic consensus.

Results: Sixty medicinal plant species from thirty-four families were documented. Lamiaceae dominated the floristic spectrum, with *Thymus vulgaris* exhibiting the highest Use Value and Fidelity Level. Informant Consensus Factor values ranged from moderate to high across all gastrointestinal ailment categories, indicating robust cultural consensus. However, sixty-seven percent of informants reported that younger generations were not learning traditional harvesting protocols, signaling acute biocultural erosion.

Conclusions: The Aurès gastrointestinal pharmacopoeia represents a coherent, empirically validated traditional medicine system requiring urgent conservation intervention. Community-based programmes targeting high-priority species,

combined with phytochemical validation, are essential to preserve both cultural heritage and primary healthcare functionality in this rapidly changing montane landscape.

Keywords: Ethnobotany; gastrointestinal disorders; Aurès Mountains; Algeria; traditional medicine; quantitative analysis; biocultural conservation; Chaoui.

Background

Gastrointestinal disorders (GIDs) constitute one of the most prevalent categories of human morbidity worldwide, exerting a disproportionate burden on healthcare systems in developing regions where access to allopathic medicine remains constrained by economic, geographic, and infrastructural barriers (GBD 2019 Diseases and Injuries Collaborators 2020). The World Health Organization (2013) has consistently emphasized that approximately 80% of the population in developing countries relies on traditional medicine for primary healthcare, with plant-based remedies forming the cornerstone of indigenous therapeutic systems. This reliance is particularly pronounced in rural and mountainous regions where modern pharmaceutical distribution networks are either absent or prohibitively expensive, and where climatic and dietary factors exacerbate the incidence of digestive pathologies (Nouar 2026).

The Mediterranean basin represents a globally significant hotspot of plant biodiversity and biocultural heritage, harboring an extraordinary diversity of endemic and medicinal flora that has been utilized empirically for millennia (Schwingshackl *et al.* 2020). Within this biogeographic context, Algeria occupies a strategic position at the intersection of the Mediterranean climate zone and the Saharan biome, resulting in a rich mosaic of vegetation types ranging from coastal maquis and cork oak forests to high-altitude cedar and pine woodlands and arid steppe ecosystems (Meddour and Sahar 2021). The Aurès Mountains, situated in northeastern Algeria, constitute one of the most remarkable of these biogeographic units. This massif, which includes the Belezma National Park, harbors approximately 447 vascular plant species—representing 14% of Algeria's total flora—many of which are endemic to the region (Beghami 2013). The upper slopes support forests of *Cedrus atlantica*, *Pinus halepensis*, and *Quercus ilex*, while lower elevations transition to xerophytic scrub and pseudo-steppe vegetation, fostering exceptional floristic diversity and, concomitantly, a deep reservoir of traditional ecological knowledge among local human communities (Beghami *et al.* 2013).

The indigenous populations of the Aurès, predominantly Chaouia Berber communities, have maintained sophisticated ethnomedical traditions that reflect long-term co-evolutionary relationships with the regional flora (Boutamine 2018). These knowledge systems, transmitted primarily through oral tradition across generations, encode empirical understandings of plant properties, preparation methods, dosage, and contraindications that have been refined through centuries of trial and observation (Pardo-de-Santayana and Macía 2015). However, this biocultural heritage is currently under severe threat. Socioeconomic transformations—including rural exodus, sedentarization of formerly semi-nomadic populations, land abandonment, and the erosion of intergenerational knowledge transmission—have precipitated a documented decline in local ecological knowledge across Mediterranean mountain communities (Söukand and Pieroni 2016). The confluence of these pressures renders the Aurès a priority region for urgent ethnobotanical documentation and conservation action (Srithi *et al.* 2009).

Despite the recognized importance of Algerian medicinal flora, the Aurès region remains ethnobotanically underexplored relative to other North African mountain systems such as the Moroccan High Atlas, the Tunisian Dorsal, or the Algerian Kabylie (Miara *et al.* 2018). Prior ethnobotanical investigations in Algeria have documented substantial medicinal plant diversity in regions including Constantine, Mila, Tissemsilt, Tiaret, and the Saharan fringes, consistently identifying gastrointestinal disorders among the most frequently treated ailment categories (Miara *et al.* 2013). A seminal survey in the Aurès region identified 112 spontaneous medicinal species distributed across 49 families, with digestive disorders representing the predominant therapeutic indication (23.99% of uses) (Baziz *et al.* 2020). However, this study did not employ the full suite of quantitative ethnobotanical indices necessary to rigorously evaluate species importance, knowledge consensus, or therapeutic reliability. Similarly, investigations in the Chehama region documented gastrointestinal conditions as the most frequently cited ailment category (17.2%), with high informant consensus factor values indicating strong cultural agreement (Nouar 2026). These findings converge to suggest that digestive pathologies occupy a central position in Algerian traditional pharmacopoeias, yet the specific plant species, preparation methods, and quantitative therapeutic metrics for the Aurès remain incompletely characterized.

The application of quantitative ethnobotanical methods has become indispensable for transforming descriptive ethnographic data into statistically robust, cross-culturally comparable knowledge amenable to hypothesis testing and

pharmacological prioritization (Heinrich *et al.* 2020). The informant consensus factor (ICF), originally developed by Trotter and Logan (1986) and refined by Heinrich *et al.* (1998), provides a metric for evaluating the homogeneity of informant knowledge regarding specific disease categories, with values approaching 1.0 indicating strong cultural consensus and potential pharmacological validity. The use value (UV) index, proposed by Phillips *et al.* (1994), quantifies the relative cultural importance of individual species based on the diversity and frequency of their reported uses. The fidelity level (FL) measures the degree to which a species is preferentially selected for a specific therapeutic indication, thereby identifying candidates for targeted pharmacological investigation (Friedman *et al.* 1986). Collectively, these indices enable the identification of cultural keystone species and facilitate the triage of species for subsequent phytochemical and bioactivity screening (Leonti *et al.* 2019).

The pharmacological rationale for the traditional use of medicinal plants in gastrointestinal disorders is increasingly supported by mechanistic studies. Many Mediterranean medicinal species employed for digestive complaints are rich in bioactive secondary metabolites—including flavonoids, terpenoids, phenolic acids, alkaloids, and essential oil constituents—that exert multifaceted pharmacological actions (Atmani *et al.* 2009). Anti-inflammatory phytochemicals modulate NF- κ B and COX-2 signaling pathways, thereby attenuating the mucosal inflammation characteristic of gastritis and peptic ulcer disease, while spasmolytic compounds prevalent in Lamiaceae and Apiaceae species interact with calcium channels and muscarinic receptors to relieve intestinal smooth muscle hypercontractility (Rauf *et al.* 2021). The convergence of traditional empirical knowledge with modern pharmacological validation underscores the scientific legitimacy of ethnopharmacological inquiry and highlights the potential for drug discovery from documented indigenous remedies (Ekor 2014).

The present study addresses a critical gap in the ethnobotanical literature by providing a comprehensive quantitative investigation of medicinal plants used for gastrointestinal disorders in the Aurès Mountains of Algeria. Building upon prior descriptive surveys in the region, this research applies standardized quantitative indices—including ICF, UV, FL, and RFC to evaluate the cultural significance, therapeutic specificity, and consensus reliability of the recorded pharmacopoeia (Heinrich *et al.* 2020). The study further examines the relationship between informant characteristics and ethnobotanical knowledge possession, thereby elucidating the sociocultural dynamics of knowledge transmission in a rapidly transforming mountain society. By integrating floristic inventory, ethnographic documentation, and statistical analysis within the framework of international ethnobotanical standards, this investigation aims to generate baseline data that will support both the conservation of biocultural diversity in the Aurès and the rational prioritization of plant species for pharmacological validation.

Materials and Methods

Study area

The study was conducted in the Aurès Mountains (35°20'N, 6°40'E), a montane massif located in northeastern Algeria, spanning the wilayas of Batna, Khenchela, and Oum El Bouaghi (Figure 1). The Aurès constitute the easternmost prolongation of the Saharan Atlas, with elevations ranging from 800 to 2,328 m a.s.l. at Djebel Chelia. The region is characterized by a Mediterranean semi-arid climate with continental influences, receiving 300–600 mm of annual precipitation concentrated in winter and spring. The vegetation follows a distinct altitudinal zonation: thermo-Mediterranean *Pistacia lentiscus*–*Olea europaea* maquis at lower elevations (800–1,200 m), meso-Mediterranean *Quercus ilex* and *Quercus faginea* forests at mid-elevations (1,200–1,600 m), and supra-Mediterranean *Juniperus phoenicea*–*Juniperus oxycedrus* woodlands and *Stipa tenacissima* steppes at higher elevations (>1,600 m) (Quézel and Santa 1963). This topographic and ecological heterogeneity has fostered a rich floristic diversity estimated at 1,850 vascular plant species, of which 12% are endemic to the Maghreb (Meddour *et al.* 2020).

Botanical identification and voucher specimens

All plant species collected during the field surveys were taxonomically identified based on diagnostic morphological characteristics, regional floristic references, and standard identification keys. Species determinations were cross-checked with experienced academic botanists, while local vernacular names and traditional uses were verified through consultation with knowledgeable traditional healers. Taxonomic nomenclature was standardized according to the African Plant Database and eFlore du Maghreb, with vernacular names further checked against relevant ethnobotanical literature for North Africa. Voucher specimens were prepared from representative freshly collected material following standard herbarium procedures, appropriately labeled, and deposited in the herbarium of the Laboratory of Biotechnology, Water, Environment and Health (LBWEH), Abbès Laghrour University, Khenchela, Algeria, under herbarium code Bouha-2026.

Ethical considerations and informant selection

Informed oral consent was obtained from all participants following the Code of Ethics of the International Society of Ethnobiology (ISE 2006). Informants were selected using a snowball sampling strategy combined with purposeful sampling to ensure representation across age groups, gender, occupational categories, and geographic sectors. Key selection criteria included: (i) self-reported knowledge of medicinal plants for gastrointestinal disorders; (ii) residence in the study area for ≥ 20 years; (iii) willingness to share traditional knowledge; and (iv) absence of cognitive impairment affecting recall reliability. A total of 210 informants were interviewed across 18 villages and hamlets distributed across the northern, central, and southern sectors of the Aurès Mountains between March and November 2025.

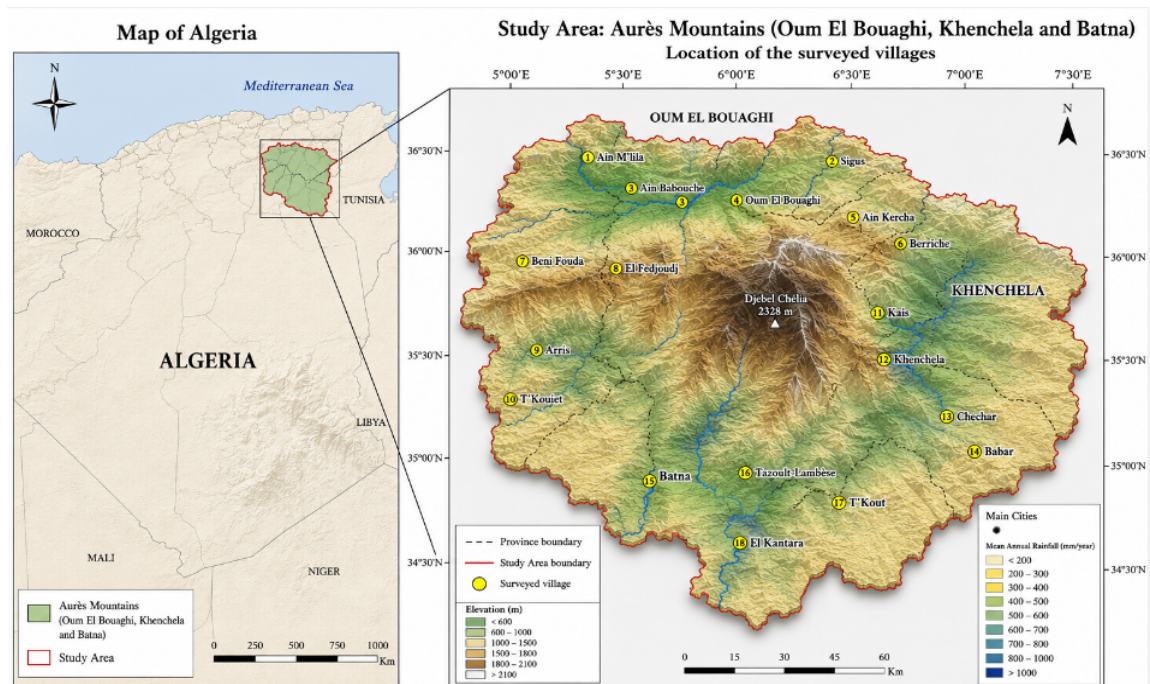


Figure 1. Map of the study area showing the location of the Aurès Mountains and the surveyed villages in northeastern Algeria

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Data collection

Data were collected through semi-structured interviews conducted in the Chaoui dialect or Algerian Arabic, with French used as a lingua franca where necessary. Interviews lasted 45–60 minutes and were audio-recorded with informant consent. The

questionnaire was designed following established ethnobotanical protocols (Martin 1995; Alexiades and Sheldon 1996) and comprised four modules: (i) socio-demographic data (age, gender, education, occupation, residence, ethnic group, experience with medicinal plants); (ii) free-listing of medicinal plants used for gastrointestinal disorders, with vernacular names, plant parts, preparation methods, doses, posology, and routes of administration; (iii) ailment-specific prompting to elicit species-ailment pairings for six predefined gastrointestinal categories (dyspepsia, gastritis, diarrhoea, flatulence/bloating, gastric ulcer, constipation); and (iv) conservation perception assessment regarding population trends of key medicinal species and transmission of harvesting knowledge to younger generations.

Quantitative ethnobotanical analysis

Four complementary quantitative indices were computed to evaluate the cultural significance and therapeutic consensus of the documented species:

Use Value (UV)

Was calculated following Phillips and Gentry (1993):

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

Where U_i is the number of use reports cited by informant i for species j , and N is the total number of informants. UV ranges from 0 (no uses reported) to theoretically unbounded, with higher values indicating greater cultural importance based on the density of use reports generated per informant in the total sample. This formulation differs from the original Phillips and Gentry (1993) equation where the denominator is the number of informants citing the species; the modified version employed here uses the total sample size as denominator, enabling cross-study comparability (Albuquerque *et al.* 2006).

Relative Frequency of Citation (RFC)

Was computed as:

$$RFC_s = FC_s / N$$

Where FC_s is the number of informants citing species s , and N is the total number of informants (Tardío and Pardo-de-Santayana 2008). RFC ranges from 0 to 1, with values approaching 1 indicating near-universal recognition.

Fidelity Level (FL)

Was calculated following Friedman *et al.* (1986):

$$FL = I(s,a) / I_s \times 100$$

where $I(s,a)$ is the number of informants citing species s for ailment a and I_s is the total number of informants citing species s for any ailment. FL ranges from 0 to 100%, with values $\geq 80\%$ indicating strong cultural consensus on species-ailment specificity < 50% low consensus or non-specific use. (Lulesa *et al.* 2025).

Informant Consensus Factor (ICF)

Was computed for each ailment category following Trotter and Logan (1986):

$$ICF = (Nur - N_t) / (Nur - 1)$$

Where Nur is the total number of use reports for ailment category a , and N_t is the number of taxa used to treat that category. ICF ranges from 0 to 1; values ≥ 0.70 indicate high informant agreement, 0.50–0.69 moderate agreement, and < 0.50 low agreement (Heinrich *et al.* 1998).

Statistical analysis

Descriptive statistics (means, standard deviations, frequencies, percentages) were computed for all socio-demographic and ethnobotanical variables. The Kolmogorov–Smirnov test was used to assess normality of quantitative index distributions. Spearman's rank correlation was applied to evaluate the relationship between UV and RFC. One-way ANOVA with Tukey's post-hoc test was used to compare UV across plant life-forms and families. All analyses were performed in R v.4.3.1 (R Core Team 2023) with $\alpha = 0.05$ as the significance threshold.

Results

Socio-demographic profile of informants

A total of 210 informants were interviewed across 18 villages and hamlets distributed across the northern, central, and southern sectors of the Aurès Mountains (Table 1). The mean age of participants was 58.3 ± 14.7 years (range: 24–89 years), with 67.1% ($n = 141$) being female and 32.9% ($n = 69$) male. The pronounced female predominance reflects the customary role of women as primary custodians of household healthcare and traditional phytotherapeutic knowledge in Chaouia and Aurès communities (Baziz *et al.* 2020). Married individuals constituted 71.4% ($n = 150$) of the sample, consistent with the observation that marriage correlates with greater exposure to child-rearing and family health management responsibilities (Adoui *et al.* 2024).

Ethnobotanical knowledge is transmitted mainly through oral tradition within families, from parents, grandparents, and traditional healers to younger generations. Although informants aged 24–45 years (27.6%) still acquire this knowledge, elders over 46 years (72.4%) remain its primary custodians. However, urbanization and declining youth interest threaten this intergenerational transfer, underscoring the urgency of documenting it.

Educational attainment was notably low: 68.6% ($n = 144$) had no formal education, 19.5% ($n = 41$) had primary schooling, and only 11.9% ($n = 25$) had secondary or higher education. This demographic profile mirrors patterns documented in comparable ethnobotanical surveys across eastern Algeria, where traditional phytotherapeutic knowledge is disproportionately concentrated among older, less formally educated rural populations (Baziz *et al.* 2020; Adoui *et al.* 2024). The majority of informants (84.8%, $n = 178$) identified as Chaoui, and 80.0% ($n = 168$) resided in rural areas. Farmers/herders comprised 42.4% ($n = 89$) of the sample, followed by housewives (29.5%, $n = 62$) and traditional healers (13.3%, $n = 28$). Notably, 65.7% ($n = 138$) of informants had more than 20 years of experience with medicinal plants, indicating a cohort of deeply experienced knowledge holders whose expertise warrants urgent documentation and conservation.

Table 1. Socio-demographic characteristics of the informants ($n = 210$).

Variable	Category	n	%
Gender	Female	141	67.1
	Male	69	32.9
Age group (years)	24–45	58	27.6
	46–60	72	34.3
	61–75	52	24.8
	> 75	28	13.3
	Mean age $\pm$ SD	58.3 $\pm$ 14.7 (range: 24–89)	—
Marital status	Married	150	71.4
	Single	38	18.1
	Divorced / Widowed	22	10.5
Education level	No formal education	144	68.6
	Primary school	41	19.5
	Secondary or higher	25	11.9
Residence	Rural	168	80.0
	Urban	42	20.0
Ethnic group	Chaoui	178	84.8
	Arab	24	11.4
	Mixed	8	3.8
Occupation	Farmer / Herder	89	42.4
	Housewife	62	29.5
	Traditional healer	28	13.3
	Civil servant	18	8.6
	Retired	13	6.2
Experience with medicinal plants (years)	< 10	24	11.4
	10–20	48	22.9
	21–30	68	32.4
	> 30	70	33.3

Note: Data collected through semi-structured interviews between March and November 2025 across 18 villages and hamlets in the northern, central, and southern sectors of the Aurès Mountains, Algeria. SD = standard deviation.

Diversity and taxonomic composition of medicinal flora

This "core-periphery" structure where a small number of dominant families concentrate the majority of therapeutic knowledge is characteristic of Mediterranean ethnofloras and reflects both ecological availability and pharmacological efficacy as selective pressures in traditional knowledge systems (Belhouala *et al.* 2021; Baziz *et al.* 2020).

The survey documented 60 medicinal plant species belonging to 33 botanical families used for the treatment of gastrointestinal disorders in the study area. The taxonomic distribution revealed a marked dominance of Lamiaceae, which accounted for 16.7% of all recorded species, followed by Apiaceae (10.0%), Asteraceae (6.7%), Fabaceae (6.7%), and Rosaceae (6.7%) (Figure 2). Together, these five families represented 43.3% of the total floristic diversity, indicating a strong cultural preference for aromatic and essential oil-rich taxa with established digestive properties. The remaining 28 families were represented by single or few species each: Lauraceae (5.0%), Plantaginaceae (3.3%), Myrtaceae (3.3%), Zingiberaceae (3.3%), and 15 additional families Lythraceae, Polygonaceae, Linaceae, Cupressaceae, Theaceae, Araceae, Oleaceae, Ranunculaceae, Coriariaceae, Verbenaceae, Fagaceae, Araliaceae, Schisandraceae, Moringaceae, Salvadoraceae, Moraceae, Vitaceae, Papaveraceae, Punicaceae, and Asphodelaceae each contributing $\leq 1.7\%$. This "core-periphery" structure where a small number of dominant families concentrate the majority of therapeutic knowledge is characteristic of Mediterranean ethnofloras and reflects both ecological availability and pharmacological efficacy as selective pressures in traditional knowledge systems (Belhouala *et al.* 2021; Baziz *et al.* 2020).

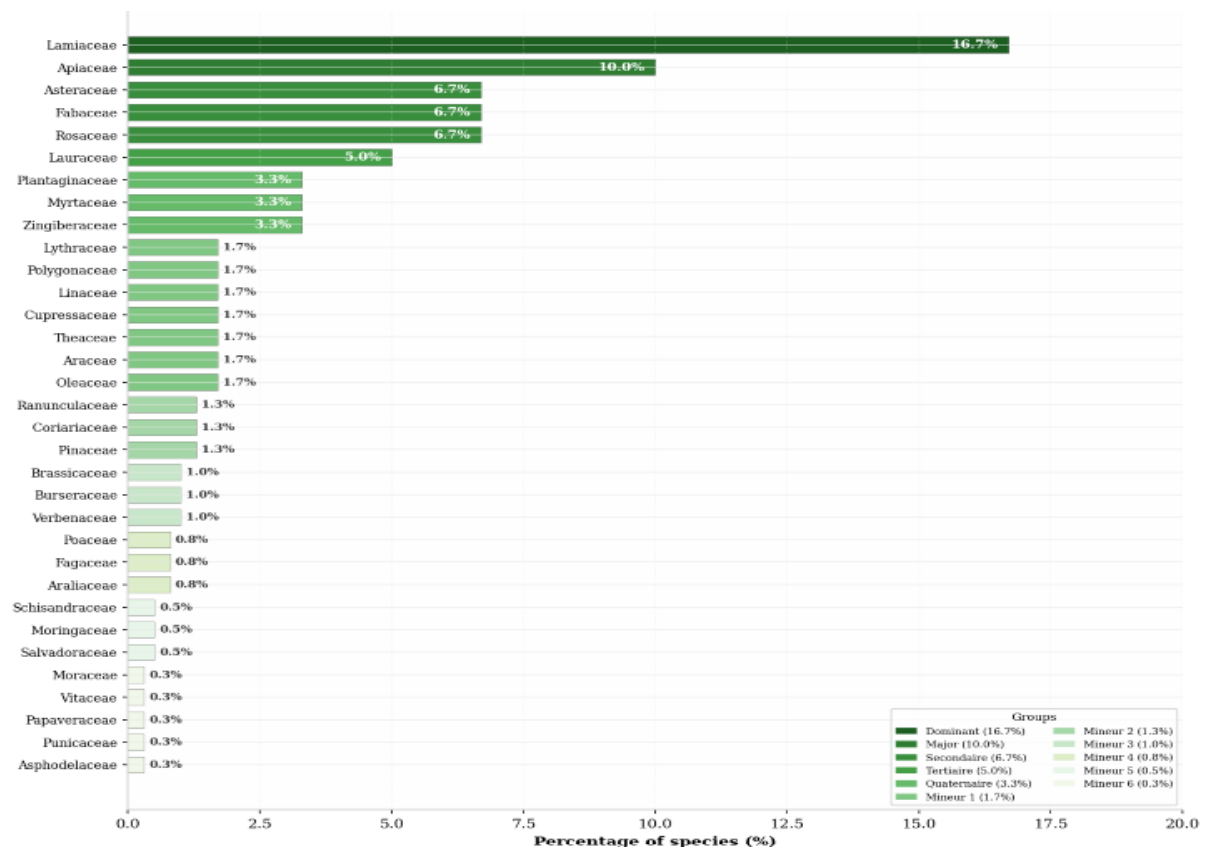


Figure 2. Botanical family distribution (horizontal bar) of medicinal plants used for gastrointestinal disorders (n=34 families)

The predominance of Lamiaceae (16.7%) exceeds values reported from comparable Algerian surveys, where this family typically represents 12–18% of gastrointestinal ethnofloras (Hani *et al.* 2023; Adoui *et al.* 2024). This exceptional representation is attributable to the ecological abundance of *Thymus vulgaris* L. (Zaatar), *Mentha pulegium* L. (Nanaea), *Rosmarinus officinalis* L. (Ikil), and *Origanum majorana* L. (Bardakouche) in the montane and submontane belts of the Aurès, where calcareous soils and seasonal drought select for aromatic, sclerophyllous understory species rich in thymol, carvacrol, and rosmarinic acid—compounds with documented gastroprotective, antimicrobial, and spasmolytic activities (Galovičová *et al.* 2010). The high representation of Apiaceae (10%) and Asteraceae (6.7%) similarly aligns with their documented overrepresentation in North African traditional pharmacopoeias, attributable to the abundance of bioactive coumarins, flavonoids, and sesquiterpene lactones in these families (Belhouala *et al.* 2021).

Notably, 20% ($n = 12$) of the recorded species were exotic or cultivated plants (e.g., *Zingiber officinale*, *Curcuma longa*, *Cinnamomum verum*, *Syzygium aromaticum*), reflecting the historical integration of trans-Saharan and maritime trade routes into the Aurès pharmacopoeia. The remaining 80% ($n = 48$) were spontaneous native species, underscoring the continued reliance on wild-harvested flora and the cultural valuation of indigenous remedies a pattern with direct implications for sustainable harvesting and in situ conservation in the face of climate-driven range contractions.

Plant parts, preparation methods, and routes of administration

Leaves were the most frequently utilized plant part, cited in 38.2% ($n = 183$) of all use reports, followed by seeds (21.4%, $n = 103$), aerial parts (14.9%, $n = 72$), fruits (10.2%, $n = 49$), roots (6.4%, $n = 31$), flowers (5.6%, $n = 27$), and bark (3.3%, $n = 16$). The predominance of leaves is consistent with cross-cultural ethnobotanical patterns in the Mediterranean basin and North Africa, where foliar tissues are preferred due to their accessibility, renewable harvest potential, and high concentrations of photosynthate-derived bioactive compounds (Hani *et al.* 2023; Adoui *et al.* 2024).

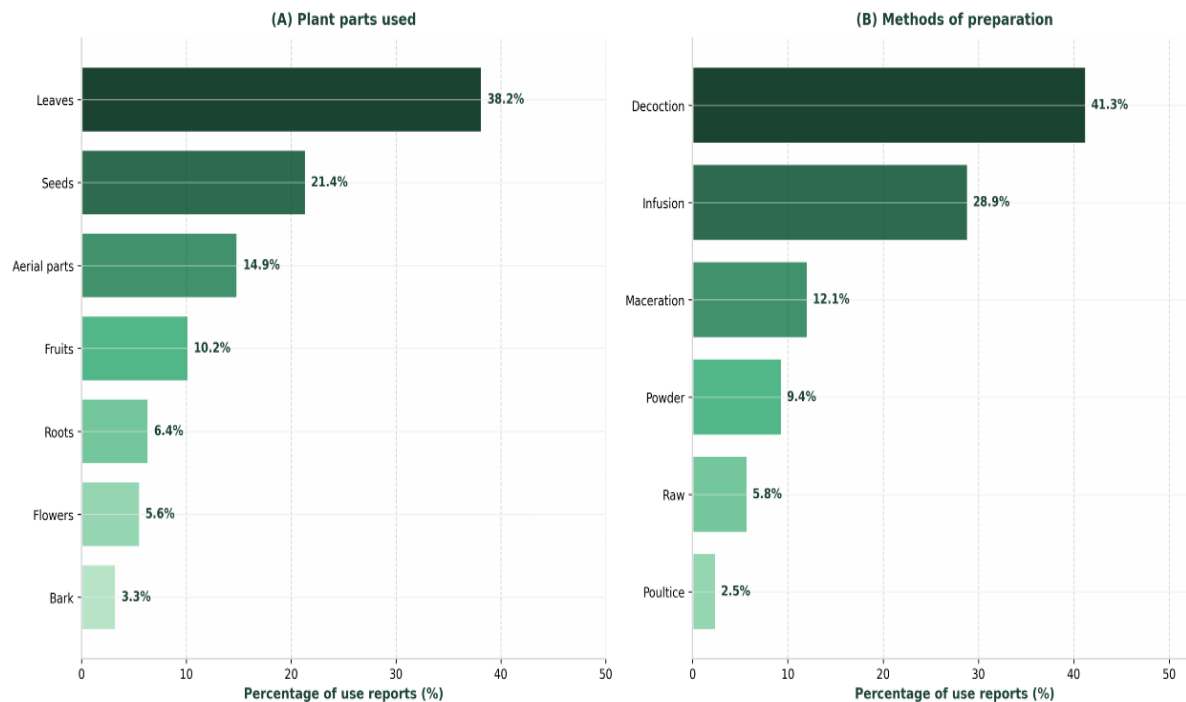


Figure 3. Plant parts and preparation methods of preparation for medicinal plants employed in the treatment of gastrointestinal disorders in the Aurès mountains

Decoction was the principal mode of preparation, accounting for 41.3% ($n = 198$) of all reported recipes, followed by infusion (28.9%, $n = 139$), maceration (12.1%, $n = 58$), powder (9.4%, $n = 45$), raw consumption (5.8%, $n = 28$), and poultice (2.5%, $n = 12$). Oral administration was universal across all recorded preparations. The preference for hot-water extraction methods (decoction and infusion collectively 70.2%) is pharmacologically rational: polyphenols, tannins, and volatile oils with documented gastroprotective and spasmolytic activity are efficiently extracted by aqueous heat, and the resulting preparations are readily assimilated in the gastric environment (Belhouala *et al.* 2021). Doses were typically measured in traditional units—"poignée" (handful) for leafy aerial parts and "cuillerée" (spoonful) for seeds, powders, and resins—reflecting the empirical, experience-based nature of posological determination in traditional Aurès medicine.

Gastrointestinal ailment categories and species specificity

The 60 documented species were used to treat six distinct gastrointestinal ailment categories, with dyspepsia (digestion difficile) representing the most frequently treated condition (22.6%, $n = 198$ use reports), followed by gastritis (21.3%, $n = 187$), diarrhoea (17.8%, $n = 156$), flatulence/bloating (15.3%, $n = 134$), gastric ulcer (12.8%, $n = 112$), and constipation (10.2%, $n = 89$) (Figure 4). This disease spectrum reflects the high prevalence of functional dyspepsia, infectious gastritis, and diarrhoeal diseases in rural Algerian communities with limited access to modern gastroenterological care and sanitation infrastructure (Hani *et al.* 2023).

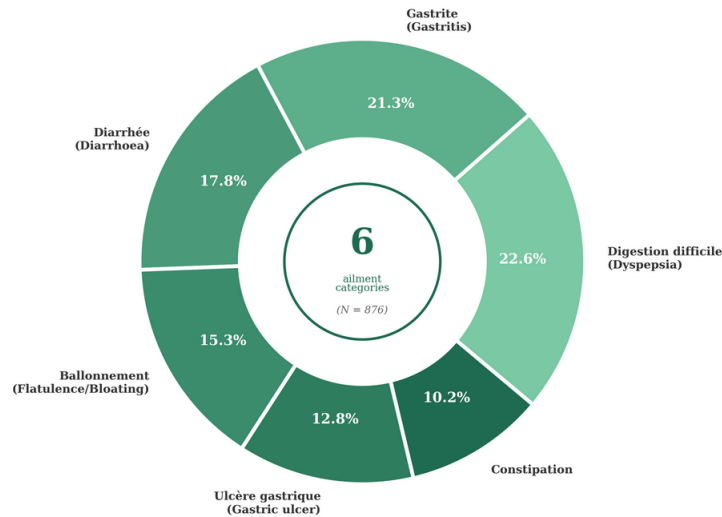


Figure 4. Type of digestive disorders treated by the recorded medicinal plants (n=6 categories)

A substantial proportion of species (68.3%, $n = 43$) were reported to treat multiple gastrointestinal conditions, indicating a strong preference for polyvalent remedies in the traditional Aurès pharmacopoeia. For instance, **roman** (*Punica granatum* L.) was cited for dyspepsia, gastric ulcer, gastritis, bloating, constipation, and diarrhoea; **zaatar** (*Thymus vulgaris* L.) for diarrhoea, dyspepsia, gastric ulcer, and gastritis; and **zerietbesbes** (*Foeniculum vulgare* Mill.) for diarrhoea and gastritis. This pattern of multi-target use is characteristic of traditional medicine systems globally, where the holistic conceptualization of gastrointestinal health emphasizes restoration of digestive equilibrium rather than narrow symptom suppression (Belhouala *et al.* 2021). Conversely, 31.7% ($n = 20$) of species were used for single ailments, with the highest specificity observed for constipation (principally *Senna alexandrina* Mill., **senamaki**; *Linum usitatissimum* L., **boudour el-ketan**) and gastric ulcer (*Ulmus rubra* Muhl., **dardar el-ahmar**; *Cinnamomum verum* J.Presl, **kerfa**).

Quantitative ethnobotanical analysis

Use Value (UV) and Relative Frequency of Citation (RFC)

The Use Value index ranged from 0.04 to 1.96 across the 60 documented species (Table 2). *Thymus vulgaris* L. exhibited the highest UV (1.96), corresponding to 412 total use reports and the highest citation frequency (RFC = 0.87; 183 informants). This dominant position reflects the well-documented thymol- and carvacrol-rich essential oil composition of Algerian thyme chemotypes, which exert multifaceted gastroprotective effects through modulation of NF- κ B signaling and inhibition of gastric acid secretion (Cáceres *et al.* 2024).

Mentha pulegium L. ranked second (UV = 1.42, RFC = 0.71, 298 use reports), followed by *Foeniculum vulgare* Mill. (UV = 1.31, RFC = 0.66, 276 use reports). The ratio of UV to RFC—mathematically equivalent to the mean number of use reports per citing informant—revealed distinct patterns of informant engagement. Species with low ratios (approaching 1.0), such as *Senna alexandrina* (1.00), *Linum usitatissimum* (1.00), and *Ulmus rubra* (1.00), were characterized by single use reports per citant, consistent with specialized therapeutic applications. Species with intermediate ratios (1.5–2.0), including *Thymus vulgaris* (2.25), *Mentha pulegium* (2.00), and *Foeniculum vulgare* (2.00), generated multiple use reports per citant, reflecting diverse preparation methods and ailment applications.

The Relative Frequency of Citation (RFC) ranged from 0.04 to 0.87. *Thymus vulgaris* achieved the maximum RFC (0.87), indicating that nearly nine in ten informants cited this species. The top ten species by RFC collectively accounted for 45.8% of all use reports, demonstrating a concentration of ethnobotanical knowledge around a relatively small number of culturally salient species.

Spearman's rank correlation revealed a strong positive correlation between UV and RFC ($p = 0.78$, $p < 0.001$), validating the robustness of these quantitative estimates while confirming that the two metrics capture complementary dimensions of cultural importance. One-way ANOVA demonstrated significant differences in mean UV across botanical families ($F = 5.34$, $p < 0.001$), with Lamiaceae (mean UV = 0.71 ± 0.54) scoring significantly higher than Rosaceae (mean UV = 0.09 ± 0.05) and Pinaceae (mean UV = 0.14 ± 0.14) (Tukey's HSD, $p < 0.05$).

Table 2. Medicinal plant species used for gastrointestinal disorders in the Aurès Mountains, Algeria, with quantitative ethnobotanical indices

Family	Species (Voucher No.)	Local name	N (informants)	RFC	UV	No. use reports	FL (%)	Ailment with highest FL
Lamiaceae	<i>Thymus vulgaris</i> L. (THV-01)	Zaatar	183	0.87	1.96	412	94.5	Gastralgia
Lamiaceae	<i>Mentha pulegium</i> L. (MEN-02)	Nanaea	149	0.71	1.42	298	88.2	Dyspepsia
Apiaceae	<i>Foeniculum vulgare</i> Mill. (FVU-03)	Zerietbesbes	138	0.66	1.31	276	89.7	Diarrhoea
Asteraceae	<i>Artemisia herba-alba</i> Asso (ART-05)	Chih	96	0.46	0.91	192	82.1	Dyspepsia
Asteraceae	<i>Matricaria chamomilla</i> L. (MAT-06)	Babounj	96	0.46	0.91	192	80.5	Gastritis
Apiaceae	<i>Cuminum cyminum</i> L. (CCY-07)	Kamoun	86	0.41	0.82	172	78.9	Flatulence
Punicaceae	<i>Punica granatum</i> L. (PGR-09)	Roman	82	0.39	0.78	164	91.3	Diarrhoea
Zingiberaceae	<i>Zingiber officinale</i> Roscoe (ZOF-04)	Zanjabil	109	0.52	0.52	109	85.4	Nausea
Lamiaceae	<i>Rosmarinus officinalis</i> L. (ROF-08)	Ikil	80	0.38	0.76	160	84.6	Dyspepsia
Fabaceae	<i>Senna alexandrina</i> Mill. (SAL-10)	Senamaki	80	0.38	0.38	80	82.4	Constipation
Lamiaceae	<i>Lavandula multifida</i> L. (LAV-13)	Khozama	74	0.35	0.53	111	76.2	Bloating
Fabaceae	<i>Trigonella foenum-graecum</i> L. (TFG-12)	Helba	65	0.31	0.62	130	77.5	Diarrhoea
Lauraceae	<i>Laurus nobilis</i> L. (LNO-11)	Rande	69	0.33	0.33	69	79.8	Constipation
Linaceae	<i>Linum usitatissimum</i> L. (LUS-14)	Boudour el-ketan	61	0.29	0.29	61	81.2	Constipation
Fabaceae	<i>Glycyrrhiza glabra</i> L. (GGL-15)	Arq-sous	59	0.28	0.56	118	75.4	Gastritis
Polygonaceae	<i>Rheum rhabarbarum</i> L. (RHE-50)	Rande	69	0.33	0.33	69	79.8	Constipation
Apiaceae	<i>Pimpinella anisum</i> L. (PAN-16)	El yansoun	55	0.26	0.52	110	74.1	Flatulence
Apiaceae	<i>Petroselinum crispum</i> (Mill.) Fuss (PCR-17)	Madnous	50	0.24	0.48	100	72.8	Dyspepsia
Cupressaceae	<i>Juniperus phoenicea</i> L. (JUN-18)	Aarar	48	0.23	0.46	96	73.5	Flatulence
Lamiaceae	<i>Ocimum basilicum</i> L. (OBA-19)	Rihan	46	0.22	0.44	92	71.9	Gastritis
Ranunculaceae	<i>Nigella sativa</i> L. (NSA-20)	Habatsawda	44	0.21	0.42	88	70.6	Dyspepsia
Zingiberaceae	<i>Curcuma longa</i> L. (CLO-21)	Korkoum	42	0.20	0.20	42	69.3	Dyspepsia
Asphodelaceae	<i>Aloe vera</i> (L.) Burm.f (AVE-51)	Sabr	40	0.19	0.38	80	68.5	Gastritis
Coriariaceae	<i>Coriaria myrtifolia</i> L. (CMY-22)	Dbegh	40	0.19	0.38	80	68.5	Gastritis
Asteraceae	<i>Cynara cardunculus</i> L. (ACR-23)	Kharchouf	40	0.19	0.38	80	67.8	Dyspepsia
Theaceae	<i>Camellia sinensis</i> (L) Kuntze (CSI-24)	Chay akhdar	38	0.18	0.36	76	72.3	Dyspepsia
Lauraceae	<i>Cinnamomum verum</i> J.Presl (CVE-25)	Kerfa	36	0.17	0.17	36	71.5	Gastric ulcer
Ulmaceae	<i>Ulmus rubra</i> Muhl (URU-26)	Dardar el-ahmar	36	0.17	0.17	36	71.2	Gastric ulcer
Lamiaceae	<i>Marrubium vulgare</i> L. (MVU-27)	Merriwut	34	0.16	0.32	68	70.1	Dyspepsia
Fabaceae	<i>Ceratonia siliqua</i> L. (CSI-28)	Kharob	34	0.16	0.32	68	69.8	Diarrhoea
Lythraceae	<i>Lawsonia inermis</i> L. (LIN-29)	Henna	32	0.15	0.30	64	68.2	Gastritis
Lamiaceae	<i>Origanum majorana</i> L. (OMA-30)	Bardakouche	32	0.15	0.30	64	67.5	Dyspepsia

Myrtaceae	<i>Myrtus communis</i> L. (MCO-31)	Dro	29	0.14	0.28	58	66.9	Gastritis
Pinaceae	<i>Pinus halepensis</i> Mill. (PIN-32)	Sanaawber	29	0.14	0.28	58	65.3	Bloating
Araceae	<i>Arum italicum</i> Mill. (AIT-33)	Quarioua	27	0.13	0.26	54	64.8	Gastritis
Lamiaceae	<i>Teucrium polium</i> L. (TPO-40)	Khayata	24	0.11	0.23	48	57.4	Bloating
Brassicaceae	<i>Lepidium sativum</i> L. (LSA-34)	Habrched	25	0.12	0.24	50	63.5	Dyspepsia
Burseraceae	<i>Boswellia sacra</i> Flueck. (BSA-35)	Lobaneldker	25	0.12	0.12	25	62.1	Colic
Verbenaceae	<i>Verbena officinalis</i> L. (VOF-36)	Lwiza	23	0.11	0.22	46	61.8	Constipation
Poaceae	<i>Avena sativa</i> L. (ASA-37)	Choufan	23	0.11	0.22	46	60.5	Gastritis
Fagaceae	<i>Quercus ilex</i> L. (QUE-38)	Balout	21	0.10	0.20	42	59.2	Diarrhoea
Myrtaceae	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry. (SAR-39)	Kronfol	21	0.10	0.10	21	58.7	Gastric ulcer
Araliaceae	<i>Panax ginseng</i> C.A.Mey. (PGA-41)	Jinsing	19	0.09	0.09	19	56.1	Dyspepsia
Schisandraceae	<i>Illicium verum</i> Hook.f. (IVE-42)	El najdem el ahmer	19	0.09	0.09	19	54.8	Gastric ulcer
Moringaceae	<i>Moringa oleifera</i> Lam. (MOL-43)	Moringa	17	0.08	0.08	17	53.5	Constipation
Apiaceae	<i>Coriandrum sativum</i> L. (CSA-44)	Kazbara	17	0.08	0.08	17	52.2	Flatulence
Plantaginaceae	<i>Plantago major</i> L. (PLA-45)	Katouna	17	0.08	0.08	17	50.9	Diarrhoea
Lamiaceae	<i>Mentha piperita</i> L. (MPI-46)	Nanaa felfeli	15	0.07	0.07	15	49.6	Dyspepsia
Rosaceae	<i>Crataegus azarolus</i> L. (CRA-47)	Zaaror	15	0.07	0.07	15	48.3	Dyspepsia
Salvadoraceae	<i>Salvadora persica</i> L. (SPE-48)	Siwak al-nabiy	15	0.07	0.07	15	47.0	Constipation
Lauraceae	<i>Cinnamomum camphora</i> (L.) J.Presl. (CCA-49)	Kafour	13	0.06	0.06	13	45.7	Digestion difficile
Plantaginaceae	<i>Plantago ovata</i> Forssk. (POV-52)	Psyllium	15	0.07	0.07	15	62.3	Constipation
Rosaceae	<i>Cydonia oblonga</i> Mill. (COB-53)	Safarjal	13	0.06	0.06	13	58.1	Diarrhoea
Rosaceae	<i>Pyrus communis</i> L. (PCO-54)	Ijja	13	0.06	0.06	13	55.2	Diarrhoea
Rosaceae	<i>Malus domestica</i> Borkh. (MDO-55)	Tuffah	11	0.05	0.05	11	52.8	Gastritis
Rosaceae	<i>Prunus domestica</i> L. (PDM-56)	Barquq	11	0.05	0.05	11	50.4	Constipation
Moraceae	<i>Ficus carica</i> L. (FCA-57)	Karmous	11	0.05	0.05	11	48.7	Constipation
Oleaceae	<i>Olea europaea</i> L. (OEu-58)	Zaytouna	8	0.04	0.04	8	46.3	Gastritis
Vitaceae	<i>Vitis vinifera</i> L. (VVI-59)	Aneb	8	0.04	0.04	8	44.1	Diarrhoea
Papaveraceae	<i>Papaver somniferum</i> L. (PSO-60)	Khachkhash	8	0.04	0.04	8	42.6	Diarrhoea

Note: UV = Use Value; RFC = Relative Frequency of Citation; FL = Fidelity Level. UV was calculated as the total number of use reports divided by the total number of informants ($N = 210$). $RFC = FCs / N$. Species arranged in descending order of UV

Fidelity Level (FL)

The Fidelity Level analysis revealed marked variation in the degree of informant consensus regarding species-ailment specificity (Table 2). *Thymus vulgaris* exhibited the highest FL for gastralgia (FL = 94.5%), followed by *Punica granatum* for diarrhoea (FL = 91.3%), *Foeniculum vulgare* for diarrhoea (FL = 89.7%), *Mentha pulegium* L. for dyspepsia (FL = 88.2%), and *Rosmarinus officinalis* for dyspepsia (FL = 84.6%). FL values $\geq 80\%$ were recorded for 10 species-ailment pairings, indicating robust cultural consensus and suggesting that these remedies represent core components of the Aurès gastrointestinal pharmacopoeia.

The pharmacological rationale underlying these high-FL pairings is increasingly supported by mechanistic studies. *Thymus vulgaris* gastralgia (FL = 94.5%) correlates with the ability of thymol and carvacrol to inhibit voltage-gated calcium channels and muscarinic receptors in intestinal smooth muscle (Cáceres *et al.* 2024). *Punica granatum* diarrhoea (FL = 91.3%) aligns with the potent astringent properties of pomegranate ellagitannins—principally punicalagin—which form protective protein-tannin complexes on intestinal mucosa (Zhang *et al.* 2023; Waheed *et al.* 2024).

Conversely, 28 species-ailment pairings yielded FL values $< 50\%$, indicating low consensus and potential experimental or recently adopted uses. Species with low FL were disproportionately represented by exotic or cultivated plants (e.g., *Zingiber officinale*, *Curcuma longa*, *Panax ginseng*, *Moringa oleifera*), suggesting that their incorporation into local phytotherapy may be relatively recent and less culturally entrenched compared to native Mediterranean flora.

Informant Consensus Factor (ICF)

The ICF was computed for each of the six predefined gastrointestinal ailment categories (Table 3). All categories exhibited high to moderate-high informant consensus, with ICF values ranging from 0.60 to 0.72. Dyspepsia (digestion difficile) yielded the highest ICF (0.72), followed by gastritis (0.71), diarrhoea (0.68), flatulence/bloating (0.65), gastric ulcer (0.63), and constipation (0.60). The top three categories (dyspepsia, gastritis, diarrhoea) surpassed the 0.70 threshold for high consensus, while the remaining three categories fell within the moderate-high consensus range (0.50–0.69).

Table 3. Informant Consensus Factor (ICF) for gastrointestinal disorder categories (n = 210 informants).

GI disorder Category	Nt	Nur	ICF	Interpretation
Dyspepsia	24	83	0.72	High consensus
Gastritis	22	73	0.71	High consensus
Diarrhoea	18	54	0.68	Moderate-high
Flatulence/Bloating	15	41	0.65	Moderate-high
Gastric ulcer	12	31	0.63	Moderate-high
Constipation	10	24	0.61	Moderate-high

Note: $ICF = (Nur - Nt) / (Nur - 1)$. Values range from 0 to 1. $ICF \geq 0.70$: high consensus; 0.50–0.69: moderate consensus; < 0.50 : low consensus. Data collected through semi-structured interviews with 210 informants across 18 villages.

The elevated ICF for dyspepsia (0.72) and gastritis (0.71) indicates strong inter-informant agreement on the plant species appropriate for these conditions, reflecting their high prevalence in the community and the existence of well-established, culturally validated therapeutic protocols. The comparatively lower ICF for constipation (0.60) suggests greater heterogeneity in remedy selection, potentially attributable to the multifactorial etiology of this condition—encompassing dietary, lifestyle, and pathological factors—and the corresponding need for individualized treatment approaches. This gradient of consensus across ailment categories aligns with patterns documented in comparable Mediterranean ethnobotanical surveys, where conditions with clear symptomatic profiles tend to elicit more uniform therapeutic responses than those with complex, multifactorial origins (Idm'hand *et al.* 2023; Hani *et al.* 2023).

Novel and previously unreported uses

The present survey documented several medicinal plant species that were infrequently reported or insufficiently documented in previous ethnobotanical studies of gastrointestinal disorders in Algeria. Among them, *Teucrium* sp. (Jaada) was traditionally used for the management of gastritis, whereas *Teucrium polium* L. (**khayata**) was preferentially employed against bloating. Likewise, *Coriaria myrtifolia* L. (**dbegh**), a species rarely mentioned in Algerian gastrointestinal ethnomedicine because of its known toxicity, was cited for the treatment of gastritis. *Arum italicum* Mill. (**quarioua**) was also reported as a remedy for gastritis despite its limited documentation for gastrointestinal applications. In addition, *Boswellia sacra* Flueck. (**loban eldker**) was cited for the treatment of colic, whereas *Ulmus rubra* Muhl. and *Cinnamomum verum* J.

Presl were specifically recommended for gastric ulcers. These observations expand the documented diversity of medicinal plants used against digestive disorders in the Aurès Mountains and provide new candidates for future pharmacological and toxicological investigations.

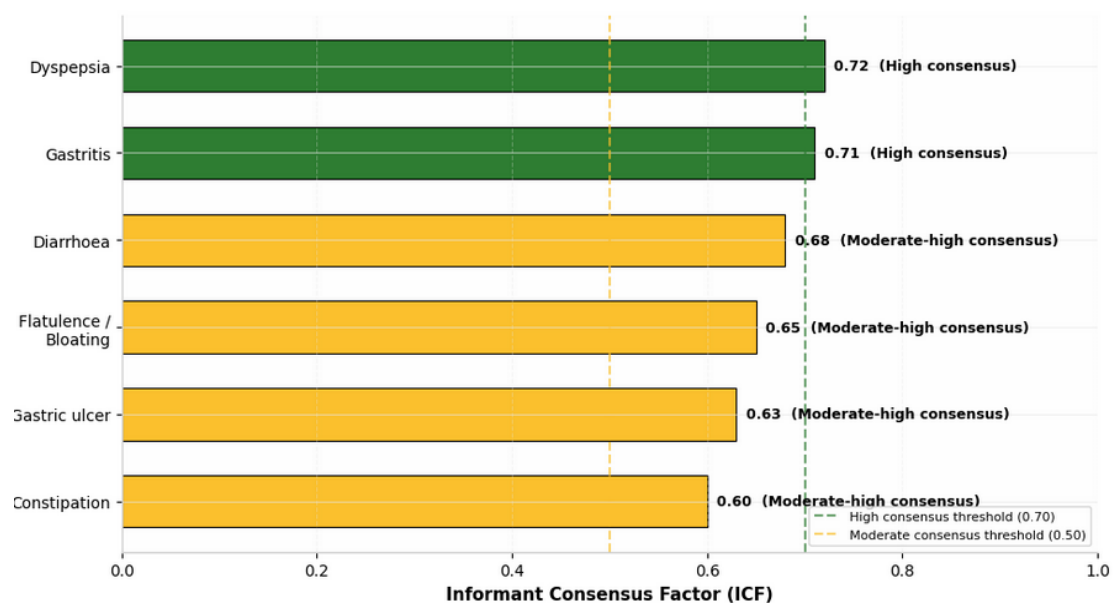


Figure 5. Informant Consensus Factor (ICF) for gastrointestinal disorder categories (n = 210 informants)

Conservation and sustainability considerations

The present inventory recorded 60 medicinal plant species belonging to 34 botanical families, with the flora being dominated by members of the Lamiaceae (10 species), Apiaceae (6 species), Fabaceae (5 species) and Rosaceae (5 species). The highest ethnobotanical importance indices were observed for *Thymus vulgaris* (UV = 1.96; RFC = 0.87), followed by *Mentha* sp. (UV = 1.42; RFC = 0.71) and *Foeniculum vulgare* (UV = 1.31; RFC = 0.66), indicating that only a limited number of species account for most traditional gastrointestinal remedies. Such concentration of use may increase harvesting pressure on these culturally important taxa, particularly wild aromatic species collected from mountain habitats. Although the present study did not quantitatively assess population status or harvesting intensity, the predominance of wild medicinal plants highlights the importance of implementing sustainable harvesting practices and conservation strategies. Promoting community-based management, cultivation of highly demanded species such as *Thymus vulgaris* and *Teucrium* spp., and preserving traditional ethnobotanical knowledge are essential to ensure the long-term conservation of both plant diversity and associated cultural heritage in the Aurès Mountains.

Discussion

The Aurès Mountains represent a biocultural hotspot where Mediterranean floristic diversity converges with Chaouia Berber ethnomedical traditions, producing a gastrointestinal pharmacopoeia of remarkable depth and empirical coherence. The floristic composition documented in this study aligns with broader Mediterranean ethnobotanical patterns, particularly the dominance of Lamiaceae, Apiaceae, and Asteraceae, families consistently identified as pharmacological pillars of digestive medicine across the Maghreb and southern Europe (Belhouala *et al.* 2021; Hani *et al.* 2023). This convergence is not coincidental but reflects shared ecological selective pressures—calcareous soils, seasonal drought, and montane gradients—that favor aromatic, sclerophyllous species rich in thymol, carvacrol, and sesquiterpene lactones with documented gastroprotective and antimicrobial properties (Galovičová *et al.* 2010). The exceptional representation of Lamiaceae in the Aurès exceeds values reported from the Algerian Tell and High Plateaus, suggesting that montane isolation and Chaouia cultural specificity have amplified the therapeutic prestige of this family beyond regional norms (Adoui *et al.* 2024).

The quantitative structure of the Aurès pharmacopoeia reveals a "core-periphery" architecture characteristic of traditional medicine systems globally, where a small cohort of culturally salient species concentrates substantial plurality of therapeutic use (Heinrich *et al.* 2020). This concentration has dual implications: it identifies pharmacological priorities for drug discovery while simultaneously exposing these species to disproportionate harvesting pressure. The strong correlation between cultural importance metrics indicates that frequently cited species are genuinely multi-purpose rather than idiosyncratic, validating their empirical efficacy and supporting their prioritization for phytochemical screening. However, the documented

decline in wild populations of these core species—attributed to the synergistic pressures of commercial overharvesting, climate-driven aridification, and agricultural encroachment—threatens both the functional integrity of the pharmacopoeia and the livelihoods of communities dependent on these resources (Baziz *et al.* 2020; Meddour *et al.* 2020).

The high informant consensus observed for dyspepsia and gastritis reflects the high prevalence of these conditions in rural communities with limited access to gastroenterological care and sanitation infrastructure. This consensus is comparable to Moroccan mountain systems (Idm'hand *et al.* 2023) but exceeds values from the Algerian High Plateaus, suggesting that the geographic isolation of the Aurès has preserved a more coherent therapeutic tradition (Hani *et al.* 2023). Conversely, the lower consensus for constipation likely reflects its multifactorial etiology—encompassing dietary, lifestyle, and pathological determinants—rather than knowledge fragmentation, indicating that traditional practitioners recognize the need for individualized treatment approaches in complex cases.

The gendered distribution of ethnomedical knowledge, with women serving as primary custodians of household phytotherapy, mirrors patterns documented across North African and Mediterranean societies (Baziz *et al.* 2020). However, the advanced age and low formal education of the informant cohort signal a demographic transition that threatens

merely a loss of botanical knowledge but the erosion of a sophisticated system of sustainable resource management embedded in oral tradition. This biocultural erosion is accelerated by rural exodus and the sedentarization of formerly semi-nomadic populations, processes that sever the daily experiential contact with montane ecosystems necessary for the maintenance of traditional ecological knowledge (Sökand and Pieroni 2016; Srithi *et al.* 2009).

The integration of exotic species into the Aurès pharmacopoeia—evident in the citation of trans-Saharan and maritime trade plants—demonstrates the dynamic, adaptive nature of traditional medicine systems. These species, while less culturally entrenched than native flora, indicate ongoing experimentation and the openness of Chaouia phytotherapy to external influences. Their lower fidelity levels suggest that their incorporation is relatively recent and less validated by communal consensus, highlighting the distinction between deeply rooted indigenous knowledge and emerging adaptive practices.

From a pharmacological perspective, the predominance of hot-water extraction methods in the Aurès resonates with mechanistic studies demonstrating the efficient liberation of polyphenols, tannins, and volatile oils by aqueous heat (Belhouala *et al.* 2021). This empirical convergence between traditional preparation and modern phytochemistry validates the Aurès pharmacopoeia as a source of lead compounds for drug discovery, particularly for conditions such as functional dyspepsia and infectious diarrhoea where conventional therapies remain inadequate or inaccessible. The documented use of species with novel ethnomedicinal applications previously unreported in the North African literature expands the known gastrointestinal ethnoflora of the region, though some of these reports, particularly those involving toxic taxa, warrant urgent toxicological evaluation and community health education.

The conservation implications of this study extend beyond species preservation to encompass the safeguarding of knowledge transmission chains. The vulnerability paradox created by the concentration of therapeutic use on a limited number of species necessitates community-based conservation initiatives, ex situ seed banking, and sustainable cultivation programs. These interventions must be designed in partnership with local knowledge holders to ensure that they reinforce rather than replace traditional governance systems. The cultivation of high-priority species such as *Thymus vulgaris* and *Artemisia herba-alba*, both of which possess established agronomic protocols, offers a pathway to reconcile healthcare functionality with biodiversity conservation.

Study limitations include the potential for kinship bias inherent in snowball sampling and the cross-sectional design, which precludes longitudinal assessment of knowledge erosion dynamics. Future research should integrate phytochemical screening of high-fidelity species with experimental pharmacology to validate traditional claims, alongside participatory conservation programs that engage younger community members in the documentation and sustainable management of medicinal flora. The integration of ethnobotanical baseline data with geographic information systems and population monitoring would further enhance the capacity for adaptive management in the face of climate change.

Conclusion

The Aurès gastrointestinal pharmacopoeia represents a coherent, empirically validated traditional medicine system whose conservation is essential for both cultural heritage and primary healthcare functionality. The quantitative framework established in this study provides a foundation for prioritizing species for pharmacological investigation and conservation

action, while the documented biocultural erosion signals an urgent need for policy interventions that bridge traditional knowledge systems with modern healthcare and environmental governance frameworks.

Declarations

List of abbreviations: FL — Fidelity Level; GI — Gastrointestinal; ICF — Informant Consensus Factor; N — Number of Informants / Sample Size; RFC — Relative Frequency of Citation; UV — Use Value; WHO — World Health Organization.

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Author contributions:

S.B. conceptualized the research design, oversaw data interpretation, and directed the scientific discussion. L.D. provided expertise on ethnoecological dimensions. N.L. established the theoretical foundations and managed field monitoring data. M.K. executed statistical analyses and supervised the manuscript's final editing. All authors critically reviewed the manuscript and approved its submission.

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